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OPHTHALMOLOGY

AND

OPHTHALMOSCOPY

FOR

Practitioners and Students of Medicine.

BY

DR. HERMANN SCHMIDT-RIMPLER,

PROFESSOR OF OPHTHALMOLOGY AND DIRECTOR OF THE OPHTHALMOLOGICAL CLINIC IN MARBURG.

TRANSLATED FROM THE THIRD GERMAN REVISED EDITION.

EDITED BY

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183 WOODCUTS AND THREE COLORED PLATES.

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PREFACE.

THIS work principally subserves didactic purposes, and is intended to present modern ophthalmology in a form which will facilitate its reception. This requires above all a distinct separation—which should also be apparent externally—of the different divisions and subdivisions, and a gradually advancing presentation of the subject, that assumes as little as possible. This explains the introduction of the optical and anatomico-physiological data which are necessary to the comprehension of the subject. This appeared to me to be especially important in the chapter on errors of refraction and accommodation, whose mastery is impossible without such preliminary knowledge. As I know from experience the widespread antipathy of physicians to mathematics—it is difficult to determine whether this is congenital or acquired—I have reduced it to such a homeopathic dose, that even the student who most dreads calculations and formulæ can tolerate it without bad effects. The retention of the formula $\frac{1}{f}=\frac{1}{a}+\frac{1}{b}$, which will suffice approximately in practice, will probably not give rise either to physical or mental strain. But this very knowledge of the errors of refraction will find an important application in medical work, when we finally discontinue the bad habit of simply sending patients to the optician for the purpose of selecting spectacles. This is somewhat similar to intrusting the apothecary with the treatment of patients. Examinations of refraction—in addition to the examination of vision and color blindness—also possess special significance for hygienists and military surgeons. I have therefore paid due attention, in the proper place, to their special needs.

Furthermore, a more detailed description has been devoted to ophthalmoscopy and everything belonging to this category, has been given, in order to furnish the student, within the limits of general ophthalmology, with a somewhat complete guide for use in

ophthalmoscopic courses. On the other hand, the operations have only been described in their salient features. What has been gained in this way, has been used to advantage in discussing other subjects.

The expert reader will soon find that I have not alone written "according to distinguished authority," but that, in addition to the critical sifting of what has been handed down to us, I have also furnished much that is new in form and contents.

H. SCHMIDT-RIMPLER.

MARBURG, October, 1884.

PREFACE TO THE SECOND EDITION.

THE favorable judgment of specialists and the rapid sale of the first edition have shown me that the labor devoted to this work has not been useless. I have endeavored to keep it abreast of the times by improvements, and by the introduction of the most recent advances (such as the use of cocaine, more exact methods of measurement of the light sense, etc.). The alphabetical index has been notably enlarged by the insertion of the general diseases, in so far as they are mentioned in the work.

H SCHMIDT-RIMPLER.

MARBURG, April 1st, 1886.

PREFACE TO THE THIRD EDITION.

THIS new edition has again been subjected to careful revision, it has been changed in accordance with the constant increase of our knowledge, and additions have been made. May its continued favorable reception permit the different editions of the work to follow the new acquisitions of ophthalmology, at not too long intervals.

H. SCHMIDT-RIMPLER.

MARBURG, December 4th, 1887.

EDITOR'S PREFACE.

THE task of editing the translation of Professor Schmidt-Rimpler's book has been an agreeable one. The work is a clearly written, comprehensive and scientific treatise, that cannot fail, I think, to secure the confidence of the profession in the English-speaking countries, as it has that of the Germans. I have at a few points added short notes, which I trust may not be considered to mar the symmetry of the original. A few illustrations, chiefly from Stellwag's treatise, the English translation of which is now out of print, have been added.

For the translation, which I believe, on careful comparison with the original, to be a faithful one, I can take no credit, since it was prepared for the publishers by a highly competent hand.

D. B. ST. JOHN ROOSA.

NEW YORK, June 26th, 1889,
20 East 30th Street.

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Part First.

General observations on the examination and treatment of the eye

Errors of refraction and accommodation

Amblyopia and amaurosis

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DISEASES OF THE EYE.

CHAPTER I.

GENERAL REMARKS ON EXAMINATION AND TREATMENT OF THE EYE.

A. Examination of the Eye.

OPHTHALMOLOGY not only endeavors to save and improve the eyesight of the patient, but it also aids the sight of him who uses his eyes in the capacity of physician—he learns to see clearly and accurately. Almost all diseases of the eye are diagnosticated by the sense of sight; an ophthalmologist with poor sight would be at a great disadvantage. But in addition to the necessary acuteness and exercise of the sight and a knowledge of the morbid pictures, a correct method of examination is also required. As in the clinics for internal medicine, great importance is attached to taking the exact present condition, in which the entire body is subjected to inspection in a certain order, so that we may avoid overlooking or neglecting any symptom, so likewise a regular sequence must be carried out in examination of the eye. In both cases, however, the experienced observer may occasionally permit himself omissions and deviations.

We should begin with an inquiry concerning the symptoms which have led the patient to consult the physician. It is especially in diseases of the eye that this point is apt to be neglected, because a single glance sometimes informs us concerning the disease; at all events, the expression, "Yes, I know," would be more often justified here than in other diseases. Nevertheless, the complaints should be carefully listened to, particularly as the affected organ may be subjected at the same time to external inspection. The symptoms sometimes refer to entirely different matters than is supposed at the first glance. A patient with chronic inflammation of the lids, perhaps, does not consult us concerning this disease, to

which he has become accustomed, but in order to have glasses prescribed. As a matter of course, excessive prolixity is to be checked.

The condition of the integument of the lids is first noticed, whether there is redness, eczema, or œdema. We notice further whether the lids can be raised easily and freely, or the eye remains entirely or partly covered by them. Attention is to be directed to epiphora or the escape of a watery, mucous, or purulent secretion which adheres to the angles of the lids or the cilia. By pulling gently on the lids, the appearance of the edge of the lid can be seen: whether it is sharp-angled and pale, or somewhat blunt and red, whether the lashes are present in normal number and what their position is. Not infrequently a few hairs rub against the globe, or the entire edge of the lid is directed against the eyeball (entropium). In other cases the edge is turned away from the globe, more or less to the outside, so that portions of the mucous membrane which cover the inner surface of the lid become visible (ectropium).

Special attention is to be paid to the *puncta lachrymalia*, particularly the lower one, which often turns outward and does not dip into the lachrymal canal. At the same time dilatation and hypersecretion of the lachrymal sac may be looked for by means of pressure with the index finger on the integument adjacent to the inner angle of the lids. If there is increased secretion of the mucous membrane of the lachrymal sac and occlusion of the lachrymal duct, fluid will be discharged from the puncta lachrymalia.

We then proceed to the examination of the eyeball itself. In some cases the eye cannot be opened on account of the swelling of the lids or, even apart from such swelling, it is kept closed spasmodically—a phenomenon which is not uncommon in children. Caution must be exercised in separating the lids, especially if we are unacquainted with the condition of the eye, because an existing extensive and deep-spreading corneal ulcer may perhaps rupture on the application of force and even the lens may protrude. In such cases it is least dangerous to place a Desmarres' elevator (Fig. 1) beneath the upper lid. The lid being slightly raised, the curved brass or tortoise-shell surface is allowed to pass between the lid and the globe, and the former is then drawn upward by placing the elevator against the upper edge of the orbit. The following method may be recommended in fixing the head in unruly children. Placing the feet upon a stool, we take a seat opposite the attendant, who holds the child upon his lap, and then place the child's head between our knees, while the attendant holds the hands and presses the legs against himself with his arm. In this way the



FIG. 1.—Desmarres' Elevator.

necessary examination may be made without special difficulty, and, in the case of children in arms, we are hardly able to effect our object in any other way.

We now notice whether the caruncles and conjunctiva bulbi are injected or swollen. An especial diagnostic significance as regards severe inflammatory processes attaches to the presence of a narrow, red vascular zone around the cornea, consisting of tolerably parallel small vascular twigs (so-called pericorneal or subconjunctival injection). When this is present, we never have to deal with

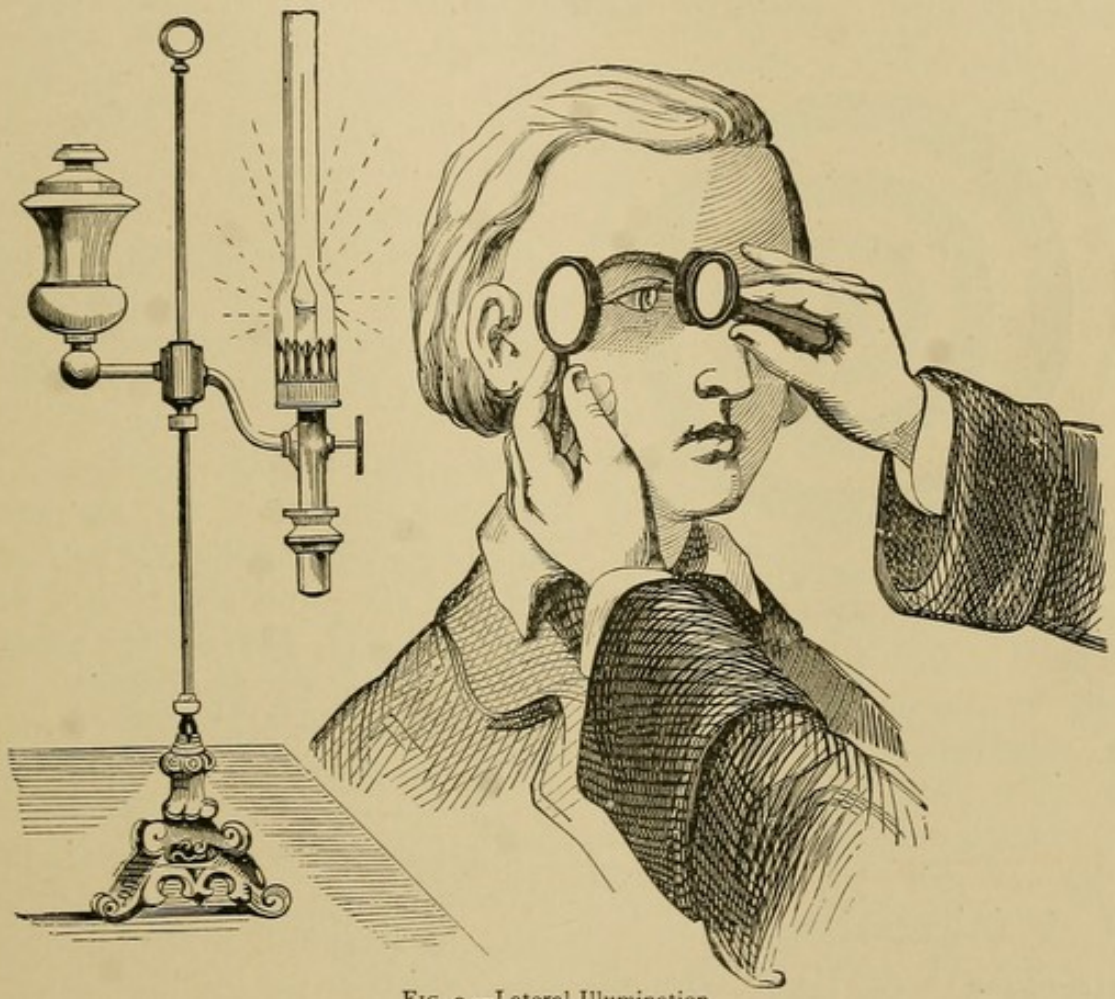


FIG. 2.—Lateral Illumination.

a simple inflammation of the conjunctiva. If the mucous membrane presents no pronounced changes (granulations or blennorrhœa), special attention must be directed to the cornea and iris. On account of the reflection of the cornea, small foreign bodies, patches, opacities, and ulcers are apt to be overlooked, and we must here strain our sight somewhat. How often are small particles of iron or coal upon the cornea overlooked? If the changes are very delicate (as in the anterior chamber, on the iris, in the lens), so-called lateral illumination must be employed, the light being concentrated by means of a convex lens upon the spot to be examined. The

details of this important method of examination will be found in the chapter on ophthalmoscopy.

The curvature of the cornea, which acts like a convex mirror, is well shown by the image it reproduces of objects situated opposite. If the patient sits with his face turned toward a window, we will see distinctly the miniature image of the window and can infer an error in the corneal curve from an irregularity or distortion of the image. A more distinct image is obtained by the use of the keratoscope (Fig. 3). This consists essentially of a pasteboard or metal disk, upon which are drawn concentric black rings, like a target. This disk is held in front of the eye of the patient, who sits with his back turned toward the window, and we then look, through the opening in its centre, at the rings reflected on the cornea. Distortion, resulting from irregular reflection of the cornea, is then very easily recognized.

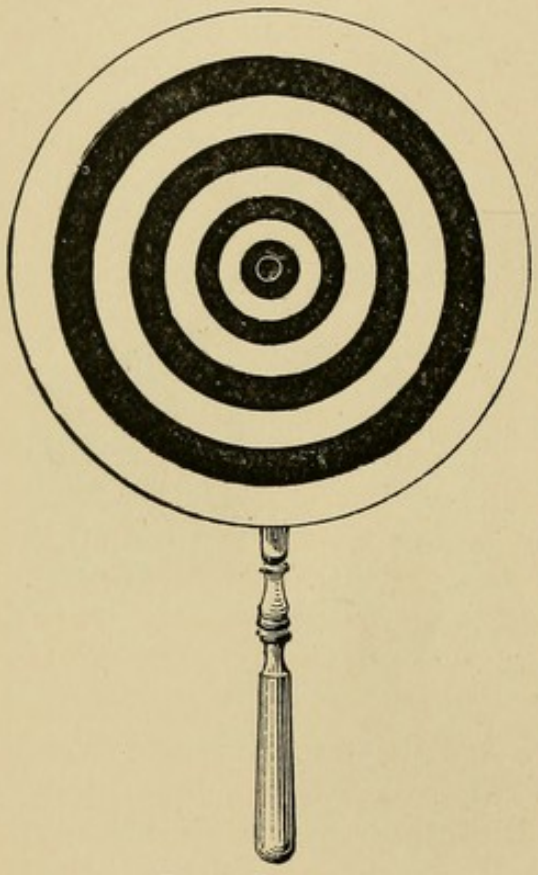


FIG. 3.—Keratoscope.

We then inspect the anterior chamber, its depth, *i.e.*, the distance between the iris and lens on the one side, and the cornea on the other side, whether the aqueous humor is transparent or cloudy, whether blood (hyphæma) or pus (hypopyon) is visible in it. With regard to the iris, attention is paid to the color, especially in comparison with the healthy eye, the position, brilliancy, and structure of the tissue. Furthermore, whether the pupil contracts well to light, whether it is uniformly round or angular (as from adhesions to the capsule of the lens, posterior synechia), whether it is abnormally large (mydriasis) or small (myosis). A dilated pupil associated with marked inflammation of the eye occurs almost exclusively in glaucoma. As a matter of course, we must have previously excluded dilatation by medicinal agents, for example, atropine. The pupil is normally black. If there is a defect on the capsule of the lens or opacities in the lens itself (cataract), the pupil has a gray, white, or yellowish-brown color, either throughout or in circumscribed places. Artificial dilatation of the pupil is necessary in order to get a thorough view of the lens, its position, and of any

opacities which may be situated peripherally; but this may be dispensed with, as a rule, unless the results of the previous examination and of the subsequent ophthalmoscopic examination render it probable that there is some anomaly of the lens.

The external objective examination of the eye is made thus far in this order. If the individual parts were examined in their consecutive order, the examination of the palpebral conjunctiva (the mucous membrane covering the lids) and of the transition fold of the conjunctiva palpebralis into the conjunctiva scleræ, should have followed the examination of the conjunctiva bulbi. But it is well to leave this until the end of the external examination just mentioned, because the patients are apt to grow frightened and timid, the tears begin to overflow, and the eye reddens, on account of the inconvenience and pain connected with examination of the palpebral conjunctiva. Moreover, the lids should be everted with the greatest care—in order to avoid pressure on the globe—in cases of large, deep ulcers of the cornea, prolapse of the iris, and similar diseases. In the worst event, we must desist for a time from examination of the mucous membrane of the lids, especially of the upper one, whose eversion is the more difficult.

As a rule, the lower lid can be everted very easily. The patient is directed to look up, the index and middle fingers are placed upon the integument, immediately below the edge of the lid, and the latter drawn down until the mucous membrane turns out, and can thus be seen as far as the globe. In everting the upper lid, the patient is first directed to look sharply downward. This is extremely important to the success of the manipulation and we must make sure that the patient really does look down, because, upon grasping the lid or globe, there is a tendency to look up. With the thumb of the left hand, placed upon the lid immediately below the edge of the orbit, the lid and therefore its rim are raised somewhat from the globe, so that it can be grasped between the thumb and index finger of the right hand. The lid, which is grasped at the edge, not at the lashes, is now drawn somewhat downward, and, while the index finger of the left hand or a penholder, placed immediately below the orbital rim, presses the lid a little backward, is turned upon this fulcrum, so that the edge of the lid is brought against the upper edge of the orbit. The palpebral portion of the mucous membrane thus becomes visible. A view of the transition part to the globe, often requires still further elevation and posterior version of the rim of the lid, the patient being constantly directed to look downward. Resisting patients, who continually withdraw the head, must be seated in such a way that either the head can be held or can be supported against the

chair or wall. With some practice, we can, as a rule, effect the desired object. This practice must be obtained, not alone in order to avoid hurting the patient, who will forthwith acquire distrust of the physician, on account of unskilful manipulation, but also in order that this examination may not be neglected on account of the consciousness of inability. Injection, irregularities, deposits, or foreign bodies must be looked for upon the everted mucous membrane.

After this external examination, the globe is palpated in order to ascertain its tension. Since the coverings of the eye are elastic membranes inclosing fluid contents, the tension will vary, as in a rubber bag filled with water, according to the relation between the contents and the size of the coverings. When the contents increase, the coverings will be stretched more firmly, and the eye will feel harder on palpation. This will also happen if the size of the capsule diminishes while the contents remain the same.

If, on the other hand, the coverings are large in proportion to the contents, or the latter are relatively small, the eye will feel soft. This examination, accordingly, will furnish data for determining the pressure which prevails in the interior of the eye and is exercised upon the walls from within. We therefore speak of the tension of the eye or of the amount of intraocular pressure. The harder the eye the greater the tension and intraocular pressure. Abnormal hardness is known as hypertony, abnormal softness as hypotony. The best way of testing the tension is to allow the eye to be gently closed, and then placing the index fingers on the upper lid to the inside and outside, to determine the hardness between the fingers by slight, alternating pressure. Palpation with one finger is less advisable because the globe is then readily pushed backward and in this way it is rather a test of the resistance of the orbital contents than of the eyeball. But we can often effect our object even in this way, by exercising very gentle pressure and avoiding displacement. Instruments (tonometers) have also been devised for the measurement of the tension (see Glaucoma).

It is also to be noted whether there is unusual prominence of the globe (exophthalmus) or deep sinking in (enophthalmus).

When the objective external examination of the eye is finished, before proceeding to internal examination with the ophthalmoscope or oblique illumination, it is usually advisable to determine the refraction and acuteness of vision of each eye separately. As a rule, both measurements are combined, the objects selected for the determination of refraction, by means of spectacles, being tables which contain letters or numbers in which, as, for example, in Snellen's and Schweigger's tables, the distance is also known at

which they must be recognized by the normal eye. Hence, the relation of the patient's acuity of vision (V) to the normal is furnished forthwith.

In order to ascertain the power of accommodation, we first determine the near-point of the eye (punctum proxissimum). But inasmuch as the determination of the acuteness of central vision is insufficient, it is also necessary to ascertain the visual power of the peripheral portions of the retina, we must determine the visual field, *i.e.*, the eccentric region in which, with constant central fixation of a point, sight is still possible. As a matter of course, the acuity of vision is not as great in the peripheral regions as in the central portion. This examination is most simply made by directing the patient to look closely at the pupil of the physician's eye, which is situated opposite. When the distance between the fixed and fixing eye is about 50 cm., the physician moves his hand from the periphery toward the centre, in a plane which is situated at right angles to the middle of the line connecting both eyes. As soon as the patient states that he sees the hand, the boundary of his peripheral field of vision is reached. Whether this corresponds to the normal may be determined by a comparison with the surgeon's own eye, since in this examination the examiner (whose other eye is naturally closed) must see the approaching hand at the same time as the patient, if the field of vision has the uniform normal extent. If the patient does not see the hand until later, he suffers from a contraction of the field of vision which, according to its position, is called a defect above, below, etc. In these tests we should be careful that the patient does not turn his eye directly upon the approaching hand, but continues the central fixation on the physician's eye. For accurate measurement of the field of vision and eccentric vision we employ certain instruments (perimeter) (see Amblyopia and Amaurosis).

This examination is followed by a test of the color sense and the light sense. With regard to the latter, we will simply mention here that there are diseases of the eye in which the normally lessened acuteness of vision on lowering of the illumination diminishes in an entirely abnormal, and unusually high degree. After each eye has been examined separately in this way, the co-operation of both eyes with regard to accurate convergence upon the fixed object, to mobility and binocular vision is ascertained (see Diseases of the Ocular Muscles).

In order to prevent injury to the eye from the strain, if there are notable signs of inflammation, the above-mentioned examinations should not be prolonged too far, and we must be satisfied with somewhat less exact results. Indeed, certain tests must be

omitted if they are not directly necessary to our judgment of the case. If exactness in examination can only be attained by injury to the patient, the choice will not prove difficult to the conscientious physician who does not regard his suffering fellow-creatures as exactly synonymous with "clinical material." Such considerations should guide us in making an ophthalmoscopic examination. While a hasty glimpse will hardly cause any bad effects, even if the eye is very much inflamed, prolonged examination must be avoided.

In examination with the ophthalmoscope the light is, at first, simply thrown into the eye and the patient directed to look up and down, to the inside and outside. If there are opacities of the cornea, lens, or vitreous humor, we will then see darker shadows appear upon the red fundus. Their position is shown by oblique illumination, by means of which we can directly recognize opacities of the refracting media, even in the lens and the adjacent portions of the vitreous humor. With the interposition of a convex lens we then examine with the ophthalmoscope the fundus of the eye, in the inverted image (see Ophthalmoscopy); first, the entrance of the optic nerve (papilla optica), then the macula lutea, and other parts. As the enlargement in the inverted image of the fundus, which is thrown by the interposed convex lens, is less than that in the direct image (in which the fundus is simply looked at through the refractive media of the eye which act as a magnifying glass), in order to gain a more rapid oversight, it is better to employ the former method before the latter. Finally, the refraction is determined objectively with the ophthalmoscope.

With such a methodical examination of the eye and its functions, there is not much risk of overlooking important data. If the morbid symptoms and the disease are recognized, it remains to ascertain whether and to what extent, a connection of the affection of the eye with special morbific influences, or with anomalies of the general constitution, is demonstrable. Here the general medical education comes into play. Without this foundation there can be, in many cases, no thought of a successful and appropriate treatment of the disease of the eye. It is to be hoped that the time will soon pass in which the public may ask, whether the ophthalmologist is also a physician. Very often the disease of the eye is the direct cause of the recognition or proper interpretation of other diseases. I will merely remind you of the connection between neuralgias and errors of refraction, of the significance of diseases of the optic nerve and ocular muscles in affections of the brain and nerves, and of the not uncommon cases in which the patient visits the physician on account of impaired vision, and the examination reveals an inflammation of the retina as the result

of a renal disease, or feebleness of accommodation, impaired sight or cataract, as the result of diabetes. Tubercles of the choroid or retinal hemorrhages may occasionally be decisive in the diagnosis of miliary tuberculosis or septicæmic processes.

In the same way that every oculist must possess a sufficient knowledge of the other branches of medicine, so the general practitioner can only make a thoroughly scientific diagnosis of diseases of other organs when he has a certain amount of practice in the recognition of diseases of the eye.

B. Treatment of Diseases of the Eye.

Diseases of the eye demand certain special directions, apart from those which are necessary in other conditions. Straining the eyes is particularly to be avoided. In the more severe inflammatory processes of the eyeball itself, accurate vision, such as is required in reading or writing, must be dispensed with. Here, as a rule, the mere entrance of light is injurious and therefore the patients are kept in darkened rooms. Absolute darkness is necessary only in exceptional instances. The light can be kept out by draping the windows with dark (dark blue or black) soft cotton fabrics. This is better than letting down the ordinary shades through which, as a rule, side light enters. If the photophobia is less, a dark gray material will suffice; bright colors—also light blue—are to be avoided. It is preferable if the room is not exposed to direct sunlight. Precautions are also necessary with regard to the entrance of light through the door. But care must always be taken that the air is not excluded with the light. The air should be as pure as possible. A stay in dusty apartments or those filled with tobacco smoke is to be avoided in all inflammatory diseases of the eye. In severe cases of inflammation and after operations the patient should be kept in bed entirely or during the greater part of the day.

If the room is only darkened moderately, or if, in mild forms of inflammation, the patient is allowed to go out, the affected eye is protected by a shield of linen or black silk, which is fastened to a narrow band passing around the forehead and head. If the eye may be used to a certain extent, the dazzling and excessive entrance of light must be prevented by the use of shades, veils, or, better still, colored glasses.

For the latter, plane round or oval glasses, curved like a watch glass, of a blue or smoke gray color are used. As the shell-shaped glass disperses the rays of light somewhat (like feeble concave glasses) they are better adapted for short-sighted than for normal

or far-sighted patients. The color should not be of too dark a shade. As a rule No. III. will suffice (they are usually numbered from I. to VIII., I. being very feebly blue or gray). The blue glasses not alone diminish the intensity of the light, but also exclude, in part, the red rays and in this way appear to act as a direct therapeutic agent in certain affections (Boehm). The fact that smoke glasses do not exclude the different colored rays in a uniform manner is easily seen on looking through several of them or through very dark glasses. Objects then assume a slightly yellowish, a bluish-violet or some other color. In certain diseases it is also important to exclude the rays which enter laterally through the sclera; we may then use specially constructed shell-shaped spectacles. The abandonment of these protective glasses must occur as soon as possible after recovery has occurred, but it should take place gradually; the glasses should be at first removed in the room or at twilight, but worn at night in the lamplight and upon the street.

Complete occlusion of the diseased or operated eye is effected by a protective bandage or compress. This immobilizes the eye and, if the pressure is marked, also acts upon the circulation. A certain diminution of tension is sometimes distinctly observed under its action. An oval soft piece of linen, a piece of mull that covers the lids completely, is placed directly on the closed eye. Upon this are placed small pledgets of cotton to fill out the space between the edge of the forehead, ridge of the nose, and the cheek. The frequent application of the palm of the hand shows us that the space is filled uniformly, without projecting or pressing in any one spot. If an antiseptic action is also required, as always occurs after operations, a piece of borated lint is applied instead of linen, the smooth surface being directed toward the eye, and the filling is done with salicylated cotton, or the eye is covered with compresses of mull dipped in a solution of corrosive sublimate.

This dressing is retained by a bandage, consisting of an oval piece of flannel, about 14 cm. long and 6 cm. wide in the middle, to both ends of which is stitched a narrow band. The upper band is drawn across the opposite frontal prominence toward the occiput, where it crosses the lower band which is carried below the ear on the same side, and then, after turning horizontally to the side, is tied in front of the forehead. If greater pressure is to be exercised, and, as after most operations, if greater firmness of the dressing is required, a monoculus is applied by means of a bandage (6 to 7 m. long and about 7 cm. wide) of good mull or dressed gauze (the turns of the latter adhere together when moistened). Beginning at the angle of the lower jaw on the same side, we pass

obliquely across the eye to the opposite forehead, then make a complete circular turn immediately above the ear (around the occiput and forehead), then pass from the occiput below the ear of the diseased side and thus come to the first turn of the bandage; then upon this begins the second turn, which passes in a more vertical direction over the eye. This turn runs the same course, otherwise, as the first, and is followed by a third which is situated superiorly. It is well to add a series of similar turns which pass obliquely and cover the ear on the same side. After operations, the healthy eye, which is covered with cotton, may be closed with a few turns of a bandage and protected against light. The beginning and end are fastened with pins; also various parts of the circular turns, especially posteriorly, which have a tendency to slip up.

The following are the principal local measures which are employed specially in diseases of the eye.

Abstraction of Blood.—In external affections, as a rule, we naturally use leeches, four to six being applied, in adults, to the temples. Prolonged after-bleeding should be avoided, and it is preferable to increase the number of leeches. Application to the lids is decidedly objectionable because suggillations and swelling are apt to occur in the flaccid tissues. Cases are also known in which the leeches have sucked the eyeball itself. In internal inflammations of the eye (opacities of the vitreous, choroidal and retinal affections), the abstraction of blood by means of the artificial Heurteloup leech, seems to be more advantageous. It occurs more rapidly and may be well gauged; in addition, a larger portion of the skin is congested, as in the use of dry cups. The instrument consists of a cutting punch (Fig. 4) which rotates in its frame by pulling on a cord, and makes a circular cutaneous wound about 3 mm. in diameter. The punch is pushed more or less out of its frame, according to the thickness of the skin and adipose tissue. After we are satisfied that the wound bleeds sufficiently or have increased the hemorrhage by the use of warm water, the blood is abstracted by applying the glass cylinder (B) which gradually produces a vacuum by screwing up a tightly fitting cork piston. After the first few turns of the screw,

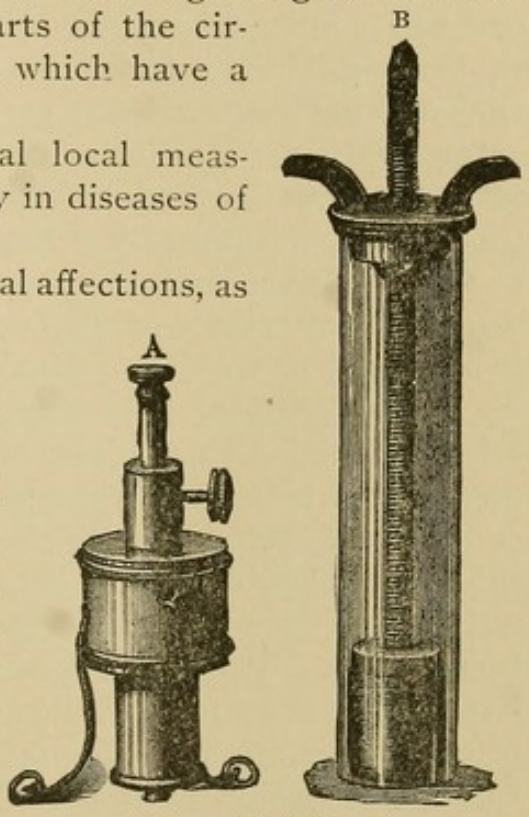


FIG. 4.—Artificial Leech.

the cylinder should no longer be pressed so firmly against the skin, since the latter is apt to press forcibly into the vacuum and thus interrupt the flow of blood on account of the constriction produced at the edge. This is a frequent cause of the failure of the little operation. The abstraction of one cylinderful of blood (about 25 to 30 gm.) is usually sufficient. The temples are used as the site of application, but care must be taken not to incise a large vessel.

Cold compresses, used particularly in conjunctival inflammations, are made with ice water, or medicated solutions. When ice is used, small pieces are placed in specially prepared ice-bags and then applied to the eye, but the pressure is often annoying. In order to convey a constant stream of cold water over the eye, the rubber bag, which is filled with water, is provided at both ends with rubber tubes which convey the water from an elevated vessel and carry it into a lower one. As a general thing, a large number of linen compresses are placed directly on ice or in ice water, and are then changed frequently (every minute or two). It is not necessary to apply the compresses constantly. Even in the most violent disease (blennorrhœa of the conjunctiva), as a rule, a rest of half an hour or an hour may be taken after an hour's constant application. To avoid irritation of the skin, especially in little children, the eyelid is covered with a piece of linen smeared with almond oil or unguentum leniens, so that the compresses do not come in direct contact with the skin. Weak solutions of boracic acid, corrosive sublimate, or lead are also used instead of compresses of pure cold water which are only used for fifteen to thirty minutes three or four times a day, in the less severe inflammations of the conjunctiva. A favorite prescription is acetate of lead, of which ten to fifteen drops are put in a cup of water. The lead wash made in this way is weaker than the officinal preparation, and is more convenient to the patient. But these compresses are to be avoided in corneal ulcers, because precipitation into them may occur occasionally. Patients who go about should be reminded not to go out too soon after using cold compresses, and not to apply the latter when they are heated.

Lukewarm compresses, which are employed particularly in inflammations of the cornea, are made usually with chamomile tea, or antiseptic solutions such as acid. boric. (two to four per cent), acid. salicylic. in a solution of acid. boric. (℞ Acid. salicyl., 5.0; Acid. boric., 15.0; Aq. destil., 500.0) or corrosive sublimate (1 : 5000). Carbolic acid solutions, when stronger than one to two per cent, irritate the cornea. The temperature of the compresses should be 42 to 45° C.

A very good moist, warm antiseptic dressing may also be made

by moistening the above-mentioned lint and salicylated cotton dressing with a warm solution of boric acid, and then fastening with rubber instead of the flannel bandage. In order to retain the desired temperature it must be moistened every hour.

The *medicinal topical agents* in common use in ophthalmology are not very numerous. At all events we can manage with comparatively few, but they must be suited to the cases and skilfully employed. Among the drugs which are used in substance, we may mention smooth pencils of sulphate of copper, alum, and the mitigated stick (argenti nitras cum potassii nitrate). We speak of "touching" if the diseased parts are directly brushed with the stick. In using nitrate of silver, the excess is neutralized, as a rule, by an after-brushing with a weak solution of salt, which is in turn washed away with water. Calomel is often applied as a powder by means of a small brush, or a special powder-blower; it must be protected against moisture which rolls it up into small granules. Iodoform is used in the same way. Other remedies are used, as a rule, in solutions or the form of ointment. Not more than 6.0 to 8.0 of the solutions should be prescribed because this will last for a sufficiently long time. It is dropped into the eye with a dropper, after everting the lower lid, or a brush, which is dipped into the solution and thoroughly filled with it, it is brushed across the everted edge of the lid. The eye is then closed. Careful counting of the drops is superfluous; an excess will overflow spontaneously from the small conjunctival sac. If the patient or his family is to perform the manipulation, it is better to use the brush, inasmuch as the glass tube is apt to injure if used unskilfully, and the insertion by drops is more difficult. Zinc. sulph., tannin, cupr. sulph., alum. sulph., sodæ biborac., in one-tenth to one and one-half per cent, and corrosive sublimate (1 : 5000 in blennorrhœa and for prophylactic antisepsis) are often given in solutions. Nitrate of silver and acetate of lead in stronger doses (one and one-half per cent) are chiefly used for direct brushing of the mucous membrane, the excess being neutralized or washed away with water. [Instead of a brush, absorbent cotton, twisted upon a bit of wood or the like, is a better means of making applications to the eyes.—St. J. R.] Ointments which are to be applied to the eye are made of vaseline, or, on account of its solubility in the lachrymal fluid, of unguentum glycerini (tragacanth 1, spiritus 5, glycerin 50, according to the new pharmacopœia. The latter is tough and stringy. The old preparation (amylum and glycerin) was better, but was more difficult of preparation and easily decomposed). An ointment of hydrarg. oxyd. flav. (Pagenstecher) is used a good deal, particularly in phlyctenular processes of the

conjunctiva; it is more finely subdivided than the long renowned ophthalmic remedy hydrarg. oxyd. rubrum. We usually employ ℞ Hydrarg. oxyd. flav., 0.2; ung. paraffini, 5.0. M. f. ung. D. S. a piece as large as a hempseed is smeared into the eye with the aid of a piece of paper, and there rubbed up while the lids are kept closed. At the end of five minutes undissolved particles are to be removed with a sponge from the conjunctival sac. In diseases of the lids we may use this ointment to advantage, likewise hydrarg. præcip. alb. or zinc. oxyd. A favorite antiphlogistic and derivative in internal inflammations of the eye, is Arlt's forehead ointment (Hydrarg. præc. alb., 1.0; Extr. balladon., 1.0; Ung. simpl., 10.0 or ung. ciner. with ung. simpl. āā and extr. bellad.). A piece as large as a pea is rubbed into the forehead and temple.

As a rule, the ointments, like the majority of astringent eye-washes, are used only once.

This is not true of mydriatic remedies. The best and most effective mydriatic is atropine (0.02 to 0.08 to 8.0 aqua destill. or in the form of ointment or gr. ij. ad ℥ i.). It is used in all inflammations and hyperæmias of the iris, not infrequently six times daily or more often. It causes immobility and dilatation of the pupil by paralysis of the fibres of the third nerve supplying the iris (sphincter iridis) and irritation of the sympathetic branches (dilator iridis or the muscular coat of the vessels). The theory that the sympathetic is irritated, is favored by the fact that the size of the atropinized pupil is considerably larger than that found in simple paralysis of the sphincter. In normal eyes a single instillation is usually followed in about half an hour by maximum dilatation of the pupil, which is merely surrounded by a narrow border of the iris. The dilatation is less marked in the new-born and in very old people. In addition to this action on the iris, paralysis of the muscle of accommodation (ciliary muscle) is observed; the eye is accommodated for distant objects. The attention of the patients must be called to this circumstance and to the further fact that several days elapse before the effect is entirely gone, because otherwise they are apt to be rendered uneasy by the confused vision, the inability to see near objects and to read. Whether a diminution of intraocular pressure is produced by atropine in the vitreous body in normal eyes (Weber), or in the vitreous body and anterior chamber (Pflueger) must be settled by further investigation. The action of the remedy results from its direct absorption by the aqueous humor. No general symptoms occur even after prolonged and vigorous instillation, if the escape through the lachrymal canal into the nose and pharynx is prevented. This is done by closing the eye after the instillation and then pressing for some time upon the

lachrymal canal with the tip of the finger. The first symptom which indicates general absorption is the complaint of dryness in the throat. Marked toxic symptoms (weakness, nausea, spasm of the bladder, hallucinations, etc.) are rarely observed after local applications. Injections of morphine (0.01 to 0.02) have often been useful as an antidote; pilocarpine is also recommended. In some cases, violent conjunctivitis, associated with epiphora and severe eczema of the lids, sets in as the result of an idiosyncrasy against atropine, or of its excessive use, or of a poor preparation. Small pale projections (follicles) upon the conjunctiva also develop in some cases without violent symptoms. The atropine must then be discontinued unless the process is cured or, at least, kept within bounds by touching the mucous membrane with a solution of the neutral acetate of lead, which is particularly effective in such cases. In former times resort was then had to solutions of extr. belladonnæ or extr. hyoscyami. Now we prefer the alkaloids, especially homatropine hydrobromate and duboisine (from Duboisia myoporoides). The latter remedy possesses a vigorous mydriatic and accommodation-paralyzing action. When a rapidly passing dilatation of the pupil is desired, as for ophthalmoscopic purposes, it is advisable to use homatropine (0.04 to 8.0) or cocaine (4 per cent, dropped in several times); the latter possesses the advantage of exerting hardly any effect on accommodation. If we wish to use atropine for this purpose, a weak solution (0.008 to 8.0) must be employed. Hyoscyamine and daturine (from Datura stramonium) are used comparatively little, but hyoscinum hydroiodatum (one-tenth to one-half per cent solution) is recommended as a very vigorous mydriatic (Emmert).

Eserine or physostigmine, the alkaloid of the Calabar bean (Physostigma venenosum) is used especially as a myotic. It is a white powder, which very soon becomes reddish in solution, even in dark bottles, but without any notable diminution in efficiency. The most permanent form is physostigm. salicylicum (one half to one per cent). In addition to the contraction of the pupil, instillation into the conjunctival sac is followed by spasmodic contraction of the ciliary muscle (*vide* "Spasm of accommodation"), so that accommodation is increased and the far-point brought nearer. In the normal eye it is said to increase the general intraocular pressure (Pflueger), according to Weber in the vitreous body alone, while it diminishes the pressure in the anterior chamber. Hoeltzke regards the latter effect as the result of the pupil-contracting action of eserine. It is undeniable that a diminution of intraocular pressure occurs in glaucomatous eyes. Apart from eserine or extr. calabarense (1 : 10 filtered), myosis may also be produced by instillation

of solutions of pilocarpine muriaticum (one to two per cent). This remedy acts less vigorously than eserine, but possesses the advantage that it does not increase the tendency to iritis. Other myotics such as opium, nicotine, muscarine, etc., are not used locally, in part on account of the severe irritation to which they give rise.

In operations on the eye, anæsthesia is produced by instillations of cocaine (Erythroxylon coca) (Koller). This causes insensibility of the cornea and conjunctiva; in larger doses the sensibility of the iris is also diminished. In addition, the palpebral fissure is dilated and occasionally slight protrusion of the eyeball is produced. The intra-ocular pressure diminishes, the pupil dilates, but still reacts, as a general thing, to light. The near-point is somewhat farther removed, but only for a very short time. The vessels of the conjunctiva and iris are constricted. Hence we have to deal with paralysis of peripheral trigeminal branches and irritation of sympathetic fibres. The degree of anæsthesia sufficient for operations is best secured by introducing a two to four per cent solution of cocaine muriaticum repeatedly (four to six times) at intervals of five minutes. A little aqua chlori may be added to keep the solution aseptic. The insensibility lasts about ten minutes. There are notable individual differences as regards the abolition of sensibility; inflamed eyes are rendered anæsthetic with greater difficulty. Even minor operations, such as removal of foreign bodies from the cornea, application of the galvano-cautery, and probing of the lachrymal duct, can be made painless by the previous instillation or injection of cocaine. In order to make the tendons insensible in operations for squint, a solution of cocaine is applied directly after division of the conjunctiva. It may also be injected into the orbital cellular tissue in enucleation of the globe. But great caution must then be exercised, because general symptoms (pallor, cold sweats, vomting, etc.) have been observed after the introduction of five drops of a three-per-cent solution. In very rare cases this unpleasant effect was also observed after instillation into the conjunctival sac. The administration of wine or inhalation of amyl nitrite proved useful in such cases. Circumscribed detachment of the epithelium of the cornea and slight opacity of the tissues occasionally occur locally, after instillation of cocaine. But as a rule these very rare symptoms are insignificant and rapidly subside. They are best avoided by keeping the eyes closed after each application.

The epoch-making discovery of the action of cocaine has very much restricted the employment of narcosis in operations of the eye. Chloroform or ether is only used exceptionally, in uncontrollable children, in cases in which every movement and pressure

of the lids must be prevented in order to avoid loss of the vitreous, and generally in enucleation of the eyeball.

The greatest possible cleanliness and asepsis of the hands, instruments, and dressings are to be secured in all operations. The advantages of the antiseptic method in ocular surgery admits of no doubt. I use absolute alcohol for cleaning the instruments which are kept in a glass case; they are dried with a fresh linen cloth. The integument of the lids and surrounding parts is washed with aqua chlori or corrosive sublimate (1 : 5000), the conjunctiva is irrigated with the same fluids. After the performance of the operation—during which fresh pledgets of mull, dipped in a solution of corrosive sublimate or boracic acid (four per cent) are used for cleansing—the parts are again irrigated with the antiseptic solution. The excessive use of corrosive sublimate is to be avoided, because it may give rise to conjunctival irrigation and corneal opacities.

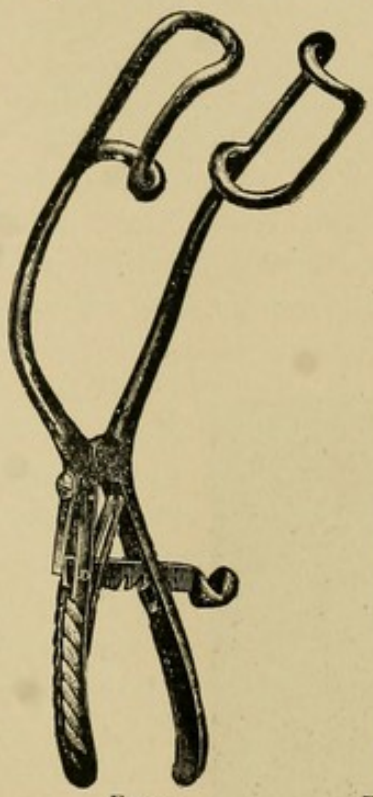


FIG. 5.



FIG. 6.

Before every operation on the globe, special attention must be paid to the existence of a chronic blennorrhœa of the lachrymal sac. As the secretion of this disease is enormously infectious to corneal wounds, the affection of the lachrymal sac must first be relieved as effectually as possible, or if this is impossible, the sac must at least be disinfected. This can be done completely by dividing it from the outside and dusting it with iodoform. Preliminary injections of aqua chlori and, after the operation, daily irrigation of the conjunctival sac with this fluid often prove sufficient.

In order to expose the globe, fixation of the lids is necessary, and this can be done with the fingers or with elevators. If only one lid is to be raised, Desmarres' elevator is used; otherwise, as a rule, a clamp elevator (Fig. 5) is employed. The fixation forceps (Fig. 6) is used for fixation of the globe. This is provided with a small clamp arrangement, so that it may be handed, when closed, to an assistant.

CHAPTER II.

ERRORS OF REFRACTION AND ACCOMMODATION.

A. General Part.

1. Optical Introduction.

An object can only be seen distinctly when the rays of light emanating from it are united into a distinct image upon the retina. The various refracting media of the eye (cornea, aqueous humor, crystalline lens, and vitreous humor) form an optical system whose united action is that of a convex lens.

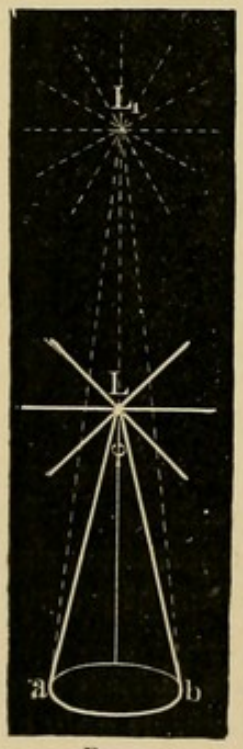


Fig. 7.

The term "rays of light" is an expression derived from the Newton corpuscular theory of light. According to this theory, every bright point constantly sends brilliant corpuscles in all directions along imaginary axes (rays). This hypothesis is now abandoned in favor of the wave theory (Huygens, Thomas Young), according to which light is developed and propagated by undulatory movements in the ether.

The radial connection of the tops of the waves would correspond to the course of the rays of light, if the light is emitted from one point. This point forms the centre from which diverging rays of light pass in all directions. The number of these rays which reach a certain surface *ab* (Fig. 7) depends upon the size of this surface and its distance from the point of light. If *ab* is spherical, it receives a cone of light rays, whose base is formed by *ab*, and whose apex is situated in the source of light *L;* in a cut section *La* and *Lb* would be the most divergent rays of those which fall on *ab; x* represents the angle of divergence. If the source of light is removed to L_1, a narrower cone of rays will fall upon the surface, the extreme rays L_1a and L_1b will be less divergent. If the source of light is finally removed an infinite distance (∞), the rays of light may be regarded as parallel to one another, because mathematically we apply the

term parallel lines to those which meet at infinity. But if the receiving surface is very small, for example, the pupil of the eye, the cone of light which enters will be so narrow, even if the source of light is not very remote, and the rays will diverge so little, that they may be called parallel. Hence, in determining the refraction of the human eye, the test object is placed at a distance of about six metres, though we regard the rays of light emanating from it as parallel.

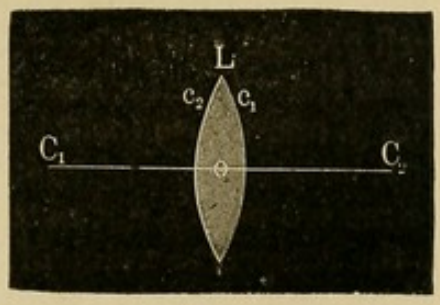


FIG. 8.

While parallel and divergent rays of light enter our eye under natural conditions, convergence of the rays can only be produced artificially by optical means.

Convex lenses are used for this purpose. A spectacle case contains, as a rule, biconvex glasses, *i.e.*, lenses whose surfaces are segments of spheres which have an equal radius. In the biconvex lens L (Fig. 8), C_1 would be the centre of the sphere whose segment is the surface c_1, and C_2 the centre of the second sphere, whose segment is the surface c_2. C_1 and C_2 are at equal distances from the optical centre o of the lens; the line connecting them is known as the principal axis of the lens.

When parallel rays strike a convex lens at not too great a distance from the principal axis, they are converged into one point. This point is known as the principal focus of the lens, and its distance from the optical centre as the principal focal length, or briefly as the focal length of the lens. As the parallel rays may impinge upon the lens from the right as well as from the left, we must assume two principal foci, situated on different sides of the lens, on the left, the first focus F_1 (Fig. 9); on the right, the second focus F_2. They are both at an equal distance from the optical centre

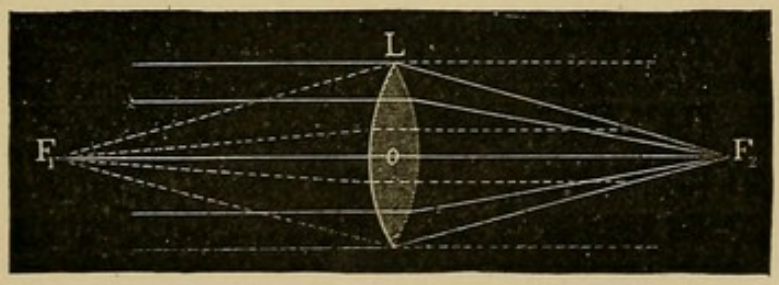


FIG. 9.

(*i.e.*, the first focal length is equal to the second) if the lens is bounded on both sides by the atmosphere or any uniformly refracting medium. In biconvex lenses, the principal focal length equals the radius of curvature (C_1o, Fig. 8), provided that the glass has an index of refraction $=1.5$ (see the section on physiological

optics), but usually this is not exactly the case. As a rule, the indices of refraction of plate and crown glass are somewhat higher, but do not exceed 1.53; hence the focal length is somewhat shorter.* The length of the radius of curvature in inches is usually given upon the older lenses. We are, therefore, not strictly justified in regarding this figure as equal to the principal focal length. This is usually done, however, because if the lenses are otherwise well ground, the differences have no notable practical significance. Lens No. 2 is one whose principal focal length is two inches, lens No. 3, one whose focal length is three inches, etc. In ophthalmology, however, the lenses are numbered, as a rule, according to their refractive power, not according to their focal lengths. The former is the reciprocal value of the latter; it is expressed by a fraction whose numerator is 1, and denominator is equal to the focal length. A lens with two inches focal length is called ½, one with four inches focal length ¼. Two lenses of ¼ refractive power, when combined, equal a lens of ½. The refractive power of a lens, *i.e.*, its action upon incident rays of light, is, therefore, so much feebler the greater its focal length.

By means of a formula which contains the focal length of the convex lens f, the distance of the source of light a and of the image b, we can easily ascertain one of these values when the two others are known. This formula, which is extremely important in the practical determination of refraction and accommodation, and is very easily remembered, reads as follows:

$$\frac{1}{f}=\frac{1}{a}+\frac{1}{b}\ \dagger$$

For example, the source of light a is situated at a distance of twenty inches; the rays emitted by it, fall upon a lens with a focal length of ten inches. At what distance are the rays united, or, in other words, where is the image of the source of light?

---

* The formula for the focal length (f) of the convex lens is $\frac{1}{f}=(n-1)(\frac{1}{r}+\frac{1}{r_1})$ in which r and r_1 are the radii of curvature of the surfaces and n the index of refraction. When $r=r_1$ and $n=1.5$, then $\frac{1}{f}=0.5\times\frac{2}{r}=\frac{1}{r}$, *i.e.*, $f=r$. When $n=1.53$, then $\frac{1}{f}=0.53.\ \frac{2}{r}=\frac{1.06}{r}$, *i.e.*, $f=\frac{r}{1.06}$; f is therefore smaller than before.

† Another common formula is $l_1 l_2=f_1 f_1$. Here l_1 = the distance of the object from the first focus, l_2 = the distance of its image from the second focus. l_1 becomes positive when it is situated in front of the first focus, (*i.e.*, to the left, like a in Fig. 10), l_2 is positive when it is situated behind the second focus. l_1 is negative when situated behind the first focus, and l_2 is negative when situated in front of the second focus. f_1 and f_2, the first and second focal lengths, will be equal if the lens is bounded by the atmosphere in front and behind.

$$\frac{1}{10}=\frac{1}{20}+\frac{1}{b}$$

$$\frac{1}{10}-\frac{1}{20}=\frac{1}{b}$$

$$+\frac{1}{20}=\frac{1}{b}$$

$$+\frac{1}{20}=b$$

It is to be taken into consideration, that the distance of the image *b* (Fig. 10) has a positive sign if it is on the side of the convex lens opposite to the source of light. In this case, the rays converge at *b* into a real image which can be received upon a surface, such as that in the camera obscura of the photographer. It

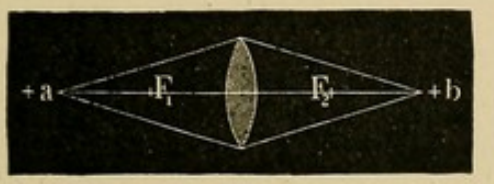


FIG. 10.

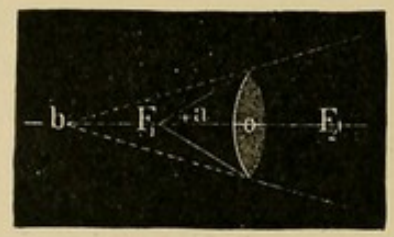


FIG. 11.

is a real image of *a*. If we have, for example, the same lens, but the source of light is only six inches distant, we get

$$\frac{1}{10}=\frac{1}{6}+\frac{1}{b}$$

$$-\frac{1}{15}=\frac{1}{b}$$

$$-\frac{1}{15}=b$$

Now, as the negative sign shows (Fig. 11), the image is situated on the same side as the source of light. The rays which have passed through the lens are converged, but not sufficiently to produce a real image on the opposite side. They simply appear to come from a more distant point *b*. The image is now a virtual one.

It is evident and proven by the formula, that if the rays of light in Fig. 10 had emanated from *b* or if, in Fig. 11, those directed upon *b* had impinged on the lens, its refraction would have caused them to converge upon *a*. On account of this reciprocal relation *a* and *b* are called conjugate foci; at one time *a* is the focus (or image) of *b*, at another time *b* is the focus (or image) of *a*.

We have hitherto referred merely to a point of light, but the image of any illuminated object can readily be determined, if we

know its distance from the lens in the above formula. It is to be noted that the rays which pass through the nodal point of the lens —this coincides with the optical centre *o*, in the biconvex lens— are not converged (so-called direction rays).

If the position of the image of *b*, which belongs to the object *acb* (Fig. 12) is to be constructed, a line is drawn between *b* and *o*

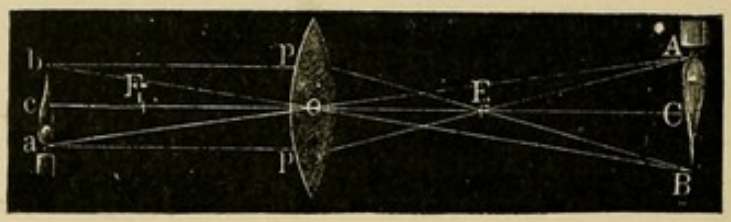


Fig. 12.

and prolonged; this corresponds to the undiverged rays passing through the optical centre of the lens. Then a line *bp* is drawn parallel to the main axis F_1F_2. We know that rays which are parallel to the main axis will, if they impinge upon the lens, pass through the principal focus; hence *bp* goes to F_2. The prolongation of this line meets the prolongation of *bo* at B and thus gives the position of the image of *b*. The position of the image of *a* is determined in the same way. We thus obtain a real reversed, here enlarged image of *bca* in ACB. On the other hand, rays of light which would be emitted by ACB as the source of light, would unite in *bca* in a reversed, smaller image. The size of ACB is proportioned to that of *acb* as their distances from the lens: ACB : *acb*= *Co* : *co*. The distance at which the image develops can easily be calculated according to the lens formula.

If the object *acb* is situated within the focal length of the convex lens, the apparent image ACB is situated, as we have seen

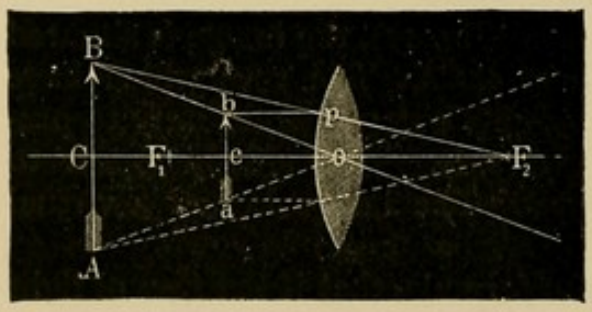


Fig. 13.

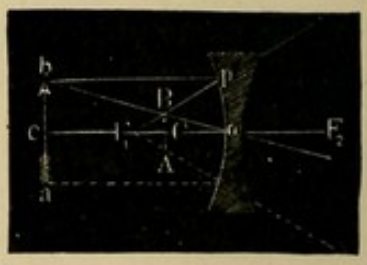


Fig. 14.

above, upon the same side of the lens as the object; it is a virtual, erect, enlarged image. The lines *bo* and bpF_2 do not meet behind the lens, but in their backward prolongation (Fig. 13) upon the side B on which *bca* is situated. In the lens formula $\frac{1}{f}=\frac{1}{a}+\frac{1}{f}$ we then

find that *b* (the distance *Co*) has a negative value. Objects are represented in this manner when we use convex lenses as magnifying glasses.

Concave Lenses.—The spectacle case usually contains biconcave lenses. With regard to their construction, the position of their principal foci and centres of curvature, the same statements hold good as with regard to biconvex lenses. The lens formula is also the same, except that the principal focal length is negative:— $\frac{1}{f}=\frac{1}{a}+\frac{1}{f}$. These lenses refract parallel and divergent rays in such a way that they appear to come from a nearer point on the same side of the lens. The formation of the image is shown in Fig. 14.

F_1 is the focus from which rays that are parallel to the main axis and impinge upon the concave lens appear to come after refraction. The ray *pb* from the object *acb* is therefore refracted in such a way as if it came in the direction of F_1p; the ray *bo* is unrefracted (passing through the nodal point). Both rays meet at B, and this is the image of *b*. Hence a virtual, erect and diminished image ACB is formed. Its distance from the optical centre *o* is furnished by the lens formula. For example, if $f=4$ and $oc=8$, then

$$-\frac{1}{4}=\frac{1}{8}+\frac{1}{b}$$

$$-\frac{1}{4}-\frac{1}{8}=\frac{1}{b}$$

$$-\frac{3}{8}=-\frac{1}{2\frac{2}{3}}=\frac{1}{b}$$

$$b=-2\frac{2}{3}$$

This also gives the size of the image, because *bca*: BCA=8 : $2\frac{2}{3}$.

As the lenses of the trial case are not numbered according to their focal lengths, but according to the radius of the segment of the sphere upon which they are ground, in accurate scientific examinations their focal length must be determined directly. This is also occasionally necessary at other times, when the optician has not cut the number upon the lenses. Snellen and Badal have devised special instruments (phakometer) for this purpose. The principal focal length of convex lenses is easily found by throwing the reverse distinct image of the sun or some other distant object upon a plane surface, and then measuring the distance between the lens and image. In testing concave lenses, we look through the lens at a distant test object, and compare the consequent change or indistinctness with that which appears on looking through a concave lens of known focal distance. If the change in the distinctness of vision is the same, the focal distances of the lenses are also equal.

But this method of examination possesses various sources of error. It is better to use, in making the test, convex lenses of known focal distance. If the focal distance of the concave lens is equal to that of a certain convex lens, no change will appear in looking at a distant test object, when one lens is placed upon the other. Vision is then the same as in looking through plane, parallel glass. If the refracting power of the concave lens is greater, *i.e.*, if the combination of lenses acts like a concave lens, it will be noticed, on moving it from above downward in front of the eye, that the fixed object makes an apparent movement in the same direction as the lens. If the convex is stronger, an apparent movement of the object occurs in the opposite direction, on moving the lens up and down. This depends upon the fact that the prismatic action of the convex and concave lenses comes into play on looking, not through the centre, but through the rims of the lens. The concave lens (Fig. 15) acts as a prism whose base is next to the rim, the convex lens as a prism whose edge is next to the rim.

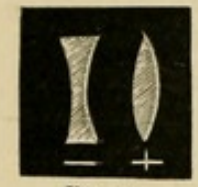


FIG. 15.

Inasmuch as the apparent motion teaches us which of the lenses in juxtaposition is the stronger, we are soon able to find the convex lens of known focal distance which entirely corrects the action of the concave lens, *i.e.*, corresponds to its focal length.

A manipulation which is based on the same principle also shows whether we see through the centre of the lens or through its periphery. With one hand the lens is held at some distance in front of one eye and then, after closing the other eye, we look at two large intersecting lines, for example, a window frame. We then see the middle of the frame through the lens, the peripheral prolongations of the intersecting lines with the unaided eye. The latter form an uninterrupted and direct continuation of the central portion of the frame only on looking through the optical centre of the lens. The

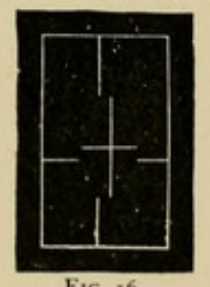


FIG. 16.

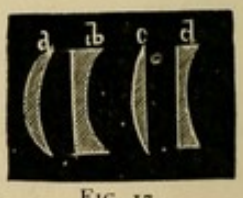


FIG. 17.

latter may be marked with ink by pressing the point of a pen upon that point of the lens whose projection coincides with the intersection of the uninterrupted linear cross. If, on looking through other parts of the lens, the cross appears broken or distorted (Fig. 16), as occurs on looking through peripheral parts in consequence of the prismatic action of the lens, the lens must be moved to and

fro, in front of the eye, until an uninterrupted cross is seen (Knapp). This "centring" of the lenses is important as regards accurate insertion in the spectacle frame.

In addition to biconvex and biconcave lenses, concavo-convex lenses are also used; these have a concave surface on one side and a convex surface on the other side. If the concave surface has a greater curvature, they have a dispersing action (negative meniscus, *b*, Fig. 17); if the convex surface has a greater curvature, they have a converging action (convex meniscus, *a*). These lenses possess the advantage, especially if the concave surface is turned toward the eye, that very slight distortion of the images occurs on looking through the periphery. They have therefore been recommended as periscopic spectacles. In addition, there are also plano-convex *c* and plano-concave *d* lenses. These are very little used because they refract the rays of light which pass through the periphery, even more irregularly (spherical aberration) than do biconvex and biconcave lenses. Like the latter, they also have a prismatic action on looking through the periphery.

The number of trial lenses in use is quite large. As a matter of necessity, the lenses of feeble refracting power are comparatively more numerous. For example, if lens $\frac{1}{6}$ is followed in the spectacle case by lens $\frac{1}{7}$ (difference $\frac{1}{42}$), lens $\frac{1}{60}$ is followed by lens $\frac{1}{80}$ (difference $\frac{1}{240}$). In 1864 Burow expressed the wish that there should be equal differences of refraction between the individual spectacle lenses. With the introduction of the metric system a further step has been taken in this direction, but the necessities of practice have opposed the strict carrying out of an uniform refraction interval. In 1875, the metric system was introduced in measurements of focal lengths, particularly at the instigation of Nagel and Donders. This removed the inaccuracy which lay in the fact that the inch measure does not everywhere possess uniform dimensions. The basis of the entire system is the metre lens (ml), *i.e.*, a lens whose principal focal length is one metre. The refracting power of this lens is known as 1 diopter. A lens of 2.0 diopters has twice the power of refraction, its focal length is ½ m. A lens 3.0 has a focal length of ⅓ m., etc. In order to obtain smaller intervals of refraction, 0.5 and 0.25 diopters were introduced. The weakest lenses were termed fractions of diopters: 0.5 is a lens whose focal length is 2 m.

It cannot be denied that the former method of designating the refracting power of a lens by a fraction was more convenient, as the focal length was shown at once by the denominator. In employing diopters, a division into 1 m. is necessary, in order to obtain the focal length. Absurd figures then result very often, in ex-

pressing the fraction of a metre in centimetres. For example, the focal length of a lens 7.0 is $\frac{1}{7}$ m: 14.285714 . . . cm.!

The conversion from the inch measure into diopters is easy. One metre may be regarded as 40 inches, though it really equals 38.23 inches. But as the biconvex and biconcave trial lenses are numbered by the opticians or lens grinders according to the radius of curvature, and as this is equal to the focal length only when the index of refraction of the glass is 1.5, it is probably quite accurate to regard the refracting power of a biconvex or biconcave lens of 40 inches radius, *i.e.*, $\frac{1}{40}$, as equal to 1.0 diopter, because the focal length is somewhat less, on account of the usually higher index of refraction.

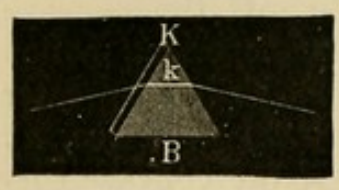


FIG. 18.

In order to convert the refracting power of a lens, which is given in inches, into diopters, the fraction is multiplied by 40; the reverse is done by dividing the number of dioptries by 40. For example, $\frac{1}{20}=\frac{40}{20}$ diopters=2.0; 5.0 D=$\frac{5}{40}=\frac{1}{8}$ according to the inch measure. In order to distinguish trial lenses, which are numbered according to the inch measure and which the opticians usually mark with whole numbers (for example, 8 instead of $\frac{1}{8}$), from those marked according to diopters, the latter are usually provided with a decimal point; for example, 8 diopters is written 8.0.

The lenses hitherto considered are spherical, inasmuch as they correspond to segments of a sphere. Another form of lenses which are constructed out of cylinders, will be discussed later (see Astigmatism).

Prismatic Glasses.—The term prism is applied in optics to a transparent medium which is bounded by two surfaces inclined to one another. The edge K (Fig. 18) of the prism is the line in which the two boundary surfaces unite, or would unite, if sufficiently prolonged; the base is any surface B situated opposite the edge K; the angle of refraction is the angle between the two surfaces of the prism (K). The prism is numbered according to the size of this angle. Thus, a prism of eight degrees is one whose surfaces intersect at an angle of eight degrees. The edge and base of the prisms in our trial cases are usually easily recognized, because they have the shape depicted above. When used in spectacle frames, they have a round shape and this interferes somewhat with the accurate recognition of the situation of the base.

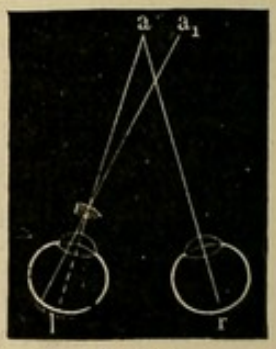


FIG. 19.

Rays which enter a prism are deflected toward the base, and

so much more strongly the greater the angle of refraction. The minimum deflection occurs when the incident rays have the same angle as the prism. In weak prisms, the angle of deflection may be regarded as approximately equal to half the angle of the prism, so that a prism of 10° effects an approximate deflection of 5°. If a powerful prism (about 25°) is held in front of the left eye (Fig. 19) with the base to the outside, and an object *a* situated some distance is fixed, it will be seen double. The naked right eye sees the object with the macula lutea, the centre of the retina, and therefore projects it upon that position in space in which it is really situated. The rays of light which enter the left eye are deflected toward the base of the prism, in this case to the outside. They do not reach the macula lutea, but a portion of the retina situated on its temporal side; the image produced here will be attributed, accordingly, to an object situated to the nasal side; double images are formed, which lie alongside of one another. In this experiment it is easily seen that the deflection of the rays differs according to the direction in which they impinge upon the prism, in other words, according to the angle of incidence. If the prism in front of the left eye is turned upon its vertical axis in such a way that, for example, the edge is turned away from the eye, the distance between the double images will increase.

If the rays of different colors pass through a prism, they experience a deflection of varying degrees. Violet light is deflected most, red light least. White sunlight is thus resolved into its constituent rays (spectrum colors).

The larger spectacle cases contain prisms from one to eighteen degrees. Only the weaker ones (up to six degrees) are used in spectacle frames, because stronger ones would be too heavy and, on peripheral vision, would produce marked deflection and dispersion of colors. The introduction of prismatic lenses in practical ophthalmology originated with Donders, as did the stenopaic apparatus. These are opaque cups or plates with small round openings or linear slits. Their name is derived from στενός narrow and ὀπή peep-hole. They permit the entrance of light into the eye only through the opening and thus exclude a large part of the rays. This is occasionally advantageous if the refraction in the excluded part is so irregular as to give rise to disturbances of vision. The exclusion of the peripheral, diffuse illumination of the retina through the sclera is also important, in some cases, in securing improvement of vision.

Instruments for the Measurement of the Smallest Images.—Helmholtz measured the radius of curvature of the cornea by means of the ophthalmometer. It is based upon the fact that the cornea

acts like a convex mirror (or like the reflecting globes placed in gardens) and forms smaller, erect images of distant objects. The construction of these images is evident from Fig. 20. From the object A the line *As* is drawn parallel to the main axis to the surface of the mirror. The rays passing in this direction are deflected through the focus F_1; then a line is drawn from A toward the centre of curvature of the mirror C; the corresponding ray will be undeflected. The image of A is situated at *a*, the intersection of sF_1 and AC.

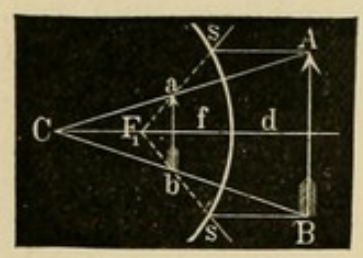


FIG. 20.

These images are larger when the radius of curvature of the mirror is larger, smaller when this radius is smaller, because the principal focal length of the convex mirror is half its radius of curvature and, as we have seen in the case of convex lenses, the size of the object is to the size of the image as the distance of the object from the mirror is to the distance of the image. If the object is so remote or so small that the rays emerging from it and impinging upon the middle of the mirror may be regarded as approximately parallel, the image will be formed at the focus of the mirror. In this event, $\frac{AB}{ab}=\frac{d}{f}$. But as the focal length of the convex mirror (f)=half the radius of curvature,

$$\frac{AB}{ab}=\frac{d}{\frac{1}{2}r} \text{ or } \frac{1}{2}r=\frac{ab.d}{AB}$$

If an object of known size A is placed at not too small a distance *d* from the eye, and the mirror image *a* which is formed behind the cornea is measured, the radius of curvature is obtained according to this formula. Helmholtz's ophthalmometer utilizes the displacement which an object undergoes when seen through an obliquely held glass plate, in order to measure the small mirror images. When two plane glass plates which lie upon one another, and are in contact at the edges, are turned in opposite directions in front of a spy-glass, the fixed image will be displaced by one plate to the right, by the other to the left. If the displacement has become so great that the images are only in contact at the edges, the displacement, as a matter of course, is equal to the size of the images. If it has been determined empirically with the ophthalmometer that a rotation of the glass plates through so and so many degrees effects a displacement of so and so many millimetres, the size of the image observed can be accurately determined from the amount of rotation.

The Javal-Schloetz apparatus may also be used to advantage for finer measurements. Its principle is the following: the corneal

mirror image is furnished by a square of white paper, that may be made larger and smaller. The mirror image is not looked at directly, but through a tube (situated behind the paper square) which has an objective at the end next to the observer's eye. In the first place the objective forms, through a convex lens, a reversed real image of the corneal image, and, in the second place, it doubles it by means of a double refracting calc spar prism, situated behind it (as was employed before by Coccius). The action of this prism is such that, at the corresponding and constant distance of the instrument from the eye, a corneal image (*a*, Fig. 21), which is 3 mm. wide, appears double *aa*, in such a way that the edges are in contact. By diminishing or enlarging the size of the paper square which furnishes the mirror image, until the double mirror images just come in contact with one another, a corneal image 3 mm. in size may be created. The size of the paper square necessary for this purpose is easily read off, and from this the corresponding radius of the cornea may be calculated.



FIG. 21.

Simpler methods suffice for practical purposes. Hirschberg's keratoscope is very useful. The keratoscope, fastened to a stand, is placed opposite the individual to be tested. While he fixes the centre of the keratoscope, the observer watches the mirror image on the cornea through the opening in the instrument. Behind and below the keratoscope is a millimetre scale, which is reflected in a small oblique mirror, situated above the peep-hole. On looking through the opening, this image of the millimetre scale may be made to cover the image of the keratoscope thrown by the cornea, and thus the size of the latter approximately measured.

2. PHYSIOLOGICAL OPTICS.

According to Donders, the average size of the corneal radius at the point where it is intersected by the line of vision is 7.8 mm in normally refracting eyes. But measurements with the Javal-Schloetz instrument, which are easily made, have shown that there are marked individual variations that are connected, in part, with the size of the individual. The radius of the vertical meridian is usually smaller than that of the horizontal meridian; hence the cornea possesses a greater vertical curvature. The radius of curvature of the anterior surface of the lens is 10 mm., that of the posterior surface 6 mm. The index of refraction of the cornea, vitreous body, and aqueous humor is about 1.33, that of the crystalline lens 1.43.

A schematic eye has been constructed on the basis of these measurements for the purpose of optical considerations and calcu-

lations. This furnishes the position of the so-called cardinal points which are requisite in the calculation of compound optical systems. There are three pairs of cardinal points in every centred system, *i.e.*, a system in which the centres of the spherical surfaces are situated in a straight line, the principal axis of the system. We have already learned one pair, the foci, in discussing biconvex lenses. We distinguish the first focus f_1, in which parallel rays impinging upon the optical system from the right side are united in one point; and the second focus, f_2, which is the point of union of rays coming from the left. The distance of the focus from the optical centre is called the focal length (1 or 2). But this is only approximately true; the focal length is really the distance between the focus (1 or 2) and the main point (1 or 2). Both main points (or the main planes indicated by them) are characterized by the fact that an image (of equal size and direction) of an illuminated object situated in the first main point, will develop in the second,

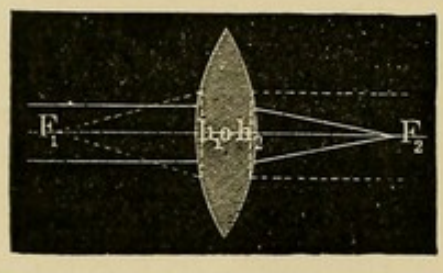


FIG. 22.

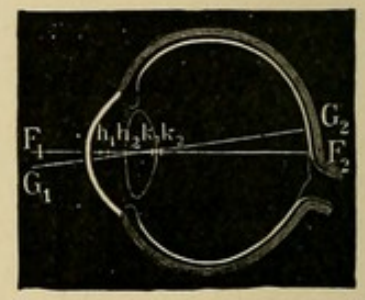


FIG. 23.

if the rays have been refracted by the entire system. The third pair of cardinal points, the nodal points, are determined by the fact that each ray, which passes through the first nodal point before refraction, passes through the second one after refraction, and thus remains parallel to its first direction. Their distance from one another is equal to that between the main points. In biconvex lenses both nodal points coincide with the main points ($h_1=k_1$ and $h_2=k_2$) if the lenses have the same medium in front and behind. We have already seen that, under such circumstances, both principal focal lengths are equal. This proposition is based upon the fact that in optical systems the two principal focal lengths correspond to the exponents of refraction of the first and last medium.

In the eye, in which the rays from the atmosphere enter the more strongly refracting ocular media, the first (anterior) and second (posterior) focal lengths are not equal. Helmholtz (1886) furnished the following figures for the schematic eye constructed by Listing: the anterior focus is situated 13.745 mm. in front of the apex of the cornea; the first main point 1.753 mm., the second 2.106

mm., the first nodal point 6.968 mm., the second nodal point 7.321 mm., the second focus 22.819 mm. behind the apex of the cornea. F_1 F_2 (Fig. 22) is the axis of the eye; this is not coincident with the visual line, G_1 G_2 (line connecting the macula lutea and the seen object). On a horizontal section the latter usually passes through the cornea, to the inside of the former.

The use of a still simpler ocular model, the reduced normal eye of Donders, is sufficient for the calculations of ophthalmological practice. This is represented by a single curved refracting surface of 5 mm. radius. The common chief point lies at the apex, the common nodal point 5 mm. posteriorly in the centre of curvature. Air is situated in front of the eye, water within it.

The index of refraction of the water n is $\frac{4}{3}$, *i.e.*, when a ray of light passes from air into water, it is deflected in such a way that

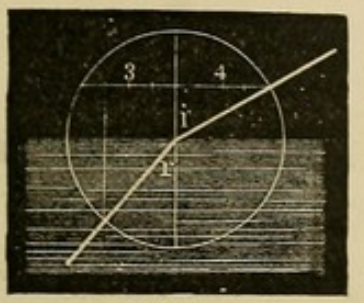


FIG. 24.

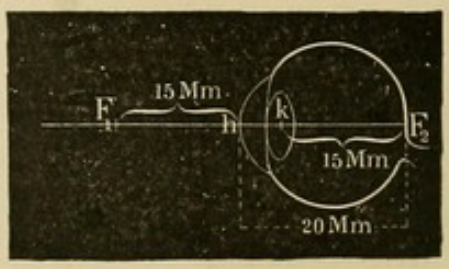


FIG. 25.

the sine of the angle of incidence (i) is to the sine of the angle of refraction (r) as 4 : 3 or $\frac{\text{sine } i}{\text{sine } r} = w$. The opposite condition holds when the ray of light passes from water into air; its exponent of refraction is 3 : 4. The greatest possible value of the angle of incidence is 90°, when the ray of light is parallel to the surface of the water.

In this event sine i=sine 90°=1, and $\frac{1}{\text{sine } r}=n$; sine $r=\frac{1}{n}=\frac{3}{4}$ =0.75. Inasmuch as 0.75=sine 48° 28′, this is the boundary angle for air and water. If a ray of light in the water would reach the surface of the water at this angle (r), it would be parallel to the surface of separation on passing into the air. But if the angle (r) is greater, the angle i becomes greater than 90°, *i.e.*, the ray of light in the water does not enter the air, but is reflected in such a manner at the surface of separation that it remains in the water. This is known as total reflection. This (so far as it occurs between air and water in which $n=\frac{3}{2}$) is utilized in some ophthalmoscopes.

The anterior focal length (F_1h, Fig. 25) of the reduced eye is 15 mm., the posterior (F_2h) 20 mm. The calculations are made according to the formula $l_1 l_2 = f_1 f_2$.

3. Refraction and Accommodation.

I. *Refraction.*

The schematic eye furnishes us with the picture of a normally refracting eye in a condition of rest. Hence it is accommodated for parallel rays; the retina lies in the principal focus of an optical system. Donders, to whom, with Stellwag, we owe the elucidation of this subject, has applied to it the term "emmetropic eye" (ἔμμετρος, holding the mean, ὤψ, the eye). We may accordingly define an emmetropic eye as one which will unite parallel rays in a sharp image upon the retina. This is true only of central rays which unite in the macula lutea, or its vicinity; peripheral parallel rays do not converge, even in an emmetropic eye, into a sharp image upon the retina.

It is presupposed that the eye is in a condition of rest, *i.e.*, that the accommodation—which, by increasing the curvature of the crystalline lens, enables us to converge into a distinct retinal image even those rays which come from a very near object—is completely relaxed.

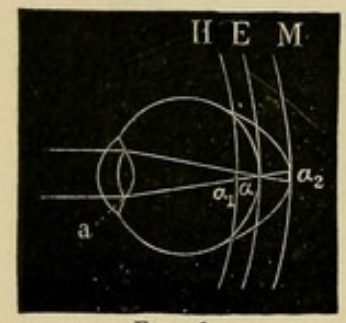


Fig. 26.

All measures of refraction deal with the eye at rest, *i.e.*, accommodated for distance. The far-point of the emmetropic eye is situated at an infinite distance, inasmuch as it unites upon its retina the parallel rays which come from that distance.

Still assuming the absence of accommodation, eyes in which parallel rays do not unite upon the retina are called ametropic. As a rule, this deviation does not depend upon a difference in the refracting power of these eyes (refraction ametropia), but upon a different length of the ocular axes (axial ametropia). If the axis is too long, there is myopia (brachymetropia, short-sightedness); if it is too short, hypermetropia (hyperopia, far-sightedness). As Fig. 25 shows, the principal focus—assuming equal refraction of the ocular media—is situated in front of the retina M, in the longer myopic eye, and behind the retina H, in the hyperopic eye. In both cases, therefore, no sharp images of parallel rays, but circles of dispersion (at a_1 in H, and a_2 in M) will form upon the ametropic retina.

The myopic eye requires concave lenses in order to converge parallel rays upon its retina. The lenses disperse the parallel rays and convert them into diverging ones. If the lens is properly adapted to the corresponding length of the ocular axis, it will cause such a degree of divergence of the rays that they will be united in

a point (sharp image), upon the retina (*m*, Fig. 26) after the refraction of the ocular media has acted upon them. The refracting power of the correcting concave lenses expresses the degree of shortsightedness. For example, if a short-sighted person forms a clear image of parallel rays with −20.0 (concave ½ according to inches), the shortsightedness is known as 20.0 or M (myopia) 20.0 (M ½ according to the inch scale). Concave 20.0 disperses parallel rays so that they appear to come from a distance of $\frac{1}{20}$ m. (+R, Fig. 26). If we disregard the distance of the concave lens from the eye, this also expresses the fact that the eye is accommodated optically for divergent rays which come from a distance of $\frac{1}{20}$ m.; its far-point (R) is situated 5 cm. in front of the eye.

The hypermetropic eye requires convex lenses in order to unite parallel rays upon its retina. As the length of its axis is less than that of the emmetropic eye, parallel rays—again assuming equal refractive power of the optical media—would be collected into a

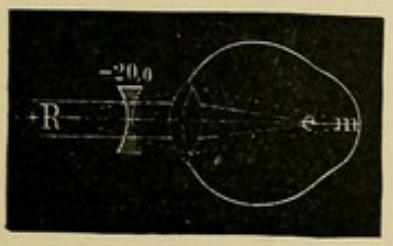


FIG. 27.

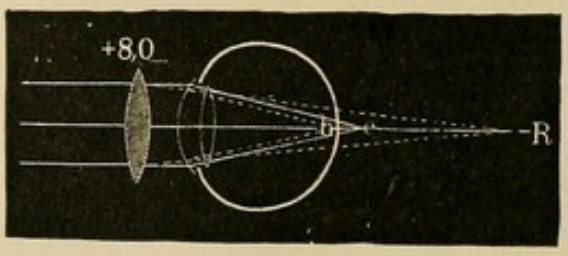


FIG. 28.

point (*e*, Fig. 27) behind the retina. The convergence of the rays upon the retina *h* is secured by the selection of a correspondingly strong convex lens. The refracting power of the correcting convex lens expresses the degree of hyperopia. For example, if a hypermetrope can see distant objects sharply with 8.0, his hypermetropia is 8.0. His eye is really accommodated for convergent rays of light, the far-point of the eye is situated at the place where these rays—if the refraction of the eye did not come into play—would unite, *i.e.*, behind the eye (−R). In order to indicate this position or direction, we say that the hyperopic eye has a negative far-point; in our illustration this would be ⅛ m. behind the eye.

The three conditions of refraction may be arranged in the following table: (p. 36.)

II. *Accommodation.*

The eye may see distinctly at various distances by "accommodating" itself to the corresponding rays of light. When the accommodation is abolished, it is adjusted for its far point.

	Emmetropia.	Myopia.	Hyperopia.
Parallel rays unite	upon the retina.	in front of the retina.	behind the retina.
The far-point (punct. remotissimum = R) is situated	at an indefinite distance	at a certain finite distance in front of the eye (+)	at a certain finite distance behind the eye (—)
The eye, in a condition of rest, is accommodated	for parallel rays.	for divergent rays.	for convergent rays.
In a condition of rest it sees distant objects (∞)	without lenses.	with concave lenses.	with convex lenses.

Rays which would now enter the eye from a nearer point (p, Fig. 29) would only unite behind the retina and would form a confused image upon the retina. In an emmetropic eye (adjusted, accordingly, for parallel rays) the rays coming from p, for example, would unite at p_1. In order to unite upon the retina, they must be refracted more strongly. This is effected by increasing the curvature of the crystalline lens l. Its own power of refraction is then increased by the refracting power of the convex lens a (Fig. 30), which is marked by oblique lines. If this increase in the power of refraction corresponds to the divergence of the

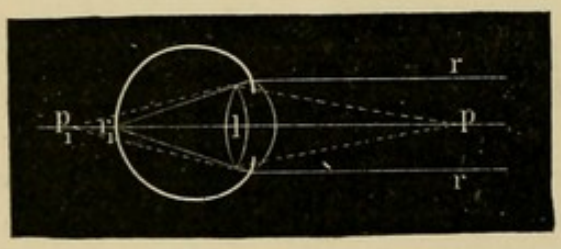


Fig. 29.

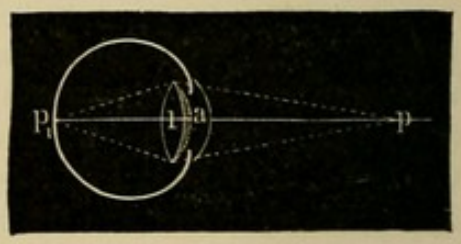


Fig. 30

rays emanating from the point p, these will unite upon the retina at the point p_1; p is seen distinctly. It follows, as a matter of course, from this increase of refractive power ($um \frac{1}{a}$) that parallel rays will now unite in front of the retina and therefore form indistinct images. At any single moment, the eye can be accurately adjusted optically for only a single distance.

This is easily observed. For example, if we look through a pane of glass which contains bubbles or other small imperfections at an object situated outside, the latter appears distinct; hardly anything is seen of the bubbles in the pane of glass, because they only form circles of dispersion on the retina. But if we direct our

attention to the pane of glass, the bubbles and imperfections stand out sharply and the former fixed object becomes confused. A similar proof is usually secured by Scheiner's experiment, in which we employ an opaque card, perforated by two small openings in close apposition to one another. These openings are in such close juxtaposition that they both fall within the territory of the pupil, when held before the eye. If we look through them at a small object, such as the head of a pin A, this appears sharp and single when accommodation is good. But if a second pin is held in front of, or behind the first, while the latter is permanently fixed, the image of the second one (B) is confused and double. This also happens when the first pin is moved so far from or toward us that the eye can no longer accommodate. The double vision is explained by Fig. 31. The rays emanating from B unite behind the retina, and form upon the latter two circles of dispersion, b_1 and b_2, which are separated by an unilluminated space, corresponding to the piece of cardboard situated between the openings.

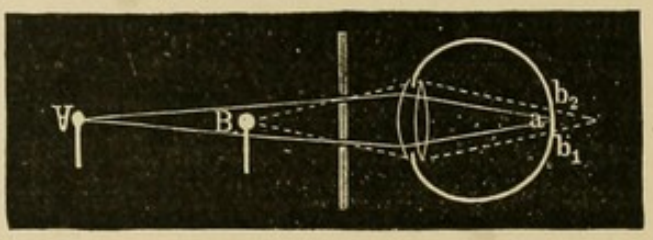


FIG. 31.

The change in the curvature of the crystalline lens during accommodation for near objects, can be demonstrated upon the living eye. On looking into the eye from the side, the increase in the convexity of the anterior surface of the lens is especially distinct, and is associated with an advance of the rim of the pupil toward the cornea. The curvature of the posterior surface of the lens also increases, although to a less extent. The lens, therefore, grows thicker on looking at near objects. These changes have been carefully studied by measuring the mirror images furnished by the lens (M. Langenbeck, Cramer, Helmholtz), like the measurement of the curvature of the cornea; on increase of the curvature the images diminish in size. If, in an otherwise dark room, a lamp is placed to the side and on the same level as the eye to be observed, in such a way that its rays of light enter the pupil of the eye, we can recognize, on looking into the eye from the opposite side, the diminished images of the flame. The first is a very bright, erect image, furnished by the cornea which acts as a convex mirror; next, a very much feebler and more confused, but larger image on the convex anterior surface of the lens, and finally a smaller, inverted image, which appears as a bright point, from the concave posterior surface of the lens. If the observed eye accommodates for near objects, the image of the anterior surface of the lens becomes smaller and

usually approaches the middle of the pupil (Purkinje-Sanson's experiment). Among the other changes observed during accommodation, an important one is the contraction of the pupil, associated with slight displacement to the nasal side. Contraction of the pupil is also observed when both eyes are converged upon a near object, *i.e.*, coincidently with the contraction of the internal recti. Under ordinary circumstances, the convergence of the visual axes is associated, as a rule, with a corresponding accommodation upon the fixed point, and it is difficult to decide whether the contraction of the pupil is associated with the convergence or with the accommodation. But inasmuch as, without any variation in convergence, accommodation may be changed, either by practice or by the application of concave lenses, in using which the eye must accommodate differently in order to maintain the fixation of a certain object, it can be proved that the pupillary change is associated with accommodation alone (Cramer, Donders). Nevertheless I find that accommodation and convergence produce greater contraction of the pupil than the former alone. The contraction of the pupil has no direct influence on the production of accommodation. Cases are known in which there was complete power of accommodation despite the absence of the iris (v. Graefe). It has not been proven that accommodation for near objects can be effected by other factors, such as changes in the curvature of the cornea or elongation of the ocular axis by the pressure of the external ocular muscles. Without the crystalline lens there is no accommodation.

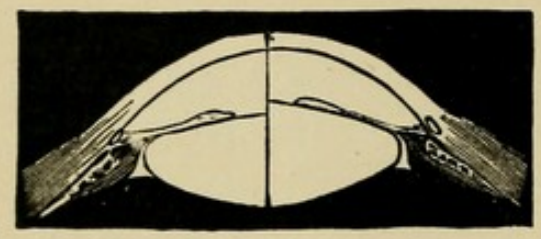


FIG. 32.

The changes in the curvature of the crystalline lens during accommodation are effected by the action of the ciliary muscle or tensor of the choroid (Bruecke). According to Helmholtz, whose opinions were confirmed by later investigations (especially by Hensen and Voelckers) the act of accommodation is explained in the following way. During the condition of rest of the eye (adjustment for distance) the zonula Zinnii, which lies between the ciliary body and the rim of the lens, as a suspensory ligament of the latter, is so tense that the inherent tendency of the lens to an increased curvature (the lens has a much greater curvature after removal from the eye) cannot come into play. The contraction of the circular fibres of the ciliary muscle (*see* the Anatomy of the Uveal Tract) diminishes the circle around the lens, and thus makes the zonula less tense. This diminution of tension is increased still further by the fact that, at the same time, the longitudinal fibres of

the ciliary muscle, whose anterior insertion is situated in the region of the scleral limbus, its posterior insertion at the periphery of the choroid, draws the latter membrane forward. The crystalline lens, yielding to its elasticity, is curved still further; it becomes thicker in the middle, its equator grows smaller.

Among further changes in accommodation, it may be mentioned that the ciliary prolongations swell (Coccius, Hjort), the intraocular pressure increases, the globe protrudes somewhat, and the upper lid is raised (Donders).

The innervation of the muscle of accommodation is accomplished by branches of the third nerve, whose cells of origin lie at the floor of the third ventricle, separated from the somewhat posterior nucleus, from which the fibres supplying the external ocular muscles arise.

According to the above presentation, the eye is adjusted for the far-point when the ciliary muscle is at rest, for near-points during contraction of the muscle. Despite the assumptions of certain authors, it is not probable from the data at our command that this muscle may also effect a flattening of the lens, *i.e.*, its adjustment beyond the ordinary far-point (negative accommodation). The accommodation impulse occurs with equal intensity in both eyes (Hering). This is especially important in individuals whose eyes possess different power of refraction. Compensation by different degrees of accommodation for both eyes is impossible (Schweigger). It is only in imperfect binocular vision that an absence of accommodation may occur upon the excluded eye (Werth).

Range of Accommodation.—The range of accommodation includes the entire extent of distinct vision, *i.e.*, the distance between the far and near points. The near-point (P) is that point nearest to the eye which can still be seen sharply, with the greatest possible exercise of the entire power of accommodation; if the test object is brought still nearer, it looks blurred.

In order to have a comparable measure of the range of accommodation ($\frac{1}{a}$ or, according to diopters, a) under different circumstances, Donders expressed it by the refracting power of the convex lens which converges the rays coming from the near-point (*i.e.*, more strongly diverging) as if they came from the far-point R. Hence the range of accommodation furnishes the expression for the vital increase of curvature which the crystalline lens must assume in accommodating for the near-point. We will assume that in Fig. 33 the lens $\frac{1}{1}$ represents the refracting power of the eye, *i.e.*, the refracting power which unite rays that come from the far point R

into one point upon the retina. In order that rays from the near-point P should unite upon the retina, the refracting power must be increased by accommodation. In Fig. 33 let this increase in the curvature of the crystalline lens be expressed by the convex lens $\frac{I}{A}$. This will possess the suitable refracting power, when it converges the rays coming from P as if they came from R; in an emmetropic eye when it makes them parallel. We find the value of $\frac{I}{A}$ by the previously mentioned formula for convex lenses $\frac{I}{f}=\frac{I}{a}+\frac{I}{b}$. Here f is the focal length of the convex lens (A), which converges rays coming from an object situated at P, in such a manner that they unite in an image at b, or, if the image is a virtual one, that they appear to come from b (here R). As we have seen, the position of the image is expressed with the positive sign in the formula when the image is on the other side of the lens, *i.e.*, where the object really exists; if it is on the other side it is negative. The latter occurs only in emmetropic and myopic eyes. Here the far-point is on the same side as the near-point (in front of the eye). In such eyes the formula for the range of accommodation will read:

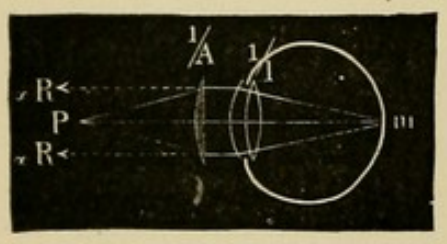


FIG. 33.

$$\frac{I}{A}=\frac{I}{P}-\frac{I}{R}$$

In hypermetropic eyes, on the other hand, the far-point is situated behind the eye, *i.e.*, on the other side. Hence the formula becomes:

$$\frac{I}{A}=\frac{I}{P}+\frac{I}{R}$$

If desired, the first formula for the range of accommodation may be retained, but the distance from R in the hyperopic eye must then be made negative:

$$\frac{I}{A}=\frac{I}{P}-(-\frac{I}{R})$$

Illustrations. Emmetropia and near-point at four inches; then, inasmuch as R is at an infinite distance in emmetropia, the formula becomes:

$$\frac{I}{A}=\frac{I}{4}-\frac{I}{\infty}=\frac{I}{4}$$

Myopia $\frac{1}{20}$, near-point 3 inches: $\frac{I}{A}=\frac{I}{3}-\frac{I}{20}=\frac{17}{60}=\frac{I}{3\frac{9}{17}}$

Hyperopia $\frac{1}{30}$, near-point 6 inches: $\frac{1}{A}=\frac{1}{6}+\frac{1}{30}=\frac{1}{5}$

Donders has changed this formula of the range of accommodation in such a way as to employ it for diopters.

On studying the formula closely, it will be found that each part expresses the reciprocal value of the corresponding focal length, *i.e.*, the refracting power of the corresponding lenses. In using diopters which, as we have seen, are an expression of refracting power, the formula must be expressed not in fractions, but as follows: $a=p-r$ (Donders).

The following are a few illustrations. 1. Emmetropia; near-point at 25 cm. The far-point of E is at an infinite distance, the refracting power of a lens with a focal length of ∞ metre is $\frac{1}{\infty}=0$, therefore $r=0$. p is the refracting power of a lens with a focal length of 25 cm. or $\frac{1}{4}$ m., therefore equals 4.0 diopters. Hence $a=4.0$. 2. Myopia 1.0, near-point at $\frac{1}{3}$ m. Then $a=5.0-1.0=4.0$. 3. Hyperopia 2.0, near-point at $\frac{1}{2}$ m. Then $a=2.0-(-2.0)=4.0$. The addition of the 2.0 diopters in hyperopia is also explained on comparing the process of accommodation with that in the emmetrope. While the latter requires no accommodative increase of the curvature of the lens, in order to unite parallel rays upon the retina, the hyperope 2.0 must accommodate these 2.0 diopters. Then the requisite curvature of the lens for the near-point occurs in both in the same way.

The last examples also show that the same range of accommodation (4.0) or the same increase in the curvature of the crystalline lens is necessary, in order to accommodate, 1st, from an infinite distance to 25 cm. or, 2d, from 100 cm. to 20 cm. or, 3d, from 50 cm. negative or an infinite distance on the other side to 50 cm. The optical value of the range of accommodation therefore furnishes no information concerning the distance over which distinct vision is possible.

The range of accommodation is either determined for each eye alone (absolute range of accommodation a) or for both eyes together (binocular range of accommodation a_2). a and a_2 vary in amount. This is owing to the influence exerted by the convergence of the visual lines upon the degree of possible accommodative tension. It was formerly believed that convergence of the visual lines and accommodation coincided. For example, if both eyes were directed upon a point 25 cm. distant, the eyes were also supposed to be accommodated for this distance and could not undergo any change in their condition of accommodation. But Volkmann (1836) and particularly Donders (1846) showed that this is

not true. There is indeed a certain connection between convergence of the visual lines and accommodation, but it is a variable one. We can easily convince ourselves of this, by fixing test type held at a certain distance and then placing feeble concave and convex lenses in front of the eye. The type can be seen and read distinctly with quite a considerable series of such lenses. Hence, in order to compensate the refraction of the rays of light produced by the lenses, there must be a change in the refracting power of the eye by increase of curvature (when the lens used is concave), or diminution of the curvature (when the lens is convex). Changes of accommodation thus occur despite the same degree of convergence of the visual lines.

On the other hand, it may be shown that, while the accommodation for the test type remains the same, the convergence of the visual lines may change, for example, when squint is induced by placing a not too strong prism (with its base to the inside) in front of the eye.

Let us return to the experiment of holding spherical lenses before the eyes. It then becomes evident that, on fixation of a near object, accommodation may be relaxed (as is proven by the ability to see with the aid of certain convex lenses), and the optical adjustment for a more distinct object may thus actually be made; but that adjustment for the true far-point, such as the eye possesses on looking at a distance with approximately parallel visual lines, cannot be effected. A certain degree of accommodative tension remains associated with the convergence of the visual lines; the stronger the convergence the greater the tension. The most marked convergence also enables us to secure the greatest accommodative tension. This occurs when the visual lines converge still more strongly than the proximity of the very near test object requires. Let us assume that both eyes of an emmetrope are directed upon an object situated at a distance 10 cm. in the median line between both eyes, and can see it distinctly, then the necessary power of accommodation = 10.0. If the object approaches still more closely, to 8 cm., the eyes may still be converged for this distance, but can no longer be accommodated; the eye does not possess the necessary power of accommodation of 12.5 diopters ($\frac{100}{8} = 12.5$). Nevertheless the increased convergence causes a change of accommodation in so far as to make it somewhat greater than in convergence on 10 cm., and the optical adjustment is thus made for a somewhat nearer object (about 9.5 cm.). But as the eyes converge to 8 cm. and not to this distance, the image of the object does not reach identical parts of the retina and appears double. The diplopia may be avoided if one eye is covered while the other

alone sees. It is then also possible that the covered eye converges still more (*i.e.*, squints inward) and that the accommodative tension induced thereby, and which also comes to the aid of the open eye, may qualify the latter for increased accommodation.

The monocular test, therefore, secures a nearer near-point than the binocular, and thus the absolute range of accommodation ($a=p-r$) is also greater than in binocular vision ($a_2=p_2-r_2$); the far point remains in the same position in both cases.

The range of accommodation plays a great part in occupations at a short distance. In emmetropes and hyperopes, its diminution is apt to produce lack of endurance and symptoms of exhaustion, to which we will again refer later. Its examination is therefore practically important. This is also true of the third form or the relative range of accommodation (a_1). On every convergence of the visual lines accommodation may still vary, as we have seen, within certain limits. This can be expressed by the sum of the refracting power of the strongest concave lens and also of the strongest convex lens, which can be overcome while looking at an object which remains at the same distance. It is "relative" to the convergence or, in other words, to the distance of the fixed object. There are, therefore, as many relative ranges of accommodation as there are convergences of the visual lines. Of special importance is the range of accommodation for that convergence which the eyes must assume, in ordinary near work (for example, in reading).

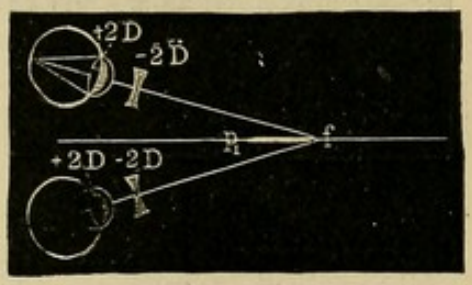


FIG. 34.

In Fig. 34 both eyes converge toward *f*. Let us assume that, with coincident accommodation, the crystalline lens of each eye has a refracting power of three diopters. If convex lenses are placed in front of both eyes, the point *f* can still be seen distinctly so long as compensation for the dispersing power of the lenses is possible by increased accommodation, *i.e.*, by increase of the curvature of the crystalline lens. By applying concave lenses of various strengths, we find, for example, that distinct vision is still possible with -2.0, but not with -2.5; -2.0 then indicates the maximum increment of accommodation which the eye can furnish, while maintaining the convergence on *f*. This lens will, therefore, express directly the increase in the curvature of the crystalline lens, provided that we neglect the slight difference arising from the fact that the concave lens is situated in front of the eye. The shaded portion of the crystalline lens indicates this increase of curvature ($=2.0$).

The latter actually adjusts the eye to a point p, which is nearer than f. Its position is easily ascertained by the lens formula, as we will show later by an illustration.

On the other hand, convex lenses are used in order to secure the greatest possible relaxation of accommodation, again with convergence of the visual lines on f. The strongest lens with which f (Fig. 35) can still be seen distinctly, corresponds to the greatest possible flattening of the crystalline lens. If, for example, the convex lens 1.0 is the proper one, the compensating diminution in the curvature of the crystalline lens, indicated by the shaded portion, is equal to 1.0.

This greatest flattening of the crystalline lens indicates the condition of rest of the eye or its accommodation for the far-point, such as is possible while maintaining the convergence upon f. The increase of curvature which the crystalline lens can undergo from this condition of rest, gives us the relative range of accommodation (a_1); the latter, therefore, $= 1.0 + 2.0 = 3.0$. The convex lens (2.0) corresponds to the still possible increase of accommodation while the convergence was maintained, the convex lens (1.0) the still possible relaxation. The first portion (fp_1 in the figure) is called the positive range of accommodation, the other (fr_1) the negative range.

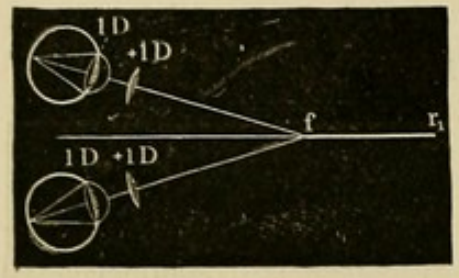


FIG. 35.

The relative range of accommodation can also be ascertained in another way with the aid of the range of accommodation in formula $a_1 = p_1 - r_1$. This will be shown by an illustration. Both eyes are fixed and accommodated upon test type at a distance of 30 cm. Concave lenses of equal focal lengths, passing gradually from weaker to stronger ones, are now held in front of both eyes. Let us assume that 4.0 D is the strongest concave lens with which distinct vision is just barely possible. The same manipulation with convex lenses, 2.5 being the strongest one which can be overcome. The positive range of accommodation then $= 4.0$, the negative range $= 2.5$; the entire relative range of accommodation for a distance of 30 cm. $= 6.5$ according to this calculation. Let us now calculate where the relative near-point (p_1) really is, *i.e.*, for which rays the eye accommodates when they start at a distance of 30 cm. and are refracted by a concave lens 4.0. In the lens formula $\frac{1}{f} = \frac{1}{a} + \frac{1}{b}$ $f = -25$ cm. (*i.e.*, the focal length of the concave lens 4.0), $a = 30$ cm. and $b = p_1$. Then, $-\frac{1}{25} = \frac{1}{30} + \frac{1}{p_1}$; $\frac{1}{p_1} = -\frac{1}{25} - \frac{1}{30} = -\frac{1}{13\frac{7}{11}}$ cm. The

near-point p_1 therefore is $13\frac{7}{11}$ cm. in front of the eye (or of the concave lens held in front of the eye), because the negative sign indicates that it is situated on the same side of the lens as the fixed object *f*. The far-point is calculated in the same way. As the rays are refracted by a convex lens 2.5 (=40 cm. focal length), $\frac{1}{40}=\frac{1}{30}+\frac{1}{r_1}$; $\frac{1}{r_1}=\frac{1}{120}$ cm., $r_1=120$ cm.

The extent of the entire relative range of accommodation is, therefore, from $13\frac{7}{11}$ cm. (p_1) to 120 cm. (r_1). The distance from $13\frac{7}{11}$ to 30 cm. is positive, that from 30 cm. to 120 cm. is negative.

According to the accommodation formula, $a_1=\frac{1}{13\frac{7}{11}}-\frac{1}{120}=$ 7.33 D−0.83 D=6.5 D, the same result that was obtained above.

The measurement of the relative range of accommodation is of special practical importance because accommodation can be maintained for a long time and without exhaustion for such a distance in which the positive part (here 4.0) is large in comparison with the negative part (here 2.5). It is also important with regard to the selection of spectacles, inasmuch as it possesses different dimensions in the various conditions of refraction (despite the same distance of the point of convergence. This is easily seen from the following illustration. When an emmetrope converges to 20 cm., his relative far-point is situated about at a distance of 50 cm., his relative near-point at 10 cm. If a myope 8.0, whose absolute far-point is at a distance of 12.5 cm., also converges his eyes upon an object 20 cm. away, his relative far-point is about at 12 cm., his relative near-point at 9.5 cm.; *i.e.*, his entire relative range of accommodation is situated on this side of the point of convergence and is positive. Donders' investigations in this direction have shown that, 1st, with parallel rays the emmetropic eye can utilize about $\frac{1}{3}$, the myopic eye only $\frac{1}{4\frac{1}{2}}$, the hypermetropic eye $\frac{3}{8}$ of its absolute power of accommodation; 2d, with slight convergence the myopic eye has much less, the hypermetropic eye much more power of accommodation than the emmetropic eye; and 3d, with marked convergence the power of accommodation of the myopic eye increases very much, that of the hypermetropic eye increases but slightly. If the attempt were made to convert a myopic or hypermetropic eye into an emmetropic eye by means of corrective lenses with which the far-point is removed to infinity, this could not succeed completely, because the relative range of accommodation is different, and at first will remain so. But inasmuch as exercise and habit effect changes, the eyes of youthful individuals, who are ametropic, but are corrected by constantly worn glasses,

may gradually be made equal to emmetropic eyes in their relative range of accommodation.

III. *Presbyopia.*

The extent of the range of accommodation depends upon the age. It is greatest in youth and gradually diminishes with years. In the thirtieth year it is about half as large as in the tenth year. Its diminution results from the gradual removal of the near-point from the eye. At the age of forty years it is situated about at the distance of 22 cm. in emmetropes. Its further removal is usually associated with inconveniences in certain near work (for example, in reading fine print) and will tire the eyes after a time. Hence, this is regarded as the beginning of presbyopia. This signifies, therefore, a physiological diminution of the range of accommodation, corresponding to the age, in which the near-point is removed farther than 22 cm. (or eight inches, as was formerly assumed) from the eye. It is distinguished from paralysis of accommodation, which is also manifested by diminution or abolition of the range of accommodation, by the fact that the latter is pathological, while presbyopia is physiological and develops in a degree corresponding to the age. In order to determine the latter, certain data must be noted. According to Donders, the range of accommodation at

10 years	equals	14.0	
15 "	"	12.0	
20 "	"	10.0	
25 "	"	8.5	
30 "	"	7.0	
35 "	"	5.5	
40 "	"	4.5	
45 years	equals	3.5	
50 "	"	2.5	
55 "	"	1.75	
60 "	"	1.0	
65 "	"	0.75	
70 "	"	0.25	
75 "	"	0.	

Until the age of fifty years the far-point remains in its normal position, but later it begins to move farther away, so that, for example, in the fifty-fifth year an emmetrope becomes hypermetropic 0.25, in the sixty-fifth year hypermetropic 0.75, and in the seventy-fifth year hypermetropic 1.75. This diminution of refracting power often is decidedly advantageous to myopes of slight grade at an advanced age.

The causes of presbyopia probably consist chiefly in the hardening and diminished elasticity of the lens, because a diminution in the power of the ciliary muscle is not probable, at least in the earlier years.

IV. *Measurement of Refraction, Accommodation, and Visual Power.*

Inasmuch as accommodative tension is to be excluded in all measurements of refraction, they must be made during parallel direction of the eyes at distant objects and without convergence of the visual axes, unless accommodation is directly paralyzed by atropine or some similar agent. For this purpose test types (the large Snellen types down to No. III.) are pasted on pasteboard at a distance of 6 m. and well lighted, and the patient directed to look at them. This distance is sufficiently great to permit us to regard as parallel the rays of light which enter the pupil from the small type. Snellen's tables contain letters or hooks of various sizes. The largest are recognized at 60 m. by an eye with normal refraction and vision, then follow smaller ones, which may be recognized at 36 m., 24 m., down to 6 m., 4 m., etc. These tables also enable us to determine the sharpness of vision.

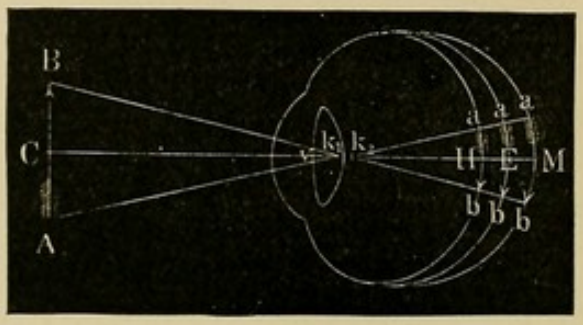


FIG. 36.

Despite the fact that, with proper refraction of the rays entering the eye, distinct retinal images develop, they will not be perceived if the retina is no longer sensitive to them and if it does not distinguish different parts of the image as such. It is self-evident that the obstacle to the perception of the retinal images may also be situated in the paths from the retina to the brain or in the latter itself. We therefore mean by visual power (S or V) the power to perceive sharply defined and correspondingly bright images of a certain size which have formed on the retina—the visual power is so much greater the smaller the images that can be perceived. This definition shows that in those cases in which sharply defined images do not form upon the retina on account of imperfect refraction of the ocular media, this error of refraction must first be corrected, as far as possible, by suitable lenses before the visual power can be determined. On the average it is observed, as a matter of experience, that if, as in the Snellen test types, letters are used as the test objects, an eye of normal visual power will perceive images or recognize points of light distinctly when they are separated 0.004 mm.

In an emmetropic eye, these form a visual angle (v) of one minute. If the object AB throws its image on the retina of the eye, the necessary construction, if two nodal points are drawn in the schematic eye, is made by uniting A and B with K (Fig. 36).

From K_2 the line K_2a is drawn parallel to K_1A, and K_2b parallel to K_1B; these bound the retinal image *ab*. The angle Ak_1B is known as the visual angle (v). This will be equal to the angle bk_2a if, as in Donders' reduced eye, both nodal points are allowed to coalesce so that the line Aka is straight. With small visual angles, therefore, the sizes of ACB and aFb vary as kC to kE (in the reduced eye kE=15 mm.).

If there is ametropia in consequence of unequal length of ocular axes, the retinal image in the hypermetropic eye (H) would be somewhat smaller despite the same size of the visual angle, in the myopic eye (M) it would be somewhat larger, as shown in Fig. 36, if these eyes of different lengths but the same power of refraction received sharp images upon their retina. But this is not possible. For sight at a distance concave lenses must be used in measuring the visual power in myopes, convex lenses in hypermetropes. On account of the use of these lenses, the nodal points of the now changed optical system suffer a displacement which depends particularly upon the distance of the corrective glass from the eye. The size of the retinal image depends upon the position of the second nodal point; the nearer it is to the retina the larger the retinal image. The size of the visual angle, on the other hand, is influenced by the position of the first nodal point. The farther the latter is from the retina the greater is the visual angle. As the distance between the two nodal points is by no means the same in the various optical systems which result from the use of corrective lenses, etc., the size of the visual angle does not possess a constant relation to the size of the retinal image.

[According to Mauthner's calculations, the use of concave lenses for the correction of myopia always moves the second nodal point backward toward the retina, and so much the more the further the correcting lens is situated from the eye. The retinal image for the corrected eye is therefore made smaller. This is true of myopia dependent on elongation of the ocular axis as well as that dependent on excessive refraction of the dioptric system. But if we compare the size of the retinal image of the axial myopic corrected eye with that of the emmetropic eye, the former is in reality only smaller than the latter when the correcting glass is held in front of the anterior focus of the eye.

Fig. 37 illustrates the latter position of the concave lens and at the same time shows the resulting displacement of the first and second nodal points to K_1 and K_2; the visual angle at K_1 has become larger, the retinal image, corresponding to the angle at K_2, has become smaller. The dotted lines show the course of the rays in the uncorrected eye with the two nodal points K_1 and K_2. E is

the position of the retina of the emmetropic eye, M that of the myopic eye.

The correction of hypermetropia by the suitable convex lens always displaces the second nodal point anteriorly toward the cornea and so much the more the greater the distance of the correcting lens from the eye.

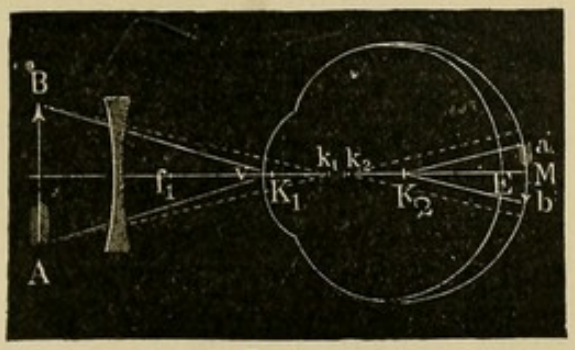


FIG. 37.

From these diagrams it is also evident that the size of the visual angle does not correspond to the size of the retinal image. The determination of the visual power according to the former is, therefore, somewhat unnatural, especially as our perception of the test object is the result of stimulation of the retina, and thus the direct effect of the retinal image. But this does not affect the practical utility of Snellen's types. This depends simply on the general agreement that the recognition of letters, whose strokes are seen under a visual angle of one minute by an emmetropic eye looking at distance (without accomodation) is to be regarded as normal and that this visual power is to be called 1.]

All letters of Snellen's test types, whose single strokes appear under a visual angle of 1 minute, occupy a visual angle of 5 minutes (Fig.38). If No. VI. of the test types is seen at 6 m., vision is $\frac{6}{12}$. The distance at which the letters are seen *d* by the patient, after correcting any errors of refraction which may be present, is divided by the distance marked alongside the letters (D) at which they ought to be seen, in order to find the visual power: $V = \frac{d}{D}$ (*vide* central vision in: Amblyopia and Amaurosis).

Each eye is examined separately. The test types must be recognized and named, down to the smallest ones which can be seen without glasses. If No. VI. can be seen at 6 m., we may not infer that the individual is an emmetrope possessing complete vision. It is possible that he could see more with the aid of feeble concave or convex lenses and hence the test is to be continued in this direction. In this case the test without glasses merely shows that he possesses at least full visual power. We then try to ascertain whether sight is improved by the aid of feeble convex glasses (say 0.5 and 0.75), *i.e.*, whether smaller letters can be recognized at the same distance or whether those seen appear as clearly and distinctly. The strength of the convex lenses is

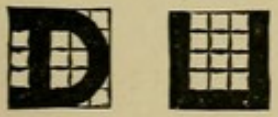


FIG. 38.

then gradually increased until we reach the one which permits the maximum of vision. This corresponds to the degree of hypermetropia.

Various difficulties arise during these tests. In the first place all the letters on the same row, which should be seen, according to Snellen, at the same distance, are not recognized with equal clearness. It is said that the distance at which all are recognized alone should be regarded as the measure of vision. But this leads occasionally to very remarkable results, inasmuch as one or another letter of a series is not yet recognized, while the letters of the next row, which are much smaller, are seen. On the whole, we are then satisfied if all the letters of one row, with the exception of an especially difficult one, are named, and then, for example, describe S $< \frac{5}{6}$. Moreover, by allowing the patient to come nearer or to go a little farther from the test tables (than the accepted 6 m.), we can determine more accurately the distance at which the entire row is seen.

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In order to make the difference in distinctness clear to the patient, we ask him, after we are merely halting between lenses with slight differences in refraction, to fix a certain letter which he is barely able to recognize and then, after rapidly changing the lenses in question, to mention with which lens the letter is seen most distinctly.

Some individuals observe very inaccurately, so that they overlook slight differences in distinctness. For example, they state that they see more poorly with 0.5, while considerable improvement of vision is demonstrable with 2.0. It is therefore always well, even if impairment is mentioned, to try a stronger lens. In the same way, the letters seen should be named in order to avoid self-deception on the part of the patient. If there is feeble sight, corneal opacities, or astigmatism, the patients often state that they see equally well with lenses of very different refracting powers. This is partly explained by the fact that the somewhat greater or less sharpness of the images resulting from the use of spherical lenses disappears in comparison with the otherwise confused character of the images or the weakness of the retinal capacity for perception. It is then well to use atropine and, after testing for astigmatism, to employ the ophthalmoscopic measurement of refraction in order to decide the question.

In the case of individuals who do not know the alphabet, we employ hooks and direct them to tell us in which direction they are open. As a general thing these are recognized at a greater distance than letters of the same number. Hence it follows also that the test for vision possesses only an approximate accuracy.

We should, therefore, insist so much the more that only one and the same test (Snellen's, the oldest and most commonly used) should serve as the basis of our measurements.

If the same highest degree of vision—this is an important feature—is attained with convex lenses of different strengths, the hypermetropia is expressed by the strongest one. For example, if an individual sees No. VI. at 6 m. equally well with +2.0 and with +1.0 and not demonstrably better with either of these lenses, he has hyperopia +2.0 (H $\frac{1}{2^{1}0}$). There is also hyperopia if the patient sees equally well with and without convex lenses.

This conclusion depends on the fact that the refraction represents the ocular refractive power without any accommodative tension. But if an hyperope sees as well with a convex lens 2.0 as with 1.0, the eye is in a condition of the greatest accommodative relaxation when using lens 2.0, since in order to attain the same sharpness of the retinal images with 1.0, the crystalline lens must have a greater curvature of 1.0 (Fig. 39).

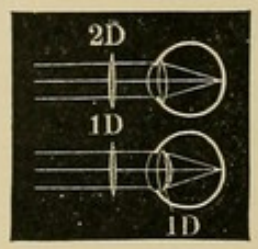


Fig. 39.

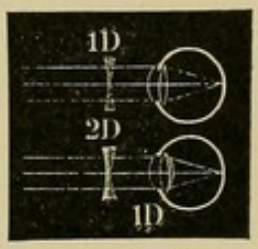


Fig. 40.

If vision is found to be impaired by the use of convex lenses, concave lenses are tried, passing gradually from weaker to stronger ones in the manner described above. If the patient sees equally well with concave lenses of different strengths, and the maximum of vision is reached, the weakest convex lens indicates the degree of shortsightedness. Emmetropia is present if vision is as good without lenses as with concave lenses. The reason is the same as with regard to convex lenses, viz., exclusion of accommodative tension in the determination of refraction. If vision is as good with concave 2.0 ($\frac{1}{2^{1}0}$) as with concave 1.0 ($\frac{1}{4^{1}0}$), the crystalline lens must have been curved as much more while using the first lens, as concave 2.0 disperses the rays more than 1.0; hence there is really myopia 1.0 (M $\frac{1}{4^{1}0}$).

Patients not infrequently claim to see better with stronger concave lenses (for example, −1.0), although they are unable to prove that they can recognize with concave 2.0 a letter which could not be distinguished with concave 1.0. If such a distinct difference is not demonstrable despite examination directed to it, the weaker lens is regarded as corresponding to the myopia. The apparent improvement of sight usually depends on an unconscious false judgment. Accommodation must be performed with the stronger concave lens. As accommodation normally occurs only for nearer objects, the letter, to which he accommodates artificially and un-

consciously, appears to the patient to be nearer and therefore smaller, because the retinal image remains approximately of the size which corresponds to the distance at which it is really situated. The more indistinctly the patient had seen the objects the larger they appeared to him on account of the circles of dispersion at the edges. If he now sees the object especially small, this creates in him the impression of unusual distinctness.

As we have mentioned, the degree of the error of refraction is determined by the refracting power of the correcting lens. We assume, at the same time, that the lens is held immediately in front of the eye, at all events that its distance from the eye is extremely small in comparison with its focal length. In order to be accurate, this distance must be taken into consideration. For example, if most distinct vision was obtained with concave 10.0 D held 2 cm. in front of the vertex of the cornea, this means that the eye was adjusted for rays which come apparently from a point 10 cm. from the lens, *i.e.*, 10+2 cm. from the vertex of the cornea. Hence, the real far-point is 12 cm. from the cornea, and the myopia is $\frac{100}{12}=8.33$. The myopia is, therefore, so much less the farther the correcting glass is removed from the eye. This circumstance can also be utilized in the measurement of the refraction. The concave lens which corresponds approximately to the myopia is held further away from the eye; if vision remains equally good, the refracting power of the lens employed is too great.

The reverse holds good with convex lenses. For example, the corrective lens is convex 10.0 D and is held 2 cm. in front of the eye. The eye is then adjusted for rays which converge to a point 10 cm. behind the lens or 8 cm. (*i.e.*, 10−2) behind the vertex of the cornea. The negative far-point of the eye is therefore situated 8 cm. behind the vertex of the cornea, and the degree of hypermetropia is $\frac{100}{8}=12.5$ (c.H $\frac{1}{3\frac{1}{2}}$).

It is proper to measure the position of the far-point (or the refraction) from the vertex of the cornea, because in the reduced eye the latter coincides with the main point, and it is from the latter that the main focal length of optical systems is usually determined. The measurement of the position of the far-point from the nodal point (which is situated 5 mm. behind the vertex of the cornea in the reduced eye) appears less suitable, but this slight difference has no practical significance.

The refraction also determines the position of the far-point. In order to measure the range of accommodation, the position of the near-point (P) must also be ascertained. As a rule, very small test-types (about No. 1 of Jaeger's or 0.4 of Snellen's) are used for

this purpose. These are read and then brought nearer to the eye until they become illegible. The point at which these letters can still be seen sharply and distinctly, although with straining, is the near-point of accommodation, whose distance from the eye is to be measured. As the smallest possible objects are necessary for these tests, other objects are preferable to the test-types. For example, fine silk threads stretched in a frame (v. Graefe's optometer) or the fine punctate tests of Burchardt or Scheine's tests (Porterfield-Young optometer).

If the near-point is far away, these small objects cannot be used because, when held at the necessary distance, they no longer furnish correspondingly large retinal images. This is also to be considered when weak eyes are examined. But on the other hand this should not induce us to choose too large tests objects. These would be recognized at so small a distance that accommodation is no longer possible because the large size of the retinal images permits recognition despite the circles of dispersion. We can easily convince ourselves of this by bringing very large print close to the eye. But as it is difficult, when the near-point is far removed and its position is unknown, to choose the proper and sufficiently large test types, we use convex lenses through which the patient is allowed to read. Small test types may now be used because the accommodative tract is brought closer to the eye on account of the convex lens. For example, if convex 8.0 ($+\frac{1}{8}$) is held in front of an emmetrope, whose accommodation is completely paralyzed, he will read the test type at $\frac{1}{8}$ m. (12.5 cm. or about 5 inches), as the rays coming from that distance are made parallel by the convex lens. In order to determine the near-point in the above-mentioned cases, it will therefore be well to use a convex lens (about 5.0 to 8.0) and to allow the test type to be read; by constantly bringing the lens nearer to the eye, we note the nearest distance at which distinct vision is possible. The distance between the latter and the convex lens is then measured, and by means of the lens formula $\frac{1}{f}=\frac{1}{a}+\frac{1}{b}$ we can calculate the point from which the rays that have been converged by the convex lens actually come. That is the near-point of the eye. For example, if it has been found that with +5.0 (focal length 20 cm.) the eye can still accommodate to 10 cm., then $\frac{1}{b}$ (or $\frac{1}{P}$)$=\frac{1}{20}-\frac{1}{10}=-\frac{1}{20}$, and P=20 cm.

Optometer.—Convex lenses may be used in the same way to determine the far-point of the eye, and thus the refraction, by removing the test types as far from the eye as they can still be recognized distinctly. Upon this circumstance are based a number of

optometers. But more consideration should be paid to the fact that, as a rule, this only determines the relative far-point. Although the test types are situated in a straight line in front of the examined eye, nevertheless the other eye, which is covered with the hand, converges upon this point. The far-point is therefore determined during convergence of the visual axes. In such an event, however, complete relaxation of accommodation is usually impossible, as we have learned in our discussion of the relative range of accommodation. As we have also seen, the degree of possible relaxation varies according to the different condition of refraction.

In order to prevent convergence, to a certain extent, in these cases, the second, non-examined eye is allowed to remain open and is prevented from seeing the test object by the interposition of a screen. At the same time the patient is directed to look as far away as possible. In this way we endeavor to artificially create parallel visual axes. Divergent squint and therefore a change in the convergence of the visual axes may also be produced by placing a prism (with the base turned inward) in front of the second eye, during fixation of the test object. But these aids do not always prove successful.

In using a simple convex lens as an optometer, we allow the patient to read suitably large test type with the lens and then by gradually removing the type, endeavor to determine the apparent far point of the eye, whose actual position is then calculated by the aid of the lens formula.

This calculation may be avoided and the refraction obtained at once by a very simple rule, if a convex lens of 10.0, held at a distance of 10 cm from the eye, is used for the examination. If the test object is distinctly seen at a distance of 10 cm. (= principal focal length of 10.0) from the lens, there is emmetropia (rays from a distance of 10 cm. are made parallel by +10.0); every difference of a centimetre gives an error of refraction of one dioptry, myopia on approaching the object, hypermetropia on removing it. For example, if the test object is seen distinctly at 8 cm., there is M 2.0 (= 10−8), at 6 cm. there is M 4.0, etc. If the object is seen distinctly at 14 cm., there is H 4.0 (=14−10), etc.

[If we know the distance at which a point, seen distinctly with a convex lens, is situated and denote the difference between this distance and the focal length of the lens (f) by d, the formula which obtains for the apparent distance of the object from the eye is $\frac{f_2}{d}$, assuming that the lens is separated from the edge by a distance equal to its own focal length. In using a lens +10.0 (10 cm. focal

length) $\frac{f^2}{d}=\frac{100}{d}$. If, for example, d is then equal to 2, the image of the object in question is situated at 50 cm., *i.e.*, the eye is adjusted for 50 cm. distance (in a negative or positive direction); there is ametropia 2.0.

This formula is very easily obtained from the lens formula $\frac{1}{f}=\frac{1}{a}+\frac{1}{b}$. If, when myopia is present, the distance between A (position of the test object) and the convex lens L (Fig. 40) is put at $f-d$, then

$$\frac{1}{f}-\frac{1}{f-d}=\frac{1}{d} \text{ or}$$
$$b\,(f-d)-fb=f\,(f-d)$$
$$b\,(f-d-f)=f^2-fd$$
$$-bd=f^2-fd$$
$$-b=\frac{f^2}{d}-f$$

The myopic eye is therefore adjusted for rays which come from the distance $\frac{f^2}{d}-f$ on the other side of the lens (from A_1). But the lens itself is at the distance f from the eye, hence the eye is accommodated for a far point $\frac{f^2}{d}-f+f=\frac{f^2}{d}$. In hypermetropic eyes $A=f+d$, and similar calculations result in the same formula.]

Burow constructed an optometer consisting of a convex lens (¼), which formed the eye-piece in a tube in whose other end was contained the test object, which could be drawn out. Badal (1876)

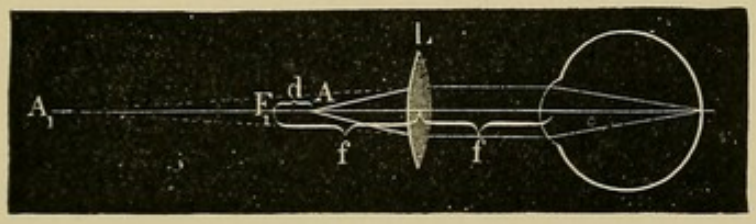


FIG. 41.

used an eye-piece +16 D in his similarly constructed optometer; each displacement of 4 mm. corresponds here to a change in refraction of 1.0 D. The refraction-measurer devised by myself and which is used particularly for ophthalmoscopic examination may also be used as an optometer. A tape measure which can be rolled in and out of a box by pressure on a button and is arrested on letting go the button, serves to measure the distance. The convex lens is placed on a metallic rod which is applied to the lower wall of the orbit and is then held constantly at a uniform distance from

the eye. In determining the far point, we pass gradually away from the lens, beginning in the closest proximity, in order to relax the accommodation as much as possible. If a convex lens 10.0 is used, the distance found gives the refraction at once, according to the above formula. In Burchardt's optometer the tape measure is replaced by a movable rod on which the corresponding error of refraction is indicated.

In Seggel's optometer the test object is placed on transparent glass at the end of a tube which can be drawn out; a convex lens forms the eye-piece. The refraction corresponding to the degree to which the tube is drawn in and out is indicated upon the tube. In order to avoid convergence of the visual axes, a second tube, whose far end is closed, is placed alongside the first (like a binocular opera glass). The non-examined eye looks into the second tube. There is no doubt that a certain parallelism of the visual axes is attained in this way in many individuals.

The Loiseau optometer, employed in the Belgian army for the selection of recruits, consists of a tube upon whose posterior end is

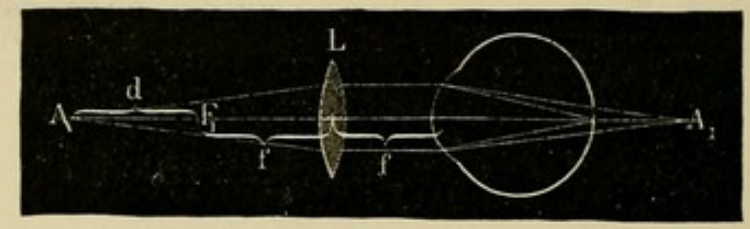


FIG. 42.

situated the test object, painted on milk glass. A series of lenses of different focal lengths is used as the eye-piece. The lenses are very small, so that a sufficient number can be inserted in the periphery of two small disks and, by turning, can be brought successively in front of the opening of the tube. The refraction is given by a table which corresponds to the lens employed. The test object may be placed at two distances (5 and 10 cm.) in front of the lenses, according to the greater or less degree of the error of refraction. The determination of the far-point is rendered more difficult, particularly in ignorant individuals, by the fact that it is not carried out by moving back the test object, but by the difference in the convex lenses used; with the proper accommodation vision will be distinct with a series of lenses.

In addition to the determination of the refraction, the last-mentioned optometers are also intended to ascertain the visual power. This appears somewhat astonishing at first sight. For example, if in using Badal's or Burchardt's optometer upon an emmetrope, a certain small test type must be moved farther away (corresponding

to the position of the far point) than in the myope, it would be assumed *a priori* that the recognition of this test type by the emmetrope presupposes a higher degree of visual power than in the myope to whom it is brought somewhat nearer. It might therefore appear wrong to draw any conclusion concerning the visual power from the size of the test types recognized in this method. But if we assume that the focus of the convex lens coincides with the nodal point of the eye, then the visual angle under which the test type is seen, remains the same despite its greater distance from a greater proximity to the lens.

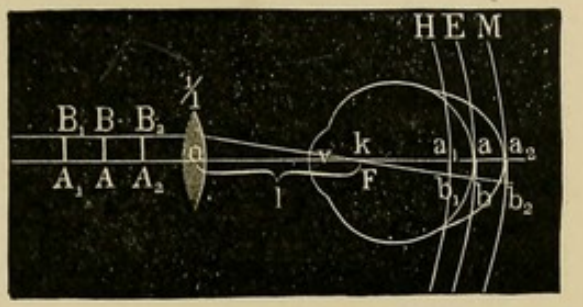


FIG. 43.

Let AB (Fig. 43) be the test object, *o* the centre of the convex lens $\frac{1}{1}$, whose focus F coincides with K, the nodal point of the eye. A ray passing from B parallel to the main axis will be refracted by the lens $\frac{1}{1}$ so that it passes through the focus F or K. Its image will fall upon the prolongation of this line. All rays emanating from A will unite upon the prolongation of the line A*o*K. This occurs if AB is a little farther removed (A_1B_1) or is brought somewhat nearer (A_2B_2). If the individual sees AB distinctly, the image falls upon his retina. If there is axial hyperopia, the retina will be situated nearer to the eye; if there is axial myopia, farther from the eye; but the visual angle *v* always remains the same. If we regard this as the measure of the visual power, the latter remains the same. The retinal images, however, will have different sizes; they are smaller upon the retina of the hyperopic eye, larger upon that of the myopic eye. If the retinal images are to remain of equal size, the focus of the lens must coincide with the anterior focus of the eye (Barvais, Nagel) as shown in Fig. 44. The rays which are parallel to the principal axis pass through the focus of the lens F_1, which coincides with the anterior focus of the eye (f_1). All rays which start from the latter pass through the eye parallel to the principal axis.

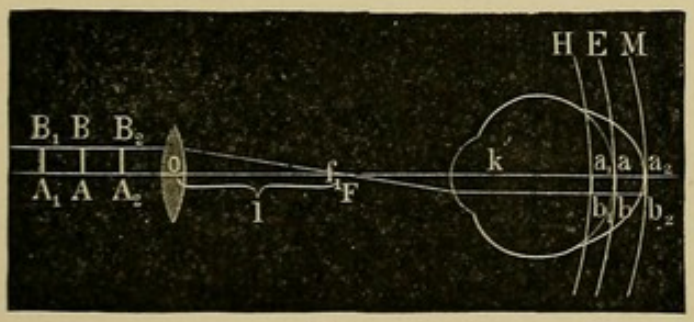


FIG. 44.

Badal, in his optometer, has introduced a number of photographic miniatures of Snellen's types upon the transparent object plate, which is directed toward the light, and has noted the visual

power requisite for recognizing them. Burchardt adopted similar means with the punctate tests. The determination of the visual power is effected in the same or a similar manner by the optometers of Seggel, Loiseau, etc. But it is to be remembered that the focus of the lens does not really coincide accurately with the nodal point of the eye, inasmuch as we must first ascertain the position of the latter in each individual case. But even in this form the measurement of the visual power furnishes approximate accuracy. But in using test types which are situated on transparent plates of milk glass the radiation at the edges is annoying.

Instead of spectacle glasses the telescope-optometer of A. v. Graefe, Hirschberg and Plehn, combined with Snellen's test types, may be used to measure refraction when the visual axes are parallel. Graefe's instrument consists of a sort of Galilean telescope (opera glass). The eye-piece is a concave, the objective a convex lens. By the varying distance of these lenses from one another and the differences in the strength of the concave lens, the approximately parallel rays of the distant test object which enter the tube are refracted in such a way that they represent the varying divergences and convergences of the rays, which correspond to the different errors of refraction. In Hirschberg's optometer, which is made according to the principle of the astronomical telescope with a convex lens as an eye-piece and a convex lens as objective, a similar object is effected by giving the lenses different focal lengths and by varying their distance from one another. For example, if the lenses are separated by a distance equal to the sum of their focal lengths parallel rays which impinge upon the objective will also leave the eye-piece in a parallel direction; the second focus of the objective coincides with the first focus of the eye-piece.

Both optometers enlarge the test types to a varying extent, according to the adjustment which must be made for the individual degrees of refraction. They are therefore of little use in determining the visual power. In Plehn's optometer, which contains two movable convex lenses with a focal length of 5 cm., an attempt is made to overcome this objection by making the focus of the convex lens of the eye-piece coincide with the nodal point of the examined eye. Thus, despite the movement of the objective to and fro, the inverted images thrown by the latter in the air are always seen under the same visual angle.

The objective measurement of refraction with the ophthalmoscope will be discussed in the section on Ophthalmoscopy.

B. Special Part.

1. Myopia.

The eyes of myopes (*μύειν*, blinking), in a condition of rest of the eye, are adjusted for divergent rays, *i.e.*, for objects which are situated at less than an infinite distance. As a rule, this depends upon the relatively excessive length of the visual axes (axial myopia), more rarely upon excessive refraction or curvature alone (curvature myopia). In the latter event the cornea, in particular, presents the abnormal curvature. Apart from the above-mentioned exact methods of examining refraction, the higher grades of shortsightedness can be determined approximately by allowing the individual to read fine print and then gradually removing it from the eye until it becomes illegible. The far-point of the eye is situated approximately in this locality. Test types of different sizes (say Snellen 0.4 which are seen, with perfect vision, at 40 cm., or 0.8 which are seen at 80 cm.) can be read at about the same distance by myopes. This distinguishes them at once from those with weak sight. For example, an emmetropic weak-sighted individual with $V=\frac{1}{2}$ will read Snellen's test 0.4 at only 20 cm. on account of his weak sight, 0.8 at 40 cm. and correspondingly larger type at greater distances. The myope, however, will recognize all these types at such a distance alone as the position of his far-point permits.

Myopia occurs in all degrees, from the slightest up to M 30.0 ($\frac{1}{1\frac{1}{3}}$), perhaps even higher. It has therefore been divided into various classes: slight myopia up to M 2.0 ($\frac{1}{2\frac{1}{0}}$), moderate up to M 6.5 (about $\frac{1}{6}$) and marked myopia. It is to be noted that the large majority of myopes do not really have diseased eyes; even extremely short-sighted eyes may be entirely normal in their functions, apart from the absence of far sight and an eventual diminution of visual power, and may remain free from every inflammatory affection. [I am hardly able to agree to this statement. In my experience the large majority of myopes have diseased eyes. Indeed a myopia of any considerable degree implies such a softening in the ciliary region, such an elongation of the antero-posterior diameter as to cause us to consider an eye thus affected as essentially a diseased one. I should rather say that the large majority of myopes have diseased eyes, than the contrary; or to put it more strongly, that myopia is essentially a disease.—St. J. R.] On the other hand we find a series of myopic eye—and these include particularly the markedly progressive and pronounced forms—which are attacked by serious internal diseases and are even exposed to the loss of vision.

Subjective Symptoms.—In myopia of the slightest grades the inconveniences connected with seeing poorly at a distance are not prominent. There are individuals who have no suspicion of their shortsightedness and are only convinced by the use of concave lenses that they could see more than they really do.

In the higher grades the inconveniences are serious and may even interfere with free movements while walking on the streets. Inasmuch as the circles of dispersion are larger when the pupil is dilated, myopes, in order to see better, attempt to cover part of the pupil by narrowing the palpebral fissure and by blinking. In other respects, also, there is a certain degree of awkwardness in the outward manners of a very short-sighted individual, unless the suitable correction is effected by glasses. Dechales, a Jesuit of the seventeenth century, made the noteworthy observation, that there is often much more of the world's happenings that escape them than they are conscious of, and that they have a less correct knowledge of many things because they supply what is lacking by a lively imagination. The different manner in which pronounced myopia is borne by different individuals is very striking. While very many, especially if the myopia prevails in the entire family and is hereditary, are perfectly satisfied with their condition—as a compensation for the imperfect far sight they can, as they say, see very well at close quarters—or at least bear it with equanimity, in some we find marked mental depression, that is constantly fostered by comparison with that which can be seen by others. Unfortunately they cannot always be relieved by the use of concave glasses.

[For an interesting account of the influence of myopia upon the intellectual development and character, see Donders, "Errors of Refraction and Accommodation," and Loring, Transactions Medical Society, State of New York, 1879.—St. J. R.]

This is particularly true of myopes of the higher grades, in whom perfectly normal visual power for distance usually cannot be attained. My examinations of students in the gymnasia (3,420 eyes) showed that while there was complete or more than complete visual power in 89 per cent of emmetropes, this was found in only 60.3 per cent in M 1—3, in 41 per cent. in M 3—6, and in only 16.2 per cent in M>6. The visual power is often only ½–⅓ the normal in pronounced myopia, although no other objectively demonstrable cause is present. The explanation of this fact cannot be sought in the action of the correcting concave lenses—although the backward displacement of the second nodal point makes the retinal image smaller than it was in the uncorrected myopic eye—because we have seen before (Fig. 36) that this relatively smaller retinal image of a certain object is still larger than in the emme-

tropic eye. But if the ability to perceive such a retinal image is nevertheless insufficient in myopes, we might assume with Donders and Knapp that the elongation of the ocular axis has resulted in separation of the individual rods and cones of the macula lutea and the posterior pole in such a way that there are fewer perceptive elements, even upon a larger surface, than in the emmetropic eye. But even without this assumption the relative weak sight of the majority of pronounced myopes can be explained by other morbid changes of the layer of rods and cones, or by separation of the vitreous body which is demonstrable in many cases.

The peripheral field of vision is also somewhat narrower, as a rule, in myopes than in emmetropes. My examinations have also taught me that the perception of light is often diminished, especially in severe myopia. This explains the frequent complaint of notable impairment of vision in twilight. Myopes, as a rule those of the higher grades, suffer not infrequently from mouches volantes (myodesopsia). They perceive the shadows of the small formed elements (rings, chains, threads, plates, etc.) situated in the vitreous body and are very much annoyed thereby. These shadows are especially prominent in them because all rays emanating from remote points of light are not united in a sharp point on the retina, but form circles of dispersion. The opaque elements of the vitreous, which are situated in the course of these bundles of rays, obstruct the light and thus throw shadows into the circles of dispersion. The complaints of myodesopsia therefore disappear often when corrective glasses are worn; the point of light on the retina, which is now distinct, is made somewhat less bright by the obstruction of the rays in the vitreous, but has no room for shadows. The frequency of myodesopsia is also explained by the fact that pathological productions are often found in the vitreous body of myopes. If they are so large as to be visible with the ophthalmoscope, they are known as opacities of the vitreous humor. Increased irritability of the retina, which is often manifested at the same time by symptoms of dazzling and impaired sight on looking toward the light, may also give rise to annoying perception of the mouches volantes.

Metamorphopsia also occurs in myopes. Objects, especially distant ones, assume a different shape, straight lines look curved with the concavity directed toward the point of fixation (Foerster). This is usually owing to displacement of the retinal cones.

Asthenopic symptoms are not infrequent in myopes. They are lacking in endurance when working at close quarters. In reading the letters finally swim before them, pressure and burning in the eyes, even headache set in. This asthenopia is especially frequent

in the progressive stage of myopia as the result of hyperæmia within the eye or abnormal accommodative tension. In other cases it depends on insufficiency of the internal recti which makes prolonged convergence of the visual axes impossible.

[Yet not so large a proportion of myopes as hypermetropes seem to suffer from asthenopia.—St. J. R.]

Objective Changes.—On account of their elongated oval shape, myopic eyes often protrude strongly from the orbits and appear larger. If they are turned strongly to the nasal side, we recognize the more oval curvature compared with the spherical shape in hypermetropes and emmetropes. The pupils are, on the average, larger, so that the eyes have an expression of greater fire. The anterior chamber is deeper. There is not infrequently moderate flapping of the iris (iridodonesis) on movement. A striking rotation inward of the eyes (apparent convergent strabismus of myopes) is occasionally

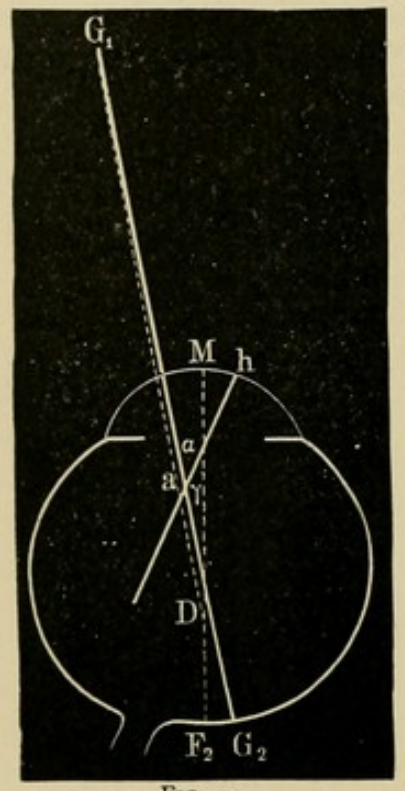


Fig. 45.

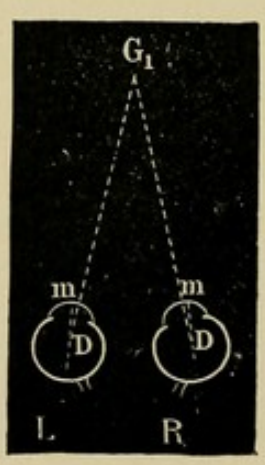


Fig. 46.

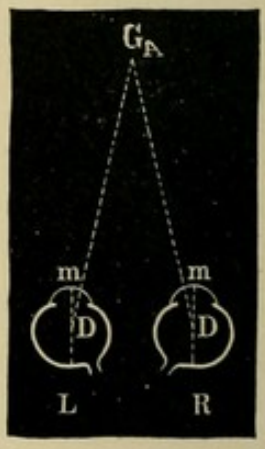


Fig. 47.

noticed. But if the eyes, which are fixing an object, are covered alternately with the hand, no displacement of the visual lines takes place. The visual line which connects the rotatory point of the eye (Fig. 45 D) with the fixed object G_1, like the line of sight (which connects the macula lutea G_2 with the object G_1) does not, as a rule, intersect the cornea exactly in the middle M, but a little to the inside (to the nasal side). If the middle of the cornea is connected with the centre of rotation D by a straight line (the continuation of this line, the visual axis, meets the retina between the entrance of the optic nerve and the macula lutea at F_2), this line intersects the visual line at an angle called γ (MDG_1) by Woinow. This angle is, on the average, larger in hypermetropes than in emmetropes. In myopes, on the other hand, it is smaller

than in emmetropes, indeed even negative, inasmuch as the visual line falls to the outside of the middle of the cornea. As we are accustomed to determine the position of both eyes, while fixing an object situated at a certain distance, by the position of the middle of the cornea (Figs. 46 and 47, *m*), we are struck by more marked changes in the position of the latter. Convergent squint (Fig. 46) appears to be present in eyes the middle of whose cornea is turned more toward the nasal side than we are accustomed to (as occurs in myopes on account of the small size of the angle γ) and external squint (Fig. 47) when the angle γ is larger. Donders, who first studied these relations, attributed them erroneously to the dimensions of the angle α, formed by the line of sight (G_1G_2) and the major axis of the cornea (*h a*). Inasmuch as the latter passes approximately through the middle of the corresponding plane of the cornea (M and *h* would then coincide approximately. In Fig. 45 they have been separated too much for the sake of clearness), there

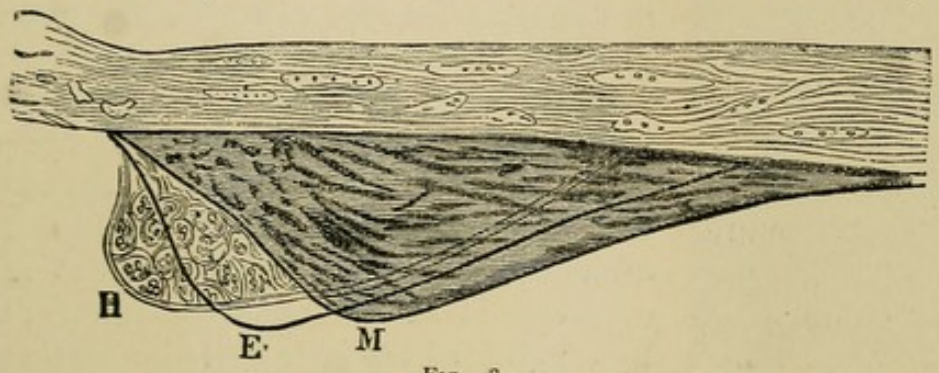


FIG. 48.

is practically no notable difference between the angles α and γ (Mauthner).

[There may be, however, such a convergent squint in myopia as to destroy binocular vision and demand operation for its correction. I have found this in one per cent of my cases.—St. J. R.]

The ciliary muscle (Fig. 48 M) of the myopic eye is moved backward, thicker and longer than in emmetropes. According to Iwanoff's investigations, there is hypertrophy of the meridional muscular fibres as compared with the emmetropic (E) and hypermetropic (H); the circular fibres are very much less prominent. But this difference appears to result chiefly from the different lengths of the ocular axes. On account of the enlargement of the latter in the myopic eye, the circular fibres are compressed into a smaller territory, while the radial or meridional fibres are more expanded (Duke Charles Theodore).

As the myopic eyeball is enlarged particularly in the direction of the ocular axis, it assumes an ovoid shape (Arlt). The portion of the sclera in the vicinity of the posterior pole is thinned and

distended. In view of this fact, the existence of a "staphyloma posticum" (Scarpa) may be assumed for the majority of myopic eyes. In the stricter sense, the expression is limited to a partial, circumscribed protrusion which is found (relatively rarely in a marked form) next to the entrance of the optic nerve and usually toward the side of the macula (Fig. 49, *sta*). At the same time there is an enlargement of the space between the external and internal optic sheaths (*i*) (sclerectasia posterior) in this staphyloma posticum. The entrance of the optic nerve (optic papilla) is thus pressed somewhat to one side and is directed obliquely to the ocular axis. On account of the enlargement of the globe in the direction of the ocular axis, the backward displacement of the posterior pole of the eye, drags the choroid from its adhesion to the optic nerve and causes atrophy of the choroid in this locality (traction atrophy). Inasmuch as the traction chiefly affects the part turned toward the macula, this explains the fact that in ophthalmoscopic examination the whitish atrophic spot usually has the shape of a crescent with its convexity turned toward the macula. In severe cases an atrophic portion of the choroid finally surrounds the entire papilla (*vide* Diseases of the Choroid). But occasionally there are circumscribed atrophic crescents in other directions (above, below). The myopic crescents must be distinguished from the congenital crescents (coni) which are also found not infrequently in emmetropes and hypermetropes. As a rule, the latter have a perfectly white color, like the sclera, and are comparatively narrow. The coni situated inferiorly, and which are usually associated with a certain diminution of visual power, may be attributed to incomplete closure of the fœtal eye fissure.

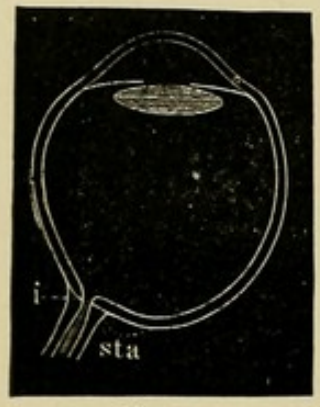


FIG. 49.

The retinal rod layer is absent, as a rule, or there is no perceptive function in the atrophic crescents, as is shown by the corresponding enlargement of the blind spot. The traction which results from the extension of the posterior pole of the eye not only occasionally detaches portions of the choroid and retina from the temporal border of the papilla, but portions situated on the opposite side may follow the same traction and may be drawn somewhat across the nasal border of the papilla (Nagel). The changes in question are demonstrable ophthalmoscopically.

Staphyloma is associated more often with marked inflammatory affections of the choroid—cases to which we may apply the term sclerotico-choroiditis posterior which was introduced by v. Graefe and often used for atrophic posterior staphyloma.

All eyes with very pronounced myopia have a tendency to these changes; they are hardly ever absent in the highest grades of axial myopia (beyond M 20.0). They are often associated with opacities of the virteous which may be followed by posterior polar cataract and, finally, though rarely, by detachment of the retina.[1]

Etiology and Course.—Myopia is congenital only in exceptional cases. The ophthalmoscopic measurement of refraction in atropinized new-born has shown that there is hyperopia in the large majority of cases (Koenigstein, Schleich, Germann), more rarely emmetropia, hardly ever myopia (Ely, Horstmann). [The observations of the late Edward T. Ely, Archives of Otology, Vol. IX., No. 1, p. 29, were the first to demonstrate the now universally admitted fact that hypermetropia and not myopia is the usual refractive condition in the eyes of the newly born.—St. J. R.] It is also observed very infrequently even at the age of four to seven years. In determining the refraction of village children between the ages of six and thirteen years, Cohn found among 456 eyes 435 emmetropic, 17 hypermetropic, and only 4 myopic. The larger number of the emmetropic eyes were atropinized; hypermetropia was found in all these cases after paralysis of accommodation. Myopia generally appears after the tenth year. Its greatest increase occurs from this time until about the twenty-second year. If the myopia continues, slight (about $\frac{1}{2}\frac{1}{0}$) during the period of development, it usually remains permanently stationary.

The development of myopia and the intensification of its degree are affected by injurious influences which depend upon constant work upon objects situated in close proximity, particularly during the period when the body is in vigorous development. Even the highest grades of myopia may be produced in this way without demonstrable heredity or congenital anomalies of the eye But my investigations have shown that such cases are very often associated with abnormal accommodative tension. Convincing observations have also been made, in which the children of hyperopic parents presented similar refraction until the eleventh or twelfth year, even associated with converging strabismus, and then became near-sighted without any external disease of the eye.

The examinations *en masse* of Cohn, Erismann, and others are especially noteworthy as regards the conditions under considera-

[1] German Army Order of Sept. 28th, 1875 (Par. 8, Sec. 4, and Par. 7, Sec. 1): *Permamanently disabled:* myopia, in which the distance of the far-point of the better eye is 0.15 m. or less, even if there is perfect visual power. *Conditionally disabled* (as a rule, reserve substitutes of the first class, in case of necessity may also be called upon at once for active duty): myopia with the far-point at a greater distance than 0.15 m. if the visual power is more than half the normal.

tion. According to Cohn's statistics, there are, among 50,000 pupils in different districts, 42.5 per cent of myopes in the gymnasia, 30 per cent in the real schools, 17 per cent in the higher girls' schools, and 10 per cent in the middle schools. There were 7 per cent in twenty primary city schools, only 1 per cent in six village schools. The degree of myopia and the number of myopes increase in the advanced classes, and especially with the age or school age. From present data there hardly appears to be any doubt of the influence exerted by the "injuries" associated with higher education and advancing culture, such as constant close work, over-exertion, neglect of physical development, and excessive duration of the gymnasial period and the like, upon the development and frequency of myopia (and even, although rarely, of the highest grades). This view is supported by the investigations made in races who are outside the pale of our civilization, such as the Kabyles, Nubians, Patagonians, Laplanders, etc.; in them myopia is entirely absent.

[Myopia is said to be almost unknown among the North American Indians. But exact observations are still wanting on this point. Certain it is, however, that quite a proportion of myopia exists among the uneducated classes of the United States and Great Britain and Ireland. It is not exclusively a condition of intellectual and cultivated life.—St. J. R.]

In order to explain the fact that some eyes do not grow near-sighted despite the action of the same injuries to which the others succumb—although no hereditary disposition is present—a congenital predisposition has been suspected and sought for in diminished resistance of the sclera and particularly of the posterior pole of the eye. Keeping in mind the fœtal fissure of the secondary ocular vesicle, in which errors of development—retinal and choroidal colobomata—often occur, it was believed that the abnormal distensibility of the sclera in the myopic eye could be attributed to imperfect development of this membrane within the tract of the former fœtal fissure (Jaeger, Schnabel). On the other hand, it may be contended that the true retinal and choroidal colobomata (see Ophthalmoscopy), which are associated more or less closely with closure of the fœtal fissure, are situated below the optic papilla, not at the posterior pole, where the distention of the myopic eye really occurs. The similar ophthalmoscopic appearances at the macula lutea, the so-called macular colobomata, do not prove that the fœtal fissure has extended to that locality. But the embryological investigations have not been concluded. There remains the possibility—and according to v. Ammon and, recently, to Vossius, it is really the fact—that the globe makes a rotation during fœtal

life in such a way that the fœtal fissure, which was formerly directed downward, is directed toward the temples. But even then, apart from the fact that the frequent choroidal and iris-colobomata, which are directed downward, would require another explanation, we are unable to understand why the posterior pole of the eye alone, and not the entire tract of the former fissure, should be distended.

Wherein consist the injurious influences of close work? Particularly in the constant and marked convergence of the visual lines. On account of this convergence, the external recti are stretched more diagonally and permanently, are thus applied over a greater extent of the outer side of the globe and impress greater pressure upon the globe. In addition to the mechanical action, which consists of a sort of flattening of the youthful, hitherto spherical globe, stasis of blood with secondary increase of the ocular contents may result from the pressure on the veins. This will be particularly marked if the externi *per se* are stronger than the interni (insufficiency of the interni), as is not uncommon in myopia. Moreover, direct traction is exercised by the optic sheath during convergence, upon the posterior portions of the sclera, situated to the outside of the optic papilla (Hasner, Emmert). The optic nerve runs from within (the optic foramen) somewhat to the outside, in order to enter the globe. If the globe is rotated strongly to the inside, the temporal side of the optic sheath experiences greater stretching or traction than the nasal side. This traction may extend (particularly when the optic nerve is short) to the temporal portion of the sclera, situated next to the optic papilla and into which the optic sheath is inserted, so that distention of the sclera is produced; this is the part at which posterior staphyloma develops most frequently and early (*vide* Fig. 49). With regard to this traction and the pressure on the capsule of the eye, Stilling attaches more importance to the varying contractions of the superior oblique muscle, which is brought into play in reading and writing with the eyes directed downward. He attributes the greater or less predisposition of each individual to myopia to the demonstrated variations in the insertion of the tendon of the oblique.

The injurious influences of the movement of convergence will be particularly prominent if the eye already has an elongated structure and is near-sighted. The additional factor then comes into play that the angle γ is smaller than in the emmetropic eye, or, in other words, that the middle of the cornea is nearer to the point of incidence of the visual line which is situated to its inner side. If the myope looks at a near object, he will be compelled to turn

the middle of the cornea and therefore the globe farther to the inside than the emmetrope.

The bending over forward of the head, in which the venous return in the vessels of the neck is impeded, also gives rise to stasis of blood in the eye and to secondary increase in the amount of the ocular contents.

That, as is often maintained, axial myopia may result from permanent strain of accommodation seems less plausible. It is possible that the forward movement of the choroid, which occurs according to the experiments of Hensen and Voelcker, may result in traction and hyperæmia of the retinal vessels and increased transudation. But this factor is of no significance in a certain degree of myopia, in which strain of accommodation is unnecessary on account of the nearness of the far-point. The view that strain of accommodation exercises a special influence is also opposed by the experience (which has been particularly emphasized by Foerster) that myopes who constantly wear corrective or even over-corrective concave glasses, with which they are compelled to strain the accommodation very vigorously, very often do not show any advance in their myopia.

Curvature myopia occurs in transparent keratoconus from the increased curvature of the cornea and also in the kerectasiæ which are not infrequent after pannous keratitis. Other corneal processes which have not resulted in any great loss of substance, may induce myopia by the persistent, slight, more or less diffuse opacities. This is owing in fact to an increase of curvature, in part to the increased approximation resulting from secondary feeble sight, of objects looked at and which causes elongation of the axis by excessive convergence. The latter condition also explains the fact that true axial myopia may finally develop from permanent abnormal accommodative tension or from spasm of accommodation. Further details will be considered in the discussion of diseases of accommodation.

Prophylaxis.—As we are unable to secure the disappearance of axial myopia, it is so much the more our task to combat the injurious agents which aid its development—a hygienic demand which has been recently emphasized on all sides and has been more clearly elucidated by exhaustive studies (Cohn, Erismann, Ad. Weber, Laqueur, etc.). Here we must consider the conditions obtaining in school and education, but these circumstances must be regarded no less carefully at home.

1. *Illumination.* — In order to obtain sufficient light in the school-room there should be one square metre of window surface to every five square metres of floor space. This will suffice if the

school has an open situation and its light is not influenced by the surroundings. In addition the light should come from the left, but if the rooms are too large, bilateral illumination may be employed; light from above would be best, but unfortunately this cannot always be secured. On account of the direct sunlight, the windows should not face south, nor should very strongly reflecting walls and surfaces be brought opposite to the eye. The ophthalmologist not infrequently sees cases in which patients attribute feeble sight to the fact that they sat for a long period while working, opposite a wall which was brightly illuminated by the sun. And indeed similar conditions, though in a lesser degree, may here occur as they do in those who look at the sun with the naked eye, perhaps while observing an eclipse. I have also seen spasm of accommodation arise under these conditions in the same way as after protracted work with insufficient illumination. If the sunlight which enters the room is too blinding, it should be moderated by gray shades or some other arrangement. Writing and reading must be discontinued at twilight or artificial illumination secured at once. In this respect we sin a great deal and we all probably find ourselves occasionally working in the twilight; it is only on looking up or on being spoken to by others, that we become aware that the room has grown dark. The visual power also diminishes with the diminution of light. When the former has sunk to one-half the normal, which is present during daylight, even writing, which demands less visual power in the expert than reading, strains the eyes, as I have found on trial. If the visual power fall to one-third, reading or writing is done with difficulty. With the diminution of visual power in twilight is associated closer approximation to the writing and print. In addition, the letters are recognized less clearly on paper which has grown dark and require greater strain of the retina, which in turn may give rise to irritative conditions. Hence, reading and writing should be continued only so long as the illumination permits complete visual power. Fine print, which can still be recognized distinctly at a distance of 30 to 40 cm. with full visual power, may be used as a standard; if the print must be brought closer on account of beginning twilight, reading and writing should be discontinued. Errors in this direction are perhaps committed more frequently at home than at school. After the pupils have finished their school tasks, they like to avail themselves of the twilight for their own reading. But inasmuch as this, as a rule, excites the young people more than school tasks, the mental tension and the consequent increased afflux of blood to the head are added to the strained sight. That the pupils do not read at twilight must therefore be emphasized, particularly at home. It

is preferable to darken the room somewhat earlier and to light the gas. The above-mentioned tests with small objects (for example, Burchardt's punctate tests) may also be used in the school-room to determine whether the illumination of the surface of the desk is sufficient. Photometric measurements, which H. Cohn made in large numbers, or the measurement of the angle at which the direct light of the sky falls upon the writing desk (Foerster) are attended with greater difficulties and, in practical utility, do not surpass the test with test objects. Proper illumination is also required with artificial light; Cohn requires a minimum light intensity of ten metre candles (one metre candle is a standard candle situated at a distance of one metre).

2. The desks and benches of the scholars must be taken into consideration. Bending the body forward, lateral curvature of the spine, and an oblique position of the head are particularly to be avoided. These evils are especially prominent in writing. The following points must be taken into consideration as regards the desk and seat:

The surface of the desk must be at a definite distance from the seat. On the average this should be one-eighth the height of the body plus four centimetres. When the arms are dependent, the distance from the *tuber ischii* to the elbow is about one-eighth the height of the body. Inasmuch as, in writing, the hand is situated somewhat higher upon the desk, about four centimetres may be added to this distance. The eye is then at a sufficient distance from the writing book, and the forearm and hand may execute the strokes in writing without excessive elevation, which, in turn, would entail a higher position of the corresponding shoulder and curvature of the spine. As the size of the children in the same class varies, the height of the desks must also vary. On the whole, two or three forms will suffice for each class, because a certain latitude in the distance of the surface of the desk from the seat is permissible.

Furthermore, the edge of the desk should be so close to the pupil while writing, that a plumb line dropped from the edge of the desk to the seat will not touch the anterior edge of the latter (distance = 0), but a point 2 to 3 cm. from the edge (positive distance). If the desk is farther removed from the seat (negative distance), the pupil, when writing, must bend over the desk and in extreme cases sits only upon the hindermost portions of the buttocks. The approximation of the desk to the seat interferes with the children on rising and passing through. In order to make this possible the seats or desks are made movable.

The desk must have a certain inclination because excessive looking down is a source of strain and is apt to cause bending over

of the head. In reading, the book should, for the same reason, be held with the hand or a reading-board at an angle of 40 to 50° to the horizontal. In writing, this elevation is inconvenient for the hand, but an angle of about 15° should be maintained.

The seat should be at such a distance from the floor that the feet can just be planted squarely upon it; the surface of the seat must possess sufficient width. The seat should have a comfortable back to support the spine. Furthermore, care must be taken that the seats offer no obstacle to thorough cleaning of the room. The sins committed against cleanliness are almost incredible. In some schools the rooms are scrubbed only during the Easter and Michaelmas holidays, and during the school-year are merely swept twice or even only once a week.

But the children do not sit erect despite good seats; the head, in particular, is apt to be flexed and turned. Head rests are employed in order to prevent this. For example, Soenneck's chin support which is screwed to the desk and serves to support the chin; or, still better, Kallmann's stand, a large iron, suitably bent ring, covered with rubber, placed on a stand; the child's face is situated behind the ring.

But it is not enough that suitable seats be secured in the schools; the attention of parents must also be directed to this feature. Desks should be used which, constructed according to the principles enunciated above, permit variations in the height of the seat, etc., and therefore suffice for a number of years.

3. *Posture of the Children.*—Children are especially prone to sit badly while writing, less so while reading. Recent investigations have shown that the position of the head in writing is influenced to a considerable degree by the fact that in watching the strokes of the letters the movements of the eyes are made as conveniently as possible. In the majority of cases, it is only the execution of the down strokes, which is carefully followed with the eyes.

In ordinary writing, the down strokes make an angle of about forty-five to sixty degrees with the ruled lines. As the ocular movements occur most conveniently in an up-and-down direction, the position of the head in watching the down strokes must be such that a horizontal line connecting the centre of rotation of both eyes (basal line), if supposed to be projected upon the paper, forms a right angle with the down strokes of the writing. This has beer proved to be correct by numerous investigations on children engaged in writing, made by Ad. Weber and particularly by Betlin and Reinbold in Stuttgart. In 90 per cent of those examined, the angle was approximately 90°. If the child hold the paper in front of him in such a way that its lower border is parallel to the edge of the desk

(as usually is done among us), the face must be turned to the right and the head deflected somewhat toward the left side in order that the basal lines of the eyes may be perpendicular to the down strokes of the writing. If the seat is poor, the spine becomes distorted and the entire body is supported upon the left arm. But if the sheet of paper is placed in front of us directly in the middle, but with the right corner turned upward so that its lower border forms an angle of 45° with the edge of the desk, the latter will intersect the down strokes at an angle of 90°, if it forms an angle of 45° with the ruled lines. The face may then be directed straight forward and the basal line of the eyes remains parallel to the edge of the table. This position of the writing paper is to be adopted as the natural one. The dependence of the position of the head upon that of the down strokes is especially striking in children because they write with larger characters and follow the execution of the strokes with the eyes with greater care and accuracy. Adults who write rapidly usually neglect both and therefore have a better position of the head even if the sheet of paper is held straight in front of them. In vertical writing which forms a right angle to the ruled lines, the edge of the paper must naturally remain parallel to the edge of the table, if the line connecting both eyes is to intersect the writing at an angle of 90°.

In addition to these laws of ocular movement which call for a definite position of the paper, the muscular activity of the hand, which should cause as little strain as possible, must also be taken into consideration. This can also be carried out conveniently in the position described.

4. The *writing material* plays an important part. As a general thing, slate and pencil should not be recommended. The excessive reflection and the scratching of the slate, on account of which the writing is recognized with difficulty, are regarded on all sides as injurious. Thieben in Pilsen, has recently manufactured white slates, and Wenzel in Mayence white enamelled slates. Perhaps lead pencils and white paper are most practicable for beginners. It is true they are somewhat more expensive and the frequent sharpening of the pencil is inconvenient, but the advantages over the slate are patent, unless, as the result of pedagogic experience, it is preferred to begin with pen and ink. Horner found that certain letters, which were written with a pencil upon a slate, could only be recognized at a distance of 7 mm., while those written on paper with a pencil were recognized at 8 m.; the proportions between slate writing and writing with ink were as 3:4. The Zurich School Board therefore ordered (1879) pen and paper as the obligatory writing material.

5. *Reading.*—The type of text-books should also be considered. The principal points are the distance of the letters from one another, their size, and the distance between the lines. Experiments have shown that in easily-read print the height of the letters (n is taken as the standard) should be at least 1.5 mm., the distance between two letters 0.75 mm., and the distance between the lower border of the small letters and the upper border of the small letters in the line below should be 2 to 2½ mm. The length of the lines should not be too great in order to avoid inconvenient movements of the eyes; about 100 mm. is the proper length. Roman characters are preferable to the German on account of their greater simplicity and the absence of angles and flourishes. This is often adopted at the present time in order to offer works to the international market. In the higher classes, special attention should be paid to the stereotype editions of the classics, dictionaries, and maps, which are often in very fine type. In the lower classes especially the primary department, the print is usually sufficiently large. The paper is less satisfactory; it is sometimes too gray, and on account of its thinness often permits the print on the other side to be seen through. Attention should also be paid to wall maps. They should not form "black mirrors" because the strong reflection makes the print illegible.

6. *Occupation.*—Constant and uninterrupted occupation in reading and writing is injurious to the eyes, even if the injurious influences which have been mentioned are excluded. The entire development of the child also suffers unless rest is permitted and sufficient time allowed for bodily exercise. Protracted sitting should not begin too early nor be encouraged. Hence the recommendations of the Alsace-Lorraine commission are decidedly justifiable, and have been considered in the order of the Prussian Minister of Education issued on November 10, 1884. I will give the following extracts:

a. The amount of weekly work in and for the school should be, at the most:

In the seventh and eighth years, 18 school hours, ⅔ singing hours, ½–⅔ gymnastic hours, ⅔ hours for home study (24–24 ½ hours). In the ninth year, 20 school hours, ⅔ singing, ½–⅔ gymnastics, 5–6 hours for home study (28–29 ½ hours). In the tenth and eleventh years, 24 school hours, 2 singing, 2–3 gymnastics, 8 hours for home work (36–37 hours). In the twelfth to fourteenth years, 26 school hours, 2 singing, 2 gymnastics, 12 hours for home study (42 hours).

b. There should be intervals of ten minutes between the individual hours of study. If more than two study hours follow in succession, there is to be an interval of fifteen minutes between the

second and third hours. These intervals are necessary in order to interrupt the writing and reading, to air the rooms, and to give the children exercise. But the pupils should not be sent into the school yard in bad weather; a play room should be reserved, in which they may remain during the intermissions.

Useless copying and the excessive writing of arithmetical examples in the lower classes, which often strain the eyes, are to be avoided, particularly as they are generally useless as regards education on account of the mechanical manner in which they are carried out.

Various other injurious influences in the school might be mentioned. For example, drawing according to Stuhlmann's stigmographic method in a labyrinth of dots and networks which is practised here and there. A similar bad effect on the eyes is produced by the numerous oblique lines in some writing books. In girls' schools much harm is done by handwork, especially excessive sewing, embroidery, etc.

In the higher schools, care should be taken that the year's tasks may be accomplished in this time by all pupils, and the too common custom of leaving the pupils two years in one class should be abandoned.

Treatment.—Distant vision may be restored to myopes by suitable concave glasses. The wearing of spectacles first came into vogue in Italy toward the end of the thirteenth century. In Germany, concave glasses were not used often until the middle of the sixteenth century. Nero is said to have worn concave glasses. Concave glasses are also occasionally required for close work because they make it possible for patients to read and work at a greater distance and thus to avoid the injurious and excessive convergence. But we must then endeavor to have the work really performed at the corresponding distance, and this is best done by suitable tables, if necessary by a head rest. The selection of the glasses depends upon the degree of myopia, the visual power, and the range of accommodation. In speaking of the degree of myopia, we mean the real shortsightedness after excluding a complicating abnormal accommodative tension or a spasm of accommodation.

With normal visual power, great range of accommodation (about $\frac{1}{3}$ or 13 D), such as correspond to youth and a myopia up to 6.5 (about $\frac{1}{6}$), there would be no objection, from a scientific standpoint, to recommending the constant wearing of correcting or almost correcting concave glasses. It is true that, at first, the myope would present other accommodative conditions for near vision. We know that his relative range of accommodation is different from that of the emmetrope. If, for example, a myope $\frac{1}{10}$ requires

no strain of accommodation, without spectacles, to converge upon an object 10 inches distant, he would have to accommodate $\frac{1}{10}$ in looking at an object 10 inches distant through correcting glasses which remove his far point to infinity. This would be much more difficult and inconvenient, at first, than in the emmetrope, in whom this convergence upon 10 inches is always attended with accommodative tension. But the eye of a young individual gradually adapts itself to the new conditions and finally an accommodative tension (relative accommodation) will occur at once with the different convergences, as in the emmetropic eye. But this presupposes the existence of a good range of accommodation. It will always be advisable not to produce this complete change in the conditions of accommodation suddenly, if we have to deal with a higher grade of myopia. It is then better to give, for near vision, concave glasses which are weaker than the myopia. Indeed, in very high grades of myopia patients who have not worn glasses formerly are unable to read at once with perfectly correcting glasses. Normal visual power was set up as a second requisite. Every real diminution of the visual power entails the closer approximation of the object. The patient could then not hold the object at a sufficiently great distance, despite the correcting glasses. Vision would thereby be interfered with to a still greater extent because unusually high accommodation must be associated with the marked convergence upon the closely approximated object. In addition, concave lenses, as we have seen, displace the second nodal point in the eye backward and thus diminish the size of the retinal image—a disadvantage which is particularly disturbing when feebleness of vision is already present.

No objection can be raised, under certain circumstances, against the wearing of correcting concave lenses, on the contrary they possess the advantage of preventing excessive convergence and of placing the myopic eye in the same visual conditions as the emmetropic eye, yet the constant wearing of glasses is attended with so many inconveniences (nor does it serve to beautify the face) that it should only be resorted to in case of necessity. Moreover, spectacles are unnecessary for close work in all the lower grades of myopia. If the far point is situated at 40 cm., the work can be held so far away that injurious convergence of the visual axes and bending over forward of the head will be avoided. Even when the far point is at 20 cm. (M 5.0), working without glasses is permissible, assuming that the myopia is not progressive and that there is no insufficiency of the internal recti. In all these cases it is sufficient to give correcting glasses for distance. For the greater distances in which the visual power, without glasses, is not dimin-

ished very markedly (with M 2.0 it is about $\frac{1}{3}$ with lenses, when there is full visual power with lenses), the lenses may be given in the shape of eye-gasses or lorgnette, to be used only temporarily. Spectacles are better adapted for myopes of moderate grade, who wish to wear glasses for distance permanently on account of their poor sight. But on account of the inconvenience of removing them, the patients have a tendency to wear the glasses even for near objects.

Near-sighted individuals who have myopia >5.0 must wear glasses constantly to secure good vision. These may correct the myopia entirely or approximately, according to the conditions mentioned above. As there is almost constantly diminution of visual power in myopes >7.0, they should not receive full correcting glasses for near objects, but such as will place the far-point at about 25 cm.

For example, in M 10.0 the far-point would be removed to 25 cm. by concave 6.0, as is shown by the following calculation: Concave 10.0 removes the far-point to infinity. But as we wish to remove it only to 25 cm., concave 10.0 is too strong by the refracting power of a lens which will disperse parallel rays in such a way as if they came from 25 cm., *i.e.*, concave 4.0; and $10.0-4.0=6.0$. The calculation according to inches is easier. For example, in M $\frac{1}{4}$ the far-point is to be placed at 8 inches: $\frac{1}{4}-\frac{1}{8}=\frac{1}{8}$, or at about 16 inches, which usually suffices for piano playing; then $\frac{1}{4}-\frac{1}{16}=\frac{1}{5\frac{1}{3}}$.

For greater distances the lens which is required to complete the neutralization may be placed in front of the spectacles as eyeglasses or lorgnette. For example, in M $\frac{1}{4}$, when spectacles $-\frac{1}{8}$ are worn for near objects, an eye glass $-\frac{1}{4}$ may be placed in front of the spectacle lens for distance. These general rules for the selection of glasses do not exclude exceptions in individual cases. Apart from those cases in which the advance of the myopia demands the selection of glasses which make it possible to diminish the convergence, we should also consider the comfort and habits of the patient. Why insist upon glasses in the case of a lady who, despite her M 7.0, will not wear spectacles or eyeglasses for distance, and is satisfied with what she does see? It is also an astonishing fact that myopes who do not wear glasses occasionally learn to utilize their circles of dispersion for creating a correct image, and can see remarkably well without lenses. We also find very marked myopia in which the patient, without glasses, can hold the book very near him without injurious convergence by allowing one eye to deviate to the outside. In like manner we should yield in favor of a certain lens which is habitually worn if it does not over-correct or act harmfully in some other way. At all events, the question of selec-

tion of glasses is to be considered very carefully and should not be left to opticians, as is unfortunately still done even by physicians. At an advanced age when the power of accommodation is diminished, myopes will often change to weaker glasses for near objects or even dispense entirely with their spectacles.

If the myopia be rapidly advancing all work near by should be interdicted for some time, at least four to six weeks. Atropine may be introduced twice a day in order to exclude all accommodation and thus diminish the movements of convergence. The atropine cure, which was especially advocated by Schiess-Gemuseus, is useful for such cases and in this sense. But it would be wrong to extend it to all myopes or to expect a permanent diminution of the myopia from it, apart from the relatively rare cases of pathological accommodative tension or spasm of accommodation. Blue glasses should be worn during the atropine treatment as a protection against excessive light. In addition, exercises in looking at a distance, which are intended to obtain a parallel position of the visual lines, should be instituted. Out-door life is to be recommended and the bodily health improved as much as possible, with avoidance of mental strain. Iron is indicated in some chlorotic and anæmic individuals, in whom abnormal accommodative tension is likewise more frequent. If there is marked hyperæmia of the optic papilla, the artificial leech often acts very favorably, when the general condition permits its use. Suitable treatment must be adopted against pronounced and advancing choroiditis and vitreous opacities.

2. Hypermetropia.

The hypermetropic eye in a condition of rest is adjusted for convergent rays. But as objects send out either parallel or divergent rays, the latter must first be made convergent before they will unite upon the retina of the hypermetrope. This is done by the use of convex lenses or increase in the curvature of the crystalline lens (accommodation).

If the hypermetrope does not use a convex lens, he will need a certain accommodative tension even for distinct vision at a distance. In some hypermetropes this is connected so closely with the act of vision that it persists even when made superfluous by the use of suitable convex lenses, as occurs in our ordinary measurements of refraction for distance. Under these conditions the actual degree of hyperopia does not become manifest, because it is concealed partly or entirely, by the retained accommodation. We can thus distinguish manifest and latent hyperopia. For example, if a

patient mentions 1.0 as the strongest convex lens with which he attains the maximum of visual power for distance, while, after atropinizing the eye or in ophthalmoscopic examination, in which the accommodative tension is lost, hyperopia 2.0 is found, then the manifest hypermetropia (Hm) is 1.0, the latent hypermetropia (Hl) is 1.0 and the total hypermetropia (Ht) is 2.0. It is also to be noted that a single atropinization does not always make the total H appear, but that frequent and continued applications are sometimes necessary. [Usually a four-grain solution instilled three times a day for six days is sufficient for even cases of spasm. Less than three days is barely sufficient.—St. J. R.] In the ordinary examination for spectacles, patients with latent H not infrequently exhibit a striking variation in their statements, now mentioning a stronger, soon afterward a weaker lens, as the suitable one. In a series of cases, convex lenses, without atropinization, do not improve vision; the patients appear to be emmetropic, and occasionally complain even of myopia (*vide* Spasm of Accommodation). Very slight differences in refraction after atropinization cannot be utilized in the sense of abnormal accommodative tension or latent H, because atropine causes slight diminution (about 1.0) of refraction in almost every eye, inasmuch as the normal tonus of the ciliary muscle is diminished.

[This statement may perhaps be modified by the statistics which show a certain percentage of eyes that remain unaffected by even the most prolonged use of atropia. These latter are the emmetropic eyes.—St. J. R.]

Donders introduced a still further division of hypermetropia, according to the relation of accommodation to parallel rays of light. If parallel rays can be united upon the retina by simple accommodation, there is facultative hyperopia. In our ordinary tests for distance, these patients attain the maximum of their visual power even without convex lenses. If accommodation is insufficient for the union of parallel rays, absolute hyperopia is present. The patients attain the maximum of their visual power only with the aid of convex lenses. In a third category, finally, the maximum of vision for distance is reached without convex lenses, but only by rendering greater accommodation possible. This is done by abandoning the parallelism of the visual axes and converging the eyes, *i.e.*, by adopting usually a unilateral strabismus. This is called relative hypermetropia. As a matter of course, the conditions may change in an individual with the diminution of accommodation in advancing age. Thus, facultative hypermetropia will gradually pass into absolute hypermetropia. Hypermetropia varies greatly in degree; it is comparatively rarely beyond 5.0. But still higher

grades, even 20.0, do occur. It is particularly in these that I have been struck by the fact that I have occasionally observed cases in which the most careful ophthalmoscopic examination of refraction showed a considerably higher degree of hyperopia than appeared on subjective test with lenses, even in the atropinized eye.

Etiology.—As a rule, the abnormality is congenital, often inherited; the eye is too small or, more accurately, the ocular axis is too short. The anterior chamber of the hyperopic eye is tolerably flat, the pupil narrow. Hypermetropia is acquired particularly after cataract operations (aphakia); emmetropes usually become hyperopes 10.0 to 11.0 after removal of the crystalline lens. It may also develop from corneal opacities which flatten the cornea.

Difficulties and Complications.—Weak sight is often associated with the higher grades of hyperopia, and results not infrequently from regular or irregular astigmatism. At all events, there are special reasons for examining hyperopes with diminished visual power, for astigmatism.

We have already explained that an apparent diverging strabismus sometimes occurs in hyperopes, on account of the size of the angle γ. In the chapter on the subject we shall discuss in detail the fact that certain hyperopes, in order to secure, by abnormal convergence, stronger accommodation in looking at near objects, really acquire converging strabismus.

The difficulties of hyperopes depend on the degree of ametropia and the power of accommodation. Pronounced hypermetropes who, as a rule, also have absolute hypermetropia, because their power of accommodation does not suffice even for parallel rays, are often regarded as near-sighted. Like the latter they see poorly at a distance. Unlike myopes, however, they must also see near objects poorly because, as a matter of course, they are much less able to accommodate for near objects. But we find patients who do not complain of seeing poorly near by; they bring the objects very close to the eyes and then recognize them from the size of the retinal images, despite the circle of dispersion. This is entirely analogous to the previously mentioned fact that very large print can be seen far to this side of the accommodative near-point.

Hypermetropes who have moderate or slight degrees of this defect can see well at a distance, if there is no absolute hypermetropia, but for near vision require much stronger accommodation than the emmetrope, because they require even for parallel rays a degree of accommodative tension corresponding to their hypermetropia. For example, if an emmetrope reads at 8 inches he requires an accommodation $\frac{1}{8}$; a hypermetrope $\frac{1}{4}$ requires the same accommodation (from infinity to 8 inches) and in addition an accommodation $\frac{1}{4}$ cor-

responding to his H $\frac{1}{24}$, in order to unite parallel rays upon his retina; his entire accommodation, therefore, is $\frac{1}{8}+\frac{1}{24}=\frac{1}{6}$. The near-point of the hypermetrope is always farther removed than that of the emmetrope. For example, if an hyperope $\frac{1}{24}$ and an emmetrope have the same range of accommodation ($\frac{1}{A}$ about $=\frac{1}{6}$), the near-point of the hypermetrope is situated at 8 inches, that of the emmetrope at 6 inches. Although in youth, when the power of accommodation is good, constant close work is possible to the hyperope, this grows more and more difficult with the diminution in the range of accommodation which occurs with increasing age; he will become a presbyope earlier than the emmetrope. Symptoms set in at an early period if the hypermetropia is more marked or the accommodation is slight, perhaps weakened only temporarily, as is seen particularly in children after severe diseases or as the result of excessive ocular strain. These symptoms consist, as a rule, of insufficient endurance in near work (asthenopia, hebetudo visus, kopiopia). The variety under consideration is known as accommodative asthenopia (Donders). Accommodation may be effected for a certain length of time, but then it relaxes; objects become indistinct, the letters run into one another and become confused. If an intermission is taken, work may be continued for some time longer as a result of the rest. In artisans the work is sometimes done well during the first days of the week, on account of the Sunday rest, but then it grows more and more difficult. Vision is more difficult at night than in the morning and during the day. If the work is forced, pressure and burning in the eyes set in, with pain in the forehead and head. Even distinct neuralgias may be due to this overstrain. After their long continuance, however, the headache or neuralgia often assumes an independent character in the sense that it occurs without straining the eyes. But treatment shows in such cases that recovery is impossible until the accommodative strain and irritation are relieved. It is not until then that the remedies otherwise indicated produce their effect. Such cases are not very rare and the examination by the physician should accordingly include the functions of the eye.

[The author evidently takes the view of the relations of asthenopia to general disease taken by the vast majority of oculists throughout the world, that is that while certain forms of headaches, neuralgias, quite frequently depend upon ocular defects, there is no large class of constitutional diseases, such as chorea, epilepsy, or even *migraine*, in any large proportion that may be cured by the use of glasses. The whole subject of relief of constitutional diseases has been much exaggerated in importance in this country, especially by some specialists in diseases of the nervous system, led by certain

enthusiasts in the treatment of neuroses by fitting glasses and dividing ocular muscles.—St. J. R.]

Treatment.—The symptoms of hyperopes may be relieved by the proper convex lenses. In absolute hyperopia, the lens which corrects the hyperopia should always be worn in order to improve vision for distance as much as possible; the same is true of relative hyperopia. In facultative hyperopia, the patient requires no glasses for distance, but they will relieve his accommodative strain for near vision. There is no reason why he should not secure the same favorable accommodative conditions as the emmetrope, at least for close work, by the use of glasses which correct or approximately correct his hyperopia. If he does not, his muscle of accommodation is strained unnecessarily. If asthenopic symptoms develop, convex lenses must always be resorted to. They should correspond, at least, to the degree of manifest hypermetropia. But this is often insufficient and the latent hypermetropia which may be present must also be corrected. In conditions of debility, near vision requires even stronger lenses, which would secure a position of the near-point similar to that in an emmetrope of the same age. But we must individualize in these cases. The rule does not obtain in all, as there is much subjective difference, particularly in the relative range of accommodation. We must always consider the personal comfort of the one who wears the glasses. In confirmed asthenopia, constant near work is not to be permitted even with convex glasses. Intermissions must often be granted, and the period of uninterrupted work is prolonged very gradually. If serious nervous symptoms have developed as the result of the strain of accommodation, or if the asthenopia is not relieved by means of convex lenses alone, as happens in some patients, in whom every convergence produces painful tension of accommodation (Donders), it is advisable to secure complete rest of the muscle by the atropine treatment continued for several weeks, and then to permit work gradually with suitable convex lenses. When the course of the disease has been combated in this way, iron, quinine, tincture of valerian, the constant current, etc., according to circumstances, generally prove useful.

3. Astigmatism.

Rays of light which radiate from one point (homocentric) are not, strictly speaking, united into one point by the refracting media of the eye. The eye participates, though to a slight extent, in the errors of refraction of spherical surfaces in general, *viz.*, chromatic and spherical aberration. If we disregard the former and consider only single colored (homogeneous) light, then spher-

ical aberration is shown by the fact that even those rays which impinge upon a single meridian of the eye (for example, the horizontal) do not converge into one point (*ἀ* privative, *στίλμα* point) after refraction, but into a line whose anterior focus is situated at the intersection of the most refracted rays, the posterior focus at the intersection of the least refracted rays (Fig. 50). This form of astigmatism, which affects refraction in the same meridian, is known as irregular astigmatism; it is found in all eyes. The stellate form of the stars and the seeing of objects several times (polyopia monocularis) are owing to this cause. It results physiologically from the structure of the lens and is therefore absent in aphakia.

When astigmatism is present to a marked degree, vision also suffers. This abnormal irregular astigmatism may also owe its development to the lens, inasmuch as it may be produced by unusual conditions of refraction which, for example, occasionally precede the development of cataract, or by changes in position (luxations). But in the majority of cases the cornea plays a more important part. Irregular astigmatism occurs very often from slight opacities; also from ulcerations and ektesiæ, particularly from keratoconus. In addition to diminished power of vision, its symptoms consist of confusion and distortion of objects, diplopia or polyopia. Ophthalmoscopic examination, which does not give a completely distinct picture of the parts of the fundus, will assure the diagnosis; in corneal astigmatism, the keratoscope makes it even clearer. Very irregular figures are seen in the corneal reflex image instead of the regular rings. Unless we have to deal with diseases which can be relieved or improved by material means (curing of ulcers, tattooing of corneal spots with subsequent formation of a pupil, operation for keratovus, etc.), not much can be done with optical measures in irregular astigmatism. For certain purposes vision can sometimes be improved by allowing the patients to look through small holes or narrow fissures from one to three millimetres wide (stenapaic apparatus).

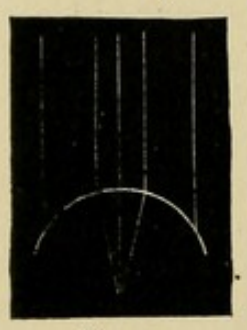


FIG. 50.

In addition, there is another and practically more important form, *viz.*, regular astigmatism. This is located chiefly in the cornea and depends upon the fact that the surface of curvature does not form part of a sphere, but of the apex of an ellipsoid. The minimum of curvature is located mainly in the horizontal meridian, the maximum in the vertical meridian (Knapp, Donders). Differences in the meridional curvature of the lens occur occasionally from partial contractions of the ciliary muscle and, if situated in the opposite direction, serve to diminish the corneal astigmatism

(Javal, Dobrowolsky). In rare cases As depends solely on anomalies in the curvature of the lens and disappears after the use of atropine.

In regular astigmatism the rays which enter in different meridians experience unequal refraction; they are not united in a point, but in a focal line (Sturm).

If we disregard the unequal refraction in the same meridian (irregular astigmatism) and assume that all homocentric rays passing through the same meridian are united in one point, Fig. 51 will illustrate the mode of convergence of parallel rays emanating from a point situated at an infinite distance. We here regard the horizontal meridian (*h h*) of the astigmatic eye as the one which has the longest radius of curvature and therefore the most feebly refracting, the vertical meridian (*v v*) as the most strongly refracting.

The vertical rays impinging on the cornea will therefore be united earlier (f_1) than the horizontal rays (f_2). Inasmuch as all rays passing through the meridian *v v* are united in a point in a vertical plane passing through f_1, while the rays entering in the horizontal meridian form, in addition, a number of converging rays, a horizontal bright line (not shown in the figure) will appear at this place; on the other hand, the bright line in f_2 will be vertical. Between these two lines (focal lines) lies the focal area (focal interval $f_1 f_2$). It contains a point at which the transverse section of the rays forms a circle (*n*), which is smaller than the transverse section of the bundle of rays in front of the eye and which presents the comparatively greatest concentration of light.

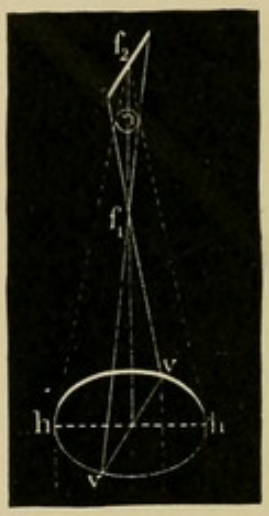


FIG. 51.

According as the retina is situated at one or another distance from *h h* and *v v*, the image thrown upon it by a point of light situated at an infinite distance will vary and correspond to the figures illustrated above. As a general thing, the image will be most distinct when the retina is situated in the plane of greatest concentration where every point is reproduced as a circle. If it is situated in the plane of a focal line, only those rays will be sharply converged which have passed through a meridian perpendicular to this line, for example, through the vertical meridian *v v* if we assume the retina situated at f_1 where the focal line is horizontal. It is evident that this position is the most advantageous for the recognition of certain objects, here, for example, horizontal lines.

The focal area will have so much greater dimensions, the greater the difference in the refraction of the two meridians which are per-

pendicular to one another; it becomes equal to *o*, *i.e.*, it will contract into a focal point, if this difference is equal to zero.

According to Donders, the degree of regular astigmatism is marked by the difference in the refraction of those meridians (usually perpendicular to one another) which present the greatest differences in refraction. For example, if the refraction in the horizontal meridian corresponds to that of an emmetropic eye, that of the vertical meridian to myopia 2.0 ($\frac{1}{2^1_0}$), the degree of astigmatism $=2.0-0\ (\frac{1}{2^1_0}-\frac{1}{\infty})=2.0\ (\frac{1}{2^1_0})$. If the horizontal meridian has myopia 1.0, the vertical one M 2.0, then there is As 1.0 in addition to the myopia belonging to the two meridians. If there is hyperopia 1.0 in the horizontal meridian myopia 2.0 in the vertical meridian, then As=1.0+2.0=3.0.

These examples also illustrate the three different forms in which regular astigmatism occurs. 1. *Simple Astigmatism:* emmetropia in one principal meridian, in the other myopia (simple myopic astigmatism Am) or hypermetropia (simple hyperopic astigmatism Ah). 2. *Compound Astigmatism: a.* myopia of different degrees in both principal meridians (M+Am); *b.* hyperopia of different degrees in both principal meridians (H+Ah). 3. *Mixed Astigmatism:* hypermetropia in one meridian, myopia in the other. According as one or the other error is more marked; *a*, mixed astigmatism with predominant H (Ahm) or *b*, with predominant M (Amh).

As is evidenced from the remarks on the curvature of the cornea, slight grades of astigmatism occur in the normal eye. When they exceed 1.0 dioptry, they must be regarded as pathological or abnormal. Distinct impairment of vision, resulting from the confusion of the retinal images, then appears in the ordinary examinations of vision with letters, hooks, etc. This is often the only subjective symptom, as the patients comparatively rarely mention spontaneously that they see lines less distinctly in one direction than in another, that squares appear as parallelograms, circles as ellipses, etc. Developed powers of observation are needed to notice this spontaneously. It is therefore well to examine for abnormal astigmatism in every impairment of vision which does not result from other demonstrable changes, which persists despite correction with spherical lenses, or in which approximately equal vision is obtained with spherical lenses of very different degrees. The stationary character of the impairment of vision is another suspicious factor. Nor should the examination be neglected when there are asthenopic symptoms, because these are sometimes due to astigmatism.

As a rule, the affection is congenital and is often complicated with hyperopia. It is found occasionally in corneal opacity and in

the diseases mentioned in the consideration of irregular astigmatism. It is especially frequent after cataract operations and may also occur after iridectomy. Laqueur made the interesting observation that traction on the upper lid, whether to the temporal or nasal side, may produce flattening of the horizontal meridian and increased curvature of the vertical meridian by pressure on the normal globe, so that regular astigmatism of 2 to 4 D develops. Some patients correct their astigmatism by similar pressure.

Cylindric glasses, whose introduction into practice is due to Donders, are used for correction and diagnosis.

The simple cylindric glass may be conceived to be developed from a glass cylinder, as shown in Fig. 51, by removing with the plane *a b c d* (parallel to the axis of the cylinder) the portion situated to the left, and then removing the part situated to the right by means of the sharply concave surface $\alpha\,\beta\,\delta\,\gamma$, whose radius is smaller than that of the cylinder. We then obtain, on the left, a positive cylindric glass (+c), on the right a negative one (−c); +c is a plano-convex cylindric glass, −c a convexo-concave or negative cylindric meniscus. A plano-concave glass would be obtained, if the concave meniscus −c were supplemented by glass, on the right side, into a parallelopipedon.

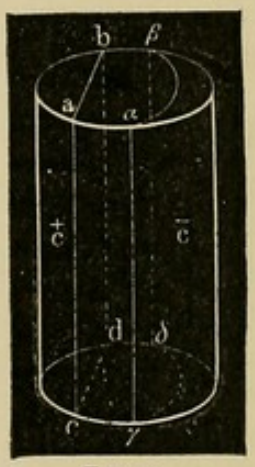


FIG. 52.

A bicylindric glass (written: concave-cylindric x, convex-cylindric y) is formed if we imagine a plano-convex cylindric and a plano concave cylindric glass with crossed axes applied to one another on the plane sides. If a plano-cylindric glass is united to a plano-spheric one in the same way, a sphero-cylindric glass results (cylindric x⌓ spherical y).

Every cylindric glass permits rays of light to pass through undeflected in the direction of the axis of the cylinder. Rays which impinge upon the glass perpendicularly to the axis, fall upon a circular section of the cylinder and are converged or dispersed as by spherical lenses. This peculiarity of refracting a portion of the rays and permitting those which are parallel to the axis to pass through undeflected, fits cylindric glasses for the correcting of regular astigmatism. The axis of the cylinder is always placed parallel to that meridian of the eye which needs no correction. In the cylindric glasses of our figure the vertical rays would pass through undeflected, the rays entering horizontally would be deflected according to the refracting power (measured in dioptries or inches as in spherical lenses. The position of the axis is usually indicated by a line (|) on the cylinder.

The astigmatism is best measured by means of the cylindric glasses. The visual power is first measured in the ordinary way with the large letters of Snellen's tables, hanging at a suitable distance. If vision is improved by spherical lenses, the weakest one with which the maximum of vision is secured, is placed in front of the eye in a spectacle frame. We now attempt to secure still further improvement by rotating a weak convex cylindric lens in front of the eye. In a certain position of the lens the patient then states that he sees better or worse, or equally well. The position in which the cylinder or, strictly speaking, its axis must be held, is now known, and improvement in vision is then sought by stronger and stronger numbers. When this is done, the strongest convex lens with which the maximum of vision is reached, gives the degree of astigmatism. If no improvement of vision occurs with convex-cylindric lenses, concave cylindric lenses are used in the same way. If improvement is then obtained, the refracting power of the weakest cylindric lens gives the degree of astigmatism.

This examination also indicates the correcting glass. If no improvement was obtained with convex or concave spherical lenses and the measurement was made without them, then there is simple astigmatism, and a simple cylindric lens will serve for correction. We then furnish the optician with the position of the axis of the cylinder by a corresponding stroke (vertical, oblique or horizontal) alongside the number; for example, concave-cylindric 2.0 | (*i.e.*, the axis vertical); or the position of the axis is designated in degrees of angles, which presupposes an agreement concerning the position of the zero point. It is well not to place the round cylindric lens permanently in the spectacle frame, but to find out the best position by first moving it slightly to and fro. If a spherical lens has been found to produce some improvement of vision, then a spherical-cylindric lens will produce the correction, and is prescribed; for example, in the following way: concave 2.0 sph. ⌓ concave 1.0 cyl.—

It is evident that, in this way, bicylindric lenses are not needed. In cases of mixed astigmatism, in which they are intended to correct the latter, the same object can be secured by spherical-cylindric lenses. For example, there is M 2.0 in the vertical meridian, H 1.0 in the horizontal meridian; this would be corrected by a bicylindric lens; concave 2.0 cyl.— ⌝ convex 1.0 cyl | . But the same object is also attained by concave 2.0 sph. ⌒ convex 3.0 cyl. | . Concave 2.0 spherical corrects the myopia of the vertical meridian, but, on account of its dispersing power, increases by 2.0 the hyperopia 1.0 in the horizontal meridian. Hence convex 3.0 cylindric with vertical axis must be used for correction of the horizontal meridian.

The existence of mixed astigmatism may be inferred, if better vision is obtained with convex and concave spherical lenses. If we wish to measure actually the refraction in the principal meridians and are not satisfied with the above-mentioned practical correction, the following method must be adopted. In order to find the position of the principal meridians directly, we may use a star figure (Green) or a half-star figure arranged as in the accompanying figure (such as is found, in the proper size, in Snellen's test types). If this figure is gradually removed from the eye, the astigmatic finally will see distinctly but a single ray, *viz.*, the one seen through the most far-sighted (feebly refracting) meridian of the eye; another ray, which is usually distant about 90° from the other, will appear most confused. In order that the figure need not be removed too far, emmetropes and hyperopes may be made myopic artificially by the aid of a strong convex lens. The direction of the two lines indicates the position of the principal meridians. The meridian which is perpendicular to the direction of the line which is seen distinctly at the greatest distance, is the most feebly refracting (or the best refracting in hyperopia). To see these lines distinctly it is necessary that their demarcation from the white interspaces appears distinctly. The rays of light which emanate from the points ($a+b$, Fig. 54) of the edges of the lines should not present any circles of dispersion toward the interspaces. This is only possible when sharp refraction occurs in the meridian *ab*. After the principal meridians have been ascertained in this way, a stenopaic slit is held first in the direction of one, then of the other meridian and the refraction determined in the ordinary way.

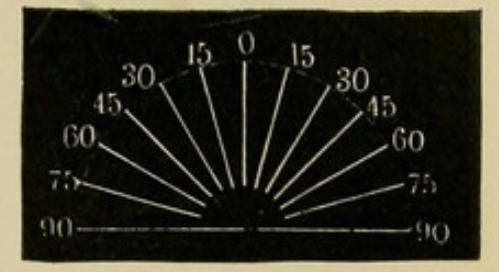


FIG. 53.

The following other methods may also be mentioned.

Stokes constructed a lens consisting of two cylindric lenses (convex $\frac{1}{10}$ and concave $\frac{1}{10}$) which are in contact at their plane surfaces and can be rotated around one another in a frame. When their axes are parallel, their action is abolished; when they are crossed they act in one meridian like $-\frac{1}{10}$, in the meridian parallel to this like $+\frac{1}{10}$. They can therefore correct As 0 to As $\frac{1}{5}$ by gradual rotation and thus replace a series of cylindric lenses. But simple cylindric lenses are preferable, because over-correction of one meridian often occurs in testing with Stokes' lens. The further disadvantage, that the position of the axis is constantly changing, has been removed by Snellen's modification.



FIG. 54.

Donders, in order to find the principal meridians, allows the patient to look at a distant point of light, which appears to the astigmatic as a line of light. We can soon find a spherical lens which makes this line appear more sharply, and then a second modifying lens (positive or negative) which, when held in front of the first, gives the light line an exactly opposite direction.

Javal has constructed a special instrument which consists of a four-cornered, extensible box, in whose anterior wall are situated two openings with convex lenses. The eye to be examined looks through one lens at a circle in which the radii are drawn. The figure is then drawn away until only a single line is distinctly visible. This is perpendicular to the meridian of feeblest refraction. Concave-cylindric lenses of different strengths (which are situated in a movable frame, and with the axis corresponding to the meridian of weakest refraction) are then placed successively in front of the eye until that one is found with which all other lines are seen distinctly. In the mean time the other eye looks, as in a stereoscope, through the second opening at a circle without radii; the blending into one stereoscopic image assures the uniform convergence of the visual lines and thus makes the accommodation less changeable.

Finally, we may refer to the letters composed of parallel small black lines, which run in different directions in each letter (Pray, Heymann). According as the astigmatic sees better in one or the other direction, he will recognize more readily the corresponding formed letters.

In all these tests the results are often disturbed and confused by partial contractions of the ciliary muscle which, as we have mentioned, may cause diminution or even abolition of the astigmatic error of refraction. The use of atropine relieves this difficulty, but it is to be noted that the correcting lenses which are then found, are often discarded by the patient on the restoration of accommodation.

[This has not been my experience. It is my habit to find the full degree of astigmatism, if it be latent, by the use of atropine, and then to correct the full degree in the glasses ordered. After years of work of this kind, I have not been often disappointed in thus ordering glasses.—St. J. R.]

Regular astigmatism can be diagnosticated objectively by means of the ophthalmoscope. Higher grades of regular corneal astigmatism become evident in the mirror images of the cornea, for example, a window appears enlarged in one direction. The drawings of the keratoscope or, for accurate measurements, the ophthalmometer can be used to still better advantage.

According to Javal, the astigmatism of hyperopes increases with age because their corneal astigmatism is partly compensated in youth by the opposite astigmatic curvature of the crystalline lens (with the aid of the muscle of accommodation).

[Presbyopes, however, find the correction of even the slighter degrees of even hyperopic astigmatism very important, since it gives great relief to asthenopia—St. J. R.]

As a rule, the use of cylindric lenses will be discarded if they produce only slight improvement of vision. They require very accurate adjustment of the axes in order to avoid producing impairment of vision or distortion. Hence, in wearing them, displacement of the spectacle frame, etc., must be avoided. In a certain number of cases cylindric glasses are notably advantageous, because they decidedly improve vision and relieve asthenopic symptoms.

4. Anisometropia.[1]

Different Refraction of the two Eyes.

Although the refraction of both eyes is usually alike, more or less pronounced differences are not rare. On the one hand, the degree of ametropia in the two eyes may vary; on the other hand, there are different combinations between emmetropic, myopic, hypermetropic, and astigmatic eyes. In all these cases, an object situated at a certain distance will throw a sharp image upon the retina of one eye alone, and will appear upon the other as circles of dispersion. Bilateral, sharp retinal images could only be produced if correct adjustment of both eyes were effected by different contraction of the ciliary muscle which corresponded to the refraction in each eye. But this possibility disappears, inasmuch as it is known, as a matter of experience, that the impulse of accommodation affects both eyes with equal intensity.

The result of the difference between both retinal images may consist of the loss of binocular vision, inasmuch as sometimes one, sometimes the other eye is used for vision, or one eye is kept constantly excluded. In the latter event, the excluded eye usually exhibits marked impairment of vision or a marked error of refraction. When an object is fixed, the eye which is excluded from vision does not, as a rule, present a perfectly accurate adjustment of its visual line; there is often a distinct deflection (diverging or converging strabismus). When the eyes are used alternately for vision, thus, the emmetropic eye for distant objects, the myopic

[1] A privative, *ἰσόμετρος* uniform, *ὤψ* sight.

eye for near objects, the visual line of the excluded eye generally deviates from the point of fixation, most frequently outward.

On the other hand, there are many cases of anisometropia in which binocular vision persists. Indeed, they form the rule in cases of slight errors of refraction or slight differences in vision.

Binocular and Corporeal or Stereoscopic Vision.—Corporeal vision which depends on the recognition of dimensions of depth, *i.e.*, in the ability to perceive whether one point is situated at a greater distance than the other, is by no means coördinate with binocular vision. It is important to lay stress on this distinction, which is not always sufficiently emphasized. The one-eyed individual also sees corporeally, though not so perfectly as the two-eyed individual. The former, who has seen with only one eye for a long time or during life, does not confound a sphere with a round surface of equal size and color.

Corporeal or stereoscopic vision is a matter of experience and is learned. Although the child sees with both eyes, he must learn to distinguish a circular plane surface from a sphere by the sense of touch. In individuals with congenital cataract, upon whom the operation was performed, the acquisition of corporeal vision has been accurately followed. I performed an operation for acquired cataract upon a child of three and a half years, who had seen well a year before, but had entirely forgotten corporeal vision in this brief period. After vision was restored he could not, at first, estimate distances, but usually grasped far beyond the object held in front of him. He could not distinguish an egg from a white paper disk of the same size, but succeeded at once on feeling the objects. He was compelled to learn anew to recognize objects, except that he recognized a cat and a calf, although they had not been shown to him since the restoration of sight.

There are greater or lesser degrees of perfection in binocular as well as in corporeal vision. In order to demonstrate binocular vision, a prism, with the base above or below, is placed in front of one eye, while the other remains free and open. Superimposed double images must then develop. Stereoscopic tests may also be used. It then appears often that both halves of the picture are seen (this is often observed in strabismus if we do not take pictures of physical objects, but perhaps differently colored wafers which adhere at unsymmetrical portions of both halves), although it is impossible to secure the physical coalescence of other pictures which are stereoscopically symmetrical. However, there are many persons, even those with exact corporeal vision, who first recognize the double pictures of the stereoscope separately, until their union suddenly occurs. The process of union of the two pictures

into one corporeal picture is evident from Fig. 55. The rays of light falling from *a* and *a* upon identical parts of the retina are interpreted as coming from A. The small prisms, with the base turned to the outside, which are situated in front of both eye-pieces, make it possible for both eyes to maintain the convergence customary for near vision.

This union of two stereoscopic pictures shows the power of corporeal vision. But the highest demands on corporeal vision are required in Hering's falling test, inasmuch as a remarkably rapid perception of depth is necessary, and certain aids for corporeal vision, the utilization of which requires a certain amount of time, cannot come into play. Both eyes look through a short pasteboard tube, in front of whose anterior end a vertical thread is stretched, at a certain distance, between two wires. A bead is fastened at the middle of the thread, and is fixed with both eyes. The experimenter then lets other beads fall in front and behind the fastened one, but as a matter of course in such a way that the fixed and falling beads do not cover one another. In accurate binocular and corporeal vision, it can be seen whether the falling bead falls in front of or behind the fixed one.

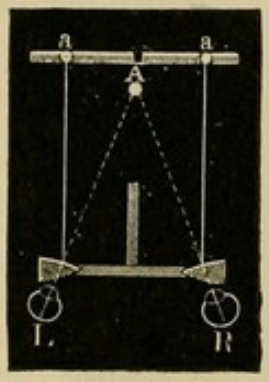


FIG. 55.

We are enabled to secure corporeal vision by various adjustments in our visual organs. The most important is the fact that we look at objects with two eyes (*i.e.*, binocular vision). Each eye sees the object from another point of view and obtains a different image of the lateral surfaces; at the same time the farthest point of the object seems to be moved over toward the side of the observing eye. We can easily convince ourselves of this by placing a long ruler, with the surfaces directed sideways, in front of the root of the nose, and directed straight forward. On looking at this with one eye (closing the right and left eyes alternately) we experience the distinct impression that the farther end of the ruler moves towards the right on looking with the right eye, toward the left on looking with the left eye. In binocular vision this difference in the images, which are united into one perception, gives an extremely distinct momentary sensation of the difference in distance between two points.

Upon this fact depends the apparent corporeal vision with the stereoscope. For example, if the image of a transparent glass pyramid, whose apex is turned toward the observer, appears to the left eye as a retinal image with the apex turned toward the right, then the apex will be turned to the left for the right eye.

The binocular union of both images then gives to one expert in corporeal vision the impression of a corporeal glass pyramid.

Apart from this difference in the images, an important element in estimating the distance between a point *a* and a more remote point *b* is the fact that in binocular fixation of the point *b*, the rays emanating from *a* fall upon the temporal half of the retina of the left eye, *i.e.*, are projected to the nasal side; a similar condition obtains in the right eye. The nearer point *a*, therefore, appears double, the image in the right eye being situated to the left, that in the left eye to the right (crossed double images). The double images of *b*, on fixing *a*, would appear differently. The image of *b* in the right eye would be projected to the right, because it falls upon the nasal half of the retina, in the left eye it would be projected to the left for the same reason (homonymous double images). This difference in the relation of the double images also influences our perception of depth.

It is also to be remembered that a near point requires greater accommodation and convergence of the visual axes than a more remote point. The shadows of objects and numerous experiences also aid corporeal vision.

The latter aids are also at the service of one-eyed individuals as well as of those who possess binocular vision. Both are subject to deception, the former more frequently than the latter. Very plastically painted objects may impress us as solid. In the numerous panoramas now in vogue, in which real objects are situated close to the observer, and then the painted canvas is superadded, the deception becomes very striking because we infer from the presence of the objects in our vicinity that the painting is also corporeal—in accordance with our experience that, in looking at a distance, one body is on same plane with the other.

From the remarks made, it follows that perfect and skilled binocular vision must also include corporeal vision.

On the other hand, a certain degree of corporeal vision may exist (with the aid of convergence of the visual axes, accommodation, and other experiences), despite monocular vision. But such individuals cannot succeed in Hering's falling test (in guessing the chances are naturally fifty per cent in their favor) or in that of Donders, who passes electric sparks in front of and behind the fixed object in a dark box, because the perception of depth here depends solely on the utilization of the different retinal images in both eyes, while convergence and accommodative changes are excluded on account of the rapidity of the process.

Experience also teaches that those who possess binocular vision do not always succeed in Hering's falling experiment. This is

observed, for example, in some patients after operations for squint: they can unite the images very well in the stereoscope, but make wrong statements in the falling experiment. They are lacking in practice or in the ability to construct the perception of depth solely and rapidly from the different retinal impressions of both eyes.

The same conditions are found in anisometropes. There are some in whom binocular vision satisfies all demands, even those of immediate corporeal vision, while, in others, binocular and corporeal vision are present, but are not sufficiently perfect to stand the test of Hering's drop experiment.

Treatment.—When binocular vision is lacking, the treatment of anisometropia endeavors to restore it, by separate visual exercises of the more poorly seeing eye with the suitable lens, the other eye being closed, and then by exercises in the union of stereoscopic pictures. These exercises are carried out in the same way as those which will be described in detail in the treatment of strabismus.

In a series of cases, particularly when one eye is strongly myopic and alone is employed for near sight, binocular vision cannot be secured. In other respects, eventual correction with glasses must be made according to the rules given with regard to errors of refraction. But it is usually more convenient, as regards the patient's vision, to wear a lens of the same strength for both eyes. We then correct the eye which presents the slighter error of refraction, provided it possesses sufficient visual power. Hence it follows that no spectacles for distance are given in cases in which one eye is emmetropic. But if the eye which possesses better vision has the greater error of refraction, for example, if it is more myopic than the other, this is provided with a suitable lens, while a weaker one is used for the other eye, adapted to its degree of refraction.

The correction of both eyes, which possess equal or approximately equal power, with the aid of lenses which compensate their special errors of refraction, usually possesses no special advantage. Despite the displacement of the far-point of both eyes to infinity, exact bilateral adjustment for near objects does not occur, inasmuch as the relative range of accommodation, as we have seen, varies with the different errors of refraction, as well as with different degrees of the same error. The same accommodation impulse for both eyes acts differently in each despite the equality of the range of accommodation (from infinity to the object upon which the visual axes converge). It is also well to act here according to the individual comfort of the anisometrope. The often expressed fear of some patients who are otherwise entirely satisfied with a

lens which corrects accurately only one eye, that without suitable correction of the other eye the latter will be excluded from vision, may be dispelled by making the above-mentioned experiment to test binocular vision. If it should then prove to be absent, an attempt to supply it with proper correcting glasses should be made; but, as a rule, it cannot be secured by the lenses alone.

5. Presbyopia.

When the range of accommodation has diminished to such an extent, as the result of increasing age, that the near-point is removed beyond 22 cm. (or 8 inches) this is usually accepted as the beginning of presbyopia. As we have stated above, the near-point is usually situated at 22 cm. in emmetropes after the age of forty years. Hypermetropes become presbyopic earlier, myopes, according to their degree, later or not at all. A myope 6.0 whose far-point is situated at about 16 cm., cannot be regarded as presbyopic in the sense mentioned, even after the loss of his entire range of accommodation.

The symptoms resulting from the removal of the near-point consist of the fact that small objects, which require greater proximity, are no longer recognized and that even ordinary print cannot be read for any length of time. This is particularly evident with artificial illumination. Presbyopes assist themselves at first, by holding the print farther from the eye, but finally this does not suffice. As a rule, real asthenopia, such as occurs in young hyperopes, does not develop, because on the one hand close work is not forced and, on the other hand, the experience that, as a rule, convex glasses for near vision must be worn in old age, soon leads them to this mode of relief. After marked strain of accommodation in presbyopes, it may suddenly become weakened to such an extent that close work becomes entirely impossible. I have observed such cases which almost created the impression of a sudden paralysis of accommodation, but disappeared after several days' rest.

The symptomatic treatment of presbyopia consists of the use of suitable convex glasses which, as a matter of course, must gradually become stronger with advancing years. It is a general rule in their selection that they should restore the near-point to 22 cm. which corresponds in emmetropes to an accommodation of 4.5. If, according to Donders' table, $a=3.5$ at the age of 45 years, the corresponding convex glasses $=1.0\ (4.5-3.5)$; at the age of 50 years, it would be $2.0\ (4.5-2.5)$. But as individual variations occur, we should first determine, by applying the lens in question,

whether the lens really enables the patient to read finest print at 22 cm. Spectacles selected in this way are not convenient for all patients. They have been accustomed to hold the print farther away, and therefore are often better satisfied with a weaker lens. This must be considered, particularly in old age; in addition, the lenses then required magnify considerably on account of their strength. As the far-point also recedes in old age, an emmetrope of 75 years has acquired H 1.75 with a=0. In order to accommodate to 22 cm., this would require a convex lens 1.75+4.5=6.25. This lens magnifies to an annoying extent and then, on account of the absence of accommodation, the patient can only see at 22 cm. with the convex lens, while he can conveniently read ordinary print at about 36 cm. A corresponding lens (2.75 [focal length about 36 cm.] +1.75=4.50) will often be more convenient. Even when accommodation is still present, strong convex glasses notably restrict and approximate the tract of distinct vision. For example, if a man of 60 years who was formerly an emmetrope but has now become H 0.50 and a =1.0, the spectacles 3.5+0.5=4.0 would bring his near-point to 22 cm.; on relaxation of his accommodation he could see to about 28 cm. (As a=1.0, *i.e.*, equal to the refracting power of a lens of 100 cm., it follows that $\frac{1}{2\,3}-\frac{1}{1\,0\,0}=C\frac{1}{2\,8}$.). Whatever is situated beyond 28 cm. becomes indistinct with the convex lens. This explains the complaint of those who are beginning to use convex glasses, that everything appears confused on looking up. It is well to tell them this beforehand, and to explain that the glasses are intended only for near vision. In consideration of these conditions, we must yield somewhat to the patient in the selection of the glasses. But if disturbances arise after prolonged work, despite the use of the glasses selected, we must pass to stronger numbers. If there is impairment of vision, a stronger lens is also necessary, because greater approximation of objects is then required.

The power of accommodation often diminishes in the course of the day and vision is often particularly difficult with artificial illumination. It is then advisable to give different spectacles, a weaker pair for the day, a stronger pair for night work. A slightly blue tinge of the glasses (about No. I. or II.) is often useful. Myopes of slight grades, who have subsequently become presbyopic, occasionally use the so-called Franklin spectacles; these consist of a concave-ground upper half for far objects, a convex-ground lower half for near objects.

6. Errors of Accommodation.

I. *Paralysis of Accommodation.*

Paralysis of accommodation results in a pathological diminution or complete abolition of the normal range of accommodation, resulting from the fact that the near-point is removed farther from the eye. According to the degree of diminution we speak of paralysis or paresis of accommodation. The latter is distinguished from presbyopia particularly in this, that the diminution of accommodation does not correspond to the age of the patient. Moreover, presbyopia usually develops gradually, while the paresis generally develops in quite a short time; the former affects both eyes, the latter may attack one eye alone. There are also occasional differences in the size of the pupils, inasmuch as paralysis of accommodation is often—not always—associated with dilatation of the pupils (mydriasis) while presbyopic eyes usually present narrow pupils.

The diagnosis of paralysis of accommodation always requires the measurement of the range of accommodation and its comparison with that which corresponds physiologically to the age of the patient.

It is to be noted that conditions of weakness such as occur after severe diseases, in anæmia and chlorosis, may also produce a certain diminution in the range of accommodation which is not to be regarded as paresis of accommodation. If an individual is unable, after a serious illness, to lift the same weight as before, we do not speak of paralysis of the muscles. But in the cases under consideration, we do not have to deal merely with diminished energy of the muscles, as Mauthner believes, but with a real diminution of power in accommodation with a decided diminution in the absolute range of accommodation. But if this corresponds to the general weakness, we are not justified in diagnosticating it as a local affection, a paresis. A profile view of the iris may be used as an objective symptom of the paralysis. When the anterior chamber is looked at from the side, the visible protrusion of the iris with flattening of the anterior chamber during accommodation (Voelckers) remains absent. The muscle affected in paralysis of accommodation is the ciliary muscle, its nerve is the ciliary branch of the third nerve.

Symptoms.—Paralysis of accommodation produces more or less severe symptoms, not alone according to its intensity, but also according to the condition of refraction of the eye. In some cases these are similar to those of accommodative asthenopia and pres-

byopia. While the emmetrope complains that near vision is less easy than before, perhaps entirely impossible, and hyperopes see more poorly even at a distance, the myope of higher or even moderate grades is less affected. For example, if the far-point of the latter is situated at 25 cm., he can still read and write, provided that he does not wear neutralizing concave lenses; this distance suffices for most work, even in total paralysis of accommodation. The patient will notice, however, that objects become indistinct on bringing them still nearer.

When, as often happens, one eye alone is affected by the paralysis, these symptoms are less decided; the patients usually complain of a certain inconvenience and blurring in binocular fixation. This depends on the fact that one eye receives circles of dispersion, while the other sees distinctly. After long continuance, this inconvenience may disappear entirely; the patients then present the same conditions as anisometropes.

Micropsia is sometimes complained of in paresis of accommodation, as it is after atropinization; objects appear smaller. This is explained by our estimation of the apparent size of objects, not alone from the size of the retinal images, but also from the distance at which, in our opinion, they are situated.

If an object at a distance of 1 m. throws a retinal image of a definite size (a), the latter will become twice as large ($2\,a$) when the object approaches to $\frac{1}{2}$ m. Nevertheless we do not regard the object as twice as large, because the effect of approximation is also taken into consideration. The latter is influenced not alone by the convergence of the visual axes, but also by the strain of accommodation required for distinct vision. When, in paresis of accommodation, the accommodative strain necessary to recognize the object at 1 m. is, for example, as great as that required previously for accommodation at $\frac{1}{2}$ m., while the retinal image does not equal $2\,a$, the object, which the patient regards as nearer than it really is, must appear smaller. As we have mentioned, mydriasis is a not infrequent complication. But this is much less marked than after atropinization, even if the nerve supplying the sphincter iridis is completely paralyzed. The reaction to light or accommodation is absent. Inasmuch as in unilateral affections the other pupil is narrowed on account of the entrance of a larger amount of light, it may at first be doubtful, for example, in cases of progressive paralysis, whether the pupillary contraction or dilatation is pathological. This must be decided by the pupillary reaction of each eye to light. In rare cases, generally in those which have lasted a long time, there may be excessive dilatation of the pupil similar to that which results from the action of atropine.

The diagnosis of paralysis of accommodation depends on the absence of accommodation; vision is distinct only at the far-point. Paresis of accommodation is present when we find, on examination, not a complete abolition, but merely diminution of the range of accommodation, which is distinctly smaller than the normal at the corresponding period of life. As a matter of course, we must take into consideration general conditions of weakness in estimating the expected power of accommodation.

If, in the etiology, we disregard palpable diseases of the central nervous system (tumors, hemorrhages, scleroses, etc.) or affections which may implicate the third nerve in its course (periostitis, tumors at the base of the skull or in the orbits), there remain a series of factors whose influence in the occurrence of paralysis of accommodation has been positively proven. We must particularly mention pharyngeal diphtheria (Donders), and syphilis. Paralysis of accommodation may occur even after very mild cases of tonsillar or pharyngeal diphtheria. The disease is sometimes entirely overlooked by the parents, and the visual disturbances alone lead to consultation of the physician. The symptoms appear in a few days or weeks after the termination of the disease and, as I have found, usually reach their height in a few days. The patients first complain of "scintillation" while reading, and the recognition of print soon becomes impossible. In the majority of cases, however, there is simply paresis, not complete paralysis of accommodation. As a rule, both eyes are affected; mydriasis is absent. Inasmuch as children are chiefly attacked, hyperopic refraction is often demonstrable during the period of paralysis. Jacobson, who was the first to devote more attention to the position of the far-point in this condition, came to the conclusion that it is farther removed than during health. But Weiss' examinations and my own, have shown that, as a rule, the diminution of refraction, if present at all, is so slight during the period of paralysis that it is explained simply by the diminished tension of the ciliary muscle, as it is after atropinization. Hence the views of a negative accommodation which was supposed to produce an active removal of the far-point by the isolated action of certain fibres of the ciliary muscle—these views which are connected with Jacobson's observations, fall to the ground.

Vision is often diminished by astigmatism which is capable of correction, but sometimes this cannot be found as the cause of the impaired vision (Voelckers, Nagel). In a case under my observation the impairment of vision (V $\frac{5}{12}$), which was associated with hyperæmia and blurring at the entrance of the optic nerve, disappeared entirely in a few weeks, together with resolution of the ab-

normal ophthalmoscopic appearances. Paralysis of the velum palati is often present. Abducens paralysis has also been observed in many cases. In some patients strabismus convergens concomitans hyperopicus occurs for the first time as the result of paresis of accommodation and may cause spontaneous diplopia.

In syphilis, paralysis of accommodation occurs at a comparatively late period. All other symptoms have often disappeared for years, when the paralysis suddenly recalls the almost forgotten malady. As a rule, the affection is unilateral.

In other cases, there is a distinct rheumatic cause (sudden change of temperature, violent draught). Paresis of accommodation is also said to occur after angina tonsillaris without diphtheria, but the overlooking of diphtheria is not excluded here. It has also been observed after severe constitutional diseases, diabetes, herpes zoster ophthalmicus, lead poisoning, poisoning from trichinæ (Scheby-Buch), working near fire (Colsmann), trigeminal neuralgia, trauma, diphtheria of wounds, acute gastritis, etc. A removal of the near-point also appears occasionally at the beginning of sympathetic ophthalmia, but my own observations have taught me that this is not always, as has been claimed, the initial symptom of sympathetic ophthalmia.

The removal of the near-point in glaucoma, like the restriction of accommodation observed by me in affections of the teeth in young individuals, is probably attributable to increased pressure in the vitreous body; this would oppose the complete relaxation of the zonula.

Finally, we may refer to the accommodation-paralyzing—and at the same time mydriatic—action of atropine, duboisine, and similar agents.

[The application of a belladonna plaster may produce paresis of accommodation.—St. J. R.]

The prognosis of paralysis of accommodation is generally favorable when it occurs after diphtheria or other severe diseases, or after injury. After diphtheria it disappears in a few weeks or months. The prognosis is more unfavorable when other etiological factors are at fault. Thus, recovery of syphilitic paralysis of accommodation is hardly ever observed (Alexander).

The treatment must vary according to the causation. In paralysis after diphtheria (which also heals spontaneously) and after severe diseases, tonic treatment is indicated (wine, quinine, iron); in syphilis, mercury or potassium iodide. The latter remedy is also used in certain other forms of the disease, as in those resulting from disease of the bones. It is also indicated in long-standing rheumatic paralysis, but better results may be expected in the be-

ginning from a sweat cure (perhaps with the aid of pilocarpine). Electricity and injections of strychnine have also been recommended. Heurteloup's abstraction of blood from the temples or stimulating ointments (veratrine) may also be tried locally, particularly in the beginning and in cases in which conditions of weakness are absent. The instillation of solutions of eserine or calabar extract have also been tried, but I have not been able to convince myself that they shorten the duration of the period necessary for recovery. They possess a prognostic significance inasmuch as the chances for recovery are slight (v. Graefe) in those cases in which neither the pupil nor tensor react to calabar (eserine).

In order to give symptomatic aid in bilateral paralysis of accommodation, convex glasses are given to hyperopes for near work, and also for distance. As a matter of course, the lenses are to be made weaker as the power of accommodation increases. As a rule, no good results are to be expected from them in unilateral paralysis, if the vision of the other eye is good. After a while the patients usually grow accustomed, as in anisometropia, to the dissimilarity of the images. Instillation of eserine may also act symptomatically, inasmuch as it secures the possibility of reading by bringing the far-point nearer. Vision is also improved during its action by the coincident marked contraction of the pupils.

II.—*Spasm of Accommodation. Abnormal Accommodative Tension.*

We have to deal here with a contraction of the ciliary muscle, which results in an approximation of the far-point. An emmetropic eye thus becomes myopic, a myopic eye becomes still more so. The term spasm of accommodation is often abused. True spasm of accommodation is to be distinguished from "abnormal accommodative tension" which, although it cannot be regarded as a spasm in the ordinary sense of the word, not infrequently simulates myopia or increases an existing myopia. The diagnostically decisive difference consists in the fact that the abnormal tension of accommodation, which simulates myopia, disappears on ophthalmoscopic examination of refraction, while this is not true of spasm of accommodation. Furthermore, in the former (for which the term "spasm of accommodation" is used almost universally) the near-point is not brought closer, as is demonstrable in true spasm of accommodation. The latter presents a relatively more frequent contraction of the pupils, while dilatation of the pupil is more apt to occur in the former.

Spasm of Accommodation.—The most complete picture of spasm is seen after instillation of preparations of calabar bean (extract of eserine) (Fraser [1862] and Argyll Robertson). Both the far-point

and the near-point are brought closer. As a rule, the maximum adjustment for the near-point is painful. In addition to the tonic contraction, clonic contractions occur not infrequently in the intervals and change the results in the individual measurements of the far-point and near-point. Unlike paralysis of accommodation, objects appear larger (macropsia) for reasons analogous to those presented there. Myosis is associated with the spasm of accommodation.

Apart from this medicinal spasm, similar cases are rarely observed. The diagnosis is made when an undoubted approximation of the far-point is shown not alone on testing with lenses, but also by the objective measurement of refraction with the ophthalmoscope, and which disappears after intense atropinization that relieves the spasm. Although the ophthalmoscopic measurement of refraction—in which, as Mauthner first showed, the abnormal tension of accommodation disappears—possesses the chief importance in differential diagnosis, attention must be paid, on the other hand, to the sources of error to which the objective examination is exposed. Thus, it sometimes requires frequent and prolonged examination and warning in order that the patients desist from attempts at vision and fixation, which necessarily induce accommodative tension. Moreover, the difference in refraction at the macula and alongside the papilla, where, as a rule, refraction is determined ophthalmoscopically, is not always immaterial (*vide* Ophthalmoscopy). The myopia resulting from spasmodic approximation of the far-point usually develops in quite a short time; occasionally, also, it disappears very rapidly. Frequent changes in refraction are very characteristic. The patients discard glasses, which had suited them, at short intervals (not infrequently during a single examination) and pass to stronger or weaker ones. Occasional diminution and frequent changes in the degree of visual power are observed (Nagel), also concentric narrowing of the field of vision (Derby). As the near-point is not always approximated, the range of accommodation, as a general thing, is diminished. Myosis is frequent. The spasm is associated with a sensation of pain in the eye and a feeling of exhaustion while working.

Spasm of accommodation is usually tonic, rarely clonic. The latter was observed by Knies, by means of ophthalmoscopic examination in an epileptic during a seizure. Liebreich observed cases in which the spasm occurred only on strong convergence. Among the etiological factors may be mentioned slight injuries (v. Graefe), in which the spasm often starts as a reflex neurosis from sensory nerves, contusions of the globe (Bertin), neuralgias (Stilling, Reich), and eye-strain. In other cases, the latter cause may give rise to simple accommodative tension. Conjunctivitis

sicca is also mentioned as an etiological factor (Samelsohn); van Millinger observed a case in conjunction with œdema of the conjunctiva. A. Graefe has seen spasm of accommodation in blepharospasm, H. Cohn in hypnotism.

It has already been said that calabar extract and physostigmine (eserine), when inserted into the conjunctival sac, give rise to the spasm. Muscarin and pilocarpine produce the same effect. A similar action has also been observed occasionally from subcutaneous injections of morphine (v. Graefe, H. Lawson).

The duration of the spasm is variable. As a rule, the form which occurs after injuries rapidly disappears.

The treatment consists chiefly of the instillation of atropine in order to relieve the tension of the ciliary muscle. Not infrequently it is necessary to continue the instillation for months. Blue or smoke-gray glasses should then be worn in order to counteract the excessive entrance of light, on account of the artificial dilatation of the pupil. Artificial leeches to the temples may be useful in local hyperæmias of the optic papilla or choroid, or after rheumatism. In other cases, according to the individual and the etiology, nerve tonics (among these strychnine injections have been recommended) and stimulant measures are indicated. So far as possible, the patient should abandon close work.

Abnormal Accommodative Tension.—This may occur in hypermetropes, emmetropes, and myopes. The former present the symptoms of myopia, the latter an increase of the already existing myopia. The true condition of refraction appears on ophthalmoscopic examination and after the use of atropine. All the symptoms of a real spasm are absent. That would be a remarkable form of spasm in which ophthalmoscopic examination serves as a curative agent. Nor is the frequent comparison of this condition (which is called spasm of accommodation) with writer's cramp a proper one. The latter presents other symptoms which occur in spasms; entire groups of muscles are affected, also those which are not concerned in writing, and exhaustion and tremor also follow. Finally, the spasm does not cease at the moment when the pen is thrown away. In abnormal accommodative tension, however, the normal condition ensues at the moment when the intention of seeing ceases (as during the ophthalmoscopic examination). The affection is usually bilateral, but is often observed on one side alone or with varying intensity in both eyes. But it is by no means so frequent as appears from certain examinations in which a diminution of refraction of less than 1.0 after atropinization is regarded as evidence of a previously existing spasm of accommodation. Such diminutions of refraction after atropine are entirely physiological

[Certainly cases are very rare with us, when atropine is to be used for months, for spasm of accommodation. Even allowing the author's discrimination between spasm and what he terms abnormal accommodative tension.—St. J. R.]

Abnormal accommodative tension occurs in some cases of progressive myopia. I have often observed the following condition of affairs. Children apparently become near-sighted; we find moderate myopia from abnormal accommodative tension, and slight hyperopia after atropinization. Under suitable treatment the latter persists for some time. Then myopia again develops gradually. Finally, after the lapse of years axial myopia develops. But it must not be imagined that the further development of the myopia is always or even usually attended with abnormal tension of accommodation.

The latter is sometimes associated with asthenopic symptoms. The eye is often slightly congested, the optic papilla reddened. The pupil is usually somewhat dilated. The range of accommodation is diminished because the far-point alone approaches. Inasmuch as the near-point is unusually remote for the supposed myopia, we can often distinguish the apparent from the real myopia by the subjective examination of the patient.

Constant convergence of the visual axes is the next most important cause of abnormal accommodative tension, which simulates myopia. The far-point (relative far-point) approaches normally with the convergence of the visual axes. In some cases, on binocular measurement of refraction with lenses, a slighter degree of myopia (up to 2.0) is found than in the ordinary monocular examination, in which one eye is covered and thus another degree of convergence is made possible (v. Reuss).

Constitutional factors, such as anæmia and nervousness, often play their part. We may include local affections of the eyes, which impair the visual power. Abnormal accommodative tension is most frequent in youth and particularly in slight degrees of hypermetropia and moderate degrees of myopia.

The treatment consists of vigorous and protracted atropinization. It is best to continue this for three or four weeks (twice a day) when near work is avoided. The diminution of refraction, which has been determined previously with the ophthalmoscope, occasionally does not occur for some time after atropinization. In addition, tonics and out-door life. Antiphlogistics are rarely necessary, apart from cold compresses of lead wash against coexisting conjunctivitis or blepharitis.

Inasmuch as there is a tendency to relapses, the patient, on returning to work, must avoid close work as much as possible, and if necessary the treatment must be repeated from time to time.

CHAPTER III.

AMBLYOPIA AND AMAUROSIS.

THE terms amblyopia, weak sight (ἀμβλύς dull sight) and amaurosis, blindness (ἀμαυρός, dark) are now employed for those disturbances of vision which do not result from dioptric hindrances or from diseases of the eye itself. To a certain extent, we have to deal, in amaurosis, with that condition which Philip v. Walther once defined as the one in which neither the patient nor the physician sees anything. But we also include in this category, certain cases of impaired sight or blindness in which a pathological ophthalmoscopic appearance, viz., atrophy of the optic nerve, subsequently develops. The absence of pronounced changes at the beginning of the disease warrants us in including it in the category of amblyopia and amaurosis. These are always connected with disturbances of the optic nerve, chiasm, optic tract or cerebral centres.

1. DIAGNOSIS.

In testing vision the following functions are to be considered:—

I. *Central Vision.*

The macula lutea possesses the greatest visual power. The mode of measuring it has been explained in the section on refraction. In order to measure vision more conveniently, Snellen has devised tables upon which are letters or quadrilateral figures, composed of individual strokes, each of which is seen under a visual angle of one minute (the entire letter includes an angle of five minutes) when held at the distance given alongside each letter. Smaller test types are also used for nearer and very near vision (30 cm.). Test numbers and types have also been constructed according to the same principle by Girard-Teulon, Wecker, Schweigger, and others. Burchardt's international tests consist of points as test objects, which are seen under a visual angle of 2.15 minutes.

The measurement of the degree of vision is made by the formula $S(V) = \frac{d}{D}$ in which d is the distance at which the patient sees the best, and D the distance at which he ought to see them. It is as-

sumed that any error of refraction has been corrected by proper lenses. As a rule, the examination, like that for refraction, with which it is directly associated, as we have seen above, is made at a considerable distance (about 6 m.). If the impairment of vision is considerable, so that the larger letters are not recognized at this distance, the patient is allowed to approach the types.

Snellen's statements express average measures because physiological vision varies between very wide limits. Thus, it varies according to age; young children, as a rule, have a much greater, even more than double, the power of vision. Haas found (in a comparatively small series of examinations) that it varies from $\frac{6}{5}$ to 1 between the ages of 10 and 40 years, is about $\frac{9}{10}$ at the age of 50 years, and about $\frac{1}{2}$ at the age of 80 years. It also varies according to race; uncultivated races have, on the average, a much greater power of vision. Illumination also exerts an influence. As a rule, it is assumed that the examination is made in bright daylight and with good illumination of the test types. In order to be independent of the changes in daylight (according to Cohn's examinations with Leonhard Weber's photometer the light varied between 19 and 196 metre candles on a summer afternoon (from five to seven o'clock) a lamp may be placed at a certain distance from the test types, or the diminution of vision in the examiner's eye, which occurs when the daylight grows poorer, is taken into consideration.

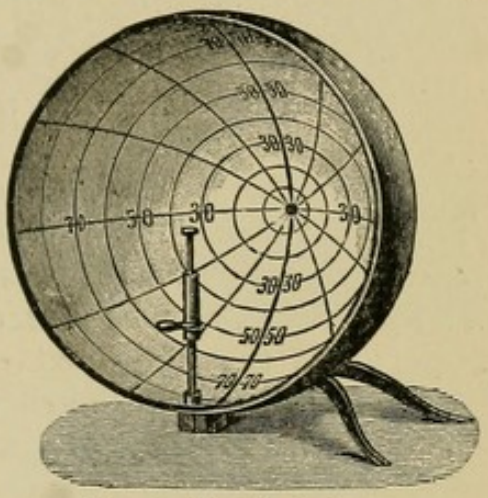


FIG. 56.—Scherk's Perimeter.

When letters are no longer recognized, we ascertain at what distance the patient can still count fingers. The physician separates them on a dark background, such as a coat, the patient's back being turned toward the window. The fingers can be counted normally at about 60 m., but this is usually decidedly easier than the recognition of Snellen No. IX., which should also be recognized at 60 m.

If the fingers can no longer be counted close by, we test whether the patient can distinguish that one or two hands are upheld. Finally, if this fails, whether he can see the motion of the hand and at what distance.

These tests—excluding that with the hand—refer to the patient's qualitative sensation of light. The examination of the simple sensation of light (with the lamp, etc.), is termed quantitative. We test whether large flame, a moderate sized, small or very small

(when a blue flame alone is produced) flame is recognized. The minimum is the recognition of sunlight.

In a series of patients, who suffer from symptoms of dazzling, it is also important to measure the visual power when the face is turned toward the window. Then we often notice considerable impairment which, as a rule, diminishes if the patient looks through nutshell-shaped spectacles (with a central opening about 10 mm. large) which excludes the lateral light. In this way we exclude the disturbing influence, experimentally proven by me, of the peripheral diffuse retinal illumination upon the perception of the macular image. Therapeutically we can aid such patients not a little by closely applied, similarly constructed spectacles, but with a larger central opening in order to avoid excessive contraction of the field of vision.

II. *Peripheral Vision* (*Visual Field and Eccentric Vision*).

In addition to the macula lutea, the remainder of the retina as far as the vicinity of its equatorial zone is also able to perceive impressions of light. The simplest mode of testing the peripheral field of vision, as we have stated in the introduction, is to determine, while the examined eye fixes an object centrally, to what distance peripherally movements of the hand are visible. In marked disturbances of vision a light is used for these tests.

The examination is made more accurately with the perimeter (Foerster, Aubert). Here the eye of the patient is situated in the centre of a semicircle, which is divided into degrees and can be rotated. Upon this circle a white globe is carried to the periphery, while the zero point is fixed with the eye, and the moment mentioned when it becomes invisible. If we reverse the procedure by starting from the periphery, the field of vision is somewhat smaller. The degrees marked upon the semicircle also indicate the visual angle at which vision is possible in this direction. In using Foerster's perimeter, the circle must be turned in the corresponding direction, according as the field of vision is to be tested from right to left (*i.e.*, in the horizontal meridian), from above downward, etc. Scherk's perimeter (Fig. 55) is simpler; it consists of a large hemisphere divided into degrees. While the zero point is fixed, a white globe is used for the test, fastened to a curved whalebone rod. If the boundaries are marked with chalk, a distinct picture of the field of vision is obtained at once. For drawing we use schematic fields of vision, containing twelve radii in the direction of which the boundaries of the field of vision are usually determined. The radii are numbered like the hands of a clock (I to

XII). The normal field of vision extends upward (XII) about 50 degrees, downward (VI) about 70 degrees, to the nasal side 60 degrees, to the temporal side 85 degrees. The boundaries are depicted in the adjacent schematic field of vision (Fig. 57); likewise the somewhat narrower boundaries for the recognition of colors (test with colored squares whose sides are 1 cm. long). It must be kept particularly in mind that the patient constantly fixes the zero point, and does not follow the moving sphere with his eyes. When the visual field is tested above, the upper lid must be elevated somewhat, because it is apt to keep off rays of light. In testing the nasal field of vision, the patient turns the head somewhat toward the side of the opposite eye, in order to obviate the obstruction of a more or less prominent nose to peripheral vision.

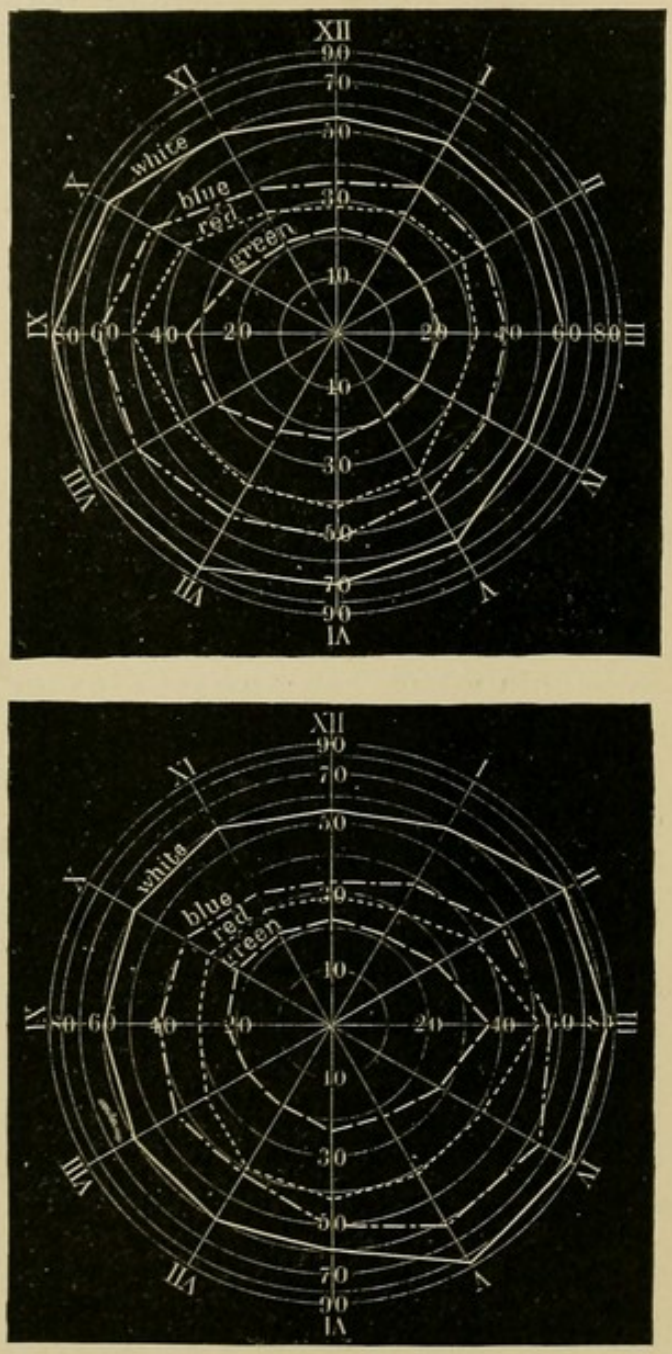


Fig. 57.

Instead of fixation of the zero point with the macula lutea, as here described, the blind spot (optic papilla) has also been taken as the centre of the visual field. As this is usually situated about 15 degrees to the temporal side, the macula lutea is fixed upon a point in the horizontal meridian situated about 15 degrees to the nasal side of the zero point. But this method has been abandoned almost entirely, especially as the position of the blind spot is by no means the same in different individuals.

Sufficient data can also be obtained by projection of the field of vision upon a vertical blackboard (campimeter) or a sheet of

paper. While the eye fixes a point in the middle, the boundaries of the field of vision are determined with a piece of chalk or the like. But the distance of the eye from the point of fixation should always be mentioned because the visual field increases with the increase in this distance. This is shown in Fig. 58. α and β are those peripheral points of the retina in the eye A which are just able to perceive light; points situated farther forward, convey no impression of light. In fixation of the point c situated at the distance Ac, a and b will be the most extreme perceptible points of the corresponding field of vision. But if the point c_1 at the distance Ac_1 is fixed, then the points a_1 and b_1 will throw their images on α and β; the field of vision is, therefore, enlarged at this greater distance.

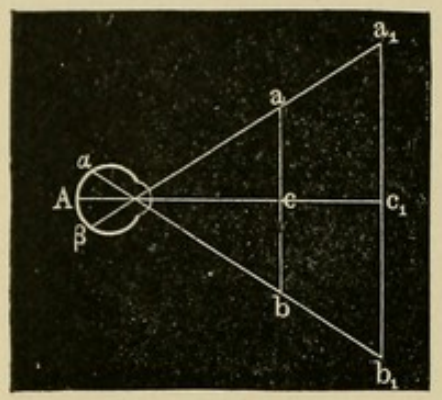


FIG. 58.

Not alone are the boundaries of the field of vision subject to pathological changes, but defects often occur in the visual field itself. These are called scotoma and may be central or peripheral. We also distinguish positive and negative scotoma according to the manner in which they appear to the patient (Foerster). In positive scotoma the patient perceives the defect in his visual field, he knows that in central scotoma, for example, a cloud is situated in front of the fixed letter and covers it, while the adjacent letters remain visible. In negative scotoma, on the other hand, the defect is not known immediately to consciousness. The absence or impairment of vision over a circumscribed spot is only shown, as in the case of the blind spot, by careful examination. In certain central scotoma it is especially important to examine with green and red squares, which suffer diminution or change of color at the situation of the scotoma. Red becomes darker or occasionally yellowish, green becomes grayish-white, etc.

A sheet of paper, upon which are numerous ink spots and a central fixation cross, is often better suited for the discovery of such very small defects in the visual field than the perimeter. The patient looks at the cross at very close quarters (15 to 20 cm.) and we then connect with pen and ink the different ink spots which he fails to see. The more intelligent patients themselves map out the scotoma.

Independently of anomalies in the extent of the field of vision, there may be pathological changes which consist of diminution of eccentric visual power. Coarser tests usually suffice. For example, we examine how far peripherally the patient can count

fingers and then compare this with our own normal eccentric vision. If more accurate results are desired, Snellen's test types are used on the perimeter, and we note the angle at which they can be deciphered peripherally. But great differences result from greater or less practice.

III. *The Light Sense.*

In the determination of the light sense two things are to be distinguished: in the first place, the minimum of illumination at which black can be distinguished from white (say a white square on a black background) (minimum of stimulus), and then the smallest difference of light which two equally illuminated objects (more or less gray rings on a white background) must have in order to be perceived as different (minimum of difference). Foerster's apparatus (photometer) serves to find out the minimum of stimulus. It consists of a closed box which receives its light from the outside through a square paper diaphragm which is illuminated by means of a candle; the diaphragm may be made larger and smaller. Snellen's table LX., which has five vertical strokes, serves as the test object. It is recognized by the normal eye when the illuminating square = 2 sq. mm. The light sense is found by the formula $L = \frac{h}{H}$ in which $h = 2$ sq. mm. and H = the number of square millimetres with the aid of which the patient sees the test object. For example, if a patient does not see the strokes until the opening is 8 sq. mm., then $L = \frac{2}{8} = \frac{1}{4}$. The scale on Foerster's photometer merely gives the diagonals (d) of the square of light, so that the latter = $\frac{1}{2} d^2$. In order to make no demands on the visual power, Treitel recommends as a test object, instead of the strokes, a white paper square (its sides 3 mm. long) upon black velvet.

Masson's disk may be used to measure the minimum of difference. Upon the central portion of a white circular surface is placed a small black sector. On rapid rotation the central portion appears more or less gray, according to the size of the black sector. The object is to determine the smallest black sector (measured in degrees) with which the patient can still distinguish the central gray of the disk from the peripheral white. In front of the rotating disk, which is black and permits, over its entire extent, the introduction of small white sectors in a slit, Treitel places a centrally perforated, firmly standing black shade. A normal eye can detect a difference between the disk, which rotates behind the central opening, and the guard, if a white sector of only 3° is inserted into the former. Pflueger uses a gray disk upon which are drawn, concentrically, large or smaller sections of black, narrow rings. On rotation the latter look like whole rings upon the gray background;

their blackness depends upon the size of the section of the ring. For the same purpose, Ole Bull constructed tables with gray letters of varying intensities on a white background, Wolfberg black velvet tables upon which were pasted gay pieces of cloth of different sizes, which must be recognized by daylight that has been mellowed by curtains of tissue paper.

Examinations made in this way have shown that, in some diseases of the eye (for example, retinitis pigmentosa), an increase of the minimum of stimulus does not always coincide with an increase of the minimum difference (Jannik-Bjerrun, Samelsohn, Raehlmann); but notable deviations occur in individual cases of the same form of disease.

Other methods of testing the sense of light also deal with the visual power which is present with certain illumination. Thus, the employment of apparatus in which transparent Snellen's types are cut into brass plates, and which are illuminated in dark rooms by lights whose intensity may be diminished by the interposition of milk glass (v. Hippel, Weber). Or the measurements of the light sense, which I employ by daylight, smoke glasses of a more or less dark shade (in a small box, like an opera glass, which excludes all side-light) being placed in front of the eye. Vision is now tested in the usual way with Snellen's types and its diminution compared with that which occurs with the same glasses in normal vision.

In all such measurements the patient must accustom himself for some time to the diminished illumination, before the tests can be applied. In old people and myopes, the sense of light is often diminished without any special disease of the eye. H. Cohn has occasionally found remarkable delicacy of the light sense in children. At all events it is subject to great individual variations. Examination with diminished illumination is occasionally necessary to discover defects of the visual field.

IV. *The Color Sense.*

According to the Young-Helmholtz theory, there are three primary colors (red, green, and violet or blue) whose perception depends on stimulation of three different nerve fibres. In objective homogeneous light, these are supposed to be stimulated in varying strength, according to the length of their waves, but always at the same time; red light stimulates chiefly the red-perceiving fibres, less the green and violet perceiving fibres; green light stimulates chiefly the green-perceiving fibres, less the red and violet perceiving fibres, etc. According to Hering's conception, we have to deal with chemical processes. He distinguishes three different chemical substances, whose destruction and reaccumulation (dissimilation and

assimilation) produces the sensations of light and color, viz., the white-black, red-green, and blue-yellow visual substance. While he connects the sensation of white with dissimilation, the sensation of black with assimilation, with regard to the complementary colors he leaves it undecided which sensation of color corresponds to one or the other of these processes.

Daltonism.—Disturbances of the color sense are known as Daltonism (after Dalton, who suffered from it) or color blindness (dyschromatopsia). According to the opposing theories of the perception of colors, some distinguish red (anerythropsia), green (achloropsia), violet (akyanopsia) blindness (Donders, Holmgren, etc.), others red-green blindness and blue-yellow blindness (Stilling). In practice it seems more convenient to apply to color blindness the terms "red-green blindness" and "blue-yellow blindness" because there are cases in which it is extremely difficult, or impossible to make a strict division between "red" or "green" blindness. Neither the characteristic mistakes in colors, which will be discussed later, nor the shortening of the spectrum toward the red side (red blindness), nor the greater feebleness of the colors for which the individual is blind, appear in a convincing manner in such cases. We may also distinguish partial color blindness (for example, red-green blindness) and total color-blindness, in which all sense of color is abolished. In a series of cases there is not complete blindness for colors, but merely a weakness of the color sense, which prevents the recognition of certain shades of color or does not permit the colors to be recognized at the normal difference. This is known as feeble color sense or incomplete color blindness.

Congenital color-blindness was found in about three per cent of the individuals examined for this purpose; in women it is comparatively very rare. The color sense of uncivilized races is similar to that of civilized peoples (Magnus).

As a rule, congenital color-blindness affects both eyes, but cases have been reported in which only one eye was affected (Becker, v. Hippel, Kolbe). Blindness for red and green is most frequent, that for violet (or blue-yellow) very rare. Daltonism is hereditary in some families. It is observed pathologically, with special frequency in affections of the optic nerve. Temporary color-blindness also occurs in hysteria (Landolt) and in hypnotism (Cohn).

Increased attention has been paid to Daltonism since Favre, of Lyons, emphasized its great importance to the general interests of transportation, inasmuch as colored signals are used in railway and marine service. It is evident that color-blind individuals, who are concerned in the employment of these signals, may occasionally cause serious accidents by mistaking them. But that these really

do occur has hardly been proven; the cases attributed to this (thus, a collision upon a Swedish railroad at Lagerlunda) are also susceptible of another interpretation. The reason for this striking phenomenon resides in the fact, that, as a rule, individuals who suffer from congenital color-blindness possess an extremely delicate light sense that enables them to perceive differences in the intensity of the light in different colors, which enables them to arrive at a proper conclusion under ordinary circumstances, with the practice acquired in the signal service. Thus the signal color "green" in the railway service has less intensity of light than "red." But if the conditions are changed artificially, if the red of the lantern for example, is darkened by placing several red glasses in front of the light, the color-blind make a mistake; also when they have to deal with comparatively small surfaces and very great distances. But from the humane standpoint, it is always well, in cases of feeble color sense or incomplete color-blindness, to decide the fitness for service of such individuals, solely upon the question whether they answer the practical requirements of the service in the recognition of signals, or not.

On the other hand, repeated examinations of the employees will be necessary from time to time in order to ascertain the development, in the interval, of an acquired color-blindness or of considerable impairment of vision, which is equally dangerous.

Diagnosis.—In all these examinations, as a rule, several tests must be employed, because one is not infrequently passed very well by the color-blind, while the mistakes appear in another test. The patients may also have practised certain tests.

It is insufficient to allow the patient merely to call colored papers, etc., by name. In the first place, some color-blind individuals learn the proper names of the principal colors, inasmuch as they utilize the differences in the intensity of the light recognizable by them, and, on the other hand, there is an astonishingly large number of individuals who do not know the correct names even of the principal colors, despite a nomal color sense. Magnus's proposition to have school exercises in the recognition of colors by the aid of colored plates, is therefore worthy of consideration.

The so-called Holmgren method is adapted to examinations *en masse*. Seebeck also, had recognized color-blind individuals by the fact that, out of a series of different colored wools, they had regarded tests of different colors as similar. According to Holmgren we begin with a wool test of light green color, in which the green possesses neither a strikingly yellow nor blue admixture and allow the individual to collect the bundles of the same color, of which there should be four to six in the wool heap. Whoever collects the

proper bundles rapidly, without any notable comparison and without delay (attention is to be paid to this point) is not color-blind. If the individual is uncertain or has collected the wrong colors, a rose-colored bundle of medium tinge (mixture of blue and red, also called purple) is given to him with the same request. But we now ask that not alone should wools of the same color be placed together, but also some of a lighter or darker shade. If this is not emphasized, even color-blind individuals will sometimes find the proper wools, inasmuch as they allow themselves to be guided entierly by their sharp sense of the light intensity of the colors. If the proper bundles are now collected, while the previous test was not passed satisfactorily, we have to deal with incomplete color-blindness or feeble color sense. As a rule, the true color-blind individual makes characteristic mistakes. As a general thing, the red-blind will place blue alongside of rose color, because the red contained in the rose color escapes him; the green-blind adds green and gray to rose color; the violet-blind adds red to rose because the violet or blue escapes him. As a rule, the latter also adds blue wool to green in the first test. It must be remembered, however, that some color-blind individuals finally succeed, by practice, in sorting the wools properly. Different colored chemical powders are also used in the same way as wool.

Daae has constructed plates, upon which series of different colored wools are arranged in such a way that they correspond to the ordinary color mistakes of Daltonists. The color-blind individual is asked which of the horizontal series, however they may vary in intensity of light, contain the same color. The corresponding errors of differentiation will then appear, although not in all color-blind individuals, because occasionally the otherwise ordinary scale of mistakes appears differently to one or the other.

These, properly speaking, pseudo-isochromatic tests are somewhat similar to those with Stilling's tables. Here colored letters, numbers or figures, whose strokes are composed of small squares or points, are printed upon a different colored, likewise punctate background. The colors on one plate are selected in such a way that they cannot be distinguished by the color-blind of a certain class. Hence the ability to recognize the letters also disappears. In the most recent editions, the tables are very complete and there is hardly any color-blind individual who could pass all the tests without error. On the other hand, the requirement may occasionally be excessive, even for one with normal color sense, because a certain power of combination is necessary in addition to the differentiation of colors. The individual tested must find the squares or points, which in combination form the entire letter, from the

different colored background and must unite them into a whole. This requires a certain knack in solving riddles, and we must therefore often be content to have the individual squares of different colors shown us. But the deciphering of certain letters is difficult even for intelligent people with a normal color sense.

When we have convinced ourselves that the individual knows the correct names for the different colors, very simple and convincing tests may be made with small circular plates of colored paper on dark velvet (Weber) or colored points on a black background (Dor's tables). It has been found that the size of these dots must vary in order that they may be recognized at the same distance. Dor has constructed tables, in which the colored dots are exactly of such a size (blue is the largest, viz., 8 mm. in diameter, green the smallest, viz., 2 mm. in diameter, for a distance of 5 m.) that they can be recognized at the distance noted upon the table by one possessing normal vision. If the individual (we assume, as a matter of course, normal vision, and, if necessary, correction of errors of refraction) must approach more closely in order to recognize the colors, he has a diminished color sense.

With this method, many will be proven color-blind who pass muster with other tests; it is found with special frequency, that green is only recognizable at a much shorter distance than by those with normal vision. But these tests possess the defect that the number of those hitherto examined does not appear to be sufficiently large to enable us to regard the relation between the size of the colored points and the distance at which they should be seen, as perfecly exact and corresponding to the physiological average. Nevertheless, notable differences may undoubtedly be regarded as abnormal.

Tests with colored glasses and colored lights (lantern test) are also valuable because they imitate the actual conditions of railroad and marine service. An opening about 4 sq. mm. is cut in a black frame, behind which is held the colored glass, illuminated by a lamp. The individual to be examined is in a dark room, at a distance of 3—6 m. from the glass, and tells the colors. An individual with normal vision notes whether the color is really recognized. Color-blind individuals occasionally describe the colors correctly for some time, but false statements are made after continued examination, especially if the intensity of the light is changed by using double plates of glass of the same color.

Examination with spectral colors falls into the same category. To the red-green blind, red appears orange and yellow, green as yellow, blue and violet as blue. The red line formed in the spectrum on burning lithium, and the yellow sodium and green thallium

line, are called by him yellow and approximately identical. A shortening of the red end is often present when the intensity of the light is slight, while it may be absent when the intensity is greater.

Although red-green blind individuals only have a perception of yellow and blue, they quite often give the proper names of the individual colors of the spectrum (green, red, etc.). In order to compare spectral colors with spectal colors, we may use a double spectrum (Donders, Hirschberg), in which the rays enter the refracting prism through two tubes. If the slit in one tube is half covered above, that in the other is half covered below, two spectrums develop, situated one above the other; by moving one tube it becomes possible to move one spectrum from right to left and vice versa beneath the other one which is at rest. A slide enables us to introduce only a single color. We now ask the color-blind individual, to move the lower spectrum by rotation of one tube until the same color appears which is present in the slide of the upper spectrum. The pronounced green-blind individual chooses the proper color almost constantly, inasmuch as the varying light intensities of the spectral colors guide him correctly. In this sense, therefore, the instrument cannot be used for the diagnosis of color-blindness.

The simultaneous contrast of colors, which can be recognized at once by one possessing normal color sense, has also been used in the diagnosis of Daltonism. H. Meyer's method with tissue paper is very simple. Upon a colored (say red) surface of paper is placed a ring cut out of gray paper. If both are now covered with a piece of tissue paper of sufficient size, the gray ring appears in the complementary color (here bluish-green); upon blue, the ring appears yellow, etc. As a matter of course, the color-blind do not recognize the complementary colors of those which they do not perceive. In a similar manner Pflueger pastes gray letters upon colored paper and covers them, according to circumstances, with one or more layer of tissue paper. When the letters have been rendered indistinct by the tissue paper they will no longer be recognized by the color-blind, while they are still perceived by an eye which perceives the complementary color.

Color-blindness can also be diagnosticated (Stilling) with the aid of the colored shadows, which appear as complementary phenomena upon surfaces with colored illumination (this observation had been made by Leonardo da Vinci).

If a white paper surface is illuminated by two sources of light (say a lamp and candle) situated at some distance, and a colored glass (say red) held in front of one (the lamp), the white surface appears illuminated with this color. If a lead pencil is now held

in front of the surface, two shadows are cast, one of the same color as the colored light which illuminates it, the other of the complementary color.

Mixed colors resulting from the combination of different colored sectors upon the rapidly rotating Maxwell's color circle, are perceived differently by the color-blind and those with normal vision. On experiment we will find mixed colors which appear like a third color to the color-blind. This mixture will differ from that which one with normal vision combines as similar to the third color.

Treatment.—Congenital color-blindness is incurable. By the use of red glasses or of glass boxes filled with a fuchsin solution (Delboeuf and Spring) we can often make it possible for the red-green blind individual to distinguish certain colors which he could not formerly. The red glasses permit the passage of red rays alone and absorb the others. Hence colors which contain no red rays will appear darker than those which contain a great deal of red. Color-blindness cannot be cured by practice as Favre believes, but the color-blind can learn by practice to pass certain tests without a mistake.

The color sense of the peripheral portions of the retina is inferior to that of the centre. The extreme periphery is physiologically entirely color-blind, then comes a zone which is red-green blind. The zone in which green is perceived extends the shortest distance toward the periphery. The schematic visual field represented above (page 107) contains the average boundaries for red, green, and blue. The test is made by bringing a colored square (1 cm. long) from the periphery of the perimeter toward the fixation point and noting the locality at which the color is recognized as such. If considerably larger colored surfaces are used, the boundaries are displaced somewhat to the outside. As we have remarked before, pathological changes in central color vision also occur in circumscribed spots. In the congenital color-blind the peripheral boundaries of the abnormal color perception are often narrowed (Scheviner); they also present early changes and contractions in certain pathological cases, particularly in optic atrophy (Schoen).

V. *Phosphenes.*

If pressure is made with the tip of the finger or a probe upon the posterior portion of the sclera, the displacement of the retina causes a subjective phenomenon of light which is projected toward the opposite side. The mechanical irritation which reaches the nervous visual apparatus causes it to respond with its specific reaction. If such pressure-phosphenes are present, conduction to the

brain cannot be entirely abolished. But the experiment is not always successful in careless observers, and a certain rapidity and depth of pressure is required in order to produce this phenomenon.

Subjective phenomena of light without external mechanical causes occur in various irritative conditions of the retina. Thus, complaints are often made concerning balls of fire, a shower of stars, blue and red clouds, a sea of light, etc. Their cause may also be situated in the visual centre. Absolutely amaurotic individuals often exhibit these phenomena.

2. Prognosis. Etiology and Treatment.

With regard to the prognosis of amblyopia it must be remembered that a certain, not too brief period of observation is always necessary in order to give any decided opinion. The examination of the different visual functions just mentioned furnishes certain data. As A. v. Graefe showed in detail, the condition of the visual field is especially important. If the boundaries of the visual field remain normal, and if eccentric vision shows an impairment which simply corresponds to that of central vision, the prognosis is relatively favorable. Blindness is also rare if there is a circumscribed central impairment (central scotoma), with free visual field, and if both remain stationary for a considerable period. But the outlook for complete recovery in these cases is slight, apart from the toxic amblyopia which will be discussed later. If the above-mentioned simple amblyopias with uniform impairment of vision (amblyopia without ophthalmoscopic appearances) resist proper treatment, careful and repeated examinations (with colors also) must be made for central scotoma. Finally, if peripheral defects in the field of vision appear early, if the peripheral visual field for colors is narrowed, a progressive character of the blindness is to be apprehended, particularly if a change in the color of the papilla appears (usually progressive optic atrophy). Constant attention must be paid to the ophthalmoscopic appearances of the papilla.

The course is usually a gradually progressing one, but the amblyopia may also reach its acme in a few days. Complete amaurosis occurs occasionally in a very short time, although no changes are demonstrable in the optic papilla and no cause of blindness can be discovered. In such cases the reaction of the pupil to light occasionally furnishes data for prognosis, the latter being more favorable when the reaction is still present. Nevertheless, recovery may occur even if the reaction to light is entirely abolished. Those who have suddenly become amaurotic, occasionally die in a short time, and even a properly conducted autopsy may fail to reveal

the cause of blindness. If the amaurosis does not disappear, pallor of the optic papilla (atrophy) develops at the end of a few months.

Apart from the etiological factors which, on account of their frequent occurrence, have given rise to the formation of certain groups of amblyopia (which will be mentioned later), we also find constitutional anomalies, congestive conditions, suppressed hemorrhoids, menstrual disorders, hysteria, colds, diseases of the brain, meningitis, typhoid fever, measles, syphilis, intermittent fever, dissipated mode of life, neurasthenia, insomnia and the like, mentioned as the causes of amblyopia. Heredity also plays its part. Thus, cases have been reported in which the members of several generations became blind at a certain age.

In treatment, it is above all necessary to individualize strictly and to combat the causal factor which may have been discovered. According to the latter, the indications point to sweat cures (pilocarpine subcutaneously 0.01–0.02), mercurial ointment or corrosive sublimate, cathartics, emmenagogues, etc.; in other cases, to tonic treament, daily injections of 0.001 strychnia nitr. into the temple (Nagel). The constant current, an ice-bag to the head or neck (Mooren) or a seton in the neck are often servicable. The application of artificial leeches to the temples is often useful. It is always advisable to apply them tentatively, unless we have to deal with distinctly anæmic or degenerative processes. After their application the patient should be kept, if possible, in a dark room for a day. The test of vision, which is made a few days later, will then determine whether the repetition of the abstraction of blood is indicated.

At the same time the patient must discontinue his ordinary occupation, the eyes must be absolutely spared. A stay in a dark room is to be recommended, at least at the outset; otherwise, protective spectacles must be worn.

Special Forms of Amblyopia.

The amblyopias and amauroses may be divided into certain groups according to their clinical history and etiology.

1. *Congenital amblyopia* may affect both eyes or, as is not uncommon, only one. It is often associated with errors of refraction; a certain degree of amblyopia is especially frequent in marked hyperopia. The complications found are microphthalmos, coloboma of the choroid and iris, nystagmus and squint. There is uniform impairment of vision in the centre and at the periphery; it is associated more rarely with moderate narrowing of the field of vision.

2. *Amblyopia from non-use of the eye* (*ex anopsia*).—When an eye is excluded from binocular vision in early youth, for example, by strabismus or corneal opacities, its visual power is diminished. As will be shown in the chapter on strabismus, we attribute this to imperfect physiological development of the central visual centre. Hence amblyopia from non-use cannot develop at a more advanced age. If both eyes of a child are incapable of vision, for instance, from congenital cataract, amblyopia ex anopsia is apt to be associated secondarily with this optical obstruction. Hence the therapeutic rule to remove optical obstructions by early operation, or to improve the vision of the amblyopic eye by separate exercises. If there are coexisting errors of refraction, correcting glasses are used for the latter purpose, or, if there is marked impairment of vision, convex glasses are used for near objects in order to enlarge the images.

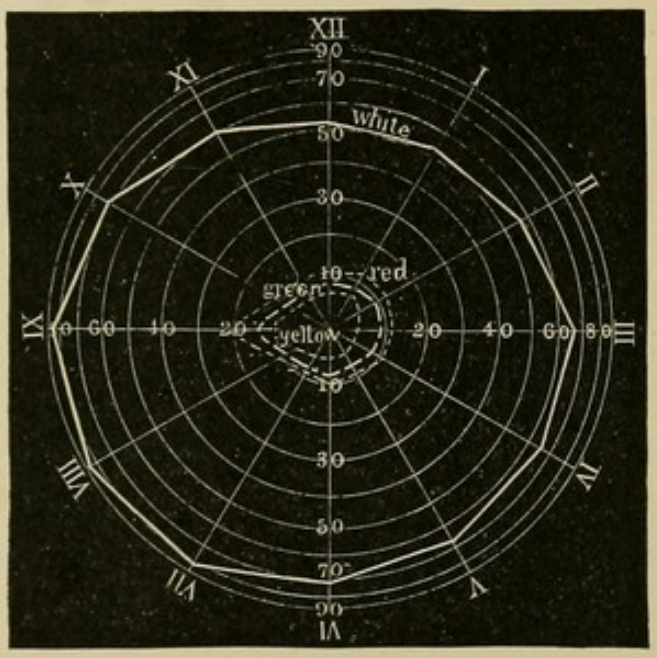


FIG. 59.

After prolonged spasmodic closure of the eye as the result of phlyctenular ophthalmia, a few cases of complete but temporary blindness have been observed in children (Schirmer, Leber) and have been attributed to non-use. But it is a question whether the blindness was not owing to the permanent mechanical pressure of the lids on the globe. In an analogous manner, we notice that in every monocular measurement of refraction, the prolonged closure of the other eye causes temporary impairment of vision, if a certain pressure has been exercised on the eye.

3. *Scotoma.*—We have to deal here chiefly with central (pericentral and paracentral) scotoma, which, as a rule, include the point of fixation and a transverse oval surrounding the latter or touching it on the side. The oval usually extends farthest in the direction of the blind spot. A white sphere often appears gray in this locality. Many patients do not notice the change in central vision until they are tested with small colored plates on the perimeter: red is then called "darker," "paler," "yellowish," etc., as soon as it enters the field of the scotoma; green is called "grayish-white," "yellowish," "duller;" yellow is called "brownish" (see Fig. 59);

here are marked the boundaries at which the colored squares lose their color, when approaching from the periphery. As a rule, blue is retained. One or the other of the above-mentioned colors may also be perceived quite normally, while another one presents deviations. Visual power is also diminished; it is usually $\frac{1}{3}-\frac{1}{10}$ the normal, sometimes even less. The peripheral visual field is free, even for perception of colors. In several cases I could not observe a diminution of the minimum stimulant of the light sense, while it was present in a pronounced degree in the scotoma resulting from central retinitis. The development of visual impairment is gradual. At first the optic papilla usually presents no change. Later a slight pallor of the macular half often develops. This typical scotoma occurs only in men, usually in middle life. It is very often the result of abuse of alcoholics or tobacco (Foerster, Hutchinson) or the combination of both factors (see Toxic amblyopias). Central scotoma also occurs occasionally in diabetes, lead poisoning, excessive use of quinine, and likewise without any demonstrable etiological factor. We usually have to deal then with a chronic retrobulbar neuritis.

In rare cases, progressive atrophy of the optic nerve may also begin with a well-marked central scotoma, the remainder of the field of vision being free, but general nervous symptoms are usually present under such circumstances. As a rule, moreover, the bilateral character is not symmetrical; peripheral contractions appear after a certain length of time. On the whole, the prognosis of pure toxic scotoma is good. At the end of a few weeks and under suitable treatment we usually notice diminution of the scotoma, in which, moreover, some perception of light is, as a rule, still retained. The prospects as regards recovery are less favorable in the central scotoma which cannot be attributed to true poisoning. In tobacco and alcohol amblyopia the treatment must, above all, prescribe strict abstinence from tobacco and alcohol. A careful watch on this score is indicated (this can be done most readily in hospital) and in addition, general tonic treatment. In pronounced congestive conditions we may use Heurteloup's leech on the temples, foot baths, and derivation to the skin. At a later period injections of strychnine seem to hasten recovery. If there are no distinct etiological factors which could give rise to intoxication, we may recommend treatment of the assumed retrobulbar neuritis by antiphlogistic measures, mercury, and later by potassium iodide.

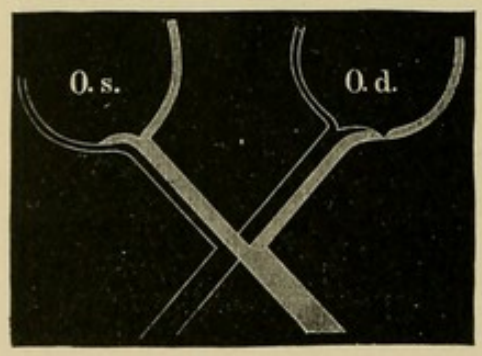


FIG. 60.

4. *Hemianopsia* (ἡμι, ἀ privative, ὤψ) (Hemiopia).—In general, the term hemianopsia is applied to a defect of one-half the visual field in both eyes (for example, the right half) when it results from a single affection of the visual apparatus within the cranium. It should not include those cases in which a similarly shaped defect of the visual fields occurs as the result of bilateral disease of the optic nerves (neuritis, atrophy) or the retina, which does not start from one focus. This confusion has led to mistakes with regard to etiology. Occasionally we have to deal, not with loss of the entire half of the field of vision, but only certain parts (incomplete hemianopsia) which are situated symmetrical (Schweigger). Pure typical hemianopsia may result from an affection of both optic nerves at the base of the brain, of the chiasm, optic tracts, or the central organ of visual perception. We start with the assumption that each tract sends fibres to both eyes, and that a semi-decussation occurs in the chiasm (see Anatomy of the Optic Nerve). The distribution of the nerve fibres takes place in such a way that, in the right eye, the optic nerve supplies the right side of the retina (from the macula) with the fibres of the tract on the same side, and the left side of the retina with the fibres of the left tract; a similar condition obtains in the left eye. Fig. 60 illustrates the distribution.

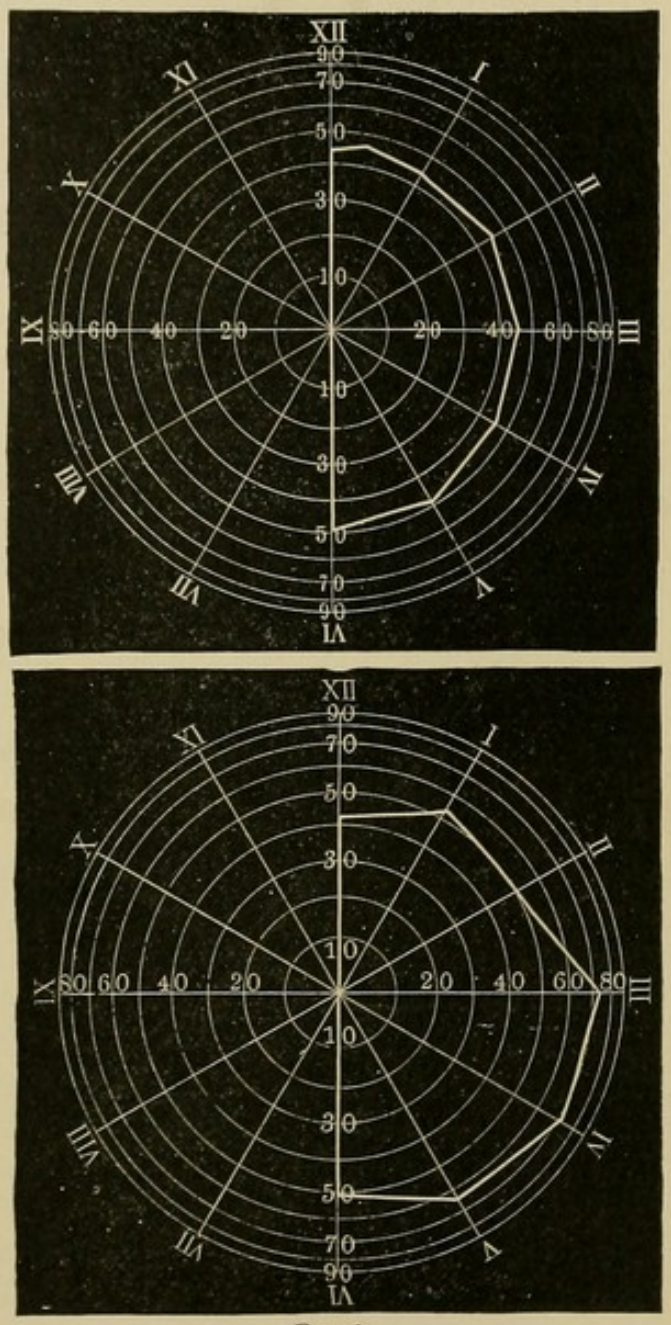


Fig. 61.

If, for example, the right optic tract is incapable of function, there will follow a loss of the left half of the field of vision of both eyes (left hemianopsia). The hemianopsia either passes directly

and vertically through the point of fixation (Fig. 61) or the latter, as appears to happen more frequently, is still surrounded by a small functionary zone which extends 3–5 degrees into the blind field. This is explained by the fact that the macula is supplied by both optic tracts in common.

When the hemianopsia of both eyes is directed toward the same side it is called homonymous. This is the most frequent form. When the chiasm or both optic nerves are affected (for example, by a tumor at the base) other forms (heteronymous hemianopsia) also appear. If, for example, a tumor is situated in the anterior or posterior angle of the chiasm (Saemisch and others) and compresses the adjacent nerve fibres, the conductibility will be destroyed in those fibres of both eyes which supply the inner halves of the retina; there occurs a bilateral loss of the outer halves of the field of vision (temporal or lateral hemianopsia). In the defects of the field of vision which are both situated to the inside (nasal hemianopsia) we would be compelled to assume a bilateral affection of both lateral angles of the chiasm or both outer portions of the optic nerves. It is questionable whether such cases occur. In a case published by Wegner and myself, and which was falsely regarded as nasal hemianopsia by Mandelstamm, we had to deal simply with the results of a bilateral neuritis. Moreover, approximately half-sided and symmetrical losses of the field of vision occur not infrequently in diseases of the optic nerve. These should not be included among the hemianopsias proper. Amblyopias and amauroses of one eye with temporal hemianopsia of the other eye, have also been observed in cases of tumor, gumma or periostitis, situated in one lateral angle of the chiasm.

Hemianopsia of central origin, in which the line of separation is not vertical but horizontal, is extremely rare (Wiethe). In amaurosis partialis fugax such phenomena are mentioned occasionally, but more accurate observation is necessary; we must also think of the possibility of a purely retinal process. It may also be mentioned that a sort of unilateral hemianopsia may occur when conduction is disturbed in one half of one optic nerve. Thus, I have seen a temporal hemianopsia of the right eye in a case of right-sided pulsating exophthalmus, in which there was an aneurism of the right internal carotid and the cavernous sinus.

The peripheral limits of the intact portion of the field of vision are usually quite normal, but narrowing sometimes occurs in the course of time. In a case of right hemianopsia under my observation, a symmetrical and concentric narrowing of the intact visual field gradually appeared on both sides, so that finally the region in the vicinity of the point of fixation alone retained full acuity of

vision. A short time before death the central acuity of vision also diminished. An extensive hæmatoma of the dura mater of both convexities was found in addition to slight grayish-red discoloration of the left optic thalamus and flattening of the left anterior corpus quadrigeminum. In the right hemisphere of the cerebellum was a small cyst, and also a larger one in the anterior extremity of the right cerebral hemisphere.

As a rule, the color sense remains intact; Quaglino reports an exception. A few cases of color hemianopsia have also been observed in which the light and visual senses were intact and only the perception of colors was absent upon the lateral half of the field of vision. Central vision is usually normal. At the beginning of the disease nothing abnormal is found on ophthalmoscopic examination. Slight pallor of the macular portion of both optic papillæ often appears later; occasionally only that optic nerve, which receives the fibres that decussate in the chiasm, becomes atrophic and pale.

The reaction of the pupils to light is retained, but it is sometimes a little sluggish. The latter phenomenon appears especially when the non-perceptive halves of the retina are illuminated. But I have never observed complete absence of reaction; even the difference in the reaction is sometimes not very distinct. This is partly owing to the fact that complete exclusion of the light from the sensitive parts of the retina is impossible, even if the image of the flame is thrown with the ophthalmoscope upon the part of the retina examined.

The patients are particularıy disturbed in getting about. Inasmuch as we read and write from left to right, patients with right hemianopsia are inconvenienced more in these occupations, than those with left hemianopsia.

In rare cases, as after apoplectic seizures, the hemianopsia may disappear. Other causes to be considered are tumors, periostitis, emboli, encephalitis, injuries. Apart from direct implication of the chiasm and optic tract, hemianopsia also occurs in disease of the corpora geniculata, corpora quadrigemina, optic thalamus, pulvinar, Gratiolet's visual fibres, and the cortex of the occipital lobe.

Munk's experiments are of great importance with regard to the latter localization. According to him, the optic tract of the same side takes its origin in the cortex of this lobe; this seems to be justified by Mauthner's critical investigations. According to Charcot's opinion, on the other hand, partial decussation of the fibres of the tract occurs in the brain, so that each eye possesses its special visual centre. Injury to Munk's cortical visual centre produces hemianopsia. Certain anatomo-pathological discoveries (Cursch-

mann, Westphal) and clinical observations (injury of the parts of the cortex in question, followed by hemianopsia), of which I have reported two, strengthen this belief. In one of my cases (left hemianopsia) the autopsy on the patient, who died of tuberculosis six and one-half years after the injury, showed that the latter was situated in the first occipital convolution of the right side, a few centimetres to the side of the longitudinal fissure. Complete visual power and normal extent of the right half of the field of vision, together with color sense, remained intact until death. The papilla with the exception of the macular quadrant, retained its normal color, this looked rather pale.

In the larger cortical centre, to which the retinal impressions of symmetrical halves of both eyes are conducted by the corresponding optic tract, according to Munk, a specially defined visual centre proper, is situated. This term is applied to the locality in which the simple visual perceptions are converted into concepts. Inasmuch as the latter are obtained from a series of perceptions which, in the course of time, are associated with one another and psychically transmuted, these concepts and experiences must disappear with the loss of the visual centre proper. For example, a whip may be perceived, but its meaning and purpose will no longer enter the consciousness. In this way mind-blindness develops. Samelsohn has observed two cases in which, after hemianopsia, the psychical interpretation of the visual perceptions was temporarily lost completely. Thus, not a single sentence could be read, but could be written accurately from a copy.

Hemiplegia or hemianæsthesia of the same side of the body, more rarely of the opposite side, is often observed as an attendant symptom of hemianopsia. Aphasia has also been observed in right hemianopsia. The treatment must be directed against the primary disease.

5. *Retinal Anæsthesia* (amblyopia of the visual field).—It is particularly in children and women that there occurs a peculiar, usually bilateral and quite rapidly developing form of moderate impairment of vision. It is attended with decided concentric narrowing of the visual field (which presents extremely variable limits in the different examinations) and with disturbances of the light and color senses. v. Graefe, who first described it, attributes it to ansæthesia of the retina, inasmuch as he attaches great importance to the retention of phosphenes. But it is more probable that we have to deal with a central disturbance, dependent on constitutional or nervous anomalies. The patients are usually anæmic, neurasthenic or hysterical individuals or convalescents from severe diseases. Vision is usually better in twilight than in bright illumination (hyperæsthe-

sia), so that better vision is secured with blue glasses. In some cases there is decided asthenopia which is associated occasionally with spasm or paresis of accommodation. Even complete blindness may develop, but a retrobulbar neuritis is probably present in the majority of such cases.

In hysterical individuals who suffer from unilateral blindness (usually without the above-mentioned symptoms of anæsthesia retinæ) it is to be noted whether we have not to deal with simple psychical suppression of the visual impressions. Stereoscopic tests in which vision with the healthy eye apparently was alone concerned, have often shown that the supposedly blind eye, saw perfectly well (Schweigger). Concentric narrowing of the field of vision has also been observed in multiple sclerosis (Guanck), chorea (Horstmann) and temporarily after epileptic and hysterical seizures.

Similar symptoms also occur after injury to the eye. As a rule the optic nerve shows no change.

On the whole the prognosis is favorable in typical anæsthesias, although occasionally recovery does not occur until the lapse of months or years. The treatment depends on the general condition. In addition to iron, quinine, etc., v. Graefe has especially recommended preparations of zinc. Injections of strychnine and the constant current have also been used to advantage. Constant stay in a dark room is indicated at the beginning of treatment; later, the wearing of dark blue protective spectacles.

6. *Hemeralopia* (ἡμέρα and ὤψ), night-blindness.—The name indicates that the patients see by day, *i.e.*, that they see disproportionately better in a bright light than in the dark or twilight. In twilight sight is occasionally so poor, that they cannot walk without a guide. Everything looks as if it were covered with a fog, the colors are duller and easily mistaken for one another Even the stars in the heavens are sometimes no longer recognized. Moreover, in passing suddenly from light to darkness, hemeralopes require a longer time to accustom themselves to the latter so that they can see to a certain extent. According to Treitel, we have to deal with a disturbance of adaptation, not of the light sense; but both defects might be interpreted as the result of torpor of the retina.

In the idiopathic form we may distinguish a chronic and an acute variety. The former is rare and usually congenital; in some families the disease is hereditary (Cunier, Donders). Its acute development usually occurs in epidemics, as among soldiers, sailors, in orphan asylums and work-houses. Adler found a large number of cases in the Vienna Deaf-Mute Institution. It is very rare that one eye alone is affected, as in Magnus' case. In daylight there is usually complete visual power and a free visual field, in darkness

there is abnormal diminution of the former, with defects in the field of vision. In the dark the pupil is unusually wide and slow. A certain degree of xerosis is often observed upon the scleral conjunctiva, also the development of yellow patches on both sides of the edge of the cornea. The ophthalmoscopic appearances are usually normal, occasionally there is redness of the papilla and cloudiness of its vicinity. The hemeralopia must be attributed to exposure to a long-continued glare with coincident general weakness of the body. It also occurs in icterus, together with yellow sight (Hirschberg).

Although true hemeralopia is observed occasionally after exposure to the glare of snow, it is not identical with true snow-blindness, in which there is cloudiness and obscurity of vision with spasm of the sphincter iridis and violent pains dependent upon this, which rapidly disappear after cessation of the glare (or after atropinization).

Hemeralopia, which reaches its acme in a few days, usually lasts months or even years. Under proper treatment, however, it generally disappears rapidly and readily, but a tendency to relapses remains. The chief remedy is protection of the eyes against light, and if possible, a stay in a dark room in the beginning. Gradual return to light after a few days. In addition, the body should be kept well nourished. Cod-liver oil has been recommended as a specific remedy. Iron, quinine, strychnine and the constant current have also been used with benefit.

Hemeralopia occurs symptomatically in retinitis pigmentosa, chorio-retinitis, detachment of the retina, etc.

7. *Nyctalopia* (νύξ and ὤψ), day blindness, is the antithesis of hemeralopia. The patient sees better in the dark and poor light than in a brief light. Unlike photophobia, the visual disturbance, not the fear of light, is the prominent annoying factor. Material changes are usually present, such as albinism, mydriasis, iris-coloboma, and affections of the retina and optic nerve. Patients who suffer from central scotoma or from progressive atrophy of the optic nerve, often state that they see better at night than in the day. Retinitis nyctalopica (Arlt) also presents this symptom. The influence of diffuse peripheral illumination of the retina upon the perception of the maculæ in age is an important factor in its explanation. Especially when there is diminution of central vision, the bright daylight which passes through the sclera, iris and rim of the pupil may serve to diminish macular perception considerably, as my experiments have shown. On the other hand, there may be a true hyperæsthesia of the retina. The affection is rarely idiopathic; it is seen occasionally after intense blinding by extensive

snow fields, in individuals who have been confined for years in dark cells, and epidemically in certain regions (Ramazzini). The pure form of nyctalopia is distinguished from the hyperæsthesia which occurs in retinal anæsthesia by the absence of concentric narrowing of the field of vision. The causal factors merit special consideration in treatment; therefore, gradual habituation to bright light by wearing suitably graduated smoke or blue glasses is to be considered.

Symptomatic nyctalopia necessitates protective spectacles, which also exclude the side light as much as possible.

8. *Asthenopia nervosa* (asthenopia retinæ).—Complaints of deficient endurance in working, with darkening and swimming of the objects looked at, occur in cases in which, after exclusion of errors of refraction and accommodation, insufficiency of the interni, etc., we can assume only nervous causes. In these cases there are usually pains in the eyes and head which continue even after the work is abandoned. There is often great sensitiveness to light. The affection is due partly to general nervousness, partly to a local hyperæsthesia of the retina.

The patients are usually anæmic, nervous, neurasthenic or hysterical individuals. Foerster has described a special kopiopia hysterica (painful sensations of various kinds, often independent of work, sensitiveness to contrasts in illumination and frequent changes in the symptoms) and attributes it to an atrophic parametritis (Freund). The latter factor probably possesses no notable etiological significance. In view of the very frequent existence of more or less marked deviation from the physiological condition in the genital organs of women, the demonstration of their real connection with the disease of the eye cannot be made in a convincing manner in the majority of cases. In recent times, genital diseases have also been emphasized as the etiological factors in other eye troubles (Mooren). It is to be remembered that the same asthenopic symptoms also occur occasionally in men.

The treatment should be chiefly directed to the cure of the constitutional anomalies. On account of the obstinacy which is often manifested by the disease, complete cessation of work and a trip to the country or the mountains are sometimes necessary. Tinct. valerian, and tinct. castorei should be given in hysterical individuals. Locally we may try the use of blue glasses, in some cases yellow glasses, and eye douches. Atropinization continued for some time is occasionally useful. Special attention and treatment must be directed to coexisting, however slight, inflammatory processes in the eye, for example, mild conjunctivitis, follicular conjunctivitis, blepharitis, peripheral choroiditis. The gradual re-

sumption of work may then be permitted. Methodical exercise may here be useful (Dyer-Derby). Reading exercises in a book with good print are carried on with proper glasses, other close work being avoided so long as no inconvenience results. The exercise is lengthened by a few minutes every day. The occurrence of pains in the interval is an indication that the exercises should be shortened.

9. *Amaurosis partialis fugax* (scintillating scotoma).—This affection is observed very frequently. The patients complain of a sudden, partial obscuration of the field of vision from which extend scintillations (often with shining zigzag rays of light) that may finally cover the entire field. Distinct vision becomes impossible. The phenomenon disappears in about one-quarter to one-half an hour. It is usually followed by headache or at least by a feeling of pressure in the head. Attacks of migraine often begin in this way. Scintillating scotoma, which occurs in a great variety of ways, sometimes starts directly from the point of fixation, the fixed letters are invisible and it is only later that the visual field is attacked. In other cases it remains very circumscribed. I have suf fered from it a couple of times, for five minutes, in a very small portion of the extreme lower periphery of the field of vision. My attention was called to the phenomenon by a certain inconvenience in vision. In other cases the scotoma is hemianoptic. In one of my patients sometimes the right, sometimes the left half of the field of vision is affected; the subsequent headache is always situated in the opposite side of the head, above the ear; at the same time the corresponding cutaneous vessels are distended and pulsating. The upper or lower halves of the field of vision may also be affected. In these temporary hemianopsias, there is often a complete defect of the visual field, the scintillation being absent. An individual who has been once attacked usually suffers again at longer or shorter intervals. In some it continues during life, but generally diminishes in frequency and intensity with advancing age. Impairment of the visual apparatus need not be apprehended. As a rule we have to deal with a central nervous phenomenon, as is shown by the hemianopsia and the almost constant bilateral occurrence. We find it often, therefore, in nervous individuals and in those who do a good deal of brain work, but it is not very rare in other individuals. Certain definite causes are sometimes found. Thus, in some it occurs after exertion on an empty stomach, in others after an abundant meal, etc. The attacks can occasionally be checked by such agents as a cup of coffee, or tea, or a glass of wine. Among medicinal agents the nervines are to be recommended; the bodily and general hygienic conditions must be regulated.

10. *Reflex and traumatic amblyopia.*—If one eye is attacked by irido-cyclitis, a sympathetic neurosis (Donders) may appear in the other eye, as shown by hyperæsthesia of the retina, asthenopia, scintillation, periodical obscuration of central vision or by amblyopia with or without concentric narrowing of the field of vision (Mooren, Brecht). The recovery from this affection after removal of the eye which was primarily affected, proves its sympathetic character.

Reflex amblyopia has also been observed to start from the dental nerves (Wecker), the supraorbital nerve (Leber) and from helminthiasis (Rampoldi). Perhaps this category includes some of the traumatic amblyopias which occur when the vicinity of the eye alone is affected by the injury, as from missiles which have flown past in close proximity, a blow with an iron upon the upper jaw (Schweigger), etc. Amauroses, which subsequently disappeared, have also been observed after a stroke of lightning. [Unfortunately a stroke of lightning sometimes causes positive inflammatory changes, choroiditis, neuro-retinitis and cataract.—St. J. R.] We must exclude from this category, the not infrequent cases in which direct injury of the optic nerve, for example by splintering of bone in the optic foramen (Hoelder-Bevlin) has given rise to the impairment of vision, and also the temporary amblyopia occurring after contusion of the globe. This depends usually on an affection of the retina (commotio retinæ), as is proven by the opacity of the retina and diminution of the light sense; these usually disappear in a few days. Even complete blindness after contusions may disappear, as in Schweigger's case, in which complete amaurosis lasted three days; slight discoloration of the optic nerve occurred subsequently.

11. *Uræmic Amauroses.*—There are usually transitory bilateral amauroses. The loss of vision is not complete at once, but reaches its height in one or two days; in rare cases amaurosis occurs at once. Even the quantitative perception of light was absent for a time in carefully observed cases. This stage is very brief, lasting a few hours to a day. There are sometimes large defects of the field of vision at this time. Then the increase in the visual power takes place rapidly, so that small print can be read in ten to eighteen hours. The entire process (from normal vision to absolute blindness and again to normal vision) thus runs its course in three to four days. The pupillary reaction is almost always retained. The ophthalmoscope, as a rule, shows no pathological changes; in one case I found œdema of the papilla. Marked ophthalmoscopic appearances are found in those cases in which uræmic amaurosis complicates an existing retinitis albuminurica.

Uræmic anauroses have been observed in acute as well as

chronic diffuse inflammations of the kidneys, particularly after scarlatina. Some of the rapidly subsiding amauroses which are attributed to lead poisoning and to eclampsia gravidarum, also belong in this category. I also include as amaurosis the case described by Traube in which the blindness disappeared after the administration of an emetic. This case, which was also under my observation, ran the course of an uræmic amaurosis; the urine contained albumin. Certain signs, though occasionally insignificant, of uræmia are always present; headache, nausea and vomiting, dulness of the sensorium, stupor, convulsions. Œdema may be present or absent. The urinary secretion is abolished or diminished.

The treatment must be directed against the uræmia; abstraction of blood behind the ears appeared to me to be useful in a number of cases.

12. *Toxic Amblyopia.*—Apart from tobacco and alcohol amblyopias, which appear, as a rule, in the form of central scotoma, those which occur after lead and quinine poisoning are especially worthy of note. In lead amblyopia there is increasing failure of vision, usually with free field of vision or central scotoma; the peripheral color boundaries are occasionally narrowed, and the light sense diminished (Stood). There is often hyperæmia of the papilla, even neuritis. The treatment is directed against the lead poisoning. Numerous observations have been made upon quinine amauroses, which occur after large doses of the drug (Gruening, Knapp). The total blindness usually disappears after the lapse of weeks or months; the field of vision remains narrow, while central vision often becomes normal. The optic papilla is pale and the retinal vessels narrow. The treatment is limited to horizontal decubitus and tonics. Amyl nitrite, strychnine and electricity were ineffectual. [My observations upon quinine amaurosis antedate both of these. Indeed those of Baldwin and Voorhes are perhaps the first. I am not certain that the use of strychnine is ineffectual. I should certainly advise it. Quinine amaurosis is a very rare disease, when we consider the wide-spread use of the drug. My case reported in the Archives of Ophthalmology Vol. IX., was the first one to call attention to the now universally recognized characteristic in the visual field and papilla of quinine amaurosis. See Transactions American Ophthalmological Society, 1887. —St. J. R.]

Visual disturbances have also been observed after large doses of salicylic acid (Reiss), carbolic acid (Nieden,) and as the result of the action of carbon bisulphide in workers in gutta-percha factories.

13. *Amaurosis after Hemorrhage.*—After hæmatemesis, intestinal

hemorrhages, hæmoptysis, menorrhagias, etc., visual disturbances are occasionally observed; they may develop at once or in the next few days. We have to deal either with moderate amblyopia, which may again diminish, or with complete amaurosis which furnishes little prospect of recovery. As a rule, slight cloudiness of the optic nerve (Horstmann), occasionally distinct neuro-retinitis (Hirschberg) are observed in recent cases. The papilla finally becomes pale. In an autopsy on a patient who had become blind several weeks before, after a hemorrhage from the stomach, Ziegler found fatty degeneration of the fibres of the optic nerve, which he regards as the result of local ischæmia. In a case of amaurosis under my observation, which developed within a few hours after curetting nasal polypi, and in which the ophthalmoscope showed no perceptible circulatory disturbance, I am inclined to assume an ischæmia in the visual centres.

The treatment must be tonic. If there is a local neuritis and no contra-indications, mercury (by inunction or hypodermic injection) may be tried in view of the great danger of total blindness.

Simulation of Amaurosis.

The simulation of poor sight or unilateral amaurosis is not very rare. It is found often in individuals who wish to escape military services.[1] I have also often observed it in children, although a definite reason for the attempt at deception could not always be discovered.

Simulation of total, bilateral blindness is less practised. It is then always suspicious if the pupils react to light, and no ophthalmoscopic appearances make the blindness probable. It is true that the pupillary reaction is occasionally retained in amauroses, but if the blindness remains stationary for a prolonged time (more than a month) the reaction, as a rule, ceases; in like manner discoloration of the optic papilla usually develops. The demeanor of the malingerers, which must be watched carefully and without their knowledge, is often suspicious. During the examination they are apt to close the eye, to exhibit photophobia, etc.—things that are not done by amaurotic individuals. A simple plan, by means of which the malingerers are often detected, consists in holding their own fingers

[1] German Army Order of Sept. 28th, 1875 (Par. 9, Sec. 4): Permanently unservicable; 25, diminution of visual power, if it is ¼ the normal or less in the better eye. 27, Blindness of one eye. Conditionally serviceable (as a rule in the substitute reserve of the 2nd class, very rarely in the reserve of the 1st class (Par. 7, Sec. 2): *a*. Diminution of visual power of both eyes, when it is half the normal or less, but more than ¼ the normal. As a rule, substitute reserve of the 1st class, but, in case of necessity, in active service (Par. 7, Sec. 1): *b*. Diminution of visual power, when it is more than half of the normal.

in front of them in various directions and directing them to look at the fingers. The blind will direct their eyes upon the fingers or at least attempt to give them the proper direction, because general sensation instructs them concerning the position of the hand and fingers. If the individual has been blind for a long time, the fingers must be firmly pressed in order to furnish accurate knowledge of the position, and the direction to adjust the eyes must be given strenuously. With these precautions we will almost always observe an, at least, approximate adjustment of the eye, unless disturbances of the ocular movements themselves have developed. In malingerers a different state of affairs obtains. They believe that by adjustment upon their fingers, they will also reveal visual power, they regard the directions given as a trap, and turn the eyes intentionally in an opposite direction. Although this test is not absolutely convincing, its success increases the suspicion very markedly.

Welz's prism test, may also be used as in simulation of unilateral blindness. Both eyes being open, a prism of ten to fourteen degrees, with the base directed outwardly, is placed in front of one eye. On fixation of an object, involuntary squinting to the inside occurs under the deflecting prism, in order to avoid the double images. As a matter of course, this presupposes the existence of binocular vision.

Tests with prisms also play a part in the detection of unilateral blindness. For example, we concern ourselves solely with the seeing eye while the supposed blind one remains open, and direct the individual to look at a light. If a prism is now placed in front of the sound eye, with the base turned upward or downward, and we tell the individual that double images will now appear, the malingerer sometimes falls into the trap and describes the superimposed images, thus proving that the supposed blind eye sees (A. v. Graefe). We must, however, exclude the production of monocular double vision by reflection at the edge of the prism. Alfred Graefe's test is more delicate, but its execution is more difficult and it is controlled less surely. While the supposed blind eye is covered with the hand, a prism (base downward) is placed before the seeing eye (which is fixed upon a light) in such a way that the horizontal edge passes traversely through the middle of the pupil, and the upper part of the pupil remains free. Monocular double vision is now produced. The rays of light pass undeflected through the upper half of the pupil, while those which pass through the lower half are deflected toward the base of the prism. The double images are situated above one another. After the malingerer has thus become convinced that he sees double with the eye, the hand is removed from the supposed blind eye, the prism being raised at the same time

unknown to the patient, so that it covers the entire pupil of the sound eye. If we now ask how many images are present, the malingerer will say two, because he supposes that they are perceived with the seeing eye. The displacement of the prism, however, over the entire pupil causes uniform deflection downward, and the second image can only come from the supposed blind eye.

The stereoscope has been much employed, particularly with the modifications of the diagrams recommended by Rabl-Rueckhard, and carried out in the Burchardt's tests.[1] Here the union of both halves of the diagram into a single whole, which occurs involuntarily in normal vision, betrays the malingerer. For example, if the diagram Fig. 62 is used, this will appear stereoscopically as Fig. 63; if the patient describes this correctly, his simulation is discovered. In this way we can also obtain a certain idea of the degree of vision of the supposed blind eye. But it is an annoying feature that not a few individuals at first see the halves of the diagram singly, although union does not occur and thus set themselves right. Furthermore some individuals, especially those in whom there is anisometropia or feeble sight in one eye, cannot see stereoscopically, while they obtain double images with prisms. For this reason I have employed a method in which true stereoscopic vision is entirely discarded and only the displacement of the images, which is effected by the prisms in the stereoscope (with the bases on both sides turned to the temporal side) is the deciding point. If the diagram Fig. 64 is used, on looking at it through the stereoscope, the square and cross of the upper row will be made to cross one another by the action of the prisms, *i.e.*, the cross will appear to the left of the square. In the second row, on the other hand, the refraction of the prisms will not be strong enough to make them cross, but they will simply approach the median line, etc. This causes such a confusion that the malingerer, when directed to name the objects seen from above downward, will be entirely ignorant as to which are seen by the right or left eye, and thus mentions figures which are situated opposite to the supposed blind eye. If the latter is really weak sighted, a starting-point will be furnished by the greater indistinctness of the figures seen with

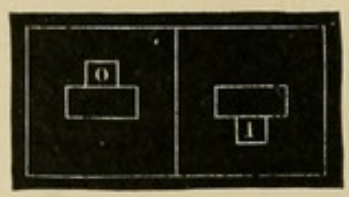


Fig. 62.



Fig. 63.

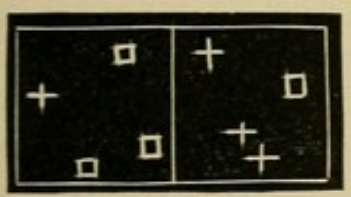


Fig. 64.

[1] "Praktische Diagnostik der Simulationen von Gefuehlslähmung, Schwerhoerigkeit und von Schwachsichtigkeit," Berlin, 1875.

this eye. This can be counteracted by making the figures larger on the corresponding side of the diagram than on that situated in front of the sound eye. Visual power can also be judged in this test by the different sizes of the figures, which are made rapidly and easily.

The so-called American stereoscope is very useful in these tests; here the diagrams can be brought nearer or carried farther away, according to the accommodation and refraction of the individual, and at the same time we can note that he does not close the supposed blind eye.

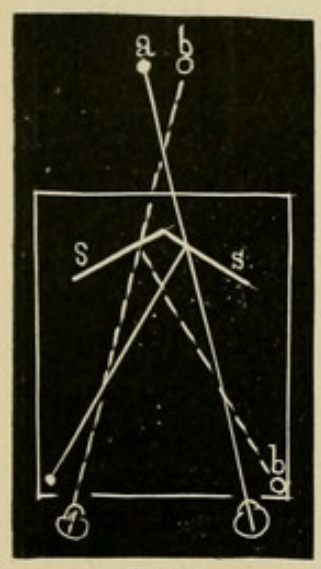


FIG. 65.

Flée's apparatus acts in the same way as the stereoscope. It consists of a box, covered with milk glass, in which are two mirrors (Fig. 65, *ss*), at an angle of 120 degrees to one another; which are situated opposite the openings for the eyes. Rays emanating from two objects *a b*, which are situated in the box alongside the openings for the eyes, are reflected by the mirrors in such a way that those emanating from the object on the left side enter the right eye, but are projected to the left; and vice versa with objects on the right side. The malingerer naturally supposes that he sees the image on the right side with the right eye, that on the left side with the left eye, and therefore makes false statements.

Rava places a red surface on the posterior wall of a box and then shoves a green glass in front of one or the other ocular opening. The colors mentioned indicate the seeing eye.

Snellen uses tables which are printed in colored letters, for example, the large Stilling color tables. If these letters are looked at through a properly colored glass, for example, the red letters through a green glass (the glass must always be tested beforehand by the examiner), they become invisible. The proper glass is now held in front of the seeing eye of the individual, if he nevertheless is able to read the letters, he sees with the supposed blind eye. A similar method is that of placing a strong concave or convex lens which refracts the rays in such a way that no recognizable images form upon the retina in front of the seeing eye. But skilful malingerers are not apt to be detected either by these methods or by the following manipulation. A ruler or similar object is placed between both eyes at the root of the nose, and the individual directed to read. If the ruler is sufficiently wide and extends nearly to the print, the left eye will be prevented from reading the lines to the right of the ruler and vice versa, while in binocular vision the whole line will be read.

The use of one or the other of these methods will probably unmask every malingerer of unilateral blindness.

It is very much more difficult when poor vision only is simulated or a really existing poor sight is exaggerated. Here the first indispensable requisite is a careful objective examination of the eye. Errors of refraction and astigmatism will soon be disclosed by ophthalmoscopic examination. Special attention should be directed to slight opacities of the cornea or to squint of one eye; both would constitute a reason for assuming the real existence of the amblyopia.

We must inform ourselves as to the degree, by testing vision at different distances and even for near objects, if necessary, with spectacles. A certain uniformity must then be found, especially if vision is relatively good. Greater differences may occur in marked amblyopia. For example, if $V = \frac{1}{12}$ for a certain distance and $V = \frac{1}{20}$ for another distance (as a matter of course, despite suitable correction with glasses), this difference is not always sufficient to warrant us in assuming unilateral simulation. Irregular astigmatism, differences in the test types, etc., may give rise to the disagreeing statements; they may be made by individuals in whom there is no question of an attempt at simulation.

It is therefore well to convince ourselves in general of the trustworthiness of the individual to be tested. For this purpose I have also used to advantage the examination of the field of vision. If we stand opposite the individual at a distance of $\frac{1}{3}$ m. and test the visual field with the hand, its dimensions are smaller than when the test is made at a greater distance (about 1 m.). On several occasions I have found that malingerers—in addition to a very improbable contraction of the field of vision—gave the same dimensions of the field for the larger as for the smaller distance. The intentional falsehood of their statements was thus proven.

If a certain degree of poor sight of one eye has appeared on the examination, a further test can be made with the stereoscope, by placing smaller test types in front of the weaker eye than correspond to its supposed visual power, and then noticing whether this eye still sees them. It is to be remembered that the convex prisms of the stereoscope magnify somewhat, so that slight differences in the statements cannot be taken into consideration.

Blindness.

It is necessary to come to a definite conclusion as to what we mean by the term "blind." As a matter of course, complete abolition of all perception of light is not necessary to constitute

blindness; in this sense the majority of the blind, would not be blind. Even the assumption that he is blind who is lacking in qualitative sight, goes too far. Individuals who can still recognize the number of hands or can still count fingers in the immediate vicinity, stand on the same footing as the blind as regards the practical utilization of their visual impressions. They are unable to find their way in strange places without a guide, they receive no notable assistance in their work from the intact remainder of their visual power, and cannot recognize writing and print even with high magnifying powers. If these individuals are children, it is best to educate them as we do the blind. With a certain increase in vision, however, its practical usefulness increases in the most distinct manner. If an individual with an approximately free field of vision can count fingers centrally at $\frac{1}{2}$ to 1 m., he can no longer be included among the blind, and does not make an impression like blind persons. We designate as blind, therefore, any one who cannot count fingers at more than $\frac{1}{3}$ m. in ordinary illumination (vision often increases in very bright illumination). This furnishes a sufficiently distinct standpoint, and it would be desirable that the limit recommended by me, which has already been accepted by Magnus,[1] should meet with general acceptance. Furthermore, as a matter of course, in speaking of blindness in the ordinary sense, it is assumed that both eyes are incurably affected. The condition of the field of vision must also be taken into consideration; when it is very markedly narrowed, blindness is assumed, despite somewhat better central vision.

The principal causes of blindness are shown in Fig. 66, which follows (with the exception of the rarer causes) the graphic representation furnished by Magnus and which is based on 2,528 cases of bilateral blindness. A considerable number of cases could be avoided by early and appropriate treatment; in a table which I collected with regard to this point, I included almost half the cases in such a category. The number of the blind varies greatly in different countries. In Prussia (1873) there was one blind to 1,111 seeing individuals, in Austria (1889) one to 1,785 [in the United States 9.73 to 10,000 in 1880].

Much, though by no means enough, has been done in recent times for the education of blind youth. The first institution for the blind was founded in Paris by Hauy, at the end of the last century. Germany now has about thirty-five educational institutions for the blind. The children are usually not admitted until the age

[1] Vide Magnus, "Die Blindheit, ihre Entstehung und Verhuetung," 1883. Schmidt-Rimpler, "Ueber Blindsein," 1880. Fuchs ("Die Ursachen und Verhuetung der Blindheit," 1885) assumes the counting of fingers at 1 metre as the limit.

of ten to twelve years. They receive a complete course of education, learn a trade (especially basket-making, rope-making, brush-making, weaving, etc.) and usually music. In the beginning they use, in reading, carved letters which are put together upon a reading board; later they use primers and readers in which the letters, pressed in relief upon thick paper, are felt by the reading index finger. The large letters of the Roman alphabet are chiefly used. The relief of the letters is produced either by pressing out the different lines of the letters as such, as is done in Berlin blind print, or by making the lines out of individual projecting points (Breslau and Stuttgart print). The former can be read longer without tiring the fingers, but the punctate print is preferable when the tactile sense is diminished (as in older blind persons).

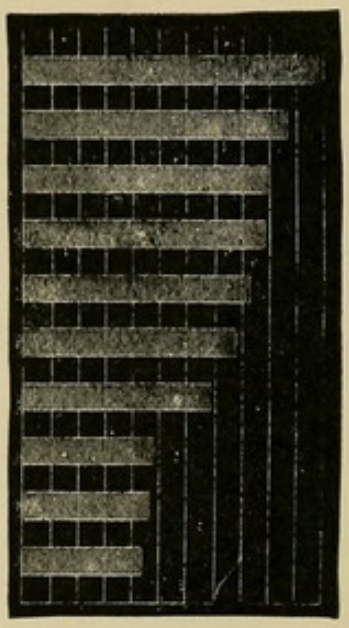


FIG. 66.

A form of stenography, in which the letters are represented by dots (for example, . A, : B, .. C) has been introduced by Braille and is used a good deal in printing and writing. In writing a tablet is used, like children's slates, traversed by very closely set transverse grooves; upon this is placed the paper, which is fastened at the edges by a frame. Upon the frame is a brass ruler, movable from below upward, which contains closely aggregated quadrilateral excavations of uniform size (thirty-one in a row) which correspond to the individual punctate letters which are to be formed. The blind individual, palpating with the left index finger the excavation in which the individual letter enters, makes the corresponding punctate impression with a pencil held in the right-hand. A uniform distance between the vertical points is secured by the transverse grooves upon the underlying tablet, three of which are situated above one another within the right angled excavation on the ruler, and into which the pencil presses on pressing in the paper. In order to produce flat writing which, as a matter of course, is legible only to persons with sight, the blind use the Roman alphabet and write with lead; the paper is placed upon a similar but smooth tablet, provided with a movable brass ruler.

Part Second.

Ophthalmoscopy

Ophthalmoscopic appearances in the healthy eye

Diseases of the optic nerve, retina, choroid and vitreous body

CHAPTER I.

OPHTHALMOSCOPY.

1. Theory of Ophthalmoscopic Examination.

THE pupil of the eye usually looks black. But it was long known with regard to certain animals that their pupils occasionally shone in a red or greenish light. Mariotte was the first who explained this phenomenon correctly by the theory that it was due to rays of light which were reflected from the choroidal tapetum of these animals. As Bruecke has shown, this tapetum forms a shining layer consisting of fibres (T. fibrosum) or cells (T. cellulosum of beasts of prey) which, occupying a larger or smaller part of the fundus of the eye, is imbedded in the choroid, between the chorio-capillaris and the choroidal stratum proper. The epithelial cells lying above it are in great part destitute of pigment. A tapetum is found in many mammalia (beasts of prey, ruminants, marsupials, the horse, etc.). The shining of the pupils is seen with special frequency in our domestic animals, the cat and dog. It has also been observed occasionally in albinos. It was therefore readily supposed that the pupil usually appeared dark only because the black choroidal pigment absorbed the rays of light and that it shone when the rays were reflected on account of the absence of pigment. This circumstance really does come into consideration, but that it is not the decisive one was shown by the methods, adopted independently by W. Cumming (1846) and Bruecke, of illuminating the pupils in normally pigmented human eyes. For this purpose a lamp, provided with a cylindrical chimney, is placed on a table, in a dark room, immediately in front of one's self; the individual to be observed is seated opposite at the distance of a few feet, so that his eye is at the level of the flame. He is now directed to look into the darkness immediately alongside the flame, while the observer looks into his pupil immediately behind the flame, against which he is protected by a shade. The pupil then shines with especial brightness when it is very wide, and the ocular media are very transparent, as in youthful individuals. In this way the inverted image of the entrance of the optic nerve and the retinal vessels may be seen distinctly, even in pronounced myopes, in whom atropine is

used to dilate the pupils. As a general thing, however, we can only see the pupil shining with a reddish or reddish-white light, the latter occurring when the pale optic papilla is situated directly opposite and reflects the light.

In determining the optic conditions which obtain in this experiment, Helmholtz discovered the ophthalmoscope (1851) and thus enabled us to recognize distinctly the details of the fundus of the eye. When Helmholtz, in his "Description of an opthalmoscope for examinations of the retina in the living eye" says: ". . . In short, I believe it is not chimerical to hope that all the changes in the vitreous body and retina which have been found in the dead body, will now be recognized in the living eye, thus promising the greatest advances in the hitherto undeveloped pathology of these structures," we may say to-day that these hopes have not alone been realized, but have been far exceeded.

The kernel of the whole question of the illuminating of the eye and ophthalmoscopy simply lies in the fact that, in distinct vision, the object and image form conjugate foci upon the retina. If the eye B is accommodated to the point *a*, a sharp image a_1, is formed upon its retina. All rays of light emanating from *a* unite in a_1; on the other hand, the rays emanating from the brightly illuminated image a_1 will again unite in *a*. Under ordinary conditions, therefore, a second and observing eye C (Fig. 67) will not perceive the rays returning from a_1; the pupil of the eye B appears black. But if C is situated in such a position that it looks directly into B and the rays reflected from the latter would have to enter its pupil, then the pupil of C becomes the object *a*. But as it emits no light, the pupil of B also appears dark and black. In order to make the latter shine, *i.e.*, in order to perceive rays of light which emanate from the fundus of eye B, certain artificial means are required. The simplest are found in Bruecke's above-mentioned experiment. Inasmuch as the eye B is not to accommodate upon the flame *a* the latter will not form a sharp image upon the retina but a circle of dispersion. The illuminated surface of the retina is, therefore, proportionately large. The rays of light are reflected from all points of this retinal surface and leave the eye in the direction of the point upon which they are accommodated. If the eye is emmetropic and looks into distance without accommodation, the rays coming from the eye will be parallel. If the eye C is now situated immediately alongside the flame *a* and in the direction of the visual line of B, a part of the rays enter the pupil of C, so that the pupil of B shines. The larger the latter and the stronger the con-

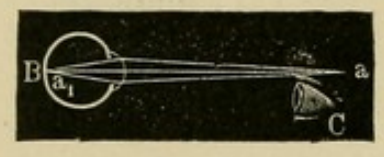


FIG. 67.

trast with the dark surroundings, the more marked will the shining appear. It also goes without saying, that the amount and intensity of the reflected light will be so much greater, the less is absorbed by the black pigment of the choroid. This explains the more marked shining of the pupils in albinos or animals provided with the tapetum. In addition, the latter usually possess hyperopic refraction and thus the reflected rays of light leave the eye in a divergent direction when accommodation is abolished.

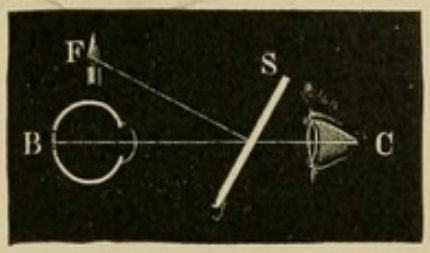


FIG. 68.

The points to be considered, therefore, are, 1st, to place the observing eye C, by a special arrangement, in such a position that it will receive the greatest possible number of rays from the fundus of the examined eye B, and 2d, that the rays reflected from B should unite in a sharp image upon the retina of the eye C. The latter will then see the fundus of B in all its details.

Helmholtz attained the first object, by placing in front of the observing eye a simple obliquely situated glass plate (S, Fig. 68) which reflected the light of a flame F into the eye B. The rays emanating from the illuminated fundus of the eye B returned in the same direction and, while some of the rays were reflected by the plate S toward F, others passed through the glass plate into the observing eye C. Subsequently the glass plate (Helmholtz ophthalmoscope) was replaced by a mirror, which was provided in the centre with an opening through which the rays of light could reach C.

Helmholtz also overcame the second difficulty by resorting to correcting concave lenses which were placed behind the mirror. In this method of examination in which the ophthalmoscope is brought very close to the examined eye, the individual parts of the fundus are seen enlarged and in their normal position, because the optical media of the eye acts like a magnifying glass. It is known as ophthalmoscopic examination of the eye in the erect image, as opposed to that in the inverted image, in which a convex lens held in front of the examined eye throws an inverted image of the fundus of the eye into the air.

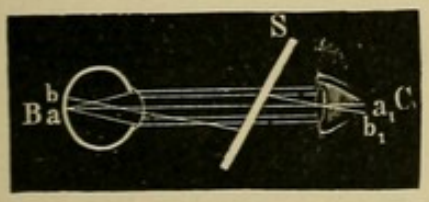


FIG. 69.

A. In examination in the erect image, the optical conditions will differ according to the refraction of the eye. We will first assume that the examining eye C (Fig. 69) and the examined eye B are emmetropic and destitute of accommodation: both eyes are adjusted for parallel rays. All rays which emanate from the reti-

nal point *a* of the eye B (illuminated by the ophthalmoscope S) leave it in a parallel direction and so pass into the eye C through the uncoated glass of the Helmholtz ophthalmoscope. C, being adjusted for parallel rays, unites them into a sharp image at the point *a*. This holds good with regard to the point *b*. C, therefore, receives a sharp image of *ab*. Inasmuch as, according to the law of projection, the image *b*, which is situated below *a*, in our drawing that is represented as a vertical section, it will be attributed to an object *b* situated above *a*, and the portion of the retina *ab* will appear in its natural position.

If the examined eye B is myopic, *i.e.*, adjusted for divergent rays, the rays emanating from the illuminated retinal point *a* (Fig. 70) will leave the eye in this direction; they therefore reach the eye C in a converging direction. Inasmuch as C is adjusted for parallel rays, a corresponding concave lens must be placed behind

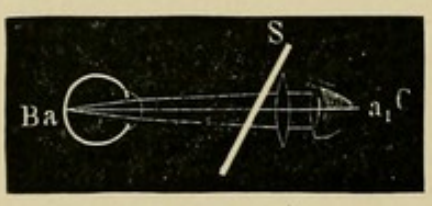


FIG. 70.



FIG. 71.

the mirror in order to make the converging rays parallel and thus to make possible their union in a sharp image at *a*.

Finally, if the examined eye is hyperopic, *i.e.*, adjusted for convergent rays, the rays emanating from *a* (Fig. 71) will leave the eye B in a direction which is divergent for the observing eye C. Here a suitable convex lens is required to make these rays parallel.

We have assumed hitherto that the examining eye is emmetropic and devoid of accommodation. If the former does not hold good, correcting spectacles will render possible the adjustment for parallel rays. It is more difficult to exclude the action of accomodation completely, if we are unwilling to resort to atropine or some other accomodation-paralyzing remedy. The consciousness that the examined eye is situated close by, also produces an adjustment for near objects, *i.e.*, for divergent rays. In examination of an emmetropic eye, the accommodated eye must therefore use concave glasses which will make the parallel rays divergent; in examination of myopic eyes, stronger concave lenses than correspond to the myopia of the eye under examination. It is only in the examination of hyperopic eyes that accommodation is useful and saves the necessity of convex lenses. For beginners, therefore, who have not yet learned to relax their accommodation, it is especially easy

to examine hyperopic eyes. In the latter the retinal vessels often appear distinctly even when the ophthalmoscope is still at a certain distance from the examined eye (say twenty to thirty centimetres), a thing which never occurs in the emmetropic eye, even if we are adjusted for parallel rays. This is explained in the following way: The retina of hypermetropes is situated in front of the principal focus of the ocular media, while that of emmetropes is situated in the focus. The enlargement of the fundus of the eye in the hypermetropic eye is therefore less than in the emmetropic eye. Inasmuch as only a very small part of the fundus of the eye can be overlooked at some distance from the examined eye ("the ophthalmoscopic field of vision" is very small), a very large blood-vessel of the emmetropic eye may entirely fill the field or even exceed it—the field of vision then appears simply red—while in the hypermetropic eye, the less enlarged vessel with its borders is distinctly visible.

But the size of the ophthalmoscopic field of vision, in the erect image, depends not alone on the distance between the examined and examining eyes, but also on the size of the pupil in the former. The larger it is, the larger is the field of vision. We can easily convince ourselves experimentally that both factors come into play by placing a sheet of paper, provided with a central opening, upon a strong convex lens (+ 20.0) and then looking through it at print which is first situated close to the eye, then at some distance (but within the focal distance of the lens), and also by having the central opening of various sizes.

When the size of the ophthalmoscopic field of vision in the erect image, was said to be dependent upon the conditions mentioned, it was assumed that the illumination of the retina, from the light thrown upon it by the mirror, was the greatest possible. But this is not always the case. When the retina is situated in the conjugate focus of the image of the flame reflected by the mirror, the distinct reverse image of the flame sometimes forms upon the retina, while the adjacent parts, despite the fact that they fall within the ophthalmoscopic field of vision, remain indistinct on account of insufficient light. The mirror and flame must then be brought at such a distance from one another, by moving to and fro, that the greatest possible diffuse illumination of the retina is secured, which occurs when a large circle of dispersion of the flame is thrown upon it. This also holds good for examination in the reverse image.

B. In 1852, Th. Ruete introduced another ophthalmoscopic method into practice, viz., examination in the reverse image. At the same time he used (but this is immaterial as regards the method) a concave mirror with a central opening, for the passage of light, instead of Helmholtz's uncovered plate of glass.

By means of a convex lens (about 20.0 [½] or 13.0 [⅓] held in front of the examined eye, the rays of light coming from the fundus are collected into a reverse, real image in the air and this image is then looked at. The image is larger that the retinal object, but not as large as the erect image.

Let us assume that the examined eye (Fig. 72) is emmetropic and the point *a* of the retina is illuminated by the light thrown from the mirror S. The rays emanating from *a*, which leave the eye in a parallel direction, will fall upon the lens and unite into the image a_1 at its focus. This is also true of the rays coming from *b* which unite at b_1. This actual image in the air is now regarded by C, which is adjusted as if for an object situated between the mirror S and the lens L.

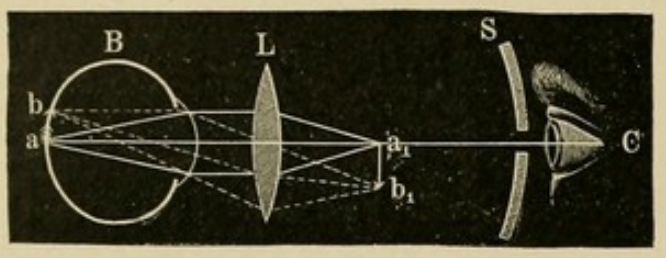


FIG. 72.

The image thus formed is reversed; a portion of the illuminated retina situated above forms an image below, a portion to the right side forms an image to the left.

The distance of the image from the convex lens will vary somewhat according to the refraction of the examined eye and its size will vary correspondingly. In the emmetropic eye, the image is situated at a distance from the lens equal to its principal focal distance; in the hyperopic eye, it is somewhat more remote (at *h*) and behind the focus *e* (Fig. 73) because the rays impinge upon the lens in a divergent manner; in the myopic eye it is somewhat nearer (at *m*). The image is therefore largest in the hyperopic, smallest in the myopic eye. As the size of the image is directly proportionate to its distance from the lens, the enlargement will be much greater in using a feeble convex lens (say, one-third) than a strong lens (say one-half.)

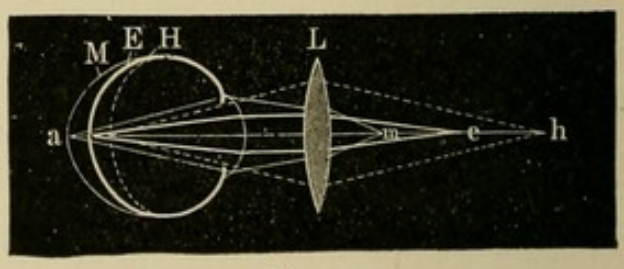


FIG. 73.

The size of the field of vision in examination in the reverse image, depends upon the distance of the convex lens from the pupil. If the latter is situated at the focal distance of the lens, it appears enlarged, and chiefly so, when its centre is situated at the focus of the lens; all the rays emanating from it will then leave the lens in a parallel direction. But the starting point of parallel rays is situated at an infinite distance, so that the image of the pupil must be

infinitely large. The pupil is no longer seen surrounded by the rim of the iris. If the pupil is situated outside the focal distance of the lens, we obtain its reverse image, larger or smaller according to the distance of the focus. It is therefore usually advisable to hold the convex lens at such a distance from the pupil that the latter is situated in the focus. How much of the pupil, which is enlarged in this way, can be seen in ophthalmoscopic examination, depends upon the size of the lens (its transverse diameter or its opening).

Enlargement of the Ophthalmoscopic Image.—The enlargement of an object which is appreciable by optical means, results from an increase in the size of the image on our retina. But the size of the latter is usually dependent upon the distance at which the object is situated. An object will form a large retinal image when situated nearer to the eye, a smaller one when situated farther away. In order to secure a point of comparison, a distance of eight inches (the so-called "distinct visual distance") has been selected for enlargement with the magnifying glass and microscope; the size of an object seen microscopically, which is situated at the distance of eight inches, is assumed as = 1. With convex $\frac{1}{2}$, for example, an object may be brought within two inches of the eye without necessitating a strain of accommodation in the emmetrope, and the retinal image is correspondingly enlarged. This enlargement is in the proportion of 8 : 2, *i.e.*, fourfold.

But this will take place exactly only where the optical centre of the lens used is assumed to coincide with that of the eye, and this, as a matter of course, is never the case. Moreover, the action of the changed accommodation upon the size of the retinal image has also been left out of the question. At a distance of eight inches the emmetropic eye would accommodate $\frac{1}{8}$, while it is adjusted for parallel rays in looking at the object with $+\frac{1}{2}$ at two inches. It may also be objected to this mode of measurement that the notion of "distinct visual distance" and its establishment at eight inches by no means any longer correspond to our present knowledge of refraction and accommodation. It would be more correct to compare the visual angles under which the objects are seen with and without optical aids (Schweigger). But the former mode of measurement is still in use and furnishes an entirely sufficient notion of the conditions. Let us assume that an emmetrope sees ophthalmoscopically in the erect image, the retina or optic papilla of another emmetrope. In the schematic non-accommodated, emmetropic eye, the retina is fifteen millimetres from the nodal point. If the eye is to be accommodated to 250 mm. (this is considered equal to the standard "distinct visual distance," twenty-five centimetres being

assumed as being equal to eight inches), the radius of the refracting surface would have to shorten 0.3 mm. according to a formula furnished by Helmholtz;[1] the nodal point is therefore removed an equal distance from the retina. It is now situated 15.3 mm. instead of 15 mm. behind the retina. If we now assume that the nodal point of the examined eye is so close to that of the examining eye, that the distance in question may be neglected, the eye which sees in the erect image will regard the pupil as through a lens of 15.3 mm. focal distance. For the emmetropic eye, therefore, the enlargement in proportion to the size which the object would have, if seen as at a distance of 250 mm. $= \frac{250}{15.3} = 16.3$ (Snellen). Mauthner, who calculates with a visual distance of eight inches and a distance between the nodal points of seven to eight lines, estimates the enlargement of the ophthalmoscopic image of an emmetropic eye at $14\frac{1}{3}$. With H $\frac{1}{3}$ resulting from shortening of the ocular axis and corrected by $\frac{1}{3\frac{1}{2}}$, $\frac{1}{2}$ inch in front of the nodal point, $= 15\frac{1}{2}$ enlargement. With the same H $\frac{1}{3}$, corrected by $\frac{1}{4}$, one inch in front of K, $= 13\frac{3}{8}$. The ophthalmoscopic enlargement therefore diminishes in hyperopia the farther the correcting glass is situated from the examined eye. The opposite is true of myopia. In M $\frac{1}{3}$, resulting from elongation of the occular axis, and corrected by $-\frac{1}{2\frac{1}{2}}$, $\frac{1}{2}$ inch in front of K, the enlargement $= 13$; with the same myopia, corrected by $-\frac{1}{2}$, one inch in front of K, the enlargement $= 16\frac{1}{3}$.

If H and M do not result, as is usually the case, from differences in the axial length, but from errors of refraction, the enlargement is smaller in H, larger in M than that stated above. This difference in the enlargement has also been utilized in order to diagnose whether we have to deal, in a given case, with axial or refraction ametropia. Weiss, who adopted this method, measured directly the enlargement of the erect image, using the method *à double vue*, which is customary in spy glasses. As is well known, a measure is placed at a certain distance and looked at with one eye directly, with the other through the spy glass. The images of both eyes then cover one another, and we can read off how many divisions of the measure seen with the naked eye form one division of the magnified measure. Weiss assumed the anatomical size of the observed optic papilla at 1.5 mm. as the basis for the enlargement found in the ophthalmoscopic image.

The enlargement is less in the examination of the reverse image.

As already mentioned, it depends upon the refraction of the convex lens employed; a weaker convex lens magnifies more than a stronger one. The distance at which the lens is held from the

[1] Physiol. Optik, p. 44, Formula 3.

nodal point of the eye is also important in ametropic eyes, while it is immaterial in an emmetropic eye, from which parallel rays always emerge upon the lens. In the hypermetropic eye, the image becomes smaller when the convex lens is held farther away from the eye, in the myopic eye it becomes larger. In order to furnish a comparison it may be mentioned that Mauthner—calculating according to the same principles as in the case of the erect image—estimates that in an emmetropic eye, with a convex lens $\frac{1}{2}$, placed about $\frac{1}{2}$ inch in front of the nodal point of the eye (it is usually held at a much greater distance), the enlargement of the reverse image is $3\frac{3}{4}$.

Schweigger compares the real size of the optic papilla with that of its reverse image. When using $+\frac{1}{3}$, held at three inches from the eye, he found that the proportion in E was 1 : 5.3, in M $\frac{1}{8}$ = 1 : 4.6; in H$\frac{1}{5}$ = 1 : 6.1.

2. Various Forms of Ophthalmoscopes.

I. Monocular Ophthalmoscope.

A. Plane Mirror.

In Helmholtz's ophthalmoscope (1851) the mirror is composed of simple, uncoated glass plates, several of which were superimposed on one another in order to obtain the greatest possible reflection and thus the relatively brightest illumination of the ocular fundus. These plates are rectangular in shape and are placed in a frame in such a way as to form an oblique angle to the flame. Behind this frame is a small tube which receives the necessary corrective glasses (Fig. 74). Helmholtz's ophthalmoscope furnishes the least illumination of all others. Its use is advisable in very photophobic eyes, and in certain cases in which the shade of color particularly of certain parts of the fundus is brought into question.

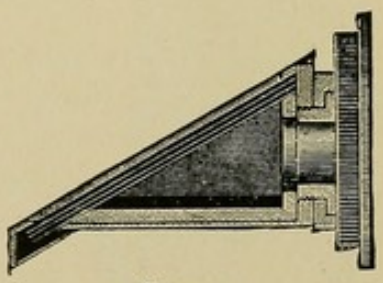


Fig. 74.

Soon afterward Epkens constructed an ophthalmoscope with a coated plane mirror, the coating being removed in the middle in order to permit the observer to look through. Subsequently a central opening was made in the mirror. The latter is preferable because the rays of light can pass through without interference, while, when the surface of the glass is made transparent by scratching off the coating, there is always a certain amount of reflection and cleansing is attended with greater difficulties. If a metallic mirror is used instead of glass, the small canal of the central open-

ing, which might prove annoying if it attained a certain length, can be reduced to a minimum on account of the greater tenuity of the reflecting surface.

Corrective lenses are placed behind the opening of the mirror in small half-rings with springs. Or we use an eccentrically fastened and revolving disk, in whose periphery the lenses are inserted (Rekoss).

With the plane mirrors, the real source of illumination for the examining eye is not the flame of the lamp, but its image thrown by the mirror. As is always true of plane mirrors, this image is a virtual, upright one and equal in size to the flame; it is situated as far behind the mirror as the flame of the lamp is situated in front of it. In examination in the reverse image the lamp is usually quite remote from the mirror, so that its image is tolerably far behind, and the illumination of the fundus of the eye is comparatively feeble. If the examination is made in the upright image, we approach much more closely to the examined eye and thus to the lamp in its vicinity. The intensity of illumination thus increases because the mirror image is brought closer. For examination in the upright image, the silvered plane mirror is entirely sufficient and indeed is often preferable to the concave mirrors which furnish more intense light.

B. Concave Mirrors.

Ruete (1852) was the first to construct a perforated silvered concave mirror for ophthalmoscopic examination. His larger instrument contained a large concave mirror upon a wooden frame, in front of which were the convex lenses necessary for examination in the reverse image; these could be moved upon a rod. Later he devised a smaller mirror which could be held in the hand. A number of similar concave mirrors have been constructed, differing in size, focal distance, etc. The best known is that of Liebreich (Fig. 75).

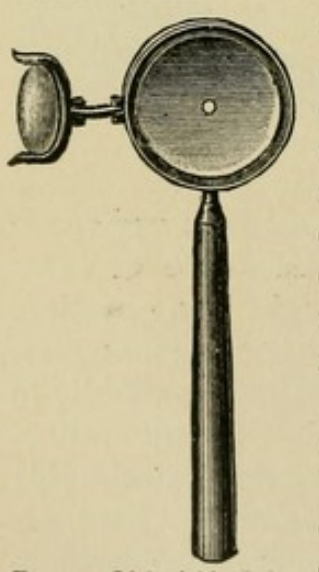


FIG. 75.—Liebreich's Ophthalmoscope.

With the concave mirror the small, reverse image of the lamp flame serves for illumination. Whether the reverse image is smaller or larger, depends upon the relation of the focal distance of the mirror to the remoteness of the lamp. If the distance of the latter, equals twice the principal focal distance of the concave mirror, the image and object are of equal size, inasmuch as the same optical laws hold for concave

mirrors as for convex lenses. As a rule, however, the lamp is farther from the mirror in examination in the reverse image than twice the principal focal distance, so that the mirror throws a smaller, but very bright reverse actual image, whose rays illuminate the fundus.

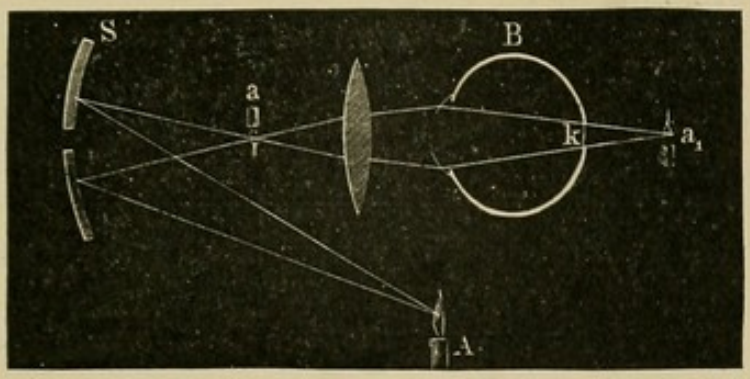


FIG. 76.

Fig. 76 shows the conditions in ophthalmoscopic examination in the reverse image, when the reverse smaller image *a* of the flame does not fall in the focus conjugate with the retina. In the figure it falls behind it; hence the image of the flame would also be formed behind the retina at *a*; a circle of dispersion *k* forms upon the retina. This mode of illumination by a circle of dispersion is more favorable, as we have stated above, than when the image of the flame (usually recognizable as a bright triangle) is thrown directly on the retina. The distance of the mirror image from the mirror can be calculated by the lens formula ($\frac{1}{f}=\frac{1}{a}+\frac{1}{b}$). If, for example, the principal focal distance of the mirror is six inches and the distance from the flame twenty-four inches, then according to the lens formula $\frac{1}{6}=\frac{1}{24}+\frac{1}{b}$ or $\frac{1}{b}=\frac{1}{6}-\frac{1}{24}$ or $\frac{1}{b}=\frac{1}{8}$, *i.e.*, the reverse image of the flame is eight inches from the mirror. The focal distance of the concave mirror in ordinary use, particularly the Liebreich mirror, is usually small, varying from four and one-half to six inches; we rarely find larger focal distances. In ordinary examinations no particular importance attaches to exact grinding of the concave mirror, but it does in the ophthalmoscopic measurement of refraction devised by me. The majority of so-called concave mirrors are ground very inaccurately. The images thrown by them are confused, and reduplication of the images is found not infrequently. It is therefore well to pay attention to this point in purchasing. The test

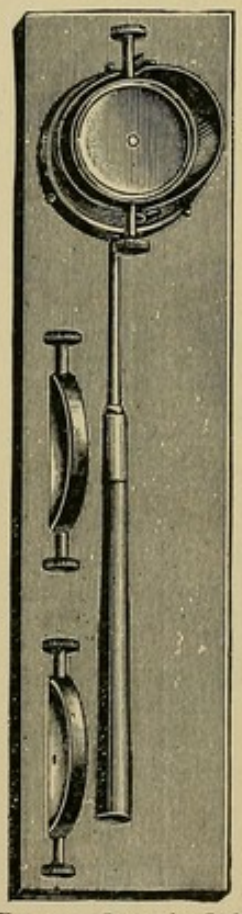


FIG. 77.—Jaeger's Ophthalmoscope.

is very easy; as in the case of convex lenses a reverse image of a distant object is thrown upon a plane surface.

Jaeger's ophthalmoscope (Fig. 77) permits the alternate insertion of a plane mirror (Helmholtz's glass plate or a coated mirror) and a concave mirror, an arrangement for grasping them being applied to the anterior extremity of a small tube, which is cut off obliquely. In addition, this possesses the advantage, as in Helmholtz's instrument, that the light can be thrown into the examined eye by a simple oblique position of the mirror, without turning the tube. As the corrective lenses are inserted at the posterior rim of the tube, which runs along the visual line of the observer, they always remain in the same vertical plane in front of his eye. In other instruments, for example, Liebreich's, the whole ophthalmoscope, and hence the corrective lenses situated behind it, must be held somewhat obliquely corresponding to the position of the flame of the lamp. Hence the rays of light pass obliquely through the corrective lenses situated immediately behind the opening, and thus experience a somewhat different refraction.

As a general thing, ophthalmoscopes, in which the mirror alone need be placed obliquely, are preferable for ophthalmoscopic measurement of refraction, but the disadvantages of other intruments are of no very great moment.

C. Combination of a Convex Lens and Plane Mirror.

Coccius (1853) devised an ophthalmoscope (Fig. 78) which can be used as a plane and concave mirror, with changeable focal distance.

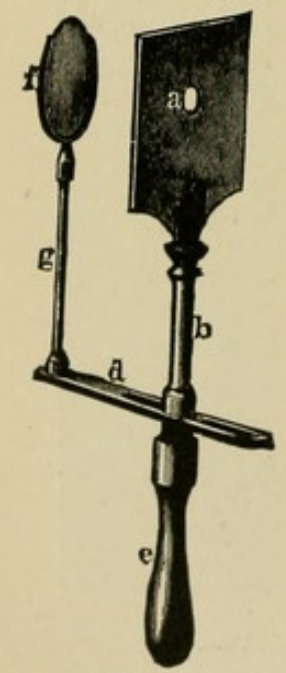


Fig. 78.

To a plane mirror *a* is fastened a metallic rod with a spring arch, which serves for the reception of a convex lens *f*. The lens (about $\frac{1}{8}$) is turned toward the flame. As the distance of the lens

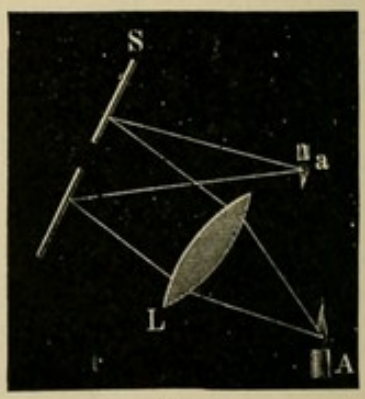


Fig. 79.

from the flame is greater, as a rule, than the focal distance of the lens, the rays of light which pass through it are refracted in such a

way that they converge upon the plane mirror. Reflected from the latter in the same way, they unite in a reverse actual image *a*, which serves to illuminate the eye, as in the case of concave mirrors (Fig. 79). This possesses the advantage that we can secure a series of concave mirrors of different focal distances by placing convex lenses of different powers in the frame.

D. Combination of a Convex Lens and Convex Mirror.

Instead of a plane mirror, Zehender (1854) used a metallic convex mirror of three inches focal distance; in front of it was situated, as in Coccius' instrument, a convex lens *e* of three inches focal distance (Fig. 80).

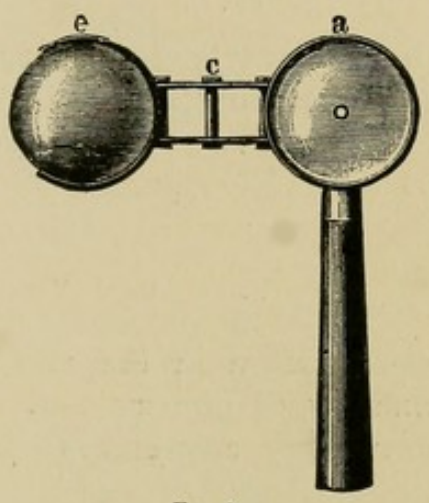


FIG. 80.

The rays of light which pass through the lens are converged toward the mirror so that they would form an imaginary image between its focus and the surface of the mirror. They are then reflected from the mirror in a convergent direction, the convergence being so much more marked the nearer the imaginary image is to the surface of the mirror. The rays would be reflected parallel, if they were directed upon the convex mirror in such a way that the imaginary image would form in its focus (vide Fig. 19, page 28). The mode of illumination of the ocular fundus can be changed considerably by simple approximation and removal of the convex lens.

E. Ophthalmoscopes Based on Various Other Principles.

Coated glass lenses have also been used as ophthalmoscopes. In order to obtain a concave ophthalmoscope, the posterior surfaces of a negative meniscus (convexo-concave lens) is coated, and the coating removed in the centre (Jaeger). As the rays from the examined eye pass through this ophthalmoscope, which also acts as a concave lens, it is adapted to examination by and for myopes. A concave ophthalmoscope would also be produced by coating one side of a biconvex lens, but this instrument would also act as a convex lens. These mirrors are not very practicable on account of the excessive reflection.

Greater importance attaches to the use of prisms in the construction of ophthalmoscopes; use being made of the total reflection of light, which loses hardly any of its original intensity.

Ulrich (1853) was the pioneer in this line. If *abc* is a section of an isosceles, right-angled glass prism, a ray of light L*m* (Fig. 81) which falls at a right angle upon the surface *bc*, will maintain its direction *mn* unchanged. At *n* it meets the hypothenuse *ac* at an angle of incidence of forty-five degrees. As this angle *i* is greater than the limiting angle of glass, the light does not pass into the air, but is totally reflected toward *o* where it meets *ab* at a right angle and passes uninterruptedly toward B. In using the prism as an ophthalmoscope, the rays returning from B can be made to enter the observing eye C by boring a parallel hole *no* in the prism (Meyerstein's ophthalmoscope).

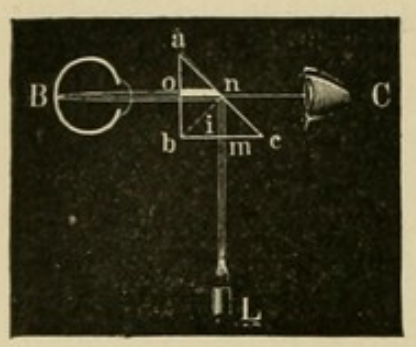


FIG. 81.

F. Refraction Ophthalmoscopes.

In the measurement of refraction by means of ophthalmoscopic examination in the erect image, we require a sufficiently large number of convex and concave lenses to correct accurately any errors of refraction which may be present.

These lenses are situated behind the opening of the mirror, and must be arranged so that they can be changed easily and rapidly. Alternate removal and insertion, as is necessary, for example, in Jaeger's ophthalmoscope, would be impracticable, because the measurement of refraction, as we will see later, depends upon the fact that the fundus of the individual is seen with maximum distinctness with a certain corrective lens. Small differences in distinctness can only be judged, however, by noting, on rapid change of the different lenses, the one which corrects most accurately. For this reason Loring (1870) added to his ophthalmoscope three Rekoss's disks, each of which contains eight lenses. By making these lenses very small, the necessary number were finally inserted into a single round, not too large plate, which was fastened to the posterior surface of the mirror (refracting ophthalmoscope of Wecker, Knapp). But inasmuch as the peep opening becomes very small when the lenses are too small, a disturbing stenopaic action may result and thus partly compensate the irregular refrac-



FIG. 82.

tion due to the error of refraction. The insertion of larger lenses without diminution of their number has been made possible by the use of two plates like those of Loring. One of these disks contains the feebler lenses, the other the stronger ones (Fig. 82); they must therefore be taken out and changed whenever necessary (Gowers, Hirschberg, Horstmann, etc.). If the ametropia of the examined eye is found just at the boundary between the strongest lens of the first and the weakest of the second disk, then the incon-

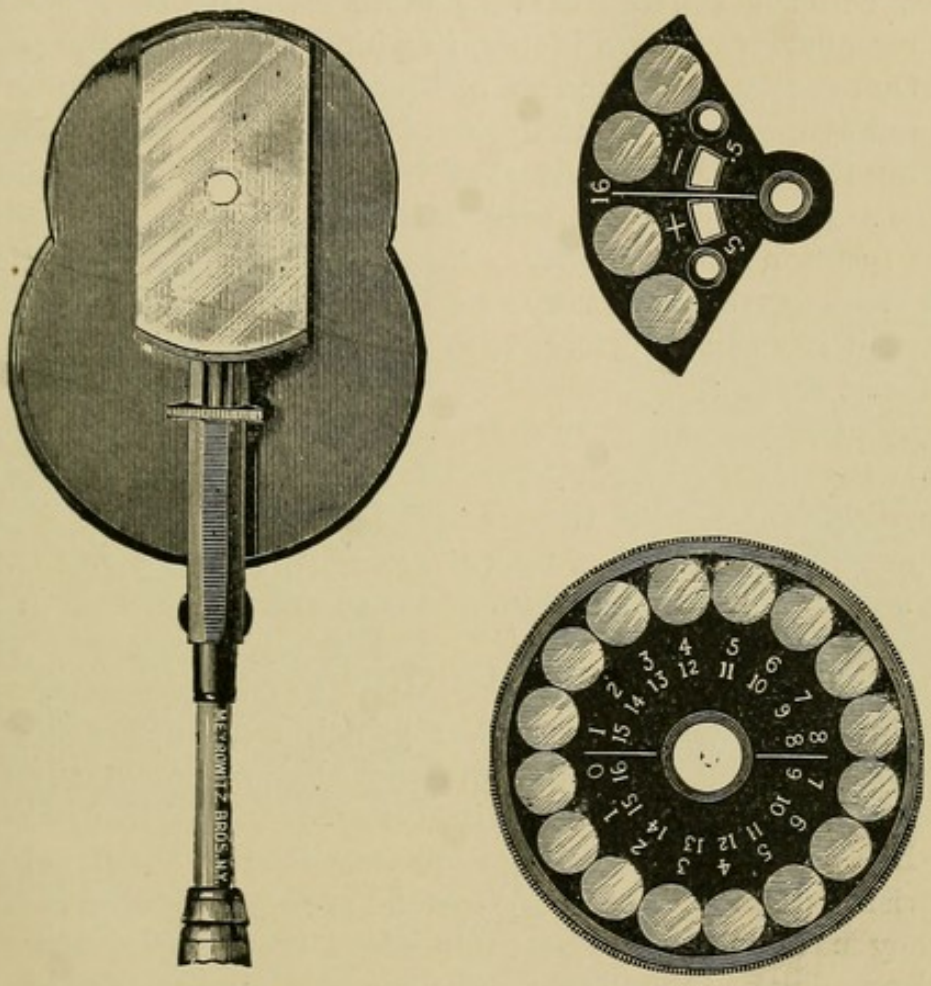


Fig. 83.

veniences of the comparatively slow change make their appearance, as mentioned above.

In addition, two disks which move upon one another have been placed above one another. In this way a large number of differently refracting lenses may be obtained by the combination of two lenses, one of the upper, another of the lower disk (Landolt, Pflueger, Schweigger).

Modifications have also been made in the shape of the mirror surface. Inasmuch as, during examination in the erect image, a too intense light may give rise to annoying contraction of the pupil, plane mirrors are usually preferred to the concave mirrors.

On account of their usual focal distance of four to seven inches, the latter, which are held within two inches of the examined eye, send converging and therefore more numerous rays into the pupil from the lamp which is situated outside of its focal distance, while in plane mirrors the diverging rays of the mirror image serve for illumination. But the inconveniences of too intense illumination by the concave mirror, can be obviated very easily by turning down the lamp or removing it a little farther. For this purpose we may also use concave mirrors of very short focal distance, about one and three-quarters to two inches, in which the inverse image of the flame, that serves as the source of illumination, falls in front of the examined eye. In an ophthalmoscope which is used for measuring refraction it is also desirable that the mirror alone—without the corrective glasses situated behind it—may assume the necessary oblique position to the flame, as in Jaeger's instrument. For this reason Wadsworth uses a very small oblique mirror, but on account of its small size this interferes with the reception of the light of the flame (see Fig. 82).

[Very early in the history of refraction ophthalmoscopes, Loring, who was the first to invent a practical one, arranged all the lenses in one disk. This, with the so-called tilting mirror of Coups, as finally accepted by Loring, makes one of the best, if not the best, ophthalmoscopes for the measurement of refraction.—St. J. R.]

II. Binocular Ophthalmoscopes.

1. Giraud-Teulon employed the principle of total reflection in his ophthalmoscope, which permits the observation of the fundus with both eyes. Fig. 84 shows its construction in transverse section. Behind a somewhat large concave mirror are situated two glass prisms (*abcd* and $a_1 b_1 c_1 d_1$) which are rhomboidal in section, so that they unite with one of their edges immediately behind the central opening of the mirror. The angles *abd* and *acd* equal forty-five degrees. Rays which fall perpendicularly or approximately so upon *ab* (or ba_1) pass undeflected through ab_1, are totally reflected by *db*, pass to *ca* where they are again totally reflected and leave the prism at a right angle (*g* or g_1). If R is the inverse image of an illuminated part of the retina (say the papilla), the beam of light emanating from it will impinge on both prisms and leave them at *g* and g_1. If both eyes of the observer are situated behind the mirror in such a way that these rays fall into their pupils, they will see R binocularly. Here it is assumed that the visual lines of the observer are parallel, corresponding to the direction of the rays emerging at *g* and g_1. As a general thing, this does not occur in looking at near objects. In order to obviate this inconvenience, a smaller

prism, with its base turned outward, is placed as in the stereoscope, behind the rhomboidal prisms. Inasmuch as the rays are now deflected to the outside, the observer may retain the convergent position of his eyes, which is also more convenient for accommodation.

As the distance between the eyes differs in different individuals, the rhomboidal prism situated to the right is bisected (at a_2 d_2). If the parts are separated by means of a screw, the ray emerging at g_1 will be displaced somewhat farther to the right. Hence, an observer whose pupils are situated farther apart than is assumed in the drawing, may receive this ray of light. Giraud-Teulon has recently devised a modification in which the mirror proper is wanting, because the source of light—a small Edison lamp—is situated directly between the two rhomboidal prisms (*b* of Fig. 84).

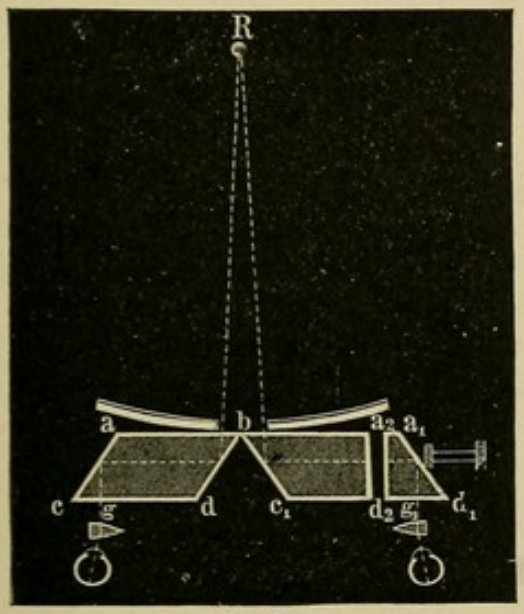


FIG. 84.

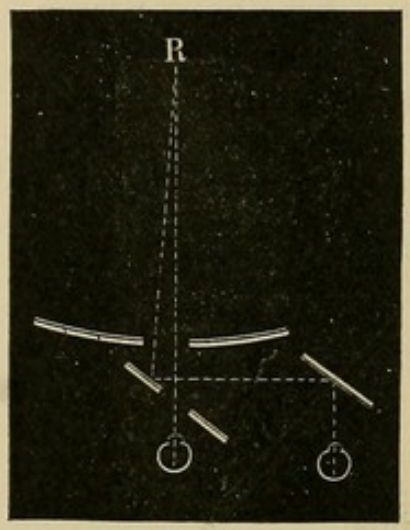


FIG. 85.

The binocular ophthalmoscope possesses the advantage that it permits a sort of stereoscopic vision and makes the objects appear in plastic form, so that an excavated papilla looks like a depression, etc. We can readily convince ourselves of this. But the height of binocular and stereoscopic vision, such as is required in Hering's falling experiments, is not attained even with the use of the binocular ophthalmoscope.

2. Behind the ordinary perforated concave mirror Coccius placed a perforated plane mirror, at an angle of about forty-five degrees to the visual line of the observer. If the left eye, for example, looking through these two openings, receives rays of light from the ophthalmoscopic image R, the right eye sees the same image in another unperforated plane mirror, which is situated at an angle of forty-five degrees to the perforated mirror (Fig. 85). But with this arrangement the eyes do not see the object from the right and left

sides at the same time, as can be done with Giraud-Teulon's instrument.

3. Lawrence used a larger mirror with two openings, while Schweigger placed a perforated mirror before each eye. But these methods are only adapted to examination of the anterior parts of the eye, and cannot be used for examination of the inverse image.

III. Demonstration Ophthalmoscopes.

These instruments serve to make the fundus of the eye visible to those who are unable to use the ophthalmoscope.

1. The Liebreich ophthalmoscope belongs to this class. A perforated concave mirror, through which the observer looks, is situated at the end of a tube, in a sector, and can be turned toward the flame of the lamp. In the tube is a movable convex lens; at the other end of the tube is the eye of the individual to be examined. Above and to the side of the tube is a button, which can be moved upon a rod. This can be placed in such a way that when the patient fixes it his papilla is situated directly opposite the tube. The ophthalmoscopist must now place the mirror and convex lens in such a position, that an inverse image of the fundus is thrown into the tube. If the patient maintains the position of his eye and accommodation, individuals who cannot use the ophthalmoscope, may perceive the ophthalmoscopic image.

Those instruments which permit control by a reliable observer, are better; two observers then look at the fundus (in the inverse image) at the same time. Giraud-Teulon's binocular ophthalmoscope may be highly recommended. The part $a_1 d_1 d_2 a_2$ of the right rhomboidal prism (vide Fig. 84) must be removed; the horizontal beam of light then continues in the same direction. This is received by the eye of the second observer, while the first observer receives the ray g with his right eye.

2. The demonstration ophthalmoscopes of Sichel and Schweigger are also constructed by resorting to total reflection. Behind the central opening of a concave ophthalmoscope a glass prism is placed, which half covers the opening. A portion of the rays of the ophthalmoscopic image therefore passes undeflected through the opening, while the other part is deflected by the prism to the right (as above) and reaches the eye of the second observer. But it is quite difficult to secure recognition of the image by two observers at the same time.

3. Peppmueller has placed in front of the central opening of the ophthalmoscope a small oblique mirror, which only covers the

opening in part so that the rays in part pass through, in part fall upon the small mirror and are reflected (Fig. 86).

4. Giraud-Teulon, in examination in the inverse image, places a glass plate obliquely, at an angle of forty-five degrees, between the convex lens and mirror. The rays from the image will pass, in part through the glass plate, in part they will be reflected, and so much the more accurately the more exactly the plate is ground. In this way two persons may observe at the same time.

5. If both observers are skilled to a certain extent in ophthalmoscopy, combined observation of the ophthalmoscopic image may be effected in the following way. Observer A, who is situated to the side and a little behind the eye to be observed, throws the rays

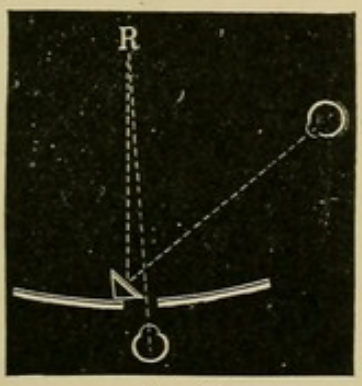


Fig. 86.

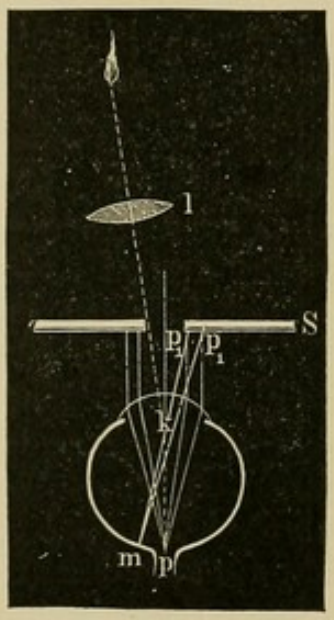


Fig. 87.

of a lamp, by means of a perforated mirror, in such a way that they fall upon the perforated plane mirror of observer B (who is situated in front of the patient), who, in turn, throws them into the patient's eye. The rays of the ophthalmoscopic image in part reach B through the central opening of his mirror, in part they are reflected from his mirror and seen by observer A.

IV. Mirror for Autophthalmoscopy.

Various methods and instruments have been devised in order to use the ophthalmoscope on one's self. According to Coccius, the pupil is to be dilated with atropine or homatropine, in order to paralyze accommodation. The emmetrope is then accommodated for parallel rays, the myope or hyperope must correct his error of refraction by a suitable lens. A plane mirror (Fig. 87, S), with the

reflecting surface turned toward the eye, is now held obliquely in front of the eye. The visual line *mk* is directed upon the edge of the opening in the mirror, light from a lamp (condensed by a convex lens *l*), enters the pupil through the opening. With a proper position of the eye we can then succeed in illuminating the optic papilla *p* by the entering rays of light. The rays emanating from the papilla leave the eye parallel to *pk*, fall upon the surface of the mirror at p_1, where they are reflected, return into the eye, and unite upon the macula. In this way the ophthalmoscopist sees his own papilla.

Heymann devised a more complicated method with prisms. The instrument has the shape of a binocular opera glass. By the skilful use of an oblique, perforated plane mirror situated at the end of one tube, and a totally reflecting prism at the end of the other tube, we can see with the second eye the fundus of the first.

The question, which ophthalmoscope is the most practical, cannot be answered in general terms, because the different instruments are more or less adapted to different purposes. Weaker mirrors (plane mirrors) are usually selected for examination in the erect image, in order to obtain the widest pupil possible. Some prefer them also in examination in the inverse image. I prefer the concave mirror because it gives much better illumination. The latter is particularly useful—even in examination in the direct image—when there are opacities in the optic media. The disadvantages of bright illumination (narrowing of the pupil, blinding), upon which too much stress is sometimes laid, may be avoided by turning down the flame of the lamp. One who is unable to secure a large and expensive ophthalmoscope, will usually manage with a small Liebreich or Coccius' instrument. Accurate ophthalmoscopic measurement of refraction cannot be made with them, except with the aid of my method in the inverse image.

[I would strongly urge the ophthalmoscopist, whether he proposes to become an amateur or an expert, to procure a well-made and therefore a somewhat expensive instrument. The American refraction ophthalmoscopes are the best. They cost from fifteen to thirty dollars.—St. J. R.]

3. Source of Illumination.

An oil, petroleum, or gas lamp, provided with a chimney, is generally used for ophthalmoscopic purposes. According to the color of their light, these flames give a certain tinge to the ocular fundus, which is somewhat more pronounced with strong than with

weaker mirrors. Diffuse daylight, therefore, has also been used. This gives a very feeble illumination of the fundus and has been especially extolled by certain authors for the recognition of slight pathological changes of color (for example, the slight pallor of the papilla in beginning atrophy of the optic nerve). I do not find that the daylight is particularly advantageous. As the entire fundus appears in a uniformly paler light, the papilla naturally is also paler. But I have not perceived, from this illumination, any differentiation in the color between a normally reddish and slightly atrophic papilla. If daylight is to be used in ophthalmoscopy, the diffuse light must be allowed to enter the otherwise dark room through a small opening in the shutters (about two centimetres in diameter). The patient stands or sits next to the opening. Moreover, diffuse daylight, as a rule, is not absolutely devoid of color, because it receives a certain light from the reflecting surfaces from which it is derived. Even the light of the clouds has different colors. As a matter of course, direct sunlight may not be used, as it would cauterize the retina.

4. Method of Ophthalmoscopic Examination.

A lamp, provided only with a chimney, is placed upon a table in a dark room, to the side and somewhat behind the head of the

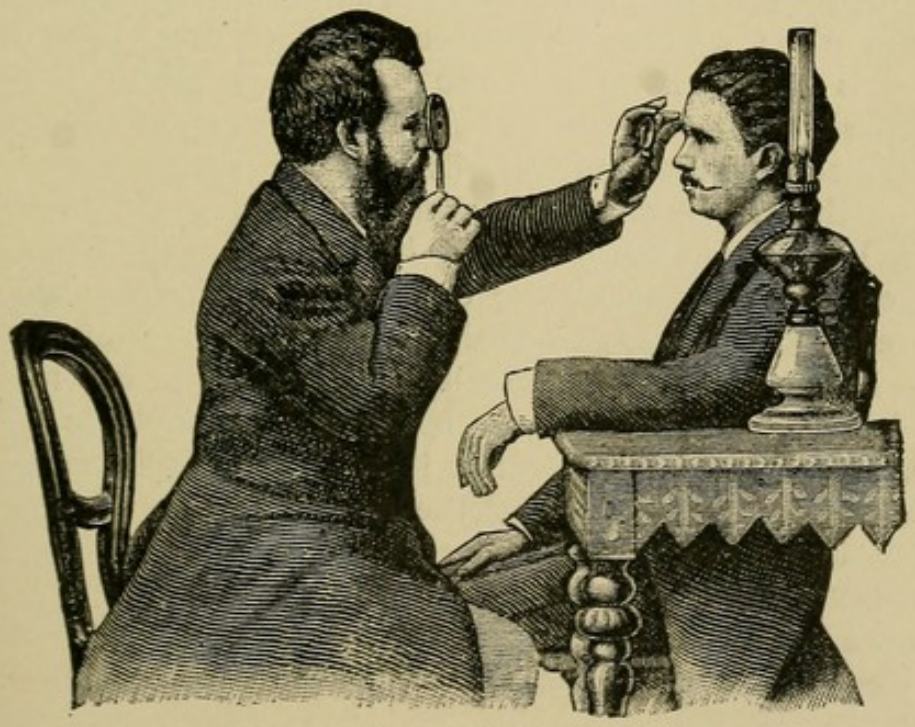


FIG. 88.—Examination with the Inverted Image.

individual to be examined, so that his face remains in shadow. In examination in the inverted image, it is advisable to place the lamp to the left side of the patient in order to avoid cutting off the light

with the left hand, which carries the convex lens, when the observer holds the mirror in front of his right eye. In examination in the direct image, it is somewhat more convenient to place the lamp to the right, when the right eye is examined. The flame of the lamp should be, as nearly as possible, at the level of the eye of the sitting patient. It is therefore useful to have an arrangement for moving the lamp up and down. In the majority of cases, an Argand lamp is better than a flat burner, because the mirror is held at different angles to the flame from which it receives the light. The physician is seated opposite to the patient, so that the chairs are quite close to one another. This is done by placing the patient's legs between his own, or the physician and patient may place their legs in opposite directions. The eye of the observer and of the patient should be, as far as possible, in a horizontal plane. Before illuminating with the mirror, it is well to assure the patient, especially if he is timid, that the examination is painless, and in an experimental way to throw the light into the pupil with the mirror.

It is advantageous to be able to examine the right eye of the patient with our own left eye, and his left eye with our right. But the beginner will be satisfied if he can see anything with one eye.

If we look with the right eye (as is usually done) the mirror is held in the right hand—in the other event in the left hand—close in front of our own eye, the upper rim being applied to the upper rim of the orbit; we then look through the opening. The light of the lamp is then thrown into the patient's pupil by a slightly oblique position of the mirror. At first this is not always easy. The beginner may then notice, with the free eye, the position of the image thrown by the mirror and by turning the mirror will gradually lead it into the pupil. If he now closes the free eye, he will see, on looking through the opening of the mirror, the pupil shining red, and thus has gained the first step in the examination.

Some individuals find it difficult to close the one eye, and only learn it by long practice. These may require a shield in front of the eye. As a matter of course, it is also possible to use the ophthalmoscope without closing the second eye, by disregarding the impressions received by this eye.

[This latter method is much to be preferred. It is much easier to relax the accommodation when both eyes are open, than when one is closed, and the habit of keeping both eyes open is less fatiguing.—St. J. R.]

In order to examine whether there are any opacities in the refracting media, the patient is directed to turn his eye up and down and from right to left, for a few times. If opacities are present—whether corneal patches, pupillary deposits, opacities of the lens

or vitreous body--gray or black specks appear in the red of the pupil. If these patches move in the same direction as the cornea, they are situated in front of the centre of rotation of the eye. We should not be led into a mistake as to the direction, by the fact, that opacities of the lens move less freely than those of the cornea.

The examination of the fundus of the eye, usually begins with that of the entrance of the optic nerve (papilla nervi optici) in the first place, because the majority of morbid processes are located in this part and its vicinity, and also because its lighter color contrasts strongly with the intense red of the remainder of the fundus and thus affords a suitable starting-point for the first accommodation of the examining eye. The optic nerve passes through the sclera a little to the nasal side of the posterior pole of the eye. If we wish to have it vis-à-vis in the examination, the patient must turn his eye a little to the nasal side and not in the direction of the mirror; in the latter event the macula lutea is situated in front of us. If the left eye of the patient is examined by the right eye of the observer, and the faces of both are directly opposite one another, the proper position will be assured if the patient is directed to look in the direction of the left ear of the observer, at the level of his eyes. When the observer wishes to examine the right eye of the patient with his own right eye, he must move his head somewhat to the left. The patient must then look a little to the outside of the right ear of the observer.

It is of great assistance to the beginner to have the papilla opposite him at once. He will succeed if the patient looks in the direction just described, but attention must be paid to it that the patient maintains the direction. Many patients are constantly looking inquisitively into the mirror. The narrowing of the pupil and the numerous reflexes will call our attention to the change of position. If, on account of improper position of the eye, we see, not the papilla, but other portions of the retina, we can reach the former by following the course of the visible retinal vessels, passing from the dichotomous branches along the constantly enlarging main branch to its beginning, which is situated in the papilla.

In order to dilate the patient's pupil as much as possible, and to relax his accommodation, he is directed to look into the darkness of the room (in the direction mentioned) and not to fix the ear itself. Covering of the other eye may also be resorted to in order to dilate the pupil.

As a rule, artificial dilatation is unnecessary. It should be employed only when the pupil is unusually narrow and the ocular media are less transparent (as occurs particularly in older people) or when it is important to examine the extreme peripheral parts of

the eye. The wide pupil facilitates the examination considerably and is therefore used more frequently by the tyro than by the expert. To secure mydriasis we may use a solution of cocaine muriat. (four per cent), of which one drop is poured into the conjunctival sac every five minutes. Dilatation sufficient for ophthalmoscopic purposes is usually attained in twenty to thirty minutes. Homatropine hydrobromate (0.1 : 10.0) acts more vigorously. The mydriasis occurs in fifteen to twenty minutes after instillation, but is associated with paralysis of accommodation which does not disappear until the lapse of twenty-four hours. Repeated instillation of homatropine or atropine is sometimes necessary in older people. If there is a suspicion of glaucoma, these remedies must be avoided, as they may be followed immediately by the outbreak of an acute attack of glaucoma.

In examination in the inverted image—and also when we wish to examine merely the anterior parts of the eye or the vitreous body—the mirror is kept farther away from the examined eye (about thirty to forty centimetres) than in examination in the direct image. A convex lens $\frac{1}{3}$ is usually best adapted for the inverted image. This produces the proper enlargement and need not be held too far from the eye. Stronger lenses ($\frac{1}{2}-\frac{1}{1\frac{1}{4}}$) are indicated in pronounced hypermetropia, detachment of the retina, in examination for cysticerci, or when we wish to overlook a large part of the fundus at one time. The convex lens is held between the index finger, placed on its upper rim, and the thumb, on its lower rim, the little finger of the outspread hand being placed on the forehead of the patient. In this way the lens can be carried to and from the eye. The pupil, centre of the lens, and the opening in the ophthalmoscope should be, as far as possible, in a horizontal line. The lens should be held at such a distance from the pupil that the latter is situated in its principal focus. When it is held closer to the eye, the red shining pupil is seen surrounded by the rim of the iris. In this event we move slowly away, until the iris disappears entirely from the field of vision; the proper distance has then been reached. The observer's own eye and the ophthalmoscope, should be so far removed from the lens that he can accommodate sufficiently upon the inverted image of the ocular fundus, which is situated in the air between the lens and the mirror. If we examine an emmetropic eye with 13.0 (= about $\frac{1}{3}$), the inverted image is formed $\frac{1}{13}$ m. = $7\frac{9}{13}$ cm. from the lens. If we assume the convenient visual distance at twenty-five centimetres, the ophthalmoscope and the eye of the observer should be about thirty-three centimetres from the lens. If the observer is so near-sighted that he cannot see distinctly at a distance of twenty-five centimetres, he approaches with the mirror

as close as seems necessary to him. Myopes who are accustomed to wear glasses constantly for near work, should also keep them on during ophthalmoscopic examination. Hyperopes require a corresponding removal with the mirror or the use of a convex lens behind the mirror. This also holds good of presbyopes. Emmetropes and myopes may also occasionally use convex glasses behind the mirror, in order to spare their muscle of accommodation and at the same time—with stronger glasses—to enlarge the image. But the use of convex lenses is not advisable for the beginner, if it is done solely for these reasons. He is thus placed in unusual conditions of accommodation, which render the examination more difficult.

The first rule is, not to attempt to look through the convex lens, but to accommodate the eye upon the image in the air between the observer and the lens. For this purpose, it is good practice to throw with convex 13.0 an inverted image of vertical print placed alongside a flame, the print being at the same time illuminated with the mirror; we thus act with the print as in ophthalmoscopic examination of the fundus. Furthermore, it is also advisable for the beginner to make ophthalmoscopic examinations of animals, especially rabbits. In dark-haired rabbits we see, in the fundus of the eye, bright red stripes upon a darker background; they are the choroidal vessels. In white rabbits the vessels appear red on a lighter background, because the sclera shines through on account of the absence of choroidal pigment. The retinal vessels are very scanty in rabbits and are sufficiently distinct only in the vicinity of the papilla. In searching for the papilla we must look into the eye from below and a little from behind. If we throw light into the pupil with the ophthalmoscope (without a convex lens), we can find the papilla most readily by moving the head to and fro, and looking for the place at which we see, not a red, but a more whitish reflex. On using the convex lens, we see the bluish-white, physiologically excavated papilla, from which slightly streaked, light white, sector-shaped figures extend into the retina, especially in pigmented rabbits. They are the optical expression of the medullated nerve fibres which run their course here. The eyes of frogs are also examined easily in the direct image; especially interesting is the observation of the circulation of blood in the vessels of the hyaloid membrane.

Apart from the proper adjustment of the eyes, a further difficulty often arises from the light-reflexes on the cornea and convex lens. The latter can be diminished by turning the lens somewhat upon its horizontal or vertical axis. It is also lessened by diminishing the intensity of the light or removing the mirror to a greater

distance. The image of the ophthalmoscope reflected by the cornea, which is sometimes seen as a small shining disk with a black point (peep hole) in the middle, is sometimes regarded by beginners as the optic papilla.

It is also disturbing, that the ophthalmoscopic field of vision is illuminated occasionally only over a small surface, inasmuch as a tolerably distinct inverted image of the light, in the shape of a brightly illuminated triangle with its base situated upward, is thrown upon the retina. The structures within this illuminated part alone are recognizable The distinctness with which the image of the light is marked upon the retina, depends upon the focal distance of the mirror, upon the distance of the latter from the eye or the convex lens, and finally upon the refraction of the examined eye. It is most distinct when the retina is situated in the conjugate focus of the flame image that serves as the source of illumination. If, in any given case, the image appears very distinctly upon the retina, the mirror is carried nearer to or farther away from the eye in order to overcome this inconvenience. At the ordinary distances which are usually maintained in examination in the inverted image, weak concave or plane mirrors throw large circles of dispersion of the image of the light and thus furnish a more diffuse illumination of the retina. With good illumination and a moderately wide pupil we can, with + 13.0, see the entire optic papilla and an adjacent zone which is about half as wide as the diameter of the papilla.

In examination in the direct image, the mirror must be brought within five to six centimetres of the examined eye, an approximation from which the beginner usually shrinks back. It is difficult, at this distance, to obtain the light from the lamp and to reflect it into the pupil. The lamp should therefore be moved somewhat farther forward and more to the side than in examination in the inverted image. We then begin to throw light into the eye from a distance of about twenty centimetres and then approach, looking constantly through the opening in the mirror and noting that the pupil remains red; this is done by suitable slight rotations of the mirror.

Examination in the direct image, is especially facilitated by examining the patient's right eye with our right eye, his left eye with our left. If the right eye is used to examine the left, the nose is often in the way on close approximation.

The optic papilla is found according to the above-mentioned rules. On account of the greater enlargement in examination in the direct image, the entire papilla cannot always be seen at once when the pupil is small.

While the emmetrope begins ophthalmoscopic examination in the direct image without corrective glasses (behind the mirror), the myope and hyperope must correct their ametropia fully by the proper lenses. The observer will thus be able to see distinctly the fundus of an emmetropic patient, because parallel rays come from it and are united into a distinct image upon the retina of the observer. But the beginner is often unable to achieve this because he accommodates involuntarily and is thus adjusted for divergent rays. In order to avoid this, the second eye should be kept open, with the tendency to stare or to diverge. Some fail to relax their accommodation and must then compensate the accommodative tension during examination by means of concave glasses (about 3.0 to 4.0).

If the patient is a myope, the observer requires concave glasses; if an hypertrope, convex glasses.

If our object is simply to see the fundus of a myope in the direct image, the concave glass used need not correspond to the

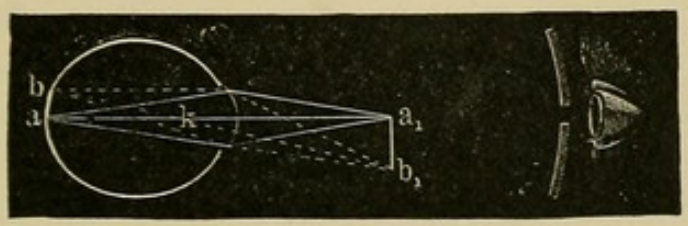


FIG. 89.

degree of myopia; it may be stronger, because the observer then compensates the excessive power of dispersion of the concave lens by his own accommodation. We can thus manage with comparatively few lenses. The highest grades of myopia cannot be examined in the direct image, because the rays coming from the fundus of such an individual unite immediately in front of the eye into an inverted image of the fundus. In myopia 20.0 D, for example, the far-point of the eye is situated at five centimetres. All rays reflected from the illuminated fundus (Fig. 89, *ab*) will unite there (a_1b_1); an image is thus formed in the air. If the myopia is greater, the image is situated still nearer. In ophthalmoscopic examination, however, we are unable to approach so closely to the eye. In these cases, therefore, we receive no direct rays of light from the fundus, but only from the inverted actual image in the air. In marked myopia this image can often be seen from a considerable distance, when the light is simply thrown into the eye with the mirror.

When the patient is an hypermetrope, the emmetropic observer, if he does not accommodate, must use corrective convex glasses

behind the mirror. He does not need them if he possesses sufficiently good accommodation. Since beginners accommodate, as a rule, it is particularly easy for them to see the fundus of pronounced hyperopes in the direct image (Fig. 90).

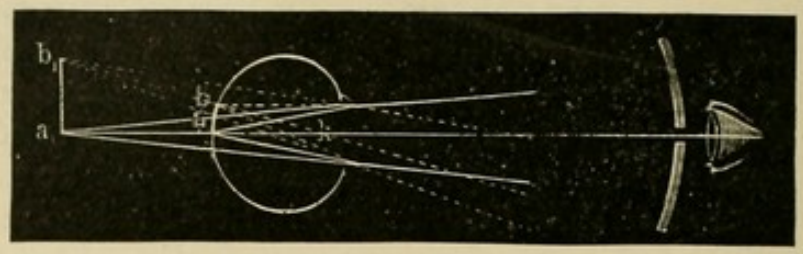


FIG. 90.

The manner in which these images of the fundus (the inverted image of high degree of myopia and the direct image of hyperopes), which can be recognized at a somewhat greater distance, may be distinguished from one another, will be described in the discussion on ophthalmoscopic measurement of refraction.

5. Focal Illumination (Lateral Illumination).

For focal illumination we use a strong convex lens which concentrates the light of the lamp upon the parts to be examined. This method was first used by Purkinje for physiological purposes, by Sanson and Himly for ophthalmological purposes. The strongest possible lenses ($+\frac{1}{1\frac{1}{2}}$ or $\frac{1}{2}$) are used. The patient is seated in a dark room next to a table. The lamp stands on his left side, but in front of his head so that the light falls in a straight line upon the parts to be examined through the convex lens which is held in front of the eye. It is often found that the lamp is placed entirely to the side (alongside or even behind the eye). The observer then tries in vain to throw the light sharply and directly through the convex lens upon the cornea or iris (see Figure 2).

But the light is not always thrown directly upon the tissues to be inspected. The changes are often recognized better if a circle of dispersion falls upon the spot, or if it lies in half shadow, *i.e.*, when the rays are thrown very obliquely on the eye. The method must be diligently practised in order to derive the greatest possible advantages in diagnosis. We use it in cases of opacities and changes in the cornea, anterior chamber, lens, and anterior parts of the vitreous body.

6. Measurement of Refraction with the Ophthalmoscope.

Helmholtz had pointed out that the ophthalmoscope may be used to recognize myopia and hypermetropia objectively. The advantages of such objective measurement of refraction are mani-

fold. They insure the physician against intentionally false statements such as are made by malingerers, and correct those which as the result of ignorance are imperfect and erroneous. There are also not a few cases in which it is desirable to ascertain the refraction in very young children who are unable to give reliable answers. Furthermore, we recognize with the ophthalmoscope latent hypermetropia, and the abnormal accommodative tension which are associated not infrequently with myopia, and which do not become manifest in examination with glasses and test-types. Mauthner in particular, has laid stress upon the fact that in ophthalmoscopic examination the examined eye relaxes its accommodation completely, and thus allows its true refraction to appear; nevertheless certain precautions are necessary. If these are adopted, it will rarely occur, as can be confirmed by any ophthalmologist, that the patient continues to accommodate. The patient must be enjoined, above all, to look far away, the proper direction being indicated to him, so that the papilla is brought opposite us. He is asked to stare as if in a dream, and not to fix any definite object. These injunctions must be repeated whenever a tendency to accommodation again shows itself; this is usually recognized by the contraction of the pupil. It is best to examine in a large room with a perfectly dark background, because here there is least occasion for fixation and accommodation. The instillation of atropine, duboisine or homatropine, for the exclusion of accommodation, is rarely necessary.

The direct as well as the inverted image may be used for accurate measurement of refraction.

A. Measurement of Refraction in the Direct Image.

If we bear in mind the above-described optical conditions which enable us to recognize, in detail, the fundus of the eye in the direct image, we will also find in them the means of measuring the accurate refraction of the examined eye. We will assume that the observer is emmetropic and his accommodation relaxed so completely that parallel rays which enter his eye, unite into a distinct image. The relaxation of accommodation may be effected by instillation of atropine or homatropine. But by practice, the majority of ophthalmoscopists, though by no means all, secure this relaxation of accommodation, at least to such an extent that no notable error results from it.

It is advisable to leave the other eye open (spasmodic closure usually causes a certain accommodative tension), especially with the endeavor to look to the outside. The attempted divergence

of the ocular axes facilitates the relaxation of accommodation. But if, despite this, complete relaxation cannot be secured, the adjustment for parallel rays can sometimes be secured by the use of the compensating concave lens. The observer is then to be regarded as a myope. In order to avoid error in the result of the examination, the corrective concave glass in the ophthalmoscopic measurement of refraction must be left out of the calculation.

If the observer is myopic or hypermetropic, he must correct his ametropia fully by the proper lenses; he will then, like the emmetrope, be adjusted for parallel rays, always assuming complete relaxation of accommodation.

As we may assume complete relaxation of accommodation in the patient B, it only remains for us to determine whether the parallel rays coming from his fundus oculi leave the eye in a convergent or divergent direction; and further to ascertain the point upon which they diverge or converge, and thus the far-point (or refraction) of B.

If the patient's eye is emmetropic and the retina illuminated by the light thrown in, the rays emanating from it will leave eye B

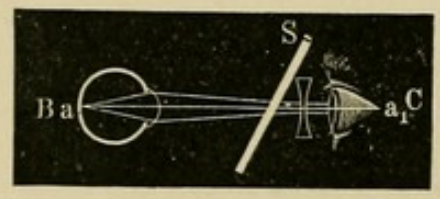


FIG. 91.



FIG. 92.

parallel and enter the examining eye C parallel, where they are united into a distinct image upon the retina (Fig. 91). Therefore, if the eye C of the observer, which is accommodated for parallel rays, receives a distinct image of the fundus oculi of B (without the addition of corrective glasses), then B is emmetropic.

The hypermetropic eye B is adjusted for convergent rays, which it unites upon its retina. Rays reflected from its fundus leave the eye in the same direction, *i.e.*, they enter divergent the opposite eye C (Fig. 92). As the latter is adjusted for parallel rays, the fundus oculi of the hypermetrope appears indistinct and blurred. The image becomes distinct and sharp when a convex lens, which makes the rays parallel, is placed behind the mirror. The refracting power of this lens then gives the basis for the degree of hyperopia of eye B. If the mirror and convex lens were situated immediately in front of the cornea of B, the lens would express directly the degree of hyperopia of B. In this event if the lens, for example, were convex $\frac{1}{20}$, the far-point of the hyperopic eye would be negative, and situated twenty inches behind the lens

and the cornea of the eye (H $\frac{1}{20}$). But if, when the fundus is seen distinctly, the same lens is situated two inches in front of the cornea, the eye is adjusted for rays which unite behind its cornea at a distance of twenty minus two inches, *i.e.*, its negative far-point is situated at eighteen inches; there is H $\frac{1}{18}$.

Inasmuch as the mirror and corrective lens are always at a certain distance from the examined eye, this distance must be measured and considered in the measurement of refraction by deducting it (in our illustration two inches) from the focal distance (in our illustration twenty inches) of the best correcting convex lens. The refracting power of the convex lens, found in this way, expresses the degrees of hypermetropia of B.

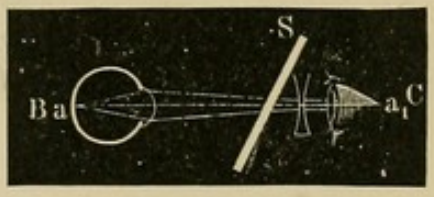


FIG. 93.

The myopic eye is adjusted for divergent rays. The observer must therefore place a concave lens behind the mirror in order to see the fundus oculi (Fig. 93). If this is properly selected, the rays will be made parallel and a distinct image formed. In order to determine the actual refraction of B, the distance of the mirror or the corrective concave glass of B situated behind it, must again be taken into consideration.

Concave $\frac{1}{20}$ placed immediately in front of an eye disperses parallel rays as if they came from a distance of twenty inches. If the eye united these rays upon its retina, its far-point would be situated at twenty inches (M $\frac{1}{20}$). But if the same lens is held two inches in front of another eye, which sees well with it for distance, then its far-point would be situated at $20 + 2 = 22$ inches (M $\frac{1}{22}$). In the myopic eye, therefore, the distance of the mirror from the examined eye must be added to the focal distance of the ophthalmoscopically best correcting concave lens. The refracting power of the concave lens obtained in this way (in our illustration $-\frac{1}{22}$) expresses the degree of myopia of B.

The part of the fundus examined in ophthalmoscopic measurement of refraction is not immaterial. It would be most accurate to select the macula lutea, because this is the part whose refraction is under consideration. The refraction is not uniform throughout. In the more equatorial regions we usually find feebler refraction (for example, emmetropic eyes are here hyperopic) and more marked (in part irregular) astigmatism.

But it is hardly possible to employ the macula for ophthalmoscopic measurement of refraction in the direct image, because it presents too few contrasts to enable us to perceive differences in the sharpness of the image. In ametropia the essential feature is

to find the corrective lens with which we see with maximum distinctness. We therefore select a retinal vessel, preferably one close to the optic papilla; the granulation of the pigment epithelium in the same locality may also be used.

Differences in the distinctness of definition, etc., of these objects can be recognized very well. Errors may sometimes be made, however, particularly in pronounced myopia, owing to the fact that the vicinity of the papilla and the vessels there, are more ectatic than the macula lutea. Considerable differences occur here; I have observed even as much as 5.0 D. They are also found in hyperopic eyes.

A refraction ophthalmoscope, which permits rapid change of the corrective lenses, is absolutely indispensable for accurate measurement of refraction in the direct image. It is only in this way that the best correcting lens can be found, because the differences in the distinctness of the image are slight with slightly differing lenses. The lens with which we see the retinal vessel most distinctly, corresponds to the refraction of the examined eye. If we see equally well with two concave lenses of different powers, it is evident that we have accommodated; the weaker of the lenses then corresponds to the refraction; in the case of convex lenses, the stronger. It must also be remembered, especially in the higher grades of ametropia, that the distance of the mirror from the examined eye must be taken into consideration; this is often neglected.

B. Measurement of Refraction in the Inverted Image.

The inverted image must be situated at a greater or less distance from the convex lens according to the condition of refraction of the examined eye (Fig. 94). If we use a convex lens of 10.0 D, the inverted image of the papilla of the emmetropic eye *e* will be situated ten centimetres from the lens, that of an hypermetropic eye *h* farther away, that of a myopic eye *m* nearer to the lens. In the same way that the rays coming from the retina unite here into a distinct image, so the rays emanating from this image (regarded as a shining object) will unite in a distinct image upon the retina, *i.e.*, the image and retina are conjugate foci. If the distance of the image of the papilla from the con-

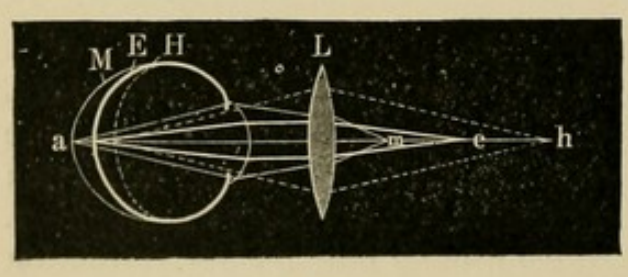


Fig. 94.

vex lens is known, we also know for what rays the examined eye is adjusted, in other words, we know its refraction. As shown above (vide Optometer), no special calculation is necessary according to the formula $\frac{f^2}{d}$ (d = difference between focus and position of image) when a convex lens 10.0 is used and held at a distance of ten centimetres from the examined eye. If the ophthalmoscopic image is ten centimetres from the lens, there is emmetropia; each centimetre nearer = 1.0 D myopia, each centimetre farther away 1.0 D hyperopia. For example, if the image is situated 6.5 cm. from the lens, there is M 3.5 (*i.e.*, 10 − 6.5); if the image is situated fifteen centimetres from the lens, there is H 5.0 (*i.e.*, 15 − 10).

The sole factor, therefore, is to ascertain the position of the image of the papilla. Snellen recommended the interposition of transparent glass between the ophthalmoscope and convex lens, and its movement to and fro until the distinct image of the papilla appears upon it. But the plan is hardly practicable in this form, because a glass which reflects well and upon which a distinct image of the papilla could be seen, would transmit too little light from the mirror, and perfectly transparent glass would reflect poorly. Warlomont and Loiseau have attempted to remove this difficulty by means of their ophthalmoscoptometer. This consists of a double tube which can be drawn out like a spy glass, containing at the end next to the examined eye a transparent glass plate (with concave parallel surfaces) which serves as a mirror and reflects the lamp light into the eye. Immediately behind it, is the suitable convex lens for throwing the inverted image. The inner movable tube contains a glass plate, which receives the image. The plate covers only the half of the calibre, permitting direct ophthalmoscopic examination through the other free half.

Another method of determining the position of the image, which is used by Mauthner and Burchardt, is based on the following considerations. If the observer is myopic (say M 5.0) or he makes himself artificially myopic by using a convex lens, he merely needs to move gradually away from the convex lens, in ophthalmoscopic examination in the inverted image, until he just sees the image of the papilla distinctly, in order to know that it is now situated at his far-point. If he knows the distance of his eye from the convex lens, he subtracts the distance of his own far-point, and obtains the position of the image of the papilla. For example, an emmetropic observer has made himself myopic by using convex 5.0 (position of the far-point = 20 cm.). When he is distant twenty-eight centimetres from the convex lens (10.0) he sees the image of the papilla distinctly. He now moves gradually away; at thirty

centimetres he still sees it distinctly, a little farther off it becomes indistinct. Hence it follows that at thirty centimetres the image was situated exactly at his far-point. The image is therefore situated 30 — 20 = 10 centimetres from the convex lens. The patient is therefore emmetropic, as stated above. In this examination my "refraction determiner" is used to advantage for holding the convex lens securely, and for making the necessary measurements.

But this method possesses the same drawback as measurement of refraction in the direct image; the observer must be able to relax his accommodation entirely and permanently, because he must accommodate for his far-point.

My method, on the other hand, dispenses entirely with a knowledge of the refraction or accommodation of the examining eye; it simply requires the ability to make the ophthalmoscopic examination in the inverted image. It can be carried out accurately by

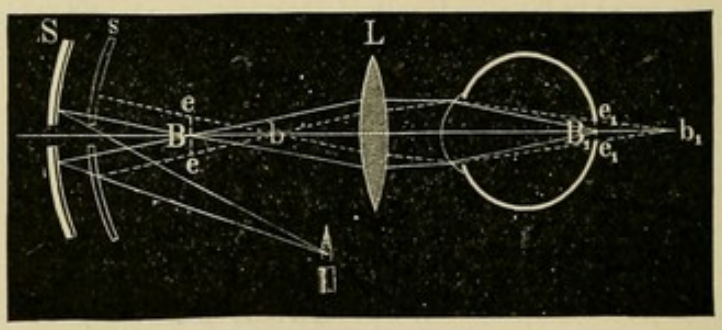


FIG. 95.

one who is unable to relax his accommodation. While the distance of the image of the papilla from the lens served as the standard in former methods, I employ the image of the flame, thrown by a concave mirror, which is formed upon the retina and being reflected thence, becomes visible in front of the convex lens.

If a concave mirror (for example, Liebreich's) of a moderate principal focal distance (say six inches) is used in examination in the inverted image, the inverted, smaller, actual image of the flame (B, Fig. 95), situated between the convex lens and mirror, forms the source of illumination of the fundus oculi. This small image can only form distinctly upon the patient's retina (B_1) when the latter is situated in the conjugate focus of the image, when, in other words, it is adjusted for the image of the flame. But then the rays reflected from the retinal image B_1 will again unite into an equally distinct image at B. This image is visible ophthalmoscopically. But if the small image thrown by the mirror is brought nearer by approximation of the mirror to the convex lens (toward *b*) or is carried farther away by removing the mirror from it, circles of

dispersion of the image (e_1e_1) will form upon the retina. The rays emanating from e_1e_1 will be reflected according to the refraction of the eye, and form an inverted image at ee. Like the retinal image, this ophthalmoscopically visible image is confused and not sharply defined. Hence, for each examined eye there is only one distance between the concave mirror and convex lens, in which an absolutely distinct image of the flame forms upon the retina and can be seen as such in the inverted image.

If we have ascertained, by moving the mirror to and fro, the distance between the mirror and convex lens at which the retinal image of the flame is seen most distinctly, we can easily calculate the distance at which the image B is situated from the convex lens and thus, from the formula f^2 we determine at once the condition of refraction of the examined eye. On measuring the distance between the

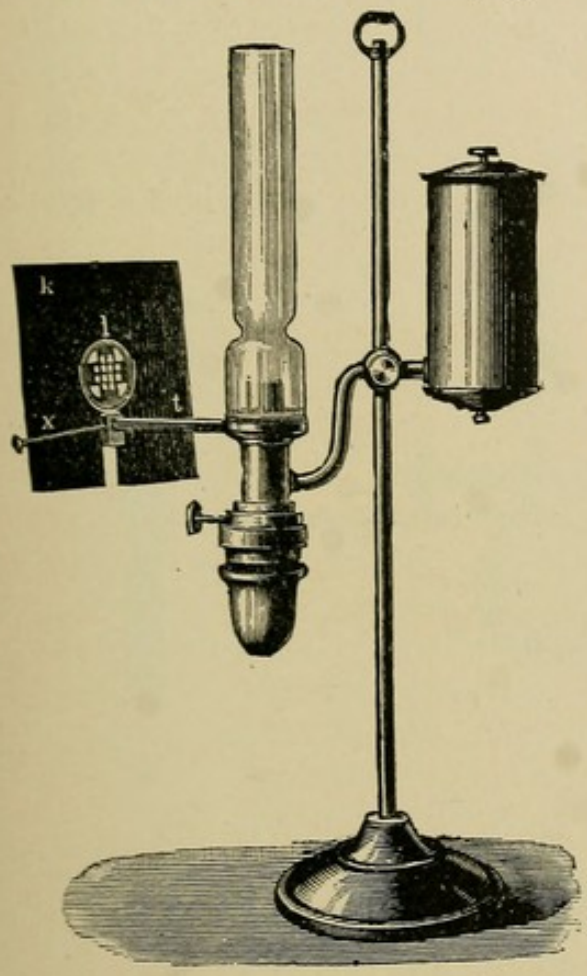


FIG. 96.

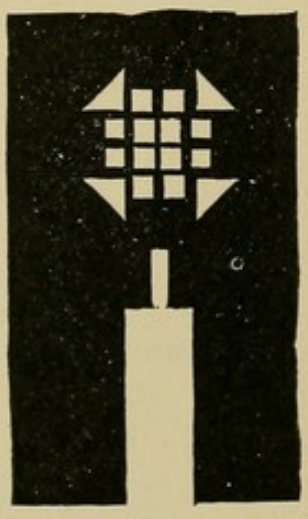


FIG. 97.

mirror and the convex lens (SL = E, Fig. 95) and subtract the focal distance of the mirror (SB = F), we obtain this distance (BL = E − F). It would be very convenient if we could always assume the principal focal distance of the concave mirror as known, if the rays from the source of illumination could be made parallel—perhaps by placing the light in the focus of a convex lens and using the rays which pass through the convex lens for illumination. But this is attended with considerable technical difficulties. It is simpler to measure directly the relative focus of the concave mirror (the focus which corresponds to the distance of the mirror

from the flame when the image on the retina is seen distinctly), the inverted image of the flame being thrown as sharply as possible, the distance being maintained, upon a black surface, and the distance in question then measured.

In order to be able to gauge very accurately the distinctness of the image of the source of light which forms upon the retina, we take as the source of illumination a bright figure divided by fine rods; the shadows of the rods then appear especially prominent and distinct upon the retina. For this purpose I have constructed the apparatus shown in Figs. 96 and 97. It consists of a flat rod *t*, nine centimetres in length (divided on one side according to inches, on the other according to metres), which is fastened by means of a spring clamp to the chimney of the lamp (flat or round burner) in such a way that the flame is at the level of the convex lens *l*, which

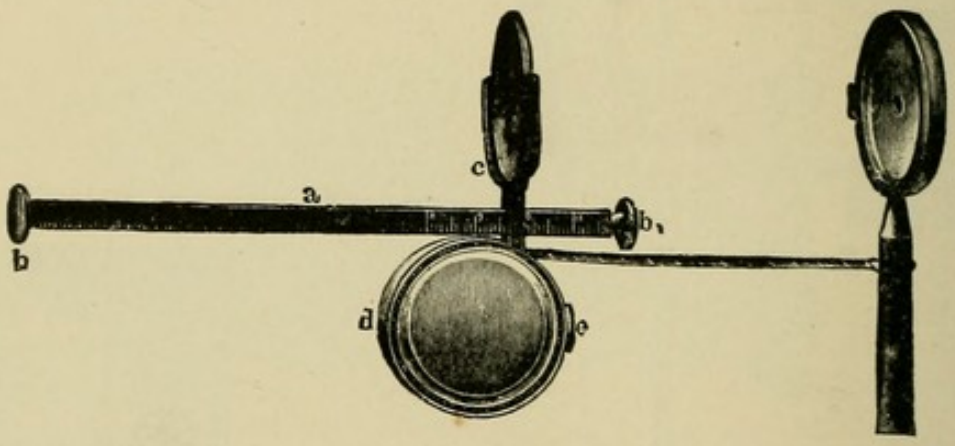


FIG. 98.

can be moved along the rod and can be fastened with the screw *x*. The lens should be at such a distance from the flame that the latter is situated at its focus; this distance is $\frac{1}{3}$ m., as I generally use convex 12.0. Immediately in front of the lens is a square black lead screen *k* (length of its sides eleven centimetres) which is carried by means of a small spring placed on the stand of the lens. In the middle of the screen are the openings which, illuminated by the lens, serve as the source of light for the mirror.

The instrument shown in Fig. 98 serves to secure a uniform distance of the convex lens 10.0 (which throws the inverted image) from the eye, and also to make the necessary measurements. The lens is placed in a frame *c* which is movable on the flat rod *c* (twelve centimetres long) and can be fastened with a screw. Below the rod, the frame carries a lentil-shaped case *d* which contains a rolled-up tape measure sixty centimetres long (divided into inches on one side, into centimetres to millimetres on the other side). The open-

ing through which the tape measure is drawn must be plumb below the lens. The small plate *b* is covered with leather and is placed against the rim of the superior maxilla below the eye which is to be examined. If the convex lens 10.0 is screwed fast at a distance of 9.5 to 10 cm. from this plate (the rod is also divided into centimetres) it will be situated quite accurately at ten centimetres from the main point of the eye, at all events slight differences are here unimportant. At the anterior extremity of the rod is a black, round leaden plate b_1, five millimetres in diameter, which is used for throwing the lattice image in measuring the relative focal distance of the mirror.

The tape measure in the case *d* is made taut by a spring, so that it can be withdrawn only when pressure is made on the button *e* and returns at once on discontinuing traction. If the pressure on the button is discontinued, the portion of the tape which has been withdrawn will remain outside. Particular care must be taken that the tape do not fly back after letting go the button.

The concave mirror must be well ground and throw distinct images. The best principal focal distance is about fifteen to seventeen centimetres.

In the examination, the handle of the mirror is placed in the small brass ring of the tape measure, which is fastened in such a way that the surface of the mirror is situated above the zero point of the measure. The apparatus is held in the left hand and pressed against the cheek of the patient, the thumb being pressed upon the button of the case containing the tape. This releases the tape, which follows the to-and-fro movements of the mirror.

The lamp, provided with the illuminating apparatus, stands to the left of the patient's head and as close as possible to him, so that the opening in the screen is at the level of the patient's and observer's eye. As great intensity of the light, which falls through the openings upon the mirror, facilitates the plan, we should look through the opening in the mirror upon the shining square, after applying the apparatus, and, if necessary, turn the lamp so that the rays fall directly on the mirror. The light is then thrown into the patient's eye, the mirror being carried to and fro until the small square with its lines of separation, which appear as dark shadows, are seen clearly and sharply on the fundus oculi. If we note the thinnest lines of shadow in the middle of the figure, it is not difficult to find the distance of the mirror at which the distinctness is greatest. A mathematically accurate lattice work, in the screen situated in front of the lamp, is unnecessary, because it serves as the source of illumination only in the shape of a much smaller, inverted image, thrown by the concave mirror. But if, in

any case, we are doubtful when the image presents its maximum distinctness, we can help ourselves by removing the lamp farther from the mirror. The image then becomes still smaller, and the appearance of differences in distinctness becomes more clear. If there is astigmatism, a uniform appearance of the entire figure is naturally impossible because a sharp image of the horizontal and vertical lines cannot be thrown upon the retina at the same distance of the mirror. Nor should we be led astray by the small square images which are occasionally reflected by the lens. These lack the red color of the image thrown on the retina, nor do they present retinal details, etc. It is advisable to throw the square of light immediately alongside the optic papilla, as that part of the fundus which is to be used for the measurement of refraction. As in measurement of refraction in the direct image, the patient is directed to look into distance as far as possible in order to relax accommodation. Care must be taken that the light squares are really situated alongside the papilla, because the refraction of the eye is different in remote parts. Upon the papilla itself the light square does not appear uniformly distinct, on account of the unevenness of the tissues.

The light squares may also be thrown upon the macula lutea. When they appear distinctly the mirror may be removed somewhat in order that the patient's accommodation may be relaxed by the associated removal of the image of the flame, and an adjustment upon his far-point effected. But this does not always secure complete relaxation of accommodation. If the patient looks at the convex lens held in front of him, he will naturally see the light squares distinctly at the same moment and at the same distance of the mirror from the convex lens, as those at which the observer sees them distinctly. If we wish to be sure of measuring accurately the refraction at the macula lutea, the patient's accommodation must first be paralyzed with atropine.

When the greatest possible distinctness of the image has been attained, the thumb is removed from the button and the distance E between the mirror and convex lens is read off upon the tape measure, the apparatus being removed from the patient's cheek. At the same time the head must be kept perfectly still, because it remains for us to determine the relative focal distance of the mirror F at this distance of the head or mirror from the source of light.[1] For this purpose the small light square is thrown by means of the mirror upon the black plate b_1, the thumb pressing upon the button in order to set the tape in motion. When the square is

[1] This measurement is necessary in every case, because the rays which emanate from the light squares are not parallel, a deflection taking place at their edges.

sharply defined the button is released and the distance between the mirror and the plate *ab* is read off. E − F gives the distance of the image from the convex lens and thus the refraction because each centimetre more or less than 10 cm. = 1.0 H or M. If, instead of the lens + 10.0. convex $\frac{1}{4}$ has been used, each inch more or less than four inches corresponds to an ametropia $\frac{1}{16}$.

In measuring E it is to be noted that the opening of the leaden case containing the tape measure is situated somewhat in front of the lens; if the number of centimetres is read off there, the small difference in the distance must be added to it;[1] this is also done if the tape measure flies back somewhat on releasing the button, instead of being arrested at once. The concave mirror must also have an exact curvature, because otherwise it will not throw a sharp image. Furthermore, the principal focal distance of the convex lens must be accurately determined in advance.

If the patient is very myopic, the mirror must be brought so close to the convex lens that the distance from it (E) is smaller than the distance of the relative focal length (F) which is determined later. For example, we find E = 18 cm. and F = 21 cm. E − F then = − 3 cm. The image is therefore situated behind the convex lens toward the examined eye. Its myopia amounts to 13.0 D because the difference in the distance of the image and the principal focal length of the lens (ten centimetres) is thirteen centimetres.

This method of measuring refraction is easily learned by any one who can examine in the inverted image, and who has a sufficient range of accommodation (in measuring extreme H and M with the aid of a concave mirror of fifteen centimetres principal focal length, the position of the images, upon which we must accommodate, varies between eighteen and forty centimetres). While there will be no notable variations in determining the sharpness of the inverted image, there is a certain source of error in the measurements, which are not always absolutely accurate. Nevertheless, comparative observations have taught me, that the measurement of refraction in the inverted image is not less accurate than that in the direct image. On the average, we may reckon upon occasional errors as high as 1.0 in both methods. This does not imply that the errors are not less in the majority of cases. But I believe that the statement that refraction can be measured ophthalmoscopically in every case without a greater error than 0.5 D, depends rather upon subjective impressions than upon assured trials.

[1] In the new apparatus the lens is situated almost at the end of the rod above *b*, and directly above the opening of the tape case. Any necessary elongation of the rod is effected by unscrewing the plate *b*.

The measurement of refraction in the inverted image presents the following advantages over that in the direct image. 1. The observer requires no relaxation of accommodation, which is absolutely impossible for some ophthalmoscopists. As Klein has correctly said, unconscious accommodative tension also occurs in expert observers, after they have made successive examinations for a long time. This accommodation becomes a source of error. 2. In the direct image, it is much more difficult to determine the maximum sharpness of the observed retinal vessel or pigment granulation, than that of the lattice work in the inverted image. 3. In the inverted image the refraction of the eye may be measured at the macula lutea, but this is not true of the direct image. 4. In the inverted image the higher and highest grades of myopia can be easily measured; this is difficult or impossible in the direct image. The measurement, when the pupil is narrow, and that of astigmatism is also done better. 5. Slight twitchings of the eye, which occur not infrequently in the patient, interfere with the direct image on account of the great enlargement. In the inverted image the refraction may be measured even in nystagmus. 6. We do not require the close approximation to the patient's head which occasionally makes examination in the direct image impossible, as, for example, in cases of severe ozæna.

On the other hand, in opacities of the cornea or of the other refracting media, the measurement of refraction in the inverted image is not effected as well as in the direct image. This is explained by the fact that, in the former, the opacities have a double action in disturbing the distinctness of the image. In the first place they interfere with the formation of a sharp image on the retina and then again they refract irregularly the rays emanating from the retinal image. Nor do the shadows of the flame image always appear absolutely distinct in marked irregularity of the choroidal pigmentation, but the expert can determine the correct refraction by the relative distinctness.

C. Keratoscopy.

Keratoscopy (the terms retinoscopy and skiascopy, now used more commonly, are more correct) is a method for measuring refraction described by Cuignet, who was unable to discover its optical principles. This was done later by Parent.

The patient is seated opposite the observer at a distance of about one metre; the lamp is situated alongside his head. The light is thrown into the pupil with a mirror; when the pupil shines red, slight movements are made with the mirror upon its vertical

axis, to the right and left as if we desired to illuminate only the right or left half of the pupil. We then notice the appearance of a darker shadow, which shows itself either on the side of the pupil toward which the mirror is directed or on the opposite side. The condition of refraction of the eye may be diagnosticated from this variation in the appearance of the shadow in the pupil.

This is explained in the following way. Let us assume that a concave mirror is used. The actual image of the flame thrown by it serves for the illumination of the eye. On holding the mirror straight, the image of the flame is situated in front of the middle of the pupil; if it is turned to the left, the image also turns to the left. If the examined eye is myopic, all the rays which are reflected from its fundus are collected at the far-point; and an inverted image forms there in the air. This image is seen by the ophthalmoscopist, who is seated one hundred centimetres from the examined eye —assuming that the myopia is less than 1.0. Its details are not recognized; only diffuse, reddish rays of light are perceived. He attributes these to the pupil of the examined eye, which appears to shine red throughout when the mirror is held straight. If the mirror is now turned to the left, only that portion of the image which is situated to the left will be illuminated. The left side of the pupil (as seen by him) now appears more brightly illuminated than the right, over which a slight shadow passes.

The conditions are different in examination of an emmetropic or hypermetropic eye. Here the pupil is illuminated by the direct image of the fundus oculi, as if it were situated behind the eye. If the mirror is turned to the left, the rays emanating from the image of the flame (which is now situated to the left) pass through the nodal point of the examined eye to the right side of the fundus (as seen by the observer) and illuminate this side of the direct image. Hence the right half of the pupil appears to shine, while the left half is in shadow.

In a myopic eye, the inverted image in the air coincides exactly or approximately with the flame image of the concave mirror which serves for illumination (at a distance of the observer of one metre and a relative focal length of the mirror of about twenty centimetres, this will happen only in the slighter grades of myopia) or if the retina is situated at least approximately in the conjugate focus of the flame image, as occurs in E and slight H, the illumination appears especially bright, the shadow sharp and more rectilinear, its excursions or movements more rapid. Slighter grades of ametropia can thus be distinguished from higher grades.

If a plane mirror is used instead of a concave one, the shadows formed on movement of the mirror appear on the opposite side,

because the flame image which serves for illumination is situated as if behind the mirror and therefore makes a movement in a direction opposite to the rotation. If the plane mirror is turned to the right side, the shadow moves to the left, and vice versa.

More accurate measurement of the degree of refraction can be made by continuing to place corrective spectacle glasses in front of the patient's eye, until there is a change in the appearance of the shadow on movement of the mirror. For example, if a concave mirror is used and the shadow appears on the side from which the mirror is turned, we have to deal with myopia. Concave lenses of increasing strength are now placed before the examined eye, the shadow appears on the opposite side on rotating the mirror. The concave lens in question corresponds to the degree of myopia. But it is difficult to determine positively the corrective lens with which this reversal of the shadow takes place, especially as the flame image, which serves for illumination, shows irregular bright and darker places. Exact measurements can only be made when the pupils are wide or dilated artificially. Moreover, the changing and application of the spectacle glasses is tedious. This inconvenience may be diminished by having a series of glasses in a ruler-like frame, which the patient passes in front of his eye. On the other hand, the recognition of the shadows as such requires no special skill in ophthalmoscopy.

Another mode of determining whether we have to deal with a very myopic or hypermetropic eye, has been referred to above. If light is simply thrown into such an eye, we see the details of the fundus, retinal vessels, etc., at a certain distance. In the myopic eye this is an inverted image in the air at the far-point of the eye, in the hyperopic eye a direct image.

These images are distinguished by the following characteristics:—1. If we gradually approach the eye, the inverted image of the myopic eye first becomes confused and finally is no longer visible, because the observer can no longer accommodate upon it and approaches so near to the eye that he receives only convergent rays. On the other hand, the direct image, situated behind the hyperopic eye, remains visible even at the closest approximation. 2. If the observer, while looking at the image, moves his head alternately to the right and left, he notices, when the eye is myopic, an apparently opposite movement of the image; when the eye is hyperopic, an apparent movement in the same direction. This depends upon the same optical delusion as that to which we are exposed in riding on a railway. The nearer objects appear to move in the opposite direction, the more remote ones in the same direction. In the ophthalmoscopic examination the image is compared with the eye

or the pupil. The inverted image is situated in front of the eye, *i.e.*, nearer to us than the pupil, the direct image behind the eye. Hence the direct image apparently moves with us, the inverted image in the opposite direction. 3. The comparison of the anatomical conditions, for example, the course of the vessels in the retina or the position of the macula lutea to the optic papilla, could also be relied upon in order to distinguish the direct from the inverted image. As a rule, however, this cannot be done, because the ophthalmoscopic field of vision, at this distance, is too small to permit us to overlook large parts.

The distance of the inverted image in a very myopic eye, and therefore the far-point, can be determined approximately, if we approach with the mirror to the examined eye B to the point at which we can just see the image with the greatest strain of accommodation.

The image is then situated at the near-point of the observer. If this distance is known (for example, fifteen centimetres) we merely need to subtract it from the distance at which the mirror is situated from eye B at the time (for example, twenty centimetres) in order to obtain the far-point of eye B (here 5 cm., *i.e.*, M 20.0).

Measurement of Astigmatism.

In irregular astigmatism the retinal image is confused and blurred, occasionally we notice a peculiar glimmering of the fixed point, for example, the papilla.

In the measurement of regular astigmatism, we possess a starting point in the unequal enlargement produced by the greater refraction of the optic media in one meridian than in the other. The round papilla becomes oval (Knapp). But as it is possible that the papilla should be anatomically oval in exceptional cases, Schweigger has recommended that its shape be determined in the direct as well as the inverted image. If the change of shape depends upon astigmatism, the anatomically round papilla will appear oval in both examinations, but with a differently directed long axis. For example, if the vertical meridian of the eye is myopic and the horizontal one hypermetropic, the enlargement in the direct image, in which the fundus is seen as through a magnifying glass, is greatest in that meridian in which the refraction is stronger, *i.e.*, in the vertical meridian. The papilla appears as an oval placed vertically. In the inverted image, on the other hand, the enlargement is less in myopia than in emmetropia. The papilla is, therefore, enlarged more in a horizontal direction and forms a transverse oval.

The degree of As is easily measured in this way. We require

further examinations, the refraction being determined in the direct image upon two retinal vessels which run in opposite directions along the principal meridians (here the vertical and horizontal). This method remains defective because such vessels are not always easily found, and the direction of the principal meridians cannot always be noted with absolute correctness.

It is proper to measure the refraction in the inverted image with the concave mirror. In irregular As, a sharp image of the lattice work is not seen at any distance of the mirror from the convex lens. In regular As, we notice, for example, that the horizontal shadow lines appear distinctly, at another distance the vertical lines.

The refraction for both lines is then measured and we then know the refraction of the corresponding meridians, *i.e.*, the refraction when the horizontal lines appear distinctly belongs to the vertical meridian of the eye, and vice versa. If we wish to make measurements in other meridians, we may use a stellate figure as the source of light in the screen. But the figure described above also suffices because the edges of the triangles run obliquely at the sides and thus fall in different meridians.

In Cuignet's method, we recognize astigmatism from the fact that the boundary of the shadow is not perpendicular to the rotation of the mirror. To determine the As, we must, as a matter of course, make the rotation in different directions (for example, from within and above outward and downward, etc.).

7. Diagnosis of Differences of Level in the Ophthalmoscopic Image of the Fundus Oculi.

Since, as a rule, we can see the ophthalmoscopic image with only one eye, exact stereoscopic vision is lacking, and it is difficult to perceive slight differences of level (for example, whether the optic papilla lies deeper than the retina or whether it projects above it). We must here resort to special aids. Especially to be recommended is the employment of parallactic displacement, which occurs at the points of the ophthalmoscopic image situated at different levels, on moving the convex lens to and fro (in a horizontal or vertical direction) during examination in the inverted image. The parts which are situated more anteriorly (for example, part of a vessel situated on the retina) move like a veil above and in front of the deeper parts (for example, the prolongation of the same vessel on the pathologically excavated papilla).

This is explained by the accompanying figure (Fig. 99). *c* is the optical centre of the convex lens used in the ophthalmoscopic

examination, *a* and *b* are two points in the papilla situated one behind the other. The inverted images of these points are supposed to be formed at α and β. The line $\beta\alpha$ is situated in the visual line of the observer. If the lens is now moved downward so that the optical centre falls to c_1, the inverted images of *a* and *b* move to α_1 and β_1. If the observer maintains the same visual line unchanged, the point β seems to have made a greater excursion (with the lens) than the point α; the point situated more anteriorly has moved over the more posterior point. In the ophthalmoscopic examination it is well to move the convex lens somewhat rapidly to and fro, noting those points which are situated exactly at the boundary of the difference in level.

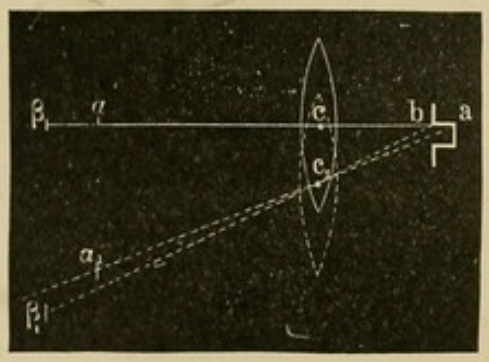


FIG. 99.

Greater differences of level may also be determined by the measurement of refraction (whether in the direct or the inverted image). The rays from the farther part of the fundus will leave the eye more convergent than those from the nearer parts. If, for example, emmetropia is noted at the latter, then myopia is present at the former. [By this measurement of refraction the difference of level may be calculated directly, taking as a basis the values of the schematic eye, according to the formule $f'' = \frac{f' \cdot F''}{f' - F'}$ (Helmholtz). Here f'' = the length of the axis of the eye, f' = the distance of the far-point R from the cornea (in hyperopia, as a matter of course, with the minus sign), $F' = 15$ mm., $F'' = 20$ mm. If, for example, myopia 10.0 (far-point 10 cm. = 100 mm.) is found at an excavated optic papilla, then the formula would read $f'' = \frac{100 \cdot 20}{100 - 15}$ 23.5 mm If in emmetropic refraction ($f'' = \frac{\infty \cdot 20}{\infty - 15} = 20$ mm.) the retina has an axial length = 20 mm., the optic papilla is 3.5 mm. deeper in the above case. One dioptry myopia is equivalent approximately to 0.3 mm. elongation of the axis.]

Examination in the inverted image with Giraud-Teulon's binocular ophthalmoscope is also very useful for detecting differences of level.

CHAPTER II.

OPHTHALMOSCOPIC APPEARANCES IN THE HEALTHY EYE.

Anatomy of the Optic Nerve, Retina, Tunica Uvea.

In the course of the optic nerve three divisions may be distinguished: the first extends from the origin in the brain to the chiasm (optic tract), the second from the chiasm to the optic foramen, the third includes the orbital portion.

The nerve leaves the brain with two roots which arise from the corpus geniculatum mediale and laterale. While some of the nerve fibres arise directly from the latter, others can be traced to the optic thalamus and anterior corpora quadrigemina. Both flat roots, at first divided by a narrow groove, soon unite into a flat band. This curves around the cerebral peduncle, passes beneath the anterior perforated space to the tuber cinereum, and unites, immediately in front of the infundibulum, with the tract of the other side to form the chiasm.

A number of investigations have been made with regard to the connections of the optic nerve with individual parts of the central organ. Stilling traced a superficial branch which passes directly from the thalamus to the corpora quadrigemina; another passes from the tract to the cerebral peduncle. Other bundles pass from the tract along the inner surface of the corp. genic. med. into the so-called fillet and thence to the inferior olivary body, still others pass to the nucleus of the motor oculi nerve, and finally to the crus cerebelli. Gratiolet and Meynert demonstrated numerous bundles passing from the optic thalamus into the white substance of the occipital lobes. These conditions furnish an anatomical basis for the hemianopsias in affections of certain parts of the occipital lobe (Munk) and for the combination of disease of the optic nerve and spinal cord, which is so often observed clinically.

In the chiasm the nerve fibres undergo semi-decussation. The lateral bundles of the tract, remaining on the same side, pass to the optic nerve of the same side, while the median bundles decussate and pass to the median side of the opposite optic nerve. But

the expression semi-decussation must be taken *cum grano salis*, because the number of fibres which decussate is much larger than that of those which do not. The decussated fibres supply the inner half of the retina—counting from the point of fixation—the non-decussated fibres supply the other half.

The semi-decussation has been attacked particularly by Biesiadecki and Michel. But if we take into consideration the detailed anatomical and experimental investigation of Gudden, certain anatomo-pathological appearances in which unilateral optic atrophy extended to both tracts, and especially the clinical observations —then the occurrence of semi-decussation in the chiasm must be regarded as assured, at least in the human subject. This also appears to hold good with regard to the monkey and dog, as shown by the interesting investigations of Munk on the visual centre in the cortex of the occipital lobes. Charcot's opinions are not well founded. According to this writer, each eye possesses a visual centre on the opposite half of the brain; the fibres of the corresponding optic nerve, which decussate in the chiasm, pass directly to this centre, while the non-decussating bundles leave the tract later at some part of the median line, beyond the geniculate bodies, and pass to the same visual centre.

While the tracts are united somewhat firmly to the brain substance, the optic nerves run perfectly free to the optic foramen, with whose periosteum they are firmly united at the upper wall. In the orbits their shape is almost circular and they pass in an S-shaped curve laterally to the globe which is twenty-six millimetres distant. They enter a little below the posterior extremity to the ocular axis. The orbital portion of the opitc nerve is twenty-eight to twenty-nine millimetres long, but there are considerable variations in the length of the nerve and in the distance between the optic foramen and the entrance into the globe. In the orbit the nerve is surrounded by an external and internal sheath. The latter is firmly adherent to the nerve, into which it sends connective-tissue septa; it is regarded as the continuation of the pia mater. In adults the nerve fibres immediately adjacent to it become atrophic (Fuchs). The external sheath presents an outer, thicker layer (dural sheath) and a thinner, delicate membrane (arachnoidal sheath of Axel Key and Retzius), which consists of fine bundles of connective tissue, twisted into a network. Fine strands connect these two parts of the outer sheath with one another. The narrow space between them, which is only recognizable with the microscope, is called the subdural space, while the larger, macroscopically visible, space between the arachnoidal and pial sheaths, which is also traversed by transverse bands, is termed

the subarachnoid space. But as these two spaces, which are to be regarded as lymph spaces (Schwalbe), communicate with one another, it is more common to speak simply of a subvaginal space which surrounds the optic nerve. Both sheaths end in the sclera. The central artery and vein of the retina enter the temporal lower quadrant of the optic nerve, before the latter passes into the globe, the former occasionally somewhat earlier; on the average at a distance of ten to twenty millimetres from the eye. Soon after its entrance the artery not infrequently gives off a tolerably large lateral branch, which terminates before it reaches the globe, while the main trunk with its branches passes into the papilla and retina. The latter obtain their blood supply in the main from this vessel. Only a few, usually very small arterial branches to the papilla and the adjacent retinal (cilio-retinal) vessels are derived from Zinn's (Haller's) vascular ring. The latter is derived from the posterior ciliary vessels and is situated in the scleral ring surrounding the optic nerve. This vascular supply plays a part in embolism of the central artery of the retina.

On its passage through the scleral and choroidal opening the optic nerve experiences a constriction, its diameter falling from about 3 mm. to 1.5 mm. It also loses its white color, the nerve fibres becoming deprived of the medullary sheath. Hence it has a gray and more transparent appearance. This locality is important in other respects. A connective-tissue network, in several layers, passes transversely through the optic nerve, starting from the sclera (the so-called lamina cribrosa). The portion of the optic nerve between the lamina cribrosa and vitreous body, is usually known as the optic papilla. But this is not a true papilla or projection. A great part lies even below the level of the retina, inasmuch as the nerve fibres do not pass into the retina in equal numbers and density at all places. The larger number of fibres pass to the nasal side, the smaller number toward the region of the macula lutea. This is often shown by more or less extensive depression on the macular side, known, when of normal size, as physiological excavation. The point of entrance of the vessels into the middle of the papilla, also presents a small funnel-shaped excavation (fovea). As a rule, the transverse diameter of the usually round papilla is 1.5 mm.

A few words with regard to the position of the fibres of the optic nerve which supply the individual parts of the retina. It is of special interest to know the situation of those fibres which supply the macula lutea. Anatomo-pathological appearances in cases which appeared clinically as central scotoma in consequence of retrobulbar neuritis, showed central atrophy of the optic nerve in

the neighborhood of the optic nerve; toward the bulb the atrophic portion turned to the temporal side (Samelsohn). Apart from this course of the macular fibres, the optic fibres situated at the periphery in the vicinity of the globe appear to be destined for the portions of the retina next to the entrance of the nerve, while the periphery of the retina is supplied by the fibres in the middle of the nerve (Bunge).

The retina shows the following layers from within outward on transverse section (Fig. 100): 1, Membrane limitans interna (hyaloid membrane); 2, Nerve-fibre layer; 3, Ganglion-cell layer; 4, Internal molecular layer; 5, Internal granular layer; 6, External molecular layer; 7, External granular layer; 8, Membrana limitans externa; 9, Layer of rods and cones; 10, Pigment epithelium. The pigment epithelium belongs embryologically to the retina because it develops from the external layer of the secondary ocular vesicle.

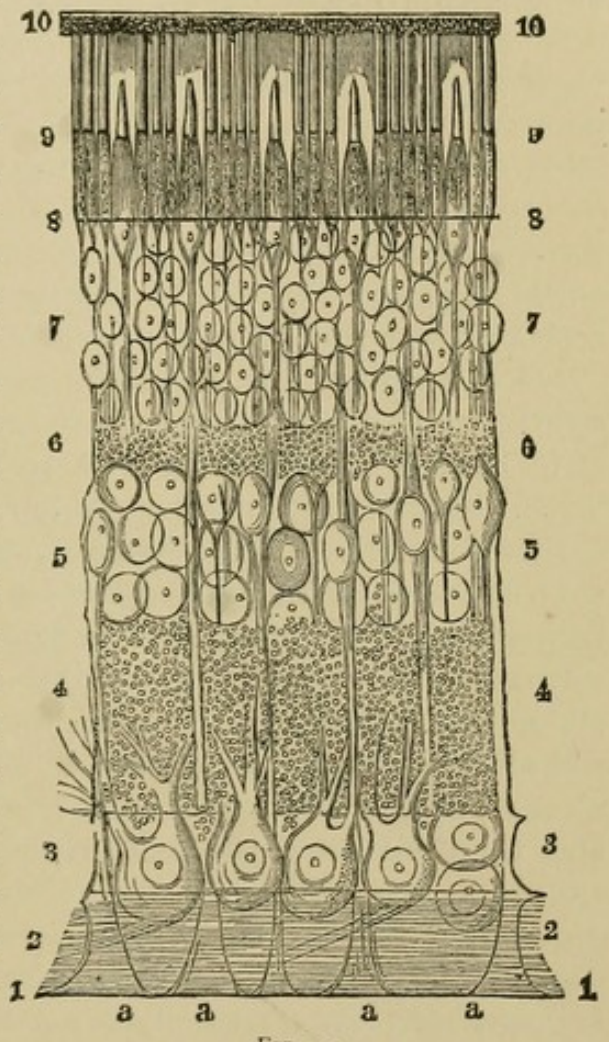


FIG. 100.

Anatomically it is described as the inner layer of the choroid, as it adheres in great part to the choroid on detachment of the retina. Fine connective-tissue fibres (Mueller's supporting or radical fibres) pass transversely through the different layers and terminate in a brush-shaped expansion *a* at the membrana limitans interna.

At the macula lutea, the retinal layers are thinned into the fovea centralis; here the rods are absent and only narrow cones are found. In the macula, the Mueller supporting fibres do not present their brush-shaped expansion toward the limitans interna.

The posterior portions of the retina are situated on the choroid, but are not united to it. Anteriorly, at the beginning of the orbiculus ciliaris, it is united more firmly in a zigzag circular line (ora serrata). From here only the connective-tissue elements pass anteriorly and traverse the inner surface of the orbiculus and corpus

ciliare, as the pars ciliaris retinæ. At an advanced age, cavities with fluid form not infrequently between Mueller's supporting fibres in the vicinity of the ora serrata (Iwanoff). At the periphery there is often hypertrophy of the connective-tissue elements and atrophy of the nervous elements (Kuhnt).

The outer layer of the retina contains, as Boll has shown, a coloring matter (visual red or visual purple) which gives its posterior surface a red appearance, but becomes pale a few minutes after removal on account of the action of the light. With a suitable covering bright figures (optograms, Kuehne) can be produced upon the retina as upon a photographic plate. The coloring matter is situated in the rods and is probably generated anew by the pigment epithelium. A further influence of light on the retina has been observed recently in the frog; the outer and inner segments of the rods shorten in the light and elongate in the dark (Angelucci, Gradenigo); this is also true of the inner segments of the cones (Engelmann). At the same time the outer granules of the retina change their shape.

If a perfectly fresh eyeball, which has just been removed by operation, is divided equatorially and the posterior half is looked at in situ, it is difficult at first to see the position of the macula lutea. But we soon find a darker, brownish-red spot which indicates its situation. This patch is about as large as the papilla, but soon becomes smaller (from the occurrence of slight opacity of the retina) and is confined to the central portion of the macula. If the retina is now removed from the choroid, and is spread upon a slide, the macula shows a slightly yellow color; the latter is not always sharply circumscribed because it gradually fades away at the edges. The yellow color is usually somewhat more extensive than the brownish patch which was seen in situ. In the centre of the yellow spot of the retina we notice a somewhat darker pigmented ring or half-ring, surrounding a small, lighter, funnel-shaped excavation (fovea centralis). The fresh retina is perfectly transparent. Hence the light yellow color of the macula does not appear upon a dark back-ground, but simply gives the latter a darker color and duller appearance (like certain varnishes or a solution of gum). This explains the darker color of the macula when it remains in situ on the choroid. By displacing the retina on the choroid, however, I could produce movement of the dark patch corresponding to the displacement of the macula. Increased pigmentation of the choroid beneath the macula, is not always demonstrable, nor, as this experiment shows, is it necessary to the production of the darker color. The appearance of the macula lutea in the fresh eye also explains, in the main, its ophthalmo-

scopic image, in which it appears of a darker color than the adjoining retina. Prior to my investigations, the appearances had only been known in eyes which already showed signs of decomposition. Then the yellow, lemon-like color of the macula appears distinctly upon the cloudy and opaque retina, even if this is situated on the choroid. Hence the ophthalmoscopic image could not be explained until this fact was demonstrated.

The main branches of the retinal vessels are situated partly upon, partly within the nerve-fibre layer A few branches pass through the outer retinal layers to the inner side of the intergranular layer. Capillaries also extend into the periphery of the macula, as can be seen very well in enucleated eyes, in which there is still injection of blood.

The tunica uvea (t. vasculosa s. media) is composed of the choroid, corpus ciliare and the iris.

The choroid is applied closely to the sclera, but is only adherent firmly to it posteriorly at the entrance of the optic nerve and anteriorly at the sulcus scleræ. Around the optic nerve the choroid passes into a thin ring, consisting of concentric fibres, which surround the foramen opticum choroidæ, being applied more or less closely to the optic nerve. The choroid is divided histologically, from without inward, into four layers: 1, suprachoroidea, which has a brown appearance; on detaching it, a portion adheres to the sclera (lamina fusca). 2, Stroma choroideæ (tunica vasculosa). Here the larger vessels run their course and subdivide. In it are situated the venæ vorticosæ, of which there are usually four principal vessels, one pair for the upper and lower halves of the choroid (Fuchs). They appear, like all the large choroidal vessels, as light streaks, because the pigment, which usually is found in the stellate cells, is accumulated chiefly between them in the darker intervascular spaces. 3, The capillary layer (membrana Ruyschiana). It contains no pigment, but numerous capillaries. 4, Lamina vitrea (vitreous or basal membrane), which is smooth and transparent in the posterior parts of the eye, but presents microscopic elevations and depressions upon and near the corpus ciliare; in advanced years gland-like enlargements develop upon it. The pigment epithelium situated upon it, which consists of black six-angled cells, belongs genetically, as we have stated, to the retina. Shortly before the transition of the choroid into the corpus ciliare, the layers of the choroid lose their regular arrangement, and the chorio-capillaris disappears entirely. This locality is known as the orbiculus ciliaris.

In the orbiculus ciliaris the beginnings of the muscular layer of the corpus ciliare commence to spread between the suprachoroidea

and the stroma. They increase in thickness anteriorly and form the main part of the ciliary body. The ciliary muscle (Bruecke's muscle, innervated by the motor oculi) forms a sharp triangle on section, the apex being directed backward. The outer layers of the muscle, directly beneath the sclera, run a meridional course, the inner layers a circular course. Between them are found transitions, the bundles diverging internally and posteriorly. The muscle is firmly adherent by a connective-tissue band (tendon of the ciliary muscle) to the inner wall of Schlemm's canal. Projections alternating with depressions (ciliary prolongations) are found in the ciliary body, directed toward the interior of the eye and the lens. They are quite constantly seventy in number (Meckel).

The iris develops from the tissue of the ciliary processes. It is connected with the cornea by the meshed ligamentum pectinatum. The latter also separates the outer part of the ciliary body from the anterior chamber. The tissue proper of the iris lies between two limiting membranes. Toward the anterior chamber, a delicate endothelial lining is found; toward the lens a membrane composed of peculiar cellular elements, the posterior surface containing a pigment layer, which extends centrally to the pupil and, bending over here, often appears as a narrow black rim of the pupil. Behind the anterior endothelial lining, is a layer of anastomosing cells, interspersed with lymphoid cells (reticular layer of Michel); next comes the vascular layer. Behind the vessels are the muscular elements, the annular sphincter iridis which surrounds the pupil, and the radial dilator. The latter extends as a thin layer of radial cells from the margo ciliaris to the free pupillary margin (Meckel); but the muscular character of these cells has been recently called into question, particularly by Eversbusch. The sphincter is supplied by the motor oculi nerve, the dilator by branches of the sympathetic. In addition, branches of the trigeminus, from the ciliary nerves, are distributed here and in the uveal tract. The pupil is not situated exactly in the middle of the iris diaphragm, but somewhat to the nasal side. In the embryo, the pupillary membrane is situated in front of it and the iris; the latter develops in the form of a process behind this membrane. Finally the pupillary membrane is converted into the anterior endothelial membrane (Michel), and disappears in the pupil.

The pigment in the iris does not form until after birth. Hence the iris of the new-born appears blue from interference (cloudy medium in front of a dark background). According to the larger or smaller amount of pigment formed (partly in round and stellate cells) the iris becomes dark brown, or gray. Rusty brown and black patches of pigment are often see upon the anterior surface.

In cases of injury, we must be on our guard against regarding them as foreign bodies. In looking at the iris, we also notice that, starting from a circular elevation about one millimetre from the rim of the pupil, there are marked, tolerably radial ridges with intervening depressions (crypts) which occupy the central part of the iris. The beginning of this formation of folds corresponds to the circ. arterios. minor. The crypts are connected with fissure-shaped cavities around the vessels of the iris, and thus effect a communication between the lymph space of the iris and lig. pectinatum and the anterior chamber (Fuchs).

The iris separates the anterior and posterior chambers, and in its movements glides upon a layer of fluid on the capsule of the lens.

The posterior portion of the uveal tract (choroid) receives its arterial blood from the short posterior ciliary vessels; the anterior portion (ciliary body and iris) from the long posterior and the anterior ciliary arteries. In this part of the choroid are also found a number of recurrent branches, which effect a communication between the anterior and posterior tracts (Leber). The posterior ciliary arteries are derived from the ophthalmic artery and penetrate the sclera in the neighborhood of the optic nerve. The anterior vessels are derived from the arteries of the recti muscles and, after giving off fine superficial branches to the sclera, rim of the cornea and conjunctiva, penetrate the sclera not far from the edge of the cornea. They form a circular vascular ring at the anterior end of the ciliary muscle (circ. arterios. iridis major).

The venous blood of the uveal tract is removed mainly by the venæ vorticosæ which are surrounded by lymphatic sheaths; they perforate the sclera behind the equator in long oblique canals. They empty in part directly into the ophthalmic vein, in part into the muscular branches. The blood is removed from the ciliary body through the venæ ciliares anticæ, which run a similar course to the corresponding arteries, but are narrower. The anterior ciliary arteries and veins form a meshed network upon the sclera at the rim of the cornea; it is especially prominent in inflammations as a fringe, several millimetres in width, which surrounds the cornea (episcleral vascular network).

The circ. venosus ciliaris (Leber) or Schlemm's canal, which is imbedded in the anterior extremity of the sclera and runs in a circle around the corneal insertion, is a venous ring which communicates with the anterior ciliary veins and the episcleral vascular network.

If the escape of blood posteriorly through the venæ vorticosæ is prevented, as we often see in increased intraocular pressure, the

blood passes anteriorly through the anterior ciliary veins which become dilated and present large episcleral branches.

The nerves are derived as short ciliary nerves from the ciliary ganglion (trigeminus, motor oculi and sympathetic branches), in part as long ciliary nerves from the naso-ciliary branch of the ophthalmic nerve. They perforate the sclera near the optic nerve and run in the suprachoroid as far as the ciliary body. Here they form a plexus from which the nerves of the iris are derived.

1. Optic Papilla.

The entrance of the optic nerve into the eye (transverse section of the optic nerve) is distinguished ophthalmoscopically from the more intense red of the remainder of the fundus by its somewhat lighter color. Its color may be called rosy, while occasionally yellowish-red. Its shape is round and it is usually sharply defined. We notice occasionally more oval forms which do not always result from astigmatic refraction of the eye.

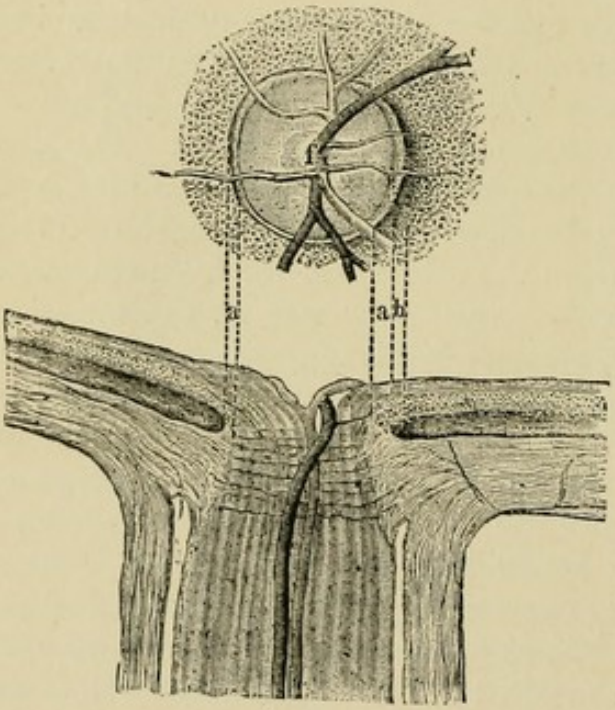


Fig. 101.

As a rule, the papilla is bounded by a fine white line (Fig. 101), but generally this does not surround the entire periphery. It is often somewhat broader toward the side of the macula and here forms a concentric figure. The formation of the boundary line (so-called connective-tissue or scleral ring) is owing to the fact that the choroid does not extend to the papilla everywhere, so that scleral tissue appears between it and the papilla. In other cases the white color is due to the fact that the boundary of the choroid which is next to the papilla contains only the vitreous membrane and connective-tissue elements without pigment and blood-vessels. Where the choroid proper begins, there is not infrequently a greater accumulation of darker pigment, forming a narrow black line *b* (choroidal ring), which is in opposition either with the papilla itself or with the white connective-tissue ring.

The color of the papilla is usually not uniform. The point of

exit of the vessels (fovea of the papilla) generally has more of a whitish color, and this occasionally extends further across the papilla, particularly in the direction toward the macula. This whitish, whitish-gray, or grayish-blue color is due to the fact that there are fewer nerve fibres and capillaries at the situation in question; the lamina cribrosa then shines through. Dark gray dots are seen occasionally on the white part, as the expression of the network of the lamina cribrosa and of the bundles of nerve fibres which pass through.

The central artery and vein of the retina usually divide in the papilla into two main branches, one passing upward, the other downward. If the division occurs before the vessels reach the surface of the papilla, only the main branches are seen ophthalmoscopically. Each branch subdivides, usually near the border of the papilla, into a nasal and temporal branch. Magnus calls these the superior and inferior nasal and the superior and inferior temporal arteries (or veins). While these branches supply the upper and lower parts of the retina, the median artery runs toward the nasal side in the horizontal meridian, and two very fine vessels, the superior and inferior macular arteries, run toward the macula. There are not infrequently deviations from this typical course, but the names mentioned usually afford sufficient basis for recognizing the parts (Fig. 102).

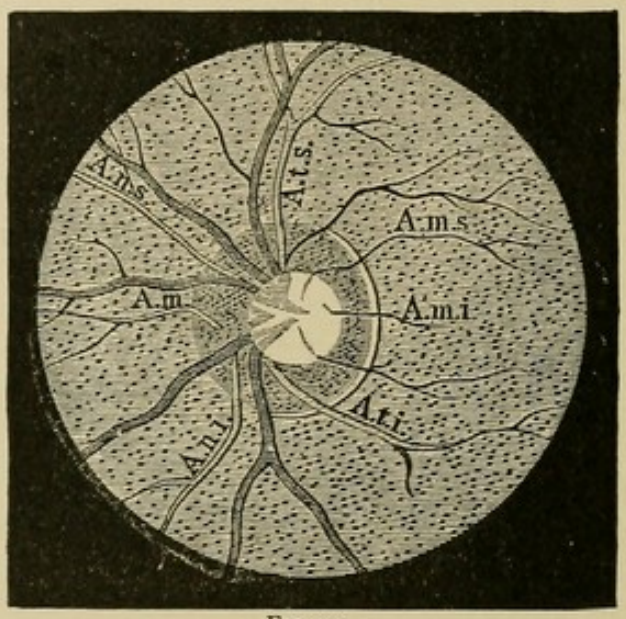


FIG. 102.

The vessels appear ophthalmoscopically as red strands. The arteries are narrower than the veins, run a straighter course, and have a somewhat lighter color. They also present a more marked central, bright light-reflex. The larger vascular trunks do not have a uniform red color, but present a light stripe in the middle, which is bounded on both sides by a red, darker line. This white stripe is not, as Helmholtz believed, the optical expression of the tissue of the vascular wall, but is a light-reflex. It depends upon the fact that the rays which pass vertically from the ophthalmoscopic mirror to the convex middle of the vessel, are reflected more perfectly into the eye of the observer than those which pass to the sides of the cylindrical vessel. Whether the wall of the vessel or

the column of blood reflects, is still a matter of dispute. According to Edward Jaeger, the blood reflects. The greater width of the central light-streak in the arteries is said to result from the lighter color of the arterial blood.

A sac-shaped, dark swelling, is sometimes noticed upon the veins of the papilla as far as the point at which they pass into the depth; here the vessel undergoes a kind of bend, which gives rise to a stasis of blood. Pulsation of the veins is sometimes seen upon the papilla and is manifested in the following manner. Shortly before the radial pulse, a main trunk (rarely several branches), particularly where it passes into the depth, becomes paler; the blood flowing back toward the periphery of the retina. After a little while—shortly after the radial pulse—the blood flows back from the periphery, the vein fills and becomes dark. This phenomenon resembles the drawing forward and backward of a dark piston rod in a glass cylinder. This pulsation, which occurs under physiological conditions, may be explained in the following way (Donders). With the systole of the heart the blood is thrown into the arteries in increased amount, more blood enters the eye, and the more distended arteries increase the intraocular pressure. An increased pressure is thus brought to bear upon the easily compressed retinal veins, particularly upon the main trunk which, being relatively nearest to the heart, has the least lateral pressure. In addition, the passage from the horizontal plane of the papilla into the perpendicular optic nerve often causes a sort of flexion which facilitates compression of this part. The result is a stasis of blood. In the mean time the cardiac systole has ceased, no more blood flows into the arteries, the intraocular pressure falls. At the same time the blood has passed through the capillary system into the veins, increases the lateral pressure in the veins, distends them, and again fills the compressed main trunk, through which it passes and is lost to sight. According to Coccius, the increased intraocular pressure first causes increased escape of blood and then a narrowing of the veins, while Helfreich attributes the pulsations to variations of pressure in the sinus cavernosus. Pulsation of the arteries occurs only in pathological cases.

Unusual enlargement of the previously described central white and deepened part of the papilla is occasionally observed. The term "physiological excavation" is used to distinguish this from the pathological variety. The vessels usually make a bend at the edge of the excavation and do not appear quite so sharply defined. We distinguish two forms of physiological excavation; one situated exactly in the centre, the other which approaches the edge and usually extends in a crescent toward the side of the macula, though

it usually does not reach the margin of the papilla. The first form is an unusual enlargement of the central fovea (vide Fig. 100). The latter is explained by the fact that the number of nerve fibres which pass directly to the macula is smaller than those running in other directions.

Strange to say, the attention of ophthalmoscopists was attracted earlier by the pathological than by the physiological excavations. Foerster (1857) was the first to mention them; H. Mueller (1858) made the first anatomical investigations. Klein made examinations concerning the frequency of physiological excavations and found that they varied in the different conditions of refraction; in emmetropes and myopes in seventy-five per cent, in hyperopes in twenty-one per cent.

In older people the papilla is paler and less shining, partly on account of local, usually atrophic changes in the nervous tissues. The difference is very striking in contrast with the papilla of young people, to the appearance of which Albrecht v. Graefe has applied the term "virginal."

Abnormal Appearances in the Papilla.

The papilla may not be sharply defined and may pass gradually and imperceptibly into the surrounding parts. It is then recognizable occasionally only by the entrance of the vessels. This congenital anomaly is not associated necessarily with any notable diminution of visual power. In other cases the papilla is considerably smaller than usual and may even be reduced to half the normal, with a more oval shape or projecting edges. The color is occasionally dull grayish-white or it is brownish-red, and even darker than the remainder of the fundus. But the latter forms are rare when vision is normal. Even slight projection of the papilla may occur in normal eyes.

In a few cases, black pigment specks are seen upon the papilla itself. I have also seen upon it peculiar white figures, partly sector shaped, partly of an irregular shape. At such places the vessels are usually interrupted or indistinct. A section of such eyes has not yet been made, but the appearance depends probably on medullated nerve fibres because these produce similar figures in the retina. I have also observed cases in which these white figures were present both upon the papilla and the retina. We often find that certain vessels do not pass directly into the papilla, but disappear in the retina immediately alongside of the boundary line. Possibly these vessels are also derived from the central vessels of the optic nerve, but in such a way that they are given off deep

below the surface of the papilla. Or we find small perforating branches which are derived from Zinn's vascular ring surrounding the papilla (cilio-retinal vessels). Small præpapillary loops of vessels, which extend into the vitreous body, also occur as a congenital condition (Czermak, Hirschberg).

Coloboma vaginæ nervi optici is the term applied to a congenital abnormality, in which a whitish, coloboma-like part is appended to the very large and excavated papilla (vide Coloboma choroideæ).

2. Retina.

In the normal condition, not much can be seen ophthalmoscopically in the retina. It is perfectly transparent, with the exception of the vessels which constantly grow narrower toward the periphery. It covers the choroid like transparent glass and it is only close to the papilla that the optic nerve layer is occasionally recognized by its pronounced whitish reflex. In the few cases in which the pigment epithelium and the choroidal pigmentation are extremely black, as in the negro, a well-marked reflex is obtained from the entire retina. The fundus then appears dark gray in the ophthalmoscopic image, because the dark pigment epithelium does not permit the shining through of the red, which is derived from the blood-vessels of the choroid and usually gives to the fundus its principal color.

After the discovery of the visual purple, the red color of the fundus in the ophthalmoscopic image was chiefly ascribed to this substance (Boll). But a number of reasons are opposed to this assumption, apart from the above-mentioned color of the fundus in darkly pigmented individuals. It is to be remembered, above all, that the macula lutea, despite its darker tone, has a decided reddish color ophthalmoscopically, and that this cannot be attributed to the visual purple which is situated only in the rods, inasmuch as the macula contains only cones. Under normal conditions any notable influence of the visual purple upon the production of the red color of the fundus in the ophthalmoscopic image, cannot be demonstrated. But in ophthalmoscopic examination in an animal, of a part of the fundus from which the choroid had been removed artificially, Becker observed a reddish color of the superjacent retina. This accords with the fact that Alder observed a rosy color in a very recent detachment of the retina, which disappeared subsequently. The fundus is occasionally found infiltrated with peculiar shining light streaks like ice figures (Schreiner), and which often, though not always, run along the course of the vessels. It there presents a sheen like a piece of moirée. This is seen particularly in children (vide Neuro-retinitis).

The macula lutea is an especially interesting part of the retina. In the inverted image it is seen as a dull, brownish-red spot, about one and one-half papillary diameters from the papilla on its nasal side. It is round or transversely oval (rarely vertically oval); its size is about equal to that of the papilla. It contains no vessels which are visible ophthalmoscopically. The macula is usually surrounded by a bright shining ring of light, which is sometimes sharply defined and uniform in width, but occasionally varies in width and presents isolated interruptions. In the middle of the macula is a darker small circle or semicircle, which often contains a bright point of light (vide colored plate Fig. 1).

These details are not present in all individuals, even when the darker color of the retina is recognized. The light-reflexes at the edges are often absent, and almost always when there are irregularities in the pigment epithelium or pathological changes in the choroid.

In the direct image we see, in the most favorable event, a small dark spot (naturally on the temporal side of the papilla) or a figure which corresponds to the two sides of an acute angle, with a central light spot. The former is the optical expression of the wall-shaped darker colored surroundings of the fovea centralis. The central light-reflex comes from the fovea centralis, which acts as a concave mirror.

It is also to be noted that the ring of light which surrounds the macula is absent or becomes feebler even in the inverted image, when the pupil is strongly dilated by atropine.

The above-mentioned anatomical conditions in the macula of the fresh eye, explain, in the main, the ophthalmoscopic image. Further explanation is required for the occurrence of the bright ring of light around the macula and its shape. The bright ring of light may be regarded as the optical expression of the contrast between the dull tone of the macula lutea, whose yellow, which does not appear in its own color upon the background of the choroid, absorbs more light, and the more strongly reflecting adjacent retina. This view is also favored by the fact that its width and extent are not always the same or uniformly defined. It is a striking fact that the light-ring is absent in the direct image; as we have to deal with a light reflex, it is plausible that the explanation is connected with the amount of light introduced. This is less in the direct image, even if a concave mirror is used, than in the inverted image. It is plausible that the light-ring will become less distinct on this account, while on excessive illumination of the retina (such as occurs in examination of a mydriatic eye in the inverted image) the contrast between the macula and surrounding

parts becomes less. Slight pathological changes (especially central choroiditis or retinal affections) also cause disappearance of the light-ring around the macula and of its sharp definition in color.

The shape and size of the macula are recognized accurately only by the boundary light-ring. Anatomically, it cannot always be defined so strictly. Although we have described it as a transverse oval, it is to be remembered that there are very many exceptions to this rule. The apparent shape of the macula is often influenced by astigmatic refraction of the eye or by astigmatic deflection of the rays dependent on holding the convex lens obliquely.

In examining the macula, whether in the direct or the inverted image, it is well to fix the optic papilla and then to bring ourselves gradually into the visual line of the patient by lateral movements with the head. If we see only the temporal part of the optic papilla in the inverted image (with $+\frac{1}{3}$), there is usually also a part of the light-ring of the macula in the field of vision. If we bring the macula opposite to us at once by directing the patient to look into the mirror, the finding of the image is made difficult by the corneal reflexes occurring in contraction of the pupil, etc. The light-reflex may be diminished by turning the convex lens somewhat around its horizontal axis, but we thus produce artificial astigmatism.

Abnormal Appearances in the Retina.

Independently of other affections of the fundus, the veins sometimes show unusual sinuosities or, in very rare cases, more or less numerous varicosities. Stenoses of the arteries or the appearance of a whitish contour of these vessels (thickening of the adventitia) are, as a rule, part symptoms or sequelæ of other affections of the optic nerve or retina.

Double-contoured Nerve Fibres.

In this condition small, white, shining figures, arranged like sectors with the base directed toward the edge of the papilla, are found in the whitish-red fundus oculi, alongside the papilla. An entire series of such sectors is occasionally present. More rarely the white patches are separated from the papilla by a part of the red fundus. The color is not always uniformly white. With a higher magnifying power (direct image) a streaked condition appears; at the edges we often see fine reddish lines which extend into the white and give the whole a flame-like appearance. If retinal vessels enter the patches, they disappear within them or become

indistinct, but again appear at the opposite border. Virchow, Recklinghausen and others, have demonstrated anatomically the occasional occurrence of double-contoured nerve fibres in the retina. I have had the opportunity in two cases, Schweigger in one case, of demonstrating by post-mortem examination that the ophthalmoscopic appearances just described really depend upon the presence of double-contoured nerve fibres. In my cases the nerve fibres, which lost their double contour in the lamina cribrosa, reassumed it immediately alongside the papilla in a part which was wedge-shaped on transverse section. The apex of the wedge was directed toward the retina, the layer here becoming thinner. This, together with the varying depths at which the retinal vessels were between the double-contoured nerve fibres, explains the gradual or sudden disappearance and the reappearance of the retinal vessels, that is observed ophthalmoscopically. Mooren's statement that he has seen double-contoured nerve fibres develop in a patient under his eyes, merely proves that retinal processes occasionally occur which may present a similar ophthalmoscopic picture. The blind spot proves, on examination, to be enlarged, corresponding to the part at which the double-contoured fibres join the papilla.

3. Choroid.

In ophthalmoscopic examination, the color of the fundus oculi varies between yellowish-red and reddish-brown. If we disregard the influence of the intensity of illumination, which varies greatly with a strong and weak mirror, in the direct and inverted image, the chief influence on the color is exerted by the greater or less pigmentation of the epithelial layer. In lightly pigmented individuals, comparatively much light comes from the choroidal vessels and is reflected with a reddish color; in darker subjects, the light is absorbed in great part by the black pigment. In the former event, the tyro must be on his guard against making the diagnosis of hyperæmia.

In albinos, the sclera even shines through with a whitish light and the choroidal vessels are seen upon it as red streaks. The latter also are seen not infrequently even in normal pigmentation (vide colored plate, Fig. 4). They are distinguished from the retinal vessels by their greater width and the absence of the characteristic ramifications. It is particularly toward the equator of the globe that the diminished pigmentation of the epithelium often enables us to recognize reddish, broad choroidal vessels, which often run approximately parallel, and between them a dark brown and blackish color (intervascular spaces) which is owing to the pig-

mented stroma cells lying between the vessels. These regular figures (vide colored plate, Fig. 1, at the lower edge) should not be mistaken for pathological accumulations of pigment (choroiditis). In slightly pigmented individuals we also see the venæ vorticosæ in their peculiar stellate course.

The six-angled epithelial cells give the fundus a granular or shagreen appearance with higher magnifying powers.

Abnormal Appearances in the Choroid.

Coloboma of the Choroid.—The ordinary form of "choroidal fissure" is situated below the papilla; within the red of the fundus it forms a whitish, extensive surface, occasionally with a somewhat grayish tinge and containing a few blackish-gray streaks. The rim of this part, which is not infrequently excavated, is often surrounded by black pigment. Upon it we recognize vessels which communicate with one another and run a peculiarly sinuous course; usually they are not connected with the retinal vessels. As a rule, the latter avoid the region of the coloboma and run along its edges. When the pigment epithelium of the eye is lighter, we can occasionally follow the prolongation of a choroidal vessel from the normally colored surrounding parts into the vessels of the coloboma. The coloboma often has a triangular shape, whose blunt apex is directed toward the papilla and its base toward the equator of the bulb. It extends occasionally so far anteriorly that the termination of the coloboma can no longer be recognized with the ophthalmoscope. In other cases it ends earlier so that the red fundus again appears at the periphery. It is sometimes divided into two parts which are situated more and less remotely from the papilla; in still other cases, it surrounds the papilla. The latter is usually quite normal; exceptionally it is so irregular in shape and color that it can only be recognized by the entrance of the vessels.

Choroidal coloboma is not infrequently associated with partial or complete coloboma of the iris. Changes are sometimes noticed even in the ciliary body and the lens, especially indentations. Microphthalmus and nystagmus often complicate choroidal coloboma, which may occur on one or both sides.

In addition to the coloboma just described, which is situated below the papilla, cases have also been reported under the title coloboma around the macula lutea. The change is here situated at the posterior pole of the eye and resembles in color and shape the coloboma which are situated inferiorly. In a boy of eight years I had the opportunity of observing a congenital anomaly of this kind in both eyes (the shape was a transverse oval, the greatest diameter = twice the diameter of the papilla).

Diagnosis.—At the first glance a coloboma may be mistaken for separation of the retina or extensive choroidal atrophy. It is distinguished from the latter by the peculiar shape and sharp definition and by the course of the vessels; nevertheless some of the reported cases of macular coloboma were probably merely choroidal atrophies. An essential difference from detachment of the retina consists in the fact that the latter forms a prominence, while the coloboma is situated either at the level of the retina or is even, in many cases, excavated. The correct diagnosis is also assured by the course of the retinal vessels described above. Nevertheless the diagnosis is sometimes difficult, when the patient suffers from nystagmus and the movement of the eye to and fro interferes with the examination.

Etiology.—Coloboma was formerly interpreted as the expression of imperfect closure of the fœtal ocular fissure. It is well known that in the development of the fœtus the anterior wall of the primary ocular vesicle is turned in by the lens, which is derived from the cervical plate, so that it is situated immediately in front of the posterior wall. In this way the formerly single-walled sphere is converted into a double-walled segment of a sphere, the so-called second ocular vesicle. The pigment epithelium is formed subsequently from the outer wall, the retina from the inner (formerly anterior) wall. During the inversion mentioned above, a groove (ocular fissure) forms in the lower half of the ocular vesicle, and passing to the optic nerve.

At the beginning this is triangular, with the base turned to the edge of the lens, the apex to the optic nerve, into which it still enters like a furrow; it passes in a tolerably straight course from behind forward. If, as was formerly supposed, the coloboma was solely the absence of the normal closure of the ocular fissure, the retina and pigment epithelium, which develop from both layers of the secondary ocular vesicle, would alone be absent there. The choroid and sclera, on the other hand, would not be affected directly because they are formed from the cervical plate. But all the microscopical examinations of colobomas, which according to their structure and position have resulted from anomalies of the closure of the ocular fissure of the retina and pigment epithelium (Haase, Lillen, Hirschberg), have shown that the choroidal tissue itself, particularly the stratum of the choriocapillaris, is lacking in the normal development at the side of the coloboma. Even the sclera often presents thinning, occasionally an ectasia at the corresponding part. The absence of closure of the ocular fissure has therefore had an injurious influence upon the development of the adjacent tissues, which are not formed directly from the secondary

ocular vesicle. Despite this complication, these cases should be called, from their genesis, retinal coloboma (not choroidal coloboma, as is commonly done).

In order to infer the existence of true retinal coloboma from the clinical examination, an absolute defect in the field of vision must be demonstrated at the corresponding locality. It is not sufficient to find a defect with the perimeter, but we must prove that all quantitative sensation of light—whether for the lamp or the ophthalmoscopic image—is there destroyed. Only in this event may we assume complete absence of the retinal elements.

If, on the other hand, quantitative sensation of light is present, this furnishes the proof that retinal elements are active at the spot. According to my observations, which have been confirmed by Haab, these cases do not appear to be rare. Certain so-called macular colobomas also belong in this category. The clinical demonstration of the presence of functionating retina has found sufficient support in microscopical examinations. Apart from the well-known older cases of Arlt, Manz (1876), and Haab (1878), in the examination of colobomas, demonstrated retinal elements and pigment epithelium, with absent or imperfect choroidal development.

In all these cases of coloboma, in which retinal elements and pigment epithelium are present, there can be no question of the absence of closure of the primary ocular fissure. We have to deal rather with imperfect or changed development, which indeed chiefly affects the region of the fœtal fissure, but appears most markedly in the choroidal tissue. As Haab has properly emphasized, the disturbance occurs genetically mainly in the tract of the tissue supplied by the cervical plate. These, in fact, are true choroidal colobomas.

If we are therefore justified in a series of cases, which correspond locally to the fœtal ocular fissure, to regard the patency of the latter as not the direct cause of the imperfect development, still more important opposing arguments are found in those cases in which the geometrical position of the clinically observed coloboma does not correspond to the fœtal fissure, so far as we are acquainted with it through embryological investigations.

The inhibitions of development in the posterior part of the ocular coverings are situated preferably in the region of the ocular fissure, but are by no means confined strictly to this territory, nor do they always depend upon its patency. Nor do the macular colobomas correspond geometrically to the hitherto assumed position of the fœtal ocular fissure. Whether the assumption recently supported anew by Vossius, of fœtal rotation of the globe, by means

of which the former inferior half is turned to the outside, is correct and can be employed to explain the connection between the so-called macular coloboma and the fœtal fissure, requires further investigation. Similar conditions may also be produced by intra-uterine diseases.

CHAPTER III.

DISEASES OF THE OPTIC NERVE.

INFLAMMATORY symptoms in the globe, which are visible externally, are wanting in diseases of the optic nerve and retina, usually also in diseases of the choroid which will be discussed later. On the other hand, the visual power is almost always lessened or altered to a lesser or greater extent.

1. HYPERÆMIA OF THE OPTIC NERVE.

The papilla appears redder and has somewhat less gloss; its contours are usually not as sharp as normally, but marked cloudiness of the tissue is absent. The diagnosis is not always made easily because the color of the optic nerve varies within wide limits. It is sometimes aided by comparison with the other, healthy eye. As a rule, we find hyperæmia of the nerve secondarily in retinitis and choroiditis, and it is also often present in iritis. In the first case the pathological changes in the retina are sufficiently prominent. On the other hand, the choroidal changes cannot always be recognized ophthalmoscopically at the beginning of the disease. The characteristic pigment and color changes often do not develop until after a certain length of time. Slighter congestion is also observed occasionally in eyes which have been irritated in other ways, for example, in non-corrected hyperopia. In the disease which has been regarded as retrobulbar neuritis by A. v. Graefe, hyperæmia of the papilla may also occur occasionally, before the atrophic changes appear.

The opinion has often been expressed that the circulation of blood in the optic papilla gives an accurate representation of the cerebral circulation, hyperæmia of the papilla being present in congestion of the brain, anæmia of the papilla in cerebral anæmia. But this is only true of comparatively few cases.

[Corresponding pathological changes in the optic nerve were said to have been seen particularly in insanity. For example, in ophthalmoscopic examination of eighty lunatics, Sebaldi obtained negative results in only nineteen cases. This is probably due to self-

deception, because the great physiological range and variations in the color of the papilla, the sharpness of its contours and the condition of the vascular system were not sufficiently noted. Among 129 patients in the Insane Wards of Prof. Westphal in Berlin, I found some, though not absolutely certain pathological changes in the optic papilla in only thirteen cases. Other ophthalmologists (Manz, Leber) have had similar results. Recently I have again examined seventy-four lunatics in the Marburg Asylum, under the supervision of Prof. Cramer. I found pathological changes belonging to this category in only six cases; as a matter of course, sclerotico-choroiditis, glaucomatous excavation and the like are not included. Nor do I consider myself warranted, as do other observers, in regarding as absolutely pathological a slight cloudiness of the papilla and the retina which appears as a sort of veiling of the fundus (it is said to be "less illuminated and duller"), when the visual power is normal. Age, pigmentation, etc., produce wide physiological differences. By including cases of this kind, Uhthoff (1883) has again obtained a very high percentage of pathological findings. Among the Marburg patients whom I examined, fifteen suffered from progressive paralysis. Although the examinations were made in the direct and inverted image, in only one case did I see any appearances which resembled the retinitis paralytica described by Klein and which did not seem to fall within pathological limits. Klein applies this term to physiological appearances which consist of retinal opacity—similar to, but more marked, than that observed in old age—and a peculiar condition of the retinal vessels, which appear widened in places, chiefly from enlargement of both dark contours, the central light reflex remaining unchanged. Among 139 lunatics, Klein observed this condition 129 times in progressive paralysis. Uhthoff also found the retinal opacity (sometimes associated with hyperæmia of the papilla) in thirty-six per cent of the paralytics, but did not observe the vascular changes. Nor could I convince myself of the pathological significance of Riva's observations, who, among 117 lunatics, found in thirty or more a less marked pallor of the choroid with slight opacity of the retina.]

According to Manz, venous hyperæmia and some opacity of the edges of the papilla are found quite constantly in acute meningitis or encephalitis. This author also demonstrated, in almost every case, a more or less marked dropsy of the sheath of the optic nerve. Even in these cases I have often failed to find any marked pathological condition, especially œdema of the adjacent retina.

Hyperæmia of the papilla, without functional disturbance, is often seen in constitutional syphilis (Schnabel, Ole Bull).

2. Papillitis, Neuritis Optico-intraocularis, Choked Disk.

We apply these terms to disease of the optic papilla proper; the extraocular portion of the optic nerve beyond the lamina cribrosa is only affected secondarily. In a marked form and bilaterally the affection is found with special frequency in tumors of the brain. The papilla projects strongly above the level of the retina, often like a mushroom, and may reach a height of one to two millimetres (Fig. 103). The edges are effaced and widened because the swollen papilla covers the edge of the choroid. The vessels are bent.

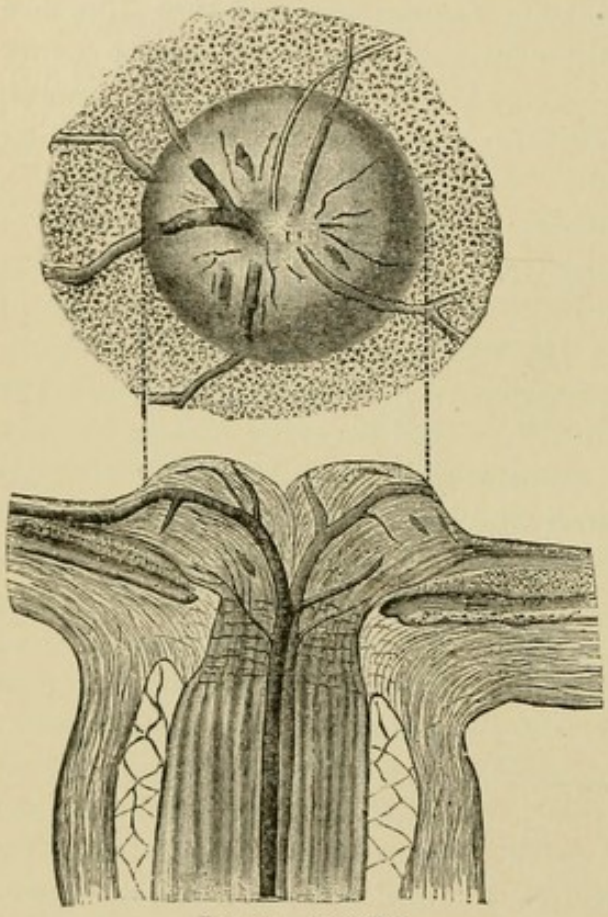


Fig. 103.—Papillitis.

With regard to the other appearances of the papilla, two forms may be clearly distinguished. In the one, very rare form, and which is less characteristic in the diagnosis of brain tumor, the tissue of the swollen head of the nerve is clear and transparent, as if œdematous, and the vessels are distinctly visible and but little changed; only the veins appear somewhat darker, wider and often sinuous, particularly upon the retina. This condition may last for a long time and even pass into atrophy, without combination with any marked opacity of the tissues. With higher magnifying powers, however, we can occasionally see whitish streaks in some parts of the papilla. In this form, moreover, as in the other, small white patches may appear upon the retina in the immediate vicinity.

The second form of choked disk, which is by far more frequent in cerebral tumors, exhibits much more considerable tissue changes. The papilla, at first hyperæmic and slightly œdematous, soon becomes cloudy and infiltrated with gray streaks, which in part cover the vessels entirely. White patches and hemorrhages are often distinctly visible. The arteries appear narrow, can hardly be followed as fine, shining lines, are often interrupted, and only regain greater width upon the retina. The veins are dark and sinuous

(vide colored plate, Fig. 7). If pressure upon the globe is made with the finger, the vessels lose their central reflex streaks, the walls come together and create the impression of bluish-red lines. Pronounced ischæmia sets in. It is only when there is slight swelling of the tissues that the vessels again fill at the systole of the heart (arterial pulse). V. Graefe observed a spontaneous arterial pulse in a few cases. In the majority of cases in which I observed the development of choked disk, the first signs were congestion of the papilla and blurring of the borders, usually on one side alone, and to such a slight extent that no positive diagnosis could be made at the time as to the real pathological significance of the image. In rare cases I observed the following mode of development: first œdema and projection of the papilla, the central fovea still perfectly white, the borders of the papilla blurred, the vessels normal. A few days later marked congestion, the central fovea reddened, the veins wide and sinuous, the arteries very full. The pronounced morbid picture then developed after a longer or shorter period. The retina is sometimes affected secondarily in choked disk proper (neuro-retinitis). Apoplexies and even extensive formation of white patches may appear and, as I have seen, may furnish the perfect image of retinitis albuminurica.

After a longer or shorter period, the choked disk becomes gray and flattened, and passes into the condition of optic atrophy. In one case I noted the presence of papillary swelling and cloudiness of the tissues for one and one-quarter year; at the end of another year I found atrophy. But, as in the atrophy of the neuro-retinitis, the blurred borders of the dull white, opaque papilla, the narrowness of the arteries and the sinuosity of the veins persist for a long time, and may subsequently assure the diagnosis of a preceding papillitis as opposed to genuine atrophy. Even at a very late period, when the papilla has become shining, bluish-white and sharply defined and the vessels are narrowed, we can diagnosticate the previous inflammation from a yellowish ring, often infiltrated with pigment, which surrounds the nerve, occasionally from a slight elevation in a circumscribed spot.

Almost complete *restitutio ad integrum*, such as has been observed by H. Jackson, Mauthner and Wernicke, occurs with extreme rarity. This may be expected most readily when the causal factor is a syphilitic tumor.

As a rule, microscopical examination of the intraocular extremity of the nerve shows marked development and new formation of fine vessels and capillaries and venous stasis. The non-medullated nerve fibres are easily isolated and often swollen, they present a series of egg-shaped varicosities, which are occasionally very small,

in other places so large that they exhibit a ganglionic appearance. These often contain a sort of nucleus or they are filled with numerous coarse granules which shine like fat. This hypertrophy of the nerve fibre gives rise to the ophthalmoscopic image of the gray streaks or individual white patches. In addition numerous round cells are scattered through the tissues. Peculiar round, perfectly homogeneous bodies, somewhat larger than blood-corpuscles, have also been seen in the nerve-fibre layer (Schweigger). More or less large cavities, such as I have seen particularly in the vicinity of the proliferated layers of the lamina cribrosa, which are pushed forward and separated from one another, must be regarded as the expression of œdematous infiltration. This view is also accepted by Iwanoff, Rosenbach, Ulrich and others. Hyperplasia of the connective tissue occurs after the inflammation has lasted a long time. The walls of the vessels often present thickening and sclerosis. The adjacent parts of the retina also are occasionally changed, Mueller's supporting fibres being prolonged externally and forming irregular projections; an œdematous condition is found occasionally in the tissue itself. The white patches in the retina are due, in great part, to deposit of granular cells in the granule layers. I have also found the adjacent or subjacent choroid occasionally implicated. I have found swelling of the vitreous membrane, fatty degeneration of the epithelium, sclerosis of the vessels of the choriocapillaris, and accumulation of granulo-fatty cells in the stratum. These appearances explain the fact that pigment changes next to the papilla or a grayish-yellow ring or half-ring are seen so often in the atrophic stage. When atrophy ensues, dense connective-tissue bands are seen in the flattened papilla, with narrowing or even disappearance of the vessels.

In choked disk, as a rule, there is usually increased filling of the subvaginal space with fluid, most marked near the globe, where it forms a sacculated or ampullary dilatation. This condition has been called dropsy of the optic sheath (hydrops vaginæ n. optici). In advanced cases the accumulation of fluid can be detected at the autopsy without special precautions; in other cases it is advisable to ligate the nerve at the optic foramen. Great flaccidity and mobility of the outer sheath, usually furnish the proof of abnormal distention of the subvaginal space, presupposing, as a matter of course, that it is not the result of anatrophic diminution of the volume of the optic nerve. This flaccidity of the sheath may still be seen distinctly in eyes hardened in Mueller's fluid.

The dropsy is not always uniform, but I have never found it absent in distinct choked disk as a result of cerebral tumors. But inasmuch as these conditions vary within certain limits, the observer

may occasionally be in doubt whether he has to deal with a pathological or physiological dilatation. Proliferation and cellular infiltration of the connective tissue network in the subvaginal space (perineuritis optica) have sometimes been found at the same time (H. Pagenstecher, Michel). On the central side of the lamina cribrosa the optic nerve, as a rule, presents no changes at the beginning of the papillitis; dilatation of the small arteries is sometimes observed immediately in front of the lamina cribrosa. Later we find œdema, infiltration of round cells (interstitial neuritis), even of granular cells and small myelin-like, shining drops (Leber), after whose disappearance gray degeneration develops with increase of the connective-tissue septa. But this atrophy usually appears to start from the periphery. In a case under my observation, the atrophy and thinning of the optic nerve were very marked near the bulb, so that, at a distance of nine millimetres from the globe, it measured only one and three-quarters millimetres in one direction, not quite three millimetres in the other direction; at a distance of twenty millimetres from the eye, the nerve presented its normal appearance. In other cases the degeneration occurs remote from the papilla, and solely in the cranial portion of the nerve, the chiasm or the optic tract (Tuerck, Boettcher). Tuerck attributes the nutritive disturbances in and near the chiasm to the pressure which is so often exercised by the dropsically distended third ventricle upon the surface of the chiasm.

As is shown by a series of cases, the visual power may be normal despite pronounced intraocular optic neuritis. For example, in a case of bilateral neuritis which had lasted six months, I found perfect vision in one eye, and V $\frac{5}{6}$ in the other. In this case the vascular changes were not marked, but small whitish streaks were visible in the papilla and adjacent retina. The latter, as stated above, are the results of ganglion-like degeneration of the nerve fibres, so that this affection appears to have no marked influence on the visual power. In another case of choked disk (tubercular tumor in the right cerebellar hemisphere) V $\frac{3}{4}$ with free field of vision and intact color sense were found by me two days before death. The microscopical examination showed choked disk which projected 1.5 mm. above the choroid, with extensive ganglion-like degeneration of the nerve fibres, new formation of vessels and cellular infiltration. In a third patient I even found V $\frac{4\frac{1}{2}}{4}$ with free field of vision and intact color sense despite pronounced choked disk with great swelling of the papilla and white patches.

Hence, ophthalmoscopic examination is urgently indicated in all patients who present any suspicious cerebral symptoms, even if there are no complaints concerning the visual power. In many

cases, the diagnosis of brain tumor can only be made by the ophthalmoscopic appearances, or at least it only receives in this way an approximately sure support. As a rule, however, visual power diminishes after a while, and pronounced amblyopia develops with defects in the field of vision, often of a concentric character. At first the color sense is intact, but it is lost as the atrophic stage approaches. According to Foerster's examinations, the light sense remains entirely or nearly normal, even in marked amblyopia; this is confirmed by my own experience. The patients complain very rarely of subjective sensations of light. In a few cases, there is paroxysmal diminution of vision or even complete blindness which may disappear in a few hours or days, and must be attributed to central causes, swelling of the brain, tumor, etc. H. Jackson has called this epileptic amaurosis.

As a rule, papillitis is bilateral in brain tumors, though it often develops unequally and somewhat later on one side than the other. Among eighty-eight cases of brain tumor with autopsy, collected by Ammske and Reich, bilateral neuritis was found eighty-two times, unilateral neuritis only twice; it was absent in four cases. But from my own observations, I concur in the opinion expressed by Mauthner that the percentage of cases in which neuritis is absent, is decidedly larger than appears from these statistics.

Explanation of the Occurrence of Papillitis.

The great frequency of choked disk in tumors of the brain, was first emphasized by A. v. Graefe (1859). Inasmuch as the optic nerve, as a rule, presented no gross changes which would render probable the direct spread of the process from the brain to the papilla, A. v. Graefe attributed the papillitis to the diminished space in the skull resulting from the tumor, and to the increased intra-cranial pressure. This was supposed to cause compression of the cavernous sinus—an assumption previously adopted by Tuerck in order to explain the retinal hemorrhages which he found in cerebral tumors. This causes stasis in the ophthalmic vein and the central vein of the retina. In the latter vessel the obstruction to the escape of blood would be most apt to produce symptoms of stasis in the region of the lamina cribrosa on account of the unyielding character of this network. On the other hand, if the stasis produced œdema here, this would again incarcerate the vessel. But v. Graefe's explanation of the occurrence of choked disk became untenable, when Sesemann (1869) showed that obstruction to the flow of blood in the cavernous sinus does not necessarily produce stasis of the arteria centralis retinæ, inasmuch as sufficient

escape may occur through the connection of the superior ophthalmic with the facial vein.

In the mean time, Schwalbe had demonstrated, by injection experiments, the connection between the subvaginal space of the optic nerve, and the subdural or subarachnoid space of the brain. In 1869 I expressed the opinion that on increase of the intracranial pressure the cerebro-spinal fluid enters the lymph space of the optic sheath, and then gives rise to œdema of the lamina cribrosa. In the calf, the lamina cribrosa had been successfully injected from the brain. But there must have been specially favorable conditions present, in the successful injection experiments in these animals, because I was subsequently unable, in human beings, to cause filling of the lamina cribrosa by direct injections into the subvaginal space. This also happened to other observers (Manz, Schwalbe) or the experiment was only partially successful, after the adoption of special precautions (Wolfring). But Wolfring succeeded, by entering directly below the inner nerve sheath, in injecting the lamina cribrosa and other spaces running along the connective-tissue septa. In this experiment, Schwalbe noticed the escape of the injection mass into the subvaginal space, and therefore assumes that the lymph of the papilla and optic nerve may escape in part, through the subvaginal space toward the brain. Quincke has also demonstrated the physiological connection between the lymph spaces of the skull and the subvaginal space of the optic nerve, by injecting finely divided cinnabar into the former and finding it subsequently in the subvaginal space. The escape of fluid from the cranium into the optic sheath, has also been observed anatomico-pathologically (pus by me, blood by Knapp, and later in pachymeningitis by Schuele and Fuerstner). These facts, taken in connection with the demonstration of dropsy of the optic sheath, make the view, that fluid passes from the skull into the subvaginal space on increase of the intracranial pressure, appear entirely justified. The result is a stasis of lymph which, on account of the demonstrated connection of the lymphatic spaces of the lamina cribrosa with the subvaginal space, must give rise to symptoms of stasis and œdema in the former. The optic papilla may now be affected directly by the spread of the œdema, or the œdema of the lamina cribrosa may first incarcerate the vessels and thus produce venous stasis, which gives rise secondarily to œdema. The ophthalmoscopic conditions testify in favor of both processes. The anatomical changes in the nerve fibres may also be explained, as Kuhnt maintains, by the influence of the œdema, because the experimental investigations of Rumpf have shown that the axis cylinder of medullated nerve fibres swells in lymph and degenerates. This

action of the lymph must be so much the more noticeable, because the nerve fibres of the papilla are not protected by a medullary sheath. In the beginning—and permanently in a small number of cases—not much else is to be seen in choked disk. The later, more inflammatory phenomena, may be atrributed to the incarceration of the arteries, because experimental investigations have shown that the obstruction of arteries may give rise to inflammation. But, on the whole, it is a striking fact that violent inflammatory symptoms are not uncommonly entirely absent in choked disk.

The theory here presented concerning the development of choked disk, finds powerful support in the investigations of Manz and recently of Schulten, who produced distinct hyperæmia and swelling of the optic papilla by the injection of water, defibrinated blood, etc., into the skulls of living rabbits. In agreement with my investigations Manz has also proven, by numerous post-mortems, the frequency of dropsy of the optic nerve in cerebral diseases, particularly brain tumors. This so-called lymph space or transportation theory may therefore be regarded as firmly established. In view of the number of conditions necessary it is not very astonishing that choked disk does not develop in some cases, despite the presence of a cerebral tumor. It requires marked increase of intracranial pressure, the passage of fluid into the optic sheath, and finally—and more importance must be attached to this factor than it usually receives—œdema of the lamina cribrosa or the papilla. Before all this occurs, the case may have terminated fatally. For example, I examined a patient (who died of sarcoma of the right cerebral hemisphere) six days before his death, and found, in the right eye, dilatation and sinuosity of the veins with opacity of the papilla, without distinct prominence. The left eye was normal. On the evening before death occurred, opacity of the papilla and hyperæmia were also observed on the left side. The autopsy showed moderate hydrops vaginæ n. optici. The existence, in a few cases, of hydrops vaginæ, without choked disk, is explained by the fact that it has not lasted long enough to produce such œdema of the lamina cribrosa as to necessitate disturbances in the circulation of the blood in the vessels through it. With regard to the few cases in which the neuritis in brain tumor remained unilateral, despite prolonged observation, it may be, as I remarked in my first paper upon this subject, that an obstruction in the region of the optic foramen cut off the communication between the brain and the sheath of the optic nerve. The fact that double choked disk has been found occasionally despite the absence of brain tumor or other cerebral disease (Noyes, Jackson, Mauthner) may also be understood, if we remember that the ophthalmoscopic appearances

of choked disk are found sometimes, though very rarely in a pronounced form, in descending neuritis and perineuritis. If we take into consideration the arterial ischæmia, I see no difficulty in explaining the development of the inflammatory processes, and I do not believe it is necessary to assume a special inflammation-producing quality of the serous exudation (as a product of intracranial inflammation) which enters the subvaginal space of the optic nerve (Leber, Deutschmann). If this exudation possessed a strong inflammation-producing quality, it is difficult to understand why all the cerebral nerves, which it constantly surrounds, should not undergo inflammation.

Parinaud has recently interpreted optic neuritis as the result of lymphatic œdema, in the sense that, in interstitial cerebral œdema, the latter is propagated through the optic nerve to the papilla. This is opposed by the anatomical conditions, which show that the papilla is the main seat of the disease, and that the more central portions of the optic nerve appear relatively free. The frequent occurrence of dropsical distention of the ventricles in cases of tumor cannot be denied; this furnishes another cause for increase of the intracranial pressure. But that simple hydrocephalus is usually insufficient to produce an increase of pressure which will give rise to choked disk, is proven by the very frequent absence of intraocular neuritis in acute primary hydrocephalus. On the other hand, I have seen cases of cerebral tumor with choked disk, in which the lateral ventricles were found, at the autopsy, to contain very little serum. Interstitial œdema of the brain is very often absent.

Benedikt's explanation (1868) of the connection between brain disease and neuritis, according to which the condition is a vaso-motor neurosis due to irritation of certain parts of the brain, leaves everything in the dark. It does not appear to me to be made more plausible by recent investigations (Betz) which have made it probable that there is anatomically a vaso-motor root for the vessels of the terminal expansion of the optic nerve. How does it happen that almost every brain tumor, wherever it may be situated, irritates merely the vaso-motor centre of the optic nerve and leaves the centres of other vascular tracts untouched? Moreover it is an important fact that the papilla often presents hyperæmia (and no narrowing of the vessels) at the beginning of the affection.

In order to explain the presence or a trace of choked disk in brain tumors, Panas (1876) distinguishes two forms, in which the increase of intracranial pressure may occur and act upon the optic nerve. When fluid accumulates in the arachnoid cavity, dropsy of the optic sheath and choked disk occur; but if pressure is exercised

directly upon the cavernous sinuses by the tumor or by fluid accumulated between the dura and the bones, stasis occurs only in the retinal veins.

Occurrence.—Double choked disk in its pronounced forms, *i.e.*, with considerable prominence and without marked implication of the retina, occurs chiefly, as we have said, in tumors of the brain (new growth, cysts, etc.). Cases in which it is observed in other conditions are extremely rare. We may mention: extreme cerebral congestion (Jackson), aneurism of the internal carotid with secondary dropsy of the optic sheath (Michel), deformities of the skull (Hirschberg), basilar meningitis—here a severe perineuritis may develop in the subvaginal space (Zacher)—pachymeningitis hemorrhagica and hemorrhages at the base of the skull with entrance of blood into the sheaths (Fuerstner), injuries to the brain (concussion, fracture of the skull) with more marked filling of the subvaginal spaces (Panas). In rare cases papillitis has also been observed in abscesses of the brain and softening spots. Its occurrence may be interpreted as the result of secondary œdema of the cerebral lymph spaces which has led to a diminution of the intracranial space; thus in recent softening, there is often no sinking in of the brain, but rather an increase in volume (Wernicke, Wilbrand). Unilateral choked disk has been observed in orbital tumors.

Treatment.—As a matter of course, the treatment must be directed against the causal factor. In violent headache, I have often used a seton to advantage. In several cases in which the eyes were almost blind, v. Wecker has incised the optic sheath in order to let out the fluid, occasionally with very satisfactory results as regards the general condition. This has been confirmed by Rowen and Broadbent. Subcutaneous injections of pilocarpine have also been useful in some cases. In vigorous individuals, local abstraction of blood may be tried against the ocular affection itself. Benedikt has recommended galvanization of the sympathetic; I have seen no special benefit from this plan.

3. Neuroretinitis.

(*Neuritis descendens. Papillo-retinitis.*)

The process is rarely confined to the papilla; as a rule, the retina is also markedly implicated. The papilla itself is hyperæmic, its borders blurred, the tissue opaque. As swelling of the tissues and œdema are often present, the appearance of the papilla occasionally resembles that of choked disk; but it is a characteristic

difference, at least in the large majority of cases, that marked swelling does not develop. The affection of the retina consists of more or less extensive opacity, venous congestion, and the appearance of hemorrhages and white patches. The latter occasionally show themselves in the neighborhood of the macula lutea, similar to those of retinitis albuminurica. v. Graefe described the process as a descending neuritis, because it progresses from the brain to the eye. In exceptional cases the papilla is permanently affected alone. Like Magnus and Leber, I have seen, in albuminuria, a pure neuritis with moderate swelling, without implication of the retina. But in some of these cases there are probably complicating diseases of the brain or optic nerve. Thus Michel found, in albuminuria, neuritis as the result of hemorrhages into the sheath of the optic nerve. In another case I also had the opportunity of observing bilateral neuritis in albuminuria (waxy kidneys) in a child, without the development of retinitis. The autopsy showed hemorrhagic pachymeningitis in addition to the renal disease.

A notable feature in this case was a peculiar glistening of the retina, which appeared in irregular patches and streaks, especially along the vessels. This gloss, which gives the fundus a moiré appearance, has often been observed by Leber in the hyperæmia of the retina which accompanies miliary tuberculosis. I have also observed it in other pathological conditions in childhood, for example, in optic nerve atrophy after meningitis and in choked disk. But Mauthner has already shown—and I concur in his opinion—that perfectly normal retinæ of children not infrequently furnish very strong reflexes whose intensity and mobility may dazzle us on movement of the eye and mirror. These children are usually poorly nourished and anæmic.

Neuro-retinitis often terminates in atrophy of the optic nerve, but recoveries have also been observed.

Occurrence.—Descending neuritis may be unilateral. When it is bilateral, as usually happens, the degree of development is not always uniform. Thus I have seen pronounced neuritis of one eye, while the other simply presented sinuosity of the veins and arteries; here, likewise, atrophy developed at a later period, although there had been no neuritis. Such a process is hardly observed in choked disk.

Descending neuritis is not rare in basilar processes, for example, in small tumors which press directly on the chiasm or optic nerve, in acute basilar meningitis, especially of a tubercular character. In the latter event it does not occur very often in a pronounced form; usually there is only hyperæmia of the papilla. Schirmer has observed neuro-retinitis in exceptional cases of epidemic cerebro-

spinal meningitis. It is found occasionally in other chronic cerebral affections, especially in children; it almost always ends in atrophy. As a rule blindness occurs very rapidly. Similar cases are also seen in adults. Noyes saw double descending neuritis in acute myelitis, and in the fatal affection recently described by Wernicke in which the autopsy showed capillary hemorrhages in the central "hœhlen-grau" without sings of increased intracranial pressure, he found hemorrhages into the fundus oculi and optic neuritis of moderate grade.

More or less marked inflammation of the optic nerve has also been observed in syphilis, lead poisoning, alcoholism, diabetes, diphtheria, anæmia, the puerperal condition (without albuminuria), after measles (Wadsworth), and scarlatina (Pflueger), abundant loss of blood, marsh fever (Poncet) and sunstroke (Holz). But in these cases the immediate cause in not a few instances is probably a demonstable intracranial affection. As has been proven in chronic meningitis, the disease of the optic nerve may be conveyed from the centre through the medium of a descending perineuritis. In other cases the papillary affection may result from atrophy of the sheath, which Manz, as we have said, found constantly in acute meningitis. The spread of the inflammation in the nerve itself has also been proven.

Secondary affection of the papilla in retinal affections, particularly in retinitis albuminurica, is not very uncommon. Neuritis and neuroretinitis resulting from infiltration and swelling of the orbital adipose and cellular tissue, are sometimes found in the initial stage of facial erysipelas; as a rule optic atrophy is then found with the ophthalmoscope in the subsequent amaurosis.

On account of the coincident and usually profound implication of the retina, vision usually suffers more markedly than in simple choked disk. Narrowing of the field of vision, also for colors, is observed. I found complete amaurosis in double neuro-retinitis apoplectica in a young girl who suffered from frontal headache and vertigo. At the end of three months the vision had increased to $\frac{1}{10}$ in one eye, to about $\frac{1}{20}$ in the other eye. Five years later there was V $\frac{1}{8}$ in the better eye; atrophy of the optic nerve on both sides. The termination in the ophthalmoscopic appearances of optic atrophy, does not always signify complete blindness. Despite well-marked pallor of the papilla, not all the nerve fibres are necessarily atrophic, so that comparatively fair vision may persist.

The treatment, after taking into consideration the etiological conditions, must often consist of vigorous antiphlogosis by means of abstraction of blood, perhaps also the administration of mercury.

4. True Inflammation of the Optic Nerve.

Appearances similar to those of the descending neuritis just described, may be here described. But we generally have to deal merely with hyperæmia of the papilla, with more or less distinct cloudiness of the tissues. Real projection and swelling of the papilla and the formation of white patches in the retina are extremely rare. The veins are also smaller in size. In some cases, indeed, all ophthalmoscopic changes are wanting. Only the sudden blindness, in connection with the atrophy, which is often visible only at the end of weeks, makes it probable that there is a direct affection of the optic nerve in its extrabulbar course. A. v. Graefe has applied to the latter variety the term retrobulbar neuritis. Apart from the direct influence of the disease of the optic nerve fibres, the sudden blindness may also be due to compression of the vessels in the trunk of the nerve and ischæmia of the retina (v. Graefe).

The disease may occur in an acute form, blindness developing suddenly, or it may develop slowly. Recovery takes place not infrequently in the acute form, even if complete amaurosis has lasted for days. It has been observed in severe febrile diseases, but perhaps this condition has sometimes been mistaken for uræmic amaurosis. It has also been seen as the result of suppression of the menses, syphilis, uterine diseases, lead poisoning and after colds. Nettleship describes a form in which the amblyopia increases quite rapidly, though sudden blindness does not occur, and only one eye is attacked. The papilla shows slight inflammatory appearances and recovery usually follows. Headache is often present. He finds a clinical resemblance to rheumatic facial paralysis. Another group, in which there are pain on movement of the eye or spontaneous pain in the eye and forehead, has been attributed to diseases of the orbit, such as periostitis at the optic foramen. The affection is generally unilateral; complete blindness sometimes results (Schiess, Schweigger). All demonstrable causes are sometimes absent. Thus Hirschberg observed a case of neuritis in a healthy boy of seven years, in which the sudden blindness gradually disappeared at the end of a week. A very noteworthy condition is the hereditary optic neuritis which appears in certain families, usually at the period of puberty (Leber).

Chronic neuritis does not always show distinct changes in the papilla. The latter is sometimes moderately congested with slight opacity of its edges. But even these changes may be so fugitive that they escape observation and the disease is simply called "amblyopia without lesion." Schweigger has reported several cases of

unilateral amblyopia which belong in this category. I have also observed bilateral cases (in one complete amaurosis developed, but disappeared). As a rule, a white color (usually partial) of the papilla develops later. Vision may suffer in various ways. Especially frequent and peculiar is that form in which the impairment affects only the site and immediate vicinity of central vision. At first the central scotoma sometimes appears in such a way that only the color sense is disturbed; green is mistaken for gray, red looks darker, etc. The diagnosis is easily made with small pieces of colored paper, which are carried toward the point of fixation. These scotomata are not perceived directly by the patient. The ophthalmoscopic appearances are usually negative. In two cases which were examined post mortem, Samelsohn and Vossius found, along the nerve trunk, circumscribed changes which could be attributed to inflammatory processes (axial neuritis, Foerster). The patients generally maintain that they see better in twilight. If the peripheral field of vision is intact and the central scotoma has come to a standstill, a favorable prognosis may be given in this form in so far as complete blindness is not apt to occur. The disease is almost always bilateral and hardly ever occurs except in men. The causes cannot always be determined; cold, blinding by bright sunlight, syphilis have been accused. This form of disease is also observed in multiple sclerosis. Diabetes existed in two of my cases which ran a perfectly typical course. Very many cases were so-called intoxication-amblyopias.

Treatment.—Attention must be paid chiefly to the etiological factors. Potassium iodide is the favorite remedy; sweat cures, for example by means of pilocarpine injections, and sodium salicylate have also been recommended. From my experience I prefer mercury (injections of corrosive sublimate) in acute and highly inflammatory forms. Among local measures the application of artificial leeches, when the patient is not too weak, is especially useful, but their influence on vision should be carefully controlled by frequent examinations. Inunctions of weak mercurial ointment into the forehead and temple are also commonly used. If symptoms of atrophy have set in, strychnine injections into the temple may be tried.

5. Atrophy of the Optic Nerve.

On ophthalmoscopic examination, the normally reddish papilla has become pale, of a white, whitish-gray or whitish-blue color (vide colored plate, Fig. 4). The difference in color is usually retained longer by those parts which formerly appeared white, such

as the fovea from which the vessels emerge, or an existing physiological excavation. The edges are sharp, the scleral ring usually distinct. In certain cases, the papilla loses its round contour, becomes irregular in shape, and also appears smaller. The vessels are either normal in width or narrowed; the narrowing is often especially prominent in the arteries. When the nerve fibres disappear and no substitute of new-formed connective tissue is produced, a cup-shaped depression results, at the base of which the lamina cribrosa with its fine network shines through (the so-called atrophic excavation).

At the beginning the discoloration of the papilla is not always easily diagnosticated. I have not found that greater success attends ophthalmoscopic examination with daylight. The pallor of the papilla probably depends in part upon the obliteration of the finest vessels. When the atrophy has developed as the result of neuritis, whether intraocular or retrobulbar, the narrowness of the vessels is usually striking. In the arteries it is often associated with thickening of the walls, so that the red column of blood appears narrowed. After papillitis, as we have mentioned above, the edges of the paplila remain blurred for some time and the veins present greater width and sinuosity. Later, a yellow ring or streak often appears around the papilla, and is broader and of a different color than the normal white scleral or connective-tissue ring. Pigment changes are often found in such cases. In the latter event, as we have already remarked, the visual power may be relatively good despite pronounced atrophy of the papilla. Thus, in a unilateral white atrophy I found V $\frac{4}{9}$ and the visual field intact, but almost complete abolition of the color sense. It is particularly in this form that vision may be expected to remain at a standstill.

I have now had under observation for eight years a patient whose visual power has remained unchanged despite the most pronounced double optic atrophy. It is a notable fact that these patients are easily tired during examination, so that at the beginning they see much better than later.

The partial atrophy of the optic nerve which is observed as the result of direct injury (for example, a stab in the orbit), often after the lapse of a few days, is also apt to remain stationary. Thus, I know a patient who, as the result of a stab wound through the upper lid, has suffered from superior hemianopsia (with a horizontal dividing line) with V $\frac{1}{6}$. The position of the specially atrophic portions of the papilla in these cases often, though by no means always, corresponds to the position of the defect of the field of vision.

The atrophy of retinitis pigmentosa is very peculiar. Here the color is peculiarly waxy, and the vessels, especially the arteries,

are remarkably narrow. The existence of retinal pigmentation may sometimes be foretold from the appearance of the papilla.

After phthisis of the globe, as the result of iridocyclitis or purulent intraocular processes, atrophy of the optic nerve usually develops, but, as a matter of course, is not accessible to ophthalmoscopic examination. After the lapse of years, it may extend to the chiasm and beyond. The optic nerve grows considerably thinner and acquires a grayish, glistening appearance. Under the microscope, amyloid corpuscles are found occasionally in the atrophic nervous tissue. The latter may degenerate to such an extent as to become unrecognizable in transverse sections of hardened preparations. We then see only the very thick and broad network of connective tissue, whose meshes are empty.

Independent atrophy of the optic nerve, which develops gradually without any previous distinct inflammatory processes, and furnishes the symptomatology of progressive amaurosis, generally occurs as gray degeneration (Leber).

It attacks the nerve either throughout its entire extent or in patches. The atrophic bundles which are smaller and irregular on transverse section, contain non-medullated, pale fibres which are afterward converted into quite resisting fibrillæ. Between them are found numerous granulo-fatty cells and shining, fat-like drops. When the process is not extensive it is not recognizable microscopically; when it is more marked, the nerve becomes thinner and acquires a yellowish, translucent appearance.

The affection is generally associated with diseases of the spinal cord or brain, but may also occur independently. Syphilis is often demonstrable. In addition to the white color of the papilla, which occasionally does not develop until later, there is a gradually increasing diminution of visual power with coincident narrowing of the field of vision. The defects in the visual field may appear in any direction, but not infrequently appear first at the outside. The narrowing of the field of vision is sometimes very marked, while central vision is still relatively good. Thus the patient, whose field of vision is shown in Fig. 104, had almost perfect vision on the right side, $\frac{5}{6}$ on the left side. Color-blindness usually appears early; as a rule, the outer boundaries at which the different colors are recognized, gradually grow narrower and approach the point of fixation. Green and red are lost earliest. It is only in rare cases that the disease begins with a central color scotoma. The light sense is usually normal as regards the limit of stimulus, but is generally impaired as regards the increment of stimulus. There is very little complaint of subjective sensations of light and color. As a rule, the disease is bilateral.

Sooner or later, the disease almost always terminates in blindness, although a standstill with tolerable vision is observed occasionally, even lasting for years. The prognosis is especially unfavorable when the malady is connected with spinal affections. Here the pupil is often narrow (myosis in so-called spinal amaurosis). Attention should also be paid to ataxia, characteristic pains, paralyses, etc. The disappearance of the patellar reflex, which Westphal has emphasized as an early symptom of tabes, may also be important in prognosis.

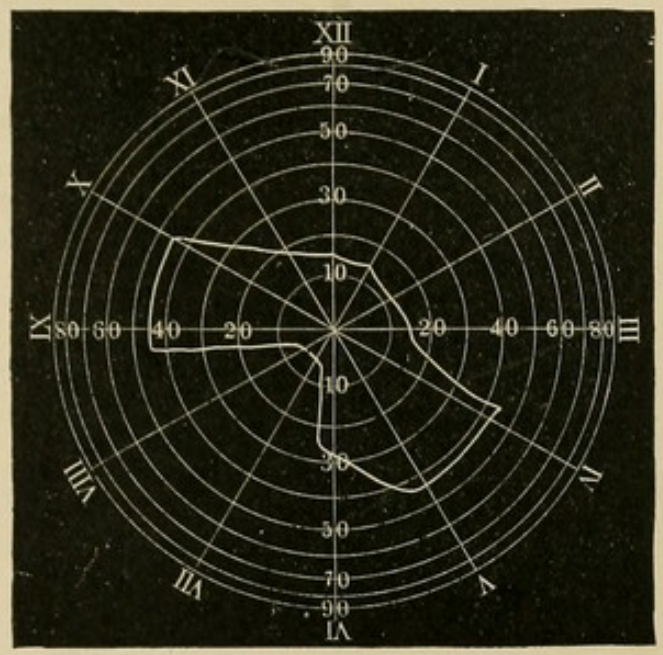


Fig. 104.—Right Eye.

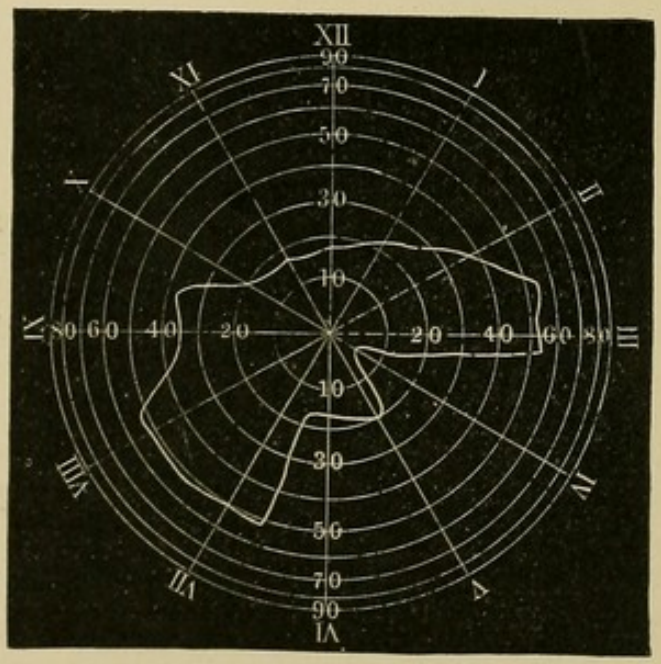


Fig. 104.—Left Eye.

The treatment must, above all, avoid exhausting influences. Mountain air, good diet, and the use of the constant current (the cathode being placed on the closed lid, the anode on the neck, or the current passed transversely through the head) offer the best chances. Among medicinal agents, silver nitrate and potassium iodide have been particularly recommended. I have seen better results from strychnine injections into the temples (Nagel) in those forms of atrophy which are of neuritic origin. Mercurial inunctions may be used in patients who have suffered from syphilis if we may assume the existence of syphilitic products (gummata which press upon the nerve) that are capable of resolution. But inunctions must be used very cautiously, if there is advanced atrophy of the nerve and other symptoms indicate a more diffused implication of the central nervous system. Vigorous mercurial

treatment is then very apt to accelerate the destruction of the visual power.

In cases of cerebral disease, we more often have to deal with a direct implication of the nerve, as in tumors of the base of the skull pressing directly on the optic nerve, in exostoses, gummata, internal hydrocephalus, chronic meningitis, and multiple sclerosis. Pronounced atrophy of the nerve generally develops after severe injuries to the head which nave produced amaurosis or amblyopia. In such cases fracture of the optic foramen with hemorrhage into the subvaginal space or direct bearing, which has been observed so often by Hoelder, may be regarded as the immediate cause (Berlin).

If cerebral congestions are at fault, derivative treatment (abstraction of blood, seton) is indicated. Mooren recommends later the internal administration of nitrate of silver.

In some cases there is no indication pointing to any of the etiological factors mentioned. The origin of this grave affection of the optic nerve sometimes appears to be found in habitual excesses or bodily and mental strain.

6. Excavation of the Optic Papilla.

Atrophic Excavation.

In some cases of atrophy of the optic nerve, the disappearance of nerve fibres is not covered by compensatory hyperplasia of the connective tissue, and a trough-shaped depression of the papilla is the result. This shallow depression is recognizable ophthalmoscopically by the fact that the blood-vessels pass in a gradual bend to the deeper parts of the papilla (Fig. 105). On account of the different levels at which they are situated in their papillary course, the vessels at the centre of the papilla appear paler and more indistinct on fixing the retinal vessels with the ophthalmoscope. The papilla itself shows the atrophic color.

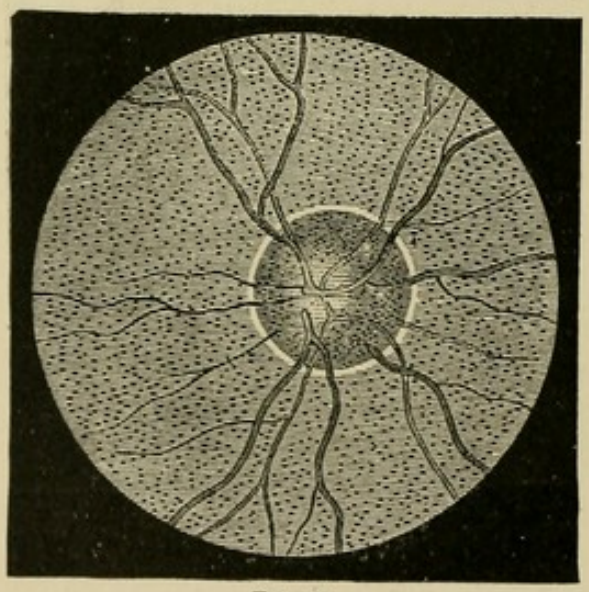


Fig. 105.

Pressure or Glaucomatous Excavation.

In glaucoma, the increase of intraocular pressure, which is associated occasionally with pathological diminution of resistance in the connective tissue of the papilla, displaces the lamina cribrosa backward and thus causes an excavation of the papilla (Fig. 106). This displacement of the lamina cribrosa is the decisive anatomical distinction from atrophic excavation in which the lamina cribrosa remains in its normal position. The excavation may have various shapes. It is usually kettle-shaped, but occasionally has, at its base, a second, central, funnel-shaped depression which corresponds to the position of the vessel canal; or a lateral depression resulting from a previously existing physiological excavation.

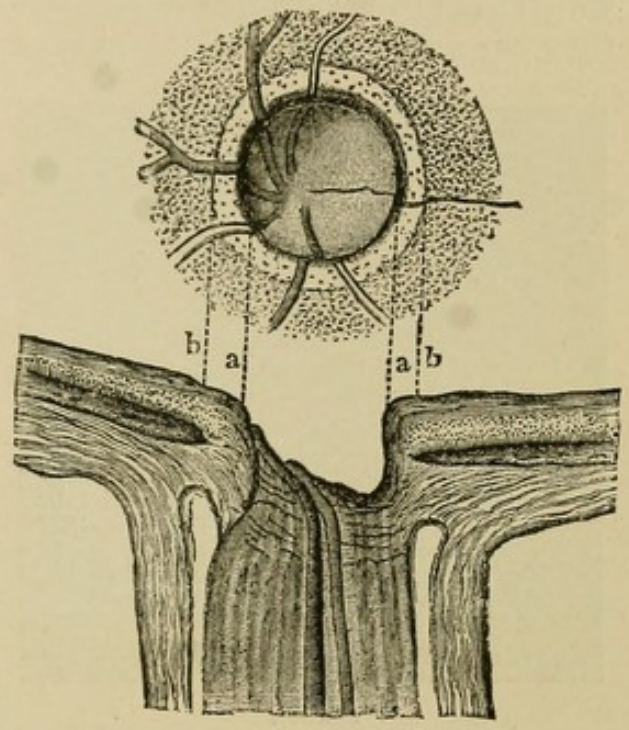


FIG. 106.

This excavation is lined by nerve fibres, which make a sharp bend at the edge of the retina, pass vertically down the side walls, and then cover the floor of the lamina cribrosa in a thin layer. After its long continuance, the stretched and compressed fibres undergo atrophy. The blood-vessels, which are usually pressed together toward the nasal side, also make a bend at the edge of the excavation and pass along the side walls to its base. The depth of the excavation may be 1.5 mm. or more; it is filled by the vitreous body.

It is characteristic of the difficulty of determining the level in the ophthalmoscopic image that this glaucomatous excavation was first described as a prominence. Heinrich Mueller's autopsy (1857) first showed with certainty that it was an excavation, although previous careful observations had raised doubts of the existence of a prominence (A. v. Graefe, Ad. Weber).

The beginning of the excavation is not easily diagnosticated ophthalmoscopically. The papilla still has a normal color, but is sometimes a little reddened. In rare cases extravasations of blood have been observed upon it. Often the centre of the papilla is first excavated, but the distinction from the often normally present

fovea in the middle of the papilla is difficult or impossible. Beginning pressure excavation cannot be diagnosticated with certainty unless a vessel makes a distinct bend at the edge of the papilla and its papillary end is situated demonstrably deeper than the retinal end. As a rule, this change of level is first seen in the vessels of the temporal side.

As the process advances, attention is attracted by the unusual course of the vessels on the retina. They all appear to be pushed toward the nasal side. The vessels, which normally passed straight up and down, now describe a curve whose concavity is directed toward the macula lutea (Fig. 107). The normally scanty branches which pass to the temporal side have disappeared almost entirely; they are only recognized with high magnifying powers and close attention. The arteries are narrower, the veins occasionally dilated and sinuous. But even the latter often undergo a diminution in size, especially in the later stages.

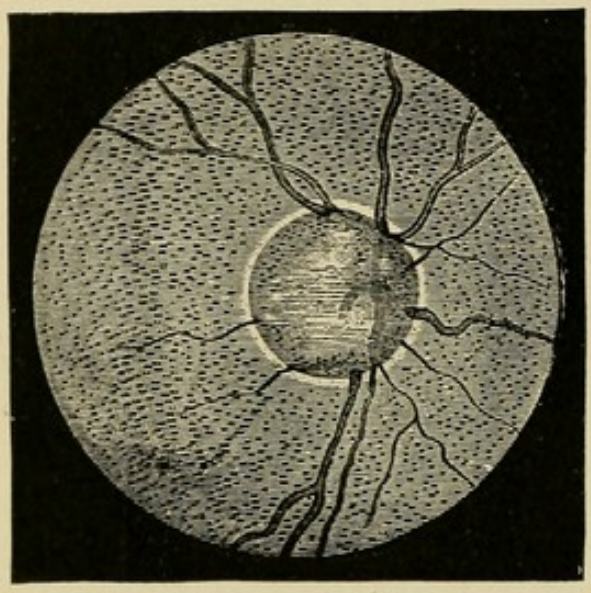


FIG. 107.

At the edge of the papilla, the vessels bend in a curve or angle. When the excavation is steep they appear to end at the edge; the veins often end in a bluish-black swelling. Their prolongation is then seen only upon the floor of the cavity, because they cannot be traced in their descent along a vertical lateral wall. Their course can be distinguished if the lateral walls are less steep, but they appear to be displaced and connected by an oblique middle piece. The terminal portions situated on the papilla itself are usually somewhat paler, of a light red color; it is often difficult to distinguish the veins from the arteries. A few finer branches, invisible in other conditions, occasionally make their appearance here. The point of exit of the vessels appears to be displaced to the nasal side.

The papilla itself gradually becomes paler, gray, bluish or white. On further atrophy the nerve acquires a slightly punctate appearance from the nerve bundles which pass between the lamina. When the excavation is pronounced, the nerve is surrounded by a quite narrow, grayish-white or yellow ring (Fig. 106, *ab*) whose development is due either to a simple atrophy of the choroid (Schweigger) or to an exudation situated between the atrophic choroid and the

retina (Haab, Kuhnt). Black pigment patches are seen occasionally here and there upon these atrophic parts. In the beginning the choroid atrophy develops chiefly on the temporal side.

Although the symptoms mentioned are, to a certain extent, characteristic of an excavation, we nevertheless need direct proof that the papilla is really excavated and situated deeper than the retina. For this purpose we resort to the previously mentioned auxiliary means of measuring the level.

Arterial pulsation can often be seen in compression excavation. This is shown by the alternating pallor and redness of the trunks of the central arteries, but often only in one branch. The pulse rarely extends beyond the border of the papilla. Its occurrence is explained by the fact that, on account of the increased intraocular pressure, blood can be forced into the compressed arteries only during the systole of the heart. The intraocular pressure will first occlude the calibre where the vessel, as upon the papilla, makes a bend in order to enter the trunk of the nerve as it passes backward.

This pulsation phenomenon is observed very rarely in the healthy eye. v. Graefe saw it twice in orbital tumors; Wadsworth and myself, during beginning syncope.

Apart from this form of pulsation with intermittent blood current, other peculiar pulsations have been described, as by Quincke in aortic insufficiency, by Becker in Basedow's disease, etc. Here the arteries of the papilla and also of the retina, particularly at their points of division, present small rhythmical swellings and sinuosities (occasionally associated with slight redness and pallor of the papilla) which are usually recognizable only with the high magnifying power of the erect image.

Differential Diagnosis of the Excavation.—In physiological excavation the entire papilla is never excavated as far as the edges. This is shown ophthalmoscopically by the condition of the vessels (vide Fig. 102). These pass from the retina for some distance across the papilla before they bend into the depth. This is particularly marked on the nasal side, while the excavation usually approaches the edge of the papilla on the side of the macula lutea; but it always remains shallow. There is no sharp curve and bend in the vessels.

Pronounced compression excavation, on the other hand, extends to the border of the retina. The bend in the vessels therefore appears distinctly at the edge of the papilla (vide Fig. 107). If a physiological excavation has already been present, the addition of the glaucomatous excavation may cause a double bend in the vessels at the edge and upon the papilla itself.

A diagnostic difference is also offered by the color of the papilla.

In physiological excavation the deepened part is paler, often even of a shining white, but the part situated at the level of the retina retains its normal reddish color. In compression excavation, at least in pronounced cases, the entire deepened papilla nowhere presents its original color, but looks pale or gray.

The tyro may perhaps make a mistake in view of the fact that, in compression excavation, the surrounding narrow grayish-white, yellow, occasionally even yellowish-red ring is apt to be regarded as part of the papilla. This may give rise to the opinion that the vessels do not bend at the edge of the papilla, but only, as in physiological excavation, after they have traversed a part of the papilla. This mere hint and increased attention are sufficient to cause the avoidance of this error.

The atrophic excavation has a narrow, trough-shaped cavity, which is often recognized with difficulty with the ophthalmoscope. When it develops in a more distinct form, especially when the atrophic excavation is added to a previously existing physiological excavation, the condition of the vessels also serves as a diagnostic factor between it and compression excavation. In the latter the vessels break off abruptly at the edge because the excavation is steep, in the former they pass gradually into the depth. Nevertheless, a doubt may still be left. In order to make the diagnosis, we must then pay attention to the annular choroidal atrophy in glaucomatous excavation—this is broad and more yellow than the physiological white scleral ring, which also appears more distinctly in simple atrophic papillæ on account of the disappearance of the nerve fibres—to pulsation phenomena and to the general morbid symptoms of glaucoma.

Finally, the attention of the beginner must be directed against mistaking glaucomatous excavation for staphyloma posticum. This may arise, perhaps, from the similar character of the general course of the vessels, viz., the displacement toward the nasal side, which here results from the oblique position of the optic papilla. The large white crescent, the extensive choroidal changes, the absence of flexion of the vessels at the edge (although slight bends may occur), guard us quite easily against this mistake.

7. Tumors of the Optic Nerve.

The orbital part of the optic nerve often presents tumors, which have either developed there primarily or extended to it secondarily from the orbital tissue. The tumor rarely extends forward to such an extent that it attacks the optic papilla as Jacobson observed in one case. The primary tumors of the optic nerve are chiefly

myomata or myxosarcomata and myxofibromata, more rarely scirrhus, carcinoma, psammoma, glioma and neuroma (Perls); the secondary tumors are mainly sarcoma. The tumor is situated occasionally within the external sheath, and the optic nerve passes through it without being implicated by it. The disease is comparatively frequent in childhood. Early blindness is characteristic when the tumors spring from the optic nerve itself. The globe is then pushed forward in the direction of the optic nerve and, unlike the majority of orbital tumors, is still easily movable. The papilla exhibits neuritis with more or less swelling or atrophy. In some cases it has been possible to extirpate the tumor, while leaving the globe intact (Knapp). On the other hand, a fatal termination, probably depending upon the retention of pus behind the globe, has been observed after this plan of operation.

CHAPTER IV.

DISEASES OF THE RETINA.

1. Hyperæmia and Anæmia of the Retina.

In hyperæmia of the retina we notice, in addition to increased redness of the optic papilla, dilatation of the retinal arteries, but particularly of the retinal veins which appear somewhat darker and sinuous. Slight blurring of the edges of the papilla is often present. But as there is quite a wide physiological range in the development of the vessels, and their shape in different individuals, a positive diagnosis cannot always be made. It can be made most readily when the hyperæmia is unilateral.

In inflammatory diseases of the eye (especially in iritis) hyperæmia often occurs as a complication. It develops likewise in errors of refraction which lead to asthenopic disturbances or after severe strain of the eyes; occasionally in cerebral affections, venous stases, cyanosis, and the first stages of constitutional syphilis. It is notably frequent in chronic anæmia (Jaeger, Raehlmann). Subjective symptoms are generally absent, occasionally there is photophobia and lack of endurance in working. The treatment must consider the causal factors. In addition, ocular hygiene, abstraction of blood and derivatives.

Anæmia of the retina (pallor of the papilla and narrowness of the retinal vessels) is observed occasionally in anæmic and leukæmic individuals, also during attacks of syncope. It is associated more frequently with processes in the optic nerve (neuritis) which effect compression of the blood-vessels. Here the arteries occasionally are remarkably narrow (vide Embolism of the central artery of the retina).

A yellow color of the retina and optic nerve (with hemeralopia and yellow sight) has been observed in jaundice (Hirschberg).

2. Retinitis Simplex (Retinitis Serosa).

The hyperæmia of the retina and papilla is here associated with a diffuse gray color of the tissues, of greater or less intensity. It is situated preferably in the vicinity of the optic papilla, whose edges

are occasionally so blurred that the entrance of the nerve is only recognized by the aggregation of the blood-vessels. In other cases there is merely a light veil over the red fundus oculi in the region of the optic papilla. But this cloudiness is also found at the macula lutea or in peripheral parts. The vessels in the slightly cloudy parts are usually distinctly visible, and the veins in particular appear as thick dark bands upon the grayish-white background. The arteries are sometimes narrowed as the result of compression, especially in the optic nerve. The vessels are occasionally covered as with a veil. As a rule, extravasations of blood are absent.

The diagnosis is not always easily made, because simple veiling of the fundus may also result from obstruction to the passage of light through the optic media. Thus, similar appearances are found in translucent diffuse cloudiness of the vitreous body or cornea; hyperæmia of the papilla and retina is not rare in such cases. It is to be noted as a differential factor that in retinitis simplex the opacity of the tissues only involves circumscribed parts of the fundus, while the entire fundus will appear quite uniformly veiled in diffuse opacity of the vitreous body.

In retinitis simplex, we chiefly find infiltration of the retina with serous fluid, although moderate escape of cells and slight parenchymatous changes, which are especially apt to appear later, are not excluded. But if these pathological changes appear ophthalmoscopically as intense opacities, tissue swellings, white patches, etc., it is better to regard the affection as retinitis parenchymatosa.

The patients complain that a mist is situated in front of objects and that their visual power is diminished. Disturbances of the light sense and of the field of vision may also occur. But these symptoms are not always proportionate to the appearances found ophthalmoscopically.

The prognosis is always serious because severe affections of the retina or even the optic nerve may be superadded. But complete or relative recovery may be expected if no advance of the disease is shown after prolonged observation. The cause of the retinitis is also an important factor. In addition to a few factors which will be mentioned later, strain, dazzling, cold, etc., have been mentioned as causes. The treatment varies according to the etiological conditions which have been discovered. In addition to protecting the eyes against strain and light, or even keeping in a dark room, we may recommend Heurteloup's leech, derivative treatment, sweating or mercurial treatment, according to the individual circumstances of the case.

Certain special forms of retinitis simplex also require consideration.

Retinitis Nyctalopica.—Under this name Arlt describes an affection which generally results from dazzling, and in which the ophthalmoscopic appearances are slight (slight cloudiness of the retina, obscuration of the borders of the papilla). The patients complain chiefly of dazzling, with only moderate impairment of vision and otherwise free field of vision. Objects at a distance appear in a light mist, the air in front of them appears to flicker. The affection develops quite rapidly and may last a long time. The ophthalmoscopic appearances usually diminish in the course of time. The treatment consists in sparing the eyes, protection against light, abstraction of blood, and mercurial treatment.

Retinitis Syphilitica.—The retinal affection *per se*, presents no changes which are so characteristic that the diagnosis of syphilis may be made from them alone. This is only made more certain from combination with peculiar affections of the choroid and vitreous body. At a very early period after infection, a certain degree of hyperæmia of the retina often appears, with slight blurring of the edges of the papilla (retinal irritation, Schnabel). This may pass into a more pronounced retinitis with opacity of the tissue, especially in the vicinity of the papilla. But the usually bilateral retinitis appears, as a rule, at a later period, one or two years after infection. It is apt to be associated with a tolerably translucent dust-like, diffuse opacity of the vitreous. The latter interferes with the diagnosis of retinitis which, as we have seen, presents, as a rule, few prominent changes (light patches and apoplexies are rare). Marked swelling of the papilla occurs only in exceptional cases. The macula lutea sometimes is alone affected (retinitis centralis, v. Graefe); it is then occupied by a gray opacity. Choroiditis and iritis are frequent complications. The choroiditis is situated especially in the equatorial region and leads to small whitish, atrophic patches, mixed with accumulations of blackish pigment. The intervascular spaces often appear distinctly on account of defects in the pigment layer. In central retinitis, choroidal changes are often seen at a later period in the region of the macula lutea. In rare cases there are extensive secondary deposits of black pigment on the retina (chorio-retinitis). In one case I observed, as the result of syphilis, the complete pictures of retinitis pigmentosa with corresponding changes in the optic nerve and vessels, and peripheral black patches of pigment like bone corpuscles, without any notable choroidal changes. Foerster and Schweigger have described similar findings.

In milder cases the patients suffer only a slight diminution of visual power (V $\frac{1}{3}$ or $\frac{1}{2}$), so that, if there are no external inflammations, they occasionally do not consult the physician until a late

period. In severe and complicated cases, especially when there is marked opacity of the vitreous, vision may be reduced to the recognition of the movements of the hand.

The field of vision is often interrupted. There are occasionally annular defects (Foerster) in which central vision is relatively intact, then follows a zone of poorer vision, while vision is again better at the periphery. In central retinitis a scotoma is found at the point of fixation. Complaint is often made of the perception of transparent patches and disks, which tremble to and fro. Occasionally there is micropsia (v. Graefe), a symptom found sometimes in other retinal diseases and dependent on the exclusion or separation of the perceptive retinal elements. Metamorphopsia (Foerster) has also been observed. Objects appear distorted, straight lines appear curved; the cause of this symptom is probably the same as that of micropsia. The metamorphopsia may continue even after the recovery of the disease. Hemeralopia is usually present.

In mild cases recovery may occur in six to eight weeks. Recovery which has not become complete in this period may gradually occur later. Other cases are very obstinate and there is also a tendency to relapses. Nevertheless a satisfactory degree of vision is finally secured, after proper, long-continued treatment, in many severe cases, if they are recent and present marked inflammatory symptoms (iritis, thick opacities of the vitreous), despite profound impairment of sight and marked defects in the field of vision. When the process has run its course, notable improvement of the existing visual power cannot be expected, if pronounced choroidal changes with secondary optic atrophy are present.

The treatment is antisyphilitic. I have had the same good effects from subcutaneous injections of corrosive sublimate (0.01) as from inunctions. But I prefer the latter—in large doses (4.0 daily, if necessary combined with the internal administration of calomel 0.03 twice a day)—when the process is complicated with thick opacity of the vitreous and iritis. Potassium iodide and sweat cures, do not offer the same advantages. But after the injection or inunction cure is finished, prolonged after-treatment with potassium iodide, either alone or in combination with hydrarg. biniod. rubr. is advisable. During the main treatment the patient should be kept in a dark room. Heurteloup's abstraction of blood is useful in full-blooded individuals.

Concussion of the Retina.—Peculiar œdematous opacities of the retina are sometimes seen after the action of blunt instruments (Berlin). In more or less extensive patches we find, instead of the normal red color of the fundus, a grayish-white color which occasionally extends in jagged prolongations into the surrounding red

region. Upon this grayish-white base, the vessels appear somewhat darker, more prominent and band-like. When the opacity is situated near the posterior pole, the macula lutea, as I have seen, may assume a yellowish, pale color, may lose its bright ring of light in the inverted image, and the fovea centralis may appear as a dark patch. Like Hock, I have also seen a hemorrhagic detachment of the retina at the macula. As a rule, all traces of the opacity disappear in a few days. Vision is usually impaired to a moderate degree (one-quarter to one-third the former vision). I have also found diminution of the sense of light in the cases examined as to this point. The subjective symptoms disappear, as a rule, in the course of a week. Spasm of accommodation is also observed occasionally as the result of contusion of the globe, and may be associated with traumatic mydriasis or myosis. The impairment of vision is not due, as Berlin assumed, to irregular astigmatism of the lens, developing suddenly from small hemorrhages into the ciliary body, but to an affection of the retina. This view is favored by the diminution in the sense of light. Moreover, I have convinced myself with the ophthalmoscope that there is no irregular astigmatism of any moment. According to Berlin's experiments on animals, small hemorrhages are found between the choroid and sclera in the places where the œdema of the retina develops. The impairment of vision is sometimes increased by slight opacity of the cornea often visible only on focal illumination and composed in part of irregular figures, or by opacity of the fluid in the anterior chamber. Spontaneous recovery is usually aided by rest of the eye, atropine, and cool compresses.

Macular Retinitis from direct Sunlight.—At the time of an eclipse of the sun, patients appear quite constantly who suffer from disturbance of sight as the result of looking directly at the sun. At first a marked central obscuration of the field of vision occurs, but this usually diminishes until, finally, only a slight cloud covers the point of fixation (central scotoma). A certain flickering is often present in the same locality; at the fixation point colors appear duller and less pronounced. But, as a rule, true color-blindness is not demonstrable, at least after vision has been restored to a certain extent. On careful examination with the ophthalmoscope, only a slight change can be seen in the centre of the macula lutea. With Haab and Deutschmann, I also found, at the site of the well-known image of the fovea, a dark, somewhat broad spot, occasionally without a light ring, which was very similar to an extravasation of blood, although I did not venture to characterize it as such. This change depends on direct cauterization of the layers of the retina by the sunlight, as has been proven by experiments on animals

(Czerny). The prognosis depends on the severity of the injury, but even transparent scotomata may last for years. The treatment consists of removal from light, abstraction of blood and derivatives. Strychnine may be tried later.

3. Retinitis Parenchymatosa.

In parenchymatous retinitis, circumscribed changes, in the shape of white or whitish-yellow patches and lines, are observed, in addition to the hyperæmia and opacity of the tissues found in retinitis simplex. Hemorrhages are not at all uncommon. On account of the more extensive implication of the tissues, the course of the vessels seems to be blurred or even completely interrupted. The arteries are sometimes narrowed and less full on account of compression. Thickening of the walls of the vessels (retinitis perivasculosa) may also be produced by hypertrophy of the adventitia. The appearance is then changed so that the narrow red line of blood is bounded on both sides by whitish lines. As a rule, the optic papilla is implicated. It is either simply cloudy and congested, and its boundary against the retina disappears, or it swells and projects somewhat above the level of the retina, so that true neuroretinitis develops.

The anatomical changes show themselves chiefly in proliferation of Mueller's radial fibres, hypertrophy and sclerosis of the nerve fibres, fatty degeneration, the occurrence of inflammatory exudations and hemorrhages.

Mueller's radial fibres are elongated, thickened and sclerotic. In connection with proliferations of the external granule layer, this produces a nodular elevation of the layer of rods and cones in circumscribed places. This occurs particularly in the vicinity of the optic papilla and, in part, causes the protrusion of the borders of the papilla.

The nerve-fibre layer in the retina and optic papilla, may undergo hypertrophy. In addition to a uniform distention, the non-medullated fibres also present circumscribed club-shaped swellings, which resemble ganglion cells and at first were described as sclerosed ganglion cells (Zenker, Virchow). H. Mueller, however, demonstrated their origin from nerve fibres. These ganglioniform degenerations often appear in foci.

The fatty degeneration affects partly Mueller's fibres, partly the granule layers in which foci of fat granules are deposited.

After hardening the eye, coagulated shining masses are found in the retinal tissue, partly infiltrated with lymph-corpuscles. Extravasations of blood are not rare. The vessels are, in part, dilated, particularly the veins and capillaries; a new formation of

vessels also occurs. The walls of the vessels of the retina and choroid often present sclerotic infiltration.

The white patches visible ophthalmoscopically, are caused in part by heaps of fat granules, in parts by nests of sclerotic and hypertrophied nerve fibres. The linear white opacities may depend on fatty degeneration of the inner ends of the radial fibres.

The chief subjective symptom is poor vision. As a rule, the field of vision is not narrowed, the sense of color and light is not disturbed. The patients often complain of a sort of misty vision; subjective light sensations also occur. Micropsia and metamorphopsia are rare.

The course is usually very tedious, the prognosis as regards improvement of sight is very doubtful and depends on the extent and etiology of the process. But instances of complete recovery have been observed. Improvement and exaccerbations often alternate. Finally atrophy of the retina and optic nerve may develop. The form of retinitis which occurs in acute nephritis (usually after scarlatina) promises the most favorable outlook.

Etiology.—Parenchymatous retinitis occasionally results from retinal hemorrhages or choroiditis. It occurs very often in albuminuria, and is also observed in diabetes, leukæmia, and anæmia. It then assumes a form which is sometimes characteristic to a certain extent of the primary disease, which will be separately discussed later. The cause often remains unknown.

Treatment.—We must secure complete rest of the eye, and the avoidance of bright light. At the beginning of the disease, if the general condition permits, we may recommend a several weeks' stay in a dark room with frequent application (about once or twice a week) of Heurteloup's leech. In order to ascertain the effect of the abstraction of blood, vision should be tested two days later. If no improvement has occurred after two applications, the further removal of blood may be discontinued. Sweat cures, mercury or potassium iodide are also employed at times. In anæmia or albuminuria we must forego the stay in the dark room and abstraction of blood. Here those measures alone are indicated which promise good results to the general condition. In order to obtain a certain degree of local derivation, we may use Arlt's forehead ointment or apply tincture of iodine to the forehead and temples.

Retinitis Albuminurica.—The parenchymatous retinitis (as a rule, bilateral), which occurs in albuminuria, sometimes appears in such a characteristic form that the primary disease may be diagnosticated from it alone with great probability. Indeed, cases are not uncommon, in which the renal affection is first recognized with the ophthalmoscope.

In the immediate vicinity of the papilla, we find white figures which sometimes radiate into the retina in the shape of sectors (like the double-contoured nerve fibres) (vide colored plate, Fig. 3). They may coalesce and surround the entire papilla with a broad whitish fringe which makes smaller convex curves at the periphery. The vessels are in part visible upon the patches, in part they disappear upon them, or become indistinct. The veins are full and sinuous. Smaller whitish, usually shining patches are also found at a greater distance in the red of the fundus oculi. The papilla is hyperæmic and its borders blurred. The region of the macula lutea is particularly characteristic. It is inclosed by fine white points or lines. The appearance is similar to that produced by throwing white paint with a brush upon a red gronud. Round a radial, cherry red and reddish-brown hemorrhages are found in various parts of the retina. Apoplexies are often seen on the papilla. In some cases the papilla takes a very active part in the process; we find upon it marked opacity of the tissues, also white patches and numerous extravasations of blood. The swelling may be so considerable that it projects like a mushroom; we then have to deal with pronounced neuroretinitis.

But that even the typical form of the ophthalmoscopic image does not absolutely justify the diagnosis of albuminuria, is shown by a case described by G. Wegner and me, in which these appearances were found in a cerebral tumor without albuminuria. Jacobson saw it in diabetes without albuminuria.

Forms of retinitis which present nothing specially characteristic, also occur quite often in albuminuria. Thus, there may be retinitis simplex with a few hemorrhages or very scanty white patches. I have also observed a case in which at first there was only a very slight change in the region of the macula. The latter was surrounded by a border zone which looked as if lightly dusted; white points were not visible. It was not until later that the characteristic appearances developed.

Detachment of the retina may also appear as a complication (v. Graefe, Brecht, Landesberg). In very rare cases the disease is confined, in albuminuria, to the optic papilla (neuritis). The microscopic appearances have been described in general; the peculiar appearance of fine lines and points, which surround the macula, is caused by fatty degeneration of the ramifications of Mueller's radial fibres, which converge toward the macula.

Retinitis is not rare in albuminuria; Frerichs found it in about thirteen per cent of the cases. It usually accompanies chronic renal diseases (Bright's diseases, cirrhotic kidney, waxy degeneration), but is also observed in acute nephritis after scarlatina and in

the nephritis of pregnancy. Diabetes and chronic lead poisoning, when albuminuria is also present, may give rise to the same ophthalmoscopic appearances of retinitis.

The cause of the retinal affection cannot be attributed, as Traube believed, to hypertrophy of the left ventricle, which is supposed to give rise to the hemorrhages as the primary affection. Hypertrophy of the heart is absent in a series of cases. Nor are hemorrhages always present in the very first stages of retinitis albuminurica. The retinitis seems rather to be the result of a chronic uræmia (v. Graefe, Leber), and this view is favored by the frequent presence of headache and nausea. Moreover, true uræmic attacks with uræmic amaurosis are observed occasionally. According to the investigations of Duke Charles Theodore, the first local changes, as the result of this alteration of the blood, is an arteritic process which is demonstrable in all the vascular parts of the eye. The occurrence of retinitis in chronic nephritis is usually of evil omen. The patients die, as a rule, in a few months to one or two years. The visual disturbances are more or less pronounced, but may diminish to a certain extent. Complete amaurosis is very rare.

Retinitis Leukæmica.—In leukæmic patients, as was first described by Liebreich, the retinæ of both eyes are sometimes opaque. The light color of the blood causes a pale red to pale yellow color of the entire fundus. The vessels also appear lighter, the veins are sinuous and inclosed by white lines. The extravasations of blood also have a lighter color. In addition, we find white round patches, which are due in part to the above-mentioned fatty degenerations and sclerotic changes in the nerve fibres, in part to accumulations of lymph-corpuscles. The choroid also presents infiltration with white blood-globules and marked dilatation of the vessels.

In other cases, however, the light or yellow color of the fundus and blood-vessels, which has been regarded as characteristic, I have found to be absent in a number of cases, despite the presence of hemorrhages and retinal opacity. The visual disturbances correspond to the local site of the disease; when the periphery alone is affected, as is usually the case, these symptoms are slight. In Becker's case, in which the macula was affected, there was central scotoma with metamorphopsia.

Retinitis albescens punctata s. striata (Mooren, Kuhnt) is the term applied to a form of parenchymatous disease of the retina in which a number of small punctate or linear, white, often shining patches, make their appearance. They may be confined to the vicinity of the macula lutea, or even involve the macula. Central scotoma was often observed. The prognosis as regards improvement of vision seems to be tolerably favorable.

4. Hemorrhage of the Retina.

Retinitis Hemorrhagica.

Hemorrhages into the retina appear as cherry red or brownish-red patches. Their color is always darker than that of the normal fundus oculi. The diagnosis of apoplexies is therefore easy, except that it is sometimes difficult to recognize them at the macula, which is itself darker. The differentiation between hemorrhages into the retina and choroid, is also occasionally attended with difficulty. After a time, the dark tone of the color is usually intensified. When larger patches are absorbed, a dark line, corresponding to the periphery, is often found as the last remains. In other cases, white patches or blackish spots form at the site of the former apoplexy. Choroidal changes—small white dots and black patches—also may develop secondarily. The hemorrhages have various shapes, round, irregular, often linear. The latter shape, which results from the radiations of Mueller's radial fibres, is not found in choroidal hemorrhages. The number of hemorrhages is more or less large. Sometimes there is only a single one which appears to occur preferably in the region of the macula lutea where it makes itself manifest by a distinct central scotoma. Small peripheral hemorrhages produce hardly any symptoms and usually escape the patient's notice entirely. Occasionally complaint is made of "scintillations." Small hemorrhages are found with comparative frequency in anæmic and leukæmic individuals. In anæmia they are sometimes associated with cloudiness of the papilla, in the highest grades with pronounced retinitis and opacity of the retina, which may even lead to amaurosis (Hirschberg).

Hemorrhages, associated with a pale and cloudy papilla and marked distention of the veins, often occur in pernicious anæmia (Horner, Biermer, Quincke). They often, though not always, show a white centre which consists of an accumulation of lymph-cells (Manz). On the other hand, this white centre is not characteristic. I have also seen it, for example, in splenic leukæmia. Litten has also observed it in some of the cases of retinal apoplexy which he found in septicæmia. Here the hemorrhages occur, as a rule, shortly before death, at the most fifty to sixty hours. They are also associated with pronounced septicæmic retinitis (Roth).

Hemorrhages are also observed in menstrual disorders, heart disease, hepatic affections, congestive conditions, atheroma of the arteries, scurvy, purpura hemorrhagica, etc. I have also seen it in diabetes. We sometimes have to deal with local changes in the walls of the vessels as, for example, in the hemorrhages which occur

spontaneously or after iridectomy in glaucomatous eyes. Injuries to the eye also cause extravasations of blood.

The hemorrhages may undergo complete absorption. In other cases it is followed by retinal atrophy which is either partial or general. This may also be associated with atrophy of the optic nerve and marked narrowing of the vessels. Secondary glaucoma is also to be dreaded, especially when the hemorrhages are numerous. But, as a general thing, these serious complications only follow very pronounced retinitis hemorrhagica.

The treatment depends on the causation. In addition to derivation to the intestinal canal, cold or a compress and bandage are indicated locally at the start, especially after injury. Later, tincture of iodine may be applied in the neighborhood of the eye. We must be cautious in the use of atropine, in order to avoid accelerating the outbreak of a secondary glaucoma.

RETINITIS HEMORRHAGICA.—When the implication of the retinal tissue is more pronounced, the process is called retinitis hemorrhagica (Liebreich). Here there is marked opacity of the tissues in addition to the apoplexies. The edges of the papilla are blurred, occasionally unrecognizable; masses of blood are situated not infrequently upon the reddened or cloudy papilla. The retinal arteries are usually narrow, the veins dark and sinuous. The hemorrhages are more or less numerous; their main site is generally around the posterior pole of the eye. White patches are sometimes seen.

The causal factors, apart from those mentioned above, consist chiefly of diseases of the vessels and heart. I have also seen hemorrhagic retinitis in orbital tumors. Some of these cases resulted probably from embolic processes.

Venous thrombosis is also a cause, as Michel demonstrated by an autopsy (thrombosis of the central vein of the retina in the optic nerve). According to Michel, the hemorrhagic retinitis dependent on thrombosis develops quite suddenly, with marked impairment of vision which again improves, if only for a time. But observations made by Angelucci, prove that retinal hemorrhages do not always result from thrombosis of the central vein. In the large majority of cases the affection develops on one side.

On the whole, the prognosis is unfavorable in extensive retinitis hemorrhagica; moreover, relapses often occur. It may also terminate in atrophy of the retina and optic nerve; secondary glaucoma follows not infrequently. Absorption may be looked for when the foci are small.

The treatment is similar to that of retinal apoplexy. We must secure quiet, ocular regimen; in the beginning, stay in a dark room, abstinence from stimulants, regulation of the bowels, and, if the

general condition warrants, derivation to the intestinal canal. Local abstraction of blood, inunctions of Arlt's forehead ointment, applications of iodine, or injections of ergotin may also be tried.

5. Pigment Degeneration of the Retina.

(*Retinitis Pigmentosa.*)

Pigment degeneration of the retina presents a very typical picture both as regards the ophthalmoscopic appearances (Fig. 108) and the symptomatology.

Small intensely black figures, chiefly at the periphery of the retina, partly in the shape of bone corpuscles with communicating prolongations, partly as small lines or dots. Larger black patches are very rare. The black lines are often situated close to the walls of the vessels; in other places they lie upon the vessels and conceal them. Their location in the retina is thus proven. The covering and concealment of the retinal vessels is the most important sign for localization, because, on account of the thinness of the retina, there is hardly any other way in which we can diagnose with certainty whether a patch of pigment is situated in it or upon the choroid. When the process is more extensive, pigment is also seen toward the posterior pole of the eye; with few exceptions the immediate vicinity of the optic papilla and macula remain free. The papilla itself is atrophic, pale yellow, and has a waxy appearance; it often appears diminished in size. Its edges are distinct. Shining bright lines and dots (enlargements of the vitreous lamella of the choroid) have been observed occasionally in its vicinity (Nieden, Aucke). The vessels present a very characteristic change. On account of the thickening of their walls their calibre is so narrowed, that they form narrow red streaks which sometimes can hardly be followed into the peripheral ramifications. The narrowing is most striking in the arteries. The stroma of the choroid appears normal; occasionally the choroidal vessels can be seen more distinctly in certain parts, on account of slight pallor of the pigment epithelium.

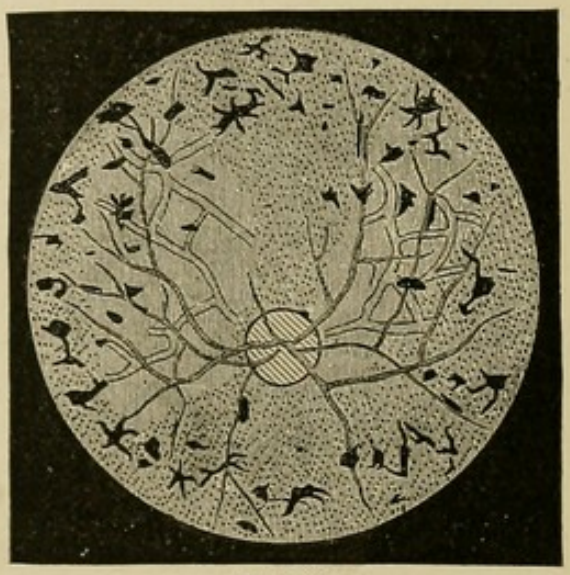


Fig. 108.

More extensive and prominent changes in the choroid (white patches, black pigment accumulations) are absent. Threads and specks are sometimes found subsequently in the vitreous body, and opacities at the posterior pole of the lens may also occur occasionally. Externally the eye looks normal. I have often been struck by the abnormally high tension.

Pronounced pigmentation is sometimes absent at the beginning of the disease. There are even cases which exhibit only the characteristic changes in the vessel and the papillary atrophy in addition to the clinical symptoms; these have been described as *retinitis pigmentosa sine pigmento.*

With rare exceptions, both eyes are attacked in typical cases. At first the subjective symptoms consist chiefly of hemeralopia. The patients complain that they see very poorly in twilight, and cannot even find their way. It is extremely rare that this hemeralopia, which depends upon torpor of the retina, is entirely absent. The statements of such patients that they see better in the twilight are due in part to "blinding" phenomena which are the result of complications, for example, partial opacity of the lens (Leber). Examination of the light sense also shows torpor of the retina. Narrowing of the field of vision occurs, usually of a concentric character. This does not always correspond strictly to the site of the pigment spots. Donders proved that certain parts occasionally do not perceive light, although they exhibit no pigmentation. For this purpose, he employed the ophthalmoscopic examination in such a way, that he threw a distinct image of the flame upon the part to be examined. Central vision then remains comparatively good at the beginning. Thus, there are not a few patients who can still read small print, and have a visual power of one-quarter to one-half, and yet cannot find their own way very well. Their vision may then be compared to that of a healthy individual who closes one eye and holds a paper roll in front of the other. On looking through the latter he can see distinctly everything situated directly in front of him, but objects situated on the sides are excluded, and thus free and rapid movement is interfered with. In exceptional cases, the narrowing of the field of vision is not concentric, but there is a zonular defect of the field (v. Graefe). With the increasing narrowing, central vision gradually diminishes more and more, until finally amaurosis develops. The color sense is only diminished in the later stages. Once I observed distinct blue-yellow-blindness.

Anatomo-pathological investigations have shown, that the layer of rods and fibres suffers particularly (Leber, Landolt), and is sometimes entirely destroyed. The inner layers as far as the ganglion

layers may also be destroyed. The nerve-fibre layer remains intact longest. The destruction of the nervous elements goes hand in hand with marked hyperplasia of the connective tissue, especially of Mueller's radial fibres. The walls of the vessels are thickened and have a homogeneous shining appearance (sclerosis). Pigment is often found in the walls. The characteristic feature of this affection, the deposit of pigment in the retina itself, results from the migration of pigmented cells or the entrance of diffuse pigment. This originates at circumscribed parts of the pigment epithelium where adhesions form, at the same time, between the epithelium and the retina. In some of these places the pigment epithelium is entirely absent, in others it had lost its pigment. But since the destruction of pigment epithelium is only moderate in the majority of cases, as can be shown ophthalmoscopically, a further proliferative process of the pigment cells in the retina itself must be assumed. Perhaps the walls of the vessels themselves also take part in the formation of pigment. The optic nerve is atrophic, its fibres show fatty degeneration (Guaita); the atrophy may extend finally beyond the chiasm. Berlin's investigations are of interest with regard to the etiology of this disease. After division of the optic nerve and ciliary vessels in animals, he noticed emigration of pigment into the opaque and atrophied retina. In retinitis pigmentosa, also, the narrowing of the vessels and the consequent diminished supply of blood form a very early symptom.

Occurrence and Course.—The disease is in part congenital, in part acquired in early childhood (before the tenth year). Pigment degeneration also develops in later years, in some cases of congenital amaurosis (Mooren, Leber). It then passes through the above-described series of subjective disturbances, usually with progressive impairment, so that blindness is complete at the age of fifty. In some cases, on the other hand, a certain degree of visual power is retained longer, even permanently. A patient under my observation, who had presented hemeralopic symptoms as a boy of six years, had, at the age of fifty-two years, V $\frac{1}{3}$ and $\frac{2}{9}$ with concentric narrowing of the field of vision up to ten degrees, on the average, around the point of fixation. Two brothers, the youngest of whom had served as a soldier, were hemeralopic as children. The one, æt. 37 years, had V $\frac{5}{8}$ and $\frac{5}{12}$; the other, æt. 50 years, had V $\frac{1}{4}$ and $\frac{1}{30}$. The field of vision was free in daylight, but narrowed when illumination was poor. Indeed, it happens not infrequently that individuals suffering from retinitis pigmentosa are drafted for military service.

Complications with congenital deformities and difficulty of hearing are not uncommon. Pigment degeneration of the retina is often found in deaf mutes.

The affection is due in part to heredity, even in the wide sense that the parents may suffer from other but similar diseases of the eye, for example, unilateral atrophy of the optic nerve. Several children are sometimes attacked in the same family. Liebreich has called attention to the factor of blood relationship between the parents. This is difficult to prove, because we do not know in what proportion of marriages in general the couples are related to one another. Nevertheless, the frequent relationships found to exist between the parents, is a striking fact.

In the later stages of syphilitic retinitis, the ophthalmoscopic appearances may be exactly like those of typical retinitis pigmentosa. But such cases are extremely rare.

As a general thing, extensive changes develop in the choroid (chorioretinitis), when a deposit of pigment takes place into the retina. A few cases of unilateral typical pigment degeneration have also been observed. I have seen one patient who, without previous syphilis, presented the described appearances completely in one eye. In such cases, however, the clinical history is different; the disease begins quite acutely and the concentric narrowing of the field of vision does not always occur in a regular form. Hemeralopia, however, is present. See colored plates for the ophthalmoscopic picture of the disease.

[I once saw the thoroughly typical picture of retinitis pigmentosa, except that some very fine white lines appeared in the choroid (choroidal rents). The blindness existed since childhood. From the statements made it was probable that the choroidal rents resulted from the unfortunate application of the forceps during delivery. The injury that may occur occasionally in this way, is shown by Steinheim's case in which the globe was forced completely out of the orbit as the result of application of the forceps.]

As a general thing, treatment is powerless. Improvement has been secured in a few cases by the constant current (Dor), abstraction of blood (Mooren, H. Pagenstecher), sweat cures (Schiess, Mayerhausen). Injections of strychnine have sometimes appeared to me to be useful. But it cannot be supposed that the advance of the disease can be permanently prevented by these agents.

[The disease remains stationary, however, in many cases for years, and this without treatment.—St. J. R.]

6. Retinitis Proliferans.

In retinitis proliferans we find, with the ophthalmoscope, white, shining and folded projections on the retina, which occasionally permit the red fundus oculi to shine through between them. Blood-

vessels usually run in the depth of the folds, and their course and calibre do not always correspond to those of the normal retinal vessels. The papilla is often invisible because it is covered by the proliferations. The affection is distinguished from detachment of the retina by the fact that the folds are very steep and project sharply against the vitreous body, like the ridge of a mountain. The condition of the vessels also differs from that in detachment of the retina; in part, it is true, they pass across the surface of the new formation, but in part they pass through the tissues. Hemorrhages are almost always present in the vitreous body and retina and may subsequently give rise to pigment patches; the iris is occasionally colored green. The visual power is diminished, the field of vision correspondingly interfered with. The disease may undergo resolution. Mercurial inunctions and Heurteloup's leech have been found useful. In a case examined anatomically, in which phthisis had finally developed, Manz found a chronic inflammation of the retina, with connective-tissue proliferations starting from its inner surface; the nervous elements were destroyed, the retinal vessels somewhat increased in number.

7. Detachment of the Retina.

(*Amotio s. Sublatio Retinæ.*)

As a rule, extensive detachment of the retina is easily recognized with the ophthalmoscope. If light is thrown into the pupil with the mirror and movements are made with the eye, we can see at a certain distance (about thirty centimetres) that the red color of the pupil is changed, in certain positions of the eye, into white or into a whitish-blue or gray. On approaching more closely, we also recognize vessels upon the whitish part (vide colored plate, Fig. 6). As the detached retina is moved forward, it is situated in the same position as in a markedly hypermetropic eye. In this case as in that, we recognize the details of the fundus easily at a certain distance. On more careful observation, it is seen that the color of larger detachments is usually not uniformly gray, but contains darker lines and streaks, which correspond to the formation of folds in the separated membrane. In these cases we also notice a to-and-fro movement of the membrane. The detachment of the retina may be positively diagnosticated from these details. The above-mentioned differences of color, which appear on movement of the eyes, may also occur in extensive choroidal atrophies, etc.

If the detachment is small and tense, or if the exudation behind the retina is more transparent, the change of color, as well as the

formation of folds, do not appear distinctly. Here the diagnosis must be made chiefly from the difference of level between the adjacent and detached retina, and best in the inverted image ($+\frac{1}{2}$ or $1\frac{1}{\infty}$). The edge of the detachment is fixed and the parallactic displacement on movement of the convex lens is noted. The vessels upon the detached parts usually have a characteristic appearance. They have a dark blue and bandlike appearance; in some places they come to the surface, in others, they become more indistinct and concealed.

Long standing detachments of the retina are particularly found in the lower half of the globe. Even those which were formerly situated above, cause detachment of the lower parts of the retina by sinking of the exudation. The detached retina sometimes hangs over the papilla like a veil, and covers it partly or entirely. In total detachment, which can usually not be seen ophthalmoscopically on account of other secondary changes, the retina is attached only at the papilla and ora serrata. It thus forms a sort of funnel, in which lies the shrunken vitreous body.

Rents in the detached retina are recognized by the somewhat everted edges and by the shining through of the reddish choroid. Opacities of the vitreous are often present, seen partly as flakes and in a circumscribed form, partly more diffuse, so that their presence is chiefly diagnosticated by the indistinctness of the ophthalmoscopic image. It appears that this diffuse opacity is especially apt to occupy a narrow space in detachment of the retina and is situated chiefly at the site of the detached retina. This explains the striking fact that we often see the details of the detached retina only indistinctly and mistily, while the adjacent retina stands out in a normally distinct manner.

The exudation beneath the retina is usually serous, rarely bloody or purulent. The hemorrhagic exudation is characterized by the dark red color, the purulent by the yellow color of the detachment. After long duration of extensive retinal detachment there follows, as a rule, secondary formation of cataract—usually appearing as a shrivelled yellow cataract—and chronic iritis and irido-cyclitis with grass-green discoloration of the iris. At the same time, the globe becomes softer, a change in consistence which is by no means always demonstrable in fresh detachments.

In recent detachment of the retina, we find anatomical changes chiefly in the layer of rods. These exhibit bends, prolongations or complete destruction. At a later period the inner layers are attacked, and the nervous elements are destroyed after hypertrophy of the connective tissue. The detachment is usually preceded by a separation of the vitreous body from the retina; the free space

between it and the retina which results from the diminished volume of the vitreous body is filled by a fluid exudation (Iwanoff).

As a rule, the visual disturbances set in quite suddenly. The patients often say that a dark cloud was situated in front of objects. Occasionally photopsiæ (fiery balls, etc.) have appeared for a few days previously. Impairment of vision is found corresponding to the site of the detachment. Defects in the field of vision, which were not demonstrable by daylight, may appear on examination by the light of a lamp. In detachments of long standing, there is usually a pronounced deficiency even for quantitative perception of light. When the detachment is at all extensive, central vision usaully suffers even if, as often happens, the macula does not fall directly within the detached part. In addition, there is pronounced torpor retinæ. Marked diminuton of the light sense is almost always present. Metamorphopsia is also observed. Disturbances of color perception are not demonstrable in all cases; green is often mistaken for blue (Dimmer). Subjective sensations of color sometimes annoy the patient and may persist for a long time.

On the whole, recovery in detachment of the retina is rare. It may occur from absorption of the subretinal fluid or its breaking through into the vitreous body. Detached parts of the retina may also be reapplied from sinking of the fluid and may again perform their function. In exceptional cases, this application and separation alternate continually for weeks. Small detachments sometimes remain stationary for many years without notable impairment of vision. In the majority of cases, however, vision constantly diminishes and incurable blindness results.

Etiology.—Among the causes of detachment of the retina may be mentioned: 1. Injuries. Thus, blunt force applied to the globe (flying corks of soda-water or champagne bottles, blow with a piece of wood, etc.); perforating wounds of the sclera which cause immediate detachment if there is a great loss of vitreous humor, or may produce detachment later from cicatricial contraction if the retina is healed into the cicatrix. Even simple choroidal ruptures may give rise eventually to detachment of the retina (Saemisch, Knapp). It also occurs occasionally long after cataract operations (especially with peripheral wound and cystoid cicatrization). 2. Advanced myopia. As a rule, changes in the choroid and opacities of the vitreous body are present. Both eyes are sometimes affected in succession. 3. Tumors of the retina and choroid not infrequently give rise to a subretinal exudation which separates the retina. The diagnosis of tumor is favored by marked increase of intraocular pressure. 4. Retinal cysticerci. The round shape of the

detached part, a peculiar glimmering white color at the periphery, movements of the worm, and occasionally the shining through of the head, serve for the diagnosis. 5. Inflammations of the orbital adipose tissue. 6. Chronic choroiditis, iridocyclitis, and diseases of the vitreous.

But in an entire series of cases of suddenly developing detachment of the retina, none of these etiological factors were discovered. A warm bath (Becker) and colds, are sometimes mentioned as the exciting cause in old people.

The mechanical development of detachment of the retina is not easily explained in all cases. If a large amount of the vitreous humor escapes, the retina may be separated by exudation from the choroidal vessels or by hemorrhages. Thick connective-tissue strands in the vitreous body, which form occasionally around foreign bodies or after severe inflammations, may also lift the retina from the choroid by traction when they are connected with the former (H. Mueller). But in the majority of cases of retinal detachment which can be diagnosticated ophthalmoscopically, such grosser changes are not present. To explain these most frequent forms, the most plausible theory would be that of increased secretion on the part of the choroid lifting up the retina. But this is antagonized by the influence of intraocular pressure, which presses the vitreous body against the retina. It is only when the vitreous suffers rapid absorption, that the retina can be detached by a choroidal exudation, without any great increase in the general ocular contents. Leber has made observations, which make probable the occurrence of traction from the vitreous body. He found, with the microscope, that in retinal detachment the vitreous is traversed by very fine slightly wavy fibrillæ, which are collected in places into stronger bands, radiate toward the retina, and pass particularly into the retinal folds. According to him, these bands, which are ophthalmoscopically invisible as such, exercise traction on the retina and cause its rupture. Indeed, in recent retinal detachment he very often found perforations with the ophthalmoscope, particularly in the equatorial parts. The vitreous body or the exudation lying between it and the retina, is supposed to enter through these retinal ruptures and cause further separation. In this way the sudden occurrence of large retinal detachments without notable changes of intraocular pressure may be explained. But even without this intermediate step of retinal rupture (which is often absent), the detachment may be attributed to traction exercised from the vitreous, in view of these microscopical findings and of the just-mentioned partial changes in the vitreous which are not infrequently demonstrable with the microscope. The choroidal exuda-

tion which occurs at the moment of detachment of the retina, must result in a certain increase of pressure, but this may remain within physiological limits, if the contents of the globe have been diminished by previous shrinking.

The treatment of retinal detachment, especially when recent and not too extensive, is not as hopeless as was formerly believed. At all events a trial is urgently indicated and sometimes leads to results which have hardly been hoped. Improvement of vision is often effected, but this is sometimes due merely to the greater clearness of the vitreous. But temporary, occasionally even permanent reapplication of the retina, may also be secured. The simplest measure is the application of a compress and bandage to the eye (Samelsohn) and rest in bed. But the explanation of the advantages of the bandage, offered by Samelsohn, does not appear to be correct. According to him, when there is a sudden diminution of pressure in the vitreous body, the sclera, which has become inelastic, does not yield and thus the exudation forms between the choroid and retina. The compress and bandage is now supposed to aid the contraction of the sclera. According to this view, an increase in the intraocular pressure must follow. On the contrary, however, it is found that the intraocular pressure diminishes markedly under the bandage, and the eyes grow softer. At the same time we may notice the development of linear opacities in the cornea, occasionally looking almost like small folds, which depend upon the diminished corneal tension. Injection of small pericorneal vessels is found quite constantly. Hence it seems more plausible that the bandage gives rise to a decided change in the conditions of circulation and secretion and thus exercises its often distinctly visible, ameliorating effect. Recovery may also be aided by the use of Heurteloup's leech, injections of pilocarpine, and derivation to the intestinal tract.

[We have very encouraging results in the Manhattan Eye and Ear Hospital, in quite a proportion of cases, from the rest, bandage and pilocarpine treatment.—St. J. R.]

Operative interference is to be recommended only after the above treatment has proven useless. The greatest benefit is promised by puncture of the sclera, as has been recently carried out, particularly by Alfred Graefe. After ascertaining accurately the position of the retinal detachment, the conjunctiva his incised and the sclera exposed at the side of detachment, the globe being rotated to the proper extent. A narrow Graefe cataract knife is now passed through the sclera and choroid, the blade turned somewhat in order to make the wound gaping, and the subretinal fluid is allowed to escape. The conjunctival wound is then united with

sutures. Wolfe uses a lance-shaped knife in incising the sclera. Recoveries, in part temporary, in part permanent, have been observed after the operation. A less valuable method, is the one of entering the globe with a broad cataract needle, at the side opposite to the detachment of the retina, and of cutting into the retina from the vitreous in order that the subretinal fluid may pass into the vitreous body (v. Graefe). Iridectomy has also been recommended recently by Drausart and Warlomont.

Wecker performs a sort of ocular drainage, by passing a gold wire through the wall of the globe below the detached retina, then drawing it out and allowing it to remain for some time after twisting the ends together. This plan is undoubtedly inferior to scleral puncture.

8. Embolism of the Arteria Centralis Retinæ.

(*Ischæmia Retinæ.*)

In embolic occlusion of the central artery of the retina, the arteries and veins appear abnormally narrow. The arteries in particular are hardly recognizable as narrow, thin, pale and bloodless threads which can occasionally be followed only for a short distance in the retina. In other cases—depending upon the more or less complete occlusion of the calibre of the vessel—an interrupted current of blood, moving in small red columns, has been seen in the arteries for a longer or shorter period after the attack (Ed. Jaeger, Hirschberg, v. Hippel, Nuel). The veins are usually larger than the arteries and appear as dark bands; the blood current in them may appear in a similar way to that in the arteries. In one of Graefe's cases and in another one observed by me, this phenomenon was demonstrable only in the veins. At the beginning of the affection, the differentiation between the veins and arteries is not always easy.

The optic papilla is usually pale. A few hours or several days after the occurrence of the embolism a light gray opacity appears upon the retina, particularly in the vicinity of the papilla and macula lutea. The central portion of the latter looks like a small blood-red patch—exactly like that seen in the macula when the retina begins to exhibit slight cadaverous opacity in a comparatively fresh eye. On account of the contrast, the brownish-red spot in the macula (retina and choroid in situ) appears more distinctly.

Vision disappears suddenly and completely. When the patients have observed the onset of blindness, they have described it as if a black cloud was rolled before the eye. Temporary obscuration sometimes precedes complete amaurosis for a few days. This is

probably due to an embolus which occludes temporarily or partially and is then carried on (Mauthner).

In a series of cases, the circulation is restored after a certain length of time and thus the power of vision may return. But as a general thing atrophy of the retina and optic nerve develops. In a case under my observation, irido-choroiditis developed on the following day, and also appeared to be embolic in origin (embolism of the ciliary vessels).

Those who are attacked by embolism of the central artery of the retina, usually suffer from heart disease. The affection has also been observed in atheroma of the arteries, pregnancy, etc.

Similar ophthalmoscopic appearances may also occur without embolism. This is seen as the result of retrobulbar neuritis with exudations and vessel disease, after retrobulbar hemorrhages (H. Pagenstecher) or hemorrhages into the optic nerve (Magnus), finally through vaso-motor influences (Jackson's retinal epilepsy) which are occasionally excited in a reflex manner by the sexual organs (Priestly Smith), for example, during childbed (Koenigstein). The latter affections are usually distinguished from embolism by their bilateral occurrence. The cases described by A. Graefe and Rothmund, as ischæmia retinæ, also belong in this category. In these cases there was bilateral blindness or marked amblyopia, lasting for a night or a few days, in which the arteries were extremely narrow with an otherwise normal fundus. Cure was effected in these cases by iridectomy, or puncture of the anterior chamber.

In order to make a probable diagnosis of embolism, we must be able to demonstrate the source of the embolism. The coincident bilateral development of the ophthalmoscopic appearances always makes the diagnosis questionable.

The anatomical demonstration of an embolus was first made by Schweigger, in a case observed clinically by v. Graefe. This was confirmed by Sichel, Nettleship, Priestly Smith, and myself. In my case the occlusion of the central artery began soon after its entrance into the optic nerve. A large branch running alongside the central artery—this branch is almost always present (Schwalbe)—was also plugged. An embolus was also situated in a retinal artery. Even the ophthalmic artery showed larger clots of blood in some places; small branches, which were given off in the neighborhood of the central artery, were occluded. We may, therefore, certainly assume that the occluding mass was situated outside of the central artery, in cases in which the pronounced picture of embolism of the central artery of the retina was present and yet no embolus or other disease was found within the optic nerve.

Various possibilities are to be noted as regards the restoration

of the circulation of blood in the retina after embolism of the central artery. The most obvious one, and that which certainly obtains in a series of cases, is that the embolus is destroyed or is carried further. The entrance of blood through the main artery would then take place. Observation, fortified by post-mortem examination, also teaches that an embolus which does not fill the calibre of the artery completely, may first produce marked ischæmia —probably as the result of temporary contraction of the artery, owing to the diminution in the current of blood—and that this may disappear after a time (Schnabel). In total permanent occlusion the development of collateral circulation must be taken into consideration. The vessels of Zinn's scleral ring, small branches of which sometimes enter the papilla, have been relied upon in explanation of this occurrence. But, as a rule, these vessels are not large enough to provide a sufficient collateral supply of blood. I would rather call attention to the smaller branch of the central artery, which runs through the optic nerve, parallel to the main trunk, and normally extends only to the lamina cribrosa. If this is not occluded—as happens when the embolus is situated near the globe—the entire mass of blood which enters the optic nerve will be thrown into this branch and will distend it. This furnishes the most favorable conditions for the development of collateral communications with the papillary vessels.

Embolism of certain branches of the artery, with corresponding defects in the field of vision, have also been observed (Schoen). The affected branch of the vessel is then found narrowed, the portion of the retina supplied by it is milky white (Saemisch), and numerous hemorrhages (hemorrhagic infarction) may develop in it (Knapp, Landsberg).

The treatment attempts to remove the embolus.

For this purpose iridectomy or paracentesis was formerly performed in a few cases. The diminution of intraocular pressure resulting from this operation will cause an increased supply of blood. But we could expect a benefit from this only when the embolus leaves the calibre of the central artery partly free. In the other event the changes in the intraocular pressure would exert no influence on the current of blood in the posterior part of the artery of the optic nerve. Benefit may be looked for, with greater confidence, in occlusion of branches of the vessel.

Early massage of the eye (Mauthner) seems to be more useful, and it has been known to be followed by restoration of the circulation of blood. We can act directly upon the embolus in the artery of the optic nerve, by making a passage to the optic nerve along the globe, as in optico-ciliary neurotomy, and by making slight

pressure upon it with the strabismus hook. In a case treated by me in this way, the circulation in the central artery returned in a few days.

9. Glioma Retinæ.

A very striking symptom-complex which is found chiefly in children (the "amaurotic cat's eye" of Beer) results, as a rule, from glioma of the retina. A yellowish reflex, which is situated behind the lens, is seen to shine from the patient's pupil. On examination with focal illumination, a whitish-yellow mass, traversed by blood-vessels, is found in the vitreous body. The vessels do not ramify in the manner characteristic of retinal vessels. Small hemorrhages are also occasionally found. At the same time the external appearance of the blind eye may be normal. The pupil is usually dilated, but it may also be narrowed and even dilated with difficulty by means of atropine. Sight is usually destroyed at a very early period. In some cases, however, the perception of light was retained for a long time (Geissler).

Symptoms of secondary glaucoma often supervene, namely, increase of intraocular pressure and distention of the veins upon the sclera. In other cases purulent choroiditis leads to phthisis bulbi; this does not lead to recovery because later the tumor again enlarges (v. Graefe). If the glioma grows, it fills the globe more and more, extends through the optic nerve backward into the brain, and may also perforate through the edge of the cornea or the sclera. Finally, the other tissues of the orbit are implicated, by the formation of episcleral tumors, sometimes even before perforation of the eye. The bony wall of the orbit often escapes for a long time. The tumor, occasionally as large as a hen's egg, assumes a reddish, fleshy, appearance, and grows out of the orbit; only traces of the individual parts of the globe can then be discovered. Even on section we find the former shape of the globe only indicated by the remains of the sclera. In exceptional cases, the orbital part of the optic nerve remains intact despite extraocular development of the fungus (Schoenemann).

In a few cases, the course differs from that described above. Thus, the tumor may be combined at an early period with detachment of the retina and the latter, being pushed forward, conceals the tumor. This makes the diagnosis more difficult.

In order to distinguish a glioma from detachment of the retina, apart from the folds usually presented by the latter, we may utilize the course of the vessels. In detachment of the retina, we see the normal ramifications of the retinal vessels, in glioma the vessels are

newly formed, run an irregular course, and are usually wider. The tension may also be employed to assist in the diagnosis; increased pressure existing in tumor, as opposed to diminished pressure in old retinal detachment. But this criterion may fail us if inflammatory conditions are present (for example, iritis) which also increase the intraocular pressure. In a case of this kind, I have seen perforation of the sclera in the shape of a yellowish protrusion as large as a pea, before the tumor was recognizable through the vitreous. As was proven after enucleation, the main part of the tumor was situated in the most anterior ciliary portions of the retina; in the posterior parts of the detached retina small nests were found, as large as a pin's head, which were situated only in the outer layers; the optic nerve was free. These complications enable us to understand why the section of eyes enucleated on account of glioma, sometimes discloses other affections, such as subretinal cysticercus (v. Graefe), fibroma of the sclera (Saemisch), even uveal diseases (Raab). With regard to the latter affections, the clinical history must be taken into consideration; in glioma the yellow reflex occurs without previous inflammatory phenomena.

Pathological Anatomy.—Virchow was the first to describe the tumors in question as glioma retinæ. Hirschberg emphasized the fact that the malignant intraocular tumors of childhood were almost always gliomata and started from the retina. The labors of Hirschberg, v. Graefe and Knapp demonstrated their clinical agreement with the "medullary cancer" (fungus hæmatodes s. medullaris) of the older writers. Microscopically the tumor is soft and marrow-like, of a whitish, sometimes slightly reddish color, like the glioma of the brain.

In very recent cases, as a rule, the tumor is found to begin in the internal granule layer. We then find deposits of numerous small round cells, which in part resemble the normal cells of the granule layer, in part are slightly granular, with a large nucleus and a narrow ring of protoplasm. The basement substance is a structureless, finely granular mass; occasionally we can recognize in it a network of delicate fibress. The tumor starts in the neuroglia of the retina. After it has lasted for some time and spread more extensively, large groups of chiefly spindle cells with a large nucleus make their appearance (glio-sarcoma), also bands of connective-tissue bundles. Yellowish-brown, smeary masses, which contain fatty cells, crystals of fat, clumps of pigment (derived in part from hemorrhages, and even calcification are found as the products of retrogressive metamorphosis.

Course.—The affection develops soon after birth or during the first few years of life. Inasmuch as inflammatory signs or pains

are absent at the beginning, the attention of the parents usually is first attracted by the yellow reflex coming from the pupil. Unless aid is sought, the affection, as a rule, causes death in one or more years, usually after the development of metastases in the adjacent lymphatic glands, the brain, liver, kidneys, bones, etc. Both eyes are sometimes attacked in succession (Geissler, Horner, Lawson, Dicket). In not very rare cases, several children in the same family are attacked by the disease (the parents being perfectly healthy). I have seen two sons (among three children) attacked by glioma.

The *treatment* consists of early enucleation. As the tumor may have extended to the optic nerve, despite its apparent intraocular position, as large a part of the nerve as possible should be extirpated. Permanent recovery may follow early enucleation, as is shown by a series of cases. This is much less probable after the tumor has attacked adjacent tissues. Here local relapses occur or, despite their absence, death may result from metastasis. But if metastases are absent, and the general condition of the child is not too bad, an attempt at the cleanest possible extirpation should be made, perhaps followed by the use of the actual cautery or the removal of the periosteum. Even in such advanced cases a few instances of recovery have been observed.

CHAPTER V.

DISEASES OF THE CHOROID.

1. Hyperæmia of the Choroid.

The remarks formerly made concerning the difficulty of diagnosis of hyperæmia of the retina, hold good here in a heightened measure. In a number of cases, on account of the marked pigmentation of the epithelium, we see nothing of the choroidal vessels, and therefore cannot make a diagnosis of hyperæmia. The choroidal vessels are only recognized in slight pigmentation of the fundus, such as occurs particularly in blondes and albinos. Even here, it is difficult to prove increased distention unless a comparison with the other healthy eye is possible. But we should not be misled, as sometimes happens to beginners, and make a diagnosis of hyperæmia because, on account of the deficiency of pigment, the fundus appears bright red and the vessels stand out distinctly. Circumscribed redness of the optic papilla, without opacity of the adjacent tissues, may be important as a factor favoring the assumption of hyperæmia, which acquires a certain degree of probability when there are other diseases of the uveal tract.

2. Exudative Choroiditis.

Exudations and tissue changes occur in true choroiditis.

If it is assumed that mere infiltration with serous exudation, is present in the beginning of certain affections (choroiditis serosa), the change cannot be diagnosticated with the ophthalmoscope. Perhaps we may include in this category a number of those cases in which the patients complain of impaired vision, metamorphopsia, glimmering before the eyes, etc., although no pathological changes are demonstrable in the beginning. Later, however, distinct signs of choroiditis appear in the form of discolorations or pigmentations.

If the macula lutea is attacked, it sometimes looks, at the beginning of the disease, as if covered with a slight mist. A notable feature, also, is the absence of the light ring, and a more distinct

definition from surrounding parts, such as is found otherwise in examination in the inverted image. The optic papilla is often congested. But as these signs are also found in central retinitis, the diagnosis at first must remain in doubt. The assumption of a central choroiditis becomes very probable when distinct choroidal changes are already present in other parts. We find slight changes with special frequency at the periphery of the fundus, while the macular region still appears intact.

We will hereafter refer to the fact, that choroiditis is usually diagnosticated in vitreous opacities which are complicated with iritis, in the absence of ophthalmoscopic findings on the choroid.

Choroiditis which is visible ophthalmoscopically, is characterized, on the whole, by the interruption of the uniform red of the fundus with patches of other colors. White, yellowish, reddish-yellow, dark red, in addition to intensely black patches are found (vide colored plate, Fig. 5). The white patches are often surrounded by black borders. There is often hyperæmia of the papilla, particularly when the process is acute. The size of the patches varies from those which are hardly recognizable as fine points with convex $\frac{1}{3}$ in the inverted image and those which far exceed the size of the papilla. They are sometimes round, occasionally of irregular shape or linear. Their position also varies. The disease is sometimes found only around the macula (central choroiditis); here we often see a round, reddish-yellow, elevated patch, which afterward grows pale and discloses small black pigmented lines. In other cases the changes occupy a large part of the fundus, in still others they are confined to the equator of the globe (equatorial choroiditis).

Ordinary exudative choroiditis has been distinguished from certain special forms which are characterized by their peculiar development.

1. *Disseminated Choroiditis.*—Here the patches appear in circumscribed foci which, as a rule, are not very large, and are separated from one another by tissue of normal appearance. The patches are usually whitish and yellowish, surrounded in part by a black border, or they are simply black.

2. *Areolar Choroiditis* (Foerster).—The macula is the centre of the morbid process. The most recent patches are as black as coal and round. They lose their color gradually, so that the older patches appear whitish and simply have a black ring. In this form of choroiditis, Aubert found, in the stroma of the choroid, roundish nodules which are directed toward the retina. Upon their surface they sometimes show small depressions into which is drawn the thin and atrophic retina. The nodules consist of a dense network

of fibres with cellular elements. Dark pigment, inclosed in cells, is found in the vicinity of the nodules and in part upon them.

3. *Syphilitic Choroiditis.*—This is characterized by the appearance of very small dark (also whitish) patches, especially in the equatorial region. In addition, there is usually a fine, dust-like opacity of the vitreous. Complication with retinitis is frequent. The etiological diagnosis cannot be made from small equatorial patches alone.

4. *Choroido-retinitis.* — Although the implication of the retina in the above-mentioned forms is shown by the impairment of vision, it is well to reserve the name choroido-retinitis for those cases in which the retina proper (and not the pigment epithelium alone) present ophthalmoscopic changes. Apart from opacities, hemorrhages, or secondary changes (atrophy of the retina with thinness of the blood-vessels and atrophy of the papilla) there are masses of blackish pigment which enter the retina in long existing or severe forms of choroiditis. Inasmuch as we can see directly with the ophthalmoscope, whether the pigment is situated in the retina or the choroid, we must be guided by the relations of the pigment—whether it is situated, in any part, upon a retinal vessel and partly covers it (vide colored plate, Fig. 5, where pigment is situated, in one part, upon an artery). In addition, there are usually diffuse changes in the choroid, such as decolorization and discoloration of larger patches, and larger or smaller pigment patches.

Choroido-retinitis is distinguished ophthalmoscopically from retinitis pigmentosa, by the fact, that the choroidal changes mentioned are demonstrable in the former, while the choroid appears intact, on the whole, in retinitis pigmentosa. The peculiar character of the pigmentation in the shape of small lines, dots, or branching figures similar to bone corpuscles, and the yellowish, wax-like atrophy of the papilla with the narrow vessels, gives to retinitis pigmentosa its peculiar character. In addition, there are the above-mentioned clinical symptoms. Nevertheless, as we have already stated, there are certain cases of ophthalmoscopically typical retinitis pigmentosa, which really belong clinically to the category of choroido-retinitis.

We may mention the following anatomo-pathological changes of choroiditis, which have been studied particularly by Iwanoff. Beneath the intact epithelium are often found foci of white blood-corpuscles, also amorphous masses of exudation in which nuclei are scattered. If the epithelium is not deeply pigmented, these foci will be recognized as light, yellowish-red patches in the normal red of the fundus. Such deposits may be entirely absorbed, but the pigment epithelium in these places often presents marked prolifer-

ation, so that later dark patches develop. The retina becomes adherent there, the epithelium may even extend into the granule layer. In other cases atrophy of the choroid develops, together with cicatricial retraction into which the hypertrophied connective-tissue of the retina grows. In addition, there is hyperplasia of the pigment. The atrophic parts look lighter than those first mentioned; occasionally large choroidal vessels are seen passing through them. When the highest degree of atrophy is reached, the choroid forms an extremely fine connective-tissue membrane through which the sclera shines with a bluish-white color. Fatty degeneration may also occur, both in the pigment epithelium and in the stroma cells of the choroid. The vessels show changes in their walls, often sclerosis.

In older persons, we often find, under the microscope, wart-like projections of the vitreous membrane of the choroid (Wedl, Donders) which push the pigment epithelium before them. They sometimes separate entirely from their base and penetrate deeply into the retina. They are rarely visible ophthalmoscopically, on account of their peripheral situation and small size. When they are visible, the corresponding part of the fundus oculi appears strewn with small drops (Wecker).

Symptoms.—One of the first and most frequent complaints of patients suffering from choroiditis, is of misty vision, which they often compare to the movement of warmed air. The diminution of visual power is not always considerable, and may even be entirely absent if the changes are situated at the periphery. Here there are merely small defects in the field of vision resulting from the disseminated foci. These are best detected by making the examination with a piece of paper covered with small dots; this is held at the proper distance (twelve to fifteen centimetres) and the dots which are not seen are noted. Sometimes there are annular defects around the point of fixation (Heising). If the affection is cerebral, the impairment of visual power is more pronounced, and there may even be positive central scotoma. Complaint is often made of micropsia, metamorphopsia, even of double vision. As a rule, the color sense is retained, but color scotoma (even for blue) have been observed. The sense of light is usually diminished. If the process recovers, the visual power may also become normal. It is often strikingly disproportionate to the fundus which is strewn with black and discolored spots. Among other changes, vitreous opacities are by no means rare. In some cases, detachment of the retina and the formation of cataract supervene. Externally the eye usually appears normal; occasionally slight injection and irritability are noted. Later iritis may develop.

The *diagnosis* of choroiditis is not always easy at first when, as in choroiditis serosa and choroiditis around the macula, no distinct changes are seen with the ophthalmoscope, despite the impairment of vision. But if we find congestion of the optic papilla and complaint is made of misty vision, choroiditis is probable, if we can exclude other, particularly neuritic processes. We must then make the ophthalmoscopic examination after dilatation of the pupil, in order to avoid overlooking peripheral choroidal changes or vitreous opacities, which strengthen the diagnosis. The pronounced forms of choroiditis are easily recognized.

The *prognosis* is always serious. The hope of recovery is greatest, the earlier the patient comes under our care. Sometimes one eye is almost lost before the patient consults the physician, his attention being attracted only by the affection of the second eye. It is not infrequent that complaint is only made of failure of vision in one eye, although the other is also attacked by the disease. Even pronounced central scotomata may disappear. There is always a great tendency to relapses, which occasionally do not occur until after the lapse of years. The hemeralopia often does not disappear, despite the restoration of complete visual power.

If the process has lasted a long time, the chances of recovery are small, although a certain degree of improvement is often obtained. If it has run its course—this is recognized from the fact that vision has remained stationary for a long time—notable improvement is usually excluded, particularly when the thinness of the retinal vessels or the pale color of the papilla, enables us to recognize atrophy of the nervous elements

The *causes* of choroiditis often remain obscure. Apart from syphilis, we are more often able to demonstrate a connection with pronounced myopia (staphyloma posticum) which is very often combined with choroiditis around the macula. The affection is also found in anæmic individuals, as well as those who are predisposed to congestive conditions. It occurs both in early life and at an advanced age.

The *treatment* must be energetic in acute cases in which the visual power has suffered. If the general condition warrants, it is best to order a prolonged stay in dark rooms, and the inunction cure or injections of corrosive sublimate (0.01 daily). This is indispensable when the disease is due to syphilis. In other cases good results are often obtained from injections of pilocarpine, followed by two to three hours' sweating. Heurteloup's leeches may be applied to the temples every four to six days. Atropine is used locally. This treatment is continued four to six weeks. If recovery has not occurred then, we must nevertheless continue the

administration of mercury (in smaller doses and internally). The patient must be kept under strict orders for a long time. He should abandon work with the eyes (reading, etc.) for months, must protect himself against bright light by wearing blue glasses, and also guard against cold, rush of blood to the head, etc.

If the disease has lasted a long time and has reached a certain standstill, milder remedies, which act gradually, are indicated. In addition to non-use of the eyes, the internal use of small doses of corrosive sublimate or potassium iodide; iodide of iron in anæmic individuals. The application of Heurteloup's leech, followed by a stay of twenty-four hours in the dark room, must be tried experimentally. If no improvement has occurred within a few days after the abstraction of blood, further applications may be abandoned.

It is often difficult to say whether a choroiditis has run its course to such an extent as to be inaccessible to curative agents. If the patient can give no satisfactory account of the condition of his vision, of late and irritative symptoms (for example, cloudy or smoky vision) are absent, we must be guided chiefly by the appearance of the optic papilla. If this is hyperæmic, antiphlogosis may be resorted to. After the inflammatory symptoms have subsided, injections of strychnine sometimes act usefully by their action on the enfeebled irritability of the retina.

3. Staphyloma posticum, Sclerectasia posterior, Conus, Sclerotico-Choroiditis posterior.

The type of this many-named disease forms a white crescent in close apposition to the optic papilla, and usually toward the side of the macula (Fig. 109 and colored plate Fig. 5). In a certain measure a semilunar widening of the normal scleral or connective-tissue boundary is formed, so that, in fact, there are cases in which it may be doubtful whether we have to deal with a somewhat wider scleral border, or with an affection which merits one of the above-mentioned names. When the process is advanced, the transverse diameter of the crescent may even be greater than that of the papilla. Moreover, the whitish discoloration is sometimes situated, not alone on one side of the papilla, but surrounds the entire periphery, so that we can no longer speak of a true crescent (Fig. 110). However, the greatest width is always directed toward the macula. The color is partly white, partly bluish-white or light rosy; individual parts often show different colors. Black pigment patches or crescent-like



Fig. 109.

pigment lines are frequent (Fig. 110, and colored plate Fig. 2). A few choroidal vessels may be visible upon the discolored places. The retinal vessels pass unchanged over them. The definition of the crescent against the normal red of the fundus is more or less distinct. Its perfect distinctness (a black streak of pigment is often found at the boundary) testifies in favor of a certain degree of completion of the process (stationary staphyloma); but if small changes in color and pigmentation are found beyond its borders, its progress is to be feared. The former boundaries are sometimes indicated upon the staphyloma by the remains of pigment streaks. The optic papilla is usually very red. This depends in part upon the contrast with the whitish surroundings, in part upon true hyperæmia of the papilla. Furthermore, the papilla appears smaller in extensive staphyloma, particularly in its transverse diameter. This depends upon its oblique position, resulting from the great distention of the sclera in the region of the posterior pole of the eye. The whitish part is occasionally curved posteriorly and excavated, *i.e.*, there is a circumscribed sclerectasia. We can inform ourselves concerning this feature by the ophthalmoscopic means at our command for determining the plane of the retina.



FIG. 110.

Complication with choroiditis in remote parts of the fundus, particularly at the macula, is not uncommon. Vitreous opacities and detachment of the retina, may be associated with the staphyloma in some cases. Glaucomatous excavation of the papilla may also occur from increase of the intraocular pressure.

The beginner in ophthalmoscopy is often inclined to include the whole neighborhood of the papilla in the latter itself, so that in these cases the papilla appears to him to be unusually large. More careful observation, however, will enable him to distinguish the boundaries of the papilla, which always has a redder color, from the staphyloma.

Staphyloma posticum, when not congenital, generally results from distention-atrophy of the choroid as the result of elongation of the ocular axis. The pigment epithelium is first changed, assumes irregular shapes, and finally disappears with the exception of a few remains. Then the choroidal stroma and the chorio-capillaris, are destroyed to a greater or less extent. Finally, only a very thin membrane remains, in which bands of connective tissue, the vitreous membrane and perhaps a few vessels can be recognized. The retina usually passes intact across the staphyloma.

In other cases there are true inflammatory processes which are

associated with apoplexies and exudations. These complicate the distention-atrophy not very infrequently. The further anatomical changes which are found in staphyloma posticum, and the causal factors have already been discussed in the chapter on Myopia. It has there been stated that the condition is observed generally, though not always, in myopic eyes.

It would be desirable to come to an agreement on the use of the different names for these individual, distinguishable processes. Thus, the simple small white crescents, whether congenital or acquired, might be called "conus," the larger atrophies attributable to distention as "staphyloma posticum," and those associated with true choroiditic changes as "sclerotico choroiditis posterior" (v. Graefe). If special stress is to be laid upon the circumscribed ectasia alongside the papilla, the term "sclerectasia posterior" may be used.

The treatment of staphyloma posticum, and the means adapted to prevent its progress, have been considered under the heading of myopia. If choroiditis is also present, its suitable treatment must be adopted.

4. Hemorrhages into the Choroid. Detachment of the Choroid.

Hemorrhages into the choroid appear as brownish-red patches, whose color is influenced by the intensity of the pigmentation of the epithelium. If they are situated at the side of the retinal vessels, the latter may be visible upon them, as distinguished from retinal hemorrhages. Furthermore, in certain cases the striped form of the hemorrhages is decisive.

The hemorrhages are usually the result of injury, although smaller ones may occur spontaneously in choroiditis. Large extravasations may break through the retina into the vitreous body.

Detachment of the choroid, like that of the retina, is characterized by projection of the detached part, like a vesicle, into the vitreous body; the folds and the flapping of the part are wanting. As a rule, it has a red color and, if the pigment epithelium is less intensely colored, the choroidal vessels are seen beneath the retina. The detachment results from hemorrhage or serous fluid. Detachment of the retina may develop secondarily after detachment of the choroid. As a general thing, phthisis bulbi finally develops. Very few cases of this kind have been observed with the ophthalmoscope (v. Graefe, Liebreich, Schweigger, Michel).

5. Rupture of the Choroid.

Ruptures of the choroid have a white color on account of the shining through of the sclera; they are yellowish only when portions of the tissue of the choroid are situated in them. Hemorrhages are often seen in recent cases; later a black pigment line usually forms along the rupture. The number and extent of choroidal ruptures may vary greatly. They are usually situated in the vicinity of the posterior pole, in the region of the macula lutea and the papilla; they are not infrequently curved, with the concavity directed toward the posterior pole of the globe. The retinal vessels generally pass across the injured parts. Although this seems to demonstrate the intact condition of the retina, the changes in the power of vision indicate that the rods and cones have suffered. If the region of the macula lutea is attacked, the patients complain of metamorphopsia. I have seen one patient who had binocular double vision as a result; the letter seen with the diseased eye was situated above that seen with the healthy eye. As this made reading impossible, it became necessary to exclude the affected eye by an opaque spectacle glass. The condition remained stationary during a period of observations extending over a year. In other cases improvement in vision takes place. Like Heising, I have observed, with the ophthalmoscope, the disappearance and healing of a choroidal rupture. In one of Saemisch's cases, detachment of the retina occurred later. These ruptures usually result from blunt force, for example, a blow with a piece of wood, gunshot wounds of the orbit, etc. The peculiar position and shape of the rupture probably depends upon the fact that, in the region of the posterior pole, the choroid is united more firmly to the sclera by means of the posterior ciliary vessels, and is more apt, after traumatic flexion of the globe, to rupture at the place where they cannot be displaced.

The early diagnosis of choroidal rupture is often prevented by hemorrhages into the anterior chamber or the vitreous body. White lines, which are very similar to choroidal ruptures, occur occasionally in older choroiditis; here the previous history must decide.

6. Tuberculosis of the Choroid.

Autenrieth (1808) was the first to give an anatomical description of tubercular nodules in the choroid. Ed. Jaeger (1855) saw them with the ophthalmoscope. Exact histological examinations were made by Manz (1858), and Cohnheim demonstrated the fre-

quency of their occurrence in acute miliary tuberculosis, especially in tubercular meningitis. The ophthalmoscopic appearances were accurately described by v. Graefe and Leber.

As a rule, both eyes are affected. The tubercles are situated chiefly in the region of the macula and papilla. With the ophthalmoscope they appear as whitish or whitish-yellow round patches of very different sizes, even as large as the papilla or more. Anatomically they are sometimes so small as to be invisible to the naked eye, occasionally they attain a diameter of two and one-half millimetres. At first they always project toward the retina, in the later stages toward the sclera. Their development begins in the chorio-capillaris. Decolorization of the pigment epithelium gradually occurs, and thus the yellowish-white patches are formed. The differential factors from disseminated foci of a similar choroiditis are: 1, the round shape of the tubercle; 2, the absence of the black pigmented edge, which the patches of choroiditis usually possess; 3, the prominence of the tubercles. This, however, is demonstrated with difficulty unless the tubercle is very large or a retinal vessel passes directly across it, so that we can utilize its parallactic displacement in the inverted image on moving the lens.

The differential diagnostic features, accordingly, are not very striking. Thus, a focal deposit of cells in the choroid, such as are found in disseminated choroiditis, may exhibit occasionally all the signs of tubercle. And, in fact, I have seen diagnostic errors made by distinguished ophthalmologists. A cautious reserve is indicated in a large proportion of the cases. The diagnosis can be made with certainty only in the case of fully developed nodules, or when, after repeated observation, we notice the appearance of new tubercles and the further development of those already present.

Although the ophthalmoscopic diagnosis may be used to advantage in these cases, in making the general diagnosis of miliary tuberculosis, I desire to warn you against an exaggerated opinion of the value of the ophthalmoscopic diagnosis. A further difficulty is that of obtaining a sufficiently accurate and prolonged examination of a very sick and often somnolent patient. Moreover, the situation of the tubercles may be so peripheral that they are no longer to be seen with the ophthalmoscope, because, although the tubercles occupy, in preference, the region of the posterior pole, I have often seen exceptions to this rule. Tuberculosis of the choroid, is sometimes associated with neuritis (Bouchert), and I have also seen this complication. More rarely there are very large tubercular deposits which result from the aggregation of smaller ones. A true tubercular inflammation of the choroid, in which the retina was separated from the choroid by a cake-shaped white thickening,

has been observed by Hirschberg. In his case a painful affection of the eye had lasted only two weeks.

7. Choroidal Tumors.

The large majority of tumors which start from the choroid and ciliary body are melano-sarcomas. Non-pigmented sarcomas (H. Pagenstecher and Genth) are much rarer; Iwanoff has observed a myosarcoma, Michel a fibroma and epithelial cancer.

The opportunity of following the development of sarcoma with the ophthalmoscope is not often presented, because, as a rule, it is soon associated with detachment of the retina. But cases are known, in which the tumor developed in the region of the macula and attained a considerable size without detaching the retina (Knapp). Even after detachment of the retina has occurred, the subjacent tumor has sometimes been diagnosticated by its peculiar vascularization (Becker). Whenever there is detachment of the retina without any demonstrable cause, the question always arises whether we have to deal with a tumor. The increase of intraocular pressure and the violent pains in the eye—which are absent in simple detachment of the retina—must arouse the suspicion of tumor. In doubtful cases, however, there is no reason why we may not convince ourselves directly of the presence or absence of a tumor by making a scleral incision, in the manner recommended by Alf. Graefe for the treatment of detachment of the retina.

Glaucomatous symptoms sometimes develop after intraocular tumors; in other cases there is profuse suppuration of the vitreous body and anterior chamber, terminating in phthisis bulbi. Such a globe, which contains a tumor, is distinguished from other phthisical eyeballs by the occurrence of spontaneous pains, and often by distention of the posterior portions of the sclera. The further development of the sarcoma may cease for some time after the phthisis.

The extraocular development of tumors occurs from extension to the optic nerve, perforation of the walls of the globe, or by the development of independent orbital foci.

Not much is known concerning the etiology. An injury sometimes appears to act as the cause. Metastatic choroidal tumors are rarely observed; when found it is shown that they started in part from nævi, in part from carcinomata. The neoplasm develops most frequently after the age of forty years, while it hardly ever occurs in early childhood, the period of glioma of the retina. Nordenson described an ossified cavernous sarcoma of the choroid in a girl of eleven years.

Enucleation of the globe has resulted in permanent recovery in

a series of cases (in twenty-five per cent of the cases collected by Hirschberg). Relapses and metastases (in the liver, brain, etc.) are frequent, when the tumor has become extraocular or when secondary glaucomatous symptoms have appeared. If the tumor has spread into the orbit, the extirpation must be performed with special care; if necessary with removal of the periosteum. Even when the tumor apparently is still intraocular, enucleation should be combined with excision of the largest possible part of the optic nerve.

An osseous formation, which starts from the inner surface of the choroid, is not infrequently found in phthisical globes. Occasionally this is merely a thick layer of connective tissue, with a few small bony plates, occasionally a complete bony shell develops and occupies the entire posterior portion of the globe; an opening is found at the site of the papilla. In these cases the lens often appears to be converted into bone, but examination usually shows only calcification. True formation of bone in the lens (Goldzieher, Berger) has also been described as the result of penetration of connective tissue after injury to the globe (O. Becker). Partial ossifications of the vitreous body also occur (Virchow, Poncet). The diagnosis of the formation of bone, can usually be made before enucleation, from the abnormal and in some places especially marked, hardness of the phthisical eyeball. In one case, in which the vitreous body was transparent and the globe intact, the ossification of the choroid, was seen with the ophthalmoscope (Laqueur). Pain and tenderness of the stump, not infrequently develop with the formation of bone, they may even give rise to sympathetic phenomena—usually only sympathetic neuroses—in the other eye, and may furnish an urgent indication for enucleation.

Purulent choroiditis and irido-choroiditis, will be discussed among diseases of the anterior uveal tract.

CHAPTER VI.

DISEASES OF THE VITREOUS BODY.

Anatomy.—The vitreous body fills the posterior part of the globe. Its gelatinous substance is perfectly transparent, contains neither vessels nor nerves, and appears to be structureless (Meckel). Some investigators believe that it is composed of segments like an orange (Hannover) or of concentric layers (Zinn). Stilling distinguishes a nucleus which is situated as in an acorn cup in the cortex, and projecting beyond the latter, extends to its edge. The peripheral parts in particular contain cellular elements, consisting in part of wandering cells (leucocytes), in part of their derivatives. The former present amœboid movements, and may be divided into three principal forms: *a*, round cells; *b*, stellate or spindle cells with one or more nuclei and long processes; *c*, cells which contain vacuoles, and one to three nuclei, and also present varicose processes (Iwanoff). Peculiar rings which are, in part, arranged like a chain alongside of one another, small fibres and plates (Donders) are also found in the vitreous body. The substance of the vitreous body is separated from the retina by the hyaloid membrane. This coincides with the membrana limitans retinæ, into which Mueller's supporting fibres radiate, but from the developmental standpoint it belongs to the vitreous body (Lieberkuehn). Anteriorly, toward the posterior chamber, the vitreous body is bounded by the zonula Zinnii, which is composed of a complicated system of fibres that arise from the vitreous lamella of the ciliary process of the retina (W. Czermak) and are applied to the anterior and posterior capsule of the lens in the vicinity of the equator of the lens. The entire space between these fibres is filled with fluid from the posterior chamber of the eye. Hence there is, in reality, no ring-shaped canal (Petit's canal) which passes around the edge of the lens (Gerlach, Czermak).

Like the vitreous body, the zonula Zinnii and the capsule of the lens develop from the middle germinal layer. Where the lens, separating itself from the corneal plate (which is situated anteriorly upon the primary ocular vesicle) and pushing back against the ocular vesicle, folds it in (secondary ocular vesicle), it pushes back, at the same time, tissue elements of the middle germinal plate (sub-

sequently vitreous body and posterior capsule of the lens), while processes from this germinal layer pass over its anterior surface (later zonula, anterior capsule of the lens, and the capsulo-pupilary membrane).

In fœtal life, the vitreous body is penetrated from behind forward by the hyaloid artery. This vessel subsequently disappears, but the hyaloid canal (canal Cloquelii) in which it ran may be demonstrated after birth (Stilling). It extends as a simple tube from the optic papilla to the neighborhood of the lens.

1. Opacities of the Vitreous Body.

The vitreous body is best examined ophthalmoscopically, by simply throwing light into the pupil with the mirror, from a distance of twenty-five to thirty centimetres. The patient then moves the eye, and if the condition in question is present, opacities and blotches are seen in the red of the fundus. These movements must often be continued for some time, before the opacity comes in view. Dark shadows will also appear, if there are opacities in or upon the cornea (for example, particles of mucus), upon the capsule of the lens or in the lens. But these dark shadows move with the cornea, while vitreous opacities, which are situated behind the rotary centre of the eye, move in the opposite direction; they move upward when the patient looks down. To secure greater certainty of diagnosis, we may use oblique illumination, which enables us to recognize directly the situation of the opacities in the globe. Vitreous opacities not infrequently make much more extensive movements than the eye itself, or they continue moving after the eye has come to rest. This occurs when the vitreous body has lost its gelatinous and coherent consistency, and has been liquefied (synchysis). Artificial dilatation of the pupil is necessary in order to examine the vitreous body carefully in its peripheral parts.

In order to determine the position of the opacity, Knapp has recommended that the examination be made in the inverted image from behind forward, first fixing the papilla or retina and then, gradually removing the convex lens from the eye, passing in review the parts situated anteriorly.

In order to detect very fine and translucent opacities, it is advisable to use a mirror of feeble illuminating power, behind which is placed a convex lens. In such cases and also when the opacity was fixed, I have often succeeded by looking across the edge of the concave mirror instead of through its opening.

We may distinguish circumscribed and diffuse opacities of the vitreous body.

The former occur in the shape of small patches, threads, strands, or membranes. Their color varies from gray, grayish-black, dark brown to black; if there is circumscribed suppuration, the color is yellowish. As a rule, diffuse hemorrhages do not present the light red color of blood, but are dark. Enveloping membranes sometimes form in the vitreous body, particularly in cases of cysticercus (v. Graefe). By using strong convex lenses ($\frac{1}{15}$) we can sometimes succeed, in the inverted image, in seeing the worm through the opacity. In other cases, especially after purulent inflammations, a vascularized, whitish, membranous structure, which exhibits a similarity to glioma retinæ, may form immediately behind the lens. The diffuse opacities are occasionally so transparent, that they merely conceal the retina like a thin veil or fine dust. This form of opacity occurs particularly with retinitis syphilitica; the differential diagnosis from opacity of the retinal tissue has already been given. In other cases the opacities are so intense, that they absorb all the incident light, and the fundus remains dark despite the ophthalmoscopic entrance of light. If this fact is noted, and the presence of opacities of the cornea, anterior chamber or lens, which might have the same effect, is excluded by means of oblique illumination, the diagnosis of intense diffuse opacity of the vitreous body is assured. If the latter results from a hemorrhage, the blood which adheres to the edge of the lens is often recognized, on oblique illumination, as a fine, light red line.

A peculiar appearance is presented by synchysis scintillans. Here numerous small cholesterin and tyrosin crystals and phosphates (Poncet) are situated in the vitreous body. On ophthalmoscopic examination, these shine and glisten in the most beautiful manner, and, on movement of the eye, often sparkle like a swarm of rockets from the fundus. A certain intensity of illumination is required, in order to see the glistening of the smaller and more transparent crystals. Examination with the concave mirror rather close to the eye, is very useful in such cases. We will then see the glistening of opacities which, in examination at a greater distance, or with a feeble mirror, appear simply as fine, transparent, gray masses.

This affection is often found in otherwise healthy eyes, especially in old people. I have found pronounced synchysis scintillans in individuals who made no complaints with regard to sight, and possessed good visual power. Apart from the disturbances which may set in after operations that may become necessary, the condition seems to be unattended with any bad results. If the lens is absent, the cholesterin crystals sometimes pass from the vitreous body into the anterior chamber (Schoeler).

If there are no complications, or if the affection of the vitreous is not secondary to an iritis, nothing abnormal is found externally in eyes affected with vitreous opacities. Tremulousness of the iris is sometimes seen when there is marked diffluence of the vitreous body.

Subjective Symptoms.—As a rule, the patients complain that they see black or gray points, little wheels, etc., floating in front of them, either entirely or partly concealing small objects. They can often describe accurately the shape of the opacities. This condition is usually termed myodesopsia. But mouches volantes also appear without true opacity of the vitreous. We then have to deal with shadows which are thrown upon the retina normally, by the formed elements in the vitreous body. Myopes are especially apt to complain of this. As soon as these opacities are seen objectively by the observer, we speak of opacities of the vitreous. Mouches volantes are also occasionally produced by small particles of mucus which pass across the cornea, during an attack of conjunctivitis. But as these are removed by the movements of the lids, the shadows produced by them also disappear.

Vision is not always impaired; the diminution depends upon the extent and intensity of the affection. Thick, circumscribed opacities impair vision less than a thin and transparent but diffuse opacity. When the opacities are floating, the results of measurement of vision often vary, according as the opacity is directly in the line of vision or not. Narrowing of the field of vision does not occur unless there are complications with affections of the retina.

The causes are often ascertained with difficulty. Myopes with staphyloma posticum are especially predisposed. The opacities also occur in choroiditis, retinitis, detachment of the retina, congestive conditions, hemorrhoids, atheroma of the vessels, after eye strain, syphilis and injuries. They are also found after severe constitutional diseases (for example, typhoid fever), usually as the result of an irido-cyclitis that has run its course. I have also observed them in anæmic girls or young men in the developmental years, without any other etiological factors. These are sometimes due to relapsing hemorrhages.

Course.—In diffuse opacities which occupy the entire vitreous body, and do not permit a view of the fundus, thick circumscribed shreds may first be aggregated, while at the same time the remainder of the mass begins to be more transparent. Complete clearing up may occur even in intense diffuse opacities, provided they were not results of a purulent irido-choroiditis or a genuine purulent hyalitis. Thick circumscribed opacities may also be absorbed, though many of them are very obstinate. Relapses are

not very infrequent. There are cases in which the opacities constantly develop anew at long intervals.

The treatment, on the whole, is the same as that of choroiditis. Apart from certain constitutional conditions, Heurteloup's leech, mercury or sweat cures are especially indicated. If there are only a few small, circumscribed opacities, we may content ourselves with ocular hygiene, Arlt's forehead ointment, occasional abstraction of blood, foot baths and laxatives. Here, as in severe cases, benefit is often derived from the use of the constant current (one pole on the back of the neck, the other upon the closed lid; sitting of five minutes with change of polarity; about four or five carbon-zinc elements, which cause very little or no light reaction), and also from repeated punctures of the anterior chamber.

2. Suppurative Hyalitis.

Suppurations in the vitreous body are usually the result of inflammation of the adjacent membranes (retina, choroid, ciliary body), but they may also start in the vitreous body itself. We must assume a primary hyalitis in the same sense as a keratitis, although in the latter the inflammatory products emigrate in great part from the outside. Until recently, however, this opinion has been vigorously opposed, despite its acceptance by Wecker, Schnabel, Schweigger, Kleins and others. As the experiments of H. Pagenstecher showed that the introduction of foreign bodies was usually tolerated without reaction, and the resulting opacity of the vitreous started simply from the wound, it was assumed, with him, that "in so-called opacities of the vitreous the irritation can never start primarily from the vitreous body." In order to disprove this view I have employed, for injections into the vitreous body, a very infectious secretion, viz., the pus of the lachrymal sac, and, in order to obviate the objection that the infection may occur from the wound, I have injected, in rabbits, the pus into the middle of the vitreous through the cornea, after extraction of the lens from the front. With the ophthalmoscope we can then follow the course of the process very distinctly. At the end of about four hours, a notable increase of the opacity is observed around the injected secretion. This gradually increases, while around it the red light of the fundus is still reflected. Later, iritis, purulent retinitis, and comparatively slight choroiditis, supervene. At the autopsy the vitreous body is found converted into whey-like fluid, which usually contains numerous micrococci. In the centre of the vitreous of an enucleated human eye, Deutschmann once found a hyaline, shining, cheesy mass of a tubercular character; inasmuch

as other tubercular affections of the eye were absent, this was to be regarded as primary tuberculosis of the vitreous. Haensell also observed an encapsulated gliomatous tumor in the vitreous.

Hence it seems to be sufficiently established, that a primary inflammation may start from the vitreous body itself. This also accords with clinical experience. Thus, after extraction of cataract or removal of staphyloma, we sometimes notice that the suppuration begins in the prolapsed vitreous body. Moreover, there are not a few cases of opacities of the vitreous, in which no pathological changes can be discovered in adjacent parts.

[I have had opportunity to verify the author's opinion, that a primary inflammation may start from a prolapsed vitreous after cataract extraction.—St. J. R.]

Another question is that of the origin of the formed elements of the inflammation—do they develop in the vitreous body or emigrate from without, not alone from the uveal tract, but from the retina and papilla (circumscribed opacities are often seen in front of the latter). According to the investigations of Haensell, Hebb, and Brailey, the development of the formed elements from the cells and cell-remains in the vitreous—in addition to extensive immigration of cells—appears to be completely proven.

Pronounced suppuration of the vitreous, recognizable by the light yellow color behind the lens, almost always results in destruction of the eye. It becomes complicated with choroiditis, etc., and panophthalmitis often develops. The globe is perforated, the pus is discharged, and finally phthisis develops. If the process occurs with less violence, the eyeball may retain its shape. If the lens remains transparent, a vascularized mass in the vitreous is occasionally seen as the termination.

If the suppuration is very circumscribed, as has been observed a few times and described as abscess of the vitreous, it may occur without notable secondary inflammation.

The treatment is the same as that of intense vitreous opacities or purulent choroiditis.

3. Foreign Bodies—Entozoa in the Vitreous.

Foreign bodies may enter the vitreous after perforation of the sclera or the cornea. In the former event, they usually pass through the lens, but occasionally they effect an entrance directly through the zonula, so that the lens remains entirely intact, and hardly anything is seen even of the wound in the iris. As a rule, they are pieces of iron or glass, grains of powder or particles of stone, fragments of cartridges, etc. Hemorrhages into the vitreous body, or

anterior chamber are usually present at the same time. The color of the foreign bodies cannot be seen distinctly with the ophthalmoscope, they usually appear merely as dark specks or patches. It is especially difficult to diagnosticate very small foreign bodies, for example, fine particles of glass. This difficulty is usually increased by the rapid development of opacity of the vitreous. Secondary opacity of the lens may also interfere with the recognition of foreign bodies. If an acute and violent inflammation follows a relatively slight injury, in connection with which the entrance of a foreign body is suspected, this suspicion is very much strengthened. It almost becomes a certainty, if purulent vitreous humor follows the operative removal of the traumatic cataract. In some cases, however, the inflammation subsides despite the entrance of a foreign body, the opaque vitreous body becomes clearer, and we can then recognize distinctly the position of the foreign body which remains free or is encapsulated. But it forms a constant source of danger to the eye; irido-cyclitis, which finally destroys vision, is an especially frequent termination. Even the other eye is threatened by sympathetic inflammation. In certain cases, however, foreign bodies have remained in the vitreous for years, without producing any noteworthy disturbances. This is most apt to occur if they are aseptic, firmly encapsulated at a distance from the ciliary body, and not movable. Not alone bacterial infection, but certain chemical irritants also appear to give rise to inflammation. Like Leber, I have seen severe purulent inflammations follow the insertion of particles of copper into the vitreous body of rabbits, despite the most careful antisepsis.

[The fact of chemical and mechanical irritation as a source of injury to the eye, has been often strangely ignored in discussions upon antiseptic surgery.—St. J. R.]

Treatment.—As a general thing, extraction must be attempted. This is attended with difficulty, especially if the foreign body is not visible and its position cannot be determined with probability even from the point of entrance. According to the force with which it entered, the foreign body may be situated close to the point of entrance, or upon the opposite wall of the globe, or it may have rebounded from the latter to the floor of the vitreous body.

After incision of the conjunctiva and, if necessary, separation of a muscle tendon (which is afterward stitched in situ), we pass with a pair of scissors to that part of the sclera at which the foreign body is suspected. A meridional incision is then made with a narrow Graefe cataract knife, and an attempt made to grasp the foreign body with forceps or a blunt hook. This succeeds most easily when the foreign body is large. If it is small, the attempt is gen-

erally hopeless. In addition it happens in many cases that several splinters have entered the eye. If one has been extracted, we might possibly be satisfied with this result, very much to the detriment of the patient, who remains exposed to sympathetic inflammation of the other eye. Thus, in one of my cases, pieces of a test tube had been hurled against the eye by an explosion a few days before, but I was unable to demonstrate, with certainty, a perforation in the sclera. In the vitreous was found a thread-shaped opacity which was connected with the choroid; as the opacity grew somewhat denser and now and then had a somewhat thicker extremity, I suspected it as the site of a small particle of glass. Extraction through a scleral incision was attempted in vain. After removal of the eye it was found, in fact, that a splinter of glass one millimetre long was situated at the end of the thread-shaped opacity, but a larger piece, which had been entirely unnoticed, was situated in the ciliary body.

If the foreign body cannot be removed, enucleation or exenteration of the globe or optico-ciliary neurotomy, is the most certain means of preventing a sympathetic affection of the other eye. The extraction of pieces of iron has been considerably facilitated by the use of magnets, which have recently been recommended anew by Brecht and M'Keown, and employed very largely by Hirschberg. A number of successes have been obtained. We may use Hirschberg's electromagnets, in which the soft iron terminates at both ends in olive-tipped sounds. The great value of this method resides particularly in the fact that it permits the extraction of small particles. By feeling around, we can also extract pieces whose situation is entirely unknown. As a rule, the magnet is passed into the globe through an incision in the sclera. In one case in which an approximately round piece of iron (about one millimetre in diameter) had been detached from the hammer while forging, and had passed through the cornea and lens, I first extracted the opaque lens in which the particle, which could not be seen, was possibly situated. As it was not found in the lens, I passed the electromagnet through the pupil into the vitreous body, in which I made palpation, particularly in the ciliary region, where there was a circumscribed painful spot. After several fruitless entrances and withdrawals, the piece was finally extracted. We should, therefore, not be afraid to prolong the attempts, the patient being placed deeply under the influence of chloroform in order to avoid the loss of the vitreous humor as much as possible. The individual just referred to recovered with V $\frac{1}{3}$. As a matter of course, there are cases in which this method fails. But it may sometimes be tried even after inflammation (irido-choroiditis) has

begun. Thus I have removed a piece of iron with the electro-magnet, after the vitreous body had become entirely opaque.

[It should never be forgotten, that the danger of sympathetic inflammation is not entirely absent, because a foreign body has been removed from the vitreous. The wound through which the foreign body enters may remain as a source of danger, and it usually becomes so.—St. J. R.]

Dislocated lenses may be situated in the vitreous humor like a foreign body. In part they become encapsulated, and the eye remains free from inflammation, in part they are followed by vigorous reaction and irido-cyclitis. If the latter threatens, an attempt at extraction should be made, the lens being grasped with my lens spoon or a hook. If it is very movable, it is first fixed by perforation with a cataract needle.

[Agnew's bident, a sharp, two-pronged fork-like instrument, is perhaps the best instrument that has been invented for the removal of dislocated lenses, especially lenses dislocated into the vitreous humor. See Transactions American Ophthalmological Society, 1887.—St. J. R.]

The after-treatment of the entrance or extraction of a foreign body, is the same as after other serious operations on the eye, viz., the application of a compress and bandage. If the pains are violent, alternate ice compresses may be applied; if the pressure of a bandage is very painful, it must be discontinued. Leeches to the temples and atropinization, are also beneficial when the inflammation is severe.

In some regions, cysticerci are found quite frequently in the eye. This depends upon the presence of the tænia solium, as the embryo of the tænia mediocanellata does not thrive in man. The individual links of the tapeworm are exfoliated and passed with the fæces. The embryos situated in the genitalia of the links, are freed outside of the body in the dung heaps (meadows, fields). The embryo enters the stomach of the suitable host (man, dog, pig, etc.) in the food or water, loses its covering through the action of the gastric juice, bores into the blood vessels with its hooks and begins to wander. Finally it becomes settled, and now begins the second stage of its development, in which it is known as cysticercus. It is converted into a vesicle with fluid contents. At one part of the periphery is a transversely striated, strand-shaped prolongation (neck) which ends in a button-shaped swelling (head), which exhibits a sucking plate and row of hooks. In this shape, the cysticercus is often encapsulated, particularly in the muscular tissue of the hog. If it then enters the stomach and intestines of the human being, it develops into the tape-worm. Although it is not impossi-

ble, it is certainly extremely rare that the cysticercus should develop from the embryo of the tape-worm in the same individual who carries the latter. As we have remarked, the embryos which are received through the mouth are converted in man into cysticerci. They reach the eye through the blood-vessels. They are sometimes situated between the choroid and retina and may then perforate into the vitreous body. This process has often been followed. Thus I noticed below the macula a small detachment of the retina about as large as the papilla (the patient had a corresponding scotoma), from which the little cysticercus penetrated into the vitreous body.

It is found most frequently in this locality. A. v. Graefe (1854) was the first one who saw it with the ophthalmoscope. In North Germany it occurs with comparative frequency; it is very much rarer in West and South Germany. Very few cases of cysticercus of the vitreous body have been reported in France and England (or America).

In the transparent vitreous, the worm is usually easily recognized as a round, bluish-green vesicle, with a white shining periphery, on which we can sometimes see, after prolonged observation, the folding in and out of the neck. The diagnosis is only difficult when the worm is very small and movements are absent, because delicate opacities of the vitreous may possibly have a vesicle-like appearance. Externally there is not infrequently a slight pericorneal injection of the globe. After the cysticercus has been present a long time, thick membrane-like opacities of the vitreous usually form; iritis and irido-choroiditis develop and the globe becomes phthisical. But the form and tension of the globe may also remain intact, as is shown by a case which was diagnosticated in 1856 by v. Graefe and was examined twenty years later by Hirschberg.

The visual disturbance varies according to the situation; as a general thing it results, in the beginning, in scotoma. Finally, however, vision is always destroyed, although I have had a case under observation for years in which vision is almost 1 and the vitreous body has remained clear. There is not much danger of sympathetic irido cyclitis (v. Graefe, Hirschberg), although slight symptoms of sympathetic irritation are often present. Jacobson also reports sympathetic amblyopia. The cysticercus has never been observed in both eyes, but two vesicles have been seen in the same eye (Becker, v. Graefe).

Treatment.—Attempts at extraction have been made in order to preserve the globe and, in favorable cases, the power of vision. Very satisfactory results are obtained by means of a meridional scleral incision, as was performed by Arlt, but particularly by

Alfred v. Graefe. The latter has devised a special localizing ophthalmoscope, in which a semicircular movable arch, divided into degrees, is fixed upon the ophthalmoscope. The zero point corresponds to the opening of the mirror. When the examined eye is in such a position that the cysticercus is directly opposite the observer, the distance between the cysticercus and the macula can be easily calculated, from the degree of deflection made by the visual line of the eye. When the situation has been accurately ascertained, a scleral incision, from before backward, is made at the locality in which the worm is situated, similar to the operation described above in detachment of the retina. The vesicle often presents itself spontaneously, otherwise it is extracted with the aid of forceps. A subretinal location is especially favorable.

If there are extensive secondary inflammations, or the globe has become phthisical, enucleation or optico-ciliary neurotomy must be performed.

[The experience of the last few years has, as it seems to me, put optico-ciliary neurotomy out of the field, leaving enucleation as the sole occupant, in these cases.—St. J. R.]

The *filaria oculi humani* has been observed in the vitreous body, in rare cases, as a thread-shaped structure (Quadri). It is apt to be mistaken for opacities of the vitreous.

4. Persistence of the Hyaloid Artery. Detachment of the Vitreous.

In rare cases the fœtal hyaloid artery persists. It appears as a gray band which passes from the optic papilla forward, toward the lens. A reddish color and wave-like movements have also been seen. The occurrence of a band-like but transparent structure, with a similar course, has also been described and regarded as the visible Cloquet canal (Wecker, Flarer).

The vitreous body, together with the hyaloid membrane (H. Mueller), is sometimes detached from the retina by injuries which result in rapid and profuse escape of the vitreous humor. In chronic inflammations of the eye, detachment of the retina, and particularly in staphyloma posticum, there may also be separation of the vitreous in the posterior part of the globe, the vitreous body becoming detached from the hyaloid membrane, which remains adherent to the retina (Iwanoff, Duke Charles Theodore). Detachment of the vitreous body in the anterior half of the eye, from serous effusion into Petit's canal, has also been observed (H. Pagenstecher). In these cases, there were usually glaucomatous symptoms.

As a rule, detachment of the vitreous cannot be recognized with the ophthalmoscope. In several cases, Galezowski diagnosticated detachment in the neighborhood of the optic papilla, by a semicircular gray rim which appeared at its border. Weiss also describes a curved stripe with a silvery shining reflex, which can be seen in myopes in the direct image on the inner side of the papilla, when using a corrective glass which is too feeble for the degree of myopia of the examined eye. He attributes this to the detachment of the vitreous which occurs in myopia at the posterior pole of the eye, as the result of distention of the globe.

DESCRIPTION OF PLATES.

PLATE I.

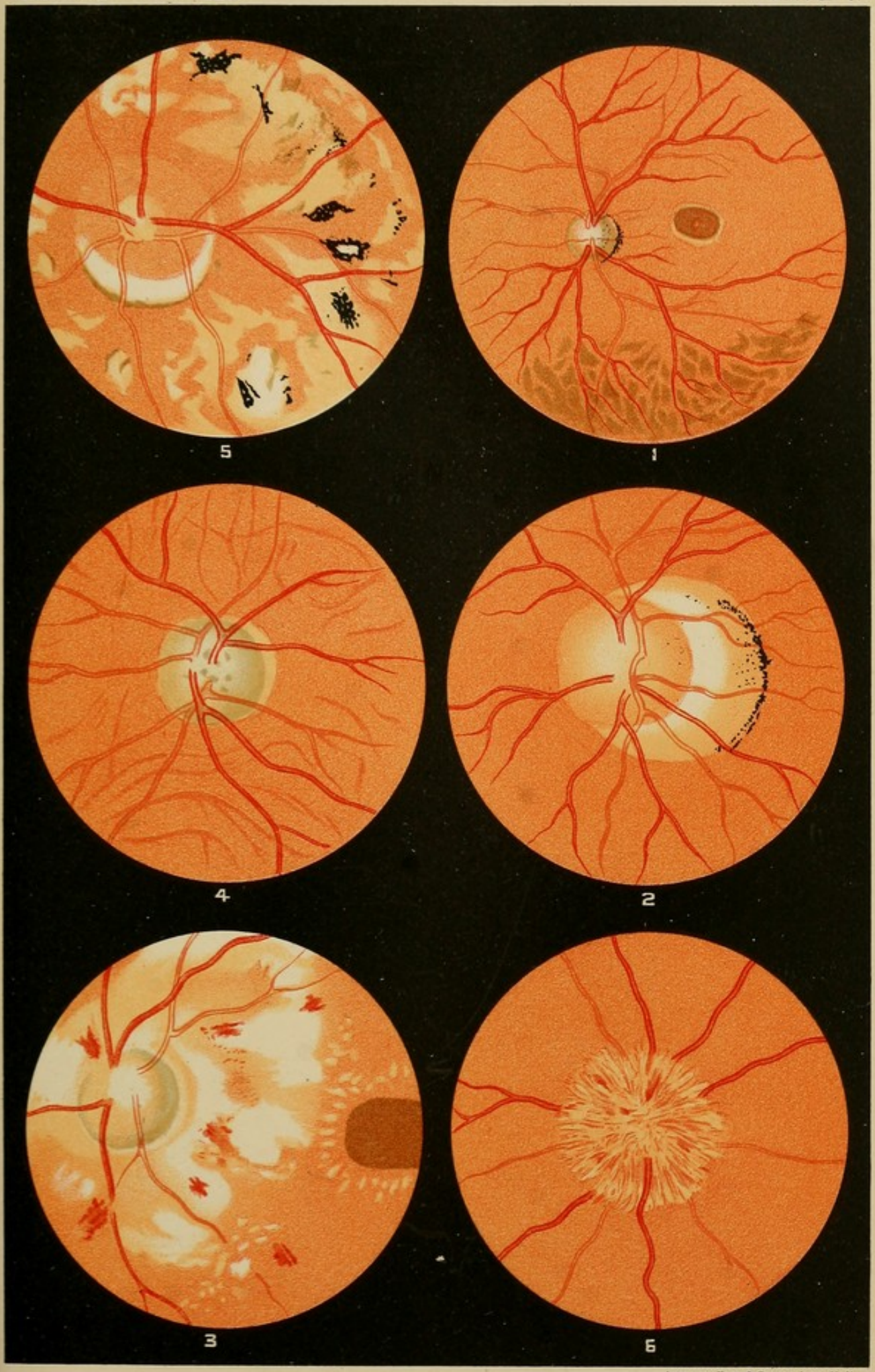
1. Normal Fundus with the Macula Lutea. In the lower part of the picture the intervascular spaces are prominent.
2. Posterior Staphyloma.
3. Retinitis Albuminurica, with the characteristic white stippling around the Macula.
4. Atrophy of the Optic Nerve. The Choroidal Vessels all plainly seen.
5. Choroiditis, at one point the Pigment has passed into the Retina and covers an Artery, Choroido-Retinitis. The Optic Papilla has a small crescent.
6. Papillitis in a case of tumor of the brain.

PLATE II.

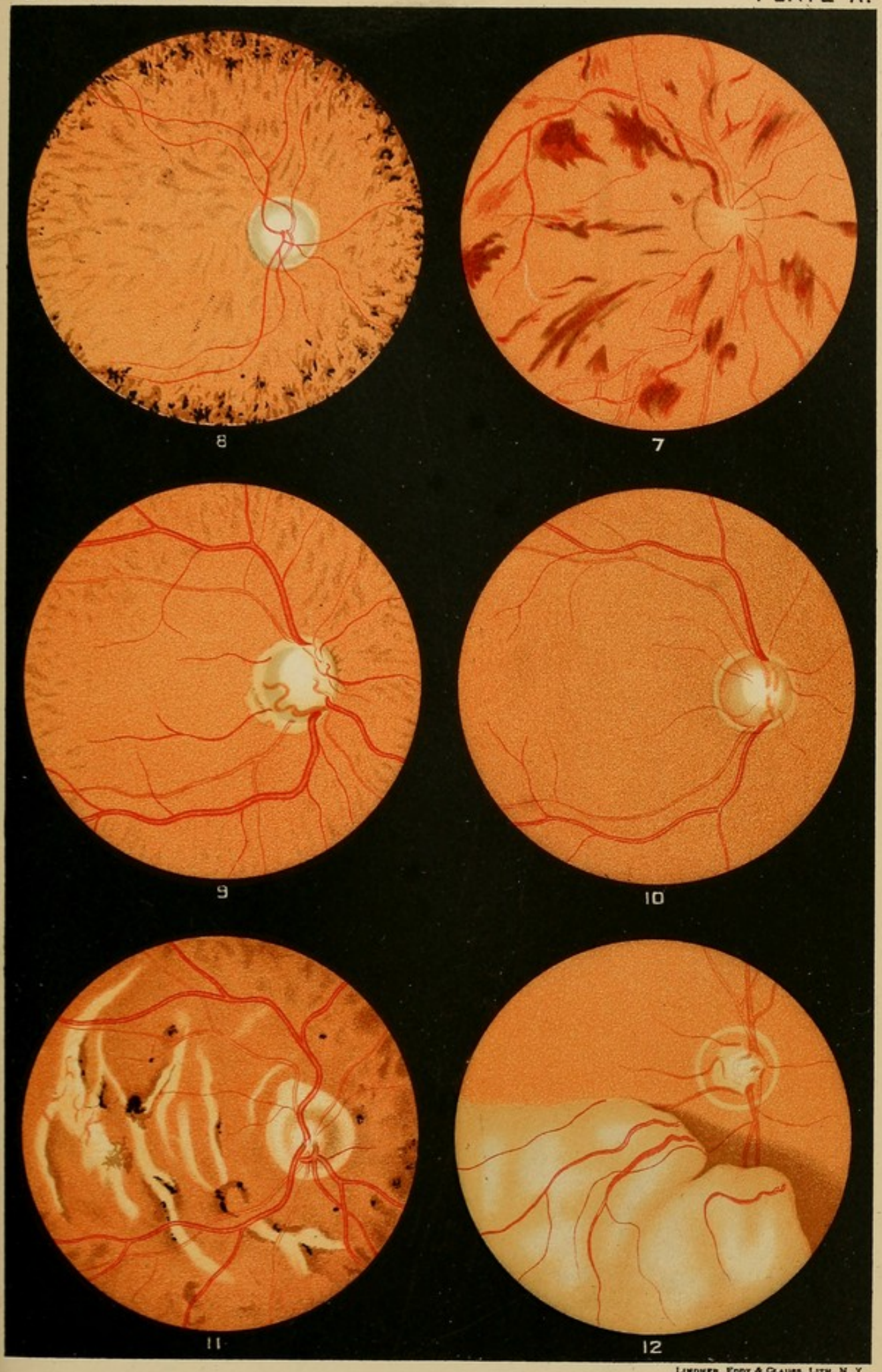
7. Retinitis Hemorrhagica.
8. Retinitis Pigmentosa, after Stellwag.
9. Glaucoma, advanced.
10. Glaucoma, first stages.
11. Choroidal Atrophy.
12. Detachment of the Retina.

PLATE III.

13. Posterior Staphyloma, partial atrophy of the Choroid and Retina (Stellwag).
14. Detachment of the Retina (Stellwag).
15. Diffuse Neuro-Retinitis (Stellwag).
16. Normal Fundus Oculi, showing central congenital excavation (from Stellwag).
17. Retinitis Apoplectica (Stellwag).
18. Detachments of the Retina below the Papilla. The Retina presents a wavy appearance.



LINDNER, EDDY & CLAUSS, LITH. N. Y.



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Part Third.

Glaucoma and ophthalmomalacia

Diseases of the lens, conjunctiva, cornea, sclera, iris and ciliary body

Sympathetic ophthalmia

Suppurative choroiditis

CHAPTER I.

GLAUCOMA AND OPHTHALMOMALACIA.

A. Glaucoma.

1. Clinical History.

THE term glaucoma (γλαῦκος, sea green) comes from a symptom of the disease, which had long been regarded as a striking one, namely, the greenish color of the pupil. Although this is by no means characteristic of all forms of this manifold disease, the name has been retained and come more and more into general use. Other names, such as ophthalmia arthritica and choroiditis serosa, which had equally little justification, have been abandoned. The type of the affection is furnished by glaucoma simplex (Donders, 1862; formerly called "amaurosis with excavation of the optic nerve" by v. Graefe). Its symptoms are: 1, increase of intraocular pressure which is manifested by increased hardness of the eyeball (increase of tension, hypertonus); 2, pressure excavation of the papilla of the optic nerve; 3, impairment of vision, progressing to blindness unless treatment interferes. If inflammatory phenomena are added to these symptoms (it must be noted that a certain length of time elapses before the excavation occurs), we speak of inflammatory glaucoma. This is subdivided into an acute, chronic, and intermittent inflammatory form, although the boundaries between them are often obscure, and one form often passes into the other. Thus, an eye affected with glaucoma simplex may be attacked by an acute, glaucomatous inflammation, or an acute glaucoma may terminate in a chronic inflammatory stage.

If the disease attacks a previously healthy eye, it is known as primary glaucoma; if the eye was already diseased and thereby predisposed to glaucoma, as secondary glaucoma.

Not infrequently certain stages in the course of the disease may be distinguished; a prodromal stage which precedes the fully developed process (glaucoma evolutum), and a terminal stage (glaucoma absolutum) in which sight is entirely destroyed. The latter is often associated with degenerative processes. According to v. Graefe, a prodromal stage is observed in about three-fourths of all

cases. It may last months and years without occurrence of pronounced glaucoma. Its symptoms appear in attacks, usually after definite causes which are often known to the patient. For example, after a heavy meal or after abstinence, after excitement, cold feet, etc. The attacks last for a longer or shorter time, but usually disappear after sleep. Their intensity also varies. They include the following; 1, seeing a rainbow-colored ring (red externally) around a lamp light. This ring is separated from the flame by a darker interval and presents a considerable intensity of color. Dull colored rings are occasionally observed by healthy individuals. If the rings border closely on the flames, they do not belong to the glaucomatous phenomena, but depend on errors of refraction. Their development is a phenomenon of interference, dependent on opacity of the refracting media. 2. Further visual disturbances, obscurations. Objects appear as if covered with a cloud. Parts of the field of vision are sometimes blotted out; central vision is more or less impaired. 3. Ciliary neuralgias. The pains radiate from the eye to the forehead, cheek and temples; they are often entirely absent. The neuralgia may be attributed to direct mechanical irritation of the nerves, by the sudden increase of intraocular pressure. As a rule, the objective symptoms during the attack are: 4, increased tension of the globe. The examination is made by palpation in a manner that has been already described. We thus arrive at more rapid and often more certain results, than by using the instruments described by Snellen, Morrits, Dor, and others, as tonometers. These are applied directly to the globe and measure the tension in figures in various ways, such as by the weight necessary to press a groove of a certain depth into the sclera. Bowman has recommended abbreviations for describing the various degrees of tension. Thus, *tn* indicates normal tension; increments are expressed by the plus sign, decrements by the minus sign, the degree by the addition of the figures 1 to 3. + T3 would indicate the highest degree of hardness ("stone hard"). If only one eye is affected, comparison of its tension with that of the healthy eye is important, because tolerably wide physiological limits are found in the eyes of different individuals. 5. Dilatation and slow movements of the pupil. This symptom is usually not prominent in the prodromal stage. The pupil, on account of its dilatation and the opacity of the media, sometimes exhibits the gray or grayish-green color, from which the disease derives its name, most markedly in developed, chronic glaucoma. But a similar reflex is often seen, independently of glaucoma, in old people whose lens reflects more strongly, after instillation of atropine. 6. Slight opacity of the anterior chamber and cornea. We shall again refer to this in de-

scribing acute glaucoma. 7. Hyperæmia and dilatation of the retinal veins, and venous pulse are also observed occasionally. The latter may also occur physiologically. The pathological arterial pulse, which will be discussed hereafter, is very rare in the prodromal attacks.

In addition to the attacks proper, the patients often exhibit a displacement outward of the far-point from diminution of the range of accommodation (early presbyopia). This may be attributed to the increase of the intraocular pressure, particularly in the vitreous body, which antagonizes the increased curvature of the crystalline lens. The anatomically demonstrated hyperæmia of the ciliary body in glaucomatous eyes may also be a factor. This is not always associated with removal of the far-point, though it is in many cases. On the contrary, we occasionally find increased refraction during the glaucomatous process, which is explained by an abnormal advance of the lens. The diminution of refraction may result from tension of the zonula Zinnii, and the consequent flattening of the lens. It does not result from flattening of the cornea, as is shown by direct measurements in glaucomatous individuals (Coccius, Laqueur).

The transition from the prodromal stage into that of fully developed glaucoma occurs when impairment of vision dependent upon the disease is observed in the interparoxysmal intervals.

I. Glaucoma Simplex.

Externally, the eye usually presents a normal appearance. The anterior chamber is occasionally flattened, the pupil, as a rule, does not become dilated and rigid until after the occurrence of blindness. The chief symptom is the impairment of vision and excavation of the papilla of the optic nerve, the latter being ophthalmoscopically demonstrable. The increase of intraocular pressure is not always marked, and is not distinctly evident at all times. It is to be remembered that the physiological limits within which the tension of the eyeball varies, are tolerably wide, so that in one case a certain tension must be regarded as the pathological increase of the formerly normal condition, while in another eye it is entirely physiological.

But even in glaucoma simplex, prolonged observation and frequent examinations almost always show a pathological increase, at least at certain times. Since Heinrich Mueller (1856) we are accustomed to attribute the glaucomatous excavation of the papilla to this increase of pressure, although in some cases in which the increase is not very great, we must assume a peculiar yielding char-

acter. It is not improbable that the resistance is occasionally diminished by pathological processes. Yet it remains a striking fact, that these excavations are not seen in other affections which are associated with intense changes in the papilla (choked disk, descending neuritis, atrophy). Increase of intraocular pressure, therefore, is also a requisite. It pushes back, as the weakest and thinnest portion of the scleral capsule, the network of the lamina cribrosa which traverses the optic nerve transversely, and thus excavates the optic papilla. At the beginning of the glaucomatous disease, the most central portion is first excavated, and the lamina cribrosa there pushed backward, as Brailey showed anatomically, and as I have observed clinically in several cases. Soon one or another portion of the edge sinks in, and the diagnosis is then assured by the bending of the vessel in that locality.

Another phenomenon, which is recognizable with the ophthalmoscope, may also be mentioned, viz., the occurrence of a spontaneous arterial pulse. We must add, however, that this is quite rare in recent cases. The statement, which is often made, that the arterial pulse is produced more readily by the pressure of the finger on the glaucomatous globe, than in normal eyes, possesses no significance of moment, in view of the physiological differences in eyes as regards this phenomenon. But if spontaneous arterial pulsation is present in the form which we have described as pressure pulsation, the diagnosis of glaucoma may usually be made positively, because this pulsation is hardly ever observed under normal conditions.

The diminution of vision and the narrowing of the field of vision, usually correspond to the degree of excavation, although there are occasional exceptions. Thus, I have had under observation for a number of years, a lady who is suffering from bilateral, pronounced pressure excavation—also diagnosticated by other ophthalmologists —with V $\frac{1}{2}$ and intact field of vision, while no other change in function has been hitherto noticeable.

In another case, in which glaucomatous symptoms have existed for ten to twelve years, vision was almost normal and the field of vision was intact, despite excavation. This also shows how long the process may remain stationary, although only in rare cases. As a general thing, the loss of central vision and the narrowing of the field of vision occur more rapidly, although in glaucoma simplex the course is much slower than in the inflammatory forms. It seems as if the cause of the disturbances of function is to be sought particularly in the flexion of the nerve fibres and the pressure upon the papilla, although the latter may meet with a different resistance in the nerve fibres, corresponding to the more rapid or

slow development of the excavation. Very rare cases with intact vision, and without other glaucomatous symptoms, lead to the suspicion that the excavation may also be congenital or that it remains as the result of a process which has run its course in childhood (Jacobson).

The narrowing of the field of vision, occasionally precedes the impairment of central vision. In the various forms of glaucoma, as a rule, the narrowing is usually more advanced toward the nasal side, upward and downward, than toward the outside. Even when the narrowing is more concentric, the field of vision is usually more extensive to the outside than to the inside, forming a transverse oval. Finally, the defect approaches the point of fixation from within, until it is lost. In very rare cases, the glaucomatous process begins with a pericentral scotoma, even when the peripheral boundaries of the field of vision are relatively free.

The disease almost always ends in complete blindness. The color sense remains intact for a long time. But the boundaries at which the individual colors are still perceived at the periphery of the field of vision, are often closer than normal to the point of fixation at an early period, although the relation between the different colors as regards their peripheral perception remains physiological. The color sense only disappears with the increase of the ascending atrophy of the optic nerve. The light sense, also, is often diminished, both as regards the minimum and particularly as regards the increment of stimulus.

As a rule, patients suffering from glaucoma simplex, consult the physician only because vision is impaired. At that time, one eye is often entirely or almost entirely blind. More observant patients have their attention roused by the difficulty in reading, arising from removal of the near-point. Temporary obstructions also occur occasionally, "a light veil, or mist, is situated in front of objects," although no special inflammatory symptoms are noticeable in the eye. Rainbow-colored rings are observed more rarely. Pains in the forehead and temples are almost always absent.

When glaucoma simplex is associated with attacks of an inflammatory character, with pronounced opacities in the media, and injection of the vessels, the disease is known as glaucoma simplex cum inflammatione intermittente. Glaucomas which exhibit an especially narrow anterior chamber, in the interparoxysmal periods, together with the other symptoms of glaucoma simplex, belong in this category.

II. Glaucoma Inflammatorium.

Acute inflammatory glaucoma presents the symptoms of an acute inflammation of the eye. It is to be noted that other symptoms, such as violent pains in the head and face, often associated with vomiting, sometimes make us overlook the local affection. The lids are slightly swollen, the tears overflow, the conjunctiva bulbi is markedly injected, often œdematous. In addition to distention of the subjunctival network which surrounds the cornea like a ring, we see thick, dark blue vessels coming from the equator of the bulb; these are situated upon the sclera and are connected with the pericorneal vessels. On account of the œdematous infiltration the cornea looks dull and cloudy, and small losses of epithelium are often present; occasionally there are punctated whitish patches upon the surface which is directed toward the anterior chamber. Its sensibility, as tested by contact with the tip of a piece of paper, is usually diminished. The anterior chamber is narrow, the iris and lens being pushed forward, so that sometimes they are almost in contact with the cornea. The aqueous fluid appears cloudy. The occurrence of a real change in its constituents and of the reception of lymphoid cells, which is doubted by some writers, is proven by direct microscopical examination, as well as by occurrences of the above-mentioned deposits on the membrane of Descemet. I have seen hemorrhages into the anterior chamber. As a rule, the pupil is dilated, occasionally to its maximum. The latter appearance is of the greatest differential diagnostic importance, because such mydriasis is observed in no other inflammation of the eye of equal violence. From this alone, we may almost make the diagnosis, if the action of atropine or paralysis of the sphincter iridis can be certainly excluded. The color of the pupil is not black, but smoke gray. The dilatation of the pupil is absent in very rare cases; even posterior synechia of the iris may be present. On examination with the ophthalmoscope, at the height of the attack, the pupil sometimes remains gray or blackish, despite the illumination; because all the entering light is absorbed by the opaque media. This absorption of light is increased by the diffuse opacity of the vitreous. Circumscribed patches are observed rarely, but I have seen them in a few cases.

If we succeed in seeing the details of the fundus, the papilla appears hyperæmic, the veins are markedly distended and sinuous, the arteries often exhibit pulsation. Excavation, however, is not present in a first attack of glaucoma, but it is found if there has been a previous chronic glaucoma. The tension of the eyeball is increased. The immediate cause of these acute symptoms and the

inflammation, is to be sought in the sudden increase of tension and the periodical interruption of the arterial current (pulsation) with its influence on the walls of the vessels.

As a rule, vision diminishes considerably during the attack; it may be lost with the exception of the quantitative perception of light. This is to be attributed to the opacity of the media, the interruption of the supply of blood to the retina, and to the direct pressure upon the latter.

Gradual improvement usually occurs without special treatment, although the former degree of vision is not attained. This is seen particularly in the mild, subacute forms. The inflammatory symptoms also subside after the lapse of days or weeks, and the eye may present approximately the normal appearance. But the disease is not extinguished; excavation of the optic nerve develops and the eye becomes blind after new attacks, or in a more chronic form.

In extremely rare cases, the first acute attack completely destroys sight in a few hours and restitution does not take place. A. v. Graefe has applied to these cases the term glaucoma fulminans. It is observed usually in older people, but I have seen it once in a woman of twenty-four years. Prodromata were absent, and the attack was attended with the most violent headache and vomiting. After iridectomy, which was attended with escape of vitreous humor, the globe became soft and slightly atrophic.

In chronic inflammatory glaucoma, the symptoms of acute glaucoma develop gradually, without the occurrence of severe inflammation. The conjunctiva itself presents few vessels, but a striking appearance is exhibited by the dark blue bands which ramify upon the anterior of the sclera, beneath the conjunctiva (anterior ciliary veins), and convey the blood from the interior of the eye in the place of the compressed venæ vorticosæ. The sclera assumes a lead-colored appearance, resulting from obliteration of the smaller arteries of the episcleral tissue. The cornea is less transparent than normal and often exhibits small losses of epithelium, the aqueous humor is sometimes periodically opaque, the anterior chamber is narrow; the pupil, at first of moderate width, afterward increases in size. The iris has a dull color, and exhibits increasing atrophy of the tissue. As a rule, the fundus can be seen with the ophthalmoscope. After the disease has lasted for some time, excavation of the papilla develops and finally leads to atrophy of the optic nerve. The tension is increased.

The complaints of the patient are similar to those in glaucoma simplex, but slight irritation of the eye, obscurations and neuralgias occur more frequently.

If one or the other of these forms has led to complete, incurable

blindness, we have to deal with glaucoma absolutum. The external condition of the eye sometimes remains approximately the same, usually with increasing opacity of the lens. In other cases degenerative processes occur, and lead to ectasiæ (scleral or corneal staphyloma) after increase of pressure, or to phthisis after diminution of tension At the same time various inflammations and changes (suppuration of the vitreous, detachment of the retina, ulceration of the cornea, keratitis bullosa, apoplexies in the cornea, etc.), may run their course together. Even after blindness, the patients sometimes suffer from violent neuralgias and, though more rarely, from annoying hallucinations.

III. *Secondary Glaucoma.*

In contrast with the forms of primary glaucoma just described, stands secondary glaucoma. This is combined with other diseases of the eye, usually with the symptoms of glaucoma simplex. Vision diminishes after the gradual appearance of defects in the field of vision, while the tension of the globe increases and the excavation of the papilla develops. As the primary affection has often given rise to opacities which interfere with ophthalmoscopic examination, the diagnosis is based in such cases on the functional disturbances and increased pressure. Certain diseases have a special tendency to lead to secondary glaucomatous processes. These include the cicatricial ectasiæ of the cornea and the synechiæ of the iris, both anterior and posterior. When there is total posterior synechia and adhesion of the iris to the capsule of the lens, loss of the eye occurs in almost every case, partly from secondary glaucoma, in other cases from irido-cyclitis. Partial synechiæ are less dangerous. Iritis serosa, which is also apt to be associated with opacity of the vitreous body, also exhibits a tendency to secondary increase of pressure. This is also true of traumatic cataract with rapid swelling and luxation of the lens, and certain intraocular tumors. Secondary glaucoma has also been observed occasionally in hemorrhagic retinal processes (so-called glaucoma hæmorrhagicum), a form which possesses a very ominous prognostic significance, even with the proper treatment.

Secondary glaucoma is found much less frequently in connection with posterior sclerotico-choroiditis, diffuse and pannous keratitis, band-shaped infiltrations and keratitis vesiculosa (herpes corneæ). In the latter affection, which possesses pathological importance in so far as the vesicles may be interpreted as ectasiæ of the lymphatics and may be associated with a stasis of lymph which gives rise to the glaucomatous process, the occurrence of acute

glaucoma was once observed by Saemisch. In a woman of fifty-six years, whose right eye had been affected for more than a year with herpes corneæ with constant relapses, I had the opportunity of observing secondary glaucoma with amaurosis, after she had not appeared at the clinic for six months. The herpes constantly recurred. Excavation of the papilla is often found in cornea globosa (hydrophthalmus congenitus).

Hock saw glaucomatous symptoms after tattooing of corneal cicatrices. Glaucoma is also observed occasionally in combination with other diseases (detachment of the retina, retinitis pigmentosa, atrophy of the optic nerve, even in aphakia and irideremia), but probably, the process must here be regarded merely as a complication.

Differential Diagnosis.—Glaucoma simplex is apt to be mistaken for simple amblyopia, or amblyopia as the result of atrophy of the optic nerve. The increased tension usually furnishes a starting-point, but this is occasionally so slight that it is difficult to recognize it as pathological. The ophthalmoscopic appearance of pressure excavation is then decisive. But the differential diagnosis of the latter from the other forms (especially the atrophic) of excavation of the papilla is not always easy. The intact condition of the color sense which is usually impaired much earlier in optic atrophy, testifies in favor of glaucoma. Attention should also be paid to narrowing of the field of vision; the occurrence of a defect, especially on the temporal side, is very rare in glaucoma.

The diagnosis is often difficult, in glaucoma with intermittent inflammations, if the patient is examined in the non-inflammatory period and the excavation is not fully developed. But we will often be guided aright by the description of the peculiar symptoms of the attack, the condition of the pupil, of the episcleral vessels, and the tension.

Acute glaucoma, when it develops typically, is not easily mistaken; the dilated pupil is characteristic. The narrowness of the anterior chamber testifies against iritis serosa, in which the pupil is often somewhat dilated. Moreover, the vascular injection and other inflammatory symptoms are usually less prominent in iritis serosa. In the latter, as a rule, there are deposits on the membrane of Descemet; in glaucoma, they are very rare. The diagnosis is more difficult when, as happens exceptionally, the pupil is narrow in acute glaucoma. Here it may be mistaken for acute iridochoroiditis, but in acute glaucoma the cornea is always somewhat opaque, the tension is greater, and the anterior chamber narrower.

If cataract develops in chronic glaucoma, it is sometimes mistaken for uncomplicated cataract. But, as a rule, the wide, rigid pupil, the large anterior ciliary veins, and the increased tension will assure the diagnosis. The examination of vision must also be taken into consideration. In glaucomatous cataract, there are defects in the field of vision and impairment of central vision, and the light of the smallest lamp is no longer perceived as it is in uncomplicated cataract. We must also mention, that intraocular tumors are sometimes complicated with glaucomatous symptoms.

2. Occurrence and Etiology.

In Europe about one per cent of all patients at the ophthalmic clinics suffer from glaucoma; in America the percentage seems to be somewhat less. The disease occurs with equal frequency in both sexes, and is most frequent after the age of fifty years. Primary glaucoma is observed exceptionally in young people. In the majority of cases the glaucomatous process attacks both eyes in succession. The acute form is much rarer than the chronic. Among 124 cases of glaucoma which I have tabulated, 24 suffered from acute glaucoma, 100 from chronic glaucoma, *i.e.*, chronic inflammatory glaucoma and glaucoma simplex. Hyperopic eyes are attacked with special frequency. The disease is hereditary in certain families.

Trigeminal neuralgia plays a part among the etiological factors. It is often noted that it precedes the disease of the eye for years. The connection of glaucoma with gout, the menopause, cessation of habitual hemorrhoidal fluxes or cutaneous secretions, atheroma of the arteries and the like, is not improbable in certain cases. Violent emotional excitement, excesses, insomnia, colds, conditions of exhaustion, febrile diseases, etc., are not infrequently the direct cause of the glaucomatous attack. Instillations of atropine or homatropine in chronic glaucoma or glaucoma simplex have sometimes produced an acute attack. A few cases have also been reported after instillation of duboisine and cocaine (Manz, Maier). Hence caution is advisable. In the same way an attack of inflammation upon the second eye, hitherto apparently healthy, or suffering from non-inflammatory glaucoma, has also been observed after iridectomy upon the glaucomatous eye. In order to avoid this, I am in the habit of instilling eserine into the non-operated eye during the operation and the after-treatment. [Leaving the non-operated eye uncovered during the whole treatment, as advised by Arlt, is of importance.—St. J. R.]

3. Pathological Anatomy.

The characteristic appearance in pronounced glaucoma is the excavation of the optic papilla, with pushing back of the lamina cribrosa (H. Mueller). The other lesions are not present in all cases, although some of them, in view of their frequency, must be considered in explanation of the glaucomatous process. We refer particularly to the obliteration of Fontana's space, which is situated between the meshes of the lig. pectinat. at the periphery of the anterior chamber (the so-called filtration angle). In recent cases, the entire surroundings of Schlemm's canal are infiltrated with cells; in cases which have run their course, cicatricial contraction usually develops concentrically toward it and occludes it. The periphery of the iris is often adherent to it (Knies). As the escape of lymph from the interior of the eye occurs at this place (Leber), its occlusion will produce stasis and increased tension. But further investigations have shown that this occlusion does not exist in all cases of glaucoma, and that it may even be associated with diminution of tension (H. Pagenstecher, Schnabel, Brailey, Fuchs, etc.).

According to Ad. Weber, the occlusion of Fontana's space is effected by venous swelling of the ciliary processes, which press the rim of the iris against the cornea. Brailey, who examined a very large number of glaucomatous eyes, emphasizes, as a constant appearance, the marked dilatation of the blood-vessels of the interior of the eye: chiefly and almost exclusively those which supply the ciliary region. This is associated with thinning of the walls of the vessels. On the other hand, chronic hyperplastic periphlebitis (Birnbacher-Czermak) has been observed in the uveal and scleral tracts, and endarteritis (Kuhnt) in the most varied vascular tracts of the eye and in the optic nerve.

Another noticeable feature, is the frequency of atrophy of the ciliary muscle, especially after the glaucomatous process has lasted for some time. Brailey connects this atrophy with the changes in the vessels; it is not the secondary effect of the increased pressure, because when it occurs in places it corresponds, as a rule, to the partial dilatation of the vessels. He regards the adhesion of the iris to the cornea as secondary; it is usually preceded by inflammation of the iris. At first, it is infiltrated with numerous cells, but finally it undergoes atrophy. The diameter of the lens is not enlarged. The retina shows no special changes, occasionally hypertrophy of Mueller's supporting fibres. Brailey, like H. Pagenstecher, Schnabel and others—and opposed to the investigations of Sattler, and recently of Birnbacher-Czermak—never found inflammatory changes in the choroid, but the equatorial pigment

epithelium is often irregularly pigmented. The iris exhibits extensive connective-tissue sclerosis with corresponding vessel changes (Ulrich). In acute cases, the vitreous body shows externally an increase of consistence, internally liquefaction. The cellular elements are increased. Detachment of the vitreous has also been described by different writers. According to Brailey, the sclerotic is not especially rigid, but it is often thick and firm. This is hardly more marked, however, in uncomplicated glaucoma than in other hyperopic eyes at the same period of life. But the fact, that the inner layers of the bundles of scleral fibres have a more parallel direction, as if they had been pressed together more closely, and that they have an increased refracting power, indicates an increase in rigidity. The demonstrated fatty degeneration (Coccius, Wedl, Weichselbaum) also favors the assumption of diminished elasticity. Direct experiments on scleral elasticity, however, have shown such wide differences in normal eyes that no conclusion can be drawn from them (Ad. Weber). In addition to epithelial changes when opacity is marked, the cornea also exhibits changes in the stroma by which the regular arrangement of the lamellæ is disturbed; in acute cases there is œdema.

4. Theory of the Pathogenesis and Nature of Glaucoma.

Opinions concerning the pathogenesis and nature of glaucoma have fluctuated greatly, and are by no means thoroughly clear at the present time. Prior to the period of anatomical examinations, the disease was regarded as an affection of the crystalline lens, vitreous body or retina. At the beginning of the thirties in this century, Canstatt and Sichel promulgated their theory that glaucoma was a choroiditis. A. v. Graefe followed them; recognizing the increased intraocular pressure as the essential nature of the disease (1865), he assumed a serous choroiditis as the cause of the increased tension, at least in inflammatory glaucoma. This was supposed to cause serous infiltration of the aqueous humor and vitreous body which, on account of the increase in volume, caused rapid increase of intraocular pressure, with compression of the retina and the further sequelæ. But it must be acknowledged that the introduction of a special name, such as choroiditis serosa, did not make the real cause of the increased pressure any clearer, especially as a choroiditis was not sufficiently proven, either clinically or anatomically. Nevertheless, this view has again found adherents in recent times (Mauthner).

That the real nature of the disease consists in the pathological increase of the intraocular pressure, is accepted almost universally.

The few cases of glaucoma simplex, in which this increase does not exceed the physiological limits, may be interpreted by assuming that an eye which stands very low in the physiological range of tension, is transferred to the upper limits by the pathological increase. Furthermore, as we have stated, an undeniable pathological tension can be demonstrated, at least temporarily, in almost all of these eyes. In those cases, on the other hand, in which the diagnosis of glaucoma is made from excavation of the papilla alone, we must think of the possibility of another cause of the excavation, such as atrophy of the optic nerve or, if vision is unimpaired, congenital anomalies. At all events, no one has ever diagnosticated glaucoma when the ocular tension was below physiological limits, with the exception, as a matter of course, of the secondary degenerative processes of glaucoma absolutum. The fact that excavation of the optic nerve may sometimes occur without demonstrable increase of pressure, does not compel us to depreciate the importance of increase of intraocular pressure in glaucomatous processes, and to recognize an independent glaucomatous excavation of the optic nerve, resulting from disease of the vessels (Jaeger).

The pathological increase of intraocular pressure, considered mechanically, may result either from abnormally excessive contents, or from abnormally diminished size and distensibility of the capsule of the eye, compared with its contents. If the effect of one of these factors is not abolished by suitable adaptation on the part of the other, the hardness of the globe must increase. This adaptation and mutual regulation seems to occur freely under normal conditions. It is only when the degree of disturbance in one or the other direction has become too great to admit of compensation, or when there is disturbance of the apparatus destined for regulation, that pathological increase of the intraocular pressure develops, and thus the starting point for glaucomatous processes. Hence it is evident, that one-sided views which always attribute the glaucoma to one and the same cause, possess but slight probability, especially if we consider the manifold form of the disease. And yet there is a constant advocacy of theories which refer all glaucomas to one and the same disturbance. Everything that favors the theory defended, is then dilated upon fully, opposing facts are concealed or misinterpreted with an astonishing degree of acumen.

In discussing the mechanical factors which come into play, we will refer to the more important theories, in so far as they find support in anatomical, experimental, and clinical appearance and results. My own opinion is, that a series of causes may give rise to the glaucomatous process in general, but that one or the other occupies the foreground in the individual case.

The abnormal excess in the contents of the capsule of the globe may result either from excessive additions to the physiological contents, or from insufficient removal. We have to deal, therefore, with the afflux and efflux of blood and lymph, with conditions of secretion and absorption. As regards the blood, measurements of tension have not shown any pathological change of intraocular pressure, either in the eyes of cholera patients (v. Graefe), anæmic or moribund individuals (Stellwag), or in conditions of plethora and fever, in which the radial pulse was extremely full and vigorous. Contrary to the manometric measurements in the eyes of animals (v. Hippel and Gruenhagen, Adamück), the general blood pressure seems under normal conditions, and with the normal regulative capacity of the eye, to exert no influence upon intraocular pressure in man.

The case is different when there are local changes in the blood-vessels of the eye itself. Here, the fact that Brailey found an almost constant dilatation of the arteries and thinning of their walls, particularly in the tract of the ciliary body, appears to possess great significance. This change may produce increased pressure both mechanically by the increased amount of blood in the dilated vessels and also by increased effusion and secretion, the latter constituting the second factor in active increase of contents. In a similar manner even local arterial stenoses and scleroses, when they affect, for example, the vessels of the iris, will give rise to secondary congestion of the ciliary body, and thus to increased secretion of this organ which is chiefly concerned in intraocular nutrition (Deutschmann, Schick). In addition, secondary disturbances may be inaugurated by primary swelling of the congested ciliary body or its processes (to which Ad. Weber has called special attention), inasmuch as the iris is pushed forward and thus occludes, in certain cases, Fontana's canal, the chief path for the removal of lymph.

But the dilatation of the arteries, which has been demonstrated anatomo-pathologically, may be the result of a primary disease of the vessels or of a vaso-motor affection, so that in the latter event the disease is neuropathic and located genetically in the tract of the sympathetic or the trigeminus. According to v. Hippel's and Gruenhagen's experimental investigations, the intraocular pressure is lowered in cats and rabbits by irritation of the superior cervical ganglion, whereby far the largest number of vaso-constrictor fibres of the eye enter the sympathetic. On the other hand, animals, in whom fluorescein had been injected, presented much more rapid and marked fluorescence of the eye on the same side after division of the cervical sympathetic or the sympathetic fibres in the ophthalmic branch of the trigeminus. This is due to more rapid and

increased secretion of the aqueous humor by the ciliary body, and posterior surface of the iris (Schoeler and Uhthoff) and must therefore give rise to increased pressure. Direct irritation of the trigeminus (Wegner, Schulten) produced increase of secretion and intraocular pressure, as the result of dilatation of the vessels and diminution of the resistances to filtration. This irritation will exercise its effect so much the more readily, the more the vascular tonus (which is controlled by the sympathetic) has suffered, as is to be assumed in old people, gouty individuals, and so forth. In addition, clinical experience shows that trigeminal neuralgia plays a prominent part in the etiology of glaucoma. The observation made by me that, in irritation of the dental nerves in young people by caries or periostitis, the near-point is very often moved farther away, and that this, in turn, results from increase of intraocular pressure, testifies in favor of the influence of the trigeminus upon the occurrence of glaucomatous processes. In secondary glaucoma, the process probably starts, in many cases, from irritation of the intraocular branches of the trigeminus, for example, those of the iris. Donders was the first who regarded glaucoma as a secretory neurosis.

On the other hand, if we regard the diminished escape of fluid, stases in the veins and lymph channels are to be taken into consideration. In regard to the effect of ligature of the veins in the immediate vicinity of the globe, experiments on animals have shown considerable increase of intraocular pressure (Adamück, Schulten). If we also bear in mind the great difficulties opposed to compensation of the increased volume of the eye, necessarily resulting from stasis in the ciliary veins, we cannot deny the influence of this factor on the development of glaucomatous increase of pressure, especially as the appearance of hyperplastic periphlebitis, particularly within the scleral ring, point directly to this factor. Sufficient compensation can hardly result from a diminished supply of arterial blood, because the firmness of the arterial walls interferes with the necessary compression. Nor can this result from an increased escape of lymph, especially as the increased serous effusion from the vessels as the results of the stasis, must be added to the purely mechanical factor of the increased amount of venous blood. There remains the yielding character and elasticity of the sclera, which will render innocuous, to a certain extent, the increase of contents resulting from stasis of blood. But if this is exceeded or the sclera is unyielding, a pathological increase of pressure must result. It must also be noted that a stasis in the veins also causes an obstruction to the outflow of lymph anteriorly, because this occurs, in great part, through the venous vessels at the periphery

of the anterior chamber (Leber, Schwalbe). We thus have, as a complicating element, that factor (interference with the escape of lymph) which has recently been dwelt upon in such a one-sided and exaggerated manner. According to experiments, the obstruction of the lymph channels in the posterior portions of the globe, does not exert a notable influence on the increase of intraocular pressure, particularly as the escape of lymph from the vitreous body takes place through the zonula of the chamber (Ulrich). On the other hand, obstruction of the anterior lymph channels by occlusion of Schlemm's canal or pressure and adhesion of the periphery of the iris to the "filtration angle" has often been observed (Knies). Stasis of lymph in this locality will undoubtedly aid in increasing intraocular pressure, although, when the sclera is sufficiently elastic, compensation by acceleration of the venous outflow is more apt to occur than in the previously discussed direct venous stasis. That the prevention of the escape of lymph from the anterior chamber does not cause enlargement of the latter, may be attributed to obliteration of the vessels of the iris which, according to Schick's investigations, secrete the aqueous humor. At all events, the occlusion of Fontana's space can hardly be regarded as the most important cause of the glaucomatous disease. Moreover, we observe not infrequently an application of the periphery of the iris to the filtration angle, with narrowing of the chamber, in slightly phthisical eyes with diminished pressure. Hence, we can attribute an etiological importance to the factors in question at the most, in certain cases of glaucoma, but by no means in all. The frequency of the above-mentioned anatomical appearances in glaucoma, may be interpreted simply as the result, owing to increased pressure in the vitreous, of the advance of the iris, and the pressure of its periphery upon the cornea, which is apt to give rise to adhesive inflammation.

It remains for us to consider the significance of the capsule of the globe, particularly the sclera, for the increase of intraocular pressure. If the sclera becomes more resistent, and loses its distensibility and elasticity, the intraocular pressure must increase in a purely mechanical manner. A permanent pathological increase of pressure will occur so much more readily because the compensation which an elastic sclera offers to temporary increase of contents, now becomes impossible. This increase of resistance is generally found in old people, thus explaining the frequent occurrence of glaucoma in them. But it appears as if the resistance of the sclera is increased still more, though not in all cases, in glaucomatous eyes than it is in others of the same age. The implication of the sclera, also explains the more frequent affection of hyperopic

eyes, because these *per se* have a relatively thick sclera, which is so much more apt to be abnormally resistant as the result of senile degeneration.

I have often observed in glaucomatous eyes, as the sign of rigidity, that while slight pressure with the tip of a probe produced a deep groove in the cornea, the sclera hardly yielded to the pressure. The difference was too great to be explained by a certain inequality of tension in the anterior and posterior chambers, which always remain in connection with one another. Hence there is full justification for attaching fresh importance to the increased rigidity of the sclera, in a series of cases of glaucoma.

The explanation of the development of the inflammatory symptoms which appear in inflammatory glaucoma, offers a certain degree of difficulty. The simplest way would be to interpret them as accidental complications, or to deny their inflammatory character and to regard the symptoms merely as concomitants of a neurosis.

But if we speak at all of inflammations of the eye, acute glaucoma, with its injection and tissue infiltration, assuredly belongs in this category. The occurrence of inflammation is more easily understood, if we pay attention to the vascular changes which are clinically noticeable in inflammatory glaucomas. The retinal vessels are very brittle, as shown particularly by apoplexies which occur after iridectomy on account of the diminution of pressure. These apoplexies are absent, as a rule, in simple glaucoma. It is readily conceived that tissue changes, similar to those which appear so clearly in the retinal vessels, are also present in the other vessels of the eye. This would explain the great facility with which emigration and diapedesis of blood-globules occur in the inflammatory forms of glaucoma.

5. Prognosis and Treatment.

The *prognosis* varies according to the effect of treatment. The latter is not always efficacious, and its efficiency varies according to the form and duration of the disease. If not treated, glaucoma leads to blindness after a longer or shorter period. Unfortunately, quite a number of cases come too late into the hands of the competent physician, partly because they were neglected, partly because they were not diagnosticated.

In general, it may be said that the inflammatory processes are the most easily cured; the results are less certain in glaucoma simplex. The outlook is also more favorable, when treatment is begun at an early stage of the process, when vision is still relatively fair, and the excavated papilla does not exhibit decided atrophy.

Treatment.—Numerous medicinal and operative procedures against the disease, the scleral puncture with evacuation of the vitreous in order to diminish the pressure (recommended by MacKenzie in 1830) and repeated paracenteses (Desmarres, 1847), had not given satisfactory results. A. v. Graefe (1856) was the first to discover an efficient remedy in iridectomy, whose influence upon the diminution of tension he had already tested in other morbid processes. This has become one of the greatest of therapeutic discoveries. In performing iridectomy (see Operations on the Iris), at least in the chronic forms of glaucoma, special weight must be attached to excising the iris as far as the ciliary periphery and to a considerable width. Smaller and less peripheral excisions often suffice in acute glaucoma. The external wound in the scleral limbus should be about 8 mm. long. We should avoid making the incision too far in the sclera, particularly in the inflammatory forms of glaucoma, because otherwise there is danger of escape of the vitreous or luxation of the lens, on account of the high intraocular pressure. The artificial pupil should be direct upward, if possible, because it is then best covered by the upper lid and very peripheral and irregularly refracted rays of light are thus excluded. But iridectomy can be performed most easily to the outside, the straight lance-shaped knife being introduced quite peripherally. This plan is advisable in very difficult cases and when the operators are not very skilful. It is also advisable to produce artificial myosis by the instillation of eserine.

Chloroform must be administered in certain cases in order to avoid strong pressure with the lids and muscles, which would be especially injurious on account of the high intraocular pressure. As a general thing, however, the anæsthetic can be dispensed with. [Cocaine does not usually sufficiently diminish the sensitiveness of the iris, to enable us to dispense with a general anæsthetic in the operation for glaucoma. I generally employ sulphuric ether.—St. J. R.]

Hemorrhages into the anterior chamber, often resulting from iridodialysis, occur not infrequently in glaucoma after iridectomy. It almost appears as if, in glaucoma, the periphery of the iris is separated more easily from the ciliary body, by the traction of the forceps. The blood should be evacuated as thoroughly as possible by making the wound gape slightly; the rest will be absorbed more or less rapidly according to the intactness of the tissue of the iris. In acute glaucoma, retinal apoplexies are also absorbed, but they disappear in a few weeks.

In a few cases, a cataract forms rapidly after the operation, owing, as a rule, to injury of the capsule [or concussion of the

lens—St. J. R.]. The corneo-scleral cicatrix is not infrequently cystoid, in other cases it exhibits a certain width and transparency, so that it appears to have a blackish color. The curative effect of the operation in acute cases, if it is performed within the first few days, is usually striking and permanent. The inflammation subsides and vision becomes normal in the course of a few weeks. In the chronic inflammatory forms, the progress of the disease is also checked, as a rule, but vision remains longer in the *status quo ante bellum*, and very slowly undergoes gradual improvement, which may be associated with visible diminution of the excavation.

The results are least certain in glaucoma simplex. A standstill or slight improvement is the most that can be expected. But in a considerable number of cases there is a decided relapse after the operation, following the latter directly. Here the globe usually retains its abnormal hardness after the operation, despite the escape of the fluid of the chamber. Slight inflammations are apt to occur and vision grows constantly worse. V. Graefe has applied to these glaucomas the term malignant. Even after a relatively good recovery, the result as regards vision may be unfavorable at once.

The prognosis, in general, is so much poorer, the more marked the excavation and atrophy of the papilla and the narrower the field of vision. In cases in which the narrowing of the field of vision has approached very close to the point of fixation, central vision is often lost after the operation. As this is true in quite a large proportion of cases, I must regard iridectomy as a very hazardous operation, with regard to its results in advanced cases of glaucoma simplex. Apart from direct impairment, the former degree of vision is often diminished by irregular astigmatism as the result of the formation of the pupil. Glaucoma absolutum also requires occasional operative interference in order to relieve violent pain or degenerative processes resulting from the increase of tension. Iridectomy or sclerotomy is usually effective.

Views differ with regard to the efficient factor of iridectomy in the glaucomatous process. It seems as if various factors may exercise a favorable influence, sometimes one, sometimes another proving especially beneficial, according to the cause of the special morbid process. A certain enlargement of the dimensions of the capsule of the globe and thus diminution of tension are produced mechanically, by the incision, when, as happens often in glaucoma, it does not unite directly, but by means of an intervening substance which is recognizable with the naked eye (Stellwag). In fact, improvement sometimes follows a simple incision into the conjunctiva and sclera at the limbus. If the incision extends into the anterior

chamber, as in iridectomy, there is a possibility of a sort of filtration of the fluid of the chamber through the cicatrix—a factor upon which stress has been laid particularly by v. Wecker. Individual cases in which the patients rapidly relieve recurring obscurations by pressure on the globe, which displaces fluid from the chamber beneath the conjunctiva, favor this notion. If, as we have seen, the pressure of the iris upon the periphery of the cornea and the occlusion of Schlemm's canal hinder the escape of lymph, this would also be antagonized by the incision, which opens a new channel of escape.

But in a series of cases in which there is complete and direct union of the edges of the wound, there can be no question of the formation of a filtration passage. Here the restoration of the normal lymph discharge could only occur when the excision of the iris causes tearing of the adhesion to the periphery of the cornea. Excision of the iris also appears to be of great importance when, as in certain forms of secondary glaucoma, total circular synechia of the iris to the capsule of the lens has caused an interruption of the communication between the anterior and posterior chambers. Here iridectomy alone will secure restoration of the communication, and thus remove the causal disease. This also holds good when irritation of the nerves of the iris has caused reflex hypersecretion and hypertonus. Exner explains the curative effects of iridectomy in general, by assuming that the entire vascular pressure in the eye (and with it the intraocular pressure) is diminished by excision of a piece of the iris. A part of the smaller vessels and their anastomosing capillary network, are removed with the excised portion of the iris. Preparations have shown that the remaining larger arteries and veins form direct anastomoses, through which the arterial blood reaches the veins directly, without passing through a capillary network. This causes lowering of the blood pressure in the iris, and also in the more posterior choroidal arteries.

But some cases of acute glaucoma make it appear plausible that the copious evacuation of the fluid of the chamber, such as occurs in iridectomy, suffices occasionally to cure the process. Cases are not uncommon in which acute glaucoma was permanently cured, although only a small central piece of the iris was removed during the iridectomy (on account of imperfect operation) or the incision was made entirely in the corneal tissue. We may here suppose that, after the evacuation of the fluid of the chamber, the regulating powers, such as the elasticity of the sclera, which had been disturbed temporarily by the acute increase of pressure, again came permanently into play.

The views, advocated by Stellwag and v. Wecker, that the

scleral incision is the really efficient factor in iridectomy, were turned to practical use by Quaglino (1871) who recommended simple sclerotomy in glaucoma instead of iridectomy. With a broad lance-shaped knife he entered the sclera, as if for an iridectomy, about one and one-half to two millimetres from the corneal insertion and pushed the lance for a third of its length into the anterior chamber. Rapid escape of the fluid of the chamber, which is apt to press the iris into and through the wound, is prevented as much as possible by slow withdrawal of the instrument. Prolapse of the iris is also prevented by the previous and subsequent instillation of calabar extract or eserine. But as prolapse of the iris cannot always be prevented in this operation, the method recommended by Wecker is preferable. A Graefe knife, not too narrow, is pushed into the anterior chamber, about one-half millimetre from the transparent edge of the cornea and, if the incision is made above, about three millimetres above the horizontal meridian, as if we were about to make an upward corneal flap in a cataract operation. After puncturing, the knife, cutting through the scleral limbus, is carried upward until about two-thirds of the entire flap incision is completed and only the upper third remains. The knife is then slowly withdrawn. The corneo-scleral connection, which remains undivided above, prevents, as far as possible, the prolapse of the iris upon the incised wound situated internally and externally.

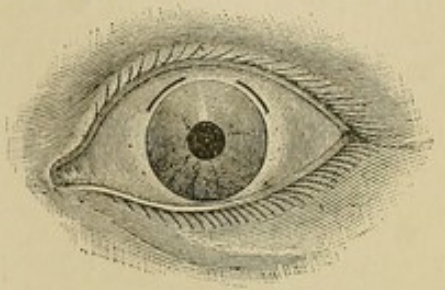


FIG. 111.

Sclerotomy has been widely performed in recent times. It cannot be denied that it would be preferable to iridectomy, if it possessed the same curative effects. The artificial pupil, which permits the entrance of the more strongly refracted peripheral rays to an increased diffuse illumination of the peripheral portions of the retina, occasionally gives rise to considerable impairment of vision, particularly in a bright light. Moreover, it always constitutes a deformity of the eye. But it seems as if iridectomy will maintain its ascendancy, on account of the more manifold curative effects to which reference has been made. I have seen cases in which iridectomy caused improvement, after fruitless sclerotomy. This is not astonishing in view of the theoretical considerations, developed above, on the causes of glaucoma. But in certain forms it is advisable to resort, as the first operative interference, to sclerotomy, the benefits of which have been demonstrated in a series of cases. In this category, I include absolutely glaucoma (in which it may be tried as the simplest means of relieving any symptoms that may be

present), glaucoma hæmorrhagicum, and glaucoma simplex (particularly the latter), and also in chronic inflammatory glaucoma when the field of vision is narrowed down to the vicinity of the point of fixation. In these cases deterioration is so frequent after iridectomy that we decidedly prefer sclerotomy, which promises few direct bad effects. In performing this operation, however, care must be taken that the iris does not prolapse and that the anterior chamber is deep enough to permit accurate handling of the knife. The action of eserine, aids us so far as regards the first point. If the pupil still contracts after the use of eserine, an injurious and irreducible prolapse of the iris need hardly be feared. In England the intraocular myotomy (division of the ciliary muscle) recommended by Hancock is employed occasionally. Hancock started from the assumption that a contraction of the ciliary muscle, and the resulting strangulation of the constricted blood-vessels and nerves, constitute the main symptoms of glaucoma. Stretching of the nasociliary nerve, which is pulled upon by grasping the infratrochlear nerve at the inner, upper angle of the orbit, has also been tried (Badal, Abadie). It is occasionally useful in ciliary neuralgias, and in glaucoma which has run its course. Among non-operative measures the use of eserine has met with a certain degree of favor, particularly on the recommendation of Laqueur and Ad. Weber. A one-half-per-cent solution is instilled two to six times a day. Under this plan, attacks of the prodromal stage and not infrequently acute attacks of glaucoma evolutum may gradually subside. A certain degree of improvement of vision also occurs in the beginning, in some chronic forms. But according to the observations hitherto made, the results, with few exceptions, are not permanent. In one case I observed recovery of an acute attack of glaucoma under instillation of eserine, although the fingers could only be seen at a distance of two feet. Vision was restored to five-sixths with cylindric glasses. The eye has remained healthy for several years. The other eye, which was attacked at the same time, was cured by iridectomy. Glaucoma simplex occasionally remains stationary for years under the use of eserine. But the prolonged use of the drug should only be tried tentatively in cases which remain under constant observation. When employed temporarily it is useful in diminishing the severe inflammatory symptoms of an acute attack of glaucoma, until the narrow chamber has become sufficiently deep to permit an accurate operation. Here we must constantly test the visual power, in order that the operation should not be delayed too long. A trial is also advisable in glaucoma hæmorrhagicum. As in the prodromal stage, eserine may be used to advantage after the operation has been performed,

if evidences of slight relapse, such as obscuration and the like, make their appearance.

If the disease is not relieved despite operation, then iridectomy or sclerotomy should be repeated, if milder measures, such as eserine or pilocarpine, prove ineffectual. When one iridectomy had been performed, v. Graefe recommended that the second operation be made in such a way that the coloboma should be directly opposite the first one. Wecker advises reopening the original cicatrix (uletomy).

Regulation of the general mode of life is important in the treatment of glaucoma. Special attention should be paid to the probable causes of the disease. Thus, coincident neuralgias are to be treated with narcotics, in rush of blood to the head derivation is to be secured, gouty or rheumatic constitutions are to be suitably treated, etc. Quinine in doses of three grains several times a day, sometimes has a decided effect in glaucomatous exacerbations. According to Adamück, this is owing to the diminution of blood pressure, but it may also be attributed to the well-known antineuralgic and antiphlogistic properties of this remedy.

B. Ophthalmomalacia.

By ophthalmomalacia (essential phthisis bulbi of v. Graefe) we mean a distinctly perceptible diminution of tension, and more or less marked diminution in the size of the globe, which occurs in the developed globe independently of any inflammation.

We may distinguish two varieties, simple and intermittent ophthalmomalacia. In the latter the softening occurs in individual attacks, which last for hours or days, and then give way to the normal condition. In the former, the condition remains unchanged for a long time and may either recover or remain permanent. Marked epiphora, a certain irritability to light, a feeling of pressure in the eye or even pronounced neuralgia, are occasionally associated with ophthalmomalacia. If the diminution of tension reaches a high degree, the globe becomes flattened in the region of the recti muscles, the cornea becomes wrinkled and thus vision is impaired.

Ophthalmomalacia must be distinguished from ordinary phthisis bulbi (atrophy), from those diminutions of tension (hypotonus) which occur in the course of the most varied inflammation (phlyctenular keratitis, keratitis diffusa, cyclitis, etc.), and from the small size of the globe dependent on imperfect development (microphthalmus congenitus and infantilis).

Ordinary phthisis is the termination of various internal inflammations of the eye, such as iridocyclitis, purulent choroiditis, and

purulent infiltrations of the vitreous. As a rule, the anatomical changes induced by these processes are sufficiently distinct to enable us to recognize the previous inflammation even after atrophy of the globe has occurred. The clinical history furnishes data concerning microphthalmus, in which, moreover, the pathological softening of the globe is wanting.

Intermittent ophthalmomalacia, which occurs very rarely, follows injuries in many cases (v. Graefe, Swanzey). It is attended by great paroxysmal softening of the eye and occasionally by pronounced photophobia and pain. The attack may last several days. In a few cases recovery did not occur for a long time. Injections of morphine are occasionally useful against the attacks.

Simple ophthalmomalacia is more frequent. The most striking sign is the diminution in the size of the globe. The affection is generally unilateral, and associated occasionally with incomplete ptosis and myosis—the symptom-complex described by Horner, as attributable to paralysis of sympathetic fibres. Nutritive disturbances may also develop in the corresponding side of the face.

The diminution of tension, usually very pronounced, may be less prominent in some cases, but increases periodically. Other pathological changes in the eye are absent. The attention of the patient himself has usually been attracted by the diminution of the globe. (As a matter of course, we must exclude apparent diminutions resulting from falling of the upper lid, such as is found, apart from true ptosis, in many conjunctival and other ocular inflammations. We must also note that atrophy of the orbital cellulo-fatty tissue, which, it is true, may be associated with ophthalmomalacia, is not the sole cause of the apparent diminution.) Ophthalmomalacia occurs occasionally after severe diseases (typhoid fever).

In one case I had the opportunity of proving volumetrically, at the autopsy, the diminution in the globe; as compared with the healthy globe, there was a difference of 1½ c.c. of water. The cellulo-adipose tissue was also diminished. In the brain the upper layers of the left optic thalamus were very soft. No notable abnormalities were found in the cervical sympathetic. In a second case, in which I observed left ophthalmomalacia in addition to ptosis and myosis, the autopsy showed chronic meningitis of the convexity of the brain in addition to a fresh extravasation in the right thalamus opticus and corpus striatum. In a similar case, Giovanni found sclerosis of the corresponding cervical sympathetic with atrophy of the ganglion cells. It seems that both cerebral affections, as well as affections of the cervical sympathetic, particularly as the individual cases present variations as regards the coincident occurrence of ptosis and myosis, may play a part as causal factors.

CHAPTER II.

DISEASES OF THE LENS.

Anatomy and Pathological Anatomy of the Lens.

The lens is situated in the plate-shaped depression of the vitreous body, and hangs in the zonula Zinnii which is inserted at the equator of the capsule of the lens, *i.e.*, at the periphery directed toward the ciliary body. Its curvature and refraction have been described. The capsule of the lens forms a transparent membrane as clear as glass. Its anterior half possesses, on its inner surface, an epithelial layer which extends to the equator. The epithelium is absent on the posterior surface of the capsule. The capsule may be removed from the lens in large pieces. In cataract opacities the connection between the capsule and the substance of the lens becomes considerably looser. In the lens itself we distinguish a soft peripheral layer (cortical layer) and a somewhat more consistent nucleus. The substance of the lens consists histologically of smooth fibres, which have the shape of elongated six-sided prisms. The fibres which belong to the cortex often exhibit granular nuclei; the latter are absent in the most central parts of the lens. There is also a difference in the contour of the edges. The latter are smooth in the cortical parts, serrated like teeth in the central parts. This is due to retraction of the fibres with age (Becker); the peripheral fibres, which are formed by the growth of the epithelial cells, particularly at the equator, are the younger ones, the central fibres are the older ones. The lens fibres are held together by a cement substance. Inasmuch as each fibre runs from the anterior to the posterior surface in the direction of the meridian, their ends meet at the poles of the lens in such a manner as to form a stellate figure. In the newly born, this has the shape of an inverted Y on the anterior surface. On the posterior surface the figure is similar, but has a different position. The straight stroke passes downward, the other two upward. In adults the figure becomes more complicated because the principal rays divide and unite with others. Hence, there is a division into sectors: this occurs particularly in cataract, but sometimes independently in advanced age; the apices of the sectors are directed toward the pole of the lens, their base toward

the equator. The fibres also become harder and have a more yellowish color. The nucleus is also separated more sharply from the cortex, by its greater hardness and a more marked yellowish reflex. The nutrition of the lens takes place from Petit's space, which is situated between the fibres of the zonula (Deutschmann, Ulrich).

Pathological Anatomy.— The occurrence of senile cataract is preceded by a diminution in the size of the lens (Priestley Smith); this is followed by an increase in volume, on account of the larger amount of water in the ripening cataract. The amount of cholesterin is also increased (Zehender, Jacobson), while the albuminoids are diminished (Michel). Microscopically, we can always detect the new formation of cells, starting from the intracapsular cells; this appears as a proliferation of the capsular epithelium (perhaps terminating in capsular cataract), also in the shape of vesiculoid cells and as an epithelioidal lining on the inner surface of the posterior capsule (Becker). Retrogressive changes are associated with these progressive, or, if we prefer, inflammatory processes. The fibres of the lens atrophy and their volume diminishes. If this retraction occurs irregularly in the peripheral layers, cavities form, in which abnormal amounts of fluid accumulate. These may form transparent, globular clots (so-called Morgagni's globules) or fibrillated formations which are divided like algæ. The lens fibres proper exhibit punctate molecular cloudiness, little drops, transverse striation, swelling, finally they undergo molecular degeneration with production of fat, crystals of cholesterin, and granules of lime.

Capsular cataracts develop according to two types. Stripe-like or gland-shaped thickenings form upon the inner surface of the capsule, in part as clear and transparent as the capsule itself, in part of a more yellowish appearance and provided with lighter and darker specks and cells (H. Mueller). These elevations grow from the epithelial cells (Becker). Another form of capsular cataract, develops from the outgrowth of the protoplasmic cell-body of the epithelium; sharp processes are thus formed and make their way into the capsule; in addition, there are nuclei and round epithelial cells. Lying close upon the capsule, is often found a transparent, clear layer, which results from splitting of the capsule (Becker). The entire mass of the capsular cataract may assume the appearance of connective tissue (Manfredi). Internally the capsular cataract is covered with normal epithelial cells, either over its entire extent (Horner) or only at the edges.

According to Becker, the capsular cataracts which follow inflammatory processes in the eye (corneal suppurations, purulent pupillary deposits) also result from proliferation of the capsular epithelium. A direct entrance of pus-corpuscles into the lens may

occur on account of erosion of the capsule by inflammatory processes. Even red blood-globules, have been found in the fatty detritus of a congenital cataract (Bock). The formation of bone has also been observed, but never when the capsule was intact (Becker).

1. Cataract.

I. *General Diagnosis. Ripeness.*

The pathological change in the lens known as cataract, is characterized by the appearance of opaque masses in place of the otherwise transparent substance. Grosser changes are seen even in daylight, if they are situated in the anterior part of the lens; the pupil does not look black, but is cloudy throughout or, in spots, is grayish or white. But examination with the mirror and oblique illumination are always necessary in order to guard against error. In grosser opacities, it is simply necessary to throw the light into the pupil with the mirror. If the entire pupil is opaque, all the light will be reflected or absorbed by the lens; if we see grayish-black patches, lines or shadows in the red of the pupil, then only certain parts are opaque. In order to recognize opacities of the lens which are still somewhat transparent, it is often advisable, in using the ophthalmoscope, to look along the edge of the mirror, and not through the central opening. But we must also satisfy ourselves that the absorption of light really occurs in the lens, and for this purpose oblique illumination offers the best means. These dark shadows on the red of the fundus, not very infrequently result from more or less transparent corneal patches or deposits in the pupillary tract. All this is determined by oblique illumination. When this is concentrated on the lens, it shows at the same time the exact situation and the shape of the opacity. Alone, however, it does not permit the diagnosis of a pathological opacity because, on its application as well as by illumination with daylight, especially in old people, the nucleus or individual sectors of the lens or even the entire lens system often reflects in a way which appears pathological, while the details of the fundus can be recognized with perfect distinctness with the ophthalmoscope. Only those opacities can be regarded as pathological, which obstruct the light thrown in with the mirror, *i.e.*, which abolish or obscure in any way the reflex of the fundus oculi.

If the anterior refracting media, including the lens, appear clear on oblique illumination, the shadows or darker patches on the fundus which may have been previously seen with the ophthalmoscope, are due to circumscribed opacities of the vitreous. Abnormal accumulations of pigment in the choroid may also appear occasionally

as darker points in the red of the pupil. Detailed examination of the fundus will furnish us with data concerning their origin.

If we wish to arrive at a perfect exact diagnosis with regard to the opacities of the lens, the pupil must be dilated with a mydriatic (homatropine or cocaine) in order to expose the peripheral parts.

The opacity may be circumscribed or total. The nucleus alone may be opaque (nuclear cataract), while the cortical substance is still transparent. In other cases the latter is opaque (cortical cataract) and the former clear. This is easily seen from the position of the opacity. Nuclear cataract is characterized by an opacity which, as a rule, has a yellowish or slightly brownish color, which is situated in the middle of the lens, and exhibits no sector-shaped divisions. Cortical cataract occupies the peripheral parts, usually shows a grayish-white color, and sector-shaped or linear, occasionally punctate and patchy opacities. If both parts of the lens are affected, as is the rule in old age, the nuclear opacity is often hidden by the overlying cortical masses, and can only be diagnosticated by the somewhat more intense yellowish color in the centre (especially noticeable when the pupil is dilated and in illumination by daylight). In rare cases, even in older people, the nucleus is milky white and has the same appearance as the cortical substance.

Below the age of thirty years, as a rule, a hard nucleus is not found in cataract. After the age of forty-five years it almost always contains a nucleus. Until this period of life, the nucleus rarely has a diameter greater than eight millimetres, and a thickness of about three millimetres. The entire cataract, extracted in the capsule, has an average diameter of nine millimetres, and a thickness of four millimetres. Its weight is less than that of normal lenses (0.13–0.19).

Apart from certain stationary forms with partial opacity, the cataract usually undergoes gradual extension. This is known as the ripening of the cataract. In this stage, the lens increases in volume, the iris is pushed forward, the anterior chamber narrowed. The cataract is called ripe (cataract matura as opposed to a cataract immatura) when the entire lens system, *i.e.*, the entire contents of the capsule, has undergone a pathological change, which is characterized by the loss of its normal transparency. As a rule, in this total opacity, which extends to the capsule, rupture of the capsule, such as is made during extraction, results in the discharge of the lens like a ripe fruit from its skin; no remnants, which may afterwards become opaque or swollen, remain adherent to the capsule. But exceptions occur. For example, if the cortical layer is mushy and soft, remnants usually remain adherent, although the opacity extended to the capsule. On the other hand, lenses with a dark yellow nucleus and a transparent cortical substance, which is infil-

trated with narrow stripes, are discharged easily and completely. This is also true of those which exhibit very fine transparent portions among large, linear and punctate opacities (Alf. Graefe), and certain cortical cataracts with a posterior, plate-shaped opacity which are comparatively clear in the anterior portions. Cataracts of young individuals, with a milky white nucleus and opalescent cortical spokes, between which are situated transparent masses, also escape readily from the capsule.

After the ripening of the cataract, a retrogressive process sets in. The lens, which has been distended and enlarged, becomes smaller and shrinks. The cataract is overripe (cataract hypermatura).

In addition to the opacity of the pupillary tract, the character of the shadow thrown by the iris upon the opaque lens, which is not directly applied to it, may be utilized as a valuable sign of the unripeness of the cataract, which is not always easily determined.

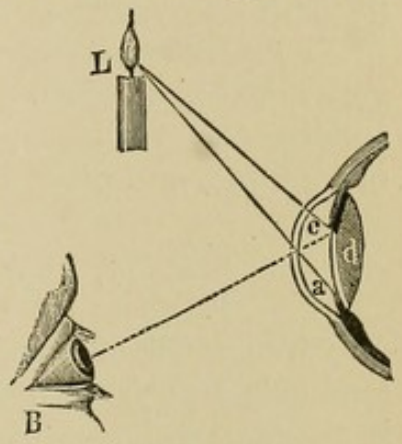


FIG. 112.

If a source of light is situated to one side at *L* (Fig. 112), the rays *La* and *Le* will enter the pupil. The eye of the observer *B* will then see, behind *c*, a black shadow thrown by the iris upon the opacity of the lens *d*. If the latter has advanced so far forward that it reaches the capsule and iris, the black interspace is abolished, the iris lies directly upon the gray opacity of the lens. Hence, the maturity of the cataract is established. We must avoid mistaking for the shadow the not infrequently observed fine black rim at the pupillary border of the iris, which results from the projection of the posterior pigment layer. It is also to be noted, that a shadow is present in a series of cases in which, on looking in very obliquely, it can be distinctly seen that the opacity is situated immediately beneath the capsule. Here the substance of the lens, especially the very much enlarged nucleus, has an amber-like translucency instead of the ordinary grayish-white color, and therefore allows the light to enter further. In these cases, also, a certain reddish reflex usually comes from the fundus in ophthalmoscopic examination. The cortical tissue often remains semi-transparent, in certain very slowly developing cataracts, with a light yellow or white, relatively small nucleus (Foerster).

In the overripe cataract, the shadow may reappear when, on account of the shrinking of the opaque lens, the latter moves farther away from the iris and an interspace is thus formed. Here,

in order to distinguish immature and mature cataract other factors must be taken into consideration. For example, the depth of the anterior chamber and the appearance of the cataract itself. Inasmuch as the volume of the lens increases with increasing ripeness, the iris will be pushed farther forward and the anterior chamber flattened; if the cataract is overripe, it falls backward on account of its shrivelling and the anterior chamber appears deeper. Flapping of the iris (iridodonesis) often develops, because it has lost its support. Moreover, the appearance of an overripe cataract is usually quite characteristic. Irregular, deep white lines and dots are seen in the cortical tissue, while the regular gray and opalescent sectors diminish or disappear completely. In other cases, total liquefaction of the cortical tissue occurs in overripe cataracts, so that a whitish, milky opacity appears with very few or no punctate or linear forms. Moreover, the capsule is more apt to be opaque in overripe cataracts.

Capsular cataracts are characterized by a deep white color and superficial extension. Their appearance is best compared with a small piece of white paper lying in the pupillary tract, of greater or less size, and often has irregular serrated edges.

II. *Partial, Non-progressive Cataract.*

Circumscribed opacities, the remainder of the substance of the lens being perfectly transparent, are not very rare. When found in young people—occasionally as small dots and lines (Cat. punctata and striata)—they may be regarded, as a rule, as congenital, and there is no reason for apprehending further opacity of the remainder of the lens, inasmuch as they usually remain unchanged for life. This is especially true when they are deep and sharply defined. If the color is more grayish or opalescent and the intervening substance is not entirely clear, the suspicion of progressive cataract must be aroused. Prolonged observation is then required to arrive at a definite conclusion. Even in older individuals a few white lines and sectors may persist for years, without the development of any further opacity. In persons at a very advanced age—over seventy-five or eighty years—partial opacities at the periphery of the lens are found very often. These partial opacities vary greatly in number — from a small whitish sector, line, or dot to numerous ones which infiltrate the lens.

Special attention should be given to: 1. stationary nuclear cataract, which occurs occasionally as a whitish, spherical opacity in young people. 2. Anterior, central capsular cataract. Here there is a round white opacity, usually as large as a pin's head, corre-

sponding to the anterior pole of the lens and extending somewhat into its substance. The opaque mass, which is always covered by the capsule of the lens, occasionally projects into the anterior chamber and forms a small pyramid (pyramidal cataract). This variety often develops after blennorrhœa neonatorum, and its situation in the middle of the pupil testifies in favor of the view that it results from direct injuries which affect this part of the lens. For example, when there is a prolonged fistulous discharge from the chamber in consequence of perforation of a corneal ulcer, the pole of the lens is in contact with the cornea, even at a time when there is a certain interspace between the cornea and iris at the periphery of the chamber on account of the accumulation of aqueous humor. If purulent secretion is also present in the chamber, the most central part of the lens is often the only part covered by it, as a result of the narrowness of the pupil, which often persists in the newborn even after instillation of atropine. This explains the development of the central capsular cataract, even when the corneal ulcer is not directly opposite the pole of the lens. That this cataract may also develop after blennorrhœa without perforation of the cornea, as some believe, seems to me to be plausible only when purulent pupillary exudations have long been present. 3. Posterior polar cataract. Here we find a whitish or whitish-yellow opacity at the posterior pole with the concavity directed forward. As affections of the vitreous are not infrequently associated with this form of cataract, further extension of the opacity is relatively frequent. 4. Laminated cataract (cataracta zonularis s. perinuclearis). The free nucleus of the lens is covered, like a skin, with a grayish-white layer of opaque, central cortical substance, which is separated in turn from the capsule by a transparent, peripheral layer of the lens (Fig. 113). The rim of the opacity is circular, as seen from the front; occasionally it exhibits slight dentations which project into the transparent peripheral substance of the lens. In rare cases a second or third, grayish-white, circular opacity surrounds the central part, separated from it by a narrow line of transparent substance.

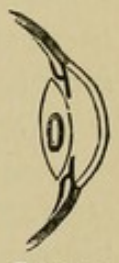


FIG. 113.

As a rule, quite broad, in part opalescent sectors can be seen in the opacity. The centre is somewhat more transparent than the periphery, where a greater absorption of light occurs on account of the close approximation of the opaque layers. Unlike nuclear opacities, the central portion of the cataract never exhibits greater intensity or a darker color. In this way, the laminated cataract is easily distinguished from nuclear cataract. The size and transparency of laminated cataract vary greatly, and with them, as a

matter of course, the degrees of visual disturbance. The opacity may be only three to four millimetres in diameter, but it sometimes extends nearly to the equator of the lens. The broader the peripheral transparent tract, the better the vision. Artificial mydriasis is required in order to overlook its entire size. When the laminated cataract is small, the patients may have perfectly satisfactory vision, and find no reason to consult a surgeon. But as the pupil narrows with advancing years, the transparent peripheral portions of the lens are covered more and more by the iris, and the impairment of vision thus produced induces the patient to seek relief. If the physician does not dilate the pupil and carefully examine the entire lens, he is apt to make the wrong diagnosis of nuclear cataract, because the development of the latter would correspond with the advanced age.

Laminated cataract may be congenital or it develops, as usually happens, in the first years of life. It is observed with special frequency in children who have suffered from convulsions due to teething, so that the cause may be assumed to be a reflex nutritive disturbance of the lens resulting from irritation of the trigeminus. As the fibres of the lens grow from the equator, a peripheral opaque layer would form around the transparent substance of the lens, as the result of a temporary disturbance of nutrition. If the nutritive disturbance ceases and normal lens tissue is again formed, a transparent mass forms around the opacity. The peculiar laminated form is explained in this way. Laminated cataract has been often observed in combination with anomalies in the formation of the teeth (Horner), and, in view of the embryological identity of these structures, must be attributed to similar causes which interfere with development.

Capsular cataracts, which develop primarily, usually remain stationary, such as those which follow slight injuries, or when purulent masses remain upon the lens for a long time during iritis, or corneal ulceration, or when there are adhesions to the iris or cornea. The secondary opacities of the adjacent parts of the cortex are also, as a rule, stationary in character.

The visual disturbances produced by the partial forms of cataract depend particularly upon their translucency, dimensions, and situation. The more peripheral they are, the less will be their injurious effect. But perfectly satisfactory vision may be present even when their situation is central.

Treatment.—Many forms require no special treatment. If scattered opacities are unusually numerous and disturbing, we may be called on to decide whether the removal of the entire lens system will not sceure more useful vision.

In young people, we must first endeavor to inaugurate artificial absorption by giving access to the fluid of the chamber, by means of an operative rupture of the capsule (discission). Swelling and opacity then occur, even in the hitherto non-opaque masses, and prepared in this manner they may be absorbed by the fluid of the chamber. A discission needle (Fig. 114), entered about three millimetres from the transparent rim, is passed through the cornea into the anterior chamber and a cut made into the capsule of the lens, the pupil being atropinized. As the capacity of the lens for swelling cannot be accurately predicted beforehand, the rent in the capsule should be carefully made small at the first operation; if necessary the trifling operation may be repeated. In the lenses of older individuals (beyond the age of twenty years) absorption is much slower, and is less complete on account of the greater development of the nucleus. The danger of secondary iritis, set up by the swelling and irritating lens substance, is also greater. Hence the removal of the cataractous mass must follow as soon as possible after complete opacity of the lens has been effected by discission. This plan is also indicated occasionally in young people, when the swelling becomes too great and gives rise to notable inflammatory symptoms. We may here resort to Graefe's modified linear extraction.



FIG. 114. Discission needle. (Stop-needle.)

Violent inflammations, which may follow simple discission, may also be prevented by iridectomy, performed about six weeks before discission. This cautious plan is even indicated in young people, when the pupil does not dilate to the maximum under atropine.

Laminated cataract requires operative interference with special frequency, because vision is markedly impaired on account of its location in the centre of the pupil. Here we must often perform discission in the above-mentioned manner. When the opacity is not too large, sufficient vision may also be secured by an iridectomy which exposes a free peripheral portion of the lens (vide Fig. 113). This possesses the advantage over destruction of the lens that the patient's power of accommodation is retained, and he is not required to use cataract glasses, which replace the lost refraction of the crystalline lens. The amount of benefit which can be derived from a suitable iridectomy can be ascertained beforehand, at least approximately, by dilating the pupil with atropine and then allowing the patient to look through a rather broad stenopæic slit. If the iridectomy suffices, we endeavor to excise the narrowest possible piece of iris and permit its most peripheral portion to remain. The opening then approximates the shape of a slit, and the rays of light, which would have passed through the outermost part of the

lens, are excluded by the remaining rim of the iris; this increases the sharpness of the retinal image. For this reason iridodesis (vide Operations on the Iris) was formerly recommended instead of iridectomy. It has been abandoned by the majority of operators, because sympathetic ophthalmia has been known to follow it in some cases. Iridotomy may also be suitable optically, and is especially advantageous in certain cases. But here there is danger of injuring the capsule of the lens with the blade of the scissors which is carried behind the iris.

III. *Total Opacities of the Lens.*

Total cataract (senile cataract) develops particularly at an advanced age. Without special etiological factors, it is comparatively rare before the age of forty years, but it has even been observed congenitally.

The consistence of the cortical substance varies. We may distinguish a pulpy (somewhat like book-binder's paste), a hard (somewhat like wax), and a fluid consistence. On extraction of the cataract the pulpy cortical substance strips easily from the nucleus, while the harder corticalis adheres more firmly and is connected more closely with it. A diagnosis of the consistence can usually be made from the appearance of the cataract prior to its extraction. When the cortical substance is pulpy, we see broad mother-of pearl-like and opalescent spokes, with the broad base directed toward the periphery of the lens, or plates in the lens; when it is hard, narrower, whiter spokes and lines appear. If the cataract is overripe, the cortical substance is shrivelled from the escape of water, and has become condensed, hard and more friable. We then find intensely white lines, dots and patches in a more uniform gray mass. The fluid corticalis, which is also found in overripe cataracts, is the product of a further retrogressive change, and is characterized by an appearance which is best compared with that of milk. Mixed conditions also occur; fluid masses in otherwise hard, retrogressive cataracts are found with special frequency.

The general color of the cataract is usually gray, the position and size of the nucleus, which may be present, being shown by a more yellowish or brownish tinge, which is recognized better in daylight than with artificial illumination. The difference in the color of the nucleus and cortical substance is often so slight that it is overlooked by beginners. And yet the correct diagnosis of the size of the nucleus, and of the consistence of the cortical substance is very important as determining the operation to be performed. In rare cases, the entire lens system has a more brownish color, so that the pupil appears almost black in daylight and with

superficial examination (black cataract). If the cortical substance is completely liquefied in a cataract of old age, the darker nucleus may undergo changes of position. If, for example, the patient assumes dorsal decubitus, the dark nucleus will sink backward and the pupillary tract appears milky white. If the head is then shaken and bent over forward, the nucleus moves toward the anterior pole of the lens, and can now be seen in its milky surroundings.

This form of cataract has received the name cataracta Morgagniana, an analogy being made with the liquor Morgagni which forms after death within the capsule of the lens. If total liquefaction of the lens occurs in young people, that is, when no nucleus remains, we speak of cataracta lactea, or, if the capsule is very firm, cataracta cystica. The latter can sometimes be removed from the eye with its contents like a cyst.

While these forms occur, as a rule, as late results of retrogressive metamorphosis of a cataract which is attended, in the usual way, with gradual opacity and swelling of the lens system, there is a series of other forms which develop after internal inflammations of the eye (cataracta complicata). In such cases we usually have a long-standing iritis, irido-choroiditis, hyalitis or detachment of the retina. They possess, accordingly, a much more serious prognostic significance. Their appearance distinguishes them, as a rule, from the previously described cataracts, inasmuch as they hardly ever exhibit the formation of spokes in the cortical substance and the sharp definition of the nucleus. As a general thing, they possess a more uniform, intensely white, paper-like appearance and are situated in the shape of a flat, compressed mass, which often contains chalky points or cholesterin crystals, in the pupillary tract, which is often narrowed by posterior synechia of the iris. The capsule is thickened and opaque. These forms have been called cataracta calcarea, cataracta arido-siliquata (dry capsular cataract) or, when the iris is adherent, cataracta accreta. In another series of cases—and this obtains particularly in affections of the deeper tissues of the eye, the vitreous body and the retina—the pupil has the usual dimensions, but the cataract situated within it has a peculiar yellow color, without the characteristic spoke shapes. With a little practice, the differences in all these cases appear so striking that we are not apt to mistake secondary and uncomplicated cataracts.

The terminal stage of traumatic cataract presents a similar appearance to the first-described form of complicated cataract. When the aqueous humor has gained access to the substance of the lens on account of the opening of the capsule, swelling and opacity of the adjacent cortical masses set in.

They project occasionally into the anterior chamber, as gray flakes, where they are gradually absorbed. Under certain circumstances, the entire lens system is gradually made opaque and finally absorbed. But, as a rule, opaque harder masses remain upon the capsule and, in combination with the latter, form a tolerably firm and thick gray membrane in the pupillary tract (after-cataract, secondary cataract). The previous history will lead to the correct diagnosis.

Visual Disturbances.

The visual disturbance produced by cataract corresponds to the optical obstruction which it entails; it varies, therefore, according to the extent and character of the opacity. Examination with the ophthalmocope furnishes us with certain data; the better the ophthalmoscopist sees the fundus, or the more red light is reflected by the latter, the better must the vision be.

In order to diagnosticate any complications which exert an influence on vision, careful test of the quantitative or qualitative perception of light must be made. Even when the lens is entirely opaque, and no red light is reflected from the fundus during ophthalmoscopic examination, the patient should at least recognize the "smallest lamp" (vide Amblyopia and Amaurosis) at about one-third metre. If the patient only sees the light when it is turned up and burns with a light yellow flame—so-called small lamp—we must suspect a complication (retinal affections, optic-nerve disease, or glaucoma). As we can easily convince ourselves, the normal eye perceives the light and darkness of the small lamp or candle, when the lids are closed. A complication of cataract is also to be assumed when the field of vision is not intact. To test this, the lamp must be turned somewhat higher and then held in various directions, the patient's eye being first covered, then uncovered. The direction (right, left, upward, downward) must be accurately given in order that we may be sure that serious complications are absent. One exception is occasionally observed. If unilateral cataract has lasted a long time, the projection may be lost or become uncertain toward the nasal side, which falls in the field of vision of the seeing eye, although no serious complication is present.

The fulfilment of the conditions just mentioned, does not prove that slighter complications, such as vitreous opacities, are not present. In young people with congenital or early acquired cataract, pronounced amblyopia may be present despite exact perception of light. Even a successful operation will aid vision very little in these cases.

Despite complete maturity of a cataract, the majority of the patients affected with it are still able to count fingers in close proximity, or at least to recognize the number or movement of the hands.

Apart from this subjective test, the appearance of the cataract and the eye itself, as well as the more or less exact reaction of the pupils to light will teach us concerning complications. A wide and rigid pupil is always suspicious, of course excluding previous atropinization. Here special attention should be paid to amaurosis and glaucoma as complications.

Observant patients usually consult the physician at an early period, because the opacities appear most frequently in both eyes at the same time and thus impair vision. The cases in which a cataract is perfectly ripe in one eye, while the other is entirely free, are more rare, and such patients are more apt to overlook the disease. Occasionally we find quite advanced cataract in both eyes, although the patients regarded their impairment of vision as merely the result of age. Myodesopsia is also found in cataractous patients, who see dark patches, lines, etc., which correspond to the shadows of the lens opacities that are visible objectively. The more central the opacity, the poorer the vision, especially when the pupil is narrow. Such patients state that they see better in cloudy weather and in the shade, when the pupil is naturally dilated and the light thus enters through the transparent parts at the rim. Hence they are fond of wearing an eye shade or blue glasses, and walk with the head bent over forward, in order to shade the eye. In other cases in which the opacities are situated chiefly in the cortical substance, the circles of dispersion which may be formed can be excluded by narrowing the pupil. Here, on the other hand, better vision is secured in a bright light.

ETIOLOGY.

1. Acute and chronic affection of the eye. As we have seen, peculiar forms of cataract are not uncommon as the result of irido-choroiditis and irido-cyclitis. In diseases of the vitreous, such as are often present in posterior sclerotico-choroiditis, cataracts also occur; beginning at the posterior pole, they may lead to regular total cataract. Final complication with cataract is almost the rule in long-standing extensive detachment of the retina, but this is usually complicated, it is true, with disease of the vitreous. Glaucoma is also complicated not infrequently with cataract, both at a stage in which relative vision is still present, as well as later when the glaucomatous process has led to amaurosis. Violent purulent inflammations (purulent choroiditis, panophthalmitis) al-

most always result in opacity and destruction of the lens system, so that finally only a gray, narrow plate remains. It is also a striking fact, that total cataract develops not infrequently after hypopyon-keratitis, especially when transverse section of the ulcer has been performed. It is probable that an emigration of pus-corpuscles or bacteria into the lens takes place through a traumatic, but a very delicate rent in the capsule, and may give rise to the formation of cataract (Deutschmann).

2. Age. Total cataract occurs with special frequency after the age of fifty years; it develops not infrequently in patients who have passed the age of seventy. It is a disease of age. It is often found to begin when the diminishing bodily vigor has been impaired still further by other diseases. But younger individuals, even those in the thirties, occasionally suffer from cataracts which exhibit the perfect type of cataract of old age, although no special etiological factors can be found.

3. Diabetes mellitus. Sugar is found not infrequently in the urine of cataractous patients. We may thus discover diabetes in which other pronounced symptoms of the disease are absent. Cataract at an early age is especially suspicious. In these cases sugar has been found in the cataractous lens as well as the fluids of the eye. The latter condition makes it probable that the development of the cataract depends upon a greater concentration of the fluids surrounding the lens and to the resulting abstraction of water from the substance of the lens. Thus, according to Kunde's experiments, which have been confirmed by Heubel, subcutaneous injections of sodium chloride produce opacity of the lens in frogs.

Albuminuria is present in a few cases of cataract, but, according to Becker's statistics, an etiological connection between these conditions is not probable. 4. Ergotism. The occurrence of cataract was observed in a few epidemics of ergotism (J. Meier). In an epidemic under my observation in Hessen, I found a single case of cataract in a comparatively young woman, who also suffered, however, from severe convulsive seizures. No other corroborative observations have been made. 5. V. Rothmund has seen complicating cataract in certain cutaneous affections. 6. Epileptic and hysterical spasms are seen with striking frequency in young and middle-aged cataractous individuals. Not infrequently the nucleus is alone affected at the beginning, while the periphery long remains clear. In some cases, however, the cortical substance is first attacked.

7. Atheroma of the carotid (Michel). According to the investigations of others, however, with whom I concur, this factor possesses no prominent etiological significance.

8. Heredity. [Heredity has a particular prominence in cataracts. There are cataractous families. I have myself operated upon three members of one family, father and two sons; and in another I have performed three operations, upon three different members; I have diagnosticated a fourth case in another member, and one of my colleagues has operated upon a fifth of the same family.—St. J. R.]

9. Injuries. In this category is included, in a certain sense, the occurrence of cataract after a stroke of lightning. It is usually associated with mydriasis, paralysis of accommodation, and optic neuritis or secondary atrophy.

Meyrhoefer found cataract unusually frequent among young glass-workers. He attributes this to the greater increased loss of water experienced by these workmen on account of their profuse sweating. Cataract (in addition to synchysis, white patches in the retina) has been recently produced artificially in rabbits by feeding them with naphthalin (Bouchard).

Treatment.

In very slight opacity of the lens the physician must consider whether he should communicate to the patient the diagnosis of cataract. Individual striæ may remain stationary for a long time and even permanently, especially if they are sharply defined in transparent substance; on the other hand, they are observed very often at an advanced age, although considerable increase or ripening of the cataract never occurs. Why cloud their hopes of the future with the bugbear cataract? At the most it will suffice—in order to protect ourselves against the more inconsiderate revelation of the diagnosis by other physicians—to tell the patient that there are slight opacities in the lens, without using the expression cataract. If necessary, the truth may be told to the patient's family.

In unripe cataract, we must try to improve vision by optical means, as by the correction of errors of refraction with suitable spectacles. Increased refraction develops very often during the formation of cataract; emmetropes usually become myopic. If necessary, improvement of vision for near objects can be attempted with strong convex lenses or magnifying glasses. If, when the opacity is further advanced, the nucleus is chiefly affected while the cortical substances is still free, vision may be improved by artificial dilatation of the pupil, whether by a mydriatic or iridectomy. Darker spectacles are also useful because they dilate the pupil. Attention must also be paid to the general condition of the patient in order to put him in the best possible condition of health—a feature of importance with regard to the termination of the subse-

quent operation. Treatment must also be directed against other general diseases, such as diabetes, which stand in more direct relations to the development of the cataract. Local affections such as conjunctivitis, etc., must also be relieved. Special attention should be paid to old affections of the lachrymal sac, because their secretion is apt to infect the wound made in operating and may thus lead to suppuration.

In very slowly progressing cataracts, which interfere considerably with vision, we are occasionally forced to accelerate ripening in order to be able to perform an earlier operation. The opacity often increases more rapidly after an iridectomy. At the same time this is advantageous as a preliminary operation to the extraction of cataract. In order to secure a sort of concussion of the lens, Foerster recommends that, immediately after iridectomy, the cornea be rubbed with a squint hook, if the lens is closely applied to it after the escape of the fluid of the chamber (trituration or massage). I have also seen rapid ripening after this procedure, although it occasionally gives rise to iritic irritation.

Permanent recovery and clearing up of well-marked cataract (traumatic, circumscribed opacities of the lens occasionally disappear after closure of the capsule) are not to be expected. Very few cases, in which complete absorption of uncomplicated overripe cataracts was observed after the formation of cholesterin crystals within the uninjured capsule, speak for the possibility of such an occurrence (Brettauer). No suitable remedies are at our command; Carlsbad water has been recommended in diabetes. The constant current (five Siemens' elements, anode stabile on the back of the neck, cathode upon the closed lids, stabile-labile, with changing polarity; gradually increasing to fifteen elements; daily sittings of fifteen minutes) has been employed in cataract by Neftel. But the cases reported in recommendation of this method are not convincing (improvement of vision during the development of cataract has been observed occasionally after the cure of complications, for example, opacities of the vitreous body). Moreover, further trials, which I have also made, have given no positive results.

In ripe cataracts, benefit is derived only from operation. This furnishes a relatively very favorable prognosis. "Good" results are obtained in about 90 per cent, of the cases, *i.e.*, the patients can read medium print, "half" results are obtained in 6 per cent (fingers can be counted at a considerable distance), and failures 4 per cent. If only one eye is cataractous and the other healthy, the operation, as a rule, is not advisable. The advantage that the field of vision may be enlarged toward the side of the operated eye, does not appear to be sufficiently great, compared with the possible dis-

advantages, particularly as binocular vision cannot be restored on account of the inequality in refraction. Occasionally, though by no means always, the operated eye disturbs the healthy one in vision. Above all it must be borne in mind that inflammations (iridocyclitis) may develop after the operation, and may injure the healthy eye by sympathetic means. Hence, the operation in monocular cataract should be performed only on the most urgent desire of the patient. The case is different, when the other eye sees poorly and perhaps shows beginning cataract; extraction may then be performed without hesitation.

If both eyes have ripe cataracts, the operation on both may be performed at one sitting, especially if the operation on the first eye has gone off well. But it is more prudent to await the recovery of the first eye, and to perform the second operation six or eight days later. Unexpected accidents, for example, delirium of the patient, may happen and put recovery very seriously in question; this would be injurious in a double operation. Moreover, if the result is unfavorable in the first eye, one or another injurious element may be avoided in the second operation.

Cataract Operations.

Flap Extraction and Graefe's Peripheral Linear Extraction.—The most radical operation of cataract consists in its removal. Jacob Daviel (1748), of Marseilles, was the first who practised extraction of cataract through a large corneal incision. He circumcised about two-thirds of the cornea, opened the anterior chamber, and removed the lens from its slit capsule.

There are two principal methods, viz., flap and linear extraction, according to the shape of the incision for the removal of the lens, and which, as a matter of course, must be situated in the cornea or the corneal limbus. In linear extraction an incision is made as nearly as possible like a straight line. This can only be done when the incision is made in a "largest circle" of the spherical surface of the eye, because the shortest distance between two points upon the surface of a sphere, *i.e.*, the line which is most nearly straight, falls in the largest circle. The largest circle which passes through two points on the surface of a sphere, is situated in a plane passing through these points and the centre of the sphere. For example, if *a* (Fig. 115) is the point of entrance of the knife, *b* the point of

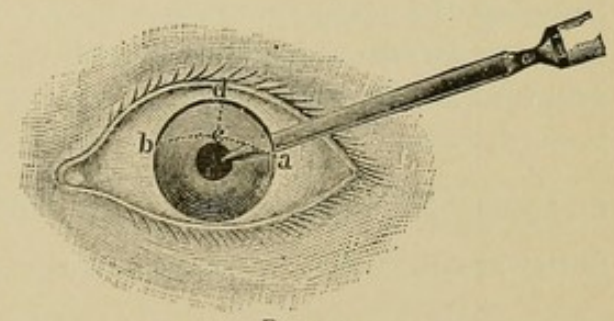


Fig. 115.

emergence, then the dotted line (*a b c*) between *a* and *b* would fall approximately in a largest circle, because a plane passing through *ab* and the centre of curvature of the cornea would intersect the surface at this place. A linear incision between *a* and *b* would therefore run in this direction. But if, after the knife has been removed at *b*, the incision is carried parallel to the iris at the edge of the cornea, as indicated by the line *adb*, we obtain a flap incision, *abcd* being the flap thus formed. The "height of the flap" is the term applied to the length of the line *cd*, which is let fall from the highest point *d* of the flap incision to the linear incision. The more the flap incision deviates from the latter, the greater is the height of the flap. We thus speak of a height of the flap of 1, 2 or more mm.

Every incision must be so large that the cataractous lens, whose horizontal section is an ellipse, can emerge conveniently. In the flap incision, extraction is performed by bending the flap of the cornea away from the sclera. The length of the incision must here approximate the diameter of the cataract from right to left, for example 8 to 9 mm., while the height of the flap must at least equal the antero-posterior diameter of the cataract, for example, 3 to 4 mm. If we assume the horizontal transverse diameter of the transparent cornea—excluding the scleral limbus, which can be moved over about 0.5 mm. on each side—at 11 mm. (height of the flap above 5 mm.), a flap incision made here would even exceed the dimensions of the largest cataract. But it must be remembered that the size of the wound in the membrana Descemetii (inner corneal wound) is somewhat smaller than that in the outer corneal layer (external corneal wound). If the cataract is to pass through a linear incision, the latter must be made to gape. This is done by bringing the ends somewhat closer together, so that an ellipsoidal opening is formed. The length of the incision must therefore be greater than the diameter of the lens from right to left. Its size is determined when we know the circumference (U) of the ellipse necessary for the passage of the lens. It equals $\frac{(a+b)\,\pi}{2}$, where *a* is the smallest diameter, *b* the large diameter of the ellipse. If the cataract is 4 mm. in thickness and 9 mm. in diameter, $U=\frac{(4+9)\,\pi}{2}$ $=6.5+3.14=2.041$. The linear incision which is to be converted into an ellipse by the approximation of its ends, must therefore be half as long, or about 10 mm. [In this calculation we disregard the fact that we have to deal with ellipses or incisions not upon a plane but upon a spherical surface.] A linear incision of such length can only be made by passing through the transparent cor-

neal tissues. If the incision is made in great part in the edge of the cornea, as is usually done, we must abandon an absolutely linear character; the majority of so-called linear incisions are really flap incisions although of small flap height. It is to be regarded as a special advantage of linear incisions that they have a less tendency to gape than flap incisions; strong intraocular pressure is capable of lifting up the flap.

The length of the incision must depend on the size and consistence of the cataract. Thus, a soft cortical cataract, which is displaced during extraction and changes its shape according to the wound, requires a smaller opening than a hard cataract. The size of the nucleus is also important.

Performance of Extraction.

We distinguish as the stages of the operation: 1, the formation of the incision; 2, the cutting of the capsule (cystitomy); 3, the delivery of the lens. Iridectomy, when it is indicated, is interposed between the first and second stages. It will always be necessary when the incision is so peripheral, *i.e.*, is so close to the edge of the sclera, that the iris is pushed out by the escaping fluid of the chamber and is prolapsed; this is also true when it interferes with



FIG. 116.—Beer's Knife.

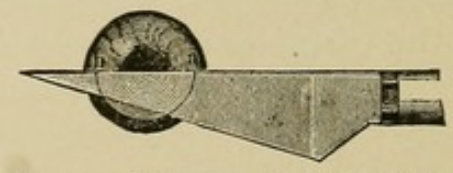


FIG. 117.—Extraction with Conical Flaps.

the escape of the lens. Iridectomy also possesses the advantage of counteracting a secondary iritis. Its disadvantages are the deformity of the pupil, the more unfavorable refraction, inasmuch as very peripheral rays now reach the retina, and occasionally symptoms of dazzling.

a. The flap incision is usually made with a triangular knife (such as Beer's cataract knife, Fig. 116). After the lids have been drawn away from the globe by a clamp elevator or by means of the fingers, the globe is grasped by the operator with fixation forceps. According to the old method, the incision should be made entirely in the transparent cornea about one-half millimetre centrally from the scleral limbus. The knife is entered approximately in the horizontal meridian of the cornea (point of puncture, Fig. 117), carried transversely through the anterior chamber and brought out on the opposite side (contra-puncture). If the knife is then pushed farther, it divides the entire cornea on account of its wedge shape.

An upper or lower flap is obtained, according as the cutting edge is directed upward or downward.

In 1863, Jacobson proposed that the incision be made, not in the transparent cornea, but in the scleral limbus (Fig. 118). As we thereby gain about one-half millimetre on each side in the length of the incision, we can introduce and withdraw the knife somewhat farther (two millimetres higher or lower) from the horizontal meridian of the cornea. This method was extensively employed on account of the lesser height of the corneal flap and the consequent diminished tendency to gaping, and also the more favorable conditions for the healing of wounds situated in the scleral limbus. The very peripheral situation of the incision, however, necessitates excision of the iris.

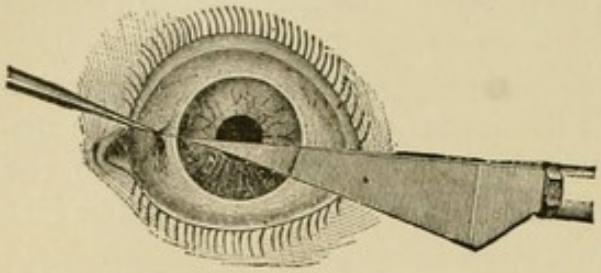


FIG. 118.—Flap Extraction in the Scleral Limbus. (After Jacobson.)

Of late years the flap incision, without iridectomy, has again been adopted more generally. But unlike the Daviel method proper, the incision is made directly in the edge of the transparent cornea and with it one-third to two-fifths of the periphery are divided (Wecker). The iris can often be kept in its normal position by the use of eserine, and iridectomy thus avoided. But prolapse of the iris may occur even in the period of healing, so that the number of anterior synechias developing after this method of operation is considerable.

b. The use of the linear incision for the extraction even of cataracts of old age was advocated chiefly by A. v. Graefe (peripheral linear extraction). Graefe employed a stalk-like knife (Fig. 119).



FIG. 119.—Graefe's Cataract Knife.

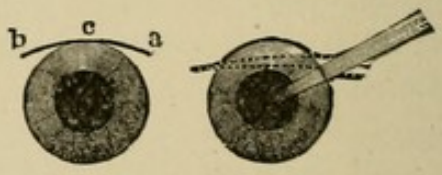


FIG. 120.—Peripheric Linear Extraction. (After v. Graefe.)

When the incision was made in an upward direction, the puncture was made 1.0 mm. from the edge of the cornea in the scleral limbus at a point (*a*, Fig. 120) about 1.5 mm. below the tangent supposed to be applied to the highest point of the cornea. The knife entered with the point directed straight against the middle of the pupil and then pushed toward the point of contrapuncture *b*

by depressing the handle. The incision was completed by pushing the knife forward and backward, the cutting edge being turned somewhat forward from its hitherto upward direction, so that the highest point of the incision *c*, in the tendency to assume the linear character, falls somewhat within the transparent cornea. The tendency toward the middle of the pupil on entering the knife, makes the inner corneal wound as large as the outer.

The strict linear character has been gradually abandoned somewhat, because the incision of a sufficiently large wound must be brought too close to the ciliary body. This is apt to produce prolapse of the vitreous and also entails greater danger of secondary cyclitis. Many operators, retaining the narrow knife and its introduction in a direction toward the middle of the pupil, have adopted a flat flap incision. I make the points of puncture and contrapuncture in the scleral limbus, about one millimetre from the edge of the transparent cornea and, turning the cutting edge of the knife slightly, divide the cornea anteriorly in such a way that the apex of the flap just touches the border of the transparent cornea. According to the size of the cataract, the points of introduction and removal of the knife are situated two to three millimetres below (or above) the horizontal diameter of the cornea.

After the anterior chamber has been opened by the incision, the fluid of the chamber escapes and the iris usually enters the wound, if the incision is peripheral. This is true both of Graefe's scleral incision and of the flap incision in the corneal limbus. Iridectomy must then be performed in both cases. After the closed fixation forceps have been handed to the assistant, the iris is grasped with the iris forceps and is cut off with the scissors. It is not advisable to excise too large a piece. We must always be careful that none of the iris remains in the wound, and that the edges of the pupillary border of the sphincter are withdrawn from the wound. If this does not occur spontaneously, the careful introduction of a small spatula or the instillation of eserine is indicated. In order to avoid the tendency to such prolapse of the iris, with subsequent cystoid cicatrization, which is still further increased under the prevalent use of cocaine as an anæsthetic, I instil a drop of a solution of eserine (0.03 : 10.0) two or three hours before the operation. The cocaine mydriasis is then absent or is very slight.

The third stage of extraction is cystitomy, the opening of the capsule of the lens. We use Graefe's lancet-shaped cystitome (Fig. 121 *a*) (or Ad. Weber's cystitome which is provided with two hooks) and make a transverse incision in the capsule as large as possible. The incisions in the capsule may also be made in such a way that they inclose a quadrangular piece, which is removed from the eye

with the lens. In order to prevent the capsule from falling into and healing in the wound, and on the other hand, to facilitate, after removal of the lens, the closure of the capsule (which prevents the injurious and irritating swelling of the remaining cortical masses) Knapp makes only a single, peripheral incision into the capsule, parallel to the corneal wound. As a rule, however, an after-cataract forms after this method, and requires subsequent discission. This form of incision of the capsule is especially advisable in Morgagni's cataract, in order to secure the rapid and certain removal of the nucleus floating in the fluid. Capsular forceps may be used to advantage in order to tear out larger pieces of the capsule.



Fig. 121. Graefe's Cystitome with Schmidt-Rimpler's spoon.

The fourth stage is the delivery of the lens, a spoon (Fig. 121 *b*), which is fixed to the handle of the cystitome, being pressed upon the cornea in the region of the edge of the lens situated opposite to the incision. The edge situated next to the wound is thus directed forward and enters the wound. The entire lens is then pushed out by stroking toward the wound. Instead of Graefe's rubber spoon (Fig. 122) I use the metallic spoon represented in Fig. 121; this is also adapted, when necessary, to entering the eye, grasping the lens directly and extracting it.

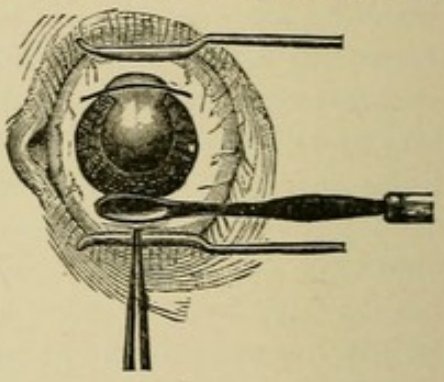


Fig. 122.

If no cortical masses remain behind, the operation is then completed. Otherwise we attempt to remove them by pressure with the spoon or, after removal of the lid elevator, by pressing and pushing with the corresponding lid, while the wound is made to gape somewhat, by pressure with the other lid upon the scleral edge of the wound. Thorough evacuation of the remaining masses is of great importance as regards recovery. Special attention must be paid that large fragments do not remain in or close to the wound. Irrigation of the anterior chamber with a lukewarm one per cent solution of boracic acid, etc., has been recently employed for this purpose.

[The so-called simple extraction, that is to say, the method by which a flap is made with Graefe's knife, no iridectomy being performed, is just now the operation most frequently performed by New York ophthalmic surgeons.—St. J. R.]

Among the unfavorable accidents during the operation, may be mentioned prolapse of the vitreous before the lens is removed. In such a case, whether cystitomy has been performed or not, we must at once introduce the lens spoon (or the wire loop, Fig. 123) and remove the lens through the wound by passing behind the lens and pressing against the cornea. The beginner must be particularly careful that, immediately after passing through the corneal wound with the spoon, whose handle is suitably curved, he penetrates sufficiently deep into the vitreous to reach behind the lens; if he merely reaches the edge of the lens the latter will be depressed still more. If the lens unfortunately disappear entirely, and the great loss of the vitreous humor forbids further search, we cover the eye with a bandage, and wait some time for the reaccumulation of fluid in the eye. The patient then lies upon his face. The lens then sinks forward toward the cornea and it may be possible to extract it with the spoon. Small hooks may be used instead of the spoon, but they seem to me to be less serviceable because they do not grasp so securely and are more apt to strip off the cortical substance. The latter disadvantage also attends the use of the wire loop, as compared with my spoon. A not too great loss of vitreous substance is, on the whole, innocuous, but according to extensive statistics gathered in Arlt's clinic, the prognosis is always somewhat less favorable when instruments have been introduced into the vitreous. Prolapse of the vitreous, before removal of the lens, indicates rupture of the zonula Zinnii. Since this is very thin, as a rule, in overripe cataracts or in demonstrable tremulousness of the iris, we must be prepared particularly for this accident in such cases; also, as a matter of course, in dislocation of the lens which may be produced during the operation itself, by excessive pressure and traction with the cystitome. If the lens presents itself, but is



FIG. 123. Weber Wire Loop.

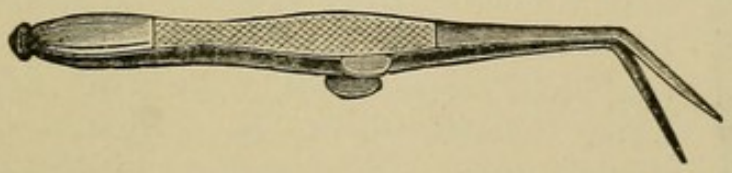


FIG. 124.

unable to escape, because the wound is too small, pressure with the spoon upon the cornea may cause the vitreous to enter the wound behind the lens. If the insufficient length of the wound is noticed early, it is best to enlarge it with Wecker's scissors (Fig. 124); blunt knives (couteaux mousses) are also used for this purpose.

More favorable results are obtained and the operation is easier,

if iridectomy is not performed at the same time as extraction, but about six to eight weeks previously. Albrecht v. Graefe did this in especially unfavorable cases, or if a former operation had terminated in suppuration. In 1862, Mooren recommended it for all cases, to be followed by flap incision. Apart from the inconvenience of subjecting the patient to an operation at two different times and of the double confinement in bed—this is not always a matter of indifference in old age—preliminary iridectomy can be recommended if we wish to act with the greatest possible certainty.

In extractions the incision may be directed upward or downward; on the whole the former is preferable. The coloboma, which is directed upward, is covered somewhat better by the upper lid. In older people, also, entropium of the lower lid is apt to form beneath the compress and bandage, and pushes against the wound when directed downward. But I have not seen this followed by a direct injurious influence on the healing of the wound, especially as the entropium does not develop, as a rule, until union by first intention has occurred. [Unfortunately, if the flap is small entropium of the lower lid may in a downward section, open a wound that has healed.—St. J. R.] The incision downward is easier, because the upper rim of the orbit may be an obstruction, particularly in deeply sunken eyes, and because the majority of patients have the tendency to roll the eyes upward.

Other Methods of Extraction of Cataract.

Reclination.—Ad. Weber makes the incision with a concave lance-shaped knife (Fig. 125); its broad surface is ground concave in the horizontal direction. A series of these knives of different widths, corresponding to the different sizes of the cataracts, must be at our disposal. After the conjunctiva has been grasped with Weber's fixation forceps (Fig. 126) near the corneal rim and the eye drawn downward, the lance is pushed into the uppermost point of the vertical meridian of the cornea. It is carried parallel to the iris through the anterior chamber, its tip being directed toward the deepest point of the cornea. The incision of the concave knife is approximately linear (with a slight flap height) and has little tendency to gape. A disadvantage of the operation, which is otherwise easier than Graefe's, consists in the instrument. It is extremely difficult to obtain these broad concave knives sufficiently sharp and pointed; it is also inconvenient that we must have a knife for each different width of the lens. Jaeger

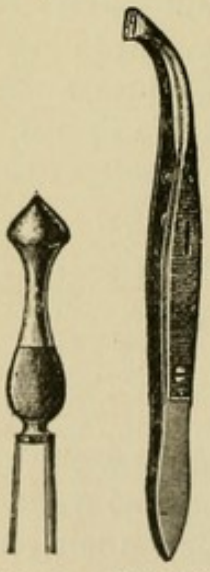


Fig. 125.

Fig. 126.

has recommended a Beer's cataract knife, ground concave, for the incision.

In order to avoid iridectomy, Liebreich made an approximately linear incision, Graefe's knife being introduced and removed (Fig. 127, *a* and *b*) immediately below the horizontal meridian of the cornea, and the transparent cornea being divided in such a way that the remaining lower part constituted about a third of its height. Anterior synechiæ are often left over, because the iris becomes applied to the wound. Lebrun employed a similar incision above.



FIG. 127. Extraction after Liebreich.

The ideal form of cataract extraction is the removal of the lens with the capsule. This prevents the irritation of the remaining cortical masses, and the proliferation of the capsule epithelium. Pagenstecher has recently practised and developed this method. After the anterior chamber is opened by the incision, he passes a specially constructed spoon into the plate-shaped groove behind the lens; at the same time the assistant presses against the opposite rim of the lens with the rubber spoon upon the cornea, as in Graefe's operation. It is true that the lens can often be extracted in the capsule in this way. But loss of the vitreous often occurs and this is not altogether indifferent as regards recovery. Moreover, according to Arlt's experience, the introduction of the spoon has an unfavorable influence on the general percentage of recoveries. The method is most indicated in overripe cataract, flattening of the iris, and the cataracts of very myopic eyes, in fine, wherever great thinness of the zonula Zinnii is suspected.

[I have practised a method of extracting the lens in its capsule, different from that of Pagenstecher. The lens is dislocated in making the section by turning the back of the knife upon it. No instrument is used to enter the eye except the knife.[1]—St. J. R.]

The methods described are employed particularly in the cataract of old age which requires a large wound on account of its size. Discission, which has been discussed under the head of partial cataract, is not indicated here on account of the hardness of the nucleus, which is not absorbed. But in young people (below the age of twenty to twenty-five years) a total cataract which has no hard nucleus, as a rule, at this age, may be absorbed by discission, with the exception of a few cases of gray or white congenital cataract that resist discission on account of the hardness of the nucleus (Alfr. Graefe). If iritic irritation or increased pressure within the eye sets in after discission, the lens is easily evacuated, on account of its mushy consistence, through a small linear incision in the

[1] Transactions New York State Medical Society, 1886.

cornea with the iris lance or Graefe's knife. The process of absorption, however, always lasts many months. The pupil must be kept dilated to its maximum width by atropinization, during this entire period in order to prevent iritis. Discission may also be preceded by iridectomy, as the best means of avoiding this complication. This operation is absolutely necessary when the pupil does not dilate to the maximum on tentative atropinization.

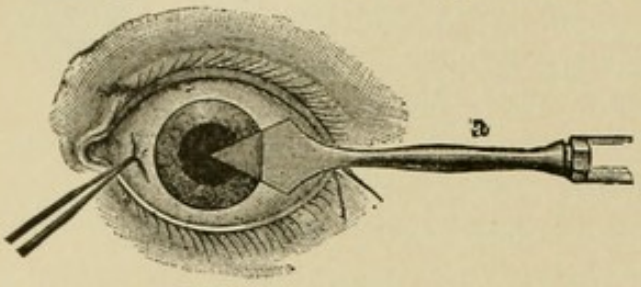


FIG. 128.

Albr. v. Graefe, before he introduced his peripheral linear extraction, had often used, in the extraction of the soft cataracts of young people, the linear corneal incision, with the aid of a broad lance-shaped knife (Fig. 128, *a*), inserted toward the temporal side; iridectomy was performed before opening the capsule (so-called modified linear extraction). As the wound was too small to allow the passage of the cataract in its entirety, the mushy masses were evacuated by causing gaping of the wound from the pressure of a Daviel spoon (Fig. 129) against the scleral edge of the wound. If necessary, the spoon can be introduced directly and the lens removed. The methods of Waldau, Critchett and others, who removed also the cataracts of old age by means of a spoon or hook introduced through a similar incision, have been abandoned. Even in the soft cataract of young people, unless discission is preferable, peripheral extraction is usually practiced with the narrow knife above or below, because the incision may be made as small as desired, and it is more advantageous optically to have the artificial pupil situated above or below.


FIG. 129. Daviel's Spoon.

The suction method has also been employed in these soft cataracts, the cataractous mass being sucked, through a canula, with the mouth (Langier) or a syringe (Coppez). Very fluid cataracts are removed more easily by an incision.

Shrivelled cataracts (for example, cataract aridosiliquata with narrow pupil and posterior synechia), such as occur as the result of chronic iritis or after cyclitis, are often extracted with difficulty on account of the callous adhesions to the posterior surface of the iris. Here the following plan is advisable. When Beer's cataract knife is in the anterior chamber, it should at once be pushed through the iris, pass behind it and contrapuncture performed on the opposite side (Wenzel's

operation); the incision should not be too peripheral on account of danger of loss of the vitreous. The excised portion of the iris is removed with forceps. A satisfactory result is sometimes obtained in this way. In the complicated cataracts which develop in sympathetic irido-cyclitis, Critchett advises that extraction be not performed, but that a central hole be gradually bored into the cataract with the discission needle. This plan undoubtedly presents less immediate danger. Discission, especially after previous iridectomy, is also suitable in the shrunken cataracts which are sometimes congenital, as the result of intra-uterine inflammations. Extraction of these cataracts is often followed by cyclitis.

The remains of traumatic cataracts are also suited to discission. If the injury to the lens has just occurred, we first attempt to prevent iritis by vigorous atropinization. The patient is kept in bed and treated antiphlogistically with leeches, etc. If great swelling is feared on account of the size of the wound, an early iridectomy may be performed, but without attempting to remove the still unswollen and transparent lens masses, as in the modified linear extraction. The latter is to be performed when, together with pronounced swelling, the iris is irritated and symptoms of increased pressure appear. In some cases, however, chronic iritis with coincident implication of the ciliary body develops, despite all our endeavors.

Prior to Daviel, who adopted the flap incision in all senile cataracts, on account of the good result he obtained from extraction of a lens which had fallen into the anterior chamber, the depression of the cataract into the vitreous was practised. This method has been used, at least in certain cases, until the middle of this century.

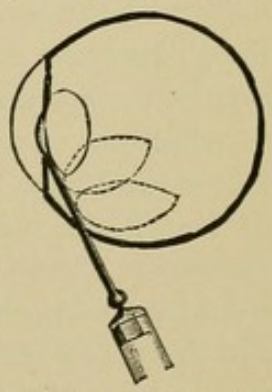


FIG. 130.—Reclination (diagramatic).

A cataract needle was passed through the sclera (scleratonyxis), about three or four millimetres from the temporal edge of the cornea and a little below the horizontal meridian into the vitreous body, then pushed behind the iris—one surface anteriorly, the other posteriorly—to the middle of the pupil and the lens then pushed out of the pupillary tract downward and outward into the vitreous. A large number of methods and cataract needles have been devised for this purpose. The term depression was used when the lens was simply dislocated downward, and reclination (Fig. 130) when it was also turned backward, and downward and outward, around its horizontal axis. This method often has good immediate results, inasmuch as the pupil becomes free and permits the entrance of rays of light, but the subsequent inflammations (irido-

cyclitis, etc.) become dangerous. According to Sichel's statistics, forty per cent of immediate successes were obtained, but about twenty per cent of these were subsequently lost.

After-Treatment.

After extraction, an antiseptic compress and bandage is placed on the operated eye. The non-operated eye may also be covered with cotton, which is retained by a few turns of a bandage, or it may be simply closed with English plaster. The patient is placed in bed, the room is darkened. As a general thing pains are absent or slight. If the patient does not sleep, opium or chloral hydrate is given at night. The dressing is left in situ for twenty-four to forty-eight hours. It is only when the pains are more severe that it is taken off earlier, and is again applied after slightly opening the lids, without permitting the entrance of light. The pains are often caused by too firm application or displacement of the bandage. In the next three to ten days the bandage is renewed every twenty-four hours. The eye need not be opened before the fourth day, because the pains and purulent secretion on the dressing would indicate an unfavorable condition without looking into the eye. If such symptoms have not appeared by the end of the fourth day, the healing of the wound is to be regarded as assured. Atropine is now instilled once or twice a day, in order to prevent iritis which may result from the swelling lens masses. If everything goes well, a lighter protective dressing may be applied on the eighth to tenth day, and the patient may be allowed to sit up a little or even to rise. But the dressing should not be abandoned much earlier. As a rule, everything will do well without it, but I have seen one case in which an accidental blow on the operated eye caused rupture of the wound and suppuration of the vitreous. As the entire future of the patient is at stake, it is better to exercise even excessive caution. From the twelfth to fourteenth day the wearing of a shield and blue spectacles usually suffice; the latter also moderate the light for the other eye; the protective dressing should be still applied at night. In the first few days the diet should be fluid in order to obviate mastication, and the stools are to be retarded as much as possible because the attendant straining may be injurious. If an evacuation has not been had by the fifth day, it should be secured by artificial means. Very old and feeble patients may leave the bed earlier, and be treated with tonics. After two or three weeks, the patients may usually leave the room if everything has gone well.

Disturbances in the Healing of the Wound.—The greatest dan-

ger after the operation, is suppuration of the cornea and vitreous body. It usually begins at the end of thirty-six to forty-eight hours. The patients generally complain of pains in the eye and forehead, but the increased conjunctival secretion is more important. When the dressing on the eye, on removal during the first two or three days, is found covered with an abundant, thin, pus-like secretion, the eye is always in extreme danger, assuming, as a matter of course, that the increased secretion is not explained by some previous conjunctival process. Pains are sometimes wanting. For this reason frequent change of dressing is indicated in order to acquaint ourselves with the conditon of the wound. On first opening the eye we then find, as a general thing, hyperæmia of the ocular conjunctiva and moderate œdema. The cornea is usually clear and nothing abnormal is seen at the edges of the wound. But in the course of the next twenty-four hours, the edges of the wound become yellowish, infiltrated and thicker, and stand away from the scleral flap. The iris is somewhat discolored and the anterior chamber contains pus. In rare cases, especially after loss of the vitreous during the operation, the cornea may still be perfectly transparent, while the vitreous is yellowish and infiltrated. If the process advances, panophthalmitis or at least purulent chroroiditis develops. We can rarely succeed in checking an affection which begins so early, and even when this is done, notable posterior synechiæ of the iris and after-cataract usually develop. When suppuration begins, the wound is brushed two or three times a day with a strong solution of corrosive sublimate (1 : 1000) or it is cauterized with the galvano-cautery (Abadie). At intervals of two hours, during which the compress and bandage are left on the eye, compresses of a cold, weaker solution of corrosive sublimate (1 : 5000) are applied for half an hour; in addition, atropine. Reopening of the wound has also been advised. As a result of greater cleanliness and antisepsis, these grave processes have fortunately become very rare. But they are sometimes excited later by the conduct of the patient, especially when delirium sets in. This delirium after cataract operations, first described by Sichel, is not a surgical delirium, but the simple result of the action of deprivation of light upon individuals who are in a feeble bodily or mental condition. I have also observed it in other patients who were kept in a darkened room. It is distinguished from delirium tremens by the absence of tremor and alcoholism, and by the different character of the hallucinations. As a rule it disappears in one or two days, when the patient again receives light impressions from opening the eyes.

Inflammations of the iris usually develop later; the purulent forms may also lead to destruction of the eye. This also results

from insidious irido-cyclitis which occasionally even gives rise to sympathetic inflammations of the healthy eye. Our attention is attracted by pains, pericorneal injection, and changes in the pupil. The inflammation is produced, as a rule, by remains of the cataract. The treatment consists of vigorous atropinization. If the process is very violent, mercurialization is to be recommended as the most active remedy.

Less strict treatment is required after discission, but sufficient mydriasis is to be secured by atropine.

IV. *After-Cataract. Secondary Cataract.*

After-cataract is also found often after successful operations, whose course of recovery has not been especially disturbed. As the capsule is left behind, in most methods of operation, and, as a rule, some of the cortex remains adherent to it, we almost always see translucent thickenings and opacities in some parts of the pupillary tract, on oblique illumination. We usually speak of after-cataract only after somewhat thicker membranes, which interfere with sight, have formed. This may also develop later, even years after the operation, from proliferation of the capsular epithelium. If it is thin, a discission needle is passed through the cornea and then into the secondary cataract, the opening being made as central and large as possible by transverse cuts. When the membrane is very hard and firm, this does not always succeed. Repeated discissions must then be performed. Bowman's plan may also be resorted to. He introduced two discission needles on the nasal and temporal sides at two opposite parts of the cornea, brought their tips together at the same place in the secondary cataract and then attempted to make an opening by drawing them apart in opposite directions. In some cases this method is insufficient. We must then divide the secondary cataract with Wecker's scissors or even excise a portion. Extraction of secondary cataract, as well as the reclination which has been recommended, are dangerous on account of the attendant traction on the ciliary body. We can avoid this by making peripheral circumcision of the secondary cataract with the discission needle in several sittings (this is best done with lateral illumination from an electric light) and thus separating it from its connections with the ciliary body before performing extraction.

If the pupil is occluded by the tissue of the iris, which is sometimes displaced entirely toward the corneal wound, iridectomy or iridotomy must be performed. The latter operation is less severe and sometimes gives very good results, because it also divides adhesions which may be situated behind the iris. Concerning the spectacles of cataract patients, see below.

2. Aphakia.

Aphakia (ἀ privative, φακῆ lens) is the term applied to absence of the crystalline lens. Every patient from whom a cataract has been extracted is aphakic. The absence of the lens is usually recognized by the greater depth of the anterior chamber, and the unusual blackness of the pupil; the lens reflex, which is especially noticeable in old people, is absent. Oscillation of the iris is often present. The Purkinje-Sanson test may also be used; the small reflex lens images are wanting in aphakia. But as the surface of the vitreous also reflects, and the lens reflexes require very close observation, the latter symptom, which is otherwise decisive, is of slight importance in practice. As a rule, better information is obtained by examination with oblique illumination and dilated pupil, because then, as a rule, we see traces of the opaque capsule which is left behind. The refraction of aphakic eyes is usually very hypermetropic. Eyes formerly emmetropic acquire about H 10.0. The power of accommodation is also lost.

Treatment.—In order to give vision to aphakics and those operated for cataract, we must give them convex glasses (cataract glasses); far and near spectacles—the latter for reading and near work—are usually prescribed. As the visual power of the patients rarely = 1, and, apart from young individuals, usually is only three-fourths to one-third, we attempt, by means of the spectacles, to bring the distance in which they are to read and recognize small objects, as close as possible. If convex 10.0 is given for distance, then about 20.0 is given for near work; with the latter spectacles the patient can then read at 10 cm. Strictly speaking, both these spectacles would only afford to aphakics the possibility of uniting rays upon their retina, which come from an infinite distance and those which come from a distance of 10 cm. Everything else is seen in more or less large circles of dispersion. But they soon become accustomed to this, especially as they can adjust the eyes for nearer points by moving the distance glasses farther away from the eye, and in this way can see at various distances with the same glasses. In addition, the accommodation is always very little at an advanced age—and the majority of aphakics are those operated upon for senile cataract—so that there is no notable difference from the previous condition. After the operation, some very myopic individuals require, for distance, no convex glasses or very feeble ones. In a large number of patients, however, spherically ground glasses do not suffice for perfect correction, because the operation is often followed by astigmatism; the latter is subject to certain variations for a long time (three to four months). The greater

curvature is usually situated in the horizontal diameter of the cornea. We must then select combinations with cylindric glasses. The use of glasses in aphakia should not be permitted too soon after cataract operations. It is well to allow six to eight weeks to elapse, and then begin with wearing the distance spectacles for a few hours.

A few patients, who have been operated for cataract, complain of suddenly occurring attacks of red vision (erythropia) which subside after some time. This depends generally upon exhaustion of the retina by the more strongly refracted rays of light (Purtscher, Hirschler), but the symptoms may also be produced, independent of the eye, by cerebral irritation. In a case under my observation, the red vision was confined exclusively to a peripheral portion of the field of vision.

3. Anomalies of Position.

When the lens is congenitally situated in an abnormal position, and is adherent in the vitreous or at a more remote part of the ocular coverings, the condition is known as ectopia. As a rule, other developmental anomalies are also found in the eye, particularly microphthalmus.

We speak of luxation or subluxation of the lens when the latter originally had the normal position and subsequently left it.

In the former case the lens, after separation of the zonula, is no longer situated in the plate-shaped depression, but is moved into the posterior or anterior chamber, has sunk into the vitreous or even passed out beneath the conjunctiva through a scleral rupture. These changes of position are usually produced by contusions of the globe, but spontaneous luxations occur occasionally, usually as the result of liquefaction of the vitreous. They have also been observed as the result of heredity. Lenses which move in their capsule may retain their transparency for a long time, especially if they remained in the posterior chamber and thus in part in the plate-shaped depression. If they pass into the vitreous, the anterior chamber, or beneath the conjunctiva, they usually undergo gradual opacification and a process of shrivelling so that they form deep white, compressed cataracts. Luxation of the lens may produce monocular diplopia, when the edge of the lens passes through the pupillary tract. Some of the incident rays are then refracted and deflected by the lens, the others pass through the free pupillary tract. This form of luxation is usually easily recognized with oblique illumination. Upon throwing in the light with the ophthalmoscope, the rim of the lens appears as a dark arch in the re-

flected red of the fundus. If the lens is luxated in the vitreous, the symptoms of aphakia are present. The position of the lens can usually be ascertained with the ophthalmoscope. Cataractous, luxated lenses, often pass through the pupil into the anterior chamber from the vitreous, and vice versa. The patients can often voluntarily produce this change of position, by moving the head. A lens luxated beneath the conjunctiva through a scleral rupture near the corneal limbus and running parallel to it, is easily diagnosticated because the tumor situated beneath the conjunctiva presents the shape of the lens; the previous history and the presence of aphakia decide the question.

If the transparent lens is situated in the posterior chamber, and covers a part of the pupillary tract, double refraction of the rays entering the pupil may sometimes be prevented by the use of myotics, according to the position of the lens. If the lens has become cataractous, whether situated here or in any other part of the globe, we must endeavor to extract it as soon as it produces notable disturbances of vision, or irritative conditions. But extraction is usually attended with certain difficulties, because the vitreous, which communicates freely with the anterior chamber, usually escapes immediately after the corneal incision. The outpouring vitreous may push the lens entirely away from the wound, and if it sinks back into the vitreous through the pupil, the lens may be entirely lost to sight. A movable lens should therefore be fixed before the corneal incision is made. For this purpose, if it is situated in the vitreous, we first attempt to bring it into the anterior chamber by suitable position during marked artificial mydriasis, and then prevent its slipping back by the use of myotics. It may also be spitted with a cataract needle before the operation, and then extracted through the corneal incision with the lens spoon or a hook.

The removal of a subconjunctival lens is more simple. But occasionally the lens is still situated partly in the scleral wound and, if a long time has elapsed since the injury, adhesions may have formed with the sclera and ciliary body. If there is no special indication for operation in such a case, it is better to leave the luxated lens in position. I have seen a case of this kind in which the lens had been located beneath the conjunctiva for many years. The eye was free from inflammation and retained good visual power. It may here be mentioned that the lens is often displaced in corneal staphylomata, to which the iris is adherent, and may be situated in the corneal protrusion. It sometimes remains transparent for a long time in this position, as is seen on letting it escape during the operation for staphyloma.

Subluxations, in which the lens suffers only slight displacement

from partial rupture of the zonula, usually occur after injury and are not always easily diagnosticated. It is an especially suspicious circumstance when, in addition to marked tremulousness of the iris, the anterior chamber presents an unequal depth in different places. The pupil is usually dilated. We can sometimes succeed, if necessary with the aid of mydriatics, in recognizing with the ophthalmoscope the edge of the lens which is brought closer to the centre of the pupil. The subluxated lens may remain transparent for years. I observed an unusual case, which must be included in this category, in a man who had subluxated cataractous lens in one eye. In the other eye the lens was also cataractous but somewhat shrivelled and flattened; almost its entire periphery was separated from the zonula, being adherent only on the temporal side, so that during movements of the eye, it acted like a valve, sometimes falling back into the vitreous, sometimes covering the pupil completely. The patient could secure temporal vision by suitable movement of the eye.

CHAPTER III.

DISEASES OF THE CONJUNCTIVA.

Anatomy.

THE conjunctiva of the eye begins at the free borders of the lids, covers the surface of the lids which is directed toward the globe, and then passes to the globe itself. We distinguish three parts:

1. *Palpebral or Tarsal Conjunctiva.*—This has a white to pale-red appearance, the latter depending upon its extremely numerous small vessels. These occasionally appear distinctly in individual branches, without constituting a morbid hyperæmia. Toward the edges of the lids, the Meibomian sebaceous glands which are imbedded in the cartilage (tarsus) almost parallel with the roots of the lashes, shine through with a yellowish-red color, particularly in older people. The palpebral conjunctiva is quite firmly adherent to the posterior portion of the tarsus. Its stroma consists of adenoid connective tissue, but the peculiar network arrangement here and in the transition fold only appears during the first year after birth, the tissue insinuating itself between the fibrillary connective tissue of the inner surface of the cartilage and the epithelium. The latter contains pavement cells in the upper layers, cylindrical cells in the deeper layers. With the appearance of the adenoid tissue circumscribed prominences (so-called papillæ), small ridges and folds (Stieda's system of grooves) develop on the conjunctival surface. If the papillæ are slightly swollen, they appear as small projections, looking like the dulled point of a pin, so that the mucous membrane resembles ruffled velvet. This is seen particularly in the outer angles of the lids. Lymph follicles are also imbedded in this part of the conjunctiva, immediately beneath the surface. Microscopically these consist of completely closed, round or elongated sacs, whose cavities contain a fine capillary network; they are infiltrated with round, pale, nucleated cells. Anatomical investigations and clinical observations, favor the view that they are to be regarded as physiological in certain numbers and of a certain size, although some observers regard them as always pathological and belonging to trachoma.

2. *The reflection, transition part, or transition fold:* the part at which the conjunctiva passes from the lids to the globe. Its structure is allied to that of the palpebral portion, except that the connective tissue has coarser meshes (hence greater tendency to swelling, exudation, etc.). The papillæ also lose their circumscribed shape, and unite into ridge-like elevations. We also find a number of tubulo-acinous mucous glands, the majority of which (usually twelve to eighteen) are situated in the outer half of the upper transition fold; a few scattered ones are found in the remaining part of the upper and in the lower fold (Krause). At the inner angle of the eye the conjunctiva, before passing to the globe, forms a reduplication which occasionally contains a cartilage (plica semilunaris). Its projecting part, which is directed toward the inner angle of the eye and contains about a dozen sebaceous glands, surrounded by numerous fat cells, is called the lachrymal caruncle. It is dotted with a few very delicate hairs.

3. *Ocular or Scleral Conjunctiva.*—It covers the anterior half of the globe, and is first applied quite loosely to Tenon's capsule which, in the shape of a fibrous membrane, separates the sclera from the surrounding adipose tissue. Near to the cornea it is united more intimately to the sclera itself, after Tenon's capsule has become lost in the subconjunctival tissue. It covers the extreme periphery of the cornea, with a narrow, ring-shaped wall (conjunctival limbus or annulus), which extends a little over the outer edge of the cornea, a little further above and below than on the sides. The conjunctival covering of the cornea consists of an extension of the pavement epithelium with a subjacent structureless membrane. The ocular conjunctiva, without glands and papillæ, has a white translucent appearance; a few narrow conjunctival vessels run from the periphery of the globe toward the cornea. The arteries and veins of the tarsal conjunctiva and the transition fold communicate with the vessels of the lids. Upon the sclera we distinguish a superficial conjunctival vascular layer and a subjacent subconjunctival or episcleral layer. The former (Fig. 131) consists of the posterior, ramifying conjunctival vessels (springing from the palpebral arteries) and the anterior straight conjunctival vessels which are very slightly prominent in the normal condition; the latter spring from the episcleral vascular network, close to the cornea, and passing backward communicate with the posterior conjunctival vessels. The episcleral vascular network (Fig. 132), particularly that part which directly surrounds the cornea, is especially important. This system is derived from the anterior ciliary vessels. Around the periphery of the cornea the arteries form a network of loops, composed of small branches connected by arches with one

another. The veins, which convey the blood hence, as well as from the vessels of the ciliary muscle and conjunctiva, also form a dense network. This is actively injected in severe inflammations of the eye, when a red fringe, several millimetres in width, appears around the cornea (pericorneal injection).

A large number of lymphatics are found in the conjunctiva, near the cornea, in the shape of a ring (Teichmann). The nerves are branches of the trigeminus.

The fluid contents of the conjunctival sac are derived not alone

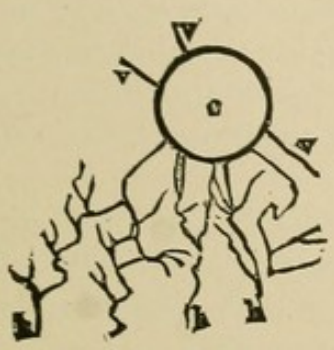


FIG. 131.—Conjunctival Vessels (Anterior and Posterior).

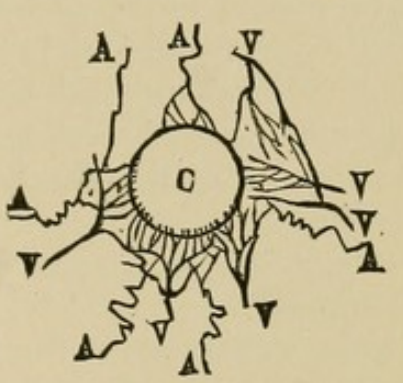


FIG. 132.—Episcleral Vessels. Ciliar Veins and Arteries. (Woerden.)

from the lachrymal glands, whose six to twelve fine excretory ducts penetrate the conjunctiva above the outer angle of the eye; the eye remains moist despite their extirpation. In addition to transudation from the vessels, a secretion is obtained from the conglomerate acinous mucous glands, whose structure exactly resembles that of the lachrymal glands. In addition to the fluid, the conjunctival secretion contains desquamated epithelial cells, detritus, and fat.

1. HYPERÆMIA OF THE CONJUNCTIVA.

The connective tissue of the lids exhibits abnormal injection. The increased ramifications of the vessels appear in part more distinctly, in part they are confused into a uniform redness. The conjunctiva thus loses its transparent appearance. Here and there the Meibomian glands in the vicinity of the lid are concealed. The papillæ occasionally swell into small, red elevations as large as the point of a pin, especially in the outer angles of the eyes. The fornix, otherwise pale, is now slightly reddened and traversed by larger vessels. Injection of the scleral conjunctiva is rare in primary hyperæmia. Injection of the pericorneal network occurs neither in hyperæmia nor in simple conjunctivitis.

In primary hyperæmia there is increased secretion of tears, but no production of mucus (catarrhus siccus). The subjective symp-

toms (heaviness of the lids, burning, the feeling of a foreign body in the eye, etc.) are extremely annoying and increase particularly at night and after using the eye. They may be so severe that reading and writing become almost impossible, and all the symptoms of asthenopia are manifest. The hyperæmia usually develops quite acutely and often disappears without medical treatment. In rare cases it is obstinate, even to medication, and is then apt to pass into a chronic condition or into conjunctival catarrh.

Diagnosis.—We must avoid regarding every prominent development of vessels on the palpebral conjunctiva as hyperæmia. Numerous examinations of healthy conjunctivæ will inform us concerning the physiological range in the development of the vessels. Simple hyperæmia is distinguished from catarrh and blennorrhœa, by the absence of secretion and the slight swelling of the mucous membrane.

Etiology.—Apart from constitutional conditions and general noxious agents (colds, etc.), conjunctival hyperæmia results chiefly from local irritations, such as foreign bodies that have entered the eye, obliquely placed or inturned eye-lashes, calcareous infarctions of the Meibomian glands, particularly in old people, eversion or occlusion of the puncta lachrymalia, which results in prolonged irritating retention of the secretion which may be present in the conjunctival sac, secretions from diseases of the lachrymal sac which reach the eye through the tear passages, tobacco smoke, dust of the streets, bad air, etc. Eye strain, use of improperly selected spectacles, and the like are not infrequent causes. Inflammations or congestion of other cutaneous coverings may cause secondary congestion of the conjunctiva.

Treatment.—When the exciting causes still continue, their relief constitutes the beginning, and often the end, of treatment. Foreign bodies (dust, small insects, etc.) must be removed. For this purpose the fornices must be examined with special care. Obliquely placed lashes must be removed, incurved ones straightened. In calcareous infarctions of the Meibomian glands, a small incision is made with a paracentesis needle and the hard contents removed with the stilet situated within the instrument; if many of these glands are present, we should operate in several sittings in order that too great irritation may not be produced. If the lower lachrymal puncture is deflected and everted instead of dipping into the tear sac (this appears particularly when the patient looks strongly upward), the lachrymal duct in the lower lid must be slit up; a similar plan is adopted in closure of the lachrymal punctum (vide Diseases of the Lids). Exciting diseases of the lachrymal sac must be treated. If such causes are absent, we should recommend great

care of the eye and the avoidance of bad air and tobacco smoke. Staying up late at night is also injurious. Quiet sleep is of the greatest importance in diseases of the eye. Locally we may recommend compresses of cold water (ten drops acetate of lead to a cup of water). A similar action is produced by the eye douche, which is used upon the closed eye several times a day, but only for two to six minutes (Fig. 133). We begin with water—to which, if required, some eau de cologne may be added—at a temperature of about twenty degrees Celsius, and it can then be diminished gradually to twelve degrees. The douche is of great advantage, particularly in violent pains and other nervous symptoms. Instead of compresses of pure water, the eye may be washed twice a day, in less acute hyperæmias, with a weak solution of zinc (℞ Zinc. sulph., 0.5; Tinct. opii, 1.0; Aq. destil., 150; Aq. fœniculi, 50.0). In more obstinate cases we must make instillations into the conjunctival sac of astringent solutions, such as a one-half-per-cent solution of sulphate of zinc or tannin, once a day, best at night. Even direct touching with the one-and-half-per-cent solution of plumb. acet. perf. neutralis, followed by washing with water, is occasionally necessary. If the nervous symptoms and pains are prominent, a two to four per cent solution of cocaine may be used. In such cases A. v. Graefe instilled tinct. opii and aqua destil. āā, into the conjunctival sac. Immediately after the instillation the pain is very violent, but is lost in about fifteen minutes. It is well to apply cold compresses after the instillation.



Fig. 133.

2. Simple (catarrhal) Conjunctivitis.

Conjunctival catarrh exhibits similar symptoms to hyperæmia, except that the swelling of the conjunctiva is more considerable and a new factor, the secretion of mucus, is superadded. The palpebral conjunctiva has a reddish color, which passes from a lighter to a darker shade according to the intensity of the disease. The transition folds are also involved in the milder forms, and contrast by a paler redness, which exhibits a notable development of larger vessels, with the more uniform, darker color of the tarsal conjunctiva. The semilunar folds and caruncle are often of a very deep red, on account of the development of larger vessels. If this part alone is affected, the disease has also been called ophthalmia angularis. The scleral conjunctiva exhibits injection only in the higher grades of inflammation. Like the other parts of the conjunctiva, it may then contain small hemorrhages. The swelling of

the tissue is usually moderate, and extensive exudation into the conjunctiva bulbi, which gives rise to œdema (chemosis) is rare in simple catarrh. Slight œdema of the lids is occasionally observed in blondes with a very delicate skin.

The secretion varies according to the height and duration of the disease. At first there is increased production of tears. A slight frothiness and somewhat changed color soon indicate an admixture with exudation. The increase of secretion is also shown by the deposit of small yellowish crusts on the edges of the lids, especially at the angle of the eyes. These crusts are not situated directly on the edges of the lids, but at a little distance from them in the lashes. They arise from drying of the secretion which occurs particularly at night, when the lids are at rest. The lids are then adherent in the morning, and the patient opens them with difficulty. Later the secreted fluid contains small light gray or yellowish flocculi, and threads, which are situated particularly in the lower fornix. When the secretion is very abundant, and the catarrh of long standing, we also find excoriations of the lids, particularly in the outer angle, and inflammations of the edges of the lids (blepharitis marginalis).

The subjective symptoms are similar to those of conjunctival hyperæmia—heaviness of the lids, itching, the feeling of a foreign body in the eye. The latter sensation depends probably on the rubbing of the distended vascular loops in the papilla against the ocular conjunctiva which is rich in nerves. This feeling is often so deceptive, that the patient constantly maintains that there is something in his eye. The more fiercely and closely the lids are applied to the globe, the more will such sensations appear, the more loosely the less marked will they be. In addition, there is usually moderate photophobia, slight endurance of use of the eyes, visual disturbances. The latter consist of occasional cloudy vision and of small colored circles, which are situated, for example, around the flame of a candle. This is owing to the thin flocculi and epithelial cells which are pushed across the cornea. The symptoms disappear when the cornea is cleansed by frequent winking. An actual diminution of vision may also occur as the result of simple conjunctival catarrh, when the patients have suffered from previous corneal affections and secondary opacities; the latter suffer a temporary increase in intensity from the inflammation.

With proper management simple catarrh disappears in eight to fourteen days. In rare cases, when the causal factors continue, or in old people, it passes into the chronic form. The subjective symptoms then diminish, but objectively the conjunctiva exhibits greater relaxation, it assumes a peculiar light bluish color, particu-

larly in the tarsal portion and fornix of the lower lid, and finally, we may even find a few small, tendon-like streaks which develop as the result of epithelial losses and partial retraction of the conjunctival tissue. If the cicatrices are larger, they occasionally (though rarely) lead to inversion of the edges of the lids (entropium). In the majority of these cases, on the contrary, the lower lid loses its hold, inasmuch as the relaxation of the conjunctiva is also associated with that of the orbicularis and the skin—and thus ectropium develops. Corneal affections as the result of a simple conjunctival catarrh are rare and insignificant.

Diagnosis.—Conjunctival catarrh is distinguished from blennorrhœa conjunctivæ, by the much greater swelling of the mucous membrane in the latter disease and the more abundant development of folds. Moreover, acute blennorrhœa develops much more violently. It exhibits marked œdema of the lids and ocular conjunctiva, greater secretion of catarrhal or pus-like exudation, pericorneal injection, not infrequently rapidly developing and severe corneal affections. In chronic blennorrhœa, the symptoms are less pronounced, but the swelling and proliferation of the papillæ and the great tendency to corneal affections serve to distinguish it from catarrh.

Etiology.—The mechanical causes which produce hyperæmia of the conjunctiva may also lead to catarrh. Among other factors may be mentioned: catarrhal diseases of the nasal mucous membrane or bronchi, diseases of the integument of the face (eczema, impetigo, etc.), facial erysipelas, measles, scarlatina, typhoid fever.

Treatment.—We first endeavor, by inverting the lids, to ascertain whether a foreign body is the cause of the catarrh; entropium or ectropium must undergo operation when necessary (vide Diseases of the lids). If the disease is associated with nasal or bronchial catarrh, diaphoresis must be stimulated. In genuine conjunctivitis, general treatment is usually unnecessary; we must simply secure regular evacuations from the bowels and guard the patient against changes of temperature. In the acute stage, the patient should remain in a slightly darkened room and should abstain from work. The edges of the lids are to be cleansed frequently with a soft sponge dipped in lukewarm water. Cool compresses of water or lead wash, for one-quarter to one-half hour four times a day, are usually well tolerated and hasten recovery. In this way the most violent inflammatory symptoms are allowed to subside.

If the secretion is more abundant and the mucous membrane more succulent, we use stronger solutions of acetate of lead, or boracic acid (two per cent) for compresses. Instillations of one-half to one per cent solutions of sulphate of zinc and tannin, or one-

eighth per cent of nitrate of silver, act still more vigorously on the relaxed and hyperæmic mucous membrane. In chronic catarrh the mucous membrane is touched directly. The following remedies may be mentioned in the order of their astringent action: tannin, neutral acetate of lead (one and one-half to two per cent), solid alum, and one and one-half per cent solution of silver nitrate. After each application, which is made once a day, cold compresses are used for fifteen to thirty minutes. The eye douche may also be used to advantage in these chronic cases. Some patients tolerate eye washes very poorly; we then use the remedies in the form of ointments, particularly lead ointment (plumb. acet. perf. neutral, 0.2; ung. paraffin, 8.0). Lead wash compresses and applications of nitrate of silver (one and one-half per cent) are used against secondary inflammations of the edges of the lids. Smearing the edges of the lids with glycerin, almond oil or lead ointment may be recommended for the dryness of the eyes, especially on waking, which continues not infrequently for some time after the catarrh.

3. Conjunctivitis Phlyctænulosa (Conjunctivitis scrophulosa; Conj. exanthematica; Herpes conjunctivæ).

In phlyctænular conjunctivitis, small vesicles, pustules, or infiltrations are found, partly upon the scleral conjunctiva, partly in close apposition to the edge of the cornea; they are situated at the tip of a bundle of vessels which, coming from the periphery, gradually grows narrower.

The vesicles contain a slightly cloudy, whey-like fluid, the pustules a yellowish, pus-like fluid; the infiltrations form more or less prominent nodules of a grayish-white color. Occasionally, a distinct phlyctænular development is wanting, and the type of disease is only recognized from the peculiar, wedge-shaped vascular injection. If the phlyctænulæ are situated near the cornea, subconjunctival injection appears at the same place. The remainder of the mucous membrane may appear to be entirely unaffected in this process, and it is only when there is an abundant formation of phlyctænulæ, and the disease has lasted a long time, that we notice a coincident inflammation of the palpebral conjunctiva and the fornix. We may distinguish three forms of phlyctænular conjunctivitis which are also important as regards treatment: 1. Simple phlyctænulæ. They occur singly or in small numbers, and are situated commonly in the scleral conjunctiva or the outermost rim of the cornea. The vessels leading to it form a tuft. In a short time (one to two weeks) the phlyctænulæ are either absorbed without further change, or small ulcers form at their apices from loss of the epithelial covering;

these have a great tendency to heal. 2. Disseminated phlyctænulæ at the rim of the cornea. They appear in large numbers as small elevations, about as large as a pin's head, at the edge of the cornea and are often located over the entire circumference so that the conjunctival limbus looks as if strewn with fine sand. There is also quite pronounced injection of the conjunctival and subconjunctival vessels. At the end of a few days the majority are converted into small, shallow ulcers. 3. Broad phlyctænulæ. These form elevated nodules, about one and a half to two millimetres in size, which are situated chiefly at the edge of the cornea or, at least, in its vicinity. Their number varies, but is never as large as that of the disseminated phlyctænulæ. After a time, their apex softens and tolerably deep ulcers form, with ragged, irregular edges and a yellowish base. This form is the most protracted and often lasts four to six weeks. Phlyctænulæ of the conjunctiva are associated not infrequently with corneal affections, such as small infiltrations and superficial ulcers. The tuft-shaped keratitis also often develops from a phlyctænula at the edge of the cornea.

Diffuse superficial opacity of the entire cornea, with new formation of vessels (pannus phlyctænulosa) may follow long-standing phlyctænular disease.

In conjunctivitis phlyctænulosa, the secretory anomaly consists merely in increased secretion of tears. There is usually a very considerable and characteristic photophobia, which may terminate in blepharospasm, especially in children. Some children lie all day with the face and closed eyes upon the arm or pillow. Violent pains are only present before the beginning of the eruption; a feeling of pressure and burning in the eyes is common.

As a rule, the disease runs a favorable course under proper treatment. Secondary corneal processes or catarrhal swelling of the conjunctiva retard recovery. Moreover, relapses are very frequent.

Etiology.—The disease occurs chiefly in children, scrofulous children furnishing the main contingent. Cutaneous eruptions are not infrequently present at the same time. Phlyctænulæ also occur after measles, scarlatina, and variola. The disease occurs more rarely in adults, in many cases merely as the characteristic vascular injection.

Treatment.—In children, the photophobia is often an obstacle to treatment as well as recovery. A good remedy for this is dipping the whole head into a pail of cold water (Juengken, v. Graefe). When the child recovers from his fear of suffocation, he will at once open the eyes. If a single dip is insufficient, it must be repeated. Instillation of cocaine is a milder remedy and is often effective.

The closure of the eyes is to be prevented as much as possible by persuasion and staying in a moderately darkened room. The greatest influence upon the relief of the photophobia is undoubtedly exercised by proper treatment of the local process. The following plan may be recommended. Against simple phlyctænulæ and simple phlyctænular injection: the application of finely powdered calomel once a day. Care must be taken that no large lumps remain in the conjunctival sac. The internal use of iodine is to be avoided, on account of the production of the caustic mercurial iodide. Calomel is not so useful in disseminated and broad phlyctænulæ. Here yellow precipitate ointment—a piece as large as a hempseed being placed in the eye, there rubbed up, and removed at the end of a few minutes—has a specific action. It often has a brilliant effect, even when there is marked redness and inflammation of the eye, but in such cases it must at first be used cautiously. If no improvement occurs after a single application, we must first employ antiphlogosis, cold compresses of lead lotion being applied three or four times a day for half an hour, and atropine instilled three or four times. The atropine is also useful in other respects. When the pupil, which is usually very narrow in the more violent phlyctænular processes, has dilated sufficiently, the photophobia generally disappears, and in children recovery usually begins with the opening of the eyes.

Touching with a solution of silver nitrate (two to five per cent) is useful in ulcerated broad phlyctænulæ. [Cocaine should always be used and anæsthesia be produced, before this is done.—St. J. R.]

If there is inflammation or swelling of the palpebral conjunctiva, the treatment must be supplemented by cold compresses and, if necessary, by direct touching with lead lotion or a solution of tannin. Without this we are often unsuccessful in catarrhs of the fornices with swelling, which often accompany long-standing phlyctænular processes. The mucous membrane is touched with the solution on one day, on the next day yellow ointment is used. The above-mentioned specific remedies, calomel and yellow precipitate ointment, may be tried, even when there are superficial corneal infiltrations in addition to the phlyctænulæ. The precipitate ointment is very efficient in pannus phlyctænulosa.

I have not seen much effect from derivatives to the skin. In a few cases I have unsuccessfully used the remedy extolled so highly by Critchett, viz., a small seton, composed of one or two silk threads, and passed through the integument of the forehead. I do not understand how this slight suppuration can help in cases in which we often find extensive eczemas on the lids, cheeks and scalp, without any curative action on the affection of the eyes. On the

contrary, I would advise against derivatives to the skin, as by fly blisters, precipitate ointment, because this is very apt to be followed by extensive suppuration and eczema in scrofulous children. But due attention must be paid to the general constitution and the necessary directions given, such as alkaline baths, cod-liver oil, stomachics, etc. The well-known Plummer's powder (calomel and stib. sulph. aurant. āā) sometimes does very good service in severe inflammation of the eye, which does not yield to other measures. Tar ointment must be applied in eczema of the lids.

It is of the greatest importance not to discontinue treatment too early, otherwise relapses are quite sure to occur. Calomel must be applied daily for weeks after the cure of phlyctænular conjunctivitis.

Spring and Summer Catarrh.

Spring catarrh (Sæmisch) has a certain resemblance to sand-like phlyctænular conjunctivitis. The conjunctival limbus is particularly affected It is covered with round prominences, as large as a pin's head, of firm consistence and grayish-white color; occasionally there is more uniform thickening and prominence. The affection rarely involves the entire periphery of the cornea. There is pericorneal and episcleral injection. The palpebral conjunctiva usually exhibits papillary proliferations, often a peculiar whitish opacity as if it were covered with milk. The secretion is moderate. The subjective symptoms are slight, apart from the almost constant photophobia.

It is characteristic of the affection, that it appears in spring and summer, and disappears in winter. It also exhibits a great tendency to relapse every year. The cornea is not attacked, and as a rule, complete recovery ensues. Only children and young people suffer; as a rule, both eyelids are attacked.

The treatment is expectant; irritation is to be avoided. If the secretion is pronounced, the mildest astringents are used; blue protective glasses against the photophobia.

4. Blennorrhœa.—Catarrh with Swelling.—Granulations. (Trachoma).—Follicular Conjunctivitis.

Pathological Anatomy and General Diagnosis.

Blennorrhœa, catarrh with swelling, trachoma and follicular conjunctivitis present, in part, similar anatomical changes, but clinically they must be kept strictly separate. In the majority of cases this can be done with certainty, but there are transitional forms—particularly between chronic blennorrhœa and catarrh with

swelling on the one hand and between granulations and follicular catarrh on the other hand—in which even the expert may be in doubt and must await the further course of the affection.

A. Anatomically, blennorrhœa exhibits, in the main, an hypertrophy of the papilla of the conjunctiva or of its ridges and folds. The latter attain an unusual size. The papillæ extend above the level of the mucous membrane like warts (occasionally intensified into proliferations like a cock's comb) and give it a nodular, uneven appearance, often of a blood-red color. The closely aggregated papillæ sometimes coalesce into pavement-like, small sections. The epithelium is markedly proliferated and is infiltrated with lymphoid corpuscles. Beneath the epithelial covering is found a deep layer of infiltration of lymphoid cells; this infiltration is diffuse and does not appear in round heaps. The mucous membrane is very hyperæmic. In the stage of resolution, as a rule, there is

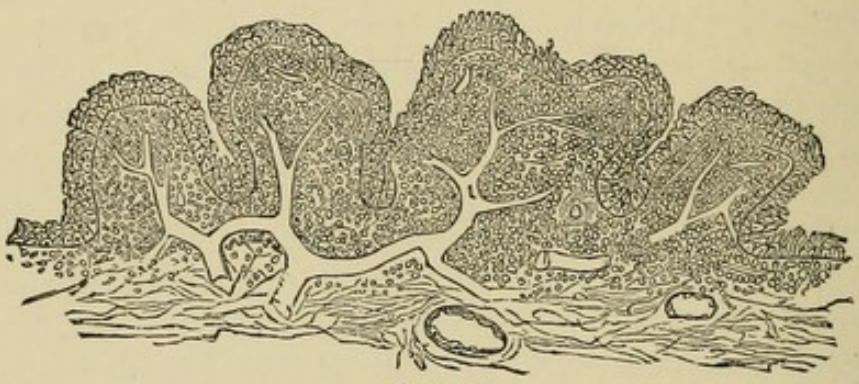


FIG. 134.

very little or no development of connective tissue. If a cicatrix forms, it usually appears in a flat shape.

B. In granulations are found peculiar new-formations, the trachoma follicles or granules. These are round or oval granules, which are situated in the adenoid tissue of the conjunctiva and shine through, microscopically, with a bluish-gray, yellowish-gray, or yellowish color. They have no similarity to wound granulations. They consist of an accumulation of lymphoid cells, arranged in such a way that those in the middle are larger, the peripheral ones smaller. The latter form a sort of boundary against the surrounding tissue (Jacobson, Jr.). But this is only true of younger trachoma follicles; the older ones have a fibrous connective-tissue covering (Mandelstamm, Raehlmann). Fine fibres and blood-vessels are found between the cells of the follicles. The vessels are seen best on examination in the fresh condition. I have also been able to see distinctly the blood-vessels and connective-tissue covering, in trachoma follicles of the scleral conjunctiva. The contents of the granulation may soften and form a mushy mass, or

it undergoes induration, thickened connective-tissue fibres passing from the capsule through the granulation cavity. Sclerosed blood-vessels also appear to play a part in this connective-tissue transformation (Sattler). The tendency to the formation of cicatrices is very pronounced. The connective tissue between the individual trachoma follicles also contains lymphoid cells, situated either diffusely or in nests. The diffuse infiltration sometimes interferes with the differentiation of the individual trachoma follicles. In addition there is abundant development of blood-vessels and lymphatics. Proliferation of the papillæ may be entirely wanting, but it usually develops at a later period in a more or less pronounced form, often only in certain parts of the palpebral mucous membrane. The epithelium gradually loses its cylindrical character and becomes flattened; exfoliations also take place with formation of ulcerations which may result in extensive cicatricial changes on the surface (Raehlmann). Tubular epithelial depressions (Berlin-

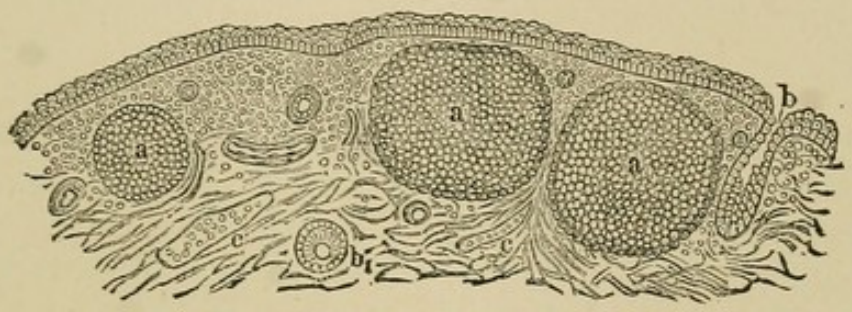


FIG. 135.

Iwanoff's trachoma glands) are found in very large numbers. These are not to be regarded as specific inflammatory products of trachoma, but as enlargements of the normal depressions (Reich, Sattler, Jacobson), together with the new-formed interspaces resulting from hypertrophy of the folds. If the outlets of these depressions grow together, cystoid structures may form. These tubes also occur often in follicular conjunctivitis (Freudenstein) and blennorrhœa.

According to this, blennorrhœa (and, to a slighter degree, catarrh with swelling) is characterized by hyperplasia of the papillary body, with diffuse cell infiltration, granulations by the occurrence of trachoma follicles and the spherical accumulations of lymphoid cells.

There are also mixed forms between blennorrhœa and granulations. If the blennorrhœa becomes chronic, we not infrequently find a few follicles here and there, especially at the angles of the lids, but they are so few that they do not obscure the clinical picture.

In granulations the case is different. If they are followed by

proliferation of the papillary body, the papillæ, on account of their red color and their warty prominences, may conceal the granulations. But, as a rule, the primary disease is recognized by the prominence of circumscribed round figures and by the yellowish color which shines through. This condition has also been described as mixed trachoma. It is better to speak of "trachoma (granulations) with secondary blennorrhœa."

If the papillary proliferation is slight, or has already undergone resolution, the follicles may be found in the conjunctiva as rows of gray or grayish-yellow granules, like the frog's spawn.

When cicatrices have formed, whitish streaks are seen in the mucous membrane, which usually has a peculiar shining appearance; stellate figures, starting from a patch-like centre, are often seen on the tarsal portion of the upper lid. On the lower lid the mucous membrane has a peculiar, light-blue color instead of the normal white with the sharply defined little vessels. In addition to these cicatrices, we may find a few follicles or only papillary proliferations. But as blennorrhœa does not produce such stellate cicatrices, the diagnosis "cicatricial trachoma" must be made in such cases. It is particularly in these cases that we occasionally find in the fornix an elongated, grayish-yellow, tolerably uniform, circumscribed infiltration (Stellwag's gelatinous trachoma).

C. Follicular Conjunctivitis.—Saemisch attempted to make the following anatomical distinction between trachoma proper and follicular conjunctivitis. In trachoma the individual granules are composed of a nest-shaped infiltration of lymphoid cells without a surrounding capsule, while the capsule is present in follicular conjunctivitis. Such an anatomical distinction cannot be strictly carried out, because, as we have seen, the trachoma follicles may also possess a capsule. The difference between simple follicular formations and the trachoma follicles of certain stages of the trachomatous process cannot be recognized under the microscope. It is easier to demonstrate differences in the surrounding conjunctival tissue. Thus, unless there is a complication with pronounced inflammation, the follicles are more prominent in microscopical sections, while the trachoma follicles project less above the surface, because the tissue between them is also swollen from infiltration with numerous lymphoid cells. Furthermore, the lymphatics and blood-vessels are usually more numerous between and around the trachoma follicles than in simple follicular conjunctivitis. The greatest difference is in the termination of the processes. In the latter stages of trachoma there is always more or less extensive development of cicatricial tissue, often cheesy degeneration and secondary extensive proliferation of the papillæ—processes that

are never observed as sequelæ of follicular conjunctivitis. In a series of cases belonging to the latter category, we simply find swelling and prominence of follicles which are present physiologically.

We must separate from the latter, other smaller vesicular prominences of the conjunctiva, but which are more transparent and have a delicate surface. These are elevations of the epithelium or the basal membrane resulting from exudation of lymph; when pricked they usually discharge clear fluid.

The follicles proper are found in a conjunctiva which is either perfectly normal or in an inflamed and congested, but not swollen and proliferated membrane. I have never seen a pronounced follicular conjunctivitis which led to the formation of granulations or cicatrices, although I have followed many cases for years. The separation of the two affections is undoubtedly of the greatest practical importance, and it is to the great credit of Saemisch that, in conjunction with A. v. Graefe, he emphasized the clinical differential factors between this disease and trachoma. Perhaps this was done somewhat too sharply, because it cannot be denied that in some cases the diagnosis may be doubtful at the onset. Almost all of such cases belong to the variety of follicular conjunctivitis, in which the appearance of the follicle is attended with inflammatory conjunctivitis. I have often seen acute granulations develop with such appearances, in the second eye of a patient, whose other eye already suffered from pronounced granulations. But all doubts were soon removed by the large number and size of the follicles and by the pronounced implication of the conjunctival tissue. A similar experience is occasionally observed in "catarrh with swelling," which turns out, at the end of a few days, to be "acute granulations." But such morbid pictures which give rise to some uncertainty in diagnosis at the beginning of the disease, furnish no reason—especially as they occur rarely—for confusing diseases which are so different in their prognosis and course.

Horner's interpretation of follicular degeneration, as the product of miasmatic infection of the adenoid tissue, and of granular conjunctivitis as "the product of a contagious secretory infection of a miasmatically prepared conjunctiva," may be agreed to, in part, as regards the follicular degeneration because it often develops in schools and barracks under miasmatic influences. But it also occurs without such causes, children exhibiting a special predisposition. The opinion that follicular degeneration is a preliminary stage to granulations, does not seem to be correct. In the first place, as we have mentioned, true follicular conjunctivitis does not pass into granulations, and, in the second place, we often find that

an acute infectious granular ophthalmia often appears in a previously healthy mucous membrane. The diplococcus found by Sattler and Michel, and regarded as the cause of trachoma infection, and the inoculation of which upon the human conjunctiva gave rise to the development of follicles, cannot serve as a proof of the similarity of both affections, especially as later experiments have shown me that the bacterium described by Michel is absent in a number of trachoma cases. In order to demonstrate the pathogenic properties of the so-called trachoma diplococcus, we require further inoculations in which sufficiently frequent inoculations from cultures completely excludes the transmission of particles of the original material, and, on the other hand, the production of a true trachomatous inflammation. Simple enlargement of the follicles is found after other irritants, even after continued instillation of atropine.

I. *Conjunctivitis Blennorrhoica.*

As we have already said, the folds and papillæ of the mucous membrane form the anatomical substratum of blennorrhœa. But unevenness of the mucous membrane from their hypertrophy, does not occur at the beginning of an acute blennorrhœa. It is only after a certain lapse of time that the fornix is enlarged by the new-formation of parallel folds, the conjunctival tissue increases in amount. Closely aggregated, red prominences, of a tolerably uniform height and about as large as a pin's head, then appear upon these reddened folds or upon the smooth mucous membrane of the tarsal portion. The longer the process lasts, the more rough and swollen the mucous membrane becomes. If the disease is cured the swelling and folds disappear. The latter disappear partly as the result of adhesion. In the fully developed stage of the disease we often find several rows of parallel folds in the fornix. Somewhat later, the number of folds diminishes, the individual ones have become broader. If the lid is everted and drawn down somewhat forcibly, we can sometimes succeed in tearing a broad fold into two narrower ones. In the more chronic cases, the papillæ gradually grow pale, become smoother from mutual pressure and finally disappear. A few of the masses of papillæ may continue to grow, although this is extremely rare in simple blennorrhœa, and finally form cock's comb and warty prominences (Stellwag's papillary trachoma). A few yellowish granules (follicles) are occasionally found scattered among the papillary proliferations.

Acute Blennorrhœa.—The first and most striking symptom is the great swelling of the integument of the lids. The œdematous

and reddened upper lid hangs down over the eye, and the latter is opened with difficulty. The palpebral conjunctiva and the fornix are strongly injected and swollen. The ocular conjunctiva is also congested. At the start, we can clearly see the injection of the subconjunctival vessels around the cornea; but, when the inflammation increases, this is soon concealed by serous exudation into the flaccid conjunctival tissue. The chemosis then forms an annular wall around the cornea, often extending beyond the periphery of the latter.

The secretion changes its character in the different stages of the inflammation. At the beginning the eye swims in tears, which are frothy as in catarrh. But the secretion soon becomes more opaque and whey-like, and is more abundant than in catarrh. After the disease has lasted two or three days, larger numbers of mucous and pus cells are formed and make the secretion thicker. On opening the eye, careful cleansing is necessary in order to permit distinct recognition of the parts, because the secretion overflows the conjunctiva and globe and adheres to them. Later, the secretion is converted, gradually or abruptly, into a yellowish, even pus-like fluid (pyorrhœa).

The local temperature is always increased in pronounced blennorrhœa; fever is rarely present, only in the most intense forms of inflammations and in very sensitive individuals. The first subjective symptoms are similar to those of catarrh: burning, the sensation of a foreign body in the eye, etc. But, as a rule, violent pains soon appear in the eye and forehead; they diminish when the discharge becomes more abundant.

Acute blennorrhœa is one of the most severe diseases of the eye. In especially favorable cases it may recover in three or four weeks. The œdema of the lids first disappears, then the serous swelling and injection of the conjunctiva are gradually lost, the secretion subsides, and the papillæ of the mucous membrane return to their former size. But such a rapid course is comparatively rare; complications are very frequent and require a long time for recovery. Chronic blennorrhœa may also develop from an acute attack.

Chronic blennorrhœa may also follow chronic inflammations of the conjunctiva or lids. The inflammatory symptoms are by no means as violent as in the acute form. There is no œdema of the lids, and the ocular conjunctiva is usually not strongly injected. On the other hand, the palpebral conjunctiva and fornix are reddened and their papillæ often appear more hypertrophied than in the acute form. The secretion is usually more abundant than in ordinary catarrh, has a more yellowish color, and occasionally a pus-

like appearance. Chronic blennorrhœa, like the acute form, has a great tendency to cause corneal affections, although not in such a severe form.

Complications.—It is particularly the affection of the cornea which involves such great danger to the eye in blennorrhœic conjunctivitis. If the chemosis of acute blennorrhœa lasts for some time, a nutritive disturbance of the cornea sets in, manifested at first by a slight, translucent, diffuse, grayish opacity of the entire membrane. So long as it remains in this state, the condition is not serious, and the opacity disappears with the resolution of the blennorrhœic process. A more serious matter is the formation of a circumscribed gray infiltration of the cornea. At the end of a few hours or days, this usually assumes a dirty yellow color, breaks down and forms a true corneal ulcer; the more it spreads and the deeper it extends into the substance, the greater is the danger. If the ulcer has a tendency to recovery, a light gray ring forms in its vicinity and vessels extend to it from the edge of the cornea; a yellowish, cheesy ring, on the contrary, is evidence of further degeneration.

The corneal affection may also appear in another, and especially dangerous form. We notice a slightly grayish, circumscribed opacity of the tissue, which is somewhat elevated above the transparent surroundings. Then the epithelium is exfoliated and the formerly elevated grayish patch is converted into a transparent ulcer. The transparency of the ulcer may persist despite its great extension. As the patient sees to a corresponding extent, the danger to which the eye is exposed is sometimes not noticed. In addition the thin base of the ulcer is pushed somewhat forward, by the pressure of the fluid in the chamber, and is thus situated almost at the same level with the normal edge of the cornea. The accurate diagnosis can only be made, in many cases, by the use of oblique illumination, but the attention of the experienced surgeon will be attracted by unusual transparency of the cornea and the consequent unusual blackness of the pupil. Early and extensive perforation always threatens in such cases. Fortunately these forms occur rarely in simple blennorrhœa; they are more frequent in diphtheritis.

If perforation of the cornea occurs, the anterior chamber is evacuated and the iris or lens is displaced into the base of the ulcer. If the openings of perforation are small, the iris may return to the chamber when the fluid reaccumulates and may be restored to its normal position when the ulcer closes up. This occurs rarely. As a general thing, the prolapsed part unites with the cornea, by a grayish-white cicatricial mass, and forms a leucoma ad-

herens, if the cicatrix is flat and situated in the level of the cornea, or a staphyloma corneæ if it is prominent. In a few cases, the inflammatory process extends to the iris. Even panophthalmitis develops occasionally, and may lead to destruction and shrivelling of the globe. If the lens is displaced into the base of the ulcer, partial opacity usually develops in the capsule and may also extend into the substance of the lens. When the corneal rupture occurs suddenly, and over a large area, and the ocular capsule is subjected to strong pressure from within, there may even follow a rupture of the zonula Zinnii, with secondary escape of the lens and vitreous from the wound in the cornea.

Chronic blennorrhœa, although exceptionally it produces similar corneal affections, gives rise, in the large majority of cases in which the cornea is implicated, only to small infiltrations and ulcerations or to pannus.

Diagnosis.—A very acute blennorrhœa with its great swelling of the integument of the lids, hypersecretion, etc., is not apt to give rise to mistakes. But there are subacute forms which may be interpreted as transitions to catarrh with swelling. Here it must be left to the individual judgment, whether the case should be placed in this or that morbid group. Blennorrhœa is distinguished from acute granulations (trachoma) by the fact, that even in the initial stage of the former, in which the granulations are not yet very distinct, the inflammatory symptoms are much less violent and the secretion is not so profuse. The granulations appear in two or three days and then the diagnosis is assured. After the granulations have lasted for some time, chronic blennorrhœa is not infrequently superadded.

For the differential diagnosis between blennorrhœa and diphtheria, see the section on the latter disease.

I will also mention that considerable œdematous swelling of the integument of the lid, serous effusion into the ocular conjunctiva. and abundant secretion of mucus occur occasionally at the beginning of an acute chalazion, so that the condition may simulate blennorrhœa. The diagnosis is made more difficult when the infiltration of the lid, especially if the chalazion is situated at the angle of the lids, interferes with eversion and a view of the mucous membrane. But in chalazion, a circumscribed hard and infiltrated spot is always found in the vicinity of the edge of the lid. Moreover, the subsequent course soon clears up the diagnosis.

We must also be on our guard against mistaking the disease for erysipelas of the lids, or purulent choroiditis (panophthalmitis). In the latter affection the lids are also reddened and swollen, the secretion is muco-purulent and increased. The great redness, in-

creased tension and prominence of the eyeball itself, as well as the other recognizable symptoms of choroiditis, in combination with the previous history, enable us to make a correct diagnosis forthwith.

Etiology.—The most frequent cause of severe acute blennorrhœa, is the direct transmission of infectious matters to the eye. As subacute and chronic blennorrhœa may develop gradually in conjunction with and from other diseases of the eye, independent of such transmission, the possibility of the genuine development of such severe forms cannot be denied, and so much the less because well-observed cases have made a rheumatic cause probable.

Neisser's gonococci (usually in the form of diplococci, situated on the pus-corpuscles or in mulberry-shaped colonies) are often found in the secretion of acute blennorrhœa. The following factors seem suited to the production of blennorrhœa: 1. The secretions of acute and chronic conjunctival blennorrhœa. According to Piringer, strong dilution with water weakens the infectiousness, and one hundredfold dilution abolishes it entirely. 2. The secretion of diphtheritic conjunctivitis. This may produce blennorrhœa and vice versa the blennorrhœic secretion may produce diphtheria. 3. Gonorrhœa in the male or female. The secretion of a clap of long standing is also infectious when brought in contact with the conjunctiva. 4. Vaginal leucorrhœa, which is an especially frequent cause of blennorrhœa in the new-born. Little girls often suffer from vaginal leucorrhœa and may thus inoculate themselves with blennorrhœa. According to the investigations of E. Fraenkel, a coccus very similar to, but still different from, Neisser's diplococcus is found in this colpitis of children. The same micrococcus subflavus has also been found in the lochial discharge (Bumm). In making examinations of the blennorrhœic secretion of the eye, it is therefore well not to diagnosticate gonorrhœal infection from the microscopical discovery of diplococci.

Finally, it is not improbable from our experience that the secretion of granular ophthalmia may occasionally produce subacute blennorrhœa in the infected eye.

Treatment.—In the way of prophylaxis, we should endeavor to prevent infection as much as possible. The attention of patients with clap and leucorrhœic individuals, must be called to the danger to which they are exposed from conveying the secretion to the eye. Special attention must be paid to the underclothing and towels. I have seen cases in which the infection, in patients with clap, probably was conveyed through the medium of the eyeglasses, which, in bending over, came in contact with the urethral secretion. Likewise in the treatment of blennorrhœa itself, we must

exercise the greatest caution in order to avoid infecting healthy individuals, or those suffering from other diseases of the eye. Individuals suffering from acute blennorrhœa should be kept in a separate hospital ward. If, despite this, we suspect that infection has occurred in another, we may attempt to destroy the virus by instillation and washing with aqua chlorata. If only one eye is attacked, the other must be guarded against infection by a protective dressing. A pledget of borated lint is placed on the eye, and upon this salicylated cotton. When the excavation is completely filled, a large piece of linen, of suitable shape, is laid upon the charpie and made to adhere to the forehead, cheek, and ridge of the nose by smearing its edges and the adjacent skin thickly with collodion. The remainder of the surface of the linen is also brushed in order to prevent, by means of the water-proof layer of collodion, the escape of infecting secretion. Instead of the collodion and linen, we may use a large piece of yellow adhesive plaster; this is applied more easily, but adheres less firmly. The dressing must be renewed every twenty-four hours in order that the physician may convince himself of the condition of the covered eye. Hyperæmia or slight catarrh of the conjunctiva occasionally develops under the dressing; this furnishes no contra-indication to the protective dressing. The latter is to be discontinued only when blennorrhœa really begins. An accurately closing, egg-shaped cup, made of glass, and firmly fixed in leather or adhesive plaster which is placed over the healthy eye, has also been employed as a protective dressing (Snellen). This allows the patient the use of his eye. In acute blennorrhœa the patient should be kept in bed. The main requisite is frequent cleansing of the eye and removal of the secretion accumulated between the lids. For this purpose we use salicylated cotton dipped in a solution of boracic acid. After separating the lids, the moist cotton is squeezed out over the eye at some height, and the overflowing water removes the more consistent particles. The irrigation recommended for this purpose is apt to cause injury in deep-seated affections of the cornea. In the more malignant forms, the cleansing must be carried out every half-hour, even during the night. Ice-cold compresses are applied during the intervals. It must be insisted upon that the compresses are really cold. In the initial stage almost constant refrigeration is necessary, but short intervals of rest may be allowed, say one-half to one hour interval after two hours' constant application. The free instillation of fresh aqua chlori every two hours, as a mild but strongly antiseptic agent, is also advisable in the first stage. The lids should be dried occasionally with soft linen; in order to prevent eczema, which is apt to result from the moisture, they may

be smeared with oleum amygdalæ dulcis. If the inflammation diminishes in a few days, and the swelling subsides, we may allow longer intervals of rest, for example, one hour compresses and one hour interval. Still later the compresses are only needed for one-half to one hour, two to four times a day, always immediately after the application of the topical remedies. In vigorous adults, four to six leeches may be applied to the temples at the beginning of the disease, and repeated if necessary. If the tension of the lids is very great and they are applied firmly to the globe, the pressure, to which the conjunctiva and globe are subjected by the lids and the orbicularis, may be diminished considerably by enlargement of the outer commissure, and at the same time the requisite bleeding secured. The incision is made horizontally in the outer angle of the lids, extending about six millimetres to the outside through the skin, muscles, and fascia. This divides a small arterial branch which gives a tolerably profuse hemorrhage, especially in children. Pressure of the lids between the fingers or stroking (massage, if we wish to use the term) often causes a striking diminution of the œdema and swelling of the lids, so that patients who were previously unable to open their eyes spontaneously, can do so immediately afterward. This is of great benefit because more rapid circulation of blood sets in and the venous stasis is relieved.

Atropine is instilled two to three times a day, in order to relieve the hyperæmia of the iris which is usually present. Among other local remedies, nitrate of silver plays a principal part in blennorrhœa. But this is often abused by cauterizing too early and intensely—a practice which may result in great increase of the inflammation and even in diphtheria. We must wait until the lids have lost their firm tension, the mucous membrane exhibits pronounced papillary proliferation and has become soft and succulent, and a muco-purulent secretion has set in. In severe, acute blennorrhœa, this occurs on about the third or fourth day. Earlier touching, as is done in order to abort the disease, is injurious. I even think it is better, at this time, to use instead of the nitrate of silver, a one and one-half per cent solution of acetate of lead for one to two days in order to see how this plan is tolerated; if suitable, this milder astringent may be applied morning and evening. But if the secretion and swelling of the mucous membrane increase, the two-per-cent solution of nitrate of silver is indicated. If this proves insufficient after a few days, if purulent fluid is constantly secreted and the mucous membrane is greatly swollen, we resort to the mitigated stick with subsequent neutralization. It is very important to reach the entire swollen mucous membrane of the lids with the remedy; we must therefore evert the lid thoroughly

and, if necessary, the non-everted lid must be drawn away by an assistant.

[The caution of the author in the use of nitrate of silver too early in this disease, cannot be too strongly urged. I usually use only alum as an astringent, and this when the great swelling has subsided.—St. J. R.]

As a rule, one application daily is sufficient. The cauterization should not be repeated if an extensive scurf is still present or if, after its exfoliation, the epithelium is not completely regenerated. This is recognized by the less smooth appearance of the corresponding part of the conjunctiva and the readiness with which it bleeds. At all events, such a part should not be cauterized again. When there is marked hyperæmia and swelling, useful diminution of tension and hemorrhage may be produced, after cauterization, by superficial small incisions with the scarificator (Fig. 136). Even when corneal affections have developed, the cauterization must be continued in order to confine the blennorrhagic process, but neutralization must be performed so much more carefully. As a general thing, the ocular conjunctiva should not be cauterized. If considerable œdematous infiltration (chemosis) appears, small incisions are made with the scissors radially toward the cornea and the fluid thus allowed to escape. Simple antiseptic treatment (with solutions of corrosive sublimate, etc.) is decidedly inferior to cauterization in severe cases of blennorrhœa.



FIG. 136. Scarificator. Desmarres.

Instead of direct cauterization, some employ instillations of eye washes in stronger solution (for example, nitrate of silver). This is more convenient for the physician, but in this way we also cauterize the cornea and may induce deeper corneal affections by destroying the epithelium. Weaker eye washes are useless.

In milder blennorrhœas and in the retrogressive stage we use, in addition to cold compresses, washes of nitrate of silver, sulphate of zinc, tannin, etc., but when there is marked swelling and secretion, the diseased mucous membrane must be touched directly. If corneal affections develop, they must be suitably treated (vide Diseases of the Cornea). If a corneal ulcer threatens to rupture, this may be prevented by early paracentesis. In extensive ulceration, the unfolding of the iris by eserine often secures a desirable protective wall against the entrance of the lens and vitreous. If the displaced lens enters the opening of the ulcer, it is allowed to escape, after tearing the capsule of the lens, in order to prevent internal inflammations of the eye which are otherwise apt to occur. When ectropion of the lid develops during the treatment of acute blen-

norrhœa, we must attempt permanent restoration. This is best done by applying a compress and bandage, after reposition, and allowing it to remain twelve to twenty-four hours. Reposition is very important as regards treatment because, for example, cold compresses are not well borne by the everted and exposed mucous membrane.

Chronic blennorrhœa, when there is great proliferation of the mucous membrane and profuse secretion, is best treated by daily touching of the conjunctiva with solution of nitrate of silver, lead or tannin, according to the severity of the case, and by cold compresses. Sticks of alum and sulphate of copper are often useful. If the application of nitrate of silver is continued too long, a grayish-black color (argyrosis of the conjunctiva) may result from the absorption of silver by the tissues. For this reason the applications should be changed. Moreover, the mucous membrane becomes accustomed in a little while to the topical remedies and better results are then obtained from others. Great benefit is also derived, in chronic blennorrhœa, from the astringent eye washes and salves, especially as they possess the advantage that the patient may use them at home without the aid of the physician. Nitrate of silver, acetate of lead, sulphate of zinc, etc., are used as washes, sulphate of copper and acetate of lead (about two per cent) as salves. Lead should be used only when corneal ulcerations are absent, because a precipitate may form in the ulcer. A very useful preparation, especially when pannus is also present, is the modified Guthrie ointment (Argent. nitrat. fus., 0.4; plumb. acet., gtt. iv.; ung. vaselin., 8.0). A piece as large as a hempseed to be smeared into the eye every day.

Ophthalmia Gonorrhoica.

This term is applied, as a rule, to the acute conjunctivitis blennorrhoica which occurs as the result of the transmission of gonorrhœal secretion to the conjunctiva. Such direct transmission is by far the most frequent cause of ophthalmia gonorrhoica. Ricord and Roosbroek have also described a consensual blennorrhœa in clap cases, which always runs a very mild course and is usually associated with articular affections. Thus, in Roosbroek's case the patient suffered, in six years, from five attacks of blennorrhœa of both eyes, together with clap and joint affections. I have also seen, in conjunction with gonorrhœal rheumatism, several cases of bilateral conjunctivitis, running the course of a very mild blennorrhœa or a catarrh with swelling. One of these patients was attacked some time afterward by a mild iritis. Haltenhoff has recently col-

lected a number of such cases. The ophthalmia gonorrhoica resulting from direct infection manifests itself like an extremely acute blennorrhœa; not infrequently it appears as diphtheritis with a great tendency to corneal affections. As we have mentioned, simple iritis also occurs occasionally as the result of gonorrhœa, especially when gonorrhœal rheumatism is also present.

Ophthalmia Neonatorum.

Under this term are included various affections of the conjunctiva in the newborn: hyperæmia, catarrhal conjunctivitis, blennorrhœa conjunctivæ, keratomalacia, and diphtheria (extremely rare at this period of life). The frequency of these diseases in the newborn—slight secretion of the conjunctiva with swelling of the lower lid is extremely common in the first days of life—is explained in part by the unusual light stimulus, changes of temperature, uncleanliness, etc. Blennorrhœas proper are usually attributable to the transmission of infecting secretion, but they are not always due to gonorrhœal virus. Thus among ninety-two cases of blennorrhœa neonatorum Kroner failed, in twenty-nine cases, to find Neisser's gonococcus. It seems plausible, that the non-gonorrhœal secretion of simple leucorrhœa or the lochia may also give rise to blennorrhœa neonatorum (as in Bockhardt's experiments urethritis was produced by non-gonorrhœal vaginal secretion), particularly as, in the newborn, there is a special tendency of the conjunctiva and palpebral integument to hyperæmias and conditions of swelling. However, a few attempts at inoculation with lochial secretion have been attended with negative results (Zweifel-Sattler). The fact that blennorrhœa sometimes runs a milder, sometimes a more severe course also testifies in favor of a difference in the infectious matters.

The prophylaxis is of special importance. In addition to irrigation of the vagina of leucorrhœic women with antiseptic solutions before and during delivery (Haussmann), the lids of the newborn should be carefully washed immediately after birth, if possible before the bandage is applied. Credé, in his Maternity Hospital, has extended the prophylaxis to all the newborn. In addition to cleansing the lids, he instils a drop of two-per-cent solution of nitrate of silver into the conjunctival sac for direct disinfection. It is true that this is sometimes followed by slight irritation, but it has been attended with the best results in many lying-in institutions. I would recommend the use of aqua chlorata as less irritating and, at least, equally disinfectant. The greatest cleanliness as regards the sponges and water must also be observed later in washing and bathing the child.

Ophthalmia neonatorum usually develops on the third to the eighth day after birth. If the blennorrhœa has resulted from gonorrhœal virus, the affection is always serious, but decidedly less grave thna the similar disease in adults.

The treatment naturally depends upon the character of the affection. In simple hyperæmias and catarrhs, frequent cleansing, cold compresses, and astringent washes will suffice. In blennorrhœa we require more intense application of cold and cauterization with a solution of nitrate of silver, or the mitigated stick. As a rule, the process heals under suitable and early treatment, without destruction of the cornea. Circumscribed perforations may occur, but extensive leucomas and staphylomas, which furnish such a large percentage of blindness after ophthalmia neonatorum, are almost always the result of too late or improper treatment. But we must distinguish the keratomalacia of cachectic newborn from blennorrhœa neonatorum. In the former the cornea softens, exfoliates, and is hopelessly lost; the coexisting, comparatively slight, mucopurulent secretion and conjunctivitis without swelling of the lids may occasionally cause confusion with blennorrhœa. These children usually die in a short time. In the examination and treatment of blennorrhœic children, the physician will do well to wear protective spectacles because the secretion often spirts out like a fountain on forcible separation of the lids.

[I must venture, in spite of the high authority of the author, to advise against the use of nitrate of silver in any form, in any of the earlier periods of this disease.—St. J. R.]

Membranous Conjunctivitis.

In certain blennorrhœas, especially in younger children, the palpebral conjunctiva is covered with a croupous membrane, which can be removed from the underlying mucous membrane. Occasionally, however, a little piece may be more firmly adherent, so that it cannot be removed. The affection is usually distinguished from true diphtheria of the conjunctiva, by the greater thinness of the membranes and by the fact that the latter can be removed. This is not true, at least to this extent, in diphtheria, in which they are imbedded in the tissue of the mucous membrane itself. The disease occurs often in scrofulous children; it may follow the secondary catarrh with swelling of a phlyctænular ophthalmia or eruptions on the lids. On the whole, the prognosis of membranous conjunctivitis is favorable, inasmuch as the cornea is attacked with comparative rarity. The treatment consists in removal of the membranes, which sometimes extend even to the scleral conjunc-

tiva and in touching the exposed mucous membrane with astringents (tannin, lead, or nitrate of silver). In addition, cold compresses with weak solutions of boracic acid.

II. *Catarrh with Swelling* (*Epidemic Catarrh*).

This occurs in the form of acute conjunctival catarrh, but is distinguished from the latter by the fact that it exhibits much greater swelling, infiltration, and hyperæmia of the fornices. The muco-purulent secretion is also more abundant. Catarrh with swelling forms, in a measure, a transition between simple conjunctivitis and blennorrhœa. It sometimes occurs primarily in smaller epidemics; its secretion is infectious. It is particularly apt to occur secondarily after scrofulous diseases of the eye, for example, phlyctænula or purulent infiltration of the cornea, so that Klein has described it as "blennorrhœa scrophulosa." Its course is like that of acute catarrh, but it is usually much more protracted. In primary catarrh with swelling, the treatment must first be derivative and antiphlogistic: laxatives, cold compresses with water or weak solution of boracic acid, one-half to one hour, several times a day. Aqua chlori may be instilled with benefit at an early period; excellent service is rendered not infrequently by the application of a solution of tannin. If the inflammatory phenomena have disappeared, the disease must be treated, like catarrhal conjunctivitis, with astringents, best by direct application to the fornix. This is also indicated in secondary catarrh with swelling.

Exanthematous Ophthalmia.

Measles, scarlatina, facial erysipelas, and variola are usually associated, during the period of eruption and acme, with affections of the conjunctiva, which may appear as pure hyperæmia or catarrh. It is only in rare cases, when the eruption is situated directly on the lids, that the inflammation is intensified into catarrh with swelling. The latter, associated with circumscribed infiltration of the cornea, is especially frequent in the scrofulous diathesis. Notable photophobia is characteristic even of the mildest forms. But if such inflammations of the eye appear in the stage of desquamation, they are much more dangerous and give rise to pronounced catarrh with swelling, even to slight blennorrhœas and corneal affections. Abscesses like variolous pustules are found in the cornea, especially in variola, and not infrequently lead to perforation. Severe purulent corneal processes may appear with conjunctival affections, even after measles and scarlatina. Moreover, a tendency

to relapsing eye affections dates back not infrequently to the period of the exanthematic disease.

In the simple hyperæmias and catarrhs, it is usually sufficient to protect the eyes against bright light by moderate darkening of the room. But it is well to permit so much light to enter, that the children will be induced to keep their eyes open in playing with toys. The eyes should be washed frequently with lukewarm water. In more marked conjunctivitis, compresses of cold water may be applied two or three times a day, the sensitive skin being protected by pieces of linen which are moistened with almond oil and placed on the lids. In addition, astringents may be used, according to the form and severity of the disease.

III. *Conjunctivitis Granulosa s. Trachoma.*

The granulations may appear with severe inflammation of the conjunctiva (acute granulations) or in a chronic form without special inflammatory phenomena. Acute conjunctivitis, even the development of phlyctænulæ, not infrequently complicates chronic granulations from time to time.

1. *Acute Granulations.*—The development of granulations occurs with the symptoms of an intense conjunctival catarrh. The conjunctiva is very red, but the swelling is only moderate. In addition, there is increased secretion of tears, which are mixed with very scanty flakes of mucus.

Unlike simple catarrh, pericorneal injection is almost always present. But this may soon disappear and is never so extensive and deep as in diseases of the cornea, iris, etc. The granulations are situated, at first, upon the palpebral conjunctiva, especially near the fornix and the outer angle of the eye. They appear as whitish-yellow, somewhat translucent prominences, from the size of a pin's head to that of a millet seed. It is particularly upon the reddened tarsal mucous membrane of the upper lid that we find, in addition, deep gray or yellowish patches, as large as a pin's head, that are situated almost entirely on the level (crude granulations). In a few days the granulations enlarge and become less transparent. The transition folds are now involved to a greater extent. Moderate swelling of the conjunctival folds and papillæ soon follows.

In eight to ten days, the granulations are usually lost to sight on account of the redness and swelling of the mucous membrane and papillæ, their yellowish-white color and hemispherical or oval shape not shining through so distinctly. The affection may now present symptoms similar to those of secondary blennorrhœa. But the round shape of the elevation still enables us to recognize the

original disease, especially as transparent granulations are still found here and there. The subjective symptoms are those of an acute catarrh.

This condition may last for weeks, until finally the mucous membrane returns to the normal after absorption of the granulations. In other cases the swelling of the mucous membrane and papillæ becomes chronic or it disappears and leaves only the granulations behind, as coarse, sago-like grains.

The cornea is very little endangered in the acute affections; small ulcerations or abscesses at the edge, in rare cases an opacity traversed by vessels (pannus) may develop secondarily.

2. *Chronic Granulations.*—The chronic granulations either remain after the cessation of an acute granulation process or they appear from the start without special inflammatory symptoms as grayish-yellow, slightly translucent granules, about as large as a millet-seed. At first they often appear as small points in the mucous membrane and are gradually elevated above it in the shape of a hemisphere. Their principal site is the palpebral conjunctiva near the fornix, especially in the region of the outer angle. Later they may extend over the entire conjunctival sac and then grow to a larger size, particularly in the fornix. True granulations may appear even upon the bulbar conjunctiva.

The diagnostic differences between granulations and follicular conjunctivitis will be considered in discussing the latter affection.

Chronic granulations are always associated with very notable changes in the condition of the remainder of the mucous membrane. The vascular injection is usually increased, the mucous membrane exhibits more or less swelling of the papillæ. The papillæ may be so small—as large as a pin's head—that they give the membrane the appearance of stroked velvet, or they may proliferate into small warts.

On account of the pronounced, palisade-like, reddish hypertrophies of the papillæ we must sometimes look very closely in order not to overlook the small yellowish granulations. Stellwag describes this form as mixed trachoma, while he discusses pure granulations (trachoma) as "pure granular trachoma." This so-called "pure papillary trachoma" is better regarded as chronic blennorrhœa, because the papillæ alone form the substratum of the morbid process.

In later stages, usually after cicatrization has developed, there is a more diffuse coalescence of the granulations. The mucous membrane, especially at the orbital rim of the tarsal conjunctiva, is then infiltrated with a grayish, opaque mass, which is no longer divisible into separate granules (gelatinous trachoma).

The ocular conjunctiva is occasionally injected. Indeed, a certain tendency to congestive conditions is rarely absent; it follows every slight irritation, on waking from sleep, even after emotional excitement. But there are many cases in which chronic granulations have lasted for a long time without their knowledge, because they attach no importance to the slight subjective and hardly visible objective symptoms.

The secretion varies extremely in chronic granulations. In simple deposits, which are small in number, secretion may be almost entirely absent or there is merely increased flow of tears, usually mixed with small flakes of opaque mucus. But the more the papillæ are affected secondarily by the process, the greater may be the similarity to blennorrhœic secretion.

At first the subjective symptoms are often trifling. On account of the increased irritability of the eyes, tobacco smoke, strong winds, dust, etc., are not well tolerated by the patient. The eyes lose their power of endurance in a bright light, especially in artificial light.

Course.—Chronic granulations may last months and years. Their spontaneous recovery is rare. With persistent and suitable treatment complete absorption may be effected so that after years hardly a trace of the former disease remains. But there usually remains a peculiar diffuse, somewhat bluish-white color of the otherwise intact mucous membrane, which leads the expert to a diagnosis of the former condition.

Extensive conjunctival retraction occurs in neglected cases. The cicatrices are situated, as tendinous, milky-white streaks, in the palpebral conjunctiva, especially in the upper lid. The fornix is also traversed by vertical tendinous folds; a few granulations or papillary proliferations are often situated between the cicatrices (cicatricial trachoma). If the retraction is very extensive, the entire fornix may be obliterated, the palpebral conjunctiva passing directly into the bulbar conjunctiva (symblepharon posticus). A still higher grade involves the scleral conjunctiva in the process and causes it to disappear. The conjunctiva of the edge of the lid then appears to be united to the rim of the cornea (symblepharon anterius). The lids can no longer be closed, and lagophthalmus develops. Such changes in the mucous membrane naturally diminish the moisture of the eye, and the parts become dry. The epithelium, where still present, is no longer removed by the insufficient fluid and carried off, and appears rough and dry (xerophthalmus). The cicatricial and retraction processes in the conjunctiva also lead to changes in the position of the lashes (trichiasis and distichiasis). Entropion develops not infrequently, especially in

the upper lid. The bowl-shaped appearance of the lid, visible externally, indicates the retraction of the mucous membrane. Narrowing of the palpebral fissure (blepharophimosis) is frequent. The lid may also be turned outward, though more rarely, by softening and changes of shape of the tarsal cartilage, when this takes part in the inflammatory process, and by hypertrophy of the mucous membrane. This also causes eversion of the lachrymal points, particularly in the lower lid. As a result the tears no longer pass into the nose in the normal way, and run down the cheek (epiphora).

The cornea is affected in various ways: by small epithelial losses, ulcerations, infiltrations, but particularly by pannus. The pannus, usually beginning in the upper half of the cornea, develops from the formation of true granulations in the cornea or from the mechanical friction of granulations and obliquely placed lashes against the cornea, giving rise to small losses of substance and infiltrations. After attaining a certain intensity, it is with difficulty made to absorb; even when this succeeds, there is a tendency to relapses. But with perseverance we can often obtain surprising results as regards vision. It is only deep-seated, intense opacities which are incapable of sufficient clearing up. The frequent irregular curvature of the cornea (kerectasia, etc.) is equally disturbing as regards vision.

Etiology.—The granulations develop from the direct transmission of infectious secretion, usually from other granulations. The more transmission is favored by many people living together (barracks, orphan asylums, etc.), by uncleanliness (use of the same towels, etc.), or mutual contact (as in sleeping together), the more frequent is the disease. Epidemics or endemics may thus develop. It is doubtful whether granular ophthalmia may develop without direct contagion. But a few cases, in which infection seemed to me to be absolutely excluded, and others in which the development of granulations is observed occasionally after long-standing conjunctival processes, seem to favor this opinion. Trachoma is extremely rare in children below the age of two years.

The *prognosis* is so much more favorable, the earlier proper treatment is adopted. If the process has not advanced too far, if pronounced cicatricial changes or deep corneal affections are absent, a cure may often be obtained by treatment, which must be protracted and careful, often continued for years.

Treatment.—At the beginning of acute granulations, cold compresses with weak solutions of lead or boracic acid should be applied. Smearing the integument of the lid with acetate of lead or nitrate of silver in solution, is used to advantage in marked swelling of the lids. At the same time absolute rest of the eye and protection

against bright light are to be recommended. As soon as the papillary proliferation increases, we make instillations of aqua chlori and then pass to stronger astringents. A certain amount of judgment must here be exercised, because a certain degree of inflammation and swelling of the conjunctiva must be allowed to remain, in order to cause absorption of the granulations and prevent their chronicity. Indications are thus presented, according to the condition of irritation, for the use of feeble astringents (tannin, alum, sulphate of zinc, acetate of lead) up to solutions of nitrate of silver. But the latter is to be employed only in pronounced secondary blennorrhœa.

The corneal affections are to be combated with sulphate of atropine, or in obstinate cases according to the rules which will be given later under diseases of the cornea.

If the granulations have passed into the chronic stage or they have developed as such without passing through an inflammatory stage, the treatment must be directed toward securing the most rapid absorption possible, because the formation of cicatrices is then least. Direct destruction, which also seems advisable in certain cases, must be considered as of minor importance, on account of the consequent diminution in the area of the surface and the formation of cicatrices.

Experience teaches that absorption takes place best in a certain condition of conjunctival injection and swelling. The important feature is to maintain this necessary degree of inflammation: to excite it when absent, to diminish it when too violent. Upon this depends the selection of topical remedies. If the granulations are situated in a mucous membrane which is only slightly hyperæmic and without notable papillary proliferation, we attempt to stimulate the inflammation somewhat by touching it daily with a crystal of sulphate of copper, the instillation of copper-glycerin (1 : 20) or copper ointment. Immediately after touching with the copper the pain is usually quite severe. We may then apply cool compresses of water for one-quarter to one-half hour, or, if necessary, instill cocaine. The cauterization should not be repeated until the irritative condition produced has subsided; one application daily is usually sufficient.

If the granulations are attended by an excessive irritative condition, if the papillæ are markedly hypertrophied, in short if the condition assumes more of the character of a blennorrhœa, the treatment must be similar to that of acute granulations or chronic blennorrhœa. After eversion of the lids the mucous membrane, especially the fornix, is touched daily with the above-mentioned astringents or corresponding solutions are given for instillation. The copper crystal also acts favorably when there are thick fleshy

papillary proliferations. Squeezing of the individual granulations between the finger nails is occasionally useful.

If cicatrices are found between the individual papillary hypertrophies, the application, as a matter of course, should be made only to the latter. The remedies employed must be changed from time to time.

In very obstinate cases, the granulations may be destroyed directly, by perforation or cauterization with the galvano-cautery (Korn) or by excision. Formerly only the repeated excision of individual granulations was employed (Pilz), but recently the entire fornix (Galezowski) or at least large pieces of the mucous membrane (infiltrated with granulations) and the subjacent diseased tarsus, one and one-half centimetres long and one centimetre wide, have been excised at one sitting. The wound is closed with sutures and an ice-bag applied two to four days to the eye, which is kept closed by a moist compress and bandage (Heisroth in Jacobson's clinic). Such vigorous antiphlogosis is not required after the excision of somewhat smaller pieces, and good curative effects are also obtained.

The complication of granulations with pannus requires no deviation from the ordinary mode of treatment; it usually subsides with the disappearance of the granulations. If not, it must be treated separately (vide Pannous Keratitis).

Recently a remedy which has long been used in Brazil for granulations, viz., jequirity has been adopted by us, especially on Wecker's recommendation. A two or three per cent maceration of the decorticated and powdered grains of Abrus precatorius, which is best prepared fresh by three hours' steeping in cold water, is employed. When it becomes too old (more than four or five weeks), it loses its action if it has been prepared without the addition of carbolic acid (one per cent) or salicylic acid. If the everted granular mucous membrane is thoroughly brushed with such a solution several times inside of a quarter of an hour, a characteristic conjunctival inflammation usually begins in a few hours. The integument of the lid swells and becomes tense, red and extremely hard, the conjunctiva shows a croupous deposit on the next day, and a watery, whey-like secretion flows abundantly from the eye. Severe pains and insomnia set in when the inflammation is more violent. The period of irritation with new formation of a croupous deposit and secretion of a muco-purulent discharge continues several days, then the swelling gradually subsides. The integument of the cheek often swells, and even gangrene has been observed (Vossius). A single application is not always sufficient and it must then be repeated on the following day; if necessary, compresses of the solution must be

applied for ten minutes. Some eyes exhibit very little tendency to violent reaction, and the acute symptoms are especially apt to be absent in cicatricial trachoma.

The action of the jequirity infusion was first attributed by Sattler to the numerous bacilli, which, according to him, it contains after standing for some time. But the experiments of v. Hippel who produced the same ophthalmia despite the absence of bacteria (in carbolized solutions) and also other investigations (Neisser, Salomonson) have proven the untenableness of this view. The secretion itself is not infectious, hence transmission to the other eye need not be feared. As the cornea is sometimes attacked, it is best not to employ inoculation of jequirity when the cornea is intact, especially as its good effects are most marked in pannus, whether it occurs in chronic granulations (but without secondary papillary proliferation and blennorrhœal swelling, in which the inoculation is contra-indicated) or in cicatricial trachoma. As a rule, the good effects are obtained only after repeated inoculations, so that, on account of the long period required, it is difficult to arrive at certain results in comparing it with other methods of treatment.

[Jequirity has been very useful in the treatment of inveterate pannus in the Manhattan Eye and Ear Hospital. We use the powder instead of the solution. In our experience, after the subsidence of the membranous inflammation, the cases readily yield to the ordinary remedies in a large proportion of cases, so that reinoculation is not necessary.—St. J. R.]

At all events jequirity-ophthalmia is preferable to the inoculation of gonorrhœal secretion, which has been recommended for the cure of pannus. Its influence upon the absorption of the granulations themselves is slight.

Trichiasis, blepharophimosis, and ectropion usually require operation.

Ophthalmia Militaris (Ægyptica).

Various epidemic diseases of the eyes occurring among soldiers have been grouped together under this name. The first epidemic of this kind, was carefully described by Larrey (1798) in the French army in Egypt. Later, epidemics raged in the French army in Italy, in the English troops, in the Prussian army in 1813, and in recent times in the Belgian army. It is also certain that such epidemics occurred at an earlier period. We find statements concerning them in Aëtius. The spread of these diseases was favored by forced marches, overcrowding, insufficient clothing, etc. Officers, surgeons and orderlies were attacked much less frequently. The

so-called military ophthalmia includes simple catarrhs, epidemic catarrhs, granulations, blennorrhœas, perhaps also diphtheria, as appears from the statement of Juengken, that the eyes are not infrequently lost in twenty-four hours.

IV. *Follicular Conjunctivitis.*

In follicular conjunctivitis are found whitish, pale red or pale yellow, hemispherical or oval, often transparent and vesicle-like granules, which project moderately above the level of the conjunctiva. They are often situated in the outer angle of the eye, and on the whole are quite scanty. As a rule, the upper lid is normal. The development of the follicles may be associated with more or less pronounced conjunctivitis. It is found with special frequency—without notable conjunctivitis—in children at school or in anæmic individuals.

The follicles are often very obstinate, but involve no danger to the eye and, unlike granulations, are not followed by cicatrices. If the follicles develop acutely with conjunctivitis, more rapid recovery usually follows.

In some cases, the etiology is furnished by the life in small, poorly ventilated rooms; in others, the constitution, particularly anæmia and scrofula, appears to exert an influence. In some individuals the follicles appear after long-continued instillations of atropine; I have also observed them after instillations of eserine.

Special attention is merited by the following factors which permit the differential diagnosis from granulations. The follicles are never as numerous as the granulations; they are usually situated, in small numbers, at the outer angle or in the anterior part of the fornix; they hardly ever extend to the anterior part of the tarsal mucous membrane. In the upper lid they are entirely wanting, except that a couple of small follicles are seen occasionally at the orbital rim or in the outer angle of the tarsal mucous membrane. The prominences of follicular conjunctivitis often have a more transparent, vesicular appearance and are about as large as a pin's head; the granulations are, on the average, less transparent and more yellowish, and also usually larger. But even in follicular conjunctivitis, some of the granules are larger and, like granulations, may appear as yellowish, oval structures in the form of a pearl necklace; in the former, however, notable implication of the true conjunctival tissue is always wanting. Even when the follicles are of long standing, the conjunctiva retains its transparent, smooth appearance, while thickening, red irregularities and larger prominences soon develop in granulations. Even in torpid granulations the mucous

membrane assumes a peculiar opaque, occasionally waxy appearance. As soon as cicatrices are visible, follicular conjunctivitis is no longer to be thought of. In the majority of cases the diagnosis between follicular conjunctivitis and granulations can be made with certainty. Nevertheless mistakes are often made. Many a so-called granulation epidemic in a body of troops or a school, disappeared as soon as another physician recognized it as follicular conjunctivitis. Moreover, parents whose children exhibit a couple of follicles in the mucous membrane of the lower lid, are often frightened unnecessarily with the scarecrow of granular ophthalmia.

It is only in individual cases that the diagnosis cannot be made forthwith with certainty. Thus, at the very beginning acute granulations—before the occurrence of proliferation of the mucous membrane—may resemble the development of follicles with acute conjunctivitis, and on the other hand the differentiation from chronic granulations may be difficult when the follicles are numerous and there is unusual hyperæmia and swelling of the conjunctiva. In such cases prolonged observation will decide: in follicular conjunctivitis cicatrices and pannus do not develop.

The local treatment must combat severe conjunctivitis by cool compresses and astringents. If there is no hyperæmia of the conjunctiva, we may congest the conjunctiva occasionally, and thus facilitate the absorption of the follicles, by occasional applications of sulphate of copper (about once a week) or instillation of copper-glycerin. The follicles, which are found in childhood, often disappear spontaneously with increasing years. We must also pay attention to sanitary conditions as regards air and food.

5. Diphtheritic Conjunctivitis.

Diphtheria of the conjunctiva is characterized by the deposit of fibrinous exudation in the tissues. At the very outset of the disease the conjunctiva presents only the signs of catarrh; it is reddened, and the tears and secretion are increased. But a certain stiffness of the lids on palpation and eversion, which soon increases to an almost board-like hardness, points to fibrinous deposits, even before they are visible to the eye. In a short time, usually twelve to twenty-four hours, this is associated with œdema of the integument of the lid, together with lowering of the tense, shining upper lid and chemosis. The imbedded fibrinous masses now appear upon the palpebral conjunctiva as whitish-gray patches in which the normal vessels are entirely absent. Between these patches the mucous membrane is moderately reddened and we can distinguish in it larger vessels which are cut off suddenly at the edge of the deposits.

According to the extent and amount of the diphtheritic patches A. v. Græfe has distinguished three forms which are also important from a prognostic standpoint: 1. Partial diphtheria; a few not very large patches are found imbedded in the palpebral conjunctiva, not infrequently in a triangular form, with the base directed toward the edge of the lid. 2. The disseminated form. Small patches, often only as large as a millet-seed, are scattered through the entire palpebral conjunctiva and partly in the fornix, and give it a marbled appearance, on account of the alternation with the reddened, non-infiltrated portions. 3. The confluent form. Here the separate deposits coalesce into large grayish-white stripes and patches, so that there is very little free mucous membrane. This form also extends to the bulbar conjunctiva. In extensive diphtheria, the edges of the lids and the outer integument are not infrequently attacked. Fibrinous membranes, which can be removed, are often situated on the conjunctiva: beneath them is found the infiltrated conjunctival tissue. Similar false membranes may also occur, as we have mentioned, in membranous blennorrhœa, but here the underlying conjunctival tissue is not infiltrated with fibrinous exudation; moreover the rigidity and hardness of the lids are wanting. But it must be remembered that in some epidemics of diphtheria, the lids remain comparatively soft and can be easily everted. Under the microscope the membrane exhibits an amorphous, more or less granular, streaked mass, to whose surface and edges pus-cells adhere. It contains numerous micrococci. The secretion in diphtheritic conjunctivitis consists of a thin, dirty-colored fluid, in which float a few yellowish flakes. Considerable pain is usually present in this affection, and is often intensified to an intolerable degree on touching lids. In some cases we may even be compelled to resort to chloroform in order to evert the lids. In addition there is often fever; I have observed very high temperatures, particularly in children.

Course.—On the sixth to the twelfth day, occasionally even earlier, diphtheritis passes into blennorrhœa when it runs a favorable course. The rigid lids become softer and more elastic. The deposits gradually disappear, being partly absorbed, partly exfoliated; the conjunctival tissue becomes more congested and succulent.

The increased papillary proliferation appears in the shape of small reddish elevations. The secretion also assumes a muco-purulent, blennorrhœic character. The further course now resembles that of blennorrhœa, but the quickly occurring retraction and the development of extensive cicatricial tissue enable us to infer the previous deep infiltrations. Affections of the cornea are especially dangerous to the eye in diphtheria. They occur in various forms,

sometimes with such rapidity that a normal cornea is converted into a yellowish pulp within twenty-four hours; this ruptures and permits partial escape of the ocular contents. Finally, the eye undergoes atrophy and the cornea remains as a small yellowish disk. In the less violent affections a slightly grayish opacity forms over the entire cornea; at one point this exhibits an ulcer, covered with dirty, yellowish-gray detritus, which spreads rapidly downward and perforates into the anterior chamber. But these perforations close very rapidly in diphtheria, a whitish coherent diphtheritic mass forming upon them like a cap. A third form of secondary corneal affection, is the exfoliation of the epithelium and the individual corneal lamellæ described under the heading of blennorrhœa, and in which the transparency is long retained. The sequelæ (prolapse of the iris, loss of the lens, etc.), described under blennorrhœa, may occur after perforation of the cornea.

The *prognosis* is so much more favorable the later, *i.e.*, the nearer to the blennorrhœic stage, the corneal affection occurs. The worst outlook in this respect is presented by confluent diphtheria, in which the cornea is usually lost very early. Here it is hardly possible to preserve a useful eye. The prognosis is less unfavorable in the disseminated form, and still more favorable in the partial form. But even the mildest form of diphtheria may lead to destruction of the eye.

Differential Diagnosis.—We will here confine ourselves to noting the differences between blennorrhœa and diphtheria, because the other conjunctival diseases, apart from the membranous conjunctivitis already described, can hardly be mistaken for diphtheria. 1. Diphtheria is a general disease. In children pharyngeal and laryngeal diphtheria sometimes follow, but rarely precede it. 2. There is much greater development of heat in the diphtheritic eye. 3. As a rule, in diphtheria there is great rigidity of the lid, which feels like a board and is everted with difficulty, even after the disease has lasted some time; in blennorrhœa the initial rigidity disappears much earlier. 4. The diphtheritic mucous membrane exhibits smooth, yellowish, non-vascular patches, which are imbedded over a larger or smaller surface. In addition, there are reddened patches which are infiltrated with small hemorrhages. In blennorrhœa there is uniform redness, with marked succulent swelling of the conjunctiva, later development of folds with papillary proliferatious. 5. In diphtheria, the tissue is infiltrated deeply (as shown on section) with fibrinous exudation, while in blennor rhœa the mucous membrane is only swollen by fluid and cellular exudation beneath the epithelium. If a membranous deposit is found—this occurs particularly in children—it can be removed or

brushed off in great part. 6. In diphtheria, the circulation of blood is interfered with by the infiltration, and the mucous membrane contains little blood; in blennorrhœa the circulation is relatively free, the mucous membrane traversed by numerous distended vessels. 7. In diphtheria the pain is severe and constant, especially on touching the lids; in blennorrhœa it is milder and often disappears early.

As we have remarked, diphtheria finally passes into a blennorrhœic stage, in which, as a matter of course, the symptoms of both affections coincide.

Etiology.—Conjunctival diphtheria often occurs epidemically. The severest epidemics seem to appear in spring and autumn. The second to fourth years of life are attacked most frequently. The diphtheritic contagion can be conveyed by direct transmission, but, on the other hand, diphtheria may also result from blennorrhœic, gonorrhœal, leucorrhœal infection of the eye. Inflammations of the eye and recent traumatism predispose to this affection, during an existing epidemic of diphtheria. Foul ulcerations of the edges of the lids in scrofulous children, often extend to the conjunctiva and there form diphtheritic infiltrations. Diphtheria is especially frequent in North Germany; in other countries (for example, Austria and England [and in the United States—St. J. R.]) it is very rare.

Treatment.—If only one eye is attacked by the diphtheria, we must attempt to guard the other by a protective dressing. Inasmuch as the affection starts from a general disease, this is less apt to prove successful than in blennorrhœa. Ice compresses are applied to the diseased eye, at first frequently, later with greater intermissions. Some ophthalmologists recommend warm compresses. The eye must be frequently cleansed with a disinfectant solution (for example, corrosive sublimate 1 : 5000). I have often seen benefit from scarifications of the conjunctiva (Jacobson) into the red vascular tissue between the infiltrated patches. I can also recommend the treatment extolled by Wolfing, *i.e.*, vigorous rubbing of yellow precipitate ointment (0.3 to 10 vaseline) with the finger, once or twice a day, directly into the infiltrated part of the everted mucous membrane. Not much may be expected from brushing with lime-water.

Local abstraction of blood from the temples should only be made in vigorous individuals when great pain is experienced. Cauterization of the mucous membrane with nitrate of silver at the height of the disease, is to be deprecated.

It is only when the blennorrhœic stage is well marked, that we may make applications in the manner described under the treatment of blennorrhœa, at first very cautiously, beginning with a lead wash.

Acute mercurialization has also been tried because it appears to exert an influence on the conversion of diphtheria into blennorrhœa (v. Græfe). A. v. Græfe gave adults calomel 0.05 every two hours, night and day, and also inunctions of ung. ciner. 4.0–6.0, rubbed into the arms and thighs, three times a day. Children received 0.01 calomel every two hours and inunctions of ung. cinerit. 1.0 t. i. d. But it is better to avoid the internal administration of calomel, although, as a rule, diphtheria of the eye is not such a serious constitutional disease that we need fear a fatal termination. I have observed this only in rare cases and in very feeble children. Atropine is to be instilled early in order to prevent congestion of the iris. When there are deep, circumscribed corneal ulcers we make paracentesis at the base of the ulcer, and endeavor to maintain the constant discharge of the fluid in the chamber, and thus diminution of intraocular pressure, by constantly removing the diphtheritic valve which closes the opening.

6. Pterygium.

Pterygium is formed by an hypertrophic fold of conjunctiva that extends from the periphery of the globe toward the edge of the cornea and sometimes extends across it. It has a certain similarity to the wing of a fly. We can distinguish in it: 1, the trunk, which is lost peripherally in the conjunctiva, usually in the scleral portion; 2, the neck, which is situated across the edge of the cornea and appears chiefly as a fold; it can be moved to and fro, and the sound sometimes passes two to three millimetres beneath its tilted edges; 3, the head, which is generally situated on the cornea as a white, often tendon-like, rounded patch; it is usually surmounted by a zone due to opacity of the epithelium. The color of the pterygium varies according to the degree of hypertrophy of the tissue and vessels; it may pass from white into a unifom red. In the latter event it is known as pterygium crassum s. carnosum. Pterygium is situated most frequently at the inner side of the bulb, more rarely at the outer, still more rarely at the upper or lower. Its position usually corresponds to the course of the recti muscles. Several pterygia often appear in the same eye.

Microscopical examination shows, in great part, the constitutents of the conjunctiva: connective tissue with scattered elastic fibres, traversed by numerous meridional vessels. An epithelial layer covers not alone the surface of the pterygium, but also the part situated on the cornea.

In the majority of cases there is a kind of tumor formation, consisting of hypertrophy of the conjunctival tissue. Other cases (cicatricial pterygium) start from small ulcerations, their cicatri-

zation involving the adjacent conjunctiva, so that this serves to supply the defect and a small fold is thus produced by traction (Arlt). Small ulcerations, which act in the same way, also form occasionally in the depression between the edge of the cornea and a pinguecula situated in its vicinity (Horner). Furthermore, during a blennorrhœa in which the conjunctiva is raised around the cornea, like an œdematous wall, a part of this chemosis may adhere to a corneal ulcer. It is then found frequently, when the ulcer is somewhat remote from the periphery, that a tubular passage is situated beneath the neck of the pterygium (false pterygium).

The disease is found chiefly in certain occupations which are exposed to slight injuries of the eye by the entrance of dust, etc.; for example, cigar-makers, bricklayers, masons, etc. As its development is favored by increased relaxation of the conjunctiva, old people are especially apt to suffer. It is most frequent in southern climates. [Pterygium is much more common in the Southern and Western States of this country than in the Eastern and middle.—St. J. R.] When the pterygium has formed, it often remains stationary, but further growth may also take place, especially from irritation of the eye. The nearer the head of the pterygium approaches the centre of the cornea, the more the harmful influence of this opaque tissue on vision is made manifest. Pterygia situated just at the edge of the cornea do not interfere very much with vision, but their removal is often desirable for cosmetic purposes.

Treatment.—We must above all endeavor to prevent the development of pterygium by careful treatment of ulcers at the rim of the cornea. If inflammation and injection of the pterygium occur, we may apply astringent solutions and cool compresses.

If vision is threatened by the advance of the process or if its removal is desired, the operation is easily performed, though not always with satisfactory results.

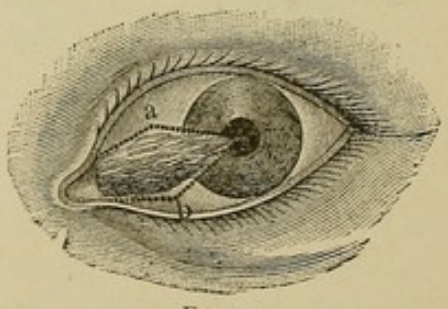


FIG. 137.

The apex, situated on the cornea, is first divided carefully with a cataract knife or lance, and then the neck dissected from the cornea, for two to four millimetres from the edge of the cornea toward the periphery. The diverging edges of the wound, which has been formed in this way, are now united by two converging incisions directed toward the periphery of the bulb, and the intervening pterygium is then removed. The rhomboidal defect is covered by stitching together the edges of the wound in the conjunctiva. A linear cicatrix is thus formed (Fig. 137, in which *a* and *b* are united by sutures). When the ptery-

gium is very large, it is not removed entirely to the periphery, but a part of the base is allowed to remain, in order that the scar may not be too large. Otherwise the retraction of the conjunctiva,

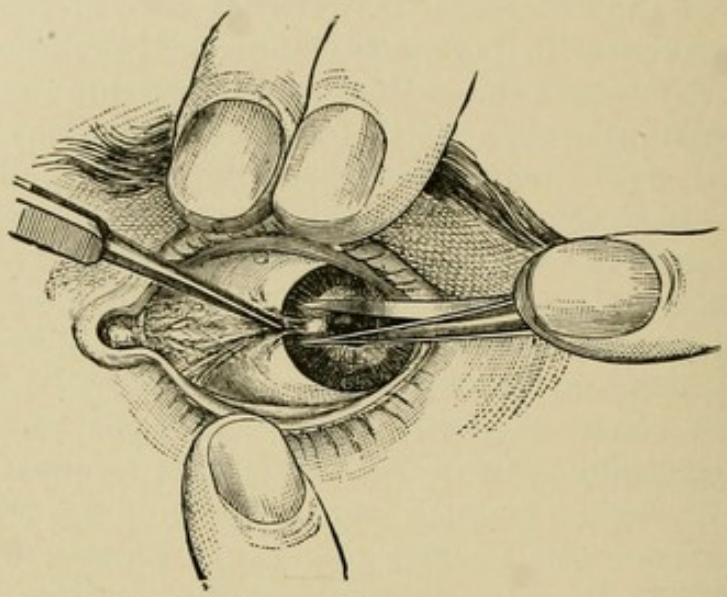


FIG. 138.—Removal of Pterygium. (Stellwag.)

which has been used for covering the wound, may lead in time to interference with mobility, even to complete lateral position of the globe. In order to antagonize this, Desmarres dissects up the pterygium as far as the base, but without dividing the latter; about four millimetres from the edge of the cornea an incision, parallel to the latter, is then made for six to eight millimetres from the lower edge of the wound into the conjunctiva. The apex of the separated pterygium is then stitched into the angle formed by the separation of the edges of this new incision.

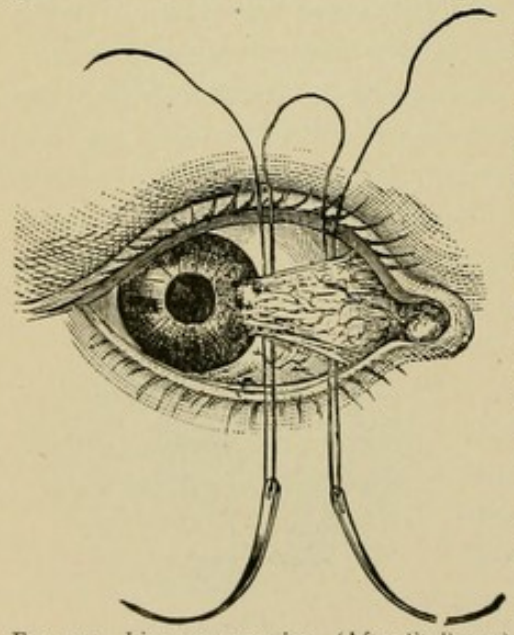


FIG. 139.—Ligation operation. (After Stellwag.)

Knapp makes a similar incision upward through the conjunctiva. The pterygium is then divided by an incision along its length and the upper half is sewed into the upper conjunctival wound, the lower half into the lower wound. The horizontal conjunctival wound, which corresponds to the original site of the pterygium, is closed with sutures.

7. Xerosis Conjunctivæ.

We may distinguish parenchymatous and epithelial xerosis of the conjunctiva.

The former, dependent on parenchymatous changes, leads to more or less extensive dryness of the conjunctiva and cornea, as the result of absence of the normal moisture. It is the result of cicatricial metamorphosis of the conjunctival tissue in separate places or in its entirety. The epithelium becomes firm and dry, its appearance approaches that of epidermis. The complete atrophy and cicatricial retraction of the conjunctiva, subconjunctival tissue, tarsus and secretory organs, leads to the condition known as xerophthalmus squamosus or totalis. Here the fornix and semilunar fold have usually disappeared entirely, the cicatricial tissue, which represents the conjunctiva, passing directly from the tarsus to the sclera. As the excretory ducts of the lachrymal glands are also adherent, the moisture of the eye is thus completely abolished. The eye is covered with fine scales, which are composed of dried epithelium, similar to plates of epidermis, fat, mucus, etc., and give it a dusty appearance. The cornea exhibits a pannous opacity or is covered with opaque, tendon-like epithelium, which interferes more or less with the shining through of the deeper structures of the eye. The sensibility is diminished, the mobility of the lids impaired on account of the disappearance of the conjunctival sac, and closure of the eye is often impossible. The prominent subjective symptoms are: diminished visual power, corresponding to the corneal opacities and a feeling of notable dryness in the eye. Parenchymatous xerophthalmus forms the termination of long-standing inflammations of the conjunctiva, such as those resulting from granulations, blennorrhœic or diphtheritic conjunctivitis, entropion or ectropion; it results more rarely from chemical cauterization. It may occur at any age, and is incurable. The medical problem is its prevention by suitable treatment of the causal disease. We may attempt to relieve the affection symptomatically by moistening the eye with milk, glycerin, almond oil, or weak solutions of the alkaline carbonates or caustic alkalies. Protective spectacles should be worn to keep off dust and wind. The transplantation of the rabbit's mucous membrane has also been tried.

The epithelial form is transitory; it often appears in epidemics, and is usually associated with hemeralopia (Bilot), occasionally even with concentric narrowing of the field of vision (Alf. Græfe, Kuschbert).

The mucous membrane of the globe, over the extent of the palpebral fissure, appears dry, devoid of gloss, and contains small

specks, as if white foam had dried there. The change rarely extends to the cornea (vide Xerosis corneæ). At the same time the bulbar conjunctiva is loosened, and lays itself in folds on movements of the eyes. There is often increased secretion. The deposits usually are removed after a number of weeks and recovery occurs. Sometimes the integument of the body also has a dirty color, is gray, dry, and exhibits branny desquamation.

Complications with catarrhal conditions are not rare. In an epidemic observed by Kuschbert, Neisser constantly found bacilli in the conjunctival deposit. Schleich has seen the same bacilli in the frothy secretion of various conjunctival diseases, although xerosis was not present.

Recovery usually occurs spontaneously. Constitutional anomalies (anæmia, scurvy, etc.), which are present, must receive treatment. The local application of warm compresses of solutions of salicylic acid is also advisable.

8. Symblepharon.

The mucous membrane of the lids may grow to the globe at certain parts of the tarsal portion by means of adhesions (symblepharon anterius), or in its entirety by direct shortening or retraction of the fornix (symblepharon posterius). In the former event we find folds or bridges consisting of bands of connective tissue and blood-vessels, beneath which the sound may be passed, and extending from the lid to the globe. If such adhesions pass to the cornea, they give rise to more or less notable disturbances of vision; at all events, the free mobility of the eye is hindered, so that even a decided squint may develop.

Among the causes of symblepharon may be mentioned: protracted inflammations of the conjunctiva (blennorrhœa, granulations); cauterization, especially by chemicals, and other injuries attended with loss of substance. As the result of pemphigus of the conjunctiva which appears as circumscribed yellowish deposits rather than in the shape of vesicles, there may also develop shrinking of the conjunctival sac and opacity of the cornea. So-called "essential shrinking of the conjunctiva" (Alf. Græfe) has also been observed independently of pemphigus.

Treatment.—If partial adhesions threaten after injury, we can attempt to prevent a symblepharon by covering the loss of scleral conjunctiva by displacing and stitching together the undermined adjacent conjunctiva. The transplantation of mucous membrane may also be tried at the beginning. Otherwise, the globe is moved freely, the lid is everted and, if necessary, kept in this position by

a bandage until the wound has healed. But a satisfactory result can hardly be expected if the burn extends deeply into the fornix. After the occurrence of symblepharon, the bridge-like adhesions offer the best chances for recovery, but even here we should not be too certain of the prognosis. Fold-shaped symblephara are to be converted into bridge-shaped ones, a moderately thick lead wire being drawn transversely through the deepest part of the adhesion by means of a curved needle, the ends drawn out of the conjunctival sac and fastened to the integument of the lids. The wire is kept in position until a lined canal has formed beneath the symblepharon.

Arlt's method of operation may be recommended. A threaded needle is passed transversely through that part of the symblepharon which is situated on the globe. The symblepharon is then separated completely from the globe by careful incisions below the thead, so that it forms a flap situated on the lid, and through whose free extremity the thread runs transversely. A needle is now threaded with the other end of the thread, the symblepharon flap is turned inward, so that its formerly outer surface lies opposite the wound in the globe and is fastened in this position by passing both needles out through the lid and tying the ends of the threads on the integument of the lids. The defect in the ocular conjunctiva is covered by stitching together the edges of the wounds. After complete union the symblepharon is also removed from the palpebral conjunctiva. Transplantation of the mucous membrane (Wolfe) may be tried in posterior symblepharon and extensive retraction of the mucous membrane. The transplanted part may be taken from the lids, the human conjunctiva, or that of the rabbit. At first the effect is often very satisfactory, but after a certain length of time the transplanted flap usually undergoes retraction.

9. Subconjunctival Hemorrhage (Hyposphagma). Chemosis. Lymphangiectases.

Extravasations into the subconjunctival tissue often result from injury, cerebral congestion, epilepsy, attacks of pertussis, etc., in other cases they occur spontaneously. In orbital fractures the hemorrhage may extend from the cellulo-fatty tissue to beneath the conjunctiva. The size varies from that of a pin's head to complete filling of the entire scleral conjunctiva, even of the fornix. The hemorrhage is gradually absorbed after corresponding changes in color.

Chemosis of the conjunctiva occurs in many severe diseases of the eye as a serous infiltration of the tissue, with occasional wall-

shaped elevation around the cornea. Apart from severe conjunctival diseases, it is observed particularly in purulent choroiditis. It is seen occasionally in older people without catarrh or other inflammation. In one case under my observation, retinal hemorrhages due to atheroma of the arteries occurred a few years later. If the chemosis is very tense, small incisions are made with the scissors in order to remove the fluid.

Vesicles, about as large as a pin's head and arranged in rows like a pearl necklace, are observed not very rarely upon the conjunctiva. They are sometimes attended with unilateral headache and swelling of the lids; notable injection of the blood-vessels may be absent. This condition is due to lymphangiectases.

10. Syphilis. Lupus. Tuberculosis. Amyloid.

Syphilitic affections of the conjunctiva are found in constitutional syphilis, in the shape of condylomata or cutaneous gummata which extend to the mucous membrane, or they occur as the result of direct infection. In the latter event, a lardaceous-looking ulcer is usually situated at the edge of the lid. Indurations with subsequent ulceration have also been observed in the conjunctival sac proper, for example, in a physician, in whom syphilitic secretion had flown into the eye. Secondary syphilitic ulcers also occur upon the semilunar fold, and gummous tumors of a livid color upon the scleral conjunctiva. The diagnosis is easy if constitutional syphilis is demonstrable; it is more difficult in primary affection of the conjunctiva. I remember a girl of fifteen years with a suspicious ulcer at the edge of the lid and in whom the examination revealed no traces of syphilis, and perfect virginity. Roseola appeared later; infection had occurred though a kiss. The treatment is that of syphilis.

Lupus extends from the edge of the lid to the conjunctiva, or develops independently upon the latter. On everting the thickened lid, the mucous membrane is seen covered, over a greater or less area, with large, red, cock's-comb-like proliferations of the papillæ; among these are lardaceous ulcerations; the latter may heal spontaneously with cicatricial retraction. The process presents similarity to a neglected trachoma mixtum; we may mention as differential features that lupus, as a rule, attacks only one eye, and also that it extends not infrequently to the intermarginal portion of the lid. The treatment consists in curretting the individual nodules with the sharp spoon; the use of the galvano-cautery or touching with nitrate of silver.

Tuberculosis of the conjunctiva exhibits a similar appearance,

apart from the exceptional cases in which an eruption of grayish translucent tubercular nodules has occurred. The absence of lupus of the skin may be utilized in differential diagnosis; moreover, conjunctival tuberculosis does not extend beyond the edges of the lids and does not cicatrize spontaneously (Walb, Haab). It also occurs in otherwise healthy individuals. The treatment is the same as that of lupus.

Amyloid degeneration occurs first in the subconjunctival tissue, usually in the fornix. The surface of the new-growth is smooth, but occasionally infiltrated with nodules like grains of sago; its appearance is light yellow and vitreous to reddish or reddish brown; the consistence of the less vascular tumors is firm, elastic or brittle, in the others it is soft. Trachoma is also present in a large number of cases. With the advance of the disease the scleral conjunctiva and caruncle may also be attacked. The waxy changes are preceded by hyaline degeneration of the tissue (Raehlmann). Calcifications and ossifications may occur later (Kubli). The treatment consists of total or repeated partial extirpation.

11. Injuries of the Conjunctiva.

Foreign bodies, that enter the conjunctival sac, are usually carried by the movements of the lids and the tears into the inner angle of the lids, whence they can readily be wiped way. But small particles (dust, smoke, etc.), sometimes remain adherent, especially to the tarsal portion of the upper lid; little grains or somewhat larger bodies are often situated firmly in the fornix and cause inflammation and pain. If they remain in situ a long time, secondary hypertrophy of the papillæ ensues and imbeds them. Thus, I once found a "crab's eye" which had been shoved under the upper lid in order to remove a small foreign body had been forgotten and remained there a year. After eversion of the lids removal is usually effected with ease. When the fornix of the upper lid cannot be brought into view, we must occasionally examine the suspected part with Daviel's spoon. It is also to be remembered that patients often maintain that there is something in the eye although no foreign body is present. A catarrh may give rise to such a sensation.

Burns of the conjunctiva from acids, lime or glowing masses (such as iron) are more serious. Here the tissue is often destroyed in its entire thickness, and the porcelain-colored sclera is laid bare. If the burns are not too extensive, recovery occurs after marked injection and exfoliation. Danger always attaches to those burns in which the scleral conjunctiva and the opposing surface of the palpebral conjunctiva are affected at the same time, because ad-

hesion of the lid and globe is very apt to occur. The more extensive the loss of substance the more serious is the prognosis. In a man in whom fluid molten iron had been spirted into both eyes, so that the mass, when hardened, formed a cast of the anterior surface of the globe, I observed complete adhesion of the lids and globe and of the edges of the lids. In a recent burn, we must attempt to make the materia peccans innocuous; in the case of acids, by applying weak solutions of carbonate of soda; in alkalies, by applying milk. If the substance is solid or has become so, careful examination of the entire conjunctival sac is necessary to its removal. Small particles which have entered deeply into the tissues and become innocuous, such as grains of powder or small particles of stone (observed not infrequently as the result of explosion of dynamite cartridges) may be allowed to remain. The further treatment consists of cold compresses and antiphlogosis. The development of symblepharon may be counteracted by the measures recommended above.

Incised wounds of the conjunctiva readily heal spontaneously, larger ones may be stitched together.

12. Tumors of the Conjunctiva.

Pinguecula.—A small yellowish prominence, about as large as a millet-seed, is very often found, especially in old people, upon the conjunctiva in the vicinity of the external or internal rim of the cornea. Despite the term pinguecula, this does not consist of fat, but of hyperplastic connective tissue, which is covered with a thickened layer of epithelium. When large conjunctival vessels run toward it, it might be mistaken for phlyctenular conjunctivitis, but the color and smooth surface of the pinguecula combat this assumption. The tumor is entirely innocuous; we are hardly ever called upon to remove it, even for cosmetic reasons.

Lipomata are situated particularly between the superior and external recti (v. Graefe). They form soft yellowish masses with an irregular surface. They are always congenital, but may grow later. When symptoms are produced, extirpation must be performed.

Dermoids are found congenitally at the edge of the cornea and often extend to the cornea, into whose tissue they grow. *Polypi* of the conjunctiva are relatively frequent in the inner angle of the eye, upon the semilunar fold or caruncle, but they also occur upon the mucous membrane of the lid. They form soft reddish excrescences with a smooth or lobulated surface. Very small polypi sometimes give rise to repeated conjunctival hemorrhages. Profuse hemorrhage is also apt to occur on extirpation, but it is

readily checked by touching with nitrate of silver and a compress and bandage.

Cysts of the conjunctiva appear as spherical or oval, almost transparent prominences, usually in the bulbar conjunctiva. I also saw a slightly elevated cyst, five millimetres long, and two millimetres broad, on the head of a pterygium, and a cyst as large as a bean in the inferior fornix. They are either congenital or the result of an injury (Zander and Geissler, Uhthoff). Partial removal of the cyst-wall followed by injection of a solution of nitrate of silver usually suffices for recovery.

Subconjunctival *cysticerci* present a similar appearance, but the vesicle is more opaque, and a circumscribed white patch (neck of the cysticercus) is occasionally recognizable. As a rule, the cysticercus produces a certain irritation in the overlying conjunctiva (A. v. Græfe).

Sarcomata of the conjunctiva occur as small tumors, as large as a pin's head, especially at the corneal limbus or immediately adjacent to it. They are whitish-gray or brownish-black. The lighter sarcomata seem to be less dangerous, and extirpation may result in permanent recovery. In one case I observed that, after extirpation of a white sarcoma as large as a millet-seed, a small melano-sarcoma developed at a little distance from the original site after the lapse of years. Melano-sarcomata exhibit a greater tendency to relapses as soon as they pass into the stage of enlargement and proliferation, in which they cover the rim of the cornea like a fungus. They may form extensive, lobulated tumors which bleed readily. In a case of this kind, I also observed multiple brown patches upon the palpebral conjunctiva, which did not project above the surface. Even after total removal of the tumor the patients often die of metastases (brain, liver, skin, etc.). Extirpation of the eye which is still capable of vision, is sometimes necessary to secure complete safety.

Non-projecting blackish-brown patches occur occasionally upon the conjunctiva, as the result of injuries. They may persist without undergoing change, while, in other cases, they develop into tumors. Angioma, epithelioma, and carcinoma may also be mentioned.

CHAPTER IV.

DISEASES OF THE CORNEA.

Anatomy.

The curvature of the cornea is to be regarded as part of an ellipsoid of rotation, produced by the rotation of an ellipse around its longitudinal axis. Seen from the anterior chamber it presents anatomically a perfectly circular periphery, while from the front it resembles a horizontal ellipse, whose transverse diameter is about 11 mm., and vertical diameter about 10.5 mm., the sclera anteriorly being pushed somewhat over the transparent periphery of the cornea, slightly more above and below. This part forms the corneal or scleral limbus, whose horizontal diameter on each side is about 0.5 mm. On a transverse section of the cornea we distinguish, from behind forward, five layers: 1. Corneal epithelium, composed of several layers of pavement epithelium. 2. Bowman's (Reichert's) or the anterior basal membrane. It forms a thin layer of very refractile, homogeneous tissue. 3. Substantia propria or the principal mass of tissue. This consists of a tolerably dense mass which is composed of bundles of fibrillæ that are united into superimposed lamellæ, and a cement substance situated between the fibrillæ. In the interfibrillary cement substance is found a system of spaces with a configuration like that of the osseous corpuscles (Recklinghausen's juice canals). In these spaces and the tissue juice which they contain are found the fixed corneal cells, consisting of protoplasm and a nucleus; they do not fill the spaces completely. In addition, the spaces contain wandering cells which correspond to the shape of the white blood-globules. 4. The elastic membrane of Descemet forms the posterior boundary. It is clear as glass, very resisting, and is often found intact in a rolled-up condition even in severe destruction of the cornea. In older people it exhibits globular excrescences. 5. Upon it is situated, toward the anterior chamber, a layer of flat endothelial cells. The nerves enter at the edge of the cornea into the substantia propria, partly from the sclera, partly from the conjunctiva, and ramify as fine axial fibrillæ. They often form meshes which are also situated among and beneath the epithelium. Waldeyer never observed that the

nerve filaments project with free floating ends above the level of the anterior epithelium, or that they are provided with terminal bulbs (Cohnheim). Under normal conditions the cornea proper does not contain vessels. At its rim beneath the epithelium is found the episcleral network, derived from the anterior ciliary arteries.

1. Keratitis.

Keratitis appears in manifold forms, not all of which present a sharply defined clinical history. In the main the pathological changes may be divided into the following types:

I. Circumscribed superficial affections of the cornea. Grayish-yellow superficial patches develop acutely; they may be single or multiple, peripheral or central. They may ulcerate superficially, but heal without leaving any deep opacities.

II. Vesicles.

III. Purulent affections, either circumscribed or diffuse. Here the opaque patches exhibit a decided yellow pus color. The disease extends deeply into the corneal tissue, which it destroys, and usually leaves dense opacities. If the surface is exfoliated, deeply spread ulcers result. These result very often in perforation, so that the fluid of the chamber escapes. Accumulation of pus in the aqueous humor (hypopyon) is not uncommon; complication with iritis is also frequent.

IV. Diffuse infiltrations. They may be superficial or extend through the entire thickness of the cornea.

V. Ulcers. Small superficial ulcers, without extensive infiltration or deep ulcers, usually with opaque base or borders.

If the affected tissue does not clear up entirely, these diseases terminate in corneal patches or opacities. These may be so transparent that a very skilful use of oblique illumination is necessary to detect them, or they appear as grayish translucent parts or as deep white cicatrices. Severe affections may also result in changes of curvature, such as marked prominences (staphyloma) or, in the worst event, disappearance of the cornea (phthisis corneæ) of which only a small whitish surface is left over.

1. Circumscribed Superficial Affections of the Cornea.

Simple Corneal Infiltration.

The opacities are grayish or grayish white, usually about as large as a pin's head or even smaller. The centre has a deeper color and often projects slightly.

In children and young people, the opacities are often multiple

and exhibit greater dilatation so that they project like the point of a pin. The affection is then usually called keratitis phlyctænulosa (s. scrophulosa s. lymphatica), corresponding to the similar process on the conjunctiva with which it is often combined. Stellwag calls this form herpes corneæ, but the latter term is usually reserved for the pronounced formation of vesicles which will be described later.

In addition to the corneal affection, there is usually pericorneal injection; the latter is absent only in rare cases when the infiltrations are single. There is also epiphora and often very marked photophobia which may give rise, in children, to blepharospasm. This depends probably on irritation of the corneal nerves, along whose course are found accumulations of cells, particularly beneath the epithelium (Iwanoff). Violent pains are not common. When the superficial layers are exfoliated (ulcerating corneal infiltration) small ulcers are formed, but exhibit no notable tendency to further extension. Recovery usually occurs after the new-formation of vessels, which often start from one of the vascular networks extending beyond the edges of the cornea. At the same time, the irritative symptoms subside. The infiltration loses its deep color and its sharp boundary against the transparent surroundings and becomes more grayish. It finally heals without leaving any permanent traces. In adults the circumscribed corneal infiltrations are usually single, in children they are often multiple, more obstinate, and have a greater tendency to relapses. In children, after the affection has lasted a long time, a superficial, light gray and extensive opacity of the cornea (pannus phlyctænulosus) may develop and remain stationary; it contains ramifying superficial vessels which start from the periphery. But even such an opacity may clear up completely. Superficial corneal infiltration is apt to be complicated with considerable conjunctivitis, particularly with swelling of the fornix.

Differential Diagnosis.—Superficial corneal infiltration is distinguished, *a*, from old opacity of the cornea, 1, by the pericorneal injection and the condition of irritation; 2, by the color. It is more grayish-yellow and is situated in the corneal tissue almost like a foreign body, while the opacity of the cornea usually passes more diffusely into the surrounding parts or, when it is sharply circumscribed has a more whitish color; *b*, from purulent corneal infiltration particularly by the color; the infiltration of pus is decidedly yellow. Moreover, the simple infiltration is, on the average, smaller and has less destructive tendency.

Etiology.—Scrofula is a frequent causal factor of the multiple infiltrations of childhood, though they occur occasionally in healthy

children. The single infiltrations of adults are sometimes attributable to injury, but often no etiological factor can be determined.

The *treatment* varies according as we have to deal with phlyctenular keratitis or individual infiltrations. In the former, in addition to atropine, which is instilled three or four times daily, surprising effects are usually obtained from the use of yellow precipitate ointment. This is applied in a piece as large as a hempseed, rubbed up with closed lids, and washed out at the end of five minutes. It is to be used even when there is a marked irritative condition and pronounced pericorneal injection. As a rule, it is very well tolerated. But if the injection increases or the infiltration assumes a yellowish, purulent appearance, its use must be temporarily discontinued. We must then first treat the irritative condition by lukewarm compresses of chamomile tea or by boracic acid for a quarter of an hour three times a day. [Hot water applied by means of cloths pressed against the eye for an instant, this being continued for ten or fifteen minutes at a time, is one of the best means of treatment in this condition.—St. J. R.] If pronounced conjunctivitis is present, compresses of cool water must be used When the fornix is swollen, it should be touched directly with a solution of plumb. acet. perf. neutralis or tannin; when there is very marked swelling and purulent secretion from the conjunctiva, with a one-per cent solution of nitrate of silver, followed by immediate neutralization or irrigation. The instillation of cocaine is often useful in relieving the photophobia and blepharospasm. In other respects the treatment recommended for phlyctenular conjunctivitis should be used.

If the integument of the lids or cheeks is eczematous, cold compresses are not tolerated well. The eczema should first be treated by applications of tar-vaseline ointment, or, if the application of cold is regarded as imperatively necessary, oiled linen should first be placed on the lid and upon this the cold compresses. If scrofula is present, this must be treated by suitable internal medication and baths. The non-occurrence of annoying relapses can only be counted upon with any degree of certainty when the general condition is improved. As a local remedy for the prevention of relapses, we may recommend the occasional use of yellow ointment or calomel for weeks or months after the disappearance of the infiltration and the relief of the inflammation.

As a rule, the circumscribed infiltrations of adults do not tolerate yellow precipitate ointment. Here we recommend particularly the use of atropine, and if the conjunctiva is not affected, of warm compresses. Calomel may be used later with advantage. Above all, we must see to it that fresh injury is not received by beginning

work before complete recovery. The affection often lasts such a long time, with constantly recurring exacerbations, because it was never thoroughly cured.

Punctate Keratitis.

Punctate keratitis exhibits white punctate infiltrations in the posterior layer of the cornea. The term has been applied improperly to true Descemetitis, in which similar spots are situated upon the posterior surface of the cornea. In punctate keratitis, on the other hand, the infiltration is situated in the corneal tissue itself. The latter is preceded, as a rule, by Descemetitis which depends upon an iritis; this then gives rise to the punctate white infiltrations in the cornea. They remain after the exudation on the membrane of Descemet has disappeared, but they are gradually absorbed.

Fascicular Keratitis.

Starting from the border of the cornea—often from a phlyctenula at the edge when phlyctenular conjunctivitis is also present—a bundle of parallel vessels, about two millimetres wide, extends toward the centre of the cornea and pushes in front of it a semilunar infiltration. It is divided occasionally into two fasciculi, each with an infiltration. The vessels themselves are situated upon an infiltrated base and form a red band (scrofuloma band of vessels). The infiltration at the tip has a gray color and is sometimes slightly ulcerated. There are sometimes several of these bands of vessels on different sides. Pericorneal injection, epiphora, and photophobia are also present. When recovery begins, the vessels grow paler and disappear, but their former site is shown for some time by a light grayish streak on the cornea. The infiltration leaves behind it a white, often semilunar opacity, which naturally impairs vision when situated centrally.

Etiology.—The patients are generally scrofulous children who, as a rule, have suffered from phlyctenular conjunctivitis and keratitis.

Treatment must be directed toward preventing the spread of the infiltration toward the centre. The application of yellow precipitate ointment, as in phlyctenular keratitis, is often sufficient. In other cases the vessels over the scleral limbus must be freely excised with a knife, scissors, or the galvano-cautery and, if necessary, this little operation must be repeated a few times. Touching the infiltration with the solid stick has also been recommended. In other respects the treatment is carried out according to the

same principles as in phlyctenular keratitis, and yellow ointment or calomel is to be used for some time in order to prevent relapses.

II. Formation of Vesicles on the Cornea.

Herpes Corneæ (Keratitis vesiculosa).

Small vesicles, partly round, partly pear-shaped or linear, and filled with light, clear serum, appear upon the surface of the cornea. Under the microscope the serum contains large, shining and transparent, spherical, oval, and spindle-shaped coagulation figures, and extremely few cells and nuclei. The epithelial layer forms the covering. The size of the individual vesicles sometimes reaches that of a small pin's head, or even that of a millet-seed; they are usually arranged in groups. Their number varies; in one case I counted fifteen vesicles, occasionally we see only one or two. Their appearance is preceded, as a rule, by more or less annoyance in the eye, manifested by burning, sticking, even by intense pain. But they sometimes develop without being noticed by the patient. After a few hours or on the following day, they rupture and we then see only the epithelial loss, often with an adherent epithelial membrane. The iris is usually normal, more rarely discolored, and reacts poorly to atropine. The tension is diminished in about seventy-five per cent of the cases.

Three forms of herpes corneæ may be distinguished: 1. The inflammatory form, first described by Horner as the catarrhal form. The cornea is usually perfectly intact before the eruption of the vesicles, which is attended with pain and marked pericorneal injection. In the majority of cases there is also inflammation of the respiratory tract (pneumonia, catarrhal cough, coryza, etc.) or other mucous membranes; herpes labialis or nasalis is often present at the same time. Such general diseases are not always present. Relapses are rare. As a rule, regeneration of the epithelium proceeds slowly, the cornea becoming slightly opaque at the same time. Even purulent infiltration of the cornea and hypopyon may result.

2. Herpes neuralgicus. The cornea has usually been in a condition of irritation, either from the presence of pannus, phlyctenula, ulcers, etc., or because injuries or operations have been experienced (for example, the formation of vesicles is comparatively frequent after cataract operations). Trigeminal neuralgia is often present. This variety shows its peculiar character chiefly by the absence of notable inflammatory symptoms and rapid recovery of the individual eruptions, but a great tendency to periodical re-

lapses, which coincide occasionally with intermittent neuralgias of the trigeminal branches. If the relapses are very frequent, opacities of the cornea are apt to be left over.

3. Herpes zoster of the integument of the lid and forehead may also be associated with the formation of vesicles on the cornea, which exhibit the characteristics of inflammatory herpes. But not all corneal affections that accompany zoster appear in the shape of vesicles, and therefore the so-called ophthalmic zoster may not be regarded as the equivalent herpes corneæ.

Not alone in the herpes corneæ which is properly called neuralgic, but also in inflammatory herpes, the cause is to be sought in an affection of the nerves. This theory is favored by the frequent coexistence of herpes labialis and also of zoster.

Herpes must be distinguished from phlyctenular conjunctivitis; the latter occasionally presents small vesicles, but these possess cloudy contents.

The treatment may be passive as regards the formation of vesicles in herpes neuralgicus; when symptoms are produced, the vesicles may be ruptured by pricking or by applying coarsely powdered calomel. The matter is more serious when relapses constantly recur. Here also the application of calomel may be useful; otherwise the constant current, compress and bandage, excision of the corresponding part of the cornea (Hasner) and the ordinary nervines are to be tried; in rare cases everything proves useless.

Inflammatory herpes is treated with atropine and damp warm compress and bandage; if the pains are violent, narcotics are administered.

Keratitis Bullosa.

Large flabby vesicles with slightly cloudy, even bloody contents develop sometimes upon corneas affected with parenchymatous opacity, often upon degenerated globes, as after the termination of glaucoma or chronic irido-choroiditis. Inflammatory symptoms and pains are often present, but may also be entirely absent. The vesicles burst in a few days or persist for quite a while. Recovery generally occurs after rupture.

In addition to epithelium and Bowman's membrane, the separated corneal layer contained, in a case examined by v. Graefe, corneal tissue, and in other cases only epithelium (Schweigger, Sæmisch). We may attempt to relieve the pain by removing the anterior wall. If relapses occur and give rise to symptoms, they must be combated chiefly by treating the primary disease of the eye (for example, an existing glaucomatous process).

III. Purulent Diseases of the Cornea.

Circumscribed Purulent Infiltration of the Cornea.

A larger or smaller yellow, purulent infiltration develops in the cornea, attended with pericorneal injection. The infiltration usually penetrates into the depth of the tissue, the superficial layers are exfoliated. Perforation of the cornea often occurs, and is followed suddenly by notable improvement and decided tendency to recovery. Even before perforation, vessels usually run from the rim of the cornea toward the infiltration; these vessels are situated in the superficial as well as the deeper layers of the cornea. The infiltrations are single or multiple. The latter occurs particularly in children after the exanthemata, as in convalescence after measles and scarlatina; thick yellow infiltrations, looking somewhat distended and pustular, with a pronounced tendency to perforation, develop close to the edge of the cornea. Old corneal patches and cicatrices often undergo purulent degeneration. Hyperæmia of the iris is often demonstrable, iritis is rare. Hypopyon is generally absent and if present is usually small. Complaint is made not infrequently of photophobia, epiphora and pains, which extend into the forehead and temple.

In the majority of cases the tendency to purulent degeneration depends on a certain constitutional weakness, as after exhausting diseases or excessive lactation. Local causes also play a part. Thus purulent infiltrations are found often in granulations.

The prognosis must always be made with caution because perforation and prolapse of the iris often occur. But as this form does not exhibit the tendency to spread laterally, the eye is usually not lost.

The *treatment* varies according as conjunctivitis is present or not. If conjunctivitis and considerable secretion are present, direct touching of the everted lids with tannin or lead solutions is especially indicated. Moist warmth, which is very useful in purely purulent corneal processes, must here be avoided and, if necessary, replaced by cool compresses (one-quarter of an hour, three times a day). The congestion of the iris requires atropine. If the perforation of the ulcer is impending, we should attempt to prevent prolapse of the iris into the wound. If, for example, the ulcer is situated peripherally, eserine must be instilled in order to produce contraction of the pupil. Special curative power cannot be expected from eserine, but it may be tried occasionally when the iris is not inflamed (in iritis it is directly injurious). When the pain is very violent, particularly when the ciliary region is very tender on pressure,

three to five leeches are applied to the temples and narcotics are given, in addition to the use of Arlt's forehead ointment.

If there is no conjunctivitis, lukewarm antiseptic dressings are the most preferable. Should the constant dressings produce pain, lukewarm compresses of chamomile tea or a solution of boracic acid may be applied for half an hour several times a day. Some consideration must be paid to the subjective sensations of the patient. Certain individuals cannot tolerate lukewarm compresses on account of the increase of pain. If perforation is impending and the lowermost layers of the ulcer are already bulging, paracentesis is performed at the base of the ulcer by means of Desmarres' paracentesis or puncture needle (Fig. 140). After the escape of the fluid in the chamber, the pupil becomes narrow; the refraction is increased (Reymond). If the wound is to be kept open for some time, the adhesions which form may be divided by means of the spatula on the other end of the needle. As regards general regimen, tonics are usually indicated.

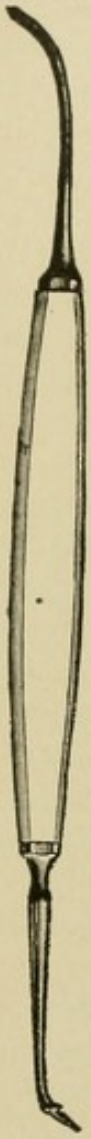


FIG. 140. Paracentesis Needle. (Desmarres.)

Hypopyon Keratitis.

This term, introduced by Roser, indicates purulent processes in the cornea which have a tendency to spread, not alone in the depth, but also along the surface, and are associated with large hypopyons. The corneal affection occurs under various forms and has therefore received different names, such as corneal abscess (Arlt, Weber), torpid purulent infiltration of the cornea (v. Graefe), and ulcus serpens (Saemisch). The destructive tendency, the complication with hypopyon, and the course and termination warrant the grouping of these forms into one category.

Ulcus serpens is the most frequent form. Here a round or oval, at first very superficial loss of substance is situated in the middle of the cornea; in this part the cornea is light gray and transparent. At a larger or smaller portion of the edge—rarely surrounding the entire ulcer—is found a thick, cheesy, grayish-white, tolerably narrow and arch-shaped infiltration; occasionally there are also punctate foci. As the infiltration of the edges is especially prominent and the surface of the ulcer appears to lie almost at the level of the remainder of the cornea, the condition presents a different appearance from other ulcers, the ditch-shaped depression is wanting.

A similar description is given by Arlt of the second stage of the process which he has called abscess, after absorption or perforation

of the pus. The original abscess forms a sacculated yellow purulent infiltration and destruction of the deeper lamellæ of the cornea; the epithelium and upper layers at first remain intact.

In torpid infiltration of pus, on the other hand, the upper layers are also infiltrated with pus. Ulcerations usually develop afterward, but without the typical appearance of ulcus serpens, inasmuch as the base remains yellow and infiltrated with pus. In common with ulcus serpens it exhibits the tendency to spread and to the formation of hypopyon.

These forms may occur as different stages of the same processes, but this is by no means necessary. For example, if the epithelium has been torn off by injury and infection of the wound occurs, an ulcus serpens usually develops forthwith and is not preceded by an abscess.

On oblique illumination, we see whitish-gray, fine lines which run from the edges of the ulcer or the infiltration of pus toward the periphery of the cornea, extending deep into the parenchyma and often connected with one another. There are early changes in the fluid of the chamber, which is apt to become cloudy; grayish-yellow fibrinous or deep yellow purulent masses are soon deposited and lie upon the floor of the chamber as hypopyon. Connecting bands can very often be traced from the corneal infiltration to the hypopyon. As the former are also evacuated after puncture of the anterior chamber, their position upon the posterior surface of the cornea—not between the corneal lamellæ—is demonstrated. Hence we have migration of the pus-cells into the anterior chamber and their sinking upon the membrane of Descemet (Horner). An accumulation of pus in the anterior chamber may also result from migration of the pus cells from the periphery of the chamber through the ligamentum pectinatum. In very rare cases the pus sinks between the corneal lamellæ; the small, yellowish half-moon, which is thus formed at the lower periphery of the cornea, is called onyx or unguis. As a rule, however, it is a true hypopyon, situated in the anterior chamber. The iris is usually implicated very slightly in the production of the pus; extensive hypopyon is observed without notable iritis. Hyperæmia of the iris, on the other hand, is rarely absent; but adhesive iritis, even irido-cyclitis may ensue.

The patients are often strikingly insensible to the disease, and are but little disturbed by the redness of the eye, epiphora, and impaired vision. In other cases they suffer from violent ciliary neuroses which deprive them of rest night and day. The ulcus serpens usually spreads very rapidly at the periphery; in a week it has sometimes destroyed the greater part of the cornea. It also

extends deeply, but this is rarely visible because it is compensated by the fact that the remaining thin layer of the cornea yields to the intraocular pressure and is pushed forward. The torpid purulent infiltrations often spread with considerable rapidity and destroy large parts of the cornea. In the abscesses proper this tendency is less marked. When perforation of the cornea has occurred, the process usually runs a more favorable course, vessels develop in the cornea and cause recovery of the loss of substance, although a white cicatrix remains; this is often adherent to the iris. Circumscribed cataracts of the capsule of the lens may form in like manner, and even lead to complete opacity of the lens. If the loss of substance has been very extensive, staphyloma or phthisis corneæ is the result. In rare cases violent internal inflammations develop and may lead to suppurative choroiditis and panophthalmitis.

Etiology.—Hypopyon keratitis is most frequently caused by septic infection, in a large number of cases by the secretion of old blennorrhœas of the lachrymal sac. This must be looked for in every hypopyon keratitis, and I have observed it in about fifty-four per cent of all cases. The disease of the lachrymal sac is sometimes on the side, not of the affected, but of the other eye. Several examinations must be made because no secretion, which can be squeezed out, may be present in the lachrymal sac at the first examination.

Inoculations of the secretion of the lachrymal sac upon the cornea of the rabbit, which I carried out, have proven its infectious action. The secretion of many blennorrhœas of the lachrymal sac (according to my inoculation experiments on the rabbit's cornea not all are equally infectious) contain various micrococci and rods; among the latter are bacilli which stain with gentian violet and are arranged in groups; they are smaller than the tubercle bacilli and are very broad in proportion to their length. Inoculations with pure cultures of the bacilli have also given rise to corneal affections (Widmark, Sattler), but they seem to possess less malignancy than inoculations with pure secretion. Bacteria are also found, though rarely, in the hypopyon. That hypopyon keratitis may be produced even by the mould fungus is shown by Leber's case in which aspergillus glaucus was found in the corneal tissue.

Injuries to the cornea by twigs, stalks of grain, etc., are usually the exciting cause of infection; the disease is especially frequent in farmers during harvest (kératite des moissonneurs).

Hypopyon keratitis may also occur without injury and demonstrable infection, as in the torpid corneal infiltrations of feeble or scrofulous children and after the exanthemata or in old emaciated individuals.

Severe purulent infiltrations of the cornea, are especially apt to occur in small-pox. These are rarely due to an eruption which is analogous to that on the skin, and occurs at the same time, but as a rule, we have to deal with corneal processes such as also occur in other feeble patients after typhoid fever, puerperal fever, diabetes, etc. During the period of cutaneous eruption in variola I have seen phlyctenular conjunctivitis.

The *prognosis* is so much poorer the later proper treatment is instituted; recovery is probable if the disease is not extensive. When treated early, the diffuse torpid purulent infiltrations of childhood often run a very favorable course and may be absorbed in a striking manner.

Treatment.—At the beginning of the ulcus serpens and when it is not too extensive, it is sufficient to apply moist warm, antiseptic dressings, in addition to atropinization of the eye and to dusting with powdered iodoform twice a day (Ravà). The latter remedy here surpasses the otherwise very useful officinal aqua chlori. The latter may be instilled freely once or twice a day, if iodoform is not tolerated or is inefficient, as sometimes happens. The direct brushing of the ulcer with aqua chlori or a solution of corrosive sublimate may also be tried. If the constantly worn moist warm antiseptic dressing, is painful on account of the pressure, moist warm compresses, with two to three per cent solutions of boracic acid may be used.

A class of milder processes recover under this treatment. Spontaneous perforation of the ulcer may also occur without any very great loss of substance. If this threatens, the atropine should be exchanged for eserine when the ulcer is situated peripherally, in order to bring the rim of the iris as far as possible from the point of rupture. Eserine sometimes appears to aid recovery, in other cases it causes exacerbation of the process: this probably depends on the greater or less implication of the iris.

Any disease of the lachrymal sac, which may be present must also be treated, free escape for the secretion into the nose being secured by sounding and the secretion disinfected. Iodoform acts admirably here; simply dusting it into the conjunctival sac occasionally checks the secretion. Or iodoform salve may be introduced with a syringe into the lachrymal sac through the dilated lachrymal canal. Injections of solutions of sulphate of zinc or aqua chlori may also be used.

In individuals who are not too feeble, the application of leeches and the use of narcotics are indicated when the pains are violent, and the globe tender on pressure. Wine and tonics are to be given to feeble patients.

The plan mentioned may be tried for two or three days even when the ulcers are large and the hypopyon considerable. But it often leaves us in the lurch in such cases and we must then, in addition to moist warm compresses and iodoform, resort to operative procedures, especially when the thin base of the ulcer bulges on account of the pressure in the chamber. Simple paracentesis is usually insufficient; a sufficient opening must be made into the anterior chamber, such as that afforded by Saemisch's transvere division. For this purpose a narrow Graefe knife is passed into the anterior chamber at the edge of the ulcer, but in healthy tissue, the knife, with the cutting edge anteriorly, is then carried along the anterior chamber behind the ulcer to the opposite edge, and there emerges, cutting transversely through the entire base of the ulcer. The fluid of the chamber now escapes and the pus is discharged, although not always completely. In many cases the entire clot may then be extracted by the careful introduction of an iris forceps. However, it does not make much difference whether a little pus remains in the chamber. The violent pains which follow evacuation of the chamber soon cease under a moist warm dressing. We must see that the chamber does not close for several days, and for this reason, the wound must be reopened daily with the tip of Weber's lachrymal canal knife. This is not always easy because the membrane of Descemet and the posterior layers of the cornea sometimes adhere so rapidly, that the wound can no longer be opened on the following day, but the tip of the knife pushes the layers in front of it into the anterior chamber. Here Graefe's knife should again be employed cautiously.

Saemisch's plan saves a series of cases which would be lost without it, and is the most reliable of the operative procedures. It has entirely displaced the iridectomy performed by v. Graefe in these cases. The opacities in the capsule of the lens, which appear later in some instances, can only be attributed to it indirectly because they are mainly the result of the prolonged contact of the lens with the ulcerated cornea and of the action of the pus which adheres to the capsule. It is possible that the operation gives rise to small ruptures of the capsule (Deutschmann), but circumscribed opacities of the lens are often seen after ulcus serpens without operation.

Benefit is sometimes derived from touching the infiltrated edges with the hot iron, the galvano-cautery (Gayet, Sattler, Nieden) or Everbush's modified thermo-cautery, the use of which is facilitated to a notable degree by cocaine anæsthesia. But it always possesses the disadvantage that a part of the corneal tissue is directly destroyed; it is particularly in large ulcers that the tendency to the development of staphyloma is thus increased.

During the period of recovery and for a long time afterward it is advisable to apply a compress and bandage and to instil eserine, which antagonizes prolapse of the vitreous and lens. In no event should the patient resume work too soon; otherwise we are apt to find that the individual, who has been dismissed with a flat corneal cicatrix, returns with a large staphyloma.

Abscesses and purulent corneal infiltrations require, on the whole, the same medicinal treatment, but the action of iodoform is not so beneficial. It is better to instil aqua chlori or one to two per cent solutions of quiniæ muriat. several times a day. If a real abscess is present, it may be punctured with a broad paracentesis needle, though this does not evacuate the cavity because the pus-cells adhere in the lamellæ of the cornea. Transverse division of the infiltrated cornea or the use of the galvano-cautery, does not appear to be indicated here or in diffuse purulent infiltration. Large hypopyons, if they occupy more than a third of the anterior chamber, are evacuated with a broad puncture needle which is inserted transversely through the purulent infiltration of the cornea. If necessary, the wound is reopened during the next few days.

Keratomalacia.

In very rare cases a purulent infiltration develops in the centre or the periphery (ring-abscess) extends in a few days over the entire cornea, and converts it into a necrotic pulp, which is partly exfoliated and leads to extensive perforations or undergoes a sort of desiccation. The final result is atrophy of the cornea, so that at last it forms only a small, flat, whitish plate at the anterior pole of the eye, which is perhaps still transparent at one spot. This course is observed occasionally after cataract extractions, acute conjunctival blennorrhœa and diphtheritis conjunctivæ, and also without local affections, in weak exhausted individuals after severe general diseases. Thus, I have seen a young but very anæmic woman who, on the third day after a normal delivery, was attacked by bilateral purulent infiltration of the cornea. In three more days both corneæ had undergone total suppuration.

Moist warm compresses and tonics may be employed, but when keratomalacia is fully developed, not much is to be expected as regards preservation of the cornea.

Keratitis Xerotica.

In cachectic individuals there has been observed a peculiar corneal ulceration, which is preceded, as a rule, by xerosis of the conjunctiva and often, as shown by Gouvêa's statements, by heme-

ralopia. The conjunctiva is dry, covered with a fine froth and scales; under the microscope these exhibit cells of pavement epithelium and fat, but in great part bacilli (Neisser). In a case under Leber's observation, the pavement epithelium cells were completely covered with peculiar, partly rod-shaped, partly cocci-shaped bacilli. The latter were also found in the deposit on the corneal ulcer, within the globe which had undergone complete suppuration, and in the renal papillæ on autopsy; R. Schulz describes similar appearances.

On moving the eyes, small vertical folds appear upon the mucous membrane lying free between the lids. The sensibility of the cornea is diminished. A few of the anterior conjunctival veins and episcleral vessels appear distinctly, although there is no pronounced pericorneal injection. The patient suffers from photophobia and epiphora.

A small, usually central, portion of the cornea becomes gray, later yellowish, the epithelium is exfoliated and progressive infiltration of pus develops with ulcerative destruction. In a short time the cornea may be destroyed entirely, or with the exception of a narrow rim, so that the complete picture of keratomalacia is produced. In other cases the process proceeds more slowly, and is confined more to the region of the palpebral fissure. The iris usually takes part in the spread of the disease; panophthalmitis may follow the exfoliation of the cornea.

v. Graefe observed a similar affection particularly in feeble children, between the age of two and five months, and described it as "corneal ulceration in infantile encephalitis." Extensive fatty degeneration of the neuroglia elements was found in the brain in these cases, although clinically there were no cerebral symptoms. But since Jastrowitz's investigations have thrown doubt on the pathological significance of abundant granulo-fatty cells in the brain of such young individuals, the affection can no longer be attributed to cerebral disease, especially as similar corneal affections are found in older individuals who suffer from other diseases. Thus, Gouvêa observed it frequently in cachectic negroes in Brazil. I have also seen it in a child of eight years, who had suffered for years from bone disease. It seems as if the immediate cause, in a number of cases, is the dryness of the surface of the cornea from incomplete closure of the lids, the palpebral fissure remaining partly open as the result of the general weakness. A further part is played by mycotic infection.

The prognosis as regards sight is poor in very young children; as a rule, moreover, death soon occurs. The prognosis is somewhat more favorable in older individuals.

The treatment must secure closure of the eyes, the application of moist warmth, and the improvement of the general condition. In view of the demonstration of bacteria, moist warm antiseptic dressings and the instillation of chlorine water, may be recommended. Gouvêa has obtained very good results from the early use of the vapor spray at 40° C., used one to three times a day for fifteen minutes. In the intervals a compress and bandage. He used chamomile tea or pure water for the spray.

Keratitis Neuro-paralytica.

The form of keratitis which develops in paralysis of the trigeminus may correspond entirely to the xerotic form in its appearance and course. In other cases there is merely simple infiltration or ulceration, which is capable of recovery. As the sensibility of the conjunctiva and cornea is abolished, small foreign bodies remain longer upon the globe before they are removed by winking. Indeed, Snellen and later Senftleben regard the keratitis as simply traumatic because its development in rabbits, after division of the trigeminus, may be prevented by proper protection to the eye. But this theory is opposed by the fact that the form and course of the inflammation differ from those observed after injury. Despite protection to the inflamed eye, the course of recovery is much slower than in traumatic inflammations of equal extent. In addition, the experiments of Meissner and Schiff, have shown that the inflammation occurs when the median portion of the trigeminus is alone divided, despite the intact sensibility of the cornea. If the median part is uninjured, inflammation does not occur (Meissner, Schoeler, Uhthoff); hence the nerve fibres in this part must be directly connected with the nutrition of the cornea. Their paralysis diminishes the power of resistance of the cornea, and thus furnishes a favorable soil for the action of traumata and for desiccation induced by diminished winking and, finally, perhaps for the immigration of bacteria. If it is maintained, in opposition to this view, that a similar inflammation of the cornea does not occur after opticociliary neurotomy, it must be remembered that, although the nerves of the cornea are in great part divided, yet the sensibility of the conjunctiva remains intact, and winking is not diminished, so that there is much less occasion for traumatism and none for desiccation. Both factors also come into play in those cases of trigeminal paralysis which are free from inflammation, and in which, on account of coincident paralysis of the third nerve, the lowered upper lid protects the eye.

The prognosis is unfavorable, because it is difficult to secure

permanent protection to the eye, when the trigeminal paralysis continues. It generally terminates in leucoma or even in total loss of the cornea.

The treatment must attempt, above all, to secure moisture of the eye and the prevention of injuries. Hence a permanent moist warm antiseptic dressing is indicated. When there is coincident conjunctivitis, this must also be treated and, in such cases, the moist heat must not be applied too long. In addition, atropine or, if iritis is absent, eserine for the reasons previously adduced. If a leucoma has developed, improvement of vision can occasionally be effected by an iridectomy which, as a rule, heals well.

IV. Diffuse Infiltrations of the Cornea.

Pannus (Keratitis pannosa).

Large ramifying vessels which develop originally from the episcleral network, but, at a later period, can usually be traced to the posterior conjunctival vessels, extend to the cornea and spread over its surface. They are situated between the epithelium and Bowman's membrane, or immediately beneath the latter. In addition, the surface of the cornea exhibits a slight diffuse opacity from accumulation of cells beneath the epithelium; also, irregularity and small losses of sustance in the epithelium. The region of distribution of the vessels may be very extensive, so that the entire cornea is infiltrated with them; in other cases they are confined to one part. In many cases the upper half alone is affected. According to the intensity of the vascular development and the corneal opacity we distinguish a pannus tenuis and pannis crassus or sarcomatosus; in the latter the cornea may assume a red appearance like meat. In severe cases, there are finally extensive connective-tissue formations in the superficial parts of the cornea. If the corneal tissue is but slightly affected, and the pathological condition consists chiefly of the superficial sinuous and ramifying vessles which are connected with the posterior conjunctival vessels, then it is more correct to speak, not of pannous keratitits, but merely of pannous vessels; in very rare cases these may give rise to small corneal hemorrhages. The subjective symptoms which often accompany its acute development are severe photophobia, epiphora and pains; later the disturbances of vision become more prominent. When the pannus is very thick, the patients cannot walk alone, and are hardly able to count the number of hands. There is often increased secretion which depends upon complicating conjunctival affections.

When the pannus undergoes resolution, the vessels disappear gradually and the cornea clears up. The opacity may yield entirely to treatment, especially in young people, or a slight transparent veil, which is often recognizable only in circumscribed places on oblique illumination, is left behind. In other cases, when the pannus has lasted a long time and, as happens not infrequently, is complicated by circumscribed corneal infiltrations, even of a purulent character, an intense superficial opacity remains, in addition to circumscribed whitish cicatrices. Such a pupulent infiltration occasionally gives rise to perforation with prolapse of the iris, so that an anterior synechia develops.

Iritis often complicates pannus. Particular attention must be paid to serous iritis, in which the anterior chamber becomes deeper without marked myosis and secondary increase of the intracular pressure sets in. In very severe cases a sort of shrivelling of the cornea occurs; it becomes whitish, dry and flattened, and usually traversed by scanty vessels.

Etiology.—1. Trachoma constitutes the most frequent cause of pannus, which is then confined for a long time to the upper half of the cornea. The immediate cause appears to be the mechanical pressure and irritation of the irregularities in the mucous membrane of the firmly applied upper lid. In rarer cases the pannus may also be due to circumscribed, gray, round foci which, consisting of lymphoid cells arranged in heaps, are analogous to the granulation process in the mucous membrane of the lids. 2. Chronic blennorrhœas, even simple catarrhs, occasionally give rise to circumscribed pannous opacity in old people. 3. Conjunctivitis and phlyctenular conjunctivitis of long standing give rise to pannus which usually occupies the entire cornea. 4. Trauma. Direct injury to the cornea by obliquely placed lashes in trichiasis and entropion or by foreign bodies and the irritation resulting in entropion from the increased exposure of the cornea may produce pannus. 5. Pannous vessels (pannus regenerativus) appear not infrequently in the period of recovery from infiltrations or ulcers.

The prognosis depends upon the cause. If this can be removed rapidly, speedy recovery may be expected. The variety occurring in trachoma is especially obstinate, but surprising results are often obtained by persistent treatment. The pannus occurring in total cicatricial change of the conjunctiva is hardly amenable to treatment. As a rule, phlyctenular pannus runs a favorable course.

Treatment.—Trachomatous pannus usually subsides with the cure of the process in the mucous membrane. This is particularly true when the mucous membrane still exhibits hyperæmia and granulations, less when extensive cicatrices have formed. But even

then good results may be obtained from treatment of the individual congestion and swollen parts of the mucous membrane which are situated between the cicatrices. The chief importance must be attached to this treatment, which is discussed in the chapter on trachoma. But if the condition of the mucous membrane offers no special indications, the pannus must be treated directly. Guthrie's ointment (Argent. nitric., 0.4; Acet. plumb., gtt. 8; Vaselin., 8.0) often has good effects in such cases. An atomizing apparatus, which throws lukewarm, feebly astringent solutions against the globe, is occasionally used to advantage. Special attention must be directed to the destruction of the vessels entering at the rim of the cornea. We may resort to punctate cauterization of the individual vessels with the actual cautery or touch them frequently with nitrate of silver (with subsequent neutralization). Direct division of the vessels is less effective. If the vascular development is very marked and extensive, it is advisable to perform peritomy or syndectomy. A circular piece of conjunctiva, two to three millimetres wide, around the edge of the cornea and in apposition with it, is excised with scissors. In order to secure interruption and destruction of the vessels, the underlying episcleral tissue is thoroughly scarified. The reaction to this operation gives rise at first to increased opacity of the cornea which gradually disappears. The good effects do not appear until the lapse of weeks or months.

Inoculation of acute blennorrhœa—the secretion of ophthalmia neonatorum is the best—was recommended by Jaeger against pannus, and recently has been used more extensively in France and England. As a matter of course, this plan may not be adopted when one eye is still intact, because transmission to and destruction of the intact cornea is apt to occur. The published results are not very gratifying. In the most favorable cases, improvement is obtained after many months' treatment, and, it seems to me, could have been secured in this period with milder measures. After four to six months' hospital treatment I have also often obtained such results that patients, who could only count fingers at a couple of metres or only the movement of the hands, obtained V ⅓ to ½. But the intense and deeply situated cicatricial tissue in the cornea does not clear up either after artificial blennorrhœa or any other remedies. The application of the jequirity maceration is, at all events, preferable to the inoculation of blennorrhœa, provided that there is no papillary swelling.

[The practitioner who gives the jequirity treatment a fair trial, that is, using it with great circumspection, having the patient under constant observation, and with a nurse, will be well satisfied with its results in otherwise incurable trachomatous pannus.—St. J. R.]

Pannus after chronic blennorrhœa is less dangerous because the primary disease is usually relieved more readily; the treatment must be directed against the latter. In phlyctenular pannus—unless the irritative condition is violent, in which event we must first treat antiphlogistically with moderately cool compresses and atropine—the best effect is obtained with yellow precipitate ointment, which, as in phlyctenular keratitis, is applied once a day and then rubbed in. The rubbing (massage) may be somewhat prolonged.

In traumatic pannus the cause must be removed. Misplaced lashes, which are occasionally overlooked on account of their fineness and white color, must be extracted with forceps or removed by palpebral operation. Calcified Meibomian glands must be opened and their contents evacuated. Distichiasis, entropion and ectropion must be subjected to operation.

Regenerative pannus is not to be treated, as a matter of course, but when necessary should be stimulated by lukewarm compresses. It usually disappears with suprising rapidity with the recovery of the primary corneal affection. If the cornea is white, cicatricial and shrunken, clearing up is not to be expected. In cases in which the conjunctiva is also shrunken, the moistening of the eye must be secured by frequent instillations of lukewarm milk or a weak solution of carbonate of soda (0.3 : 50.0).

Diffuse Parenchymatous Keratitis.

A slight, very transparent, grayish opacity first forms in the centre of the cornea or at the edge. This gradually extends and finally occupies the entire cornea so that it may present the appearance of glass which has been breathed on, especially as the surface usually exhibits delicate notching. When the disease is developed, the details of the fudus can no longer be recognized with the ophthalmoscope, while the iris and pupil are still visible. Individual parts of the cornea are not uncommonly more densely opaque than others. This occurs particularly in the stage of recovery, during which the opacity becomes denser in certain places, while other parts become transparent. Purulent degeneration is observed only in very exceptional cases. As a rule, the cornea clears up quite completely, although small, very transparent opacities, which are finally seen only with oblique illumination, are left over not infrequently. The injection of the ocular conjunctiva is often very slight and may be entirely absent, but pericorneal redness may appear on irritation of the eye. Development of vessels is never necessary to the absorption of the infiltration.

In other cases, however, conjunctival and pericorneal redness, even attended with more pronounced irritative symptoms, appear

at the beginning or a little later. Vessels may even pass into the cornea and develop into meshes; these disappear after recovery.

Apart from the visual disturbances, the subjective symptoms are sometimes almost nil, so that the patients may have pronounced unilateral diffuse keratitis, before they are led to consult a physician on account of the affection of the other eye and the consequent evident impairment of vision. The latter may be so great, that the patient can only recognize movements of the hand near by. In other cases, epiphora and photophobia are pronounced and there are also notable pains.

Complications appear upon the cornea and iris. In rare cases deep circumscribed thick infiltrations develop in the cornea and finally leave distinct white patches. The membrane of Descemet occasionally exhibits punctate deposits, due to an accompanying iritis serosa. The pupil is almost always narrow and reacts poorly to atropine. There is often more marked iritis with posterior synechia; even small hypopyons develop in rare cases. Peculiar whitish exudations, as large as a pin's head, develop occasionally at the very chamber edge of the ligamentum pectinatum, extending to the membrane of Descemet and forming small bridges (anterior synechia) which remain for a long time after recovery of the disease. More or less dense opacities of the vitreous may also develop. While the intraocular pressure, as a rule, is high, primary or secondary hypotony is occasionally observed. In two extremely remarkable cases under Klein's observation, the cornea was entirely opaque and complete phthisis with blindness resulted; the anterior chamber was obliterated and the globe became pulpy; nevertheless restitution occurred later.

The condition of the iris and the vision must always be examined carefully. In order to exclude complications, the impairment of vision must be equal to the optical obstruction resulting from the corneal opacity. In cases, for example, in which the iris is clearly visible, it must not be reduced to quantitative perception of light. As a matter of course, the field of vision is free in uncomplicated cases.

The course of the disease is extremely protracted; months, even years may elapse before an end is reached. As a rule, one eye is attacked after the other, the first being still diseased when the other is attacked. I have also seen a case in which one eye had been healthy for more than a year, when the other was attacked In rare cases one eye remains permanently intact. Almost all the patients are between the ages of six and twenty years.

In one eyeball examined by Virchow, the stellate corneal cells were found enlarged and their contents opaque.

The etiology of the affection appears to be dependent on a constitutional anomaly. In favor of this opinion are the bilateral character of the disease and the appearance of the patients. They are usually pale and anæmic, scrofula often is or was present. Young girls after the period of puberty and who exhibit a peculiar grayish-yellow complexion are attacked with relative frequency. Menstrual disorders are often present. The patients are rarely perfectly healthy.

Hutchinson regards hereditary syphilis as the cause of diffuse keratitis. He attaches special weight to the peculiar condition of the upper permanent incisors, which at first exhibit small conical crowns. These are gradually rubbed off, so that finally the crown forms a concave arch with lateral projecting lips. In Hutchinson's opinion this is a certain sign of hereditary syphilis. This form of the teeth must be distinguished from that occurring in rickets and other diseases, in which there are small serrations upon the cutting surface and transverse grooves in the enamel. But there are numerous cases of diffuse keratitis in which neither this sign, nor hereditary or acquired syphilis is present. [I am also of the opinion that diffuse keratitis often appears when there is no sign of hereditary syphilis. I am not aware that Hutchinson considers diffuse keratitis as, of itself, an evidence of the existence of hereditary syphilis. As to acquired syphilis, I think it is very rarely, if ever, the cause of diffuse keratitis.—St. J. R.]

Arlt distinguishes etiologically a lymphatic (scrofulous) keratitis, keratitis from hereditry syphilis, and keratitis after intermittent fever. He finds that in keratitis from hereditary syphilis the development of vessels in the cornea is less frequent, but inflammation of the uveal tract is more common than in scrofulous keratitis—a distinction which, to say the least, is often absent.

On the whole, the prognosis is favorable; the majority of patients recover and secure good vision. The prognosis is impaired by complications, although recovery usually follows after the lapse of years, even after severe complications.

Local treatment, as a rule, exerts no notable influence on the course of the process. It must be directed chiefly toward preventing or combating complications. It is advisable to tell the patients at the start, that the disease will last months and that the second eye will probably become affected, but that recovery and restoration of good vision are to be expected. The chief attention is to be paid to the general condition. If there is poor appetite and anæmia, nutrition must be improved by remedies which aid digestion; later, iron is indicated, iodide of iron in scrofula. The long-continued use of cod-liver oil is also advisable. In syphilitic cases,

mercury or potassium iodide is given. Atropine is used to relieve irritability of the iris. Warm compresses have been recommended to hasten the course of the disease, but they are not attended with much benefit. In a few cases, in which injection is entirely absent, application of the mitigated stick to the fornix of the lower lid, repeated every second to fourth day, appears to accelerate the clearing up. When this begins, calomel or yellow precipitate ointment may be used cautiously, attention being paid to the irritation. If there is no notable irritative condition of the eye, the patient may be allowed to go in the open air, wearing protective spectacles. When there is marked vascular injection, which remains unchanged for a long time, peritomy has been employed successfully. If iritis is present, with violent pains and pronounced injection, the application of leeches becomes necessary. If extension to the ciliary body or vitreous is feared, injections of corrosive sublimate or inunctions are to be recommended. I have also seen good effects from diaphoresis, produced by injections of pilocarpine. When there is severe Descemetitis, repeated punctures may be made, provided that the intraocular pressure is normal or increased. Iridectomy is occasionally indicated under such circumstances.

Scleritic Infiltration of the Cornea.

A scleritic or episcleritic infiltration is first found in a part adjacent to the cornea. From this vessels proceed to the cornea; at its edge a grayish-white patch then forms, which is not sharply defined from surrounding parts and gradually pushes toward the centre of the cornea. These prolongations often come from several sides. The opacity disappears slowly in the course of months. This affection is complicated, with comparative frequency, by iritis, Descemetitis, and vitreous opacities. Otherwise its course corresponds closely to that of diffuse parenchymatous keratitis, except that the opacities are not so diffuse and that bluish white discolorations, similar to the scleral tissue, are finally left over at the edge of the cornea. The sclera extends apparently into the periphery of the cornea. Upon the sclera itself dark violet patches form at the site of the previous scleritis. Both eyes are usually attacked in succession as in simple diffuse keratitis. The treatment must be directed particularly against the scleritic process and existing complications. As a rule, atropinization and expectant treatment suffice as regards the cornea. In addition, improvement of the general condition. [Hypodermic injections of pilocarpine of sufficient strength to produce moderate diaphoresis, are of great value in the treatment of this disease.—St. J. R.]

V. Ulcers of the Cornea.

Ulcers of the cornea develop from the surface, the epithelium being lost and the destruction extending inward, or they develop from within an infiltration forming and then undergoing ulceration. The base of the ulcer is generally more cloudy and opaque with the latter mode of development than with the former. They are complicated occasionally with hypopyon and iritis. If the ulcer is not too deep and recovery occurs, the opaque base first clears up, then the epithelium is regenerated, and then the lost corneal tissue is gradually restored so that depressions with a shining surface remain visible for a long time (reparation ulcers). If the loss of substance is greater, transparent restitution does not occur, but a more or less opaque cicatrix forms. This is situated either at the level of the remainder of the cornea or it projects (ectatic corneal cicatrix; when larger, staphyloma of the cornea) or, becoming flattened, it may lead to diminution of the corneal surface. In its most marked development the latter constitutes phthisis corneæ.

The beginning of the period of recovery of most deeper ulcers, is characterized by the development of vessels in the cornea. They run from the limbus to the ulcer, whose base loses, at the same time, its dirty or deep yellow color.

If the ulcers continue to extend more deeply and destroy the cornea up to its hindermost layers, the latter no longer resist the pressure of the fluid in the chamber, when the loss of substance reaches a certain superficial area, and are bulged somewhat forward (hernia corneæ or keratocele). As this posterior layer of the cornea often is almost perfectly transparent, the condition may be overlooked on cursory examination, because the difference of level from the healthy cornea has been effaced. This is especially frequent, in some ulcers which appear in acute blennorrhœa or diphtheria. Focal illumination will here reveal the state of affairs.

When perforation occurs, the fluid in the chamber escapes, the iris and lens are applied to the cornea, and the pupil contracts. The diminution of the ocular contents causes marked lowering of intraocular pressure. A very violent ciliary neuralgia, which soon subsides, usually occurs at the moment of the sudden escape of the fluid in the chamber. If the opening is very small, the aqueous humor escapes slowly, and the opening may be closed before the fluid has entirely escaped. If the intraocular pressure increases, the fluid again escapes; it sometimes trickles constantly for days, although the anterior chamber is not restored (fistula corneæ). The smaller the perforation, the less is the danger to the eye. When the opening is very extensive, the lens and portions of the vitreous

may be discharged, and even abundant intraocular hemorrhages may occur. If a large opening is situated opposite the iris, the latter usually prolapses, and even if this is restored, adhesion of the iris to the cornea (anterior synechia) usually remains. When the perforation is smaller, the iris is merely applied to the cornea, but even this may give rise to permanent anterior synechia. The latter is most to be dreaded, when the edge of the pupil falls into the corneal opening. When the surface of the iris is applied to the opening, it is more readily pushed away from the wound by the reaccumulation of the aqueous humor. Prolapse of the iris appears, at first, as a black patch or prominence; later it assumes a slate gray color. If the fluid in the chamber collects behind it, it forms a tense vesicle. After it has lasted a long time, proliferation of the prolapsed iris usually occurs, and brownish-red granulation tissue is formed. During the period of recovery, small prolapses of the iris are pushed back by the whitish cicatrix which begins at the edge of the corneal ulcer so that finally a white patch, to which the iris adheres, is left over (leucoma adherens). In other cases, however, the part retains its black color even after recovery.

If the prolapse is very large, staphyloma develops as a rule, but occasionally we can see complete restoration of prolapses three to four millimetres in diameter and recovery on the level.

All anterior synechiæ involve a certain danger for the future, inasmuch as fresh softenings or, independently of these, secondary increase of pressure with secondary glaucoma may appear. Even grave inflammations, such as subacute or acute irido-cyclitis, may make their origin from them after the lapse of years, especially when circumscribed staphylomata of the iris, that have retained their dark color and thinness, have been left over in the vicinity of the corneal periphery.

After perforation of the ulcer or during its progress, the inflammation may extend, in the severer forms and in rare cases, to the choroid and vitreous, so that the eye may even suppurate.

Etiology.—1. External injuries that lead to loss of the epithelial layer, usually heal readily. It is only after infection of the wound, as by the secretion of a blennorrhœa of the lachrymal sac, that severe affections occur, such as, for example, the ulcus serpens. 2. Conjunctival affections. There are often small ulcers at the edge in phlyctenular conjunctivitis, also in the conjunctivitis of old people, chronic conjunctivitis and trachoma; severe forms are found in blennorrhœa and diphtheria. 3. Affections of the lids: trichiasis, entropion, ectropion. 4. Previous corneal infiltrations or abscesses. 5. General constitutional diseases, especially scrofula.

The *prognosis* varies according to the depth and size of the ulcer.

If perforation has occurred, the cicatrix which there develops does not usually disappear. In more superficial loss of substance, the originally whitish cicatrix clears up more and more in the course of years; those which have developed in childhood may become almost perfectly transparent. Certain forms which will be mentioned later, exhibit a perfectly typical course.

As regards treatment, the main principle is that a stimulating plan which furthers the development of blood-vessels in the cornea is indicated. It is only in cases in which the ulceration is directly dependent on conjunctival diseases (as, for example, in blennorrhœa) that the chief attention must be paid to the latter. Here the application of cold is indicated, while it is injurious in almost all other ulcers of the cornea. Moist warmth, whether from compresses of chamomile tea, antiseptic solutions or an antiseptic moist, warm dressing, is very useful in the majority of these cases. But we must be careful that notable conjunctivitis is not produced by the moist wamth. If necessary, it may be kept within bounds by direct application of a solution of tannin to the palpebral conjunctiva. In applying compresses, care must also be taken that no precipitates enter the ulcer, such as precipitated salicylic acid. For this reason solutions of lead are to be avoided as compresses. Atropine is instilled several times a day in order to place the eye at rest by abolishing accommodation and, at the same time, to prevent hyperæmia of the iris. Leeches are occasionally useful when the pains are severe. Arlt's forehead ointment may also be used as a derivative. A similar action is secured by applications of tincture of iodine to the forehead and temple or, if the integument of the lid is very much swollen, applications of acetate of lead, or transverse cauterization of the lid with the moist solid stick, followed by neutralization. When the ulcers are very deep and resist other modes of treatment, attempts have been made to secure more favorable conditions for recovery by covering them with a detached or pedunculated conjunctival flap (Schoeler, Kuhnt).

The remedies mentioned are chiefly employed so long as the base of the ulcer or its edge is still grayish-yellow and exhibits cheesy infiltration, and a reparative pannus has not developed. When this does occur and the surface of the ulcer, after its restoration, begins to shine, the expectant plan may be adopted, apart from atropinization and the use of an eye shield. Irritant instillations, such as diluted laudanum (1 : 5), the dusting of calomel, or introduction of yellow precipate ointment are useful in ulcers which are entirely destitute of irritation and remain stationary in the reparative stage, but as a rule they should not be employed. But if the ulcer has healed, calomel may be introduced for some time

afterward, in order to avoid relapses, if phlyctenular processes have been present.

In addition to this local treatment, general treatment is necessary whenever indicated. Great importance attaches to the treatment of scrofula with cod-liver oil, iodide of iron, etc.; cutaneous eruptions must be treated locally, especially if they are situated on the lids. The latter, as a general thing, tolerate poorly the moist warmth which is necessary for the treatment of the corneal ulcer and, in addition, by spreading to the edge of the lid they may give rise to croupy deposits there and on the tarsal conjunctiva. If we wish to apply compresses during the existence of the eruptions of on the lids (which are usually treated successfully with tar ointment or nitrate of silver), the skin must be protected by a piece of oiled

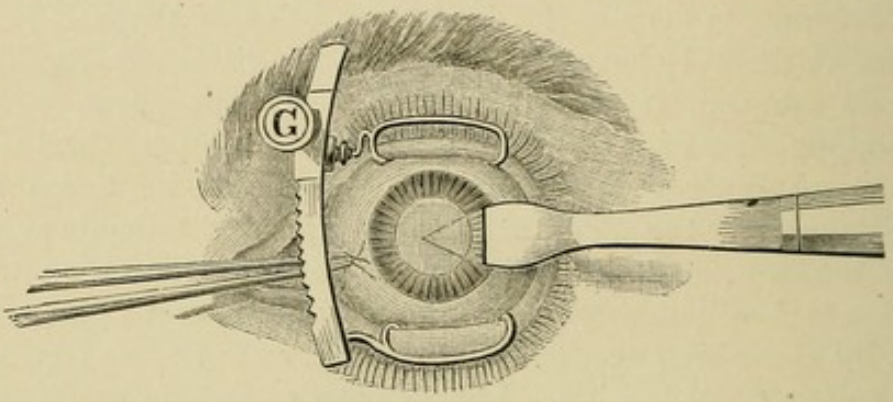


FIG. 141.—Paracentesis Corneæ.

linen. Quinine, wine, iron and generous food should be given to weak, poorly nourished patients.

When the ulcer approaches perforation, we must determine whether this should be performed artificially or left to nature. If the ulcer is small and funnel-shaped, nature may be allowed to take her course. But if the ulcer has a broader surface with more uniform thinning, puncture is preferable, because this produces only a circumscribed opening, while a much larger rupture of the base of the ulcer occurs after the later spontaneous perforation. Keratocele should always be punctured. In addition, early puncture stimulates the process of recovery, as a rule, inasmuch as the pressure against the thinned cornea is diminished after evacuation of the chamber. The puncture is made in the base of the ulcer, not in the healthy cornea. When the latter plan is adopted, the pressure of the knife upon the cornea often gives rise, at the same time, to rupture of the thin base of the ulcer, and on the other hand puncture of the ulcer, alone affords hope of a not too rapid closure of the wound and prolonged fistula. If the base of the ulcer projects a few days

after the restoration of the anterior chamber, the former wound must be reopened with the spatula.

If hypopyon is present, it is evacuated by the puncture; when the former is very fibrinous in character, thus preventing its escape, the part situated in the wound may be grasped with iris forceps and the clot thus extracted. But we need not attempt to evacuate all the pus because the absorption of small amounts occurs spontaneously. The hypopyon presents an indication for paracentesis only when it occupies more than a third of the anterior chamber and remains stationary.

If perforation is impending, or we desire to bring it about artificially, we must attempt to carry the rim of the pupil out of the area of the opening. According to the peripheral or central position of the ulcer, we instil eserine (or pilocarpine) or atropine, taking into consideration the fact that narrowing of the pupil occurs spontaneously after evacuation of the chamber.

Immediately after tapping, a compress and bandage are applied to relieve the temporary violent pains or cold compresses are made for a short time. If prolapse of the iris has developed, its puncture is necessary only when there is severe pain and vesicle-like protrusion of the prolapse. As a rule, the prolapse returns to its own level on the formation of the cicatrix. After it has lasted some time, cicatrization may sometimes be hastened by gentle touching with nitrate of silver. By such means, together with eserine and the applications of a compress and bandage, we can avoid, as a rule, excision of the prolapse which gives rise occasionally to dangerous inflammations. Patience and long-continued care are necessary. It is only exceptionally in cases of very large prolapses which do not return despite protracted treatment, that I consider excision indicated. This is done by making a lower flap with Graefe's cataract knife, grasping this with the forceps and then dividing the upper periphery of the prolapse with the scissors. This avoids the traction which would result from simple excision with the scissors. A few days after removal an increase of the prolapse usually occurs, but disappears later.

In severe cases the patients are kept in bed, in milder ones they remain in a moderately darkened room, with a shield or dressing over the eye. Walking in the open air is only allowed when the process is protracted, and very slightly inflammatory in character.

Among the manifold ulcers of the cornea a few characteristic forms are prominent. The most important one, ulcus serpens, has been discussed in the chapter on hypopyon keratitis.

Absorption and Reparative Ulcers.

These are small ulcers, about as large as a pin's head, which have very transparent base and no notable infiltration in the vicinity. The pericorneal injection is almost nil and the subjective symptoms are very slight. Healing corneal ulcers when their base is cleansed and the epithelium restored, occasionally exhibit this shining, facet-like appearance (reparative ulcers). In other cases this form of ulcer occurs primarily and progressively; in rare exceptions they even extend deeply like a crater and perforate. As they usually produce but slight disturbance, it sometimes happens that the patient is not affected by his ocular disease until the fluid in the chamber suddenly escapes.

As a rule, the course is very protracted, and reparative ulcers also remain stationary for a long time. In addition to protection to the eye and atropinization, we may recommend lukewarm compresses; in cases which are entirely free from irritation we may attempt to accelerate the course by the instillation of diluted tincture of opium (1 : 5).

Ulcus rodens.

An ulcer of a semilunar shape begins at the periphery of the cornea, and extends centripetally over its entire surface, specks of gray infiltration first appearing in the tissue immediately adjacent to the edge of the ulcer. These specks then coalesce, undergo degeneration, and exhibit an undermined rim. At a very early period paralled vessels run from the edge of the cornea to the ulcers. The process often extends by jumps and gradually wanders over the entire cornea, leaving a white cicatrix. Perforation and hypopyon are rare.

Treatment is usually ineffectual. A few cases have been cured by the application of the galvano-cautery. In one case I obtained a similar result by the use of antiseptic, lukewarm compresses and methodical scarification of the vessels at the edge of the cornea.

Annular Ulcers of the Cornea.

A long, narrow and slightly infiltrated ulcer forms at the edge of the cornea; it extends at the periphery and finally surrounds the entire cornea like a ring. The central portions remain tolerably transparent and the ulcer itself is not very opaque. As a rule, there is very marked injection of the bulbar conjunctiva. The prognosis is doubtful on account of the tendency of the ulcer to spread. In addition to antiseptic, lukewarm dressings, early and repeated paracenteses have given me the best results.

Keratitis dendritica (Furrow-Keratitis).

Linear prolongations proceed from a shallow corneal ulcer and subsequently ramify and, after exfoliation of the surface, are converted into narrow deep grooves with gray edges. There is often photophobia with pronounced epiphora. The process lasts several weeks on account of the constant new formation of the branches, and leaves characteristic opacities for some time (Emmert, Hansen-Grut). At the beginning the irrigation of the foci with a solution of corrosive sublimate and the application of eserine, appear to be useful.

2. Corneal Opacities.

The majority of corneal opacities or patches are the result of a previous inflammation, inasmuch as there has been no restitution of a perfectly transparent tissue. Similar processes may also be suspected in certain congenital opacities of the cornea which subsequently clear up in a striking manner. Furthermore, burns, cauterization with lime, etc., occasionally lead directly to destruction of the corneal tissue, in whose stead cicatricial connective tissue appears afterward.

The opacity appears as a deep white patch (leucoma) or is more transparent and slighty gray (macula) or it is entirely transparent (nubecula). Vessels sometimes pass into it (vascularized corneal opacity), but then the opacity cannot be regarded as fixed.

As a rule, the curvature of a cornea suffering from opacities is more or less irregular; this is seen distinctly with the keratoscope. The visual disturbances result from the irregular astigmatism, associated with the occlusion or dispersion of light, resulting from the patch. They are most prominent when the opacity, situated in front of the pupil, shuts off the light. If the entire pupil is covered by a large central leucoma, vision is diminished as in a cataract patient.

Small patches in the pupillary tract are less important as regards vision; deep white patches are léss disturbing than grayish transparent ones of equal size because the former, while they exclude more light, interfere less with the formation of a sharp image on the retina, while the latter blur the retinal image by their dispersing action. Eyes suffering from corneal opacities are often myopic. The patients not infrequently state, that they did not become short-sighted until after the disease of the cornea.

Donders claims that patients suffering from corneal opacities often are only apparently myopic, and that their increased vision with concave glasses depends upon the following fact. The accom-

modation with which they neutralize the lenses, causes the pupil to contract and thus excludes a part of the rays that are refracted irregularly by the corneal opacity. But the large majority of the patients are really myopic, and sufficient explanation of the occurrence of this error of refraction is furnished by the fact that the patient, on account of the impaired vision, must bring objects closer to the eye in near work.

Monocular diplopia also results occasionally from opacities of the cornea.

There is often a tendency to renewed softening of the opacities. Ulceration then occurs and even fresh infiltrations of pus. The previous history and the presence of a few intact remains of the old opacity, usually enable us to make the diagnosis of "recently softened corneal opacity" and to exclude a fresh infiltration or ulceration. As a rule, the old patches have a sharper definition and smoother surface than the infiltrations. They also lack the yellowish tinge which is often exhibited by the infiltrations. Moreover, the absence of injection and irritation must also be considered.

The diagnosis of opacity is easy when there are marked changes in transparency, which can be seen with the naked eye, but very slight opacities are often recognized with great difficulty. Here it requires the skilful use of focal illumination in which the light focus is thrown upon, alongside of and behind, the suspected spot in order to arrive at a definite conclusion. This becomes positive when, in a larger suspicious part, we surely recognize even small circumscribed spots as opaque. We may also use the incident light of the ophthalmoscope, without the concave lens. When the opacity is deep, a more or less dark, gray patch forms upon the red of the illuminated fundus. Examination with the ophthalmoscope —the plane mirror has been especially recommended—is less reliable for very transparent opacities than skilfully used focal illumination. If the opacities are extensive, a peculiar distortion of the optic papilla occurs in ophthalmoscopic examination with the reverse image, especially when the convex lens is moved a little to one side. The diagnosis of slight and transparent opacities possesses great importance; many apparent amblyopias are due to corneal opacities. The positive exclusion of such optical obstructions is particularly important to military surgeons who are so apt to suspect simulation in amblyopia without objective findings.

The medicinal treatment of corneal processes, which have run their course, usually possess slight importance. The opacities diminish spontaneously in the course of years; this is most apt to occur when young people have been attacked. But a patch remains behind, as a rule, when the opacity has been preceded by

perforation of the cornea and a white cicatrix has formed at that spot. We must avoid the premature use of irritant remedies to clear up the opacity. It is much more important to cause the most complete recovery of the affection possible, by sparing the eye and the prolonged use of atropine. Our immediate object is to prevent new inflammations. Coexisting conjunctival diseases or the tendency to phlyctenular formations or chronic inflammations of the lachrymal sac, must be treated. Treatment of the opacities should be reserved for a future period. For this purpose instillations of oil, dilute tincture of opium, the spray of warm vapors, dusting of calomel or yellow precipitate ointment, subconjunctival injection of a solution of sodium chloride (Rothmund), potassium iodide in solution or ointment (potassium iodide, 1.0; sodæ bicarb., 0.5 to 15.0), massage, the constant current and electrolysis have been recommended. In slighter opacities—not leucoma proper—electrolysis is used in the following manner. The button-shaped zinc pole of a battery of about four elements, is placed directly on the opacity and rubbed across it for ten to twenty seconds, while the copper pole is placed close to it. If necessary, the application is repeated in a few weeks. In the employment of all these remedies we must be careful that fresh softening and purulent infiltration of the patch, does not occur as the result of excessive irritation.

If there are foreign bodies, such as deposits of lead or lime incrustations, in the opacity, we should attempt to remove them with the cataract needle.

If the pupil is covered by an opacity in such a way, that no light enters when the pupil presents the normal size, lateral entrance for the rays of light may be secured by an iridectomy. These optical pupils are made preferably toward the inside because here the peripheral rays are excluded by the nose. Colobomata above or below are apt to be covered too much by the lids. The pupils should be made narrow and should not extend too far toward the periphery. In individual cases—when the lens is absent—iridotomy is preferable on account of the narrowness and less periphericity of the opening. If the pupil is not covered entirely by the opacity, so that light may enter on one side of it, the question must be weighed whether a more periphereal opening, such as that made by iridectomy, will really secure an improvement in vision. It sometimes even grows worse, because too much irregularly refracted light gains entrance. An approximate opinion as to the effect, may be obtained by dilating the pupil with atropine. If this improves vision, then a skilfully made artificial pupil will do the same. It is to be remembered that even in optically favorable cases, vision sometimes grows worse in the first period after the operation, be-

cause the cornea situated over the artificial pupil becomes somewhat opaque. It is usually old, very transparent opacities that now appear more distinctly, but, as a general thing, they clear up after a while. If the pupil is covered by an opacity which is not deep, while but transparent and which refracts the light very irregularly, improvement may be effected in some cases by making an artificial coloboma on the side and making the opacity non-transparent by tattooing with India ink. Vision is sometimes improved considerably by stenopaic spectacles, but this is useful only to a limited extent because the field of vision is thereby narrowed very much.

When only a small peripheral zone of the cornea is transparent, the excision of a piece of the iris may also be attempted, but this usually succeeds very poorly, on account of the frequent complication with callous adhesions and atrophy of the tissue. As a rule, these are sad cases, in which, despite the normal retinal function, it is impossible to effect an entrance for the light. In very recent times, attempts have been made to replace the opaque cicatricial tissue in the centre of the cornea, by a transparent medium. Thus, after excising or trephining the central piece of the opaque cornea, the attempt was made to insert a piece of glass shaped like a shirt botton (with anterior and posterior plate and a connecting piece) or to allow pieces of a freshly excised rabbit's or human cornea (from the extirpated globe) to heal in the defect, according to the method recommended by Himly, Wolfe and recently by Power. Hitherto no permanent results have been obtained; the glasses fell out and the transplanted corneæ, in so far as they persisted at all, became opaque. But v. Hippel recently succeeded in inserting a round disk of the rabbit's cornea into the trephine opening of a leucomatous cornea (the innermost layers of which had been allowed to remain) and preserved its transparency. As a matter of course, this method can only be useful when the innermost layers of the cornea are still transparent.

Operations may sometimes be performed for cosmetic reasons, in cases in which no improvement of vision can be expected. The annoying white patches may be made invisible by tattooing with India ink (Wecker). A cataract needle or a bundle of four ordinary needles, grasped in a clamp, is used for the slight operation. After the lids are separated by a clamp elevator, the patch is smeared with the not too thin India ink and the needles pushed several times into the leucoma, moderately deep and in a slightly oblique direction. The India ink enters the little openings and will adhere there if the patient is allowed to lie with open eyes for about half an hour, in order that the ink may not be wiped away. In order to

test the reaction of the eye, only a few pricks should be made at the first sitting. This is particularly necessary when the iris is adherent to the cicatrix. Fixation of the globe at the conjunctiva should be avoided, in order that the ink may not accidentally be deposited there and leave a spot. A tolerably uniform color, which lasts for years, can be obtained by a series of sittings, repeated every couple of days.

Band-shaped Corneal Opacities.

Band-shaped keratitis is a more genuine disease than the allied ordinary corneal opacities. A non-transparent, whitish, band-shaped opacity is found passing transversely through the middlle of the cornea and usually starting from the temporal and nasal sides. Inflammatory symptoms, which are connected with the corneal disease, are entirely wanting. As a rule, the eyes had been diseased long before, and had suffered especially from iridocyclitis. But healthy, non-myopic eyes are attacked occasionally, chiefly in old people, and other changes develop later. Here the impairment of vision corresponds to the optical obstruction. Iridectomy may have a good effect (v. Graefe). Scratching off the opaque layer is useless, as a rule, although it depends in part on the deposit of lime salts.

Gerontoxon.

Gerontoxon (arcus senilis) appears as a whitish opacity, one to one and a half millimetres broad, with a smooth surface which is situated at the rim of the cornea, but is usually separated from the sclera by a narrow line of transparent corneal substance. At first it appears most frequently as a half-moon at the upper and lower borders; later, the nasal and temporal borders are also affected. It does not give rise to visual disturbances. As a general thing, this opacity does not appear until an advanced age, and is due to fatty degeneration of the corneal cells (His).

3. Changes of Curvature.

I. Cicatricial Staphyloma.

Projections often develop after cicatrices of the cornea which have developed after extensive losses of substance and perforation. This condition is known as staphyloma (σταφυλή the grape); it is total when the entire cornea protrudes. The cicatricial tissue usually has a deep white color. It is only in rare cases of partial staphyloma, that a darker color is permanently produced by the

iris which has fallen into the loss of substance in the cornea. The shape of the protrusion varies. It is sometimes quite uniform and spherical, sometimes very conical and snout-shaped. It may be so pronounced that the eyelids cannot be closed. The surface then exhibits spots of irregularity and dryness. The iris is always ad-

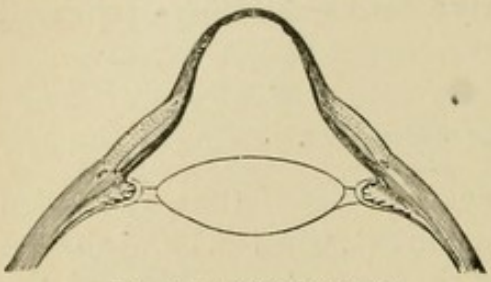


FIG. 142.—(After Stellwag.)

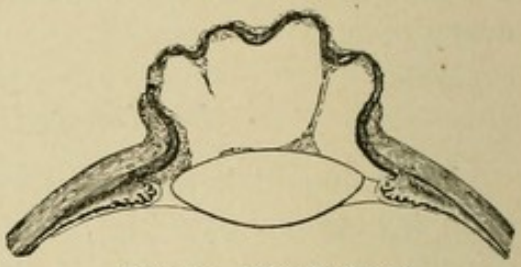


FIG. 143.—(After Stellwag.)

herent to the cicatrix apart from the extremely rare cases of partial staphyloma.

The origin is explained by the fact that the parts in question can no longer resist the intraocular pressure. Extensive losses of substance after ulcerative processes (particularly hypopyon-keratitis) are the most common causes, more rarely injuries. In some cases the lens has been evacuated with the exception of scanty, opaque, cylindrical remains; in others, it is dislocated and lies in the staphyloma; it rarely remains entirely intact in long-continued processes. Even apparently transparent lenses exhibit microscopical changes. In a lens of this kind, which was evacuated from a staphylomatous and not yet cicatrized projection occurring after perforation of the cornea and prolapse of the iris, I found on examination, made at once, nuclei and detritus lying close to the

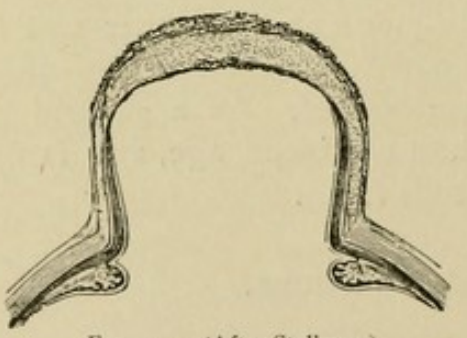


FIG. 144.—(After Stellwag.)

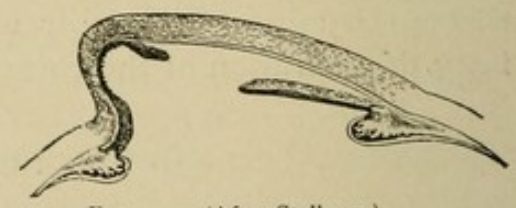


FIG. 145.—(After Stellwag.)

capsule of the lens in which ramifying fine capillaries were distributed. In the lens itself there was fine granulation and an accumulation of numerous nuclei of various sizes, in the fibres which were situated near the capsule; in other parts the fibres were normal, except that I noticed a few parallel lines, composed of very fine, irregular drops. These are regarded by Becker as fat granules.

Extensive staphyloma results, as a rule, in secondary changes in the posterior part of the globe, resulting in increased intraocular pressure and glaucoma. Externally this sequel is shown by the abolition of the narrow groove between the cornea and sclera or the development of a bluish prominence in the sclera. Even partial staphylomata often give rise to secondary glaucoma.

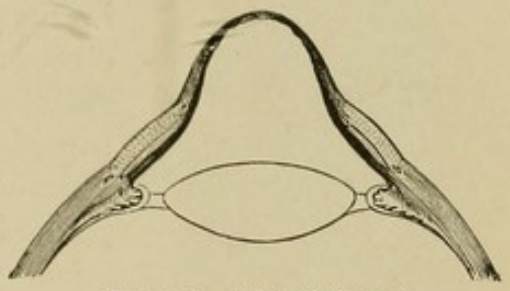


Fig. 146.—(After Stellwag.)

The visual disturbances correspond to the optical obstruction. Satisfactory vision may therefore be present in partial staphylomata which are not situated centrally. If the vision is not longer proportionate to the opacity—even in total staphyloma the vision of cataractous patients should be present approximately—complications must be assumed to be present. Increased tension usually indicates secondary glaucoma.

The *treatment* must endeavor to prevent the development of staphyloma by the proper attention to the causal affections, particularly prolapse of the iris. If partial protrusion occurs, its resolution can often be secured by an early iridectomy. This operation is indicated in the majority of cases in order to prevent the frequent secondary glaucomas. An improvement can also be obtained by an incision with the narrow knife, dividing the iris, which has been drawn to the corneal cicatrix, from its ciliary insertion. When the luxated lens is situated in the staphyloma, a good effect is obtained, especially at the beginning, by a simple transverse incision that permits the evacuation of the lens. If the staphyloma is closed and more extensive, it may be removed if it annoys the patient or is the site of irritative conditions. In total staphyloma the enucleation or exenteration of the globe instead of removal of the staphlyoma will come into question. Both have a shorter period of recovery, and when the increase of intraocular pressure is very great, are preferable to ablation on account of the abundant hemorrhages and the panophthalmitis which often follow the latter operation. But the former operations do not furnish such a good stump for an artificial eye to be worn subsequently.

Beer's ablation is the simplest of all the different staphyloma operations. Beer's cataract knife is passed transversely through the staphyloma as in the flap incision for extraction of cataract, a lower flap formed, grasped with the forceps and the upper periphery divided with the scissors. As a rule, this is followed by discharge of the vitreous, so that the operation must be performed somewhat rapidly, and the eye closed forthwith with a compress and bandage.

Hemorrhages into the interior of the eye may occur if the globe is very tense. Wecker's staphyloma operation is similar except that, prior to removal, he separates the conjunctiva from the sclera around the cornea and then carries a silk thread through its corneal periphery with in-and-out stitches, like the band which closes the opening of a tobacco pouch. After removal of the staphyloma the opening in the globe is closed by putting on the conjunctival suture, so that the conjunctiva is pushed in front of the opening. Critchett effects closure in another way. Several curved needles armed with silk threads, are passed vertically through the globe behind the scleral limbus, entering above and emerging at the lower edge of the cornea. During the operation they form a grating which keeps back the vitreous. After removal of the staphyloma is completed (according to Beer's method), the needles are removed; the wound, stitched with the threads in question, forms a horizontal line. Apart from the snout-shaped, projecting temporal and nasal angles,

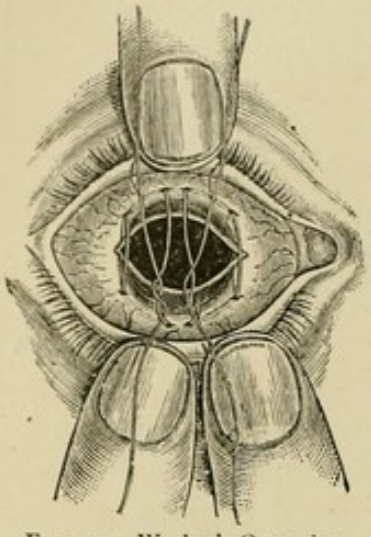


FIG. 147.—Wecker's Operation.

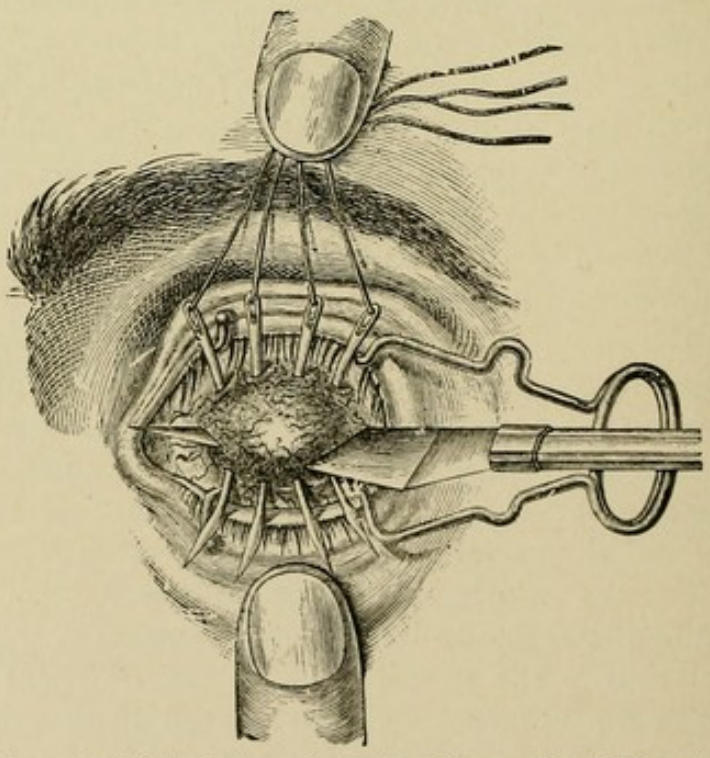


FIG. 148.—Critchett's Operation for Staphyloma. (After Stellwag.)

the ciliary body is often endangered by the sutures and needles, and the possibility of a sympathetic affection of the other eye is thus presented.

II. Non-cicatricial Kerectasiæ.

These have a spherical shape or are more conical.

The spherical protrusion of a transparent or slightly opaque cornea (cornea globosa) is found most frequently in hydrophthalmus or buphophthalmus; it is generally congenital and develops further in the first year of life. Smaller prominences also occur after pannus. Vision is disturbed by abnormal refraction and irregular astigmatism. In the pannous projections iridectomy may be useful on account of its influence upon the iritis or intraocular pressure. It is less indicated in hydrophthalmus. It is better to try eserine or sclerotomy.

The conical form occurs typically as keratoconus (staphyloma pellucidum). Beginning generally at the age of twenty years, and gradually increasing, the transparent cornea assumes the shape of a sugar-loaf hat, whose apex is sometimes a little opaque. As there are no inflammatory symptoms, the patients consult the physician merely on account of impairment of vision. There is often polyopia, usually myopia. As a rule, both eyes are attacked. The process may become stationary spontaneously.

In the beginning the diagnosis is not always easy. The change of shape is shown by the irregularity of the reflex images of the cornea (for exampe, with the keratoscope), because the enlargement of the images is less at the centre, on account of the greater curvature, than at the periphery. With the advance of the process, the abnormal shape can be seen directly on profile view. Ophthalmoscopic examination also discloses the irregular astigmatism. The condition appears to be a genuine disease of the cornea, consisting of a diminution of resistance.

Treatment.—We should endeavor to get the greatest possible correction with lenses (spherical and cylindric). Hyperbolic lenses have recently been ground, and with these considerable improvement can be obtained in a number of cases. In order to prevent the progress of the disease, Pickford recommends general tonic treatment and abstinence from all work with the eyes—a plan which has been successfully practised by Arlt in some cases. Rampoldi extols long-continued atropinization. A series of operative procedures have also been tried. Iridectomy was employed originally, but without benefit. Then v. Graefe attempted to obtain flattening by establishing a cicatricial process at the apex of the cone, and improvement was really obtained in this way. A small piece of superficial corneal tissue is removed from the centre of the cone, and an ulcer is produced by applications of nitrate of silver; perforation is brought about subsequently with the paracentesis

needle. The small cicatrix which then forms produces sufficient flattening. If the leucoma becomes too large, an iridectomy may be made later. The latter is always done in Bowman's operation, in which a central piece of the cornea is removed directly with a small trephine. This plan is not free from danger, because extensive adhesions of the iris to a large central cicatrix usually develop.

III. Flattening of the Cornea (Phthisis Corneæ).

Flattening of the cornea occurs after some extensive losses of substance, because the cicatrix contracts and becomes flat, and the remaining transparent portion is also flattened by the stretching. The diminished secretion of the fluid in the chamber also plays a part in the process. After panophthalmitis or keratomalacia, a piece of the cornea barely as large as a hempseed sometimes remains. It is situated in the anterior part of the more or less shrunken globe, and often retains a certain degree of transparency.

4. Injuries to the Cornea.

It is generally small foreign bodies, such as grains of sand, pieces of cinders (for example, in railway travel), bits of stone, and pieces of iron, which have been made to glow in welding, that enter the cornea and produce superficial losses of substance. Very careful examination, sometimes with the use of focal illumination, is often necessary to recognize the punctate particles. Apart from the history, in which the sudden occurrence of pain and epiphora usually indicate the moment of injury, suspicion will be aroused when a delicate rosy pericorneal injection is found in one eye, without other inflammatory changes. The delicacy of this injection is almost characteristic of foreign bodies upon the cornea.

The *treatment* is directed toward removal of the foreign body, which is removed with a cataract needle after the application of cocaine. Particles of iron may require a sort of etching, one plate being removed after the other. Too extensive detachment of the epithelium should be avoided, and the needle should be placed only at the side of the foreign body. Fixation of the globe with the forceps is usually unnecessary. The lids may be kept apart with the left hand and a firm position given to the eye by a certain amount of pressure. It is not always well to scrape off the finest particles. Sometimes we have finally only a mere discoloration of the tissue itself—a discoloration which may resemble a foreign body. If the removal is very difficult, we may wait a few days until the beginning suppuration has loosened the foreign body. A somewhat larger cicatrix, however, is then left over. [In such cases,

if the removal be difficult or dangerous, the patient should be placed under general anæsthesia and the removal accomplished.—St. J. R.] The use of the magnet for splinters of iron in the cornea possesses no special importance. If they are situated so loosely as to follow the magnet, they can also be removed easily with the cataract needle. If the eye is in an irritated condition, atropine is instilled after the removal of the foreign body, and cool compresses applied.

In one event, however, a certain caution is necessary even in the case of small foreign bodies, viz., when they have penetrated very deeply into the cornea or even project into the anterior chamber. Pushing them into the anterior chamber is always very serious, because they usually sink into the angle of the chamber and are lost to sight so that they cannot always be grasped, even after division of the cornea with a lance-shaped knife. In such an event the corresponding portion of the iris should be excised, if the site of the foreign body is known with probability. In order to prevent the foreign body, which has penetrated into the cornea, from falling into the anterior chamber, a narrow lance knife should be passed into the chamber, before attempting extraction, and its flat surface should press the foreign body against the cornea from behind. [A Beer's knife used in this way, as recommended by Agnew, is much better than the narrow one.—St. J. R.]

Larger wounds of the cornea are often made with scissors, knives, broken glass (also with broken spectacles); blunt objects may also produce corneal wounds. These are occasionally so large that the lens and vitreous are discharged at once. In one case I saw pieces of the retina in a corneal wound made by a cow's horn. Here early enucleation of the globe is indicated. When the wound is smaller and the injury to the eye less, we should attempt to save the eye. Wounds which run across the rim of the cornea deep into the scleral limbus, are always grave, because there is danger of cyclitis and sympathetic affection of the other eye. The septic or aseptic condition of the wounding object also plays an important part. After cleansing the wound with a solution of corrosive sublimate—if the iris has prolapsed into the wound in case it is impossible to restore it at once by means of myotics or mydriatics—it should be excised and atropia employed. A compress and bandage should be applied as after cataract extractions. Dusting of iodoform also appears to be useful. When the pains are violent, ice compresses are applied at times. If swelling of the lens substance and iritis, occur subsequently from injury to the capsule of the lens, strict antiphlogosis, with vigorous atropinization are required. If the intraocular pressure is also increased, a broad iri-

dectomy, the swollen masses of the lens being evacuated at the same time, is indicated.

The question not infrequently arises, Has a foreign body passed through the cornea into the interior of the eye? Above all, we must carefully determine the manner in which the injury occurred, and the kind of object which inflicted it. Unless the injury was inflicted by a large object, small corneal wounds, in which iris tissue is situated, always favor the view that the offending particle has passed through the cornea into the interior of the eye. This suspicion is increased still further, when opacities are found in the lens or the vitreous body. The absence of all visible changes in the lens, is no opposing reason, because the foreign body may have passed into the vitreous through the zonula Zinnii.

More extensive injuries of the cornea arise from burns and cauterization. Lime, chemicals, exploding powder or glowing iron which spirt into the eye, often cause loss of sight. In such cases, a too favorable prognosis should not be made on account of the apparent transparency and clearness of the cornea, such as are found immediately after the injury. The opacity does not occur sometimes for several days. Here focal illumination must always be used, in order to be able to see the destruction of the corneal layer.

The treatment consists in removal of the entered masses; in other respects the remarks made concerning conjunctival injuries hold good. Cold compresses are used to relieve the primary inflammation; later, we carry out the other therapeutic rules that obtain in corneal affections.

5. Tumors of the Cornea.

Primary tumors of the cornea are extremely rare. Its tissue is only attacked secondarily by tumors which have developed in the interior of the eye and grow outward (sarcoma and glioma) or by those which have developed upon the corneal limbus in the conjunctival covering. Special importance attaches to tumors at the corneal limbus; as they gradually enlarge they extend into the pupillary tract, and may thus disturb vision. As a rule, only the superficial layers of the cornea take part in the new growths. These consist usually of sarcoma, particularly melano-sarcoma.

The prognosis should be guarded because relapses, even metastases, are to be feared. Early extirpation is always indicated; as a general thing, the tumor can be scraped off from the most superficial layers of the cornea. If the growth has penetrated deeply, particularly in the scleral tract, enucleation of the globe alone remains. In addition to sarcoma, epithelioma and melano-cancroid also occur (vide Tumors of the Conjunctiva).

CHAPTER V.

DISEASES OF THE SCLERA.

Anatomy.

The sclera forms the external elastic capsule of the globe. At the nasal side of the posterior pole the optic nerve enters, and its connective-tissue sheaths ramify in it. Anteriorly it passes into the cornea. At first the innermost layers assume the transparent character of the cornea, while the outer layers retain their opacity for a short distance (scleral or corneal limbus). Shortly before the transition the sclera contains a venous plexus which run around its entire periphery like a circle (sinus venosus [Leber] or Schlemm's canal). The sclera is thickest posteriorly, becomes thinner anteriorly, and is thinnest in those places which are situated below the tendinous insertions of the muscles. The latter reinforce it somewhat. It is penetrated by nerves and vessels that pass to the interior of the eye. At the posterior pole the posterior ciliary vessels enter, a little in front of the limbus the anterior ciliary vessels enter. They supply the iris, and in part form long canals. The scleral tissue consists of coarse bundles of connective tissue; the innermost layers contain pigment cells. Calcification is often found in the sclera in old age, and also in the thickened scleræ of the phthisical globe; ossification may also occur in the latter.

1. Episcleritis and Scleritis.

In inflammations of the sclera which are observed on the surface covered by the conjunctiva, only the superficial layers of the tissue are usually affected, but the overlying episcleral or subconjunctival tissue is usually implicated. Here the most striking changes are often seen (episcleritis). At the beginning of the affection we see, at some distance from the cornea, a small bluish-red irregular patch in the sclera, above which the injected conjunctival vessels pass. Then follows infiltration of the overlying tissue, often with a hump-shaped elevation, which may exhibit a certain similarity to broad phlyctenulæ of the conjunctiva. In the latter, however, the infiltration is situated in the surface of the conjunctiva, while, in scleri-

tis, the conjunctiva may be moved to and fro across the elevation, to a certain extent. In addition, the characteristic fascicular injection of the posterior conjunctival vessels is generally absent. Moreover, that form of broad phlyctenulæ which may give rise to error, is situated close to the scleral limbus, while in scleritis and episcleritis the highest point is situated at some distance from the limbus. On the other hand, the episcleral tissue may not be involved. The scleritis is then characterized merely by the occurrence of larger or smaller bluish-violet patches.

The unaffected part of the globe often remains entirely pale and free of injection. The subjective symptoms are also very slight. Severe epiphora, photophobia, and considerable pain are rarely present.

In a number of cases the process remains confined to the sclera, but in others affections of the cornea, iris, and vitreous make their appearance. The cornea exhibits grayish infiltrations, which develop in patches, starting from the rim and situated in the deeper layers. They do not exhibit a decided purulent color or a tendency to ulceration. After recovery they disappear, and leave hardly a trace, except that gray opacities often remain at the rim and look like a prolongation of the sclera on the cornea (sclerotic opacities). Iritis, usually of the serous variety, is commonly associated with the corneal affection. Opacities of the vitreous are not infrequent in these cases.

The disease, whether complicated or not, is very protracted, and may last many months, even one or two years. Relapses appear occasionally at other parts of the sclera. One eye is first attacked, but sometimes the other is affected later.

The prognosis of simple scleritis is, on the whole, favorable; the affection either recovers completely, or permanent violet discolorations remain. The complications are more important, but even despite them satisfactory vision is usually retained.

The disease occurs mainly in adults, particularly at the beginning of the twenties and again in later life. We sometimes find rheumatic causes, syphilis, scrofula, abdominal plethora, anæmia, menstrual disorders. Jacobson has occasionally observed scleritis ophthalmoscopically, in children in the region of the posterior pole of the eye (associated with choroiditis) after measles and variola.

The local treatment of uncomplicated scleritis may be expectant. At all events, irritant measures (yellow precipitate ointment, etc.) should be avoided in the beginning. Atropinization and the use of the forehead ointment often suffice; if the pains are violent, leeches and opiates may be used. Lukewarm compresses of chamomile tea for half an hour several times a day or the moist warm com-

press and bandage are sometimes indicated. Scarifications and massage, with cocaine ointment, are useful when there is considerable infiltration of the tissue. If iritis develops, more vigorous atropinization is necessary. When the iritis is very violent and threatening opacities of the vitreous have also formed, we should resort to general mercurialization (by subcutaneous injections of corrosive sublimate 0.01 daily). This is well borne even by anæmic individuals if stimulant measures are also adopted. Sweat cures may also be tried. [Especially with pilocarpine, which I have found efficacious.—St. J. R.]

Suitable general treatment is usually required in this disease, which is often evidently connected with a constitutional diathesis. Salicylate of soda is especially praised by some when there is a rheumatic etiology. When no special indication can be discovered, the prolonged use of cod-liver oil seems to be useful.

2. Ectasia and Staphyloma of the Sclera.

General distention of the sclera is found in congenital buphophthalmus; it is usually thinned at the same time. In corneal staphyloma the anterior portion of the sclera is sometimes distended

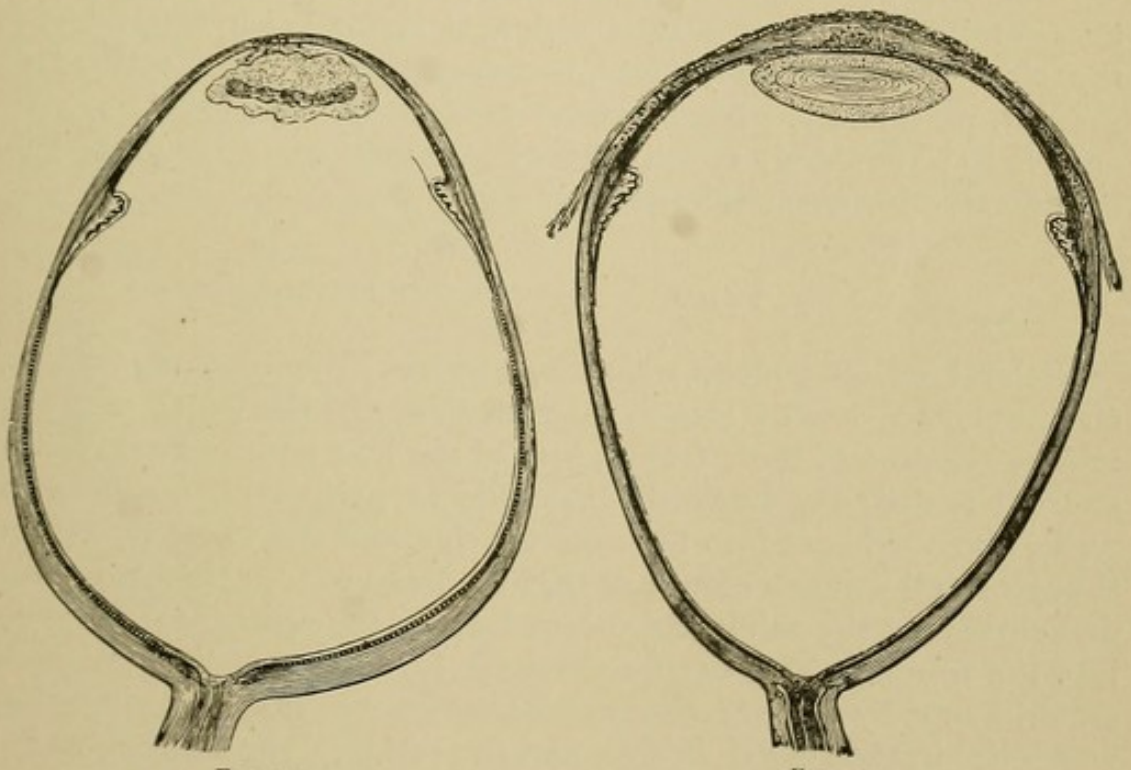


Fig. 149. Fig. 150.

Scleral Staphyloma. (After Stellwag.)

uniformly; here the abolition of the sulcus between the cornea and sclera is especially characteristic.

Partial protrusions occur in the neighborhood of the rim of the

cornea, in the conjunctival portion and immediately alongside the optic nerve. The latter, first described by Scarpa as staphyloma posticum, and then interpreted by Arlt as an accompaniment of myopia, has been described under errors of refraction. The staphyloma of the anterior part of the sclera has a bluish-black color and arises from protrusion of the thinned sclera and the adherent uvea. It is sometimes situated close to the edge of the cornea between the iris and ciliary body (staphyloma intercalare) and, in rare cases, surrounds the entire cornea as a swollen ring. The more equatorial protrusions may be mistaken for choroidal sarcomas, which push the sclera forward. On focal illumination the staphylomas proper are usually transparent and allow the passage of light, and this is not true of tumors. Circumscribed scleral protrusions are also observed occasionally in purulent inflammations of the vitreous, although perforation of the pus does not always take place. As a rule, vision is almost completely lost in the circumscribed staphylomas, because other ocular affections are present, particularly glaucomatous processes. Operative interference is to be avoided; enucleation or exenteration of the globe may be indicated for cosmetic reasons.

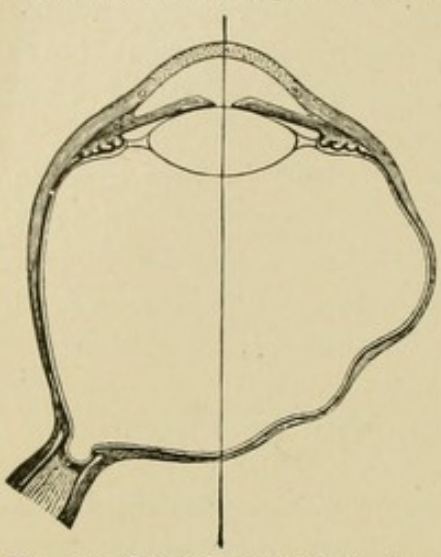


FIG. 151.—Sclero-Choroidal Staphyloma. (After Stellwag.)

3. INJURIES OF THE SCLERA.

Scleral wounds, made with more or less sharp and pointed instruments, are usually associated with injury of the uveal tract and retina. Escape of the vitreous, loss of the lens and prolapse of the choroid and ciliary body are the rule in perforating wounds, as well as hemorrhages into the anterior chamber and vitreous. Even though small wounds seem but slightly dangerous in the beginning, detachment of the retina may occur later as the result of its healing into the wound. This occurs particularly, as shown by Schoeler's experiments, by a connective-tissue union between the conjunctiva, which lies in the scleral wound, and the retina. The injuries which involve the region of the ciliary body are especially dangerous because the resulting cyclitis often induces sympathetic affection of the other eye.

Rupture of the sclera may occur from blunt force. If, for example, the lower anterior portion of the sclera is struck violently by

a blunt object, compression of the globe occurs in the direction from below and in front, upward and backward through the centre. The contents of the globe yield and stretch to the greatest extent the wall of the globe in the equator which is perpendicular to the line of direction of the force. The walls may rupture if unsupported by the orbital fat or the muscles (Arlt). In fact, the majority of scleral ruptures are found running equatorially, a few millimetres from the corneal limbus. The escaping vitreous and lens then remain beneath the conjunctiva.

The *treatment* depends upon the size, shape and position of the wound. If it is very large and considerable vitreous has escaped, if the choroid is situated in the wound, and above all, if the ciliary body is involved, immediate enucleation is the best remedy. In such cases, protracted inflammations would be unavoidable, no notable degree of vision can be expected, and the danger of a sympathetic affection is imminent. If the wound is not too large, and the ciliary body is not affected, we should attempt to secure healing. If possible, the scleral or, at least, the conjunctival wound should be closed with sutures. After suitable cleansing, some iodoform is dusted in, and an antiseptic compress and bandage applied. When the pain is very severe, narcotics are administered or ice compresses are alternated with the compress and bandage. The further treatment is the same as that after cataract extraction. If internal purulent inflammations develop, we may try abstraction of blood and occasional cold compresses. In pronounced purulent choroiditis and panophthalmitis, relief from pain is often secured by poultices, which must be very small and light, or constant lukewarm compresses.

Burns and cauterization occasionally destroy the superficial layers of the sclera with the conjunctiva, so that the uvea shines through with a bluish-gray color.

4. Ulcers and Tumors of the Sclera.

In very rare cases perforating ulcers have been observed in the sclera. Primary tumors of the sclera—apart from those in the scleral limbus which have been described above—are also remarkably rare; sarcoma and fibroma (Saemisch) have been described. Gliomata of the retina, like sarcomata of the choroid, find a great resistance in the sclera and attack it very late, and then only partially. Dark violet or blackish-brown patches (melanosis scleræ) are found congenitally, associated occasionally with similar pigmentations in other parts of the body.

CHAPTER VI.

DISEASES OF THE IRIS.

THE anatomy of the iris is found in the section on the anatomy of the uveal tract.

1. Hyperæmia of the Iris.

Hyperæmia of the iris is observed secondarily in very many acute affections of the eye, particularly in acute granulations, blennorrhœas, keratitis, scleritis, choroiditis, and cyclitis. It is also seen after external injuries which affect other parts of the globe. The hyperæmia is characterized by a change of color, arising from an admixture of reddish-yellow. A blue iris becomes deep green, a gray iris dirty green, a brown or black iris reddish-brown. In addition, there is slow contraction of the pupil to light and a tendency to myosis. Occasionally there is a slight pericorneal vascular ring. If the injection is more marked and the iris loses its gloss, we have a true inflammation.

The course varies according to the cause of the affection. The hyperæmia sometimes subsides rapidly, sometimes it develops into an iritis.

The treatment is directed toward preventing the occurrence of iritis by combating the primary disease. Above all atropine is advisable.

2. Iritis.

I. SYMPTOMATOLOGY.

Discoloration and loss of lustre, with slowness in the movements of the pupil, are the characteristic symptoms of iritis. Narrowness of the pupil and adhesions of the iris to the capsule of the lens (posterior synechia) are often added. In order to recognize the latter, which gives rise to irregular shape of the pupil, the instillation of atropine is sometimes necessary. Pericorneal injection may be absent in chronic cases. This must be remembered, because otherwise the disease is apt to be overlooked, to the detriment of the patient.

A. Objective Symptoms.

1. Hyperæmia of the conjunctiva and subconjunctival tissue. In very severe acute iritis, the cornea is surrounded by a violet-red ring, one and one-half to two millimetres broad, in which we can hardly distinguish the individual vessels. The posterior conjunctival vessels are occasionally injected, and are connected with the anterior pericorneal vessels. Moderate serous infiltration of the subconjunctival tissue is found, particularly at the very outset of the inflammation, and there may even be a slight chemotic ring around the cornea.

2. Discoloration of the iris. The different shades of color have been considered under the head of hyperæmia of the iris. Sometimes the discoloration is only partial. In very chronic iritides (as, for example, in irido-cyclitis, retinal detachment, etc.) the iris may assume a parrot-green color.

3. Loss of lustre. A normal iris has a slightly shining surface, in iritis this becomes dull.

4. Loosening and atrophy of the tissue. Certain parts appear swollen, and these often have a decided yellow color, due to purulent infiltration. Small nodules from the size of a pin head to that of a millet-seed occur occasionally, partly of a deep yellow color (accumulation of pus), partly of a rusty color (in condylomata and gummata) or whitish (tubercles and granulomata). In uniform infiltration the color and fine markings of the iris are lost.

As the result of long standing inflammation, atrophy of the iris occurs after absorption of the infiltration. The iris appears thin, without its normal markings, and usually of a slate-gray color. One or more thick red vessels may be seen in it.

5. Contraction of the pupil. The myosis is to be explained, in the main, by the greater amount of blood and the consequent increased volume of the tissues. Thus, narrowing of the pupil, associated with acute hyperæmia, is observed after puncture of the cornea and escape of the fluid in the chamber. But it cannot be denied, that the reflex contraction of the sphincter iridis may also be produced by irritation of the trigeminal fibres. The contraction of the pupil is associated with lessened reaction to light and mydriatics.

6. Posterior synechia and pupillary membrane. As a rule, the adhesions between the iris and the capsule of the lens are situated only in circumscribed parts of the edge of the pupil. They are recognized by the irregularities and angular distortions of the pupil. When the pupil is narrow, these deviations from the round shape are seen with difficulty. The pupil is then dilated by shading the eye and its shape is watched. If this is insufficient, we employ

mydriatics, especially atropine. The iris now contracts into a small volume, toward its ciliary insertion, and the places at which the edge is adherent to the capsule of the lens usually appears as tongue-shaped, black or rusty brown projections. In many cases it is only the posterior pigment layer which, remaining adherent, does not follow the contraction of the iris. In the cases in which finally complete separation of the iris occurs, dark radial sectors or points and lines remain upon the capsule of the lens. Thus, we sometimes see upon the lens a small black ring which corresponds to the former site of the rim of the myotic pupil. In the course of time these pigment remains lose their deep color. When the rim of the pupil is adherent throughout its entire extent there is total posterior synechia; sometimes the entire posterior surface of the iris is adherent to the lens, in other cases only the pupillary periphery. Accumulations of fluid in the posterior chamber then produce hump-shaped projections of the iris which, when of considerable size, bring the surface of the iris near the cornea, while the pupillary margin and the pupil are situated deep like a crater.

The pupil itself may be covered with exudation, inasmuch as the newly formed layer, which unites the pigment layer with the capsule of the lens, extends into the pupillary tract, or exudations are deposited directly from the anterior chamber. Whitish-gray membranous deposits on the pupil are known as pupillary membranes. There may also be complete closure of the pupil by an opaque membrane.

7. The opacities of the aqueous humor are very different in density according to the larger or smaller number of cellular elements suspended in the fluid of the chamber. A mass of pus-cells and fibrin is often deposited as a yellow hypopyon. This yields to the force of gravity and is deposited in the deepest part of the anterior chamber. It has a semilunar shape, the convexity corresponding to the inferior curve of the chamber. Very small hypopya are recognized with difficulty, because they are covered by the scleral limbus. But we can usually distinctly see that at the lowermost part of the cornea, the periphery of the transparent boundary of the cornea is no longer circular, but forms a small yellowish line. The recognition of these very small hypopya is often successful only on examination with a magnifying glass, with oblique illumination. A very good device consists in pushing up the lower lid, so as to bring a layer of tears over the lower edge of the cornea. This acts as a convex lens and, at the same time, prismatically. When the patients lie on the side, the hypopya move toward the deepest part of the chamber. Occasionally they fill two-thirds of the anterior chamber. But the large hypopya are found more frequently

in secondary inflammations of the iris, in corneal affections (ulcus serpens) or purulent choroiditis. Apart from the corneal processes, hypopya also occur in cyclitis, without pronounced iritis. In cyclitis, however, the hypopya are very small, are usually ephemeral and disappear again.

Pure hemorrhages into the anterior chamber (hyphæma) occur almost exclusively in injuries to the iris, but I have also seen them in attacks of whooping cough. Small stripes of blood also appear occasionally in purulent exudations. A peculiar exudation is sometimes found in the shape of so-called lenticular or gelatinous exudations. These generally have a round or lentil shape; their color is gray. The first case that I described, had a very striking similarity to a luxated, opaque lens in the anterior chamber. The absorption of the exudation, which assumes the shape of a lentil out of an originally shapeless mass, occurs usually in a few days, the diminution in size beginning at the edge and often attended with the formation of serrations. These gelatinous exudations have been observed in the most varied forms of iritis (syphilitic, traumatic—for example, after cataract operations—etc.).

Vesicles which afterward diminish in size and collapse into thin membranes also occur.

8. Precipitates on the posterior wall of the cornea. Small, grayish-white, occasionally light brown precipitates, from the size of a pin point to that of a pin head, are situated upon the membrane of Descemet; when they are present in large numbers we speak of Descemetitis or hydro-meningitis. These precipitates consist chiefly of granular round cells, often mixed with pigmented cells. Their round shape is probably due to the contraction of the fibrin in which they are situated. In some cases punctate infiltrations extend from these points anteriorly into the cornea, and secondary punctate keratitis thus develops.

When larger deposits are found on the membrane of Descemet at the periphery of the cornea, they form connections with the adjacent ciliary edge of the iris, and give rise to small button-shaped synechiæ. This is frequently observed in diffuse keratitis, which is complicated with serous iritis.

9. The cornea occasionally exhibits a slight diffuse or linear opacity which is especially prominent on oblique illumination.

B. Subjective Symptoms.

Pain is present in the acute forms and is often extremely violent. It is located in the globe (ciliary pain), and radiates thence into the forehead and temple, so that a true hemicrania may

develop. The pains exacerbate in the evening or night. The globe is usually very tender on pressure in the ciliary region, but this alone does not warrant the diagnosis of cyclitis. Photophobia is particularly annoying at the beginning of the disease, and when the onset is very acute.

The visual disturbances result from the optical obstructions; cloudiness of the fluid in the chamber, opacity of the cornea or pupillary membranes. A certain degree of congestion of the optic papilla and retina, which is often found in iritis, should also be taken into consideration. But on the whole the visual disturbances correspond approximately to the optical disturbances: a patient, who has no pupillary membrane and only moderate opacity of the fluid in the chamber, reads small test type with convex 6.0 and his field of vision is also free. Impairment of vision or narrowing of the field of vision indicates complications, usually cyclitis, vitreous opacities, retinitis, excavation of the optic nerve, etc. In severe inflammation, neither the test of sight nor the ophthalmoscopic examination should be made too carefully. For the former, it is sufficient to allow the patient to read close with a convex lens (the latter is used to correct any error of refraction).

General symptoms, such as fever, nausea and vomiting are rare.

II. Course and Terminations.

We distinguish acute and chronic forms of iritis. The former begin with considerable pain, photophobia and epiphora, generally exhibit severe pericorneal injection and a slight serous chemosis of the conjunctiva. Exudations into the anterior chamber, hypopya or posterior synechia, develop subsequently. They run their course in about four to six weeks. The chronic forms last much longer and are apt to be overlooked on account of the mild symptoms. The inflammatory phenomena are slight, often entirely absent, and this is also true of the pains and pronounced pericorneal injection. On careful examination, however, it is found that an abnormal pericorneal redness and tears appear on slight irritation of the eye. But circular synechia, and considerable diminution of vision may develop, although the patient does not believe that he is suffering from any serious disease of the eye.

Iritis may completely disappear; the tissues may become normal and the inflammatory products disappear. Or the inflammation ceases, but posterior synechia (partial or total) or pupillary membranes remain. Partial posterior synechiæ occasionally disappear after long-continued atropinization. A special influence has been attributed to them in the production of relapses, to which

iritis exhibits a great tendency. Horstmann's statistics show that eyes with posterior synechiæ exhibit more frequent relapses of iritis. The cause may reside in the tractions to which the iris is exposed by the movements of the pupil, at the site of the adhesions. On the other hand, the danger of partial synechiæ has been greatly exaggerated; despite their presence, in some cases relapses never occur.

But total posterior synechiæ are decidedly dangerous. Unless the entire posterior surface of the iris is adherent to the capsule of the lens, more or less marked protrusions occur from accumulation of fluid in the posterior chamber. As a rule, this is complicated by secondary glaucoma with increase of pressure and excavation of the optic nerve. In other cases, secondary cyclitic phenomena appear, particularly when there is extensive superficial adhesion. The globe becomes soft, the vitreous body opaque, the lens usually cataractous.

Pupillary membranes, that remain, have a variable thickness; they are sometimes white and like paper, or so thin and transparent as to be visible only on oblique illumination. The lens sometimes becomes opaque behind them, and we then find circumscribed capsule or capsule-lens cataracts, forms that have been described as cataracta accreta, spuria or lymphatica. More extensive cataracts usually develop only when the iritis is complicated with cyclitis or choroiditis.

Complications.—In some cases the iritis is complicated by a pronounced affection of the cornea, usually through the medium of the membrane of Descemet. More importance attaches, however, to the secondary affections of the posterior portions of the uveal tract. Vitreous opacities indicate, above all, the extension of the process to the ciliary body and choroid. If ophthalmoscopic examination is impossible, suspicion will be aroused by the disproportionate impairment of vision and defects in the field of vision.

Constant tenderness of the ciliary body is also found in secondary cyclitis. The test may be made with the finger or the tip of a probe. It is a striking fact, that portions of the upper half of the globe are very often tender on pressure, rarely those in the lower half. But as we have already mentioned, these painful points, which disappear later, are also found in simple iritis. The diagnosis of an acute affection of the ciliary body is favored only by the constant tenderness, especially when intense episcleral redness or œdema, corresponds to the position of the painful points. In chronic irido-cyclitis pains, whether spontaneous or on pressure, may be absent.

The tension of the globe also possesses great importance. As

the nutrition of the vitreous is changed by disease of the uveal tract, abnormal condition of tension are also found to appear. In simple iritis, the globe exhibits normal or even somewhat increased tension, but in cyclitis the tension soon diminishes after a brief and inconstant stage of increase.

In chronic irido-cyclitis the globe becomes very soft. At the same time, the changes which we will consider under sympathetic irido-cyclitis also develop.

In secondary irido-choroiditis, especially the serous form, there is usually long-continued increase of tension. Indeed, the increase of pressure may be so great that we find the complete picture of glaucoma with excavation of the optic nerve. Changes in the choroid are not always visible ophthalmoscopically, in serous irido-choroiditis. It is also probable that the ciliary body is implicated in a certain measure, because it does not appear probable that the iritis passes at once to the choroid. Hence, some writers do not draw any strict lines between the conditions under consideration, although the affections which, after long standing, exhibit increase of tension are usually called irido-choroiditis, those which exhibit diminished tension, irido-cyclitis.

Various forms of iritis are distinguished, according to their development and course, but there are also numerous transitions.

Iritis simplex seu plastica.

Here there is a special tendency to adhesions of the tissue to the capsule of the lens. As a rule, there are no deeper changes in the iris itself; purulent infiltrations, hypopya (at least to any notable extent) and deep opacities of the fluid in the chamber are wanting. The iris is discolored, dull, often slightly swollen, the pupil sluggish. Pericorneal redness is present in the acute cases; in the chronic ones it is often entirely absent. Almost all chronic forms, if they have developed without a previous acute stage, have the character of plastic iritis, and often give rise unnoticed to the most extensive synechiæ. The tissue then undergoes atrophy later, loses its structure, color and gloss.

Iritis serosa.

In serous iritis, serous hypersecretion, which leads to increase of the fluid in the chamber, occupies the foreground. The anterior chamber becomes deeper, its fluid moderately opaque. Punctate deposits are found on the posterior surface of the cornea (Descemetitis). The tissue of the iris is comparatively little affected; it is discolored, but hardly swollen at all. The pupil has no great

tendency to contraction, is often even moderately wide; extensive adhesions are absent.

Serous iritis is apt to be associated with serous choroiditis, and opacities of the vitreous. The tension of the globe is then increased. This form develops secondarily, although not in complete purity, in pannous keratitis. Pressure excavation of the optic nerve is to be apprehended when the complication with serous choroiditis lasts a long time.

Iritis suppurativa.

Distinct swelling and thickening of the iris are found, with pronounced discoloration, resulting from the formation of pus in the tissues. In some places small nodules of a light yellow color form and project slightly above the surrounding tissues, which are also profoundly changed. These thicker nodules are situated generally at the pupillary border and posterior synechiæ are apt to develop from them. There is a remarkable tendency to the formation of hypopyon, and it is this variety in which the exudation of pus reaches its greatest extent. The process sometimes spreads to the choroid, and may here give rise to suppurative processes (suppurative choroiditis). These result in increased swelling of the subconjunctival tissue and—in severe forms—in protrusion of the globe. This form of iritis develops secondarily after purulent choroiditis or injuries. It is much more dangerous than simple iritis. After the process has run its course, the tissue usually falls into a condition of moderate atrophy.

Iritis condylomatosa seu gummosa.

Iritis may develop in syphilis in various forms. The variety to which the term gummous is here specially applied, is a plastic iritis attended with the development of circumscribed condylomatous projections, from the size of a pin head to that of a millet-seed. They are distinguished from the circumscribed nodules, which often occur in suppurative iritis, by the fact that they grow like a button from tissue which is relatively little changed. They are associated very rarely with hypopyon. Their color is usually reddish brown. Microscopical examination shows a similar structure to that of gummata in other parts of the body. When they undergo resolution, a whitish-gray cicatricial tissue forms and adheres to the capsule of the lens. They are situated chiefly at the rim of the pupil, but occasionally occupy the periphery. Gummata also occur in the ciliary body and choroid, and occasionally grow outward behind the corneo-scleral boundary. The sclera then projects in a circum-

scribed spot, and has a light grayish-blue color. In two cases I have seen recovery occur under such circumstances.

The statement of certain authors that this gummous iritis is not pathognomonic of syphilis, can only be understood when we remember that gumma-like nodules, which are not gummata, occur in certain cases. Among forty-seven cases of syphilitic iritis that I have collected, seven exhibited gummous proliferations. In the majority of cases gummous as well as non-gummous syphilitic iritis occur in the secondary period (Ricord), usually associated with affections of the skin or mucous membranes. The non-gummous form of syphilitic iritis presents nothing characteristic from a clinical standpoint. But in one case in which condylomatous projections were absent during the disease, Fuchs found, with the microscope, a series of circumscribed small nodules, consisting peripherally of very small cells, centrally of giant cells. All syphilitic inflammations of the iris are characterized by great plasticity. Hypopya are extremely rare; among forty-seven cases I have seen them only twice. The pains are often very violent, especially at night, and extend over the entire head; they do not always depend upon the ocular affection, but are also connected with other syphilitic affections.

Complications with retinitis are often present, though not with pronounced forms. Hyperæmia of the papilla and retina (retinal irritation, Schnasel) are common in the early stages of syphilis, independently of other diseases of the eye. Descemetitis, and circumscribed grayish-yellow, deep-seated corneal infiltrations, are also observed, still more frequently vitreous opacities and choroiditis. As a general thing, only one eye is attacked at the start. On the whole, the course of this affection is not unfavorable. Yet gummous protuberances of the sclera are dangerous because phthisis bulbi is apt to develop. There is always a great tendency to relapses. Vision may be greatly impaired when the optic nerve and retina are implicated. On the other hand, I have seen striking improvement of pronounced amblyopias, which resulted from complicating dense opacities of the vitreous. The investigations which I have made on this point, have shown that about fifty per cent of the patients possess less than V ½ after syphilitic iritis.

III. Etiology.

As a primary disease iritis is most rare in childhood (occasionally in congenital syphilis), most frequent in middle life. It may occur in one eye alone, or in both at the same time or in rapid succession. Some authors believe that the left eye is attacked more

often than the right (Arlt, Ammon), and also that men suffer more frequently than women.

The following causes may be mentioned: 1. Direct injuries; wounds, incisions or contusions. Iritis also occurs as the result of operations, for example, after cataract operations and discissions. It may also result from foreign bodies (lashes, fragments of stone, etc.) that have entered the anterior chamber. 2. After other diseases of the eye, by the spread of the process; especially in blennorrhœas and diphtheria, in which the cornea usually is first affected; often in keratitis, perhaps most frequently in hypopyon-keratitis. From the choroid the process may also extend anteriorly—though rarely—to the iris. 3. The action of colds. Rheumatic pains are often present in other parts of the body. It is doubtful whether, as some believe, serous iritis is especially apt to result from this cause. 4. Scrofula; here corneal affections are also often present. 5. Syphilis. 6. Gout (Galezowski, Hutchinson). 7. Gonorrhœa. Iritis occurs rarely in this disease, and only when gonorrhœal rheumatism is also present or has preceded it. 8. Certain cachectic conditions following impaired nutrition or after severe constitutional diseases (typhoid fever, variola, relapsing fever, tuberculosis, diabetes, anæmia, etc.). 9. Iritis also occurs not uncommonly as a sympathetic affection.

IV. Treatment.

Atropine is the principal local remedy employed in iritis. We attempt to secure maximum dilatation of the pupil by frequent instillation. This is not always possible. Even in the severest cases we use a one per-cent solution not more than three or four times a day, the instillations being made three times in succession at intervals of five minutes. If the process is less acute or the pupil is wide, the drug is not used so often. It is wrong to insist upon using atropia in every case until the synechiæ are separated, because many of them can not be separated, no matter how long atropia be used. If atropine is not tolerated, other mydriatics should be used.

When violent pains are present, and particularly when the ciliary region is tender on pressure, three to six leeches are applied to the temples. Prompt relief of the pain very often follows, and not infrequently it is found that the atropine then acts better. Cocaine instillations, alternating with atropine, occasionally increase the action of the latter and relieve the pains. Lukewarm compresses of chamomile tea, applied several times for half an hour, are useful, but in a few cases they intensify the symptoms. They are then discontinued and also when they are followed by excessive injection

or chemosis. Arlt's forehead ointment, rubbed into the region of the forehead, is esteemed as a derivative and antiphlogistic remedy; applications of tincture of iodine to the forehead and temples may also be recommended. If necessary, rest at night should be secured by means of narcotics. [Leeching is especially valued in the early stages of iritis.—St. J. R.]

The treatment must be strictly antiphlogistic when the disease is complicated by cyclitis or choroiditis. Here acute mercurialization is often indicated. As regards general regimen, the patient is to be kept in a darkened room or even in bed in all more acute cases. At the same time, light diet and regulation of the bowels.

Special therapeutic indications arise for individual varieties and etiological factors. Thus, the treatment should begin with the administration of an emetic in iritis due to rheumatic causes or when the tongue is thickly coated. The continued administration of small doses of tartar emetic (0.05 to 0.1 : 200.0) may also be useful in such cases. Small hypopya are found to disappear rapidly under such treatment.

Sweat cures are less disagreeable to the patient. Injections of pilocarpine are often serviceable, especially when complications with opacities of the vitreous are present. Feeble patients, however, are apt to go into collapse after the use of this drug. I have even observed acute delirium with hallucinations, in the course of this plan of treatment. Salicylate of sodium, with or without diaphoresis, has also been recommended.

In purulent iritis an acute inunction cure is often indicated, in order to prevent extension to the posterior uveal tract or after this has taken place.

Evacuation of the hypopyon by means of paracentesis, depends upon the size of the purulent exudation and the condition of the fluid in the chamber. If the hypopyon is so large as to fill almost half the chamber, absorption can hardly be expected. But it is well to allow the acme of the inflammation to subside before puncturing. Otherwise the hypopyon is apt to form anew.

In iritis serosa the tension of the globe must be carefully watched. If it increases and, at the same time, the visual power diminishes, operative interference is required, either frequently repeated paracentesis (Sperino) or iridectomy. Pilocarpine injections are often serviceable here.

In condylomatous iritis and all other varieties due to syphilis, antisyphilitic treatment must be instituted, particularly with mercurials, because, as is well known, these cause the most rapid disappearance of the local symptoms. Inunctions of gray ointment are made or Lewin's subcutaneous injections of corrosive sublimate.

Internal medication is less indicated in acute cases, but when they run a chronic course, corrosive sublimate or iodide of mercury may be used to advantage. If the rapid action of mercury is desirable in very dangerous diseases of the eye, we may order two inunctions daily of gray ointment āā 2.0 to 4.0, combined, if necessary, with the internal administration of mercury.

Condylomata of the iris are especially rebellious; in very malignant cases I have seen good effects from frequently repeated paracentesis.

When the iritis is cured, it is well to continue the instillations of atropine for several weeks in order to prevent a relapse. In addition, the continued treatment of constitutional anomalies,which may possess etiological significance as regards iritis, is also indicated. Scattered synechiæ usually require no special interference; in part they are detached by the continued atropinization. When all inflammatory irritation has disappeared, we may also try the alternate instillation of atropine and eserine. If relapses occur often so that the continuance of the synechia may be regarded, with some probability, as the direct source of injury, we must resort to their operative detachment (corelysis). According to Passavant, the anterior chamber should first be opened by a peripheral incision of the cornea with a lance knife. Then the iris is grasped with an unserrated iris forceps at the site of the synechia and is drawn away from the lens. I have often tried this plan, but readhesions are not uncommon, and the operation should be recommended only when the synechiæ are very circumscribed. Streatfield and Weber separate the adhesions with a blunt hook, which is carried between the lens and the posterior surface of the iris. This may give rise to injury of the capsule of the lens. In the cases which necessitate an operation, iridectomy will commonly be performed, either above or below, according as the least optical injury is produced. Yet a certain impairment of vision is usually observed after the operation. On the one hand the artificial enlargement of the pupil causes dazzling, on the other hand astigmatic disturbances may result from a change in the curvature of the cornea. The site of the synechia should be avoided in the operation, because, when the adhesion is strong, the capsule of the lens may be injured during the necessary traction on the iris or, in other cases, the pigment layer remains adherent. Freer pupillary movement is attained by every artificial coloboma, wherever it may be situated.

Iridectomy must be performed in total posterior synechia, at least when the iris projects and the pressure is increased. Only in this way can the eye be saved. If the entire posterior surface of the iris is adherent, usually associated with diminished pressure and

irido-cyclitis, the first iridectomy does not always secure a free pupil. Sometimes even the lens, which usually is partly opaque in these cases, must also be extracted. We then adopt Wenzel's method. In some cases this operation succeeds in restoring fair vision to almost blind and soft eyes.

3. Motor Disturbances of the Iris.

Mydriasis.—The dilation of the pupil which occurs after paralysis of the sphincter iridis, is usually moderate in amount and is less than that effected by atropinization. Equally large pupils sometimes occur as the result of contusions of the globe (traumatic mydriasis). Here the pupil is not perfectly round because the muscular tissue of the iris has only been stretched and paralyzed in parts, as the result of the injury.

Moderate unilateral mydriasis is often observed in insanity (especially general paresis with ideas of grandeur) and is attributed to irritation of the sympathetic (Arndt). Unilateral mydriasis, which comes and goes, is also seen in individuals who suffer later from insanity or tabes.

In some cases mydriasis is associated with paralysis of accommodation. This occurs particularly when the mydriasis is due to cerebral causes which directly involve the anterior nucleus of the motor oculi communis. Paralysis of accommodation is often associated with unilateral mydriasis in syphilitics and is usually incurable. In other cases the mydriasis is associated with paralysis of the other branches of the third nerve that supply the external ocular muscles.

It is also said that reflex mydriasis may result from peripheral irritation, for example, worms in the intestines (Quaglino). As Eulenburg's and my experiments have shown, galvanization of the cervical sympathetic produces slight dilation of the pupil.

However, it is not very rare to find one pupil a little larger than the other. This often depends upon anisometropia (in myopic eyes the pupil is usually wider than in emmetropic or hypermetropic eyes) or upon weak sight in the corresponding eye.

The symptoms are usually trifling. The treatment must be directed against the primary disease. Eserine may be used locally.

Myosis.—In old age the pupils are often narrowed to a striking degree.

When the pupils of both eyes are unequal it is often difficult to decide whether one pupil is normal and the other mydriatic or the latter is normal and the former myotic. The reaction to light must then be watched carefully and, if necessary, atropine and eserine

used. The myosis may be spastic, from contraction of the sphincter iridis, or paralytic, from paralysis of the dilator fibres. The former occurs in poisoning (opium, nicotine, alcohol) and in certain hysterical attacks; the latter occurs particularly in diseases of the spinal cord. In tabes, as a rule, the myotic pupil no longer reacts to light, but does react to the impulse of accommodation and convergence (Robertson, Hempel). This absence of reaction to light and retention of accommodative narrowing (so-called reflex rigidity of the pupil) is also found frequently in progressive paralysis of the insane, occasionally in syphilis, typhoid fever, etc. Narrowing of the pupil occurs even after death on paracentesis of the anterior chamber. I have seen it occur thirty-one hours after death, when the posterior half of the globe had been removed at the autopsy. It may here be mentioned that dilation of the pupils takes place soon after death, and is followed in a few days by narrowing, which is often unequal in both eyes.

Hippus is a clonic spasm of the iris, in which dilatation alternates with contraction.

Iridodonesis (iris tremulans) is the term applied to a trembling and wave-like movement of the iris to and fro (tremulousness) which develops on movement of the eye. The movement may be distinct only in a circumscribed part. This tremor occurs when the posterior surface of the iris has lost its firm support, as in luxation of the lens, aphakia, and liquefaction of the vitreous. Slight tremulousness, especially in the ciliary half of the iris, is often observed in otherwise normal eyes, particularly in myopes.

4. Injuries of the Iris.

As every iridectomy shows, simple incised wounds are tolerated very well by the iris. But, as a rule, injuries with a knife or the points of a pair of scissors, also produce wounds of the lens, which lead to opacities and inflammatory irritation. Here vigorous atropinization is necessary, while a simple compress and bandage alone is required in uncomplicated cases. If the wound in the cornea or scleral limbus is large, a large part of the iris will enter. Such injuries always have a doubtful prognosis, on account of the danger of secondary cyclitis and even of sympathetic affection of the other eye. This is especially true of peripheral wounds of the scleral limbus—cyclitis generally develops after large wounds in this region—less of wounds in the cornea. Hemorrhages into the anterior chamber are frequent. If the recent injury comes under our care at once, we may remove the prolapsed iris with scissors, and then attempt to withdraw the iris from the wound by means of atropine

or eserine, according to the situation of the wound. Then, the application of a compress and bandage and if necessary, cold compresses for a short time, will relieve the pains and hemorrhage. But if the wound has closed in a measure, we should avoid operative interference. As a rule, the prolapsed iris will cicatrize smoothly in the cornea under the use of the compress and bandage, atropine or eserine, and rest in bed, and a simple anterior synechia remains. I prefer this expectant plan to operative interference (removal of the prolapsed iris, and iridectomy immediately adjacent to the prolapse). But under all circumstances, the eye must be kept under close observation for many weeks. If all irritative symptoms have been absent for months, we may perform the iridectomy which is optically necessary. Iridectomy is also indicated when increase of pressure sets in, as happens occasionally in anterior synechia, and there is thus danger of secondary glaucoma.

In large peripheral wounds, usually attended with partial luxation of the lens, hemorrhages into the anterior chamber and vitreous, the iris is often torn from its ciliary insertion. It occasionally folds over partially, so that a sort of coloboma develops, or it even passes backward in its entirety and is lost to sight. In the majority of these severe cases, which are associated with loss of sight, the most certain measure is the removal of the eyeball, inasmuch as there is danger of a sympathetic affection of the other eye. If we wish to wait a few days, a compress and bandage should be applied; when this is not tolerated on account of pain, we substitute cold compresses, apply leeches and secure rest by the aid of narcotics.

Small foreign bodies, for example, splinters of iron, may pass into the anterior chamber, and remain in the iris or perforate it. They occasionally tear off the iris from the ciliary body.

Contusions of the globe often give rise to more or less extensive separation of the iris from its ciliary insertion (iridodialysis). If hemorrhages are found in the anterior chamber after contusions, we may assume, with tolerable certainty, the occurrence of such ruptures, which are often seen with difficulty. When they are larger they may be recognized by the black fissure which appears at the periphery of the iris, and forms, as it were, a second pupil. Small ruptures may heal. Their development is explained in the following way. If a blunt body strikes the sclera, it bends the latter somewhat inward into the cavity of the globe; the portion of the sclera which borders on the cornea, with the scleral limbus and ligamentum pectinatum, are thus drawn away from the iris. The latter does not follow, but is made tense toward the pupil, because, as a rule, contraction of the sphincter iridis and the pupil occurs at the moment of contusion by a reflex irritation from the trigeminus.

Both opposing forces cause tearing off of the ciliary border of the iris. The traction, which is most marked at the point of action of the injury, also explains the occurrence of the above-mentioned traumatic mydriasis and the irregular shape which the pupil usually exhibits at the same time, especially after the use of atropine.

In very rare cases ruptures of the pupillary border or even in the continuity of the tissue of the iris, have been observed after contusions.

Immediately after the injury we may attempt to prevent further hemorrhage by cold, later by a compress and bandage. If the hyphæma continues for a long time, we may perform paracentesis and evacuate the blood through the corneal puncture. This is not infrequently followed, however, by fresh hemorrhages. If the peripheral pupil in iridodialysis interferes with vision, especially if it causes monocular double images, we must endeavor to excise the detached piece of iris.

5. Pseudoplasms and Foreign Bodies in the Iris and Anterior Chamber.

In addition to condylomata, sarcomata in the shape of yellowish or brownish tumors with a tendency to secondary increase of pressure (Fuchs), teleangiectasiæ, lymphomata (granulomas) and tubercles may develop in the tissue of the iris. When tuberculous masses are deposited experimentally in the anterior chamber of the rabbit, small whitish nodules form at the end of two or more weeks. Under the microscope these prove to be tubercles (Cohnheim) and, as a rule, lead to general tuberculosis. This experiment may be utilized in diagnosis. In man, tubercles also occur in the iris, associated generally with coincident or secondary miliary tuberculosis. As a rule, the grayish-white or grayish-red tumors, which are often dotted with miliary nodules, gradually grow and fill the entire anterior chamber; in other cases they are said to undergo absorption (Haab).

I have observed a similar case in a student, in whom a number of disseminated, gray to grayish-red nodules, about the size of a pin head or even larger, developed at the rim of the pupil in both eyes. At the same time there was a very moderate plastic iritis with circumscribed opacities of the vitreous. In the course of about nine months the nodules had disappeared and were replaced by posterior synechiæ. They were distinguished from gummata by their shape and color; nor was syphilis present. The patient did not, and does not now, suffer from tuberculosis. Such small tumors, despite the great similarity of their external appearance

to that of miliary nodules, cannot possibly be regarded as tubercles of the iris. This view is opposed by the entire clinical course. It is preferable, in such cases, to speak of lymphomata (Horner) or granulomata (v. Graefe).

Cysts of the iris have generally been observed after injuries in which small pieces of epithelium or eyelashes have been forced into the anterior chamber. Their development has been attributed to proliferation of the cells which have entered (Rothmund); according to Horch's experiments, they are especially apt to form when glands are transplanted with the small pieces of integument. Firm, atheroma-like tumors may also develop around ciliæ (Schweigger). Other, more peripheral cysts may be explained by the separation of the ligamentum pectinatum, the contiguous portion of Descemet's membrane, and the anterior layers of the iris, into which cavity fluid is then secreted (Eversbush, Guaita). There are also cases in which the iris heals into the cornea and this is followed gradually, as Wecker and I have noticed, by an accumulation of fluid with distention and atrophy of the fold of the iris and conversion into a cyst. In one case I observed the formation of a cyst in the midst of the iris tissue, without previous injury or anterior synechia. It grew as large as a pea and was then removed by making an incision with a lance knife and grasping it laterally with the iris forceps.

Cysticerci of the anterior chamber have also been observed. When the fluid in the chamber is clear and the vesicle lies free, the head and neck can be distinguished. But occasionally the worm is inclosed in pus. In an eye which was treated for diffuse vitreous opacity and iritis, I observed a plug of a dense membranous character and yellowish color, and about as large as a millet-seed, situated at the pupillary border. This plug sank to the floor of the anterior chamber and became surrounded with pus. After its removal the microscope revealed the circle of hooks of the cysticercus.

Early removal through a corneal incision of all these neoplasms, especially of sarcomas, is indicated. This is also true of foreign bodies that have entered. In a student, whose spectacles were destroyed by the blow of a cane, I extracted a piece of glass, several millimetres long, which had passed through the iris and lay partly in the posterior chamber, with good results as regards vision. A small serrated hollow hook (Knapp) is useful in extraction; if necessary, the suspected part of the iris may be excised. The electro-magnet may be used for fragments of iron. Foreign bodies sometimes become quiescent and cases are known in which they have remained in the iris for several decenniums without causing irritation (Schenkl, Berger, Birnbacher).

6. Congenital Anomalies.

The iris has a pale red color in albinos. One iris occasionally has a different color from the other in the same individual (heterophthalmus). Small black, reddish-brown and yellow patches are often scattered through the tissue of the iris and should not be mistaken for foreign bodies, as might possibly happen after injuries to the eye.

Aniridia means absence of the iris. This anomaly has been found associated with microphthalmus, even with pressure excavation (Klein). The entire iris has sometimes been torn out artificially, either with or against the will of the operator.

As a rule, congenital coloboma of the iris is directed downward and appears as an approximately triangular slit in the iris. It may extend to the ciliary border or terminate earlier. A thin pigmented membrane, which corresponds to the posterior pigment layer of the iris, is observed occasionally instead of a real defect. Choroidal coloboma is associated not infrequently with coloboma of the iris; the periphery of the lens is often notched at the corresponding point.

When the pupil is not situated, as usual, in the middle, but is moved to one side, the condition is known as korectopia. The pupil is rarely moved upward and the unilateral occurrence of the anomaly is also infrequent. Here the lens may also present indentations. These are situated usually at the lower periphery, but I have also seen them above. In addition to pure cases of korectopia, this condition may also be associated with other inhibitions of development (microphthalmus, luxation of the lens, remains of pupillary membranes) or with the remains of intra-uterine inflammations. When several pupils are present (polykoria) they generally have an irregular shape.

If the fœtal pupillary membrane persists, there may be complete closure of the pupil. The membrane is grayish-white, occasionally pigmented. As a rule, only fragments of the pupillary membrane persist. A white membrane of irregular shape is situated in the middle, and from it small threads pass to the anterior surface of the iris. This serves to distinguish it from pupillary membranes of inflammatory origin, in which any connections that may be present pass to the posterior surface of the iris.

7. Operations on the Iris.

1. *Iridectomy.*—Excision of a portion of the iris in a manner similar to that performed now, was first carried out by Beer (1798). The lids are steadied by the introduction of an elevator. The other necessary instruments are: 1, a straight or curved lance-shaped

knife (Fig. 152), perhaps a Graefe's linear knife; 2, an iris forceps, either that of Fischer (Fig. 153) or Liebreich-Mathieu (Fig. 154); 3, a small iris scissors, either curved on the flat or knee-shaped, or Wecker's scissors (Fig. 124). The latter has either blunt or pointed blades.

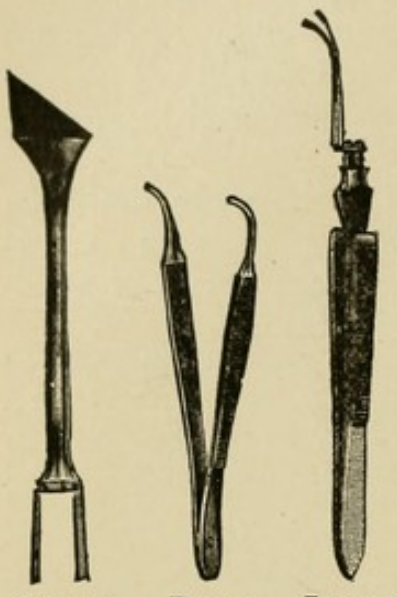


Fig. 152. Fig. 153. Fig. 154.

According as the iris is to be excised in its entire extent as far as the ciliary insertion (peripheral iridectomy) or to a less extent, the lance-shaped knife is introduced into the scleral limbus and at some distance from it in the transparent rim of the cornea. In the latter event the tip is directed, when introduced, quite perpendicularly to the middle of the globe, in order that the wound canal in the cornea may not be too long, and thus impede or perhaps render impossible the subsequent grasping of the iris. If we enter in the scleral limbus, the knife is inserted more horizontally in the plane of the iris and in front of it toward the centre of the pupil. This direction is also adopted at once, when the cornea has been perforated after introducing the knife more vertically. When the knife has been pushed sufficiently far into the anterior chamber —corresponding to the size of the incision desired—it is slowly withdrawn, the handle being depressed somewhat and the tip thus removed from the lens and iris and brought closer to the cornea, in order to avoid injury to the capsule. If necessary, the corneal incision may be somewhat enlarged on withdrawing the knife. The operation is performed most easily with the straight lance, but, on account of the lack of room, the curved knife is always necessary when the incision is made above, below, or to the inside. Instead of the lance-shaped knife, the narrow Graefe knife may also be used for the corneal incision, when the pupil is to be made above or below; the incision is made as in cataract extraction. This is especially useful in anterior synechiæ, when the free portion of the chamber is very small or very broad and peripheral iridectomies are to be made.

If, after removal of the lance or knife, the wound is found to be too small, it is enlarged with Wecker's scissors. The *couteau mousse* (Desmarres) formerly used is entirely superfluous. The second stage of the operation consists in grasping the iris and drawing it out. The closed iris forceps is passed into the anterior chamber, the blades opened shortly before reaching the pupillary rim of the iris, the latter grasped and withdrawn.

If the inner part of the corneal wound (Fig. 155, *a* external wound, *b* internal wound) is too central, the grasping and withdrawal of the iris cannot be effected. The wound must then be allowed to heal and the operation repeated. If the wound is too peripheral, the iris is pushed outward by the escaping fluid in the chamber immediately after the incision. It can then be grasped outside with the forceps, without entering the wound. In order to get the margin of the sphincter outside of the wound, the iris must be drawn outward and a little upward quite strongly, care being taken that dialysis does not occur at the ciliary edge of the adjacent part of the iris on account of the traction. In England Tyrrel's blunt hook is often used instead of the iris forceps.

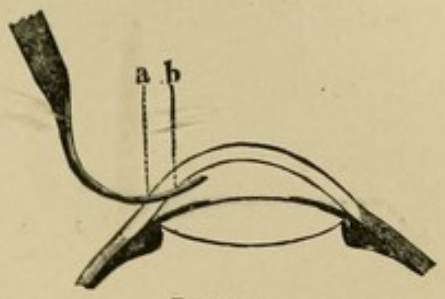


FIG. 155.

When the iris is withdrawn sufficiently, the assistant cuts it off with the scissors (third stage), the flat surfaces of the blades being pressed strongly against the globe in order to excise all the outlying parts. Instead of one cut with the curved scissors, it is better, when the excision of the iris is to be very extensive, to make several cuts with Wecker's scissors. If the operator himself wishes to cut off the iris, as is usually preferable, he hands the fixation forceps to the assistant before introducing the iris forceps, takes the latter in the left hand and grasps the iris, and then cuts with the scissors which have been taken in the right hand.

If the edge of the pupil has not been excised, a double pupil will appear when the iris has returned into the anterior chamber. This does not always give rise to diplopia, as we might suppose would happen when the eye is not accommodated upon the object looked at. As Schuleck has explained, no double images are perceived because, on account of the slight distance between the two distinct retinal images, too much diffuse light falls upon the space between them. By carefully introducing the iris forceps and grasping a part of the iris adjacent to the artificial coloboma, we may attempt to withdraw the rim of the sphincter again and then to excise it accurately.

If the lens is wanting and the iris is intimately adherent to the remaining capsule, we can sometimes succeed in withdrawing the iris better with a curved sharp iris hook (Fig. 156) than with the forceps.

The artificial coloboma, when it extends to the ciliary periphery, has the shape of a key-hole, otherwise it is more oval. Care must always be taken that the corners of the sphincters do not heal into

the corneal wound (Fig. 157, *aa*) or are drawn toward it to an abnormal extent. They can be pushed out of the wound into the anterior chamber by introducing a spatula, such as the one found on the paracentesis needle. This is likewise often effected by



FIG. 156.

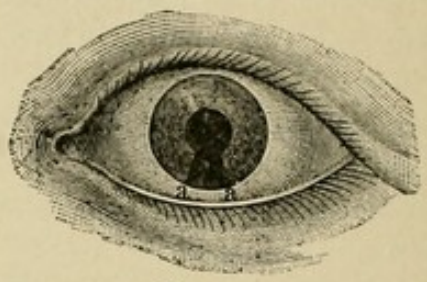


FIG. 157.



FIG. 158.

the myosis resulting from the instillation of eserine or the entrance of a bright light. If blood has flown into the anterior chamber, it may be removed by opening the corneal wound with the spatula, after the hemorrhage has been checked by cold compresses. But even extensive hyphæmata are absorbed when the tissue of the iris is approximately normal. When the iris is atrophic, on the other hand, whitish membranes are apt to remain after hemorrhages; in such cases special importance attaches to the removal of the blood.

In total posterior synechiæ and chronic iritis, the pigment layer sometimes adheres to the lens and only the anterior layers of

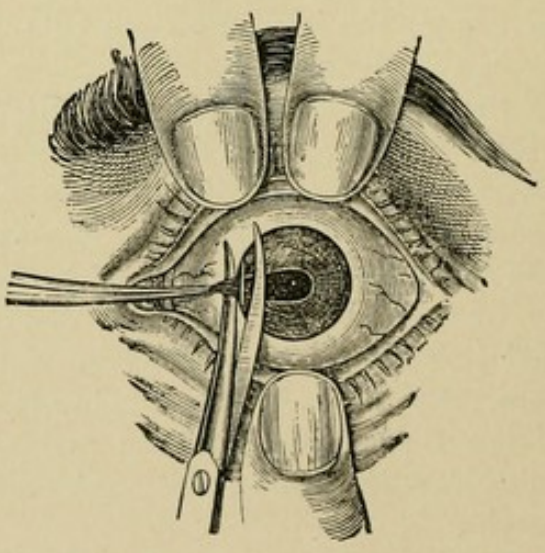


FIG. 159.—Iridectomy. (After Stellwag.)

the iris are removed. It is then found, on oblique illumination, that the apparently black artificial pupil is not transparent.

The place at which the coloboma is to be located is often determined by the indications which lead us to perform the operation. If we have the choice, it is best to locate the coloboma above,

unless a new entrance for the rays of light is to be secured, because it is then covered by the upper lid, which prevents the entrance of irregularly refracted peripheral rays. The inferior position is not quite so advantageous, but iridectomy can be performed more conveniently in this direction because, as a rule, the patient rolls the eye upward during the operation. But if we wish to secure an entrance for the light (so-called optical pupil), it is best to make the pupil on the inside, the position to the outside being less favorable. If possible, we should excise only a small piece of the iris which only extends to the periphery.

The after-treatment consists of a compress and bandage, and rest in bed for four to six days. The dressing is to be changed daily. Atropine may be instilled at the end of a few days, if any hyperæmia or iritis is present. Except in the case of posterior synechiæ, in order to avoid the entrance of the tissue of the iris into the wound, atropine is not to be used immediately after the operation. Atropine is tolerated even after iridectomy for glaucoma. For a time, the patient must remain in his room wearing a shield and sparing the eyes, and may not go into the open air in less than ten to fourteen days. As a rule, the wound heals kindly, but a few cases have been reported in which, after properly performed iridectomy, suppuration of the wound occurred without demonstrable cause. If the capsule has been injured, opacity of the lens sets in, but may remain circumscribed. When the swelling of the lens is more marked, we must proceed as in traumatic cataract.

Iridectomy is performed: 1, to relieve or prevent inflammations, as in irido-choroiditis, chronic iritis, posterior synechia, cataract extractions, etc.; 2, to diminish intraocular pressure, as in glaucoma and processes that tend to secondary glaucoma; 3, for optical purposes, as in corneal opacities, pupillary occlusion, laminated cataract and some forms of nuclear cataract, etc.; 4, for cosmetic reasons, in order to give more life and fire to an eye affected with central leucoma.

2. *Iridotomy.*—This term is applied to an incision into the iris. Cheselden (1728) had divided the iris with a cataract needle and thus secured an opening for the rays of light, when pupillary closure occurred after depression of a cataract. In recent times the operation has again been introduced by v. Graefe and Wecker. The following is Wecker's plan of operation. A corneal incision is made with a small lance knife and Wecker's scissors introduced, the blunt blade being passed through the pupillary opening, the other being situated in front of the iris; the tissue is then divided with the scissors. If there is no open pupil, through which one blade of the scissors may be passed, the corresponding opening is made with

the tip of the lance knife or with a Wecker's scissors one of whose blades is pointed. If the iris is divided in a transverse direction through the sphincter, *i.e.*, from the natural pupil toward the ciliary insertion, the wound gapes from contraction of the muscular tissue and forms a small triangle whose apex is directed toward the ciliary insertion of the iris. Simple perforation of the iris with a narrow Graefe knife seems to be less useful. [If this be done thoroughly (Loring), I deem it the best method of performing an iridotomy in many cases. The knife is introduced well across the anterior chamber, and the handle lifted almost to a right angle, so that a good cut through all the tissues may be made. Of course this method is not available when the lens is present.—St. J. R.]

Iridotomy possesses the advantage over iridectomy that it forms a small, narrow pupil—one which is optically very favorable—that it is less serious and that it will also divide callosities that are situated behind the iris. It is therefore especially advisable when, after cataract extractions, pupillary closure has occurred from iritis; also in certain extensive central adherent leucomas, in which the lens has been lost in the previous inflammation and remains of an after cataract are situated behind the iris. It is less indicated when the lens is intact, because there is danger of injury to the capsule. In laminar cataract, therefore, it is better to substitute a narrow iridectomy for iridotomy.

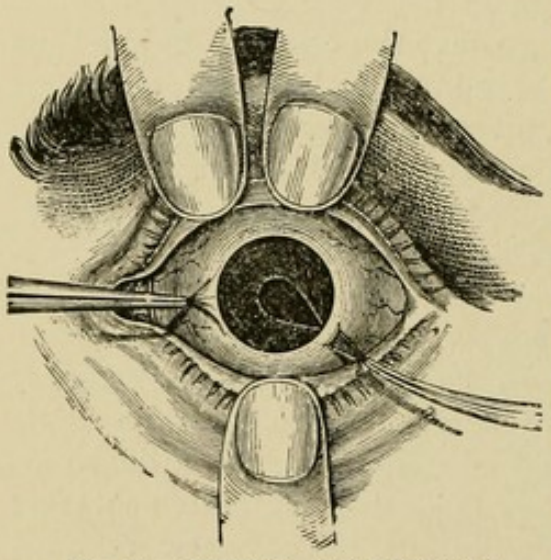


FIG. 160.—Iridodesis. (After Stellwag.)

3. *Iridodesis. Iridenkleisis.*—Critchett (1859) recommended iridodesis with the object of obtaining a narrow pupil for optical purposes (for example, in laminated cataract), which will be situated in the place most favorable for the entrance of light and, at the same time, remains capable of contraction on account of the intact condition of the sphincter. An incision is made at the scleral limbus and the periphery of the iris is drawn outside through the wound with the iris forceps. Here it is retained by a loop of thread carried through the conjunctiva and is tied in position. At the end of two days the prolapsed iris is cut off; the sphincter has healed into the wound. In this way the entire iris and the pupil are drawn toward the corresponding side. If the incision is made very peripherally (in the sclera) and very obliquely, the sphincter of the iris may be incarcerated in the wound without a loop of thread and the

emerging ciliary periphery of the iris may be cut off at once (iridenkleisis according to Himly).

Both operations are dangerous on account of the artificial incarceration of the iris, and have been quite generally abandoned. They have been followed at times by irido-choroiditis, and even by sympathetic affections.

CHAPTER VI..

DISEASES OF THE CILIARY BODY.

Sympathetic Affections. Purulent Choroiditis.

1. Cyclitis.

Disease of the ciliary body is very rare as a primary affection. It is confined only for a short time to the ciliary body, and is soon complicated with other diseases of the uveal tract, especially of the iris. It is also complicated by hyperæmia of the iris or pronounced iritis. The diagnosis of cyclitis as a primary disease may be made, when opacities are present in the anterior part of the vitreous body, with pericorneal injection and pain in the ciliary body, without demonstrable iritis. The occurrence of hypopyon without iritis or keratitis also favors the diagnosis of cyclitis. In chronic cyclitis the eye becomes soft. Even if the iris is affected secondarily, the symptoms of cyclitis usually remain the most prominent. We find such irido-cyclitis (also called irido-choroiditis when the pain in the ciliary body is absent) in general diseases, such as relapsing fever, typhoid fever, rheumatism, tuberculosis, etc.

The prognosis is serious, on the whole, but after the relief of the inflammation we occasionally find that very deep vitreous opacities disappear and that fair vision is obtained. In a child who suffered from irido-cyclitis during typhoid fever, I observed the clearing up, in about nine months, of a total vitreous opacity; a yellowish opacity alone was left at the lower border of the lens, corresponding to the position of the ciliary body from which the exudation had probably passed into the vitreous.

Moderate atropinization—very vigorous and protracted atropinization appears to be injurious in cyclitis—in addition to local and general antiphlogosis, such as that used in the severe forms of iritis, are indicated when the general condition warrants.

2. Sympathetic Diseases of the Eye.

Mackenzie called attention to the fact that in individuals who have lost one eye as the result of injury, the other eye is not infrequently attacked sympathetically and becomes blind, but that this

affection remains absent, if the injured eye is removed at an early period. As a rule, the injuries are severe penetrating wounds, especially those in which a foreign body has entered the interior of the eye (for example, fragments of stone, iron, glass) and remained there. Special danger attaches to those injuries which attack the ciliary body or its neighborhood. Sympathetic affections have also been observed after operations (extraction of cataract, iridodesis) which have been followed by cyclitis. Similar grave results may follow non-traumatic cyclitis. Thus, in a certain sense every phthisical eyeball is dangerous when cyclitis is still present in it or is again excited. The wearing of an artificial eye has occasionally excited a new cyclitis and thus formed the starting-point of a sympathetic affection. The danger is least—but not entirely excluded—in phthisical globes which have been destroyed as the result of a panophthalmitis. It is doubtful whether a sympathetic affection proper can begin without cyclitis, although nervous disturbances of the other eye—irritation, epiphora, inability to work—may occur in severe unilateral diseases without cyclitis. Even after removal of the eye first affected, these symptoms have been observed in a few cases (Snellen, Mooren, Brecht) from irritation of the trigeminus fibres in the orbit as the result of wearing an artificial eye.

Those affections are to be regarded as surely sympathetic, in which some time after an injury and secondary cyclitis, the other, hitherto healthy, eye is attacked in the ordinary and characteristic manner. Four to eight weeks usually elapse before the second eye is involved, but sympathetic disease has also been observed at the end of nine days. In exceptional cases, the hitherto healthy eye was affected at the end of fifteen to twenty years, especially if foreign bodies have remained in the eye. Here changes of position usually give rise to fresh irritation. On the other hand, in non-traumatic cyclitis, which is followed later by an affection of the other eye, it is often difficult to decide whether the disease is really sympathetic and is not, perhaps, entirely independent of the disease in the other eye. If the removal of the eye first attacked at once relieves the disease of the second eye, then the connection would be demonstrated. But the opposite result is not convincing, because we know that even undoubted sympathetic affections, after they have reached a certain intensity, are not always cured by enucleation of the eye first attacked. In arriving at a conclusion on this point, special importance attaches to the form of the secondary disease. If this corresponds to the sympathetic affection of most frequent occurrence (irido-cyclitis), the probability of a connection is increased.

As a rule, sympathetic irido-cyclitis develops in an insidious and

chronic manner, so that the beginning may be overlooked, despite careful watching. The statement, so often made, that removal of the near-point is the first symptom and precedes the inflammatory processes, according to my experience, does not always hold good. Pronounced pericorneal redness may also be absent, although the conjunctival vessels here and there are usually somewhat distended. But as this also occurs without sympathetic affection, after prolonged confinement to the room and disease of the other eye, the slight injection is not convincing. But it should always make us cautious and lead us to atropinize and carefully examine the second eye. Small posterior synechiæ may appear after atropinization, although the pupil had reacted well and was not narrowed, and the iris also appeared normal. In cases in which the sympathetic affection developed under my observation, I have even noticed at this time an unusually vigorous reaction of the pupil to light. Ophthalmoscopic examination usually shows, at an early period, a certain hyperæmia of the optic papilla, but on account of the wide physiological range in the amount of blood in the papilla, a positive diagnosis can only be made when the congestion is pronounced. In some cases small circumscribed opacities of the vitreous are found as the first symptom of the sympathetic affection. Neither spontaneous pains nor pains on pressure are present, in this stage. If the affection has existed unnoticed for some time, more extensive adhesions of the iris to the capsule of the lens are formed, the iris is discolored, the pupil becomes narrow. Now pericorneal injection is also present; pain is experienced when certain parts of the ciliary body are palpated. A pupillary membrane soon forms, the vitreous is diffusely opaque. In the further course of the disease the anterior chamber grows narrow; at the periphery the iris is drawn backward toward the ciliary body by adhesions which form between the latter and the iris. The cornea is slightly opaque, the globe grows soft. All these changes may appear without notable pains or marked symptoms of inflammation, so that some patients, especially children, are only led to consult the physician by reason of the impairment of vision. A very acute form of inflammation, attended with violent pains, severe photophobia and injection, occurs more rarely. The lens gradually becomes opaque and cataractous, and at the same time shrivels and flattens. The process may remain in this stage for many months until, finally, detachment of the retina occurs in the softened and atrophic globe, and incurable blindness thus results. In rarer cases the inflammation finally subsides, the globe is restored and acquires a more normal tension.

Treatment.—Complete restoration and cure are obtained only

in the first stages of the disease, when firm and extensive posterior synechiæ have not yet developed, and the consistence of the globe has not suffered too severely. The treatment must begin with enucleation of the eye first affected, in case this is already blind. When it still possesses a certain amount of vision, the question becomes more difficult. Here the degree of vision, and the chances of maintaining or increasing it, must be considered. If we may hope to preserve a degree of vision which is, in a measure, sufficient, the eye should not be enucleated, because enucleation does not always cure pronounced inflammation of the sympathetically diseased eye. In this first stage, it is true, we usually notice a certain amount of improvement immediately after enucleation. But the improvement is not infrequently deceptive, the process grows worse at the end of a few days, and finally leads to a disastrous termination. It is easily understood that an organ, when once diseased, may be destroyed even when the original cause of the disease is removed. But, on the other hand, the removal will exercise a favorable influence on the conditions of recovery in so far as the eye is protected against renewed injury. In addition to enucleation, vigorous inunction treatment is indicated in this stage of the sympathetic affection. Atropine is to be used locally, if necessary leeches. At the same time, light must be kept away absolutely. Operative procedures (iridectomy) should be avoided; as a rule, they aggravate the disease. If the process has lasted a long time and extensive posterior synechiæ, with flattening of the anterior chamber, diffuse opacity of the vitreous, and softening of the globe (hypotony) and almost complete loss of sight, have developed, then atropine is superfluous, often indeed injurious; even the inunction cure may be useless. The expectant plan of treatment should then be adopted, the general constitution being improved as much as possible. Above all, we should avoid too early operative interference. Months and even years must sometimes be allowed to elapse before an operation may be attempted with any prospect of success. After a time, however, sight is often irretrievably lost from detachment of the retina.

Finally, if all inflammatory symptoms have ceased, and a tolerably satisfactory degree of vision is present (even circumscribed defects in the field of vision should not deter us), we may perform extraction of the lens with iridectomy, according to Wenzel's method described above. V. Graefe has recommended the operation for these cases. The lens is not always found to be opaque; occasionally we have only a capsular cataract. The incision should not be made too peripherally in order that too much of the liquefied vitreous may not be lost. The pupillary opening which

has been made often closes again, and the iridectomy or iridotomy must then be repeated. In some cases we finally succeed in securing a moderate degree of vision. Critchett has recommended that discission of the lens alone be performed and, as it is usually covered with a thick pupillary membrane and is often opaque and shrivelled like a membrane, that a central hole be gradually bored with two discission needles in different sittings (Bowman's operation). In some cases he obtained satisfactory results. But on the whole the prognosis of the advanced forms of sympathetic irido-cyclitis is bad.

Those cases are less unfavorable in which the sympathetic affection appears in the form of iritis serosa, either alone or associated with circumscribed opacities of the vitreous. Here recovery is often observed. But even in these conditions irido-cyclitis occasionally develops after the lapse of time and destroys the eye.

Under the term sympathetic neurosis, Donders has described a symptom-complex which consists of want of endurance, photophobia and irritability of the second eye, and blepharospasm. It is comparatively rare, never leads to organic disease, and is usually relieved by enucleation of the primarily affected eye.

Amblyopia with concentric narrowing of the field of vision, diseases of the optic nerve, retina, choroid and cornea, which have developed without coexisting or secondary iritis, has also been described as a sympathetic affection, but the positive proof of a real sympathetic connection is often lacking.

Opinions differ with regard to the transmission of the inflammation from one eye to the other. It is very probable that the diseased ciliary nerves in the eye first affected exert a reflex influence on the vessels of the other eye and thus give rise to inflammatory processes. The experiments of Mooren and Rumpf have shown that irritation of the nerves of the iris of one eye, produces at first a vascular spasm and then hyperæmia of the other eye. The reflex influence upon the trophic nerves also comes into play. The affection of the ciliary nerves has been anatomically demonstrated in some cases. Thus, I and, later, Goldzieher have seen cellular infiltration between the fibrillæ. Uhthoff has described a spindle-shaped swelling of the nerve fibres. Ayres has also noticed changes of shape and proliferation of the interfibrillary nuclei. The tenderness on pressure of the ciliary region, which is present with hardly an exception, also testifies to their implication. Furthermore, sympathetic affections develop most frequently when a constant irritation of the ciliary nerves is exercised by separation of the ciliary body from the sclera and its displacement or by foreign bodies. This theory of transmission through the nerves would also

explain the above-mentioned cases, in which irritation of the orbital cavity or the trigeminus fibres within it, produced disturbances in the other eye. The occasional absence of pathological changes in the ciliary nerves is not decisive, because other functional nervous disturbances also occur without such appearances.

Others have assumed direct transmission of the inflammation from one eye to the other, through the optic nerve or its sheath (Knies). This has been regarded as infectious in character, because micrococci have been found in the vaginal space around the optic nerve (Snellen, Leber). It cannot be denied that direct transmission may occur in this way in certain cases. Deutschmann succeeded, by injections of staphylococcus pyogenes (Gifford failed in his later experiments) and of croton oil into the eyeball of a rabbit, in producing an inflammation of the other eye by conduction along the optic nerve and its sheaths. If sympathetic ophthalmia is produced in this way, it must appear first as neuro-retinitis. But experiments fail us in explanation of irido-cyclitis, the type of the affection. In cases of sympathetic ophthalmia, whose development I could trace, I have certainly found that the irido-cyclitis is not always preceded by a marked affection of the optic nerve. Not much importance should be attached to so-called hyperæmia, because apart from the uncertainty of the diagnosis, it is found occasionally in various severe diseases of the other eye. Still less may this mode of transmission be regarded as the rule, when we remember that in cases of the most exquisite and acute infectious inflammation (as in certain forms of purulent choroiditis) sympathetic disease does not develop, although affections of the optic nerve, which are anatomically pronounced, are found in the eye primarily affected. Indeed, experience has shown that the phthisical stumps remaining after purulent choroiditis or panophthalmitis, have less tendency to induce sympathetic disease than eyes which have become phthisical in other ways. In my opinion, this is the result of destruction of the ciliary nerves. Nor does the objection hold, that in slowly advancing irido-cyclitis, it is the repeated and continued transmission of the infectious masses that produce the inflammation. Purulent choroiditis also remains in the purulent stage for six to eight weeks. Even if repeated and continued transmission alone would produce the sympathetic affection, this period would surely suffice because, as is well known, sympathetic ophthalmias often develop in a much shorter time. Nor does this theory explain the special danger attending injuries to the ciliary body.

The prophylaxis of sympathetic affections is of the greatest importance, but is often the source of the most difficult and responsible decisions. It consists in the earliest possible enucleation,

optico-ciliary neurotomy or exenteration of the danger-bringing globe. It is true, that I as well as others have seen sympathetic ophthalmias develop after enucleation—in a case reported by Nettleship it occurred twenty-five days afterward—but such cases are extremely rare, and probably attributable to transmission which has already occurred, but is still latent.

If the primarily diseased eye is blind and phthisical, its removal will hardly appear hazardous, but some patients consent to it with great reluctance. In fact, a stump always looks better than the empty orbit and even possesses a certain value in the wearing of an artificial eye, because the mobility of the latter is improved thereby. Moreover, enucleation in children interferes with the development of the corresponding side of the face, because the orbital cavity is smaller than on the opposite side. [Certainly this is not always true, for I have seen many exceptions in cases where I have removed the eye in youth and in which I have years after found that the orbit was equally developed with the fellow.—St. J. R.] Furthermore, quite often we see that phthisical eyeballs remain in the orbit for life without giving rise to sympathetic disease.

Under all circumstances, however, a phthisical eyeball or blind eye must be removed or rendered innocuous by other operations, when it contains a foreign body. This also holds good when a phthisical or badly injured globe with poor vision exhibits long-continued cyclitic tenderness on pressure. The cyclitic pain—when the patient shrinks back actively on palpation of the ciliary body—is a certain sign of impending danger. Sometimes, however, it disappears although a sympathetic affection does not ensue. On the other hand, a few cases have been observed (Cohn, Mooren) in which the sympathetic disease occurred although the cyclitic pains had not been experienced. [I have seen cases in which the presence of a foreign body in a phthisical stump has been overlooked until enucleated. It is important to always carefully weigh the possibility of its presence.—St. J. R.]

Eyeballs that have suffered very extensive injuries with escape of the vitreous and the lens, detachment of the retina, etc., should be removed immediately after the injury.

The question is more difficult when the injuries are slighter, and a somewhat satisfactory degree of vision may be expected. The removal of foreign bodies that have entered must be attempted above all else. When fragments of iron are situated within the eye, the electro-magnet often does excellent service; otherwise we must use forceps and curved blunt hooks. If the foreign body is removed, we may wait for the further development of the curative process under constant, careful observation of the patient (in par-

ticular he must be kept in the dark room for a long time). If the foreign body cannot be removed, enucleation is the most certain measure. Sympathetic affections often develop soon after an injury, even though there is no foreign body in the eyeball. As we have already remarked, injuries in the region of the ciliary body are particularly dangerous.

If cyclitic pains appear in injured eyes, and do not yield rapidly to other treatment (leeches, mercury), enucleation (or optico-ciliary neurotomy or exenteration) is always advisable, even if vision is still present.

Enucleation. Exenteration.

Since Bonnet's time, enucleation has replaced the extirpation formerly in vogue. In the latter, the globe with the adherent parts, stumps of the muscles, etc., are cut out of the orbit with a knife, while in enucleation the tendons are separated carefully from the sclera and the globe peeled out of Tenon's capsule. The operation is begun by lifting up a fold of conjunctiva in front of the external or internal rectus and about three millimetres from the edge of the cornea, and making an incision into the fold with curved scissors. Then the conjunctiva is separated from the globe, over a large area toward the equator. Then the tendon of the muscle is placed on the strabismus hook and separated from the sclera. By passing the hook upward or downward, the conjunctiva is made tense, and it is now cut with the scissors in the continuation of the first conjunctival incision in a concentric circle around the cornea; then the next tendon is grasped and divided. In the same way all the recti are divided in succession; the conjunctival wound is circular and parallel to the periphery of the cornea. In order to push the globe out of the orbit and to make the optic nerve tense, the remains of the tendon of the external rectus, when we operate in front of the patient (or the internal rectus when we operate sitting behind him), are grasped with strong forceps or a double hook—we must grasp deeply and also include the underlying scleral tissue in order to prevent tearing out—the globe is drawn out vigorously and a large half-curved scissors introduced on the same side; this is pushed back along the sclera and divides the optic nerve. The increased hemorrhage and greater mobility of the globe indicate that the optic nerve is divided.

If the operation is performed without chloroform, it will be noticed, in opposition to former statements, that no sensations of light are perceived during the rapid division of the optic nerve. In many cases, however, the stump of the nerve, lying in the orbit, reacts after recovery with photopsia, whenever it is vigorously

pushed or pulled or stimulated with electricity. The globe is next drawn out still more forcibly in order to divide the tendons of the oblique muscles. Sometimes the curved scissors are not inserted sufficiently far back, and then a part of the sclera adjacent to the optic nerve will be cut, so that the globe is fenestrated. If a larger portion of the optic nerve is to be left attached to the globe, the scissors must enter so much deeper into the orbit. It is often difficult to find the nerve in the bleeding adipose tissue and to draw it out afterward.

The hemorrhage usually subsides very rapidly. After the orbit has been irrigated with a cold solution of corrosive sublimate, a firm antiseptic compress and bandage are placed upon the closed lids. As a rule, suture of the conjunctival wound or filling of the orbit with a cotton tampon, placed in sublimate mull or borated lint, is unnecessary in enucleation; it is more apt to be indicated in extirpation. The healing is completed in four or five days. The operation is almost entirely devoid of danger. Only a few cases have been reported—especially when the enucleation was performed in the stage of beginning or pronounced panophthalmitis—in which a fatal termination (from meningitis, etc.) has resulted. [Unless under exceptional circumstances I use no bandage, and apply no antiseptic application, except warm water for cleansing the orbit, and afterward iced compresses.—St. J. R.]

Alfr. Graefe has again recommended exenteration of the globe in order to avoid the latter danger and to secure a better stump. The periphery of the cornea is divided at the scleral limbus, and the entire ocular contents evacuated by introducing a flat spoon between the uvea and sclera; the anterior scleral wound is closed with sutures. But the scleral sac, which is at first distended, shrivels in the course of years and finally only a very small mass is left. Exenteration is indicated particularly in purulent choroiditis after injury. In order to prevent the diminution in size of the stump, a glass globe or gilded hollow silver globe (Mules, Kuhnt) has been successfully healed into the scleral capsule.

Optico-Ciliary Neurotomy.

Instead of removal of the eye, the attempt has been made, by dividing the ciliary and optic nerves, to destroy the conduction in the track along which the sympathetic ophthalmia is conveyed to the other eye. A. v. Graefe had recommended that the ciliary nerves, which correspond to the site of the cyclitic pain, be divided with scissors. But this idea was first carried out methodically by Schoeler, who performed optico-ciliary neurotomy, by dividing the

optic nerve and the ciliary nerves which enter around it. Somewhat earlier, Boucheron had made similar experiments in animals.

The operation is performed in the following manner. The conjunctiva is incised a little in front of the tendinous insertion of the internal rectus at a distance of about four millimetres from the rim of the cornea, and the incision enlarged sufficiently above and below, parallel to the periphery of the cornea. Then the tendon of the muscle is taken upon the strabismus hook, as in the operation for squint, and a thread carried through its peripheral portion so that, when the tendon is divided, the muscle can be held firmly and drawn away from the globe toward the nasal side. The globe is now rolled forcibly to the temporal side. Somewhat large scissors are now passed deeply along the sclera to the other side of the entrance of the optic nerve, and the latter divided in such a way that a portion of it remains attached to the globe. The globe is then drawn out as far as possible by means of a sharp hook, which is inserted into the exposed sclera, and at the same time the outer half of the globe pressed backward with forceps. We then attempt to draw the posterior pole of the globe through the conjunctival wound above the internal rectus and to bring it into view. The globe is thus really turned around. After the entrance of the optic nerve has presented, the portion which remains attached to the globe is resected and the adjacent part of the sclera, over an area of about one centimetre, is cleared up with cuts by the scissors, dividing the remains of the ciliary nerves. Then the globe is restored to position and the internal rectus sutured to its tendinous stump. The conjunctival wound is also closed with sutures. A compress and bandage is applied during the period of recovery.

Extrusion of the globe is sometimes produced by severe hemorrhages. This can be avoided with tolerable certainty if, after section of the optic nerve, the globe is not reversed at once, but the eye is first closed and the retrobulbar hemorrhage checked by firm pressure with cotton dipped in a cold solution of corrosive sublimate. Rotation of the globe is easy in phthisical eyes, more difficult in eyes of normal size or in cases of staphyloma. Here the conjunctival opening must be made comparatively large and the globe rotated with more force. In order to facilitate this, the oblique muscles may also be divided (Schweigger). Rotation of the globe and resection of the nerve are most difficult, after entering on the outside and detachment of the external rectus. However, this plan possesses the advantage that, in case the suture of the detached tendon is not successful, the resulting strabismus (internal) is less annoying than the divergent strabismus after unsuccessful suture of the tendon of the internus.

The result of the operation is uncertain unless the entrance of the optic nerve be inspected. This is made possible by rotation, and without resection of the nerve and the corresponding increased change in the position of the globe. This is especially true because the anatomical investigations of Krause have shown that new branches may grow into the globe from the central ends of the divided ciliary nerves. This, like the direct union of the stumps, must be divided as much as possible. The resulting insensibility of the cornea is an indication of the division of the ciliary nerves. The conjunctiva, which is not supplied by the ciliary nerves, retains its sensibility. But it may also persist partially upon the corneal tract proper, or it may return when, as happens not infrequently in phthisical or inflamed eyes, conjunctival vessels extend to the cornea or conjunctival nerves grow into the latter.

Optico-ciliary neurotomy does not offer the same prophylactic certainty as enucleation. Even if reunion of the nerve is prevented by resection, it is possible that certain branches of the ciliary nerves which run an abnormal course—perhaps enter the sclera farther forward—may remain undivided. Even cyclitic pains may again appear later, as I have seen in one case in which, however, resection of the optic nerve was not performed, although the immediate anæsthesia of the cornea proved the division of the ciliary nerves. In such cases enucleation must be performed later. Leber once observed the development of a sympathetic affection, despite optico-ciliary neurotomy.

On the other hand, it is sometimes an advantage to the patient to retain even a blind eye. Optico-ciliary neurotomy may be performed instead of enucleation, when we have to deal with cases which we know, from experience, are not especially dangerous, but occasionally give rise to sympathetic disease. For example, in phthisical eyes which have not become blind as the result of traumatism or in which the phthisis only occurred after preceding panophthalmitis; also in injuries which have not left a foreign body behind, etc. In cases in which the patients absolutely refuse enucleation, we may also resort to this substitute, which, as a rule, suffices.

Insertion of an Artificial Eye. Prothesis Ocularis.

After extirpation or enucleation of the globe or in phthisis bulbi we may attempt to compensate the loss by the introduction of an artificial eye (in the shape of an enamelled porcelain cup, painted to correspond with the intact eye, Fig. 161). The artificial eye presents the advantage of improving the mobility of the lids. Without it the upper lid usually hangs down slightly, because the levator

palpebræ superioris lacks sufficient support upon which it may draw the lid backward and thus elevate it. The wearing of an artificial eye also prevents diminution in the size of the orbital cavity. This is especially important in children. If they are too young to be trusted with porcelain eyes, we may use cups of celluloid (Nieden).



FIG. 161.

[I am in the habit of causing my patients to wear a small artificial eye as soon as the conjunctiva has healed sufficiently. It is important for cosmetic reasons to use an eye as soon as it is safe. Very often my patients wear an artificial eye ten days after enucleation, and find them more comfortable than the empty orbit.—St. J. R.]

The artificial eye should not be inserted until the conjunctiva and stump are free from irritation; never, so long as a phthisical eye is still sensitive on pressure. After enucleation, when the tendons of the muscles have grown to the cicatricial stump, the artificial eye makes satisfactory movements, still better when the globe is retained, even in an atrophic condition. It is then difficult, in some cases, to recognize the artificial eye as such, but it always lags behind in excessive movements of the eyes. Moreover, the cornea occasionally exhibits small particles of mucus which, in a seeing eye, would be removed at once by winking.

When the conjunctival sac is very much shrunken after extirpation of malignant affections of the conjunctiva, the introduction of an artificial eye is sometimes attended with difficulty. We must then either use very small and especially constructed pieces, or must attempt to enlarge the space by transplantation of the mucous membrane of a rabbit. The porcelain cup is inserted in the following manner. The upper lid is drawn somewhat away and the cup shoved beneath it; then the lower lid is drawn somewhat away and the lower edge of the cup allowed to glide into the orbital cavity. It should not give rise to pain and must therefore not be too large.

It is removed with a bent hairpin, which is pushed under the lower rim of the artificial eye after pulling slightly on the lower lid. The eye should always be removed from the orbit at night.

In order to replace an artificial eye, Chibret has attempted, immediately after enucleation, to maintain a rabbit's eye in the orbit by suturing the muscles and conjunctiva. But in his attempts, as well as in those of others, suppuration soon occurred and compelled the removal of the implanted globe. Bradford has reported a case, however, in which the rabbit's eye, whose optic nerve was stitched to the nerve of the enucleated eye, exhibited its normal appearance at the end of twelve weeks.

3. Suppurative Choroiditis. Panophthalmitis.

Affections of the choroid may occur without notable exudation and pus formation. They are then manifested chiefly, on ophthalmoscopic examination, by tissue changes (forms which have already been described as disseminated choroiditis, choroido-retinitis, etc.), or they give rise to more or less exudation which extends to the retina and vitreous, attended with severe inflammatory phenomena. The process also attacks the iris unless, as often happens, the inflammation has started from this part of the uvea. The latter affection is known as irido-choroiditis, when the exudation in the vitreous is not unusually abundant and is not purulent. If there is also an increase of intraocular pressure, the condition is known as serous choroiditis; its symptoms are identical with those of glaucomatous affections. The process is known as suppurative choroiditis when the exudation is purulent and abundant. Here external evidences of inflammation are always very prominent, such as marked pericorneal and conjunctival injection, œdema of the ocular conjunctiva and swelling of the lids; in addition, secretion of mucopurulent conjunctival resecretion. The globe is hard and somewhat prominent. The vitreous is perfectly opaque, the iris hyperæmic, pupil narrow, fluid in the chamber cloudy. There is often hypopyon in the anterior chamber at an early period, the cornea is slightly opaque. In addition, there are violent pains in the eye and forehead, and often fever.

If the inflammation increases still more, and the cornea and sclera undergo suppuration, panophthalmitis is the result. Here the red globe, covered with œdematous mucous membrane, is often so prominent that we might suspect a retrobulbar tumor. The lids are reddened and œdematous and can hardly be opened. After the inflammation has lasted for some time, the pus from the interior of the eye is discharged, either through an opening previously present (such as a corneal ulcer or the operation wound, if the panophthalmitis has followed an operation) or a point of perforation forms in the sclera.

On anatomical examination of eyes suffering from suppurative choroiditis, we find large masses of pus-corpuscles in the stratum and capillary layer, which give rise to considerable thickening and often push the pigment epithelium far away against the vitreous body. Mononuclear and multinuclear cells are also found among the irregularly shaped pigment cells of the epithelium, so far as it is intact as a layer. The suprachoroidea is less affected. The retina and optic papilla exhibit purulent infiltrations and the papilla often contains hemorrhagic infarctions (Virchow). The vitreous is

sometimes converted into a single mass of pus. In its freer parts we find gray hyaline masses, fibres and free fat. The sclera usually is very much thickened in the vicinity of the point of perforation.

The suppuration continues a long time and the inflammatory symptoms do not disappear for six or eight weeks. The eyeball gradually becomes much smaller, the cornea is usually diminished in circumference and becomes flattened, the anterior chamber is abolished and only the remains of the iris are visible; the pupil is closed. The tension of the stump is diminished; phthisis (atrophy) of the globe has developed. The optic nerve becomes atrophied. The atrophy gradually extends backward to the chiasm and sometimes beyond it into both optic tracts.

Suppurative choroiditis does not always develop into panophthalmitis. Despite perforation of the sclera, encapsulation of the pus and retrogression of the process may occur, so that the shape of the globe is preserved. In less severe cases a certain amount of vision may be restored, although rarely.

Among the purulent forms of choroiditis which pass not infrequently into panophthalmitis, are included metastatic irido-choroiditis, such as is observed in septicæmic processes (often associated with ulcerative endocarditis), puerperal diseases, after ligature of the veins, erysipelas, pyæmia, acute articular rheumatism, cerebro-spinal meningitis, typhoid fever, relapsing fever and tuberculosis. I have also seen purulent irido-choroiditis develop in thrombosis of the transverse sinus. This is interesting, inasmuch as unilateral exophthalmus, hyperæmia, and œdema of the conjunctiva, the orbital cellular tissue and the eyelid, are regarded as diagnostic signs of thrombosis of the cerebral sinuses (Heubner, Knapp). But this group of symptoms, only possesses a real value in the diagnosis when it is not produced by a purulent irido-choroiditis. The latter, therefore, must first be excluded.

Septic emboli of the choroidal arteries (Virchow) have been found as the cause of the disease, but in other cases these were absent. At times, especially when the general disease furnishes no cause for septic or embolic processes, the assumption seems justified that we have to deal with the results of a marantic thrombosis. In cerebro-spinal meningitis, we may think of a direct extension from the brain through the subvaginal and supravaginal lymph space of the optic nerve, to the perichoroidal lymph space.

Injuries may be mentioned as a further cause of purulent choroiditis. Leber's experiments have shown that, as a rule, aseptic bodies are tolerated by the eye without violent reaction, but the most severe purulent reaction follows infecting procedures and certain chemical actions. Purulent forms of choroiditis are also

secondarily produced by inflammations of the cornea and iris. Indeed, purulent choroiditis, which leads to panophthalmitis, sometimes develops without any visible cause, in eyes that are apparently free from inflammation. In such cases, the eyes usually have already passed through severe diseases (detachment of the retina, irido-choroiditis, etc.) or operations (cataract extraction). I have also observed the development of panophthalmitis, attended by fever, without demonstrable cause, in staphylomatous eyes which were free from inflammation.

The prognosis in pronounced panophthalmitis is always bad; moderate purulent choroiditis may possibly terminate with preservation of the normal shape of the eyeball. It is very rare that even a slight degree of vision is restored.

The occurrence of metastatic irido-choroiditis in general diseases, is prognostically unfavorable as regards life. Puerperal fever terminates fatally, with very few exceptions, when this complication is present.

The treatment, at first, must be antiphlogistic: leeches to the temples, atropine, forehead ointment, intestinal derivation. Ice compresses may also be tried. In cases of open wounds, the use of iodoform is advisable, combined with a compress and bandage. The latter must be abandoned as soon as the pains increase. The pains should be treated with narcotics. When pronounced panophthalmitis has developed, lukewarm poultices tend to accelerate its course; they must be very small in order to avoid pressure on the prominent, painful eye. They must be discontinued if they increase the pain, as happens not infrequently. Perforation of the globe, in order to facilitate the evacuation of pus, is not advisable. In the first place, it is apt to cause severe hemorrhages and, in addition, the effect is not marked, because the pus is not so thin that it will escape in large amounts. Enucleation of the globe is still less to be recommended, because it is not devoid of danger, when performed in this stage of inflammation, and has led to a fatal termination. Exenteration is preferable to enucleation.

[Investigations made in this city, in two of our ophthalmic institutions show that death as a consequence of removal of the eyeball, during the course of a panophthalmitis, is hardly to be considered, so rarely, if ever, has it occurred in a large number of cases, whose statistics have been carefully examined. I should prefer enucleation to a long and painful course of suppuration in the eyeball, and I do not hesitate to perform the operation, to save the patient days and even weeks of suffering. Should severe inflammation occur free incision of the swollen tissue, with division of the lids (Noyes) is advisable.—St. J. R.]

Part Fourth.

Diseases of the Ocular Muscles, Orbits, Eyelids, and Lachrymal Apparatus

CHAPTER I.

DISEASES OF THE OCULAR MUSCLES.

Anatomy.

The eye is moved by six muscles, the superior, inferior, external, and internal recti, and the superior and inferior oblique. The recti take their origin at the periorbita in the vicinity of the optic foramen, where they closely surround the optic and motor oculi nerves. Then they separate, run at first close to the encapsulating orbital wall, and then, passing through the cellulo-fatty tissue of the orbit, turn toward the eyeball, forming in this way a sort of funnel. In order to reach their point of insertion in the anterior part of the sclera, they penetrate Tenon's capsule. The latter forms a layer of loose connective tissue which is to be regarded as the limiting membrane of the cellulo-fatty tissue. It separates the latter from the globe and is connected anteriorly with the conjunctiva. The fasciæ of the recti send prolongations into Tenon's capsule. They are also connected with the orbital walls by means of a few connective-tissue bands, which pass through the adipose tissue, and thus form an inhibitory apparatus for excessive action of the muscles (Meckel). The tendons, after penetrating Tenon's capsule, usually adhere to the sclera anteriorly, in curved lines. They are also connected with this membrane by larger or smaller bundles of connective tissue, upon the surface directed toward the globe and also at their lateral edges. This circumstance must be taken into consideration in the operation for squint, inasmuch as not alone the tendinous insertion, but also the other connections, must be divided in order to be able to carry the muscle farther back. The distance of the tendinous insertions from the rim of the cornea varies considerably in different eyes. A series of measurements made by Meckel showed, on the average, a distance of 6.5 millimetres for the tendon of the internal rectus, 6.8 millimetres for that of the external rectus, 8.0 millimetres for that of the superior rectus, 7.2 millimetres for that of the inferior rectus. The internal rectus is the largest, the superior rectus the smallest muscle. The origin of the superior oblique is somewhat in front of that of the internal

rectus, and immediately below that of the levator palpebræ superioris. Passing along the upper wall of the orbit, its tendon passes over the trochlea to the inner part of the upper rim of the orbit, then turns back at an angle of about fifty-eight degrees and, passing beneath the superior rectus, is applied to the posterior hemisphere of the globe in its upper and outer quadrant. The inferior oblique, unlike the other muscles, takes its origin from the inner wall of the orbit anteriorly near its lower rim, passes between the globe and inferior rectus and then between the globe and external rectus, and is inserted into the posterior hemisphere of the eyeball, opposite the tendon of the superior oblique.

The superior, inferior and internal recti and the inferior oblique, are innervated by the motor oculi communis, the external rectus by the abducens, the superior oblique by the trochlearis.

The origin of the third nerve in the brain is situated partly in the floor of the third ventricle, partly below the aqueduct of Sylvius. The nuclei of origin for accommodation and the sphincter iridis are situated anteriorly, while those which supply the external ocular muscles are situated posteriorly. Still farther back is the nucleus of the trochlearis and, finally, in the floor of the anterior part of the fourth ventricle lies the nucleus of the abducens (divided from the trochlearis nucleus by the intervening trigeminal nuclei, but connected with the former by "the posterior horizontal fibres" (Flechsig).

According to Adamueck's investigations in dogs and cats, both eyes possess a common innervation, which starts from the anterior corpora quadrigemina. The right corpus controls the movements of both eyes toward the left, the left corpus those toward the right. All the various movements may be produced by irritation of different points of each corpus. Strong convergence with the visual lines directed downward, is produced by irritation of the posterior, inferior part of both corpora. Associated movements of the eyes, also result from stimulation of the cerebellum and the cerebral cortex (gyrus frontalis superior and medius, gyrus angularis).

A. General Part.

Physiological Action of the Ocular Muscles. Strabismus.

Action of the Ocular Muscles.—The muscles move the eyeball in all directions, as if it were lying in a ball-and-socket joint. The point of rotation around which these movements are effected does not correspond exactly to the centre of the globe, but is situated one millimetre behind it, on the average 13.5 millimetres behind the

apex of the cornea (Donders, Volkmann). It has a different position in the emmetropic, myopic or hyperopic eye. The ametropia resulting from differences in the length of the ocular axis also influences the amount of excursion of the movements; those of oval, myopic eyes are usually less in amount. The angle between extreme rotation of the eye to the temporal and nasal sides, varies between eighty-five and one hundred and ten degrees, and internal rotation is a few degrees greater than external rotation. The eye can usually be turned outward, so that the outermost point on the rim of the cornea almost or entirely reaches the external palpebral angle, while in the most extreme internal rotation a vertical plane through the lower lachrymal point will bisect the pupil almost exactly in the middle. The maximum excursions occur only in simultaneously movement of both eyes to the right and left (associated movements), and not when internal rotation is effected by binocular fixation of a very near object (accommodative movement).

The action of the individual muscles is shown by the position of their origin, insertion into the eye, and the point of rotation. If we imagine a plane drawn through these three points, this will correspond to the plane of muscular traction, and a line drawn perpendicular to this plane at the point of rotation, is the axis of rotation around which the movement of the eye occurs. Its position remains tolerably unchanged whatever may be the direction of the visual line (connection of the point of rotation with the fixed object).

Of the six ocular muscles, each pair has the same axis of rotation around which they move the eye in opposite directions. The axis of rotation of the external and internal recti is situated in the sagittal (vertical) plane passing through the point of rotation of the eye and is a vertical line. That of the superior and inferior recti is situated in the horizontal plane passing through the point of rotation, the inner extremity of the axis being directed somewhat anteriorly, the outer extremity somewhat posteriorly; the angle between it and the transverse diameter is about twenty-three degrees (v. Graefe). The axis of rotation of the oblique muscles is also situated approximately in the horizontal plane of the eye, but it has a direction from in front and outside backward and inward; the anterior extremity is about thirty-seven degrees from the optical axis which passes antero-posteriorly (Volkmann).

From the position of the axes of rotation we can easily determine the movements of the globe produced by the individual pairs of muscles. It is to be remembered, that in addition to changes in the direction of the visual line, rotation of the globe itself may also occur.

In determining the latter, we employ mainly the relations of the

vertical meridian (V.M), *i.e.*, the meridian in which a vertical plane passing through the anterior and posterior poles of the eye would bisect the surface of the globe. When, in rotary movements, the upper half of the V.M (from which the calculation is always made) turns toward the right side of the individual examined, we speak of positive rotation, when it turns to the left of negative rotation, or, in other words, when the iris rolls to the right the movement is called positive, when it rolls to the left it is called negative.

In considering the action of the muscles, we start from the so-called position of rest or normal position of the eye, in which both eyes are adjusted for distance in a horizontal direction with parallel ocular axes.

Action of the First Pair of Muscles.—The internal rectus draws the eye straight inward, the external rectus straight outward.

Second Pair of Muscles.—The superior rectus draws the eye upward and, at the same time, somewhat inward, because its axis is not perfectly horizontal, but runs from in front and within backward and outward. At the same time, the upper extremity of the V.M is rotated inward. The inferior rectus draws the eye downward and somewhat inward; the upper part of the V.M is rotated outward.

Third Pair of Muscles.—The superior oblique, which is inserted into the upper segment situated behind the point of rotation, draws the latter upward and inward; hence the anterior portion of the eye or the cornea moves downward and somewhat outward. The upper extremity of the V.M. is rotated to the inside. The inferior oblique draws the upper segment, situated behind the point of rotation, downward and inward, hence the cornea moves upward and somewhat outward. The upper extremity of the V.M. is rotated outward.

From this mode of action of the muscles, it follows that in up-and-down movements the muscles in question make coincident rotatory (wheel) movements which oppose one another. With a certain initial position of the eye, the movement may be performed straight up or down without rotation of the vertical meridian, because the action of the superior rectus and inferior oblique or the inferior rectus and superior oblique upon the wheel rotation mutually abolish one another. This position—which varies in different individuals and usually differs from the above-mentioned "normal position" in the fact that the eyes are not exactly horizontal, but are directed a little downward—is called the primary position, those which develop from it are called the secondary positions. Rotary movements follow in all other directions of the ocular axes. A definite degree of rotation is associated with

each direction. Thus, in looking upward and outward or downward and inward, rotation occurs to the temporal side, in looking upward and inward or downward and outward, to the nasal side (Donders' law). The mode of rotation is easily remembered, inasmuch as it corresponds to the action of the muscles whose traction chiefly determines the direction of the gaze. For example, on looking upward and inward, there is a median movement of the V.M. such as is exercised by the superior rectus that draws the eye upward and inward. In reality, however, the intermediate position is here effected in another manner. The two elevators (superior rectus and inferior oblique) unite in associated action with the internal rotator (rectus internus). It is on account of the turning in of the eye (position of adduction) resulting from the action of the internal rectus that, in this associated action, the superior rectus, as opposed to the inferior oblique, influences the "wheel rotation." We have seen that the axis of rotation and the superior and inferior recti, do not pass quite transversely through the eye, but that the internal extremity is deflected somewhat anteriorly, the external extremity somewhat posteriorly. As the position of the axes of rotation in space remains the same despite the varying direction of the gaze (in other words, in every position of the eye), then, in case we suppose the eye to be directed inward so strongly that the visual line coincides with the axis of rotation of the superior rectus, the contraction of this muscle can only turn the eye like a wheel around the visual line. The chief action of the superior rectus upon the "wheel rotation" occurs, therefore, in a position of the eye in which the visual line approaches the course of its axis of rotation, *i.e.*, in adduction.

On the other hand, the most marked action of the superior rectus upon the elevation of the eye will be present when the visual line is perpendicular to its axis of rotation, *i.e.*, when the visual line is directed strongly to the outside (position of abduction). This influence of the direction of the gaze upon the action of the muscles is of great importance, especially in paralysis. Thus, in paralysis of the superior rectus of the left eye, when the eye is directed strongly to the inside, an attempted elevation would be successful because in this position the inferior oblique effects elevation almost alone, but it would be associated with irregular wheel rotation (toward the temporal side). But if the eye is abducted forcibly, elevation would not occur. As a matter of course, these considerations hold good concerning the influence of the direction of the gaze upon the action of the oblique muscles. The latter elevate or depress the eye chiefly during adduction and rotate it during abduction.

Projection.—In direct vision, the macula lutea is adjusted upon the object. The line connecting the object with its retinal image is called the line of direction (projection or visual line).

The lines of direction cc_1, b,b, and a,a intersect at the point of intersection k, which, for points that are not situated too peripherally, coincides with the nodal point of the eye. The line of direction cc_1, which connects the macula with the point (c) directly looked at, coincides with the visual line and passes through the point of rotation. This is not true of the lines of direction for indirect vision. The direction and position of an object in space are found when we connect its retinal image with the point of intersection of the direction rays, and prolong this line outward.

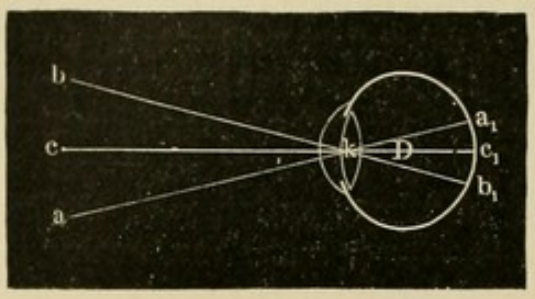


FIG. 162.

Concerning the location of the point of intersection of the direction-rays, in the various positions of the eye and direction of vision, we are sufficiently informed by the nerve stimulus that we expend upon the ocular muscles, and we can thus localize what is seen centrally in space, at least so far as regards its direction, its distance being left out of consideration. The objects belonging to the peripheral retinal images are grouped next to and around that seen centrally, in proportion to their eccentricity; this process is psychical in character and is set in action only by the peripheral stimulus. On the whole, the projection of peripheral retinal images is proportionate to the anatomical distance of the retinal image from the macula; the retinal image situated above will be projected downward, that situated on the right side will be projected to the left.

Binocular vision furnishes us with the actual position of the centrally fixed object, chiefly by the measure of the impulse for convergence of the ocular axes, while monocular vision is concerned rather with the direction of the object. According to our conception, the object is situated in that spot where we assume the point of intersection of the visual lines of both eyes.

Hence we have single vision with both eyes when both retinal images are projected upon the same place in space. This depends upon an experience originally acquired by the aid of the other senses, especially of tactile sensation, but which, as a rule, is now congenital on account of the experience of previous generations. On the whole, the retinal images of both eyes, which are attributed to the same object in space, are also anatomically identical, apart

from exceptional cases, which occur particularly under pathological conditions.

If the posterior sections of both eyes are placed over one another, so that macula is applied to macula, the retinal points which cover one another are anatomically identical. According to the so-called identity theory, these should always correspond with the physiologically identical points. As we have already said, this is generally, but not always, true. As regards the localization of the retinal images, the temporal half of the right eye is identical with the nasal half of the left eye, etc. Hence, in Fig. 163 the points *a* and *b*, in addition to the point *c*, will be seen singly because their retinal images are thrown upon the identical points a_1 and b_1.

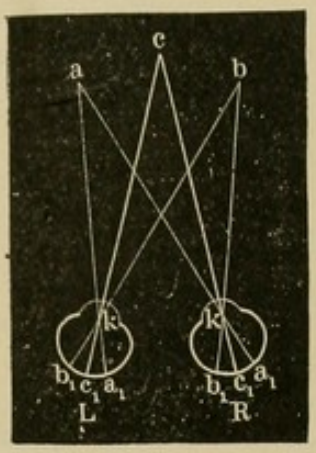


FIG. 163.

According to the principal directions taken by the deflected eye, we distinguish: 1. Strabismus convergens s. internus. Here the visual line of the eye, which is deflected to the inside, intersects that of the adjusted eye in front of the fixed object. Its image falls, therefore, upon the nasal half of the retina of this eye. Corresponding to this it is attributed to an object situated apparently on the temporal side. The image of the left eye is on the left side, that of the right eye on the right side. Such double images are called homonymous or correspondent.

For example, let the left eye be turned in (Fig. 164), while the right eye fixes the point *c*. The double images would then be produced in the following way, according to the projection theory advocated by A. Graefe and Nagel, with reference to pathological conditions.

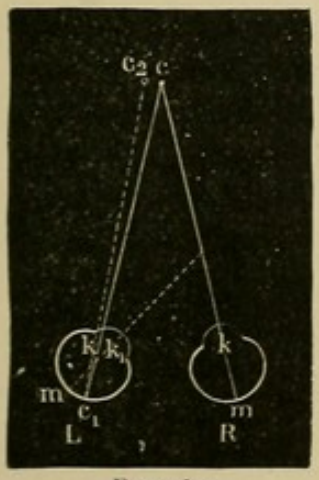


FIG. 164.

The image of the point *c*, which forms upon the macula lutea *m* in the right eye, falls upon the inner half of the retina c_1 in the left eye and is therefore projected to the outside (left) upon a point c_2. As the result of previous experiences, the patient knows that the uniform nervous impulse for both eyes which is necessary for adjustment upon the point *c* will displace the nodal point of the lines of direction to *k*. But, as a matter of experience, the position of *k* corresponds in both eyes in such a way that the connecting line between the macula lutea and the object passes through *k* in each eye. Hence, *k* will be situated symmetrically in both eyes. But

when there is abnormal convergence of the left eye (L), the point of intersection moves to k_1. As the patient projects the retinal image (c_1) according to the position k floating before him, not according to the real position k_1 of the point of intersection of the rays, he will interpret the image c_1 of the left eye as corresponding to an object that is situated at c_2 in the prolongation of the line of direction c_1k. We will enter upon this subject more in detail in discussing false projection in paralytic squint.

2. Strabismus divergens or externus. The visual line of the deflected eye would bisect the prolongation of the line of connection between the fixing eye and the fixed object behind the latter; the eye is turned outward. The rays of light which, starting from the fixed object, meet in the macula of the adjusted eye, reach the temporal side of the eye that is deflected outward. The object is therefore projected to the nasal side by this eye. Non-homonymous or crossed double images are produced; the image of the left eye is situated to the right.

3. Strabismus deorsum vergens, in which the deflected eye is turned downward so that its double image is situated above that of the fixing eye. 4. Strabismus sursum vergens, in which the deflected eye is turned upward, and its double image is below that of the fixing eye.

Strabismus, especially the convergent and divergent varieties, may be produced artificially with the aid of the prisms. For example, if a prism, with the base turned outward, is placed in front of the left eye, the rays coming from the fixed point will be deflected toward the base of the prism and, with the normal adjustment of the eyes, fall no longer upon the macula, but upon the temporal half of the retina. Crossed double images are formed. But if the distance between the double images is not too great, in other words, if the deflecting power of the prism is not too strong, the psychical repulsion to double images will produce a corresponding squint of the left eye, by which the retinal image is again brought upon the macula lutea. The eye, in compensation, will squint inward under the prism.

The prisms which are placed with the base turned outward are called adduction prisms—they adduct the eye. Prisms with the base turned inward, and which produce external squint, are called abduction prisms. The psychical stimulus which produces this squint in the interest of single vision, has been called the fusion tendency. The strength of prisms which different individuals can overcome by squinting (range of fusion) varies considerably. It depends not alone upon the muscular power of the recti that are called into action, but also upon the psychical repugnance to

double images. Hence the prism that can be overcome may not be regarded as the direct measure of the strength of the muscle. On the average it was found in a series of experiments (Becker) that, in looking at distance, emmetropes could overcome prisms of 13.2° by internal squint, prisms of 6.2° by external squint.

Nagel has calculated the deflection produced by the prisms in metre angles and has furnished a formula for the entire range of fusion (range of convergence) similar to the range of accommodation. Nagel applies the term metre angle (mw) to the angle through which every eye must rotate inward in order to fix an object situated in the median line at a distance of one metre. Upon looking at a distance $\frac{1}{2}$ m., there is a convergence of 2 mw, upon looking at 5 m. distance, the convergence is $\frac{1}{5}$ mw. If the number of a prism, which is held in front of one eye and is overcome in the interest of single vision, is divided by 7, we obtain approximately the deflection in metre angles made by each eye; for example, prism 14° requires from each eye a rotation of $\frac{14}{7}$ mw. The range of fusion (amplitude $= a$, according to Landolt) equals the difference between the maximum and minimum of convergence ($a = p$ [normally about 10 mw.] $- r$ [normally about -1 mw, *i.e.*, divergence for distance]). The near-point of convergence is determined by continuing to approach an object in the median line, so long as it is still seen singly, and then measuring the distance from the basal line of the eye (for example, $\frac{1}{10}$ m., then $p = 10$ mw). The far-point of convergence is furnished by the prism which, on looking at distance, can still be overcome by divergence (for example, 7°, base turned inward $= \frac{7}{7} = 1$ mw).

Upward and downward squint in the interest of fusion of the double images, is only possible to a slight extent, corresponding approximately to a prism of 1°, a fact that possesses importance with regard to the relief of double vision in the various forms of squint. But there are not alone individual differences of a very high grade; the eye in front of which the prism is placed must also be taken into consideration. As that eye alone will move into the squinting position, then if the recti muscles of the two eyes differ in power, prisms of different strengths may be overcome by each eye. If the tests with very strong prisms are continued for a long time, exhaustion sets in and the prisms which were overcome before can no longer be corrected by squinting. The act of fusion of the double images, occurs by the, at first, slow approximation of the distant images and then by their rapid and sudden union. According to experiments that I have made, the fusion of the double images requires, on the average, two and one-third seconds, when using the strongest abduction or adduction prisms that can be over-

come by the individual. There are great individual differences in this respect.

The deflections of an eye occur—apart from mechanical displacements by tumors, extravasations of blood, etc.—either from paralysis of a muscle (paralytic squint) or from the fact that a muscle draws the eyeball in its direction of traction as the result of increased nervous impulse, increased tension, excessive strength or its more favorably situated insertion into the sclera. The latter form is called typical, muscular or concomitant squint. Both varieties are so distinct in their character and treatment that they must be kept sharply apart.

B. Special Part.

1. Paralysis of the Ocular Muscles.

I. General Diagnosis.

We speak of paralyses and pareses.

1. Impaired mobility in the direction of traction of the paralyzed muscle. In paralyses the lack of movement appears very distinctly, in pareses it is sometimes hardly noticeable, or, at least, cannot be demonstrated with positiveness. This is still more true of those movements in whose production several muscles are active, as in looking upward and downward. In associated movements of the eyes the abnormal "wheel rotations' of the affected eye are here more striking, because the diseased muscle is lacking in efficiency when the same nervous impulse is conveyed to both eyes. We recognize these "wheel rotations" particularly on looking at the horizontal or vertical blood-vessels of the conjunctiva. These exhibit objectively the displacement of the horizontal and vertical meridian of the eye.

The mobility is tested in the following way. The finger is held about one-half metre in front of the examined eye (at first when the other eye is closed, then when it is open) and moved as far to the right and left, up and down and in intermediate positions as the eye can follow it. It must be seen that the patient looks at the finger attentively and follows it. If necessary, little manipulations, such as snapping the fingers, holding a watch instead of the finger, etc., must be resorted to. If the eye in question has feeble vision, the associated movements must be induced by the other eye. Comparison with the excursive power of the healthy eye is always necessary, because the individual limits are very different. In some people, the movements of the eyes upward are especially limited,

partly from want of practice, while in others—in sanctimonious individuals—they are abnormally great. The movement to the outside also is often below the normal. In some individuals with perfectly healthy external recti, the external rim of the cornea remains, in the most extreme lateral position, two to two and a half millimetres from the external palpebral commissure. Pathological causes must be suspected when the extreme outward position can only be reached by jerks, but this is by no means decisive.

Even where there is a distinct pathological lack of mobility to one side, paralysis of the corresponding muscle cannot be diagnosticated forthwith. Such defects are also present in concomitant squint, but here the lack of motion to one side is compensated by an excess of motion in the opposite direction. In paralytic squint, on the other hand, there is an actual deficiency of movement.

2. The position of the eye when the squint occurs. When it is simply the result of absence of muscular action, it would occur only on looking with both eyes to the side toward which the paralyzed muscle should draw the eye. In fact, this usually holds good in very recent paralysis. But as the antagonist of the paralyzed muscle has lost its counterpoise, it subsequently draws the eye toward it, as a rule, and in paralysis of an ocular muscle we therefore find a squint in a large part of the common field. Indeed, this position may be present everywhere when the antagonist has passed into a condition of abnormal contraction, when a true concomitant squint has been added to the paralytic strabismus.

Although it may be assumed, as a general thing, that the paralysis has attacked a muscle of the deflected eye, yet exceptions may occur, when the healthy eye has poor vision. Here the paralyzed eye is used for fixation, and the healthy eye squints.

The measurement of the squint position may be made objectively by measuring the deflection of the eye, or subjectively by measuring the distance between the double images. In the latter method, other factors enter which will be discussed later. The measurement of the squint according to linear measure is very simple. While fixing an object which is held at a certain distance in front of the eyes in the median line, we measure in each eye the distance in millimetres between the point on the edge of the lower lid which is bisected by the vertical meridian passing through the middle of the cornea, and the lachrymal point of the same lid. The difference exhibited by the two eyes as regards these distances furnishes the linear measure of the squint (for example, strabismus convergens of four millimetres, etc.). For this purpose we may use to advantage Laurence's small graduated instrument (strabometer) which is applied to the lower lid (Fig. 165). We can also make the measure-

ment by noting, for example, when the right eye is fixed, that point of the strabometer at which the perpendicular meridian of the cornea strikes the scale, then allowing fixation to be effected with the left eye, and reading off the ensuing deflection of the right eye. But this method is less useful because—as in paralytic squint—the degree of squint varies according as the paralyzed or healthy eye is fixed, and furthermore because, in concomitant squint, often only one eye can fix the object accurately. Hirschberg allows the patient to look at a light held at a distance of thirty centimetres in the median plane and examines the reflex images thrown by the cornea. On accurate adjustment, they are situated in the middle of the pupil on both sides. If one eye squints, the corresponding corneal image moves toward the periphery. If it falls upon the very margin of the cornea, it is distant half the corneal diameter (about six millimetres) from the centre of the pupil. Hence there is strabismus of six millimetres. The squint may also be measured according to angles, *i.e.*, we give the angle formed at the point of rotation of the eye between the direction of the gaze of the squinting eye and that which would be present were the adjustment proper. The number of degrees can be read off upon the perimeter, if the point of rotation of the squinting eye is brought into the centre of the perimeter circle and the other eye (while the head is held erect) is allowed to fix the zero point of the arch. We can then read off upon the perimeter the degree at which the squinting eye is directed. Forty-five degrees squint angle corresponds to about six millimetres linear deflection.



FIG. 165.

a. The degree of squint increases when the fixed object is carried in the direction of the traction exercised by the paralyzed muscle, and diminishes when the object is carried in the opposite direction. When the action of the muscles consists not alone in a deflection of the line of vision, but also in a "wheel rotation" (such as the superior and inferior recti, but especially the oblique muscles) the squinting, *i.e.*, the deflection of the line of vision, will occur particularly in that intermediate position of the eye in which the action upon deflection from the level falls to the paralyzed muscle. For example, in paralysis of the superior oblique the eye, in looking downward, will lag behind particularly when it has previously been directed to the nasal side.

b. The primary angle of squint is not equal to the secondary angle. When an object situated in the median line is fixed with both eyes, then, in case the healthy eye fixes, the paralyzed one will be deflected by a linear measure. For example, in paralysis

of the external rectus of the left eye, strabismus convergens of this eye will appear. We will call this deflection the primary squint angle (approximately equal to a). If the diseased left eye now fixes the same object, while the right is covered temporarily, then the ensuing associated, convergent squint of the right eye (secondary squint angle) will be larger ($a + x$) than the previous deflection of the left eye. In order to produce in the paretic external rectus of the left eye a contraction sufficient for fixation of the object, a very great nervous impulse is required. This reaches with equal intensity the associated internal rectus of the healthy eye, thus produces vigorous contraction of this muscle and therefore greater deflection of this eye.

3. Double Images. Paralyses of the ocular muscles, which usually occur suddenly and at a period of life when binocular vision is already developed, give rise to diplopia, because the images of the fixed object fall, in the squint position, upon non-identical points of the retina. If the deflection of the squinting eye is very slight, blurring of objects will be perceived instead of actual diplopia. Complaints of such visual disturbances form almost the rule in paralytic as opposed to concomitant strabismus. But spontaneous double images also occur occasionally in concomitant strabismus, especially in adults.

In order to ascertain to which eye one or the other double image belongs—or to reproduce suppressed double images—a red glass is held in front of one eye and the patient directed to look at the light of a candle. When there is a different visual power in both eyes, or permanent deflection of one eye, it is well to hold the glass in front of the eye which sees better or is permanently adjusted, because the glass absorbs light, and will thus impair still further the diminished power of vision. If the double images are not described at once, we first concentrate the attention on the image of the deflected or weak-sighted eye, by covering the adjusted eye, and then withdraw the hand rapidly from the hitherto covered eye, with the question whether a second image does not now appear. These manipulations are indicated particularly in concomitant squint, when double images are not perceived spontaneously. If these measures fail, we may sometimes obtain statements concerning double images by holding prisms, with the base turned upward or downward, in front of one eye, and thus artificially producing double images which are situated above one another.

In using prisms, it must always be remembered that their deflecting power varies according to the direction in which we look through them at an object, whether the direction of the gaze is straight ahead, upward or downward. In paralytic squint, in which

the prisms may also be used to differentiate the double image belonging to one or the other eye, they are not to be recommended, because the deflection from the level, to which they give rise, complicates the already complex conditions of the position of the double images.

As a rule, the distance between the double images is proportionate to the deflection of the paralyzed eye. It is usually measured by the metric system for a certain distance of the object, and direction of the gaze. It may also be measured in degrees, the patient being seated in such a way that the middle of his basal line occupies the centre of a perimeter hemisphere. If a white globe or a light is held in the middle of the perimeter (also laterally, in order to determine the double images with the gaze directed to the sides) and is fixed by the patient, the latter can describe the position of the double image on the perimeter and thus the angle of deflection. For greater distances a corresponding projection of the angle upon a flat wall is necessary (Landolt, Hirschberg).

Inasmuch as the deflection of one eye increases in paralytic squint as soon as the fixed object is carried in a direction which corresponds to the line of traction of the paralyzed muscle, the double images then separate, and approach one another when the gaze is directed in the opposite direction. In concomitant squint, on the other hand, the double images remain at the same distance in the different directions of the eyes.

The appearance and distance of the double images differ occasionally in paralytic squint, according as the examination begins by looking in a direction in which there is still single vision or starts from the opposite direction. In the former event the double images appear later on account of the tendency to fusion. Lateral double images, depending on paralysis of the internal or external rectus, will also have a somewhat different distance when measured with the gaze directed upward or downward, because physiologically the interni have a certain predominance in lowering, the externi in raising the direction of the gaze.

4 False projection of objects on the part of the paralyzed eye. It has been mentioned above that the projection of the retinal image into the outer world, its localization, depends not alone on the locality of the retinal image, but that phenomena connected with ocular movements, etc., also play a part. This is shown very distinctly in sudden paralysis of the muscles by the following experiment (Donders, v. Graefe). If, for example, the external rectus of the left eye is paralyzed, an object somewhat to the left is fixed by this eye, the other being closed, and the patient is directed to place the index finger rapidly on the object. Under normal con-

ditions the object is easily touched, but now the patient pushes his finger past the object to the left. This is explained in the following way. The direction of the projection is determined by the position of the retinal image, and by that of the point of intersection of the lines of direction. Concerning the latter, we are informed by the nervous impulse devoted to the contraction of the externus. When the diseased left eye is adjusted upon the object by means of the paretic externus, it requires a much greater nervous impulse than formerly. This also deceives the patient concerning the position of the point of intersection; it appears to him to be moved much more to the left. Corresponding to this, he also places the line of projection more to the left.

A healthy individual is also subject to this deception when he places a strongly refracting prism (for example, one of 24° with the base turned inward) in front of one eye, the other being closed, and rapidly applies a finger to the fixed object. He will always pass it on the outside because in adjusting the visual line (*i.e.*, the macula lutea) upon the object he must turn the eye outward with unusual vigor, inasmuch as the prism otherwise would throw the rays on the inner half of the retina. The finger must be pushed forward rapidly; if not, its direction is controlled from point to point, and thus the object is sometimes touched accurately. Correction of the false conception may develop gradually after frequent repetition of the experiment.

5. Vertigo. This depends in part upon the above-mentioned false projection, in part upon the disturbing double images.

6. A peculiar position of the head develops in some patients after the paralysis has lasted a long time. It consists in a rotation of the head which makes it possible for the patient to see single whatever is situated directly in front of him. This rotation takes place around an axis which is perpendicular to the line of traction of the paralyzed muscle, the face being turned toward the paralyzed muscle.

Paralyses of the ocular muscles are isolated or combined. In the latter event several muscles which are supplied in part by the same nerve (motor oculi communis), in part by different nerves are attacked at the same time. According to A. Graefe's statistics, which agree with other observations, the external rectus (abducens) is most often attacked separately, next comes the superior oblique (trochlearis).

II. *Special Diagnosis.*

In the drawings, explanations and statements concerning the "wheel rotations" we assume that the left eye is diseased. For fixation we use some vertical object, for example, a candle.

Paralysis or Paresis of the Left External Rectus.

1. Impaired motion in looking to the left.

2. Converging strabismus in the left half of the field of vision, increasing on looking strongly to the left.

3. Homonymous double images, standing side by side, which separate more on looking to the left, and approach one another or disappear on looking to the right.

Slight differences of level are sometimes mentioned; they depend on the dynamic predominance of a muscle exercising traction upward or downward; the latter may come into play when associated vision is abolished. If the differences in level do not increase or diminish on raising and lowering the fixed object, paralysis of the corresponding elevator or depressor may be excluded.

Paresis and Paralysis of the Left Internal Rectus.

1. Impaired motion in looking to the right.

2. Diverging strabismus in the right half of the field of vision, increasing on looking to the right.

3. Crossed double images, standing side by side, which separate on looking to the right, and approach one another or disappear on looking to the left. Slight differences of level are observed occasionally.

Paresis and Paralysis of the Left Superior Oblique.

1. The impaired mobility of the eye appears most distinctly on looking downward in the position of adduction (*i.e.*, looking downward and inward), the eye being directed somewhat upward and inward in comparison with the other eye. According to the explanation already furnished, the traction of the superior oblique in a downward and outward direction comes particularly into play, under normal conditions, in the position of adduction, and this power is now lost. On looking downward in the position of abduction (*i.e.*, looking downward and outward) an abnormal wheel rotation of the eye ensues, inasmuch as the inferior rectus, which acts as an antagonist, acquires the upper hand and turns the upper end of the vertical meridian (V.M.) to the left (negative). (In paralysis of the right eye the wheel rotation would be positive.)

2. When the glance is turned downward, homonymous double images appear, that of the left eye being somewhat lower and situated obliquely, inasmuch as its upper extremity is inclined to the right. In the position of adduction the difference in level increases, in abduction the obliquity increases. The patient sees the double

images as shown in Fig. 166. The difference in the level of the images is explained by the fact that the paralyzed eye lags behind in an upward direction. The object fixed does not throw its image upon the macula lutea, but upon a point in the upper half of the retina. The apparent position of the object is therefore projected downward.

The obliquity of the image is explained by the negative "wheel rotation." If, in the normal position of the eye, the inverted image of a vertical object (Fig. 166, *bca*) is situated upon the retina of the left eye in the vertical meridian which passes directly through the macula lutea, then when the vertical meridian undergoes a negative rotation, the image will become oblique with its upper portion directed to the left (Fig. 167, the lower circle). The upper part of

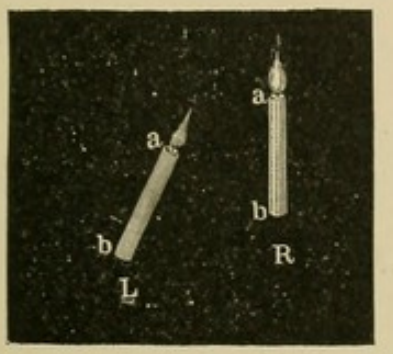


FIG. 166.

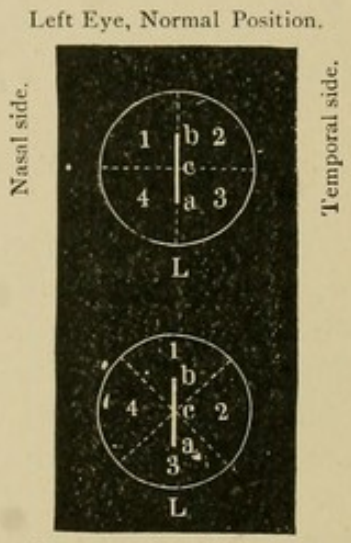


FIG. 167.—Paralysis of Superior oblique.

the image (*bc*) now falls in the upper and inner quadrant (1) of the retina, and this half of the vertical object will be projected downward. The lower half of the image (*ca*) falls in the lower outer quadrant (3) and this half of the object will be projected upward and inward. To the diseased eye the object appears to run downward and outward from above and within, in other words, it appears oblique (like the candle *ab* on the left in Fig. 166) and its upper extremity is turned to the nasal side. It is to be noted that Fig. 167 is represented as if an observer, standing in front of the diseased eye, would see the retinal image. Fig. 166 shows the double images as they appear to the patient.

It appears to some patients as if the image of the sound eye is oblique. They accordingly describe the image of the left eye as vertical, that of the right eye as oblique with its upper end turned to the nasal side. The lower image of the affected eye is very often

described as nearer (v. Graefe). This phenomenon also occurs in other paralyses when one image is lower than the other. Even to an individual with normal vision the lower one of superimposed double images of a distant object (produced artificially by the use of a prism) appears distinctly nearer and smaller; the slighter the difference of level, the less appears to be the difference in distance. This corresponds with our other experiences. As a general thing, objects looked at with a downcast glance and which are situated nearer than the object fixed, throw their images on the upper half of the retina (Foerster); for example, the edge of the paper which lies nearer to us in writing. This also occurs in other directions of the glance, as in looking at a distance when the lower objects, above which we glance, are imaged upon the upper half of the retina. From this experience, the false notion that the lower image is nearer, develops under the unknown and new conditions of a paralysis or the use of a prism as described above.

Paresis and Paralysis of the Left Inferior Rectus.

1. The loss of motion appears most distinctly on looking down in the position of abduction of the paralyzed eye (the glance directed downward and outward) because it moves somewhat to the outside and lags behind superiorly. As stated in discussing the action of the individual groups of muscles, the inferior and superior recti influence chiefly the up and down movements of the eye in the position of abduction. In the downward glance in the position of abduction, on the other hand, the abnormal "wheel rotation" appears more prominently because the paralysis robs the superior oblique of its antagonist and that muscle now turns the upper edge of the V.M to the nasal side.

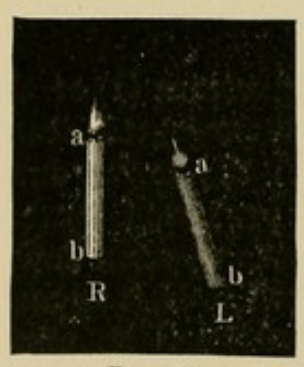


FIG. 168.

2. A slight strabismus divergens et sursum vergens in the lower half of the field of vision.

3. On looking downward, crossed double images appear, the image of the left eye is somewhat lower and is oblique, the upper extremity being inclined toward the healthy side. The difference in height increases in the position of abduction, the obliquity in the position of adduction. The patient sees the double images as drawn in Fig. 168.

The obliquity depends upon the positive wheel rotation. The retinal image of the vertical object now falls, with its upper part, upon the outer and upper quadrant; the lower part of the object will therefore be projected downward and inward. The lower part

of the retinal image, on the other hand, falls upon the inner and lower quadrant, and the upper part of the object is projected upward and outward.

As the images are crossed, the upper end of the image of the left eye (L) will be turned toward the right image.

Paresis and Paralysis of the Left Inferior Oblique.

1. The loss of motion appears most distinctly on looking up in the position of adduction of the paralyzed eye, the latter being directed somewhat to the inside and lagging behind below. On looking up in the position of abduction, the abnormal wheel rotation becomes distinct; the V.M is moved to the nasal side.

2. Slight strabismus convergens et deorsum vergens in the upper half of the field of vision.

3. On looking up, homonymous double images appear; that of the paralyzed eye is somewhat higher and is oblique, its upper extremity being turned away from that of the healthy one. The difference in height increases in adduction, the obliquity in abduction.

Paresis and Paralysis of the Left Superior Rectus.

1. The loss of motion appears most distinctly on looking up in the position of abduction of the paralyzed eye, the latter moving somewhat to the outside and lagging behind inferiorly. The abnormal rotation appears particularly on looking up in the position of adduction; the V.M is turned to the temporal side.

2. Slight strabismus divergens et deorsum vergens in the upper half of the field.

3. On looking up, crossed double images appear, the image of the paralyzed eye is somewhat higher and its upper end is turned away from the image of the healthy eye.

Paralysis of the Third Nerve.

As the function of the levator palpebræ superioris, sphincter iridis, tensor choroideæ and all the external muscles of the eye, with the exception of the external rectus and superior oblique, is lost in total paralysis of the third nerve, the eye is in a position of slight abduction; it is often displaced somewhat forward (exophthalmus paralyticus). The pupil is dilated, accommodation is lost, and the upper lid droops. Motion of the globe outward alone is possible. It cannot be moved downward because the superior oblique chiefly produces rotation in the position of abduction. Even this is hardly noticeable in many cases.

Multiple Paralyses.

The diagnosis of the extent to which the individual muscle is affected is often difficult in cases in which multiple paralyses or pareses appear in the same eye. Paralyses affecting both eyes may also give rise to difficulty. Thus, in cases in which both external recti are affected uniformly, homonymous double images appear and maintain the same distance in the field of vision, as in correspondent squint; laterally, however, they separate more and more on both sides. Cases have also been observed in which a symmetrical, finally complete paralysis of the muscles develops in both eyes without the occurrence of squint (v. Graefe). When a series of external muscles of one eye or individual ones in both eyes are paralyzed, but accommodation and pupillary contraction remain intact, we speak of ophthalmoplegia exterior (Hutchinson, Mauthner), when the fibres of the third nerve supplying the ciliary muscle and the sphincter iridis are affected, of ophthalmoplegia interior. The origin of the latter fibres is situated farther forward (at the floor of the third ventricle) than that of the others. Hence, when they are paralyzed alone, the affection must be localized in the corresponding nerve nucleus (nuclear paralysis), and also when the other fibres of the third nerve are paralyzed, with the exception of those which supply the pupil and accommodation. The disease of several nuclei of the ocular nerves, may be compared to ocular paralysis, in which a series of functionally associated nerve nuclei (hypoglossus, glosso-pharyngeus, some facial branches, etc.) are gradually involved in sclerosis and atrophy of the ganglion cells (Lichtheim). In fact, paralyses of the ocular nerves are complicated occasionally with the symptoms of bulbar paralysis, also with ataxia and paralyses of the limbs, as the result of extension of the process backward and spread of the sclerosis to the pyramidal and lateral tracts of the spinal cord. Although this is usually due to a direct affection of the nerve nuclei, a similar extension of the paralyses occurs occasionally in tumors. In a small glioma of the pons, I have observed successive paralysis of both abducens nerves, symptoms of bulbar paralysis, ataxia, and finally total paralysis of the limbs and muscles of the neck.

III. *Course and Termination.*

The paralyses may disappear or remain stationary. In the latter event, there is sometimes complete contracture of the antagonist muscle, which draws the eye toward it and fixes it almost immovably (paralytic contracture). If increased tension of the

antagonists remains after the disappearance of the paralysis, we have the symptoms of concomitant squint or of latent squint, when the tension of the antagonists is so slight that increased innervation of the previously paralyzed muscle, in the interest of single vision, secures accurate adjustment in binocular vision.

The paralysis is most apt to disappear, when it is attributable to peripheral causes, that are susceptible of treatment, such as rheumatic influences. In such cases we usually have an affection of single nerves and with complete paralysis. If the paralyses occur in both eyes in the shape of pareses, a central affection should be suspected, and the prognosis is thus grave.

IV. *Etiology.*

The ocular nerves may be diseased peripherically in their course along the orbit and base of the brain, or in their cerebral origin and course.

Among the mechanical causes that act on the nerves, we may specially mention tumors, fractures of the base, exostoses, periostitis, aneurisms (rupture of the carotid into the cavernous sinus, vide Pulsating exophthalmus), meningitic exudations. Cerebral tumors and hemorrhages, encephalitis, disseminated cerebral sclerosis, atrophy of the ganglion cells, gray degeneration of the posterior columns of the cord give rise to central paralyses, whose diagnosis is assured, as a rule, by other pathological phenomena. By taking into consideration the individual paralyses of the ocular muscles, we can sometimes obtain an idea of the locality of the affection.

It seems as if temporary hyperæmias and anæmias may give rise to pareses which, usually not affecting all the fibres of the nerve, disappear and then reappear occasionally in other places. Such slighter paralyses sometimes constitute the prodromata of severe diseases of the brain or spinal cord. [The author seems to lay little stress upon syphilis which, after careful investigation, I think is the cause in fifty per cent of the cases.—St. J. R.] Complete recovery may also occur. It is particularly in young people, that I have observed the disappearance of pareses, even bilateral, in which a central cause (nuclear affections) had to be assumed, and in which no other cerebral symptoms appeared during a period of observation lasting years. In certain cases, exposure to cold has been demonstrated with certainty. For example, a perspiring individual looks out of the window of a railway train, is exposed to the strong draught, and suffers afterward from paralysis of the abducens. The rheumatic paralyses are often accompanied by pains on the same side of the head. Syphilis is present in other

cases. In rarer cases, paralysis of ocular muscles occurs after diphtheria (almost complete bilateral ophthalmoplegia has been reported by Mendel), diabetes, or blood poisoning. Congenital paralyses have also been observed. Direct weakening of the ocular muscles has been seen as the result of traumatism and trichinosis.

V. *Treatment.*

The treatment must be directed, as far as possible, against the causal factors. In rheumatic paralyses, diaphoretic treatment (injections of pilocarpine, tartar emetic in divided doses, etc.) is indicated at the outset, later potassium iodide is given. Local abstraction of blood with the artificial leech, derivative irritation of the skin (applications of tincture of iodine and veratrine ointment to the temple and forehead) are also indicated. In syphilis, inunctions or injections of corrosive sublimate are indicated under certain conditions, but their administration must be avoided if the disease is complicated with atrophic affections of the optic nerve. Here potassium iodide is often indicated, a remedy which, in increasing doses and combined with galvanization of the sympathetic, is often recommended also in nuclear paralyses. Later, electricity may be applied locally, both poles of a not too strong induced current being applied to the closed lids in the vicinity of the paralyzed muscle, or the cathode of the induced or constant current placed directly over the muscle upon the cocainized conjunctiva. Michel has recommended orthopedic treatment of the paralyzed muscle, the conjunctiva over the antagonist being grasped with forceps, the eye drawn over to the corresponding side, and these movements repeated systematically. Strychnine injections into the temple may also be tried.

In order to relieve the suffering of the patient resulting from the occurrence of the double images, they are allowed to wear spectacles, the glass in front of the affected eye being covered with adhesive plaster or made opaque in some other way. If the healthy eye were covered, the false projection would give rise to a feeling of vertigo and discomfort. Patients with unequal vision in the two eyes, are in an especially disagreeable situation, if the better eye, which is ordinarily used, is affected by the paralysis.

We might also attempt to cause union of the double images by means by prisms. These must be applied in such a way, that the position of the base of the prism corresponds to the line of traction of the paralyzed muscle. For example, in paralysis of the left abducens, the homonymous double image will be united by a prism placed in front of the left eye, with the base turned to the temporal

side; this causes the left double image to move toward the nasal side.

(In order to inform ourselves easily and rapidly concerning the action of the prisms, it may be remembered that the corresponding double image is always situated upon the side toward which the refracting edge is turned.)

If there is a difference in height, in addition to lateral separation of the double images, the difference in level must be compensated by another prism with its base turned upward or downward. This is effected occasionally by an oblique position of one prism. When a prism of a definite angle, which causes union of the double images, has been found in this manner, it may be placed in a spectacle frame and worn. If the prism is stronger than six degrees, it becomes too heavy and furnishes annoying colored edges. Its action is then distributed by placing a prism of half the strength in front of both eyes. Thus, if a prism of ten degrees, with the base turned outward, unites the double images when held in front of the left eye, then a prism of five degrees, with the base turned outward, is placed in front of both eyes. In this way the image of the left and right eyes is displaced to the nasal side.

Apart from the fact, that often very strong and therefore impracticable lenses, are required to produce union of the double images, their use is also contra-indicated by the fact that they suffice only a certain direction of the vision, while it is especially in paralytic squint that the deflection of the eye varies considerably according to the direction of the glance.

As a rule, we must waive their use for this purpose. On the other hand, they are sometimes used for orthopædic exercises. By means of the prisms we bring the double images in such close proximity—short of complete union—that the interests of single vision are stimulated. The union of the images is then to be effected, by increased innervation of the paretic muscle. A more convenient method, is that of carrying an object from the field of single vision in front of the eyes to the field of double vision, and directing the patient to maintain single vision as long as possible. But in both methods we must be careful that the paretic muscles are not tired and thus weakened by over-exertion, as is apt to occur. Such experiments may only be made a few times in succession. If prisms are used for the exercises, we gradually pass to weaker ones, in order to stimulate an increasingly stronger contraction of the paretic muscle.

Operative procedures, such as tenotomy of the antagonists or displacement forward of the weakened muscle as practised in concomitant squint, are usually adopted only in those cases in which,

after the paralysis has run its course, a secondary increase of tension has developed in the antagonists. Premature operation would result in strabismus in the opposite direction in case of relapse of the paralysis.

2. Strabismus Concomitans (Muscular Squint).

The deflection (in contradistinction from paralytic squint) of an eye from the fixed object resulting from increased power of a muscle or increased tension or abnormal weakness of the antagonists, is called concomitant squint because the deflected eye follows the fixing eye in the various directions of the vision.

I. *General Diagnosis.*

The following features distinguish it from paralytic squint.

1. In concomitant squint there is no real deficiency of movement. It is true that in individual tests of the deflected eye the mobility in the direction opposite to the deflecting muscle is often somewhat diminished. But the general extent of the field of movement is normal, inasmuch as there is a certain displacement of the field in favor of the more strongly contracted muscle. As a rule, a similar condition, though not so pronounced, may be observed with regard to the field of movement of the non-squinting eye. Here also the homonymous muscle (in converging strabismus the internal rectus) usually exerts a stronger influence on the movement of the eye.

2. Squint position. *a.* The degree of squint remains the same throughout the entire field of movement. For example, if the flame of a candle is carried, in converging strabismus, in a horizontal plane from right to left, the degree of deflection is uniform throughout. This does not exclude change in the degree of squint on adjustment for various distances. Even in adjustment at the same distance and on the same object, the squinting eye may occasionally be deflected more or less strongly. This is especially frequent in the converging strabismus of hyperopes, when the greater or less tension of accommodation, the greater or less interest displayed in securing sharp retinal images, exercise their influence on the contraction of the internal recti in greater or less degree, as will afterward be shown in more detail. *b.* The primary squint angle is equal to the secondary angle. As we have to deal with an increase in the power of the deflecting muscle which remains the same in all directions of the glance, and not with paralysis of the antagonists, then, in case the deflected eye is adjusted, the necessary nervous impulse will act in the same way and with the same

effect upon the associated muscle of the other eye. For example, if, in converging strabismus, there is a deflection of the left eye of four millimetres, then in order to adjust this eye upon the fixed object (which can be effected by covering the right eye temporarily) the external rectus of the left eye must receive a corresponding nervous impulse. This acts in the same way on the associated internal rectus of the right eye, and deflects the right eye four millimetres to the inside. Occasionally, however, there are slight differences, particularly when there are different conditions of refraction in both eyes. These differences are associated with the greater or less accommodative influence required by one or the other eye. This accommodative impulse also influences the position of convergence to a certain extent. It is also to be remembered that, in some cases, the macula of the permanently deflected eye is not employed in fixation, but an eccentric part of the retina. As a matter of course, this affects the degree of secondary squint deflection.

3. As the squint angle remains the same, the double images, when present, also remain at the same distance throughout the entire field of movement. But double images are rarely observed spontaneously. This depends upon the fact, that, as a rule, concomitant squint develops in early youth, when the imperfect observation usually does not permit the recognition of double images. But that they are present at the beginning is shown—apart from the statements of intelligent children—by the fact that adults who are attacked by concomitant squint complain in all cases of double images. In addition, the double images will disappear more readily in youth because the binocular act is not so unchangeably established. This disappearance of the double images may occur from suppression of the images of the deflected eye or—in exceptional cases—from the development of binocular projection by means of which points of the retina that are not anatomically identical attribute the retinal image formed upon them to one and the same object in space. In using the microscope and ophthalmoscope, it is often seen to be possible, even in normal vision, to disregard entirely the visual objects presented to one eye, despite the fact that both eyes are kept open. Also in reading, when we separate what is presented to the right eye from that seen by the left eye, while holding a sheet of paper in the median line of the face. According to the side to which our attention is directed, we read with the right or the left eye. Even a special significance of the image which falls on the macula of the excluded eye, cannot be observed; everything appears blurred and disappears when the entire attention is devoted to the other eye. Nevertheless, larger objects, which are situated on the side of the excluded eye, can be distin-

guished at the same time when attention is directed to them. This is also true of most cases of squint. Thus Schweigger has shown that the squinting eye, as a rule, perceives the image of a flame, thrown in by reflex, even when it falls upon a part of the retina which corresponds to the portion of the visual field dominated by the fixing eye. In like manner, we often find that patients with concomitant squint, by simply holding a red glass in front of one eye and thus differentiating the images, succeed in perceiving them as double images. In many this experiment must be repeated frequently; the hand is held in front of one eye, and sometimes the squinting, sometimes the ordinarily adjusted eye is used for fixation, and the patient told that double images will appear at the moment of exposing the hitherto covered eye. A lively impression is created, as if very unusual exertion and attention to the images of the squinting eye are required, in order to call forth the subjective perception of the double images. If, in youth, the strabismus leads to intentional suppression of the disturbing double image, (which is weaker in the squinting eye on account of its eccentric position) and monocular vision is practised intentionally, we can easily understand that, in the further bodily and mental development, there is a diminished capacity of the retinal images of both eyes, to be transmuted in the brain at the same time, and to reach consciousness. A psychical abnormality thus develops. The external visible septum by which we can experimentally separate the visual field of both eyes in one possessing normal vision, possesses an analogue in many cases of squint in a psychical separation of both visual fields. If the attention is directed to one eye alone, the visual field of the other does not reach consciousness under ordinary circumstances, and accordingly cannot be a source of disturbance. This causes the great difference in the frequency of diplopia in paralytic and concomitant squint. As a rule, only adults are attacked by paralysis of the ocular muscles, and then they complain of diplopia. As a matter of course, it is much more difficult for them or it is even impossible to suppress the double images, because the psychical act of union of both visual fields has become in them involuntary and extremely powerful. In like manner adults in whom concomitant squint develops, often compain constantly of double images.

If paralysis of the ocular muscles occurs, as happens occasionally, in little children, complaints concerning double images are either wanting or, if present, soon disappear. The following example is instructive: an adult, who suffered from paresis of the superior rectus, which had developed in early childhood, had perfect vision in both eyes, and could voluntarily use each eye alter-

nately for seeing. Diplopia and binocular vision were wanting. Projection took place correctly.

The loss of coincident utilization of binocular impressions, may be restricted to certain regions. That portion of the retina of the squinting eye, which lies in the line of direction of the object fixed by the other eye, is excluded with special frequency. This part would furnish the most disturbing double image, viz., that of the object fixed, if the utilization of its retinal images were not excluded. This is called regional exclusion (Graefe). While, in such cases, double images are obtained neither spontaneously nor with colored glasses, they develop and are often projected in a manner corresponding to the squint position, when the rays emanating from the fixed light are deflected to peripheral portions of the retina by holding prisms in front of the eye.

The distance between the individual double images, does not always coincide with the linear deflection of the one eye. Cases of converging strabismus even occur, in which, at first after the operation for squint, which only effected a diminution of convergence, crossed double images developed, while, according to the theory of identity, only homonymous images should be present. This has been spoken of as retinal incongruence. It is more probable, especially as these crossed images, as a rule, soon disappear, that a special projection for each eye, corresponding to the former squint position, had developed and had made binocular vision without double images possible. In the assumed case of converging strabismus, accordingly, the macula lutea of the fixing eye and the part of the inner half of the retina of the deflected eye, corresponding anatomically to the other macula in this squint position, would refer their retinal images to one and the same point in space. If this correspondence is destroyed by an operation for squint, double images occur, but soon disappear under the new conditions, particularly as there is no doubt that anatomically identical parts of both retinæ have a congenital predisposition for similar projection and single vision. The rare cases of diverging strabismus, in which homonymous double images are described, may be explained in the same way by false projection. I observed a patient with strabismus divergens alternans in whom, as a general thing, the fixing eye adjusted, not the macula, but an eccentric portion to the outside, upon the object. In this squint position, there were no double images. But if the patient, as she could do voluntarily, used the macula for fixation, homonymous double images appeared, despite the persistence of diverging strabismus. These are explained by the displacement internally, of the point of intersection of the rays of direction which then occurred, and was brought to consciousness.

We may make the following resumé concerning the absence or presence of double images in concomitant squint. As a rule, there is a more or less pronounced deficiency in the psychical utilization of the retinal impressions of the squinting eye, for binocular vision. This may affect certain regions or the entire retina. The projection corresponds to the anatomical identity, or it varies more or less from it. In exceptional cases, the power of binocular utilization of both retinal images is present.

4. Poor vision of one eye. In concomitant squint, vision in one eye is very often poor; complete vision in both eyes is comparatively rare in this disease. Differences in refraction (anisometropia) are often demonstrable. The impaired sight is often explained, at least in part, by corneal opacities, irregular astigmatism, and the like. In other cases palpable causes are absent, and we have amblyopia without pathological appearances. As a rule, the field of vision is normal in extent, but occasionally it is narrowed. I have also, now and then, found impairment of the light sense. Central vision is sometimes so slight that the deflected eye—when the other is closed—does not fix the object with the macula lutea, but with an eccentric part of the retina situated to the inside. This is found particularly in converging strabismus. As the utilization of the convergent deflected eye, is confined chiefly to that portion of its temporal field of vision which cannot be seen by the adjusted eye, it is particularly the inner half of the retina that is kept exercised.

The poor vision which occurs particularly in monolateral squint, has been interpreted as amblyopia from disuse. Its development may be explained in the following way. The voluntary exclusion of the eye in the psychical working up of the retinal impressions leads to a central defect. It must also be assumed—and this really happens—that in youth this exclusion occurs at the beginning of the strabismus, *i.e.*, at a time when the brain is still developing. Opposed to the view, that this weak sight is always independent of the squint and must be regarded as congenital amblyopia, is the uncommon frequency of its occurence in monocular strabismus, and especially the fact that amblyopias in which—without pathological appearances—the greater visual power is found, as in the cases mentioned, in an eccentric portion of the retina, are not observed without coexisting squint. Cases have also been observed, in which a squinting eye, which possessed good vision in youth, became amblyopic at a later period. I operated on a boy of seven years for severe strabismus convergens of the right eye. At the time of operation he possessed full vision with $H\frac{1}{10}$ in the right eye, but without binocular vision. Strabismus convergens of about $1\frac{1}{2}$ mm.

remained. Ten years later the patient could only count fingers at four metres and fixed with a part of the inner half of the retina; there had been no disease of the eye in the mean time. The assumption of a central defect in the perception of retinal images, made to explain the suppression of double images, also enables us to understand why, at a later period, unilateral exercise of the eye only improves the lost vision to a slight extent. It is true that after such exercise, and especially after the better position of the eye following an operation, a considerable improvement in vision as regards its usefulness occurs not infrequently, and this might be erroneously interpreted as improvement of the visual power. But as Schweigger and Alf. Graefe have shown, a very careful and accurate examination of the squinting eye, after correction of the optical disturbances resulting from errors of refraction and especially of the exhaustion which often comes on rapidly during the examination, must be made in order to determine the real visual power of the eye. The results obtained in this manner, will not afterward be changed to a notable extent. But the patient often learns to use the eye again after the operation, especially if the excessive muscular tension, which interferes greatly with the function of the organ, is relieved. This tension is troublesome in the same way as if one with normal vision, should work for a long time with a strong prism, under which his eye assumes a squint position.

In a series of cases, we must infer from certain signs (for example, irregular astigmatism) a congenital weakness of sight in the squinting eye; this favors the deflection.

II. *Special Diagnosis and Etiology.*

In concomitant squint, either one eye is constantly in the squint position, while the other is used constantly for fixation (monocular squint) or both eyes are used alternately for fixation (strabismus alternans.) In the latter event, when an object is carried in front of the patient in a horizontal plane from right to left, the right eye is usually employed for fixation upon the right side of the field of movement, the left eye upon the left side.

Furthermore, we may notice either a constant or periodical deflection of the eye in squint. The latter form is very common in converging strabismus at the time when this first develops (usually between the ages of four and six years): the squint occurs when the child wishes to obtain a distinct visual impression. The eyes are usually adjusted normally. But if any small object, such as the hand of a clock, is held close in front of the eyes, the convergent deflection sets in, sometimes in a surprisingly intense degree. This

condition of periodical squint may persist or disappear spontaneously; in the majority of cases constant squint results.

According to the above-mentioned differences we diagnosticate, for example, a strabismus convergens alternans, or strabismus convergens monocularis (of the right or left eye) or strabismus convergens periodicus alternans, or strabismus convergens periodicus of the right eye, etc.

Strabismus Convergens Concomitans.

Strabismus convergens is not infrequently associated with a slight deflection in level of the squinting eye. This is either an unusual effect of contraction of the internal rectus, resulting perhaps from special conditions of insertion or innervation, or it is due to an independent affection of the superior and inferior rotators. In the former event, which is much more common, the eye deflected to the inside always rotates upward, whether fixation is performed with the right or left eye; this deflection disappears after tenotomy of the internal rectus. In the other case, the condition is as follows. In the position of fixation of the right eye, for example, the left eye is turned inward and a little upward. If the left eye is now allowed to fix the object, the right eye makes an associated movement inward and downward. Here, an additional operation on the superior rectus is often necessary.

[It is a very annoying condition when after a tenotomy of the internal rectus, upward squint occurs, and one that sometimes is not easily removed.—St. J. R.]

The large majority of those who suffer from converging strabismus are hyperopes. The influence exerted by this error of refraction on the development of converging strabismus was clearly explained by Donders. For near vision, the hyperope requires a greater strain of accommodation than the emmetrope. In the ordinary binocular convergence, directed upon the fixed object, the necessary accommodative tension is impossible for him. But as with increasing convergence, *i.e.*, with increased contraction of the internal recti, an increase of accommodative tension also occurs, the hyperope attempts to make this possible by leaving one eye in the position of convergence necessary for the fixed object, and contracting the internal rectus of the other eye more strongly, so that this eye squints inward. As the entire tension of both interni comes into play in the accommodative tension of each eye, the adjusted eye thus receives a greater accommodation. The patient can now accommodate, but abandons binocular vision. Hence we see typical periodical strabismus always occur when an object near by is

sharply looked at. It occurs most frequently in hyperopia of low and moderate degrees; then the possibility of sufficient accommodation is furnished by the increased tension of the internal rectus. In pronounced hypermetropia this increased convergence is insufficient; and here strabismus is rare. It is found to occur occasionally, when hyperopes suffer from general muscular weakness after severe diseases. During the period of health, they were able, by means of their vigorous muscle of accommodation, to accommodate sufficiently without resort to excessive convergence; now they are compelled to resort to the latter. After the return of the former muscular power the strabismus disappears.

Those hyperopes in whom binocular vision is rendered doubtful by the dissimilarity of both eyes, are most apt to suffer from strabismus. This happens when one eye has weak sight or falls into this condition (for example, as the result of corneal opacities after keratitis, such as occur after eruptive diseases), when considerable differences in refraction or irregular astigmatism, interfere with binocular union of the retinal images. The importance of the more or less firm establishment of the binocular visual act, as an aid or hindrance to the development of hyperopic converging strabismus, is also shown by the fact, that it develops, as a rule, in earliest childhood, while its development in adults with firmly established binocular vision is hardly ever observed.

The varying size of the angle γ in the different forms of refraction must also be taken into consideration. In hyperopes this angle is largest; hence the middle of the pupil or the centre of the cornea is at the greatest distance to the outside of the visual line. In adjusting both eyes upon an object at a certain distance, the eyes or the centre of the cornea, must be rotated somewhat farther to the outside in hypermetropes than in emmetropes or myopes. This requires a greater contraction of the external recti. This cannot be obtained when the demand is too great, and thus an insufficiency as compared with the interni is created.

The frequent periodical necessity for contraction of the internal rectus, may gradually induce a constant elastic increase of tension of the muscle, and a constant squint thus develops.

The absence of convergent squint in a series of cases, despite the presence of the etiological factors considered above, may be explained by individual obstacles, for example, strong repulsion to double images, weakness of the internal recti (Ulrich) or modifications of the relations existing normally between convergence and accommodative tension (Graefe).

On the other hand, converging strabismus is also observed, independently of hyperopic refraction or weakness of accommodation.

Here we have an already existing elastic predominance or unusually great power of the internal recti—muscular anomalies which Schweigger places emphatically in the foreground, even in hyperopic convergent squint. Even normally the power of the interni overbalances that of the externi; they turn the eye in the field of movement about forty degrees to the inside, while the externi move the eye only forty degrees to the outside; but this is subject to numerous variations, dependent particularly on refraction and age. It can be proven that, in a series of cases of convergent squint, the internal recti possess an excess of power which exceeds the normal limit. According to Schnetter's investigations, when the limits of the field of movement to the inside, exceed those to the outside by more than eleven to fourteen degrees, we have no longer to deal with purely accommodative squint. The cases of really muscular squint, furnish their contingent especially to the category of constant strabismus, in which are found a considerable number of emmetropes and even myopes. Yet the fact that emmetropia or slight myopia, is present at the time of examination does not exclude the primary accommodative nature of the squint. In numerous cases the former hypermetropia is converted with increasing age into emmetropia or myopia, but the converging strabismus, which developed originally as the result of the accommodative impulse, persists because a constant increase of tension has developed in the mean time in the interni.

In unilateral inflammations of the eye, with severe photophobia or under a protective dressing, a converging deflection, which was not formerly present, is noticed occasionally, when the eye is opened and examined. This is true particularly of children, but also happens in adults. After recovery, the squint disappears. It is to be interpreted in some cases as the result of a reflex irritation, as shown by the spasmodic twitchings of the internal rectus, in others as the expression of a muscular overbalance of this muscle, controlled under ordinary conditions by the binocular visual act.

A very peculiar variety is the convergent squint that develops, in myopes of moderate grade, in the second decennium of life or even later. As binocular vision is fully developed in them, they complain a good deal of double images and are much annoyed by them. At first the squint usually appears periodically; for quite a time there is correct adjustment for near objects, although convergence for distant objects is already present.

In some families squint is hereditary; as a rule, there is hyperopic refraction in these cases.

Converging strabismus (to a less degree, diverging strabismus) is often accompanied by an oblique position of the head: the side of

the face corresponding to the squinting eye is usually turned to the front. This is done in the interest of the fixing eye which, in looking straight ahead, can now assume the position of adduction corresponding to its muscular equilibrium (Hock).

Strabismus Divergens.

The constant deflection of the eye outward usually develops later than converging strabismus. While the latter chiefly attacks hyperopes, the former is found mainly among myopes. This tendency to the position of divergence is explained by various reasons, apart from already existing anomalies in the power of the muscles. Even in the normal position of the eye, there is no predominance of the interni over the externi, as there is in hypermetropes and emmetropes, both as regards the boundaries of the field of movement and the overcoming of prisms. The elongation of the eye, its oval shape in the higher grades of myopia, causes the insertion of the recti to move forward. This stretches the external rectus to a more marked degree, because it passes, from its median origin at the optic foramen, strongly to the outside and forward around the globe, while the internal rectus reaches its insertion in a straighter direction. On account of the increased stretching of the external rectus, every impulse of innervation which reaches it, produces a greater contactile effect and thus moves the eye more to the temporal side. In addition, the angle γ is smaller than in emmetropes and hyperopes. A definite position of convergence requires, in myopes, a greater internal rotation of the centre of the cornea, *i.e.*, a greater contraction of the interni than in emmetropia. Hence it follows that, with the coincident obstruction offered by the increased tension of the externus, the latter secures the prodominance more readily and draws the eye to the outside. It is also to be considered that, on account of the intimate connection between accommodation and convergence, the diminished accommodative tension required by myopes also diminishes the tendency to convergence. When we stare without accommodating, the eyes are apt to assume a position of divergence, as shown by the crossed double images that develop. This predominance of the externi in vacant staring, on account of the absence of strict fixation and accommodation, explains the fact that divergent strabismus develops so often in individuals who are blind in one eye. We rarely find that the eye is turned inward. Then we have to deal chiefly with blindness occurring in early life, when hyperopic refraction is the rule.

III. *Course.*

We must emphasize the fact that in a number of cases of convergent squint, the condition ceases spontaneously in later years. As this occurs, almost without exception, in the strabismus associated with hyperopia, it supports the view that the condition is not always due to unalterable, as it were organic changes in the power of the muscles. Periodical converging strabismus disappears with especial frequency. The number of those who state that they squinted in youth, is by no means small. It is interesting to observe that occasionally one of these individuals, when he arrives at the period of presbyopia, and does not wear the proper convex spectacles, again returns to the tricks of his youth. There is marked accommodative tendency and he rotates one eye abnormally far to the inside. Now, however, without the desired effect.

Various factors play a part in the occurence of spontaneous recovery. As A. v. Graefe has emphasized, the transformation of hypermetropic refraction into emmetropia or myopia, is by no means uncommon. The real object of squint, the facilitation of accommodation, is thereby removed, and in the absence of secondary muscular anomalies the eyes will assume a straight position, especially when the transformation occurs at a youthful age. But the squint sometimes disappears, despite the persistence of hyperopia. Here a part may be played by the diminution of the range of accommodation with increasing age, because sufficient accommodation can no longer be obtained despite the convergence, and, on the other hand, the tendency to bring objects as near as possible to the eyes, which is exhibited by young children, diminishes gradually with age. For greater distances, however, the power of accommodation suffices without abnormal convergence. Nor should we underestimate the influence of the will, which induces many adults suffering from strabismus to avoid the squint position, even if they see more poorly. Such a constant habit gradually loosens the bonds which have formed between the accommodative tendency and abnormal convergence; the patients wear convex spectacles for distinct vision, and no longer squint. The extent to which changes in the power of the muscles (which are connected with the enlargement of the orbit during the years of growth) come into play, requires further investigation.

IV. *Treatment.*

When converging strabismus is dependent upon hyperopia, the treatment must first attempt to secure normal adjustment of the eyes by non-operative means. The most favorable chances of suc-

cess are present when marked anomalies of muscular power (shown particularly by measurement of the field of movement) are absent, when vision is approximately uniform in both eyes and a certain degree of normal binocular vision (shown by the production of double images) still exists. Above all, we must make excessive accommodation unnecessary by the use of suitable convex glasses. For close work the patient should wear those convex glasses which correct the complete, often the latent hypermetropia also. The glasses for distance may correspond to the manifest hyperopia. In addition, we must attempt to strengthen the binocular visual act. If the vision in the eye is much weaker and, above all, when its usefulness has been impaired, separate exercises must be adopted. For this purpose, the better eye is covered with a shield several times a day for one-quarter to one-half hour, while the weaker eye reads large print corresponding to its visual power, and, if necessary, with the aid of convex or cylindrical glasses. A considerable improvement in the endurance and usefulness of the eye can often be obtained in this way in a little while. We then attempt to create binocular vision, and to improve the straight position by stereoscopic exercises, to which Du Bois-Reymond first called attention as a curative agent in squint.

The so-called American stereoscope is used to the best advantage. According to Javal's method, we may use colored wafers which, corresponding to the squint position, are glued somewhat nearer to the dividing median line of the plate upon the side of the convergent squinting eye. For example, upon the half plate situated in front of the left eye that squints inward, a red wafer is placed approximately in the middle, and below it a blue wafer, but so near the line of division, that the image of the red wafer falls directly upon the macula lutea of the left eye. Upon the other half, is placed a red wafer at a greater distance from the line of division, so that its image falls upon the macula of the adjusted eye; immediately above this wafer is placed a yellow one. The binocular collective picture, in which the red wafers situated in the same horizontal line cover one another, will exhibit a yellow, red and blue wafer, from above downward. If binocular vision is secured in this way, at least during the squint position of the left eye, then we gradually increase the distance of the wafers in front of the left eye, from the line of separation of the picture plates, until the distance is finally equal to that on the other side; then a normal direction of the glance has been obtained in both eyes. I use as a picture plate a white sheet of metal which contains horizontal grooves; in these small colored leaden disks (corresponding to the wafers) may be moved and thus brought more or less close to the median line.

Unfortunately these stereoscopic exercises are usually impracticable at the beginning of strabismus because, as a rule, it occurs in little children of insufficient intelligence to carry out the treatment. This is also true concerning the use of convex spectacles, they are apt to be broken at this period of life and thus endanger the eyes. Hence we must be content, as a rule, with separate exercises of the worse eye, and we must attempt to prevent the development of monolateral squint. As a rule, nothing is to be expected from the use of medicinal agents that influence accommodation. Solutions of atropine have been recommended in order to paralyze accommodation and thus to antagonize the squint position or, on the other hand, eserine instillations have been used in order, through the resulting spasm of accommodation, to make optical close adjustment possible without excessive convergence. I have not seen any permanent curative effects from either remedy. [My experience has been exactly the same.—St. J. R.]

Squint Operation.—We treat squint by means of strabotomy. Stromeyer (1838), who performed tenotomy so industriously upon other muscles, also recommended it for squint. Dieffenbach (1839) and Jules Guerin (1839) first performed it on the living subject. At first, the results were not very satisfactory, in part because the muscle was cut entirely through. A good position of the eye was obtained immediately after the operation, but after some time the antagonist pulled the eye to the other side. I have seen a man upon whom Dieffenbach operated and who had formerly had convergent squint; he now squints outward with both eyes, *i.e.*, both divided interni are almost entirely inactive. Boehm (1845) adopted the method of separation of the tendons from the sclera. It is Albr. v. Graefe's merit, that by accurate determination of the final effect and the indications he has brought the operation to its present perfection.

In the operation for squint, the tendon of the muscle which acts too strongly is separated from the sclera at its point of insertion. The antagonist can now draw the globe in its own direction. This change of position, in connection with the contraction of the tenotomized muscle itself, cause the tendon to readhere a few millimetres behind its former insertion. This removal from the anterior pole of the eye permanently diminishes the influence of the muscle upon the rotation of the eye. In addition, the length of the line of adhesion of the tendon to the sclera usually becomes smaller after reunion has occurred.

As the tendon gives off lateral spurs during its passage through Tenon's capsule, and also presents various other threads of adhesion upon the surface presented to the sclera, simple division of the

curved line of insertion will not entirely abolish the influence of the muscle on rotation of the eye, even before union takes place. The more Tenon's capsule is divided laterally, and the more completely the other connections are divided, the further backward will the new insertion of the tendon take place or, in other words, the greater will be the effect of the operation.

The operation is performed upon the external or internal rectus in the following way. A horizontal fold of conjunctiva near the insertion of the tendon, is lifted up by a pair of forceps, applied four or five millimetres from the edge of the cornea, one blade being above, the other below. With slightly curved scissors, which are blunt on both sides in order to avoid cutting the globe, the conjunctival fold is now incised vertically to the extent of five or six millimetres, then the scissors are passed beneath the conjunctiva and, keeping close to the globe and cutting with small incisions, are pushed in an oblique direction (upward and inward, or downward and inward in the case of the internus, upward and outward, or downward and outward in the case of the externus) tolerably far backward. We thus expose the entrance to the upper or lower border of the tendinous insertion. The choice of direction depends upon the convenience of making the incisions. If we are seated in front of the recumbent patient, it is more convenient to pass toward the upper edge, if seated behind his head, to the lower edge. A squint hook (Fig. 169) is then pushed into the exposed tract, in such a way that its button is turned away from the edge of the tendon. If the strabismus hook is found to be a little behind the tendinous insertion, it is carried beneath the tendon by turning the button upon the sclera toward the tendon. Now taking the hook in the left hand, the tendinous insertion is made to present and is divided immediately below the hook. The mistake is often made that the scissors as well as the hook, are not entered sufficiently deep. Only a little connective tissue, and not the tense, distinctly recognizable tendon, is then found upon the hook. After division a second smaller hook is passed upward and downward in order to draw out and divide any connections which may have been left behind. As the insertion of the external rectus is somewhat farther from the cornea (about seven millimetres) than that of the internal rectus, the conjunctival incision for the latter is made about one millimetre more remote from the edge of the cornea. We must be especially cautious as regards the degree of strabotomy of the superior or inferior rectus that may be necessary. Here partial division of the tendon is usually sufficient, while this is almost



FIG. 169.

entirely destitute of effect upon the lateral muscles. [It is a singular fact that my experience has been just the opposite of this. I find it harder to get sufficient effect from division of the superior rectus than from the inferior.—St. J. R.] Immediately after the operation it is noted whether a corresponding loss of mobility toward the operated side is demonstrable. If this is not the case, we may be sure that there are still direct connections of the tendons with the sclera and these must again be searched for with the squint hook.

An operation carefully performed in this way, without marked incisions into the lateral connections, corrects, on the average, a deflection of two to three millimetres in converging strabismus, less in diverging strabismus. As a matter of course, this is a very qualified statement, because the degree of correction depends upon many auxiliary statements (such as the power of the antagonists, refraction of the eye, etc.), some of which will be considered later.

In order to form an approximate opinion concerning the result of the operation, the following test should be made immediately afterward. With the plane of vision somewhat depressed, the patient fixes a light at a distance of three or four metres in the direction of the median line of the head, and the position of the eyes is noted. In converging strabismus a remaining internal squint of one to two millimetres is desirable. We must then test whether insufficiency of the displaced muscle has set in. The patient must be able to fix constantly an object in the median line (for example, the tip of the finger) until it is brought to a distance of about twelve centimetres. If the eye is deflected to the outside before this distance is reached, a subsequent conversion into divergence is to be feared, and the effect of the operation is to be curtailed at once. For this purpose, the peripheral cut surface of the conjunctiva which, in the above method of operation, remains partly connected with the tendon and muscle, is stitched to the corneal incision. This conjunctival suture draws the tendon, together with the peripherally displaced conjunctiva, closer to the cornea. The sutures are allowed to remain three days until the permanent healing of the tendon has occurred. But if the effect is to be increased, larger lateral incisions are made or a suture is applied under the conjunctiva of the opposite side. When this suture is tightened, it draws the conjunctiva together and thus turns the eye to the corresponding side.

Simple strabotomy has received a number of modifications. Bowman and Critchett perform the operation subcutaneously, the conjunctival incision being made horizontally, not vertically, along the lower border of the tendon, the scissors introduced (one blade in front, the other behind the tendon) and the insertion divided.

They thus avoid, at the same time, the sinking back of the peripheral part of the conjunctiva. The latter is especially annoying, from a cosmetic point of view, in the operation on the internus, because the caruncle also falls back somewhat with the conjunctiva. In order to effect the same object as the English operation, and at the same time secure free entrance to the field of operation, we may, according to Liebreich's plan, separate the conjunctiva completely from its base as far as the caruncle, and then, after tenotomy, suture the conjunctival wound. This does not diminish the effect of the operation, because the conjunctiva is no longer connected with the detached tendon. Arlt makes the conjunctival incision immediately in front of the insertion of the tendon, then lifts the conjunctiva and grasps the tendon with forceps.

In the higher grades of squint (more than three millimetres in converging strabismus and more than two millimetres in diverging strabismus), the single operation will not suffice. The operation may then be divided symmetrically upon both eyes. In converging strabismus, for example, both interni may be tenotomized. A corresponding outward deflection is thus produced on both sides. This method possesses the great advantage that, unlike a free one-sided operation, the muscle operated upon is not weakened to such an extent that an absolute deficiency of mobility in the eye is the result. On the other hand, it is to be considered that in very high grades even a third tenotomy (twice upon the same eye) may become necessary. We must be especially distrustful of this method, when the strongly squinting eye has very feeble vision. Here an accident which injures the seeing eye during the operation might lead to complete blindness.

In order to secure a greater effect in such cases, the antagonist is displaced anteriorly, after tenotomy of the contractured muscle. The requisite advancement is performed in the following manner (Critchett). The conjunctiva is incised over the weak muscle (in strabismus divergens over the internus, after strabotomy of the externus), but not too far from the rim of the cornea (about three millimetres), the tendon placed upon the squint hook after loosening the conjunctiva sufficiently from the underlying tissue, and sutures (catgut is the best) are passed through the muscle in the neighborhood of its transition into the tendinous tissue. We may use two sutures, each provided with two curved needles. One suture serves to secure the upper part of the muscle, the other the lower part. The former is passed through from behind in the neighborhood of the upper edge of the muscle, the latter in the neighborhood of the lower edge. Then the tendon is separated from the sclera, care being taken that the sutures are not divided.

By means of the latter the muscle with its tendon is now drawn forward and stitched fast, the second curved needle of each thread being passed from behind through the opposite conjunctiva (*i.e.*, the part adherent to the cornea). After removing these needles, the ends of each single thread are tied. The tendon will be advanced so much farther the nearer to the cornea the conjunctiva is perforated—if necessary, this may be done obliquely upward or downward toward the vertical meridian of the eye. Care must be taken that the muscle be advanced directly forward, not upward or downward. The conjunctival wound over the tendon is also sutured. When we have to deal with secondary divergent squint, after strabotomy of the internus, with sinking of the caruncle, the latter is best drawn forward in the following manner. After the conjunctiva has been separated from the underlying tissue as far as the caruncle, a semilunar piece of conjunctiva, several millimetres wide, is excised from the peripheral edge of the wound, and then the conjunctival wound is united with sutures.

Advancement of the weak muscle without separation of the tendon of the antagonist has but a slight effect. I have obtained a greater effect than that of the simple squint operation by advancing the weakened muscle, after tenotomy of the antagonist, in the manner described above, but without separating its tendon from its insertion. Wecker has advanced Tenon's capsule in a similar way, by making incisions above and below the tendon, and here introducing the needles.

The sutures are removed at the end of three or four days or they are allowed to suppurate through.

The after-treatment consists of the application of a compress and bandage with closure of the other eye.

For the first three days the patient is kept in a bed or at least in the room. Although, on the whole, advancement and especially simple strabotomy are to be regarded as free of danger, nevertheless cases have been reported in which the eye has been lost from suppuration in the orbital fatty tissue, scleral affections, and purulent choroiditis. These are chiefly the results of infection of the wound, but occasionally of injuries received during the period of healing.

For this very reason, it is inadvisable to operate on both eyes at the same time, when bilateral tenotomy seems to be indicated by a high grade of squint. But even with regard to the position of the eyes, it seems to be more cautious to await the after-effects of one operation. For a long time we observe the after-effects which, as a rule, increase the effect in converging strabismus, and diminish it in diverging strabismus.

The deflection existing immediately after the operation is again diminished with the union of the tendon to the sclera (after the third day), inasmuch as the muscle has now regained a firm insertion for its action. But in a third period, which begins in six to eight weeks, the effect of the operation is again increased, in converging strabismus, by relaxation of the threads of adhesion.

Whether binocular vision, even if only moderate in degree, exists or not, is decisive with regard to the final effect. When this is abolished, the tendency to divergence is considerably greater. Even a moderate grade of converging strabismus, which has been allowed to remain after the operation, may gradually pass into diverging strabismus. This will occur less often (also in cases in which binocular vision is wanting) when there is hyperopia of the seeing eye, because the accommodative strain favors the convergence. But even here it is to be noted that in young people the hyperopia is gradually converted into myopia, and hence the accommodative tendency, which opposes the conversion into divergence, is lost. Cases in which, despite former binocular vision, divergence occurs at the end of years, although in a latent form, are not infrequent, despite the fact that the operation has been performed by the best operators. There are too many factors at work here, to enable us to determine the final effect with absolute certainty. In young people we must always allow a converging strabismus of one to two millimetres to remain after the operation. Even if the convergence increases in the course of time—as happens in exceptional cases, especially in hyperopes who do not wear correcting spectacles—less is lost because the operation may then be repeated. In diverging strabismus, on the other hand, even an immediate over-correction is unattended with harm.

False dosage of the effect, which appears in the period immediately following the operation, may be compensated to a certain extent by wearing squint spectacles. If one-half of the spectacles glass is covered, and the other half, opposite the antagonist of the operated muscle, is left free, the eye must turn in this direction during vision. The insertion of the tenotomized muscle, which is not yet firm, is thus loosened and the effect of the operation is increased.

Diminution of the effect can hardly be expected from the use of the squint spectacles applied in the opposite manner. If the eye is forced to look toward the side of the tenotomized muscle, its contraction will draw upon the not yet firm tendinous insertion and the desired effect will not be obtained on account of the stretching of the antagonist. If we have to deal with hyperopic converging strabismus, greater accommodative tension may be given to the

muscle by close work without spectacles, after the tendinous insertion has been sufficiently secured for some time. On the other hand, when the effect is too slight or the position of the eyes is good, the correcting convex glasses may be worn for close work, if necessary even for distance. Complete paralysis of accommodation may diminish for a time the tendency to convergence.

If binocular stereoscopic vision can be obtained, persistent exercises for the continued proper position of the eyes are of great advantage.

The final result of squint operations will vary according to the visual power, and the degree of approach of the eyes to the normal position. In a considerable number of cases, the actual effect is purely cosmetic. In others, an increase of the usefulness and visual power of the formerly deflected eye, and more or less complete binocular vision are secured. The latter occurs occasionally, in cases in which there was regional or even complete exclusion of the eye from the visual act prior to the operation.

3. Insufficiency of the Internal Recti. Asthenopia.

In many individuals, the otherwise accurate adjustment of the eyes on looking at a near object is lost, as soon as one eye is covered with the hand; when excluded from binocular vision it is deflected, usually to the outside. This corresponds to its position of muscular rest. The abnormal adjustment of both eyes upon a near object finds further support, apart from the influence of the binocular vision and the repulsion against double images (tendency to fusion), in the accommodative tension necessary for close work and which, as we know, is always associated with contraction of the internal rectus. As myopes require less accommodation for this purpose than emmetropes and hypermetropes, this explains the fact that it is particularly in them that a marked diminution of the power of convergence appears. In the higher grades of myopia, this is associated with the other factors that, as we have already learned, favor manifest diverging strabismus. This insufficiency (dynamic divergence, latent divergent strabismus) may also be observed in emmetropes and hyperopes, although they are affected less frequently, inasmuch as they do not require such close approximation of the objects in reading and writing.

The symptoms are those of asthenopia: want of endurance in close work. For example, when the patient reads, the letters become indistinct after a time and are even seen double. In addition, there is pressure in and above the eyes; headache and nausea may also be observed. These symptoms depend on the insufficient

activity of the internal recti which soon grow tired. At first both eyes are accurately adjusted in reading; after a while the power of the interni relaxes, and the eyes assume a position of divergence. At the same time crossed double images appear, and of which the patient usually is not fully conscious; they produce merely the phenomena of "swimming" or blurring. If he again attempts to adjust properly by a new impulse of convergence, the letters again become more distinct. The repeated relaxation and tension of the muscle, the double images and the increased innervation necessary to overcome them temporarily, are the source of the complicating nervous phenomena.

This form of asthenopia is generally called muscular, as distinguished from the previously described accommodative, retinal and nervous asthenopia. But this must also be attributed occasionally to disturbances of innervation from central causes (neuralgic insufficiency). This is due chiefly, as it seems, to diminution of the range of convergence, while in true muscular insufficiency of the interni it is simply displaced to the negative side (Landolt).

Insufficiency of the external recti may also give rise to asthenopia (Noyes).

Quite high grades of insufficiency are sometimes present without the production of asthenopic symptoms. At all events, a certain part is played by the strength of the power of fusion of double images and other conditions (consciousness of accommodation, feeling of convergence); permanent correct adjustment may thus be effected even when the muscular power is insufficient (Hausen Grut). It should also be noted that the mechanical removal or compensation of the muscular insufficiency does not always cause disappearance of the symptoms. There is often a complication with nervous disturbances.

Diagnosis.—The difficulty of diagnosis resides in the fact that the muscles may exhibit temporarily their full power from increased nervous impulse. Thus, the near-point of convergence on approximation of a fixed object may be perfectly normal, likewise the range of the power of adduction, which is measured with prisms (placed in front of one eye with the base to the outside). If notable abnormalities appear, the diagnosis will follow, but as a rule, certainty is not secured by these measurements on account of the physiological variations which are by no means slight.

Albrecht v. Graefe has devised another test. By holding a prism, with the base turned upward or downward, in front of one eye, he produces superimposed double images. Now the interests of single vision which usually lead the patient to innervate the interni abnormally, and adjust the eyes correctly, no longer come in

question; the eyes will be in the position which they should assume according to their muscular equilibrium. The test (equilibrium test) is made for a distance which corresponds to the individual reading distance; this varies according to the degree of myopia and the correction by concave glasses. The object used is a black dot (ink spot) on white paper. This is better than the vertical line with a dot upon it, because the tendency to fusion may be stimulated occasionally by the line.

For example, if a prism of eighteen degrees, with the base downward, is held in front of the left eye and the gaze directed upon the black point of the paper, held at a distance of twenty-five centimetres, an individual with normal position of the eyes will see two points, one above the other; the higher one belongs to the left eye. But if divergence of the eye occurs, the higher image of the left eye moves toward the right. This appearance of crossed double images shows insufficiency of the internal recti. The degree of insufficiency is expressed by the prism which, when placed in front of the other eye with the base to the inside, again brings the double images above one another. In our case we will assume that a prism of eight degrees placed in front of the right eye, throws the image of this eye so far to the right that it is now situated directly under that of the left eye; a prism of seven degrees would displace it somewhat to the left, a prism of nine degrees would overcorrect it and cause homonymous double images to appear. Hence we have here an insufficiency of the interni of eight degrees. As a rule, both interni are insufficient. If one is more markedly insufficient, this can be ascertained in two ways. In determining the near-point of convergence, the eye in question will first be deflected with tolerable regularity; but differences in refraction and visual power may here play a decisive part. It is better to determine the power of adduction for near objects (about thirty centimetres), first ascertaining the strongest prism which, on being placed in front of the left eye (with the base to the outside) can still be overcome in the interest of single vision of the fixed object, and then—after a prolonged interval of rest—making the same measurement with a prism placed in front of the right eye. If there are differences in the strengths of the prisms, the eye which can overcome only the weaker prism by squinting has the weaker internal rectus.

The equilibrium test does not suffice for the diagnosis of all cases of insufficiency, because varying results are sometimes obtained, on account of changes of accommodation and even the tendency to fusion; the patient often finds that the points move to and fro, etc.

Alfred Graefe measures the degree of insufficiency in a some-

what different manner. He places in front of one eye a prism with the base turned inward, and the patient fixes a point at the suitable distance; then he covers the eyes alternately and notes whether a movement of adjustment is made after the eye in question is again exposed. If it moves to the nasal side, then its position of rest is more divergent, the prism, accordingly, too weak, and vice versa. The prism under which the eyes, when covered and again exposed, remain in the same position, corresponds to the position of rest.

It resides in the nature of insufficiency, that its degree varies as the eyes are turned in different directions, and is less for greater distances. It is therefore not uncommon to find that the equilibrium test shows perfectly normal position, or even latent convergent strabismus in looking at a light situated at a distance of four or five metres.

Treatment.—The treatment may be operative or non-operative. In slighter grades the latter is always preferable and even in higher grades the symptoms can often be relieved by partial correction. No improvement is to be expected, as a general thing, from exercise of the interni; overexertion, that is apt to occur, may result, on the contrary, in a serious impairment of their power. More is promised by the constant current, rest to the eye, improvement of the general condition. Symptomatic benefit is obtained by prisms, whose use is always indicated for an insufficiency of six to eight degrees. If an insufficiency of six degrees has been found at the reading distance of the patient (for example, thirty centimetres), we order, for close work, spectacles containing a prism of three degrees on each side. Prisms over six degrees are not very practicable on account of their weight and dispersion of colors. In the higher grades of insufficiency, if we do not wish to operate, we must be content with partial correction or a combination with spherical lenses. The latter remove the reading distance somewhat and then, as a rule, a slighter insufficiency will be found for the greater distance. If a myope 6.0, when he reads print at his far-point (about sixteen centimetres) has insufficiency, without correction, of ten degrees, the far-point may be removed to 33.3 cm., by a concave glass 3.0. If he now reads at twenty-five centimetres, measurement usually shows slighter insufficiency (for example, six degrees). Not alone the increased distance has exerted an influence on the diminution of the insufficiency, but also the increased accommodative tension which is observed with the spectacles. The spectacles would then be ordered in the following way: spectacles, both sides:—3.0, prism of three degrees, with the base to the outside. The mere use of spherical glasses sometimes causes disap-

pearance of the insufficiency by increasing the reading distance, or reduces it to a minimum. In the latter event we may utilize the prismatic action exercised by stronger concave lenses, on looking through their periphery. The glasses are then placed in the frame in such a way that the patient must look through the inner halves on both sides.

The operative treatment consists of the strabotomy of the external rectus; when the external rectus of one eye is stronger than that of the other, the operation is performed upon the former. A. v. Graefe cultivated this operation with great zeal and to him we owe the principal rules. His indications were somewhat extensive because he ascribed to the operation an inhibitory influence on the advance of the myopia, inasmuch as the abnormal strain on the globe by the externi is diminished. This latter view does not appear to be correct, and the operation is now performed much less often than formerly. In addition, the correct dosage is very difficult and cannot always be obtained.

As we have seen, the insufficiency varies at different distances. The reading distance and also the farther distance of four to five metres must be chiefly taken into consideration. Let us assume an insufficiency of sixteen degrees at the former distance, none at the latter. If a tenotomy of the rectus externus, equivalent to the action of a prism of sixteen degrees, would secure a position of equilibrium for the reading distance, a converging strabismus of sixteen degrees would be produced for distance. The patient would see homonymous double images at a distance. With a good power of fusion he might, perhaps, cause them to unite and would thus make the convergent strabismus latent. We should attempt to discover, prior to the operation, whether he is able to do this. Homonymous double images are produced for distance by using a prism, with the base to the inside, and we then note whether he can unite them permanently by dynamic divergence. For example, if the patient —when a prism of sixteen degrees, with the base to the inside, is placed in front of one eye—is able to unite the double images while looking at a light situated at a distance of five metres, he will probably be able to do this after tenotomy. We may therefore perform an operation equivalent to sixteen degrees. If he can only overcome a prism of ten degrees, the tenotomy must be graduated to this point; there would then remain an insufficiency of six degrees for near objects, and this may, perhaps, be corrected by prisms. If the difference is much greater, the operation cannot be performed to advantage. According to v. Graefe, tenotomy of the externus, carefully performed, gives in these cases an average final result equivalent to the deflection of a prism of sixteen degrees. In order

to make an approximate measurement of the final position, immediately after the operation, a light is held at a distance of at least three metres, about fifteen degrees toward the side of the non-operated eye, and is fixed with the plane of vision somewhat lowered. In this so-called position of election there should be equilibrium or, at the most, a convergence equal to a prism of three degrees; variations in one or the other direction should be avoided. Alfred Graefe, who has made accurate after-examinations, states that the position of election by no means corresponds in all cases to the final effect. He attaches more importance to the limitation of abduction occurring after tenotomy of the externus, and which should never exceed five millimetres, and also to the position of the point of indifference (*i.e.*, the point upon which binocular adjustment occurs, under the covering hand) which, as a rule, should not be situated closer than thirty centimetres. If this does not hold good, a suture should be inserted to diminish the effect, in order to prevent subsequent convergence.

On the whole, it will be well to confine the operation to cases in which insufficiency of the interni is also demonstrable for distance. The definitive result of the operation appears, as a rule, at the end of six to eight weeks.

[In all this, there is not a hint of the modern doctrine, which, however, has very few adherents, of the great influence upon the general condition of insufficiency of the ocular muscles. This modern teaching has as yet obtained credence only among those whom I am constrained to think are overcredulous as to the immense importance to the general system of ocular insufficiency. —St. J. R.]

4. Spasm of the Ocular Muscles. Nystagmus.

Spasm of the ocular muscles is usually tonic in character. Thus, rigid, associated directions of the eye are observed in various cerebral and meningeal affections, also in epileptic and other convulsions. In an hysterical individual I observed occasional spasmodic convergence of the visual axes, which were directed toward the bridge of the nose; it gave rise to double images and vertiginous symptoms.

The conjugate deviation, described by Prevost, is well known. Here there is marked lateral position of the eyes which are directed, in disease of the brain, to the corresponding side—the patients look at the site of disease—in affections of the pons, cerebellar peduncle, and cerebellum are directed toward the opposite side. But cases in which the opposite condition was observed have also been reported.

Nystagmus is the term applied to peculiar, trembling movements which almost always affect both eyes and are associated. When the movements take place from right to left, as is usually the case, or from above downward—a diagonal direction is rare—the nystagmus is called oscillatory; if the eyes turn around the line of sight in wheel movements, it is called rotatory nystagmus. Tottering movements of the head are made occasionally at the same time.

As a rule, nystagmus is found in children who have had feeble sight since childhood. The degree of impairment of sight is usually different in the two eyes.

Nystagmus, which has lasted since childhood, is also observed occasionally in individuals with full visual power. Despite the constant movements of the eyes there is no disturbance in the localization of visible objects. There is often a certain position of the eyes, in which approximate rest sets in (Boehm), while in the other directions the twitching is very much increased. The twitching is also increased by emotional excitement. It diminishes occasionally in old age. In predisposed eyes, temporary twitchings are observed at times during inflammatory affections when the eyes are exposed suddenly to light, after trigeminal irritation (Raehlmann), etc.

The causes of nystagmus must be sought chiefly in anomalies of innervation. It is not plausible to assume that they develop in the interest of better vision, inasmuch as different parts of the retina of the weak eye are presented to the object (Arlt). This theory is discountenanced by its occurrence in eyes which possess good vision, its absence in a number of eyes of equally poor sight, and the variety of forms of movement. Wilbrand's explanation, with a certain modification, seems correct for the majority of cases. This starts with the notion that the centres in the mid-brain and cerebellum, which influence ocular movements in response to reflexes, acquire the predominance over the visual and voluntary motor centres in the cerebrum. When the latter are suppressed, either by primary or reflex stimuli—which pass from the cutaneous nerves, the sensory fibres of the trigeminus, and the semicircular canals of the ear, to the centres in the cerebellum and mid-brain—nystagmic movements develop. Physiological and pathological conditions show that twitchings of the eyes, may result from excessive stimulation of the reflex centres. But the intention of seeing is also necessary to the production of typical nystagmus. Apart from the fact that true nystagmus is almost always absent in those who have become blind in later life, we do not find it, as a rule, in those who became amaurotic in early childhood. The latter often

exhibit involuntary associated movements of the eyes, directed now to the right, now to the left or downward, but they do not exhibit true nystagmic twitching, in which an alternation of relaxation and contraction occurs during the most excessive movements. In my opinion, a prominent part in nystagmic twitching should be ascribed to the visual act. Through it the involuntary movements which result from the predominance of the reflex centres are interrupted in the interests of vision by voluntary attempts at fixation. This gives rise to the battle between both sets of influences.

Involuntary nystagmus-like twitchings, are found occasionally in central diseases, such as pachymeningitis (Fuerstner), thrombosis of the sinuses (Nothnagel), disseminated sclerosis (Charcot), hereditary ataxia (Friedreich), and cerebro-spinal meningitis (Leyden).

A peculiar form of nystagmus is observed in coal miners (P. Schroter). In a bright light the eyes maintain their normal position, in twilight they are attacked by nystagmus. The movements are most extensive on looking upward, diminish when the line of vision is lowered. Considerable visual disturbance results from the apparent motion assumed by objects. The condition is often associated with hemeralopia (Nieden). The cause of the disease is unexplained. It has been attributed to the bent posture and the usually upward direction of the eyes which the patients must assume when at work, and to the constant strain of recognizing objects in the dark, in addition to toxic influences (v. Reuss).

The treatment of the nystagmus of poor sight is hopeless. If convergent strabismus is also present, operation upon the latter usually secures a certain diminution of the nystagmic movements. Blue spectacles are often agreeable to the patient.

The miners, who have acquired nystagmus, must abandon their occupation. Injections of strychnine and the constant current, in addition to tonic treatment, have been used to advantage. If the patients, after recovery, return to the mines, a relapse occurs as a general thing.

CHAPTER II.

DISEASES OF THE ORBIT.

Anatomy.

The shape of the orbit corresponds to that of a truncated, four-sided pyramid, whose basal opening is turned toward the face. The axes of both orbits converge posteriorly so that they would intersect at an acute angle, if prolonged to the sella turcica. This angle varies in different individuals. According to Mannhardt, it is especially large in myopes. The upper wall (roof) of the orbit is formed by the orbital part of the frontal bone, which terminates anteriorly in the supraorbital margin, and posteriorly by the lesser wing of the sphenoid. The floor is formed by the orbital plate of the superior maxilla and maxillary process of the malar (infraorbital margin), posteriorly by the orbital process of the palate bone. The inner wall is formed by the os planum of the ethmoid, the lachrymal bone and, anteriorly, by the frontal process of the superior maxilla (the latter, together with nasal process of the frontal bone, forms the inner rim of the orbit), posteriorly by the anterior part of the lateral surface of the body of the sphenoid. The outer wall is formed posteriorly by the greater wing of the sphenoid, anteriorly by the malar bone (temporal margin). The optic nerve and ophthalmic artery pass through the optic foramen which is situated at the apex of the pyramidal space. Further to the outside lies the superior orbital fissure, which affords passage to the third, fourth and sixth nerve, ophthalmic branch of the trigeminus, the superior and inferior ophthalmic veins. Below this and running in a lateral direction, is the inferior orbital fissure which affords passage to the subcutaneous malar and infraorbital nerves, the infraorbital vessels and a branch of the facial ophthalmic vein. It connects the orbit with the pterygo-palatine fossa and the inferior temporal groove; an important fact in regard to the spread of tumors.

At the upper rim of the orbit, between the inner and middle thirds, is the supraorbital notch, through which the supraorbital nerves and artery pass to the forehead. In addition to the eyeball and its muscles, vessels, etc., the orbit contains considerable adipose tissue. This is separated into two distinct parts, one inside, the

other outside the muscular funnel. Tenon's capsule forms the limiting membrane between the cellulo-fatty tissue and the globe and conjunctiva.

1. Diseases of the Bones.

As a rule, diseases of the bony walls of the orbit occur as periostitis, which is followed by caries and necrosis; the latter affections rarely occur primarily. The rim of the orbit is attacked with special frequency. The corresponding eyelid becomes swollen and reddened, and dull pain is experienced. A circumscribed swelling forms, at first very hard, but then growing soft; after perforation occurs the pus is evacuated. The sound comes in contact with rough bone. In a few cases absorption and resolution take place without suppuration. When the bone disease is situated deep in the orbit, the inflammatory symptoms are more violent. The eyeball is prominent, the bulbar conjunctiva chemotic; double vision is often produced by the displacement of the globe. This permits us to infer the extension of the inflammation to the adjacent cellulo-fatty tissue of the orbit.

The tenderness of the corresponding wall of the orbit on pressure with the finger, is regarded as specially characteristic of periostitis. In order to find the site of the disease, the orbit must be palpated and the index finger must often be introduced deeply. Even in deep-seated periostitis, the skin and subcutaneous cellular tissue are implicated less severely than in primary inflammation of the cellulo-fatty tissue of the orbit. If deep-seated periostitis is complicated, as generally happens, with inflammation of the cellulo-fatty tissue, the latter is usually circumscribed and is felt as a firm mass that presses the globe to one side, so that its mobility in the corresponding direction is impaired. Nevertheless the diagnosis between primary inflammation of the cellulo-fatty tissue, and periostitis cannot always be made with certainty. The disease is not infrequently associated with violent pains that often exacerbate at night.

Disease of the bones of the orbit, especially of its rim, is observed chiefly in childhood. In an infant of nine months I observed acute ostitis of the right superior maxilla with œdema of the lids and exophthalmus, which developed without any apparent cause. Within a week it led to extensive evacuation of pus into the alveoli and nose. The condition is due mainly to the scrofulous diathesis, and injuries are often the exciting causes. Syphilis plays an important part in later life.

The prognosis is comparatively good, if the rim alone is attacked.

But if the periostitis or caries has extended deep into the orbit, the prognosis becomes serious because grave inflammations of the eye or even extension to the brain or pyæmia may result from the spread of the disease to the cellulo-fatty tissue or the veins with consequent thrombosis. This termination is usually ushered in by sudden high fever, pronounced exophthalmus, and semi-unconsciousness.

The treatment will depend upon the general constitution. This is particularly true of scrofula and syphilis. In the latter, larger doses of potassium iodide are often useful. At the onset we may attempt to combat the inflammation locally by means of abstraction of blood, inunctions of mercurial ointment, or applications of tincture of iodine. Cold compresses are rarely useful. If the affection is more advanced and suppuration is expected, warm antiseptic compresses are indicated. An early escape for the pus should be secured by incisions with subsequent drainage. This is especially necessary in deep-seated affections. A narrow scalpel is passed through the conjunctiva as deep as possible along the orbital wall on the side on which the disease is suspected. In adults the orbit measures about four and a half centimetres in an antero-posterior direction. As a matter of course, we must be careful to avoid perforating the eyeball or the bony walls. Even when very little or no pus is discharged, the incision is generally useful on account of the resulting hemorrhage and diminution of tension, and a path is also made for the pus formed later. If suppuration exists, a drainage tube is inserted to secure evacuation. Injections are to be avoided, because they increase the orbital contents and tension. Necrotic pieces of bone that may be present must be extracted.

2. Inflammation of the Cellulo-fatty Tissue. Thrombosis of the Veins.

In inflammation of the cellulo-fatty tissue of the orbit (orbital phlegmon) there is protrusion of the eyeball (usually straight forward) with redness and chemosis of the conjunctiva. In the more severe cases, the upper lid hangs down immobile. At the same time the mobility of the globe is impaired, and double images are often present. Disturbances of vision often appear; likewise pains deep in the orbit and region of the forehead, febrile movement and dyspepsia. The eyeball and surrounding parts appear harder on palpation. If suppuration takes place, a swelling appears at a circumscribed part of the conjunctiva and subsequently fluctuates. All the symptoms change with the evacuation of pus.

The affection not infrequently extends to the eye. Purulent

choroiditis develops and leads to phthisis or the imperfect covering by the lid results in ulceration of the cornea. Affections of the optic nerve (neuritis, atrophy) are not uncommon; hemorrhages and detachment of the retina have also been observed.

The orbital veins are sometimes thrombosed and give rise to pyæmia. The thrombus often extends into the cavernous sinus and may even pass through the intercavernous sinus to the sinus cavernosus of the other side, thus giving rise to double exophthalmus. Exceptionally, as I have seen in one case, it is confined to the orbital veins. If the thrombus is septic, as is usually the case, abscesses, which are occasionally so small that they appear like dots of pus, are observed in the vicinity of the eye, especially on the lids. I have also found abscesses in the muscles of the orbit and the walls of the vessels. The cellulo-fatty tissue is infiltrated with serum, often with pus.

In these severe cases, the patients usually die from purulent meningitis, cerebral abscess, or pyæmia.

Primary thrombosis of the cerebral sinuses may give rise to symptoms similar to those of orbital phlegmon, viz., unilateral exophthalmus, hyperæmia and œdema of the conjunctiva, orbital cellular tissue and eyelid. In these cases suppuration does not occur. Purulent irido-choroiditis may also be attended by the symptoms which we have described as characteristic of inflammation of the orbital cellulo-fatty tissue. Here an examination of the globe and the recognition of its intactness will clear up the doubt.

Orbital phlegmons—apart from directly infectious injuries or operations—are excited most frequently by the spread of inflammation from adjacent morbid processes (facial erysipelas, caries of the orbit, affections of the adjacent bony cavities, diseases of the roots of the teeth of the upper jaw, etc.). As the result of circumscribed syphilitic caries of one nasal bone I have seen phlegmon of the orbit develop first on one side, then on both, followed by venous thrombosis and a fatal termination.

In other cases we have metastatic processes, as in carbuncles, splenic fever, glanders, pyæmia. Orbital phlegmons are also observed after severe typhoid fever and scarlatina. Moreover, a certain amount of inflammation of the orbital cellulo-fatty tissue is present in every panophthalmitis.

The treatment depends upon the causation. In genuine inflammation of the cellulo-fatty tissue, antiphlogistic treatment may be employed at first, as in orbital periostitis; later lukewarm antiseptic compresses and, above all, early evacuation of the pus are indicated.

In this disease, Tenon's capsule usually undergoes thickening and infiltration. It is questionable whether it may be inflamed alone,

independently of the orbital phlegmon, but the pathological findings in Kuhnt's case might be interpreted in this manner. This affection has been called Tenonitis. Its symptoms consist of impaired mobility of the globe, with slight prominence and chemosis of the conjunctiva—symptoms which are also present in orbital phlegmon, but are less violent and pronounced. These cases usually run a favorable course (Hock).

3. Exophthalmus. Basedow's Disease.

Apart from the diseases just mentioned, the globe is pushed forward (exophthalmus) when the contents of the orbit are increased by greater fulness (hyperplasia of the cellulo-fatty tissue, increased congestion and œdema (as in thrombosis of the cerebral sinuses), hemorrhages, emphysema, tumors) or when the orbital space is diminished by distention of adjacent cavities (antrum of Highmore, frontal sinuses, nasal cavity, etc.). Periodical exophthalmus on bending the head has also been observed as the result of varicose dilatation of the orbital veins (Magnus). Emphysema also develops occasionally, on sneezing, blowing the nose, after an injury to the lachrymal sac and bone as the result of abnormal communication between the nose and orbit. This soon diappears, but may return in a few days after similar exciting causes. With recovery, which usually occurs spontaneously, the path for the entrance of air into the orbit is closed.

Abnormal sinking of the eye (enophthalmus) may occur after atrophy of the cellulo-fatty tissue.

A series of exophthalmometers have been devised (H. Cohn, Emmert, Zehender, Snellen, etc.), in order to measure the degree of protrusion of the eyeball. In the main they consist of a graduated rule applied to the outer rim of the orbit (or forehead), upon which the distance of the apex of the cornea from the rim of the orbit is read off. When we wish to measure the distance by pushing a horizontal rod upon the rule against the cornea, a distinct retraction of the globe from the contact is often seen. The variations in the distance between the apex of the cornea and the orbital wall are quite large in different individuals. In pathological cases, comparison of both eyes is very important, but there are also congenital differences between the two sides of the face.

In Basedow's disease, both eyes protrude, but in exceptional cases the prominence is confined to one eye. Before this prominence assumes a distinctly pathological character, it is found that the upper lid lags behind in a striking manner on looking downward (v. Graefe). The palpebral fissure is also unusually wide and

winking occurs less frequently. These symptoms are of special importance in very myopic individuals whose eyes are often prominent. The protrusion of the eyeball, which results anatomically from dilatation of the blood-vessels, serous infiltration and hyperplasia of the cellulo-fatty tissue, may become so great at a later period that the imperfect closure of the lids gives rise to corneal ulcerations. Spontaneous pulsations are often seen in the retinal arteries. Palpitation of the heart and goitre also belong to the symptomatology of Basedow's disease, which is regarded as a neurosis of the sympathetic. A compress and bandage are indicated at night, if there is severe exophthalmus, in order to secure closure of the lids. Tarsoraphy may also be neccessary in order to diminish the size of the palpebral fissure. Suitable remedies should be used for the dryness of the eyes, or complicating conjunctivitis. The general treatment must be tonic; fresh air, cold-water cures, iron and quinine usually exercise an evident effect. Galvanization of the cervical sympathetic also seems to be useful. In women, who are mainly attacked by the disease, improvement of all annoying symptoms is often observed under this form of treatment. In men, the prognosis is more serious; secondary valvular disease of the heart, general exhaustion or dropsy often gives rise to a fatal termination.[1]

4. Tumors of the Orbit.

Tumors in the orbital cavity either develop primarily in the tissues filling the orbit, or they spread from the eyeball or adjacent parts. As a rule, they give rise to more or less pronounced exophthalmus and impairment in the mobility of the eye. If they are situated in the muscular funnel, the globe is usually protruded in the sagittal direction; if situated outside of the funnel, the displacement takes place according to the direction of their mechanical pressure. The eyeball may suffer from the protrusion or from inflammation. The optic papilla often exhibits neuritis or atrophy; detachment of the retina also occurs. As a rule, only one orbit is attacked; cases in which both orbits were involved, independent of the direct spread of the growth from one orbit to the other, are extremely rare. In a middle-aged man I have seen circumscribed nodules of sarcoma develop in both orbits within a few months; death resulted from metastases.

Among the primary tumors of the orbit we may specially mention cysts (atheroma, dermoid, echinococci, cysticerci), angioma

[1] See the full description of this disease by H. Sattler in Graefe-Saemisch, "Handbuch der gesammten Augenheilkunde."

(simple, lipomatous [van Duyse], cavernous), neurofibroma (Billroth, Marchand), lymphoma (Raymond,) and the various forms of sarcoma. Osteoma often develops from the walls of the orbit, and results occasionally from traumatism.

When the tumor is not directly visible, its situation can often be recognized by the introduction of the finger. It is difficult to determine the character of the tumor; enlargement and diminution in size have been noticed in cavernous tumors. Exploratory puncture may be necessary to make the diagnosis.

As a rule, the treatment is extirpation of the tumor, if possible with retention of the eyeball. Simple incision sometimes suffices in cysts (when necessary we must avoid mistake for the very rare encephalocele by an exploratory puncture). Spontaneous recovery has been observed in the case of cavernous tumors. Exenteration must be performed if the entire orbit is filled with tumor masses. The lids are separated from the upper, lower and outer rim of the orbit and turned to the nasal side, then the periosteum is detached and with it the entire contents of the orbit are removed.

A peculiar form of protrusion of the globe, which has been described as pulsating exophthalmus, is produced by aneurisms which are situated either in the skull or orbit. These aneurisms develop spontaneously or are traumatic in origin. They occur chiefly after rupture of the internal carotid in the cavernous sinus, particularly after fractures of the base of the skull. The main symptom of this form of exophthalmus is pulsation of the eyeball. It is easily recognized on placing the hand upon the globe and pressing it backward. A blowing murmur is heard on auscultation. Small pulsating tumors (from the passage of arterial blood into the veins) often develop later alongside the globe, especially in the upper and inner angle of the orbit. The frontal veins often exhibit pulsation. The pulsation ceases on compressing the common carotid on the same side. The eyeball suffers according to the degree of protrusion. The optic nerve is sometimes attacked, and frequently there are complicating paralyses of the ocular and facial nerves. The constant beating and roaring in the head are especially annoying to the patient; violent pains are not uncommon. The principal symptoms (even in the non-traumatic cases) usually develop suddenly with a violent pain, and then continue to increase for some time.

In the further course of the process, hemorrhages occasionally occur from the conjunctiva and may even prove fatal. Sudden death sometimes occurs after a certain period. Spontaneous involution has also been noted. In a case under my observation, the pulsation and exophthalmus disappeared at the end of about

four years. The treatment should consist, in the main, of protracted instrumental or digital compression and ligature of the common carotid. The latter was successful thirty-six times in sixty-one cases of pulsating exophthalmus; death occurred in eight cases (Sattler). As recovery may also occur without this operation, it should be delayed until dangerous symptoms supervene. At all events, instrumental or digital compression should first be tried.

5. Injuries of the Orbit.

Injuries to the orbit often consist of fractures of the bones. The roof of the orbit is often involved in fractures of the base of the skull. Special importance attaches to the fissures which pass into the optic foramen, because this gives rise to injury of the optic nerve, followed by amblyopia or amaurosis (Berlin). Hemorrhages into the orbital cellulo-fatty tissue may also occur and extend forward beneath the conjunctiva. Direct injuries of the orbital contents and its walls by projectiles, stabs or entrance of foreign bodies are not rare. These are sometimes followed by severe inflammations of the cellulo-fatty tissue. As a rule, however, simple wounds heal without inflammation, but they may endanger vision by injury to the eyeball or optic nerve. I have observed stationary defects of the field of vision after injury to the optic nerve in several cases. Very annoying diplopia is not infrequently caused by rupture of an ocular muscle. If the foreign body is still in the orbit, we must attempt to remove it under strict antiseptic precautions.

Luxations of the eyeball, have also been observed. In some places it is the custom among ruffians, engaged in fights, to attempt to gouge out the opponent's eyeball by pushing the thumb into the orbit. In forceps delivery, the pressure of the blade may also force out the eyeball. If notable injury of the optic nerve or globe has not been suffered, vision may remain intact (Rothmund). After separating the lids, we must attempt to restore the globe within the orbit, and then cover the lids with a compress and bandage.

6. Congenital Malformations of the Eye.

Congenital absence of the eyeball (anophthalmus), usually bilateral, has been observed in a number of instances. Every trace of the globe is then missing from the orbit, which is lined with conjunctiva, or a small nodule or cyst is found. I have also seen one case in which a small white speck, as large as a pea on palpation, was visible deep in one side, while the other orbit contained a phthisical eyeball, upon which the remains of the cornea (six milli-

metres in diameter) and the transparent iris could still be recognized. The conjunctival sac was small and the superior fornix was absent. Hence this condition was the result of an intra-uterine inflammation. In cyclopia, only one eye is found at the spot occupied, in the normal face, by the root of the nose. When the dimensions of the eye are smaller than normal, the term microphthalmus is used, the opposite condition is known as megalophthalmus (hydrophthalmus congenitus); here the anterior chamber is abnormally dilated and the optic nerve excavated, as the result of glaucomatous processes. But compression-excavation and the often demonstrated occlusion of Fontana's space may also be absent in hydrophthalmus.

CHAPTER III.

DISEASES OF THE EYELIDS.

Anatomy.

The upper and lower lids meet at the outer and inner angle (canthus) of the eye. Their angular point of union is known as the commissure. The inner angle is less acute; between it and the plica semilunaris is situated the lacus lachrymalis. The edges of the lids are two to three millimetres wide in the greatest part of their course; their inner angle is turned toward the conjunctiva, the outer angle toward the integument of the lid. The edges grow narrower and more rounded toward the angles of the eye. At the beginning of this narrowing in both lids and about five millimetres from the inner angle, is found a small projection (papilla lachrymalis) with a central opening, the lachrymal punctum. From these puncta and immediately beneath the surface of the edge of the lids, the lachrymal canaliculi run into the lachrymal sac, which lies in the inner angle of the orbit. The outer angle of the edge of the lid is perforated by the lashes (ciliæ) which are directed away from the globe. Their roots penetrate about two millimetres, and are situated on the outer surface of the tarsus. Sebaceous glands empty into the hair bulbs.

The transverse section of the lid consists of integument, muscle and tarsus; the surface of the tarsus, which is directed toward the eye, is covered by the conjunctiva. Beneath the easily movable and loose integument of the lids, is situated a large circular, voluntary muscle (orbicularis) which surrounds the opening of the lids and extends peripherally over the bony rim of the orbit. Its layers, which run close to the palpebral fissure, have two points of insertion, the internal palpebral ligament at the inner angle, the external palpebral ligament at the outer angle. The former takes its origin from the frontal process of the superior maxilla, passes over the upper end of the lachrymal sac, and then along its posterior wall to the posterior crest of the lachrymal bone (Henle). It forms, at the inner angle, a substitute for the orbital fascia, which is adherent

around the bony margin of the orbit, extends into the lids, and separates them from the interior of the orbit (Merkel). Muscular fibres (Horner's muscle) take their origin from the posterior limb of the internal ligament, and extending in front of the canaliculi, pass into the innermost ring of the orbicularis.

The orbicularis muscle, supplied by the facial nerve, serves to close the lids.

Beneath it and separated by connective tissue, lies a firm disk (tarsus) consisting of intertwining connective tissue, one border of which terminates at the edge of the lid; the upper free order is connected with the orbital fascia. The tarsus of the upper lid is thicker than that of the lower lid; its transverse section is about two millimetres. The posterior surface is intimately united with the conjunctiva so that they cannot be separated.

The tarsal or Meibomian glands are imbedded in the tarsus and shine through the conjunctiva with a light yellow color. They consist of long tubes upon which small acini are situated. Their finely granular, fatty secretion (sebum palpebrale) is discharged at the edge of the lid.

Elevation of the upper lid is effected by the levator palpebræ superioris which is supplied by the third nerve. It takes its origin near the optic foramen and is inserted into the upper border of the tarsus. With the eyeball as a support, it draws the tarsus backward and thus raises the lid. It is aided somewhat by Mueller's muscle which is composed of smooth muscular fibres and is innervated by the sympathetic. This muscle, also called the palpebral muscle (superior and inferior) is situated upon the conjunctival side of the lids immediately beneath the mucous membrane, is very short (about ten millimetres in the upper lid, according to Merkel) and is also inserted into the free border of the tarsus. It takes its origin in the upper lid between the fibres of the levator palpebræ superioris.

The arteries of the lids are derived chiefly from the naso-frontal branch of the ophthalmic. The superior and inferior median palpebral arteries pass laterally as terminal branches, but there are also communications with the branches of the external maxillary, especially with the angular branch. The blood of the median side of the lids is carried off through the vena angularis into the anterior facial vein, that of the lateral side through the facial and temporal veins. The sensory nerve fibres of the lids are derived from the trigeminus.

1. Diseases of the Edges of the Lids.

I. *Blepharitis Marginalis.*

The edge of the lid is not infrequently the site of hyperæmias or inflammations, which may be unattended with noteworthy implication of the adjacent parts of the integument of the lid.

Hyperæmia Marginalis.—In a series of cases there is simple redness, which occurs particularly after the action of external irritants, while walking in a brisk wind or in the cold, or as the result of eye-strain. Individuals with a delicate skin, especially blondes, are particularly apt to complain of congested edges of the lids. More intense processes, such as increased secretion of the sebaceous glands and formation of scales may be entirely wanting. The eye douche used once or twice a day, and the daily application of a one-per-cent solution of nitrate of silver, may be recommended as local remedies. Cool compresses of lead wash may be used, but are not always well tolerated. The ointments commonly used (yellow or white precipitate, zinc, etc.) are less effective. We must also examine whether the hyperæmia is not maintained by errors of refraction or conjunctivitis; if so, the proper measures must be adopted. In addition, staying in foul or too cold air or in tobacco smoke, prolonged reading by lamplight, and the like must be avoided. The general condition must be considered; scrofula or chlorosis, which are not infrequently present, must be treated.

Seborrhœa Marginalis (*Blepharadenitis*).—This is an hypersection of the sebaceous glands. The sebum hardens into small yellowish-white scales, situated upon the edge of the lids and among the lashes. If they are removed with an oiled piece of linen, the underlying skin is usually found to be slightly reddened. The patients have a feeling of burning, pricking, and pressure in the lids; occasionally they are not at all inconvenienced. When the disease lasts a long time, the lashes lose their gloss and curvature and may even fall out. In addition to the recommendations as made above, the treatment consists of solutions of acetate of lead in water or cold chamomile tea, twice a day for ten minutes, and the application of an ointment to the lids. The crusts must first be removed by softening with oil of sweet almonds or cataplasms. This must be carefully carried out, or the treatment will be of no avail. An ointment that is frequently used consists of: hydrarg. oxydat. flav., 0.4; plumb. acetat., gtt. 4; vaselini, 8.0. A piece as large as a lentil is rubbed upon the edge of the lid with the finger, none should be allowed to enter the conjunctival sac, as it would give rise to unnecessary irritation. The ointment may be rubbed in at night

and removed in the morning. We may also use similar strengths of white precipitate ointment, oxide of zinc, and acetate of lead, either singly or combined with one another. Loose lashes are to be removed with the fingers or forceps (Fig. 170); this is often opposed by the patients who unnecessarily fear permanent loss of the lashes. This occurs only when the affection is of long standing and has extended to the roots of the hairs.



FIG. 170. Ciliary Forceps.

Blepharitis Ciliaris.—The edge of the lid is the site of an eczema. It is swollen, red, moist and covered with thick yellow crusts, and excoriations are found particularly around the lashes. If deeper ulcerations develop (blepharitis ciliaris ulcerosa), the individual lashes are situated in crater-shaped ulcers. When the crusts are detached, an excoriated surface, which bleeds readily, is found beneath, unlike simple palpebral seborrhœa. The integument of the lid is often affected; extensive eczema is found particularly in scrofulous children. If recovery occurs, the ulcers are the first to disappear; the formation of crusts continues for some time. A number of the lashes fall out in this disease, and they become shorter, more rigid, and dry. The root of the hair is swollen, and is infiltrated with pus-cells in acute processes. Later the medullary substance is pigmented as far as the bulb (Schiess-Gemusens).

If the disease is neglected, the edge of the lid finally loses its quadrangular shape, becomes narrower, blunted toward the conjunctiva, and skin red and thickened. Some ciliæ are wanting, others are present as small whitish bristles, often in an oblique position (trichiasis). The conjunctival mucous membrane is hypertrophied and ectropium develops.

The blepharitis is often complicated with conjunctivitis, and long-standing cases of blepharitis are always associated with disease of the conjunctiva (blepharo-conjunctivitis).

The treatment is similar to that of seborrhœa marginalis. Compresses of lead water and chamomile tea are useful, but they are not always well tolerated, when there is eczema of the integument of the lid. The eczema is then treated with applications of tar ointment (ol. cadini, 1; vaselini, 2), Hebra's ointment (ung. diachylon) or a solution of nitrate of silver. The edges of the lids are carefully cleansed of the adherent, previously softened crusts, and smeared with one of the above-mentioned ointments. It is better to touch distinct ulcerations with a two-per-cent solution of nitrate of silver or the solid stick. The loose lashes are removed. When recovery begins, nitrate of silver is no longer required; then the ointments are preferable. Coexisting conjunctivitis should receive

proper treatment. If, as happens not infrequently, the punctum of the lower lid is everted and no longer dips into the lacus lachrymalis, the entire canaliculus is slit with Weber's knife (Fig. 171) and this groove, whose median extremity is situated in the lacus, is kept open. In not a few cases there are constitutional anomalies, in children particularly scrofula; these require due attention. Even when recovery has occurred, the ointment should be applied to the edges of the lids at night for months, as there is a great tendency to relapses.



FIG. 171. Weber's Canaliculus Knife.

As a matter of course, if the edge of the lid is blunted and thickened and the lashes are destroyed (madarosis), they cannot be restored. The redness and thickening are treated with applications of nitrate of silver; this mode of treatment is also advisable when ectropium has developed. When necessary, the latter may be treated by operation, though not always with the hope of a satisfactory result.

Sudamina (miliaria) are often found at the edge of the lid in the shape of small vesicles as clear as water. They sometimes give rise to an itching sensation. They may be emptied by puncture.

Small warts, which are easily cut off, are also found in this locality. Syphilitic ulcers, condyloma, lupus, sarcoma, and cancer are observed more rarely.

[All these forms of blepharitis are very apt to be associated with errors of refraction and corneal opacities. In the latter case, they are incurable; in the former, unless the ametropia be corrected, the improvement effected by local means will be only temporary in a large percentage of cases. See Transactions American Ophthalmological Society, 1878.—St. J. R.]

II. *Hordeolum.*

Corresponding to the situation of a sebaceous gland or hair follicle, a circumscribed infiltration appears at the outer rim of the edge of the lid, and leads to a nodular thickening. A yellow speck of pus appears sooner or later in the centre. There is a variety which is associated with pronounced inflammatory symptoms, corresponding to furuncle of the skin, and a milder form like acne.

In the former, there is marked congestion and œdematous infiltration of the surrounding skin, even the entire lid may be swollen. The conjunctiva is injected and chemotic. Considerable pain is experienced. The circumscribed infiltration, which is recognized by its hardness and tenderness, enables us to distinguish the affection at an early period from other severe diseases of the eye. The formation of pus occurs on the second or third day.

In the mild form a small nodule, from the size of a millet-seed to that of a pea, with a yellow purulent centre, is formed.

A stye is sometimes due to mechanical irritation; it is often found in ordinary blepharitis. Some individuals are annoyed by frequently relapsing styes, usually only at certain periods of life, for example, young girls at the period of puberty.

The treatment consists, at first, of lukewarm compresses of lead water. When pus has formed, it is evacuated by puncture. The evacuation may also be left to nature; it appears as if, in the latter event, the remaining infiltration lasts a shorter time and is less intense.

The use of the ocular douche and applications of a solution of nitrate of silver are advisable against relapses. The so-called Kummerfeld lotion (camphor, 0.1; lact. sulphur., 1.0; aq. calcis, aq. rosar., āā 10.0; gummi arab., 0.2), well shaken and applied to the edge of the lids with a brush every night, is also recommended.

[Styes also are often due to strain of the eyes from uncorrected errors of refraction.—St. J. R.]

III. *Distiachiasis and Trichiasis.*

When the lashes appear upon the edge of the lid in a double row, the condition is known as distichiasis, when they are small and directed obliquely, as trichiasis. The latter conditon is usually the result of blepharitis or trachoma. The tips of the hairs appear broken, the hair bulbs are irregularly swollen and atrophic, often markedly pigmented. The color of the hairs is often changed, occasionally to white or gray; when grasped with forceps they are apt to break off. The condition becomes annoying from the friction against the globe. Trichiasis gives rise to conjunctivitis and above all to corneal affections (pannus, ulcerations, etc.). Hence, great attention must always be paid to the direction of the lashes. In the examination the lid should be left in its normal position. The improperly situated ciliæ, are most readily recognized by their dipping into the tears and by their projection againts the dark background of the iris, when they rub against the cornea.

This treatment consists of their removal, whether by temporary or permanent means. If small ciliæ, which break easily, cannot be grasped with forceps, they must be cut with scissors or destroyed by inunction of a solution of calcium suphide. The conjunctiva and globe must then be protected by the insertion of Jaeger's horn spatula (Fig. 172 *a*).

A number of operations are empoyed in order to effect permanent recovery.

If there are only a few oblique ciliæ, their roots may be excised. For this purpose the horn spatula is placed—as in all lid operations—under the lid, the edge of the lid drawn somewhat forward, and its margin divided into two parts, as in Flarer's operation (see below); the part containing the oblique hairs is removed with the roots of the hairs. After recovery, the edge of the lid becomes perfectly smooth. The destruction of individual ciliæ by electrolysis—introduction of negative pole (a needle) into the root of the hair, positive pole on the back of the neck—is an efficient but very painful procedure. [I have not always found it efficient, but the pain can be easily borne.—St. J. R.]

The removal of the entire edge of the lid, as performed by Flarer, is less advisable when ciliæ, that are in a measure normal, are still present. This operation may be performed more readily

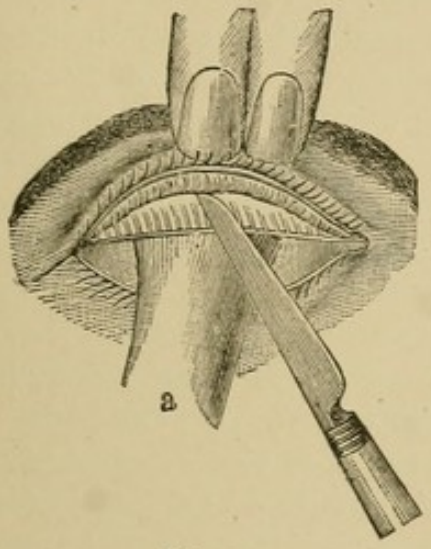


FIG. 172.

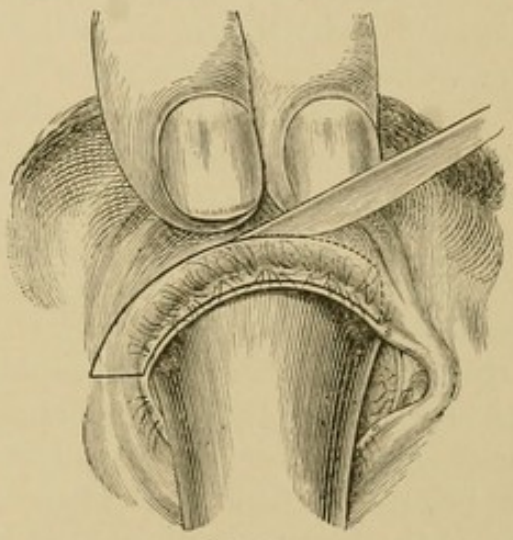


FIG. 173.

upon the lower lid, where the retention of the lashes is less important as regards protection of the eye. The operation is performed in the following manner. The edge of the lid (for example, the upper lid) is turned somewhat outward and inward with two fingers of the left hand, a pointed scalpel is introduced close to the outer angle of the eye and carried along the entire edge of the lid to the neighborhood of the punctum lachrymalis. This incision is about two millimetres deep and divides the edge of the lid into two layers, the one directed toward the conjunctiva containing the tarsus, that directed toward the integument containing the ciliæ (see Fig. 172). A second incision passing through the external integument, about two millimetres from the edge of the lid and parallel to it, then separates the portion of the edge containing the lashes.

Tamamchef does not remove the outer layer, after Flarer's division of the edge of the lid, but cauterizes the intermarginal

wound with a pointed stick. This method often has a good effect.

The ciliæ may also be transplanted instead of being removed.

Jaesche-Arlt's operation. The edge of the lid is split as in Flarer's operation; then an incision is made (for example, in the upper lid) through the integument about three or four millimetres above the edge of the lid and parallel to it, and extending somewhat on both sides beyond the plate containing the ciliæ. A second semilunar incision is situated three to five millimetres above the first, its ends uniting with those of the latter. The semilunar fold of skin, mapped out in this manner, is then excised. By uniting the edges, the needle introduced through the lower edge of the wound being drawn out near the edge of the lid, the outer, ciliæ-containing layer of the margin of the lid (which is not completely separated from its base, but only made movable) is pushed upward and is thus removed and lifted away from the globe.

This plan usually suffices in simple trichiasis, but, as a rule, it is inefficient when entropium and curvature of the tarsus are also present. The operations for entropium (see below) are then indicated.

When the trichiasis does not occupy the entire edge of the lid, I prefer Jaesche-Arlt's operation to that recommended by v. Graefe. In the latter operation the margin of the lid is deeply split into two layers, as in the above method. Then two vertical incisions, about one centimetre long, are made through the integument of the lid, meeting the ends of the divided portion of the edge of the lid. If the layer containing the lashes and the integument bounded by the vertical lines, are now separated from their base, it may be pushed upward (in the upper lid) by moving the integument upward, and may be secured in this position by means of sutures.

A very excellent plan—also in entropium—is that recommended by Hotz. After the intermarginal incision has loosened the outer edge of the lid containing the ciliæ, an incision is made through the integument, three millimetres above and parallel to the edge of the lid. From this part, the musculo-cutaneous tissue is dissected up as far as the upper rim of the tarsus (upper lid), and the latter stitched to the edge of the lid containing the ciliæ, the overlying skin, which has been dissected up, being included in the sutures.

The displacement of the layer containing the ciliæ has also been attempted in another manner. The intermarginal incision is first made, and then a parallel incision is made though the skin and muscle, about four millimetres from the edge of the lid. Above this incision (upper lid) is made a second parallel incision, at a dis-

tance of two to three millimetres, extending a little beyond the former on the nasal and temporal sides. The bandshaped flap of skin thus produced, is separated from its base and carried beneath the ciliæ-supporting bridge into the intermarginal space, where it is secured with sutures. This is then done with the flap containing the ciliæ which has been displaced upward. The transplanted flap may slough, if the bridges remaining at the lateral ends are too narrow, or have been pulled upon too strongly. The union is less certain when the intermarginal space is covered by a detached piece of the mucous membrane of the lip (Bemon).

IV. *Ankyloblepharon. Blepharophimosis.*

Adhesion of the free borders of the lids (ankyloblepharon) is partial or total. It may be congenital, the result of injury (especially burns) or severe diseases of the lids (diphtheria, lupus, etc.). Partial adhesions, which are not associated with symblepharon, are usually cured easily by incision with a pair of scissors. When necessary, the part may be lined with transplanted conjunctiva.

In blepharophimosis the palpebral fissure is shortened, usually as the result of pathological approximation of the edges of the lids, at the outer angle of the eye. This condition is often found in chronic blepharitis, but especially in trachoma. Elongation of the palpebral fissure (canthoplasty) is performed by dividing the outer angle of the eye with straight scissors, one blunt blade being introduced between the commissure and the globe, the other lying upon the skin. The incision is made of a suitable length (four to eight millimetres) and the skin is stitched to the divided conjunctiva with sutures.

2. Diseases of the Integument of the Lid and the Tarsus.

The integument of the lid presents the same diseases as other parts of the cutaneous coverings.

Eczemas which complicate diseases of the eye in scrofulous children are especially frequent. The ulcerative blepharitis which develops from a pustular eczema is a serious affection. The ulcers sometimes have a diphtheritic base, and when situated near the edge of the lid, may give rise to diphtheritic infiltrations of the conjunctiva. The treatment is similar to that adopted in other forms of eczema; tar ointments are especially useful. In ulcers with a diphtheritic base, I use solutions of nitrate of silver.

Erysipelas of the lid is often associated with inflammations of the orbital cellulo-fatty tissue, which extend in part directly to the optic nerve and produce neuritis or atrophy, and which injure the

eye indirectly by leading to thrombosis of the retinal veins and interruption of the arterial supply (with apoplexies of the retina) as the result of compression of the vessels.

Herpes zoster in the distribution of the supra-trochlear and supra-orbital nerves is also called herpes zoster ophthalmicus (Hutchinson). The eruption of the vesicles, which leave whitish permanent cicatrices, is preceded by violent neuralgic pains. The process runs its course in about three weeks. The cornea is often implicated in the shape of clear herpes vesicles or infiltrations. The statement, that the cornea is only affected when the naso-ciliary nerve is diseased and vesicles are found on the side of the nose (Hutchinson), does not hold good in all cases. The cornea may be attacked with or without the implication of this nerve. The treatment is symptomatic; the skin is covered with oiled lint.

In chromhidrosis, dark bluish patches appear upon the lids. If the colored substance is removed, it reappears after a certain length of time. This affection, which has proved to be the result of artificial coloring in a number of cases, has been observed particularly in young girls.

Œdema of the lid is not infrequent as a symptom of the more severe inflammations of the eye. It also occurs in trichinosis. Hemorrhages appear particularly after injuries. When the hemorrhage occurs as the result of fracture of the base of the skull, it usually appears first under the ocular conjunctiva and then under the integument of the lid. I have also seen extravasations beneath the skin after attacks of whooping cough.

Emphysema of the lid occasionally develops after fractures of the bony wall of the nose or the frontal sinus, after which air from the nose enters the orbital and subcutaneous cellular tissue. As a rule, recovery occurs rapidly.

The tarsus is often the site of chronic inflammations, which complicate conjunctival trachoma. Thickening and curvature of the tarsus are especially apt to occur. Amyloid degeneration has also been observed.

Syphilitic tarsitis usually attacks both lids at the same time, and is attended with swelling of the lid due to the thickening of the tarsus, the latter being as hard as cartilage. The integument of the lid exhibits venous injection, the conjunctiva is hyperplastic. The course is very slow, but completely recovery may ensue (Fuchs).

I. *Chalazion.*

In acute chalazion the integument is red and swollen near the margin of the lid, where a circumscribed hardness, about as large

as a pea, is felt. When the inflammation is very severe, the lid is affected through its entire extent; its mobility is impaired and, if the upper lid is attacked, it may hang down and cover the eye. The ocular conjunctiva is often œdematous. If the lid is everted—this is not always possible in a satisfactory degree when the chalazion is situated at the angles of the eye—a circumscribed, small, usually yellowish prominence is seen on the tarsal mucous membrane, corresponding to the situation of the Meibomian glands. When incised, it discharges a fluid which has a yellow purulent or more gelatinous, transparent appearance.

The differential diagnosis of very acute chalazion from the initial stage of acute blennorrhœa, has already been discussed.

Chronic chalazion forms a tumor, from the size of a lentil to that of a pea, which can be moved with the tarsus under the intact skin. If this tumor inflames, the overlying skin is also somewhat reddened. On everting the lid, a prominence becomes visible, and on incision, this discharges a gelatinous, occasionally somewhat thickened yellowish mass. After puncture or spontaneous perforation, red granulations may sprout from the opening in rare cases. Chronic chalazion often follows the acute form, but it may also develop independently of the latter.

The starting point is a nutritive disturbance of a Meibomian gland, with retention of secretion and inflammation of the surrounding connective and tarsal tissue. The connective tissue, muscular fibres, and thinned tarsus form a sort of capsule.

In acute chalazion, when the inflammation is severe, the treatment consists, at first, of cold, later of lukewarm compresses of lead water. If the prominence described appears upon the tarsal surface on everting the lid, it is punctured with the knife (the back of the latter being turned toward the eyeball) and the contents discharged. As a rule, evacuation by puncture from the conjunctiva is also indicated in chronic chalazion. Pressure upon the integument of the lid may be made with the handle of the scalpel in order to evacuate tough and porridge-like contents. Thorough evacuation may also be secured by the entrance of a small spoon. For this purpose I have devised a small knife, like a sharp Daviel spoon, which meets the indications mentioned (Fig. 174). Evacuation is followed by a serous or bloody accumulation in the capsule of the chalazion, causing a return of the tumor in the next few days. Then a progressive diminution takes place in the size of the tumor, but the capsule can be felt for a long time. When the chalazion is



FIG. 174. Schmidt-Rimpler's Knife Spoon.

very large and situated immediately beneath the skin, or when we wish to remove the capsule, it is extirpated through a horizontal cutaneous incision. As a rule, resolvent inunctions (iodine ointment, etc.) are useless without previous puncture. [Massage is sometimes efficacious.—St. J. R.]

II. *Tumors.*

Milium is a whitish grain, about as large as the head of a pin, which is found not infrequently in the integument of the lid. The tallow-like contents are easily discharged through a fine puncture.

Xantheloma appears, as a rule, in the shape of irregular patches on the lid, of a yellowish to brownish color. It is due to connective-tissue hyperplasia and fatty degeneration (Waldeyer, Manz). If the xanthelomata are small, they may be early excised, without giving rise to ectropium.

Nævi and teleangietases occur not infrequently as a congenital condition, and may be removed by extirpation or cauterization. The galvano-cautery is used to advantage in teleangiectases. The cavernous tumors proper usually develop during childhood.

Mention may also be made of mollusca, atheroma cysts (situated chiefly in the outer angle below the upper lid), nodules of leprosy, lipoma, fibroma, sarcoma, and epithelioma of the lids.

Ten to twelve drops of a two-per-cent solution of cocaine are injected beneath the skin, to produce local anæsthesia in minor operations on the lids.

3. Anomalies of Position.

I. *Entropium.*

In entropium the margin of the lid is turned inward, and lashes that may be present come in contact with the eyeball. This change of position is either the result of spasmodic contraction of the fibres of the orbicularis that lie next to the margin of the lid (entropium spasticum) or it is the result of cicatricial contraction of the conjunctiva, and trough-shaped internal curvature of the tarsus.

The first variety is found almost exclusively in the lower lid, and is especially frequent in old people (senile entropium), in whom its development is aided by relaxation of the skin. It is also produced by prolonged application of a compress and bandage, and is seen occasionally in acute inflammations of the eye. If the lid is drawn down by the finger, the margin resumes momentarily its normal position.

When the entropium is caused by a compress and bandage or an inflammation, the treatment may be confined to rectifying the position of the lid by a strip of adhesive plaster. This runs from above downward, beginning below the margin of the lid and terminating upon the cheek. The effect is more vigorous when a horizontal fold of the integument of the lower lid is raised, perforated from above downward with a threaded needle and the suture tied above the fold. This permanent fold usually suffices. If a still greater effect is desired, the lid is drawn down farther by means of one of the threads which is fastened to the cheek with plaster.

In senile entropium, this operation is also suitable, except that the sutures are allowed to remain until the wound suppurates. To prevent the suture cutting through, it is tied upon a roll of adhesive plaster or a bead, through which one end of the suture is drawn. Two vertical sutures (Gaillard's suture) are usually carried through the fold of skin, at some distance from one another. A cure may also be effected by vertical excision of an oval piece of the skin, or, in blepharophimosis, by canthoplasty.

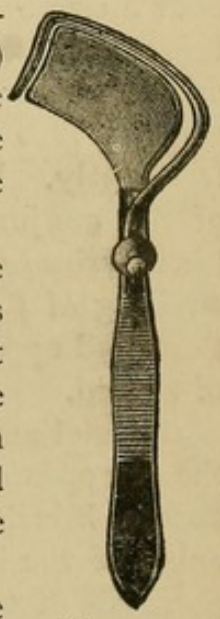


FIG. 175.

If the entropium is the result of curvature of the tarsus, the rectification of the position of the tarsus must be attempted by operation. In order to prevent hemorrhage, we generally use, instead of the simple horn plate, a blepharostat (Snellen, Knapp) in which a sort of clamp presses the integument of the lid against the horn plate, which is situated between the conjunctiva and globe (Fig. 175).

Berlin has recommended a simple and practicable operation. An incision is made through the skin, muscle, tarsus, and conjunctiva, about three to five millimeters above the lashes and parallel to the margin of the lid. By pushing back the upper cutaneous wound, the tarsus is exposed, and a horizontal band about two millimetres wide is cut from the tarsus and conjunctiva, along the entire length of the wound. The cutaneous wound is then united with sutures.

Snellen's operation is more complicated. After making a cutaneous incision three millimetres from and parallel to the margin of the lid, the underlying orbicularis is excised to the height of about two millimeters and then exposed by pushing back the tarsus. A wedge-shaped piece (base to the outside, edge toward the conjunctiva) is then excised from the tarsus along the entire wound in the skin. A suture, provided with two needles, is then passed through the upper part of the tarsus. The loop lies in the tarsus, and the

ends of the suture pass through the portion of skin adjacent to the lashes, and are there tied over a bead. Two or three sutures of this kind are used. Streatfield's method is similar. Linear cauterizations with the actual cautery about four millimetres from the margin of the lid and passing through skin and muscle into the tarsus are also very useful. In another series of cases the operations recommended in trichiasis, especially transplantation of skin into the divided margin of the lid, may prove advantageous. But relapses occur occasionally with all methods.

II. *Ectropium.*

In ectropium the lid is turned outward and the conjunctiva is exposed, sometimes along the entire length of the margin, again only over a circumscribed part. In addition to the annoying deformity, this sets up a constant irritation of the eye, especially as the tears are no longer conveyed through the lachrymal punctum, which is everted, into the lachrymal sac. The lower lid is attacked most frequently. When the ectropium results from acute hypertrophy of the conjunctiva (ectropium sarcomatosum), as, for example, in blennorrhœas, it usually subsides with the disappearance of the swelling of the conjunctiva. Recovery is accelerated by scarifications and application of a compress and bandage, after reposition of the lid.

Special and more thorough treatment is required, as a rule, by the ectropium which occurs after chronic marginal blepharitis, trachoma, injuries with secondary cutaneous cicatrices, caries, shortening of the integument of the lid as the result of eczema, or after paralysis of the ciliary portion of the orbicularis. The two latter factors give rise to ectropium with especial frequency in old people (ectropium senile).

Milder cases may be relieved by a compress and bandage applied for a long time. If the lower lachrymal punctum does not dip into the lacus lachrymalis, the canaliculus should be slit. In cicatricial ectropium in which, as, for example, in caries, the integument is connected with the bones by bands of connective tissue, Dieffenbach excised the cutaneous cicatrix in the shape of an equilateral triangle, with its base parallel to the edge of the lid; after undermining the adjacent skin, the outer and inner sides of the triangle were united by sutures (Fig. 174). Plastic operations or the transplantation of detached flaps of skin (Reverdin, Ed. Meyer) are indicated in larger losses of substance.

The more frequent form of ectropium of the lower lid which appears as the result of blepharitis, results in part from shortening

and retraction of the skin; these are attributable to the constant moisture of the integument by overflowing secretion. Here the constant inunction of the integument with almond oil is indicated above all; if necessary, coexisting eczema should be combated. Complete recovery can only be expected in the less severe forms. The simplest method is the suture operation recommended by Snellen. A suture is armed with a needle at both ends; the middle of the thread is placed horizontally upon the everted mucous membrane to the extent of about five millimetres, while each needle is passed through the conjunctiva and is then carried under the skin to the neighborhood of the rim of the orbit; here the needles are pushed through. The two ends of the suture are tied upon the skin upon a perforated bead. The pressure exercised by the middle of

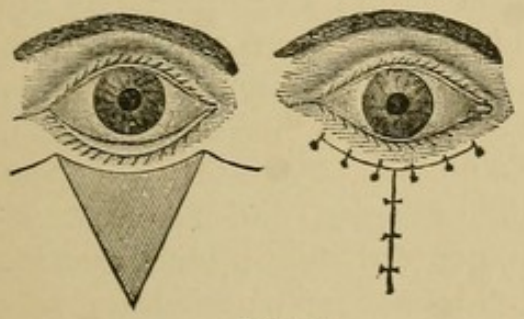


FIG. 176.

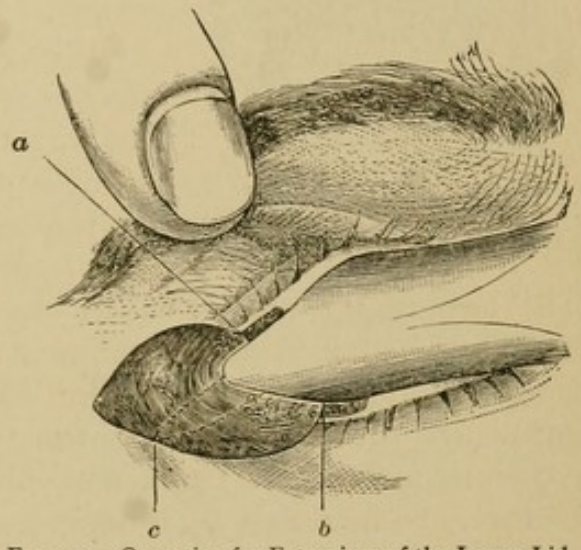


FIG. 177.—Operation for Ectropium of the Lower Lid. (After Stellwag.)

the thread upon the conjunctiva replaces the ectropium. Two or three similar sutures are introduced at some distance from one another. They should be allowed to remain until pronounced suppuration has occurred, but must not be permitted to cut through the skin. Connective tissue strands form as the result of the suppuration, and may make the position permanently correct.

Tarsoraphy is useful in other cases. This diminishes the size of the palpebral fissure, the edges along the temporal commissure, both on the upper and lower lid, being removed to the extent of about four millimetres and then united with sutures. Special attention must be paid to careful removal of the ciliæ.

It is better to remove from the skin of the temple a small triangle (*abc*) whose one side (*ab*) is the prolongation of the palpebral fissure from the outer angle of the eye and whose apex (*c*) is directed downward. After removal of the temporal end of the margin of the lid from the lower lid (which is in a condition of ectropium)

and undermining the adjacent skin, the freshened margin of the lid is pushed upward and outward in such a way that the extremity (*a*) corresponding to the angle of the eye is situated at *b* and is secured by a suture (v. Graefe).

A. v. Graefe has performed the following operation in very severe ectropium after blepharitis. A horizontal incision is made from the lachrymal punctum to the external commissure in the intermarginal portion of the lower lid (which is in a condition of ectropium), immediately behind the lashes. Starting from the ends of this incision, two vertical incisions, seventeen to twenty-one millimetres long, are made upon the cheek. The quadrilateral flap, defined in this way, is loosened from its base throughout its entire extent, grasped at its upper edge with two forceps, drawn forcibly toward the forehead and secured in this new position by sutures along the two lateral incisions, starting from below. The two upper angles, which are now considerably raised, are to be supported in a proper manner and finally the horizontal wound (conjunctiva and margin of the lid) is united. The sutures of the latter are drawn forcibly toward the forehead and fastened, in order to insure the upward displacement of the cutaneous flap. Union is to be aided by a compress and bandage applied for several days.

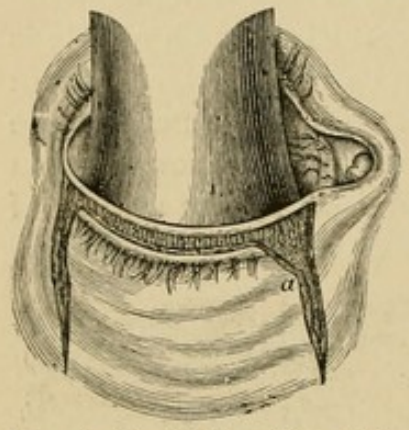


FIG. 178.—Graefe's Operation. (After Stellwag.)

III. *Blepharospasm.*

Spasmodic contraction of the orbicularis closes the eye; spasm of this muscle is sometimes so violent and constant that the eye cannot be opened for a long time despite every effort of the will.

Blepharospasm is found most frequently in inflammatory affections of the eye, and particularly in scrofulous children, who suffer from phlyctenular ophthalmia and photophobia. It rarely persists after recovery of the ocular affection. Donders described it as a sympathetic neurosis in irido-cyclitis. Permanent blepharospasm has also been observed, in exceptional instances, after a blow on the eye (Schenkl).

The treatment must be directed mainly against the eye disease (see the chapter on Phlyctenular Conjunctivitis). Antiscrofulous remedies are often indicated.

Blepharospasm also occurs independently of disease of the eye,

especially in nervous or hysterical individuals. The spasm often starts in a reflex manner from the sensory facial or dental nerves. Pressure upon the corresponding nerve (supra-orbital, infra-orbital, temporal, alveolar, etc.) then checks the spasm at once. In order to make sure, we may note the effect of a weak injection of morphine upon the painful point. If the spasm is then discontinued for some time, subcutaneous division of the nerve is indicated. This is not always attended by permanent results. At the end of some time, the spasm often develops anew, inasmuch as new pressure points appear (several must often be compressed at the same time). In this way almost all of the sensory nerves of the face were successively divided in an hysterical individual, who finally suffered from epileptiform spasms.

In cases in which the painful points are absent, the remedies ordinarily employed in hysteria and general nervousness are indicated. Electricity is to be used locally. In mild cases the occasional introduction of a clamp elevator, cold eye douches, or dipping the face in cold water may be tried with hopes of success.

Annoying movements, especially in the lower lid, which depend upon clonic contractions of individual fibres of the orbicularis, are complained of not infrequently by otherwise healthy individuals. At certain times this appears in so many people, that we might almost suspect the epidemic occurrence of the affection. After a while these twitchings usually subside spontaneously. [They generally indicate nervous exhaustion.—St. J. R.]

IV. *Ptosis. Lagophthalmus.*

Drooping of the upper lid (ptosis) may be produced mechanically, as the result of increased weight (in conjunctival blennorrhœa, trachomas, etc.) or because the base upon which the elevator of the lid draws it back into the orbit is insufficient (in phthisical globes or after enucleation). The degree of ptosis varies greatly; slight drooping of the lid is found in very many diseases of the eye. The patients are then apt to say that the eye has become smaller.

This form must be distinguished from the ptosis due to paralysis of the muscles, either the levator palpebralis superior or Mueller's muscle. When the levator is paralyzed, the ptosis is more pronounced and complete. In such cases other branches of the third nerve are often found to be paralyzed.

The slight drooping of the lid observed in paralysis of Mueller's muscle is often combined with myosis. This group of symptoms is unilateral, as a rule, and attributable to an affection of the

sympathetic fibres (Horner). In the section on ophthalmomalacia we have mentioned that diminution of tension and smaller size of the globe are often found in this condition.

Finally, ptosis, both unilateral and bilateral, may also be congenital.

The treatment of the symptomatic form of ptosis, should be directed against the causal affection of the lid or eye. When the eyeball is phthisical or wanting, the insertion of an artificial eye improves the mobility.

Paralytic ptosis should be treated by the ordinary remedies, among which electricity plays a prominent part. When the ptosis is combined with myosis, the cervical sympathetic on the same side should be galvanized, but I have seen no notable results from this plan.

Symptomatic or operative treatment is indicated in more pronounced cases of ptosis, whether the incurable remains of paralysis or congenital. Thus, a fold of skin may be elevated by a serre-fine or similarly constructed ptosis forceps. The same object has been attempted by operation by excision of a transverse oval fold of skin and muscle. The result is usually unsatisfactory, because the skin again droops or, if the excision has been free, closure of the eye is jeopardized. Those methods are better in which a cicatricial band is formed between the lid and the frontalis muscle (Drausart, H. Pagenstecher). They are based upon the observation that patients suffering from ptosis elevate the lid by corrugating the forehead. The following is the simplest plan. A needle armed with a suture, is pushed under the skin above the eyebrow (like Gaillard's sutures in ectropium) and is then carried subcutaneously to a point immediately above the margin of the lid, here drawn out, and the ends of the suture tied upon the skin. We can prevent the cutting through of the skin by tying upon a small roll of plaster. Two or three such sutures are inserted at a little distance from one another, and are allowed to remain until pronounced suppuration begins. In order to be sure that the skin will not be cut through, the sutures may be applied by arming the thread with needles at both ends, and introducing and removing then alongside of one another. Only the middle and tied ends of the suture then lie upon the skin. Excellent results are obtained with this simple method.

Stitching the levator palpebræ superioris to a lower part of the tarsus has also been performed (Eversbusch).

The palpebral fissure may be somewhat dilated by paralysis of the orbicularis or by protrusion of the globe, as in orbital tumors or Basedow's disease. The absence or insufficiency of closure of the lids (lagophthalmus), which is also observed occasionally in

serious illness, causes dryness (xerosis) of the conjunctiva and cornea and may result in severe ulceration of the cornea.

The treatment must depend upon the cause. Frequent moistening of the eye with milk is indicated symptomatically. Tarsoraphy, which makes the palpebral fissure smaller, is occasionally useful.

4. Congenital Anomalies.

Imperfect development or complete absence of the lids (blepharia totalis) is observed in rare cases. Congenital coloboma, in which the lid presents a wedge-shaped fissure, also occurs exceptionally. A tongue-shaped, membranous intermediate portion is sometimes situated in the fissure (O. Becker, Manz).

Epicanthus.

Under the term epicanthus, Ammon first described a peculiar malformation, in which a semilunar fold of skin passes from the upper to the lower lid in the inner angle of the eye. Its concave portion covers the caruncle and the adjacent parts of the eyeball; the latter is sometimes abnormally small. With increasing years the fold of skin usually diminishes, because the growing bridge of the nose draws it more toward the middle. If an operation is desired, a vertical oval flap of skin should be removed from that portion of the bridge of the nose which is situated between the eyes. The union of the edges of the wound will draw the fold of skin away from the angle of the eye. Symblepharon and ankyloblepharon may also be congenital.

CHAPTER IV.

DISEASES OF THE LACHRYMAL ORGANS.

Anatomy.

The lachrymal gland is situated at the temporal end of the upper rim of the orbit in the fossa glandulæ lachrymalis and consists of an upper and a lower part. Both are separated by a small fascia, which takes its origin from the levator palpebræ superioris and is inserted into the lateral rim of the orbit. The lower lachrymal gland lies upon the temporal portion of the fornix of the conjunctiva. The secretion of the acinous gland is discharged through

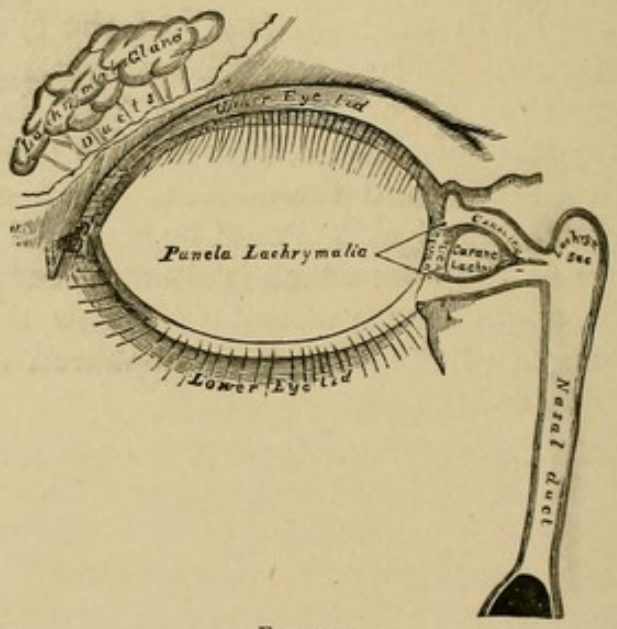


Fig. 179.

a number of excretory ducts into the conjunctival sac. From the latter the tears are discharged through the canaliculi of the upper and lower lid. These begin at the puncta lachrymalia on the margin of the lid near the inner angle of the eye. The lachrymal sac toward which they converge and in which they terminate, is situated in the inner angle of the orbit in the fossa lachrymalis, which is formed posteriorly by the lachrymal bone, anteriorly by the superior maxillary process. This sac, which is about twelve millimetres long, lies immediately beneath the integument of the face.

The internal palpebral ligament passes transversely over it, but the sac projects beyond the ligament both superiorly and inferiorly. Inferiorly it is continued into the lachrymal duct which in the greater part of its course runs in a narrow bony canal formed by the superior maxillary, lachrymal, and inferior turbinated bones, and carries the tears into the inferior meatus of the nose. The lachrymal duct does not reach its end with the bony canal, but runs a little distance through the mucous membrane of the interior meatus before it terminates in an oval fissure. Its general direction is not vertically downward, but a little posteriorly. The inner wall of the lachrymal sac and duct is formed of mucous membrane with cylindrical epithelium; this is surrounded by fibrous tissue which connects it with the periosteum.

1. Diseases of the Lachrymal Gland.

Acute inflammation of the lachrymal gland (dacryoadenitis) is very rare. The outer half of the upper lid swells, attended with violent pains, the conjunctiva becomes chemotic, and a muco-purulent discharge is secreted. There may even be slight exophthalmus, attended with fever. The inflammation passes into suppuration or undergoes resolution. The local tenderness and hardness assure the diagnosis. Lukewarm compresses, narcotics if necessary, are indicated. If there is fluctuation or pus is suspected, an early incision should be made.

Chronic inflammation and simple hypertrophy of the lachrymal gland are more frequently observed. On everting the upper lid, the enlarged gland is seen protruding into the conjunctival fornix. In chronic inflammation, circumscribed hardness is felt. Subjective symptoms are usually absent. Application of the tincture of iodine to the integument of the lid is useful; iodine ointment or gray ointment may also be tried. Potassium iodide internally.

Cystoid dilatation of an excretory duct of the lachrymal gland has been described under the term dacryops. The tumor is situated in the superior fornix of the conjunctiva. Recovery is secured by carrying a suture transversely through, tying it, and allowing it to remain until the wall has been cut through (v. Graefe).

Fistulæ of the lachrymal gland which, as a rule, are the result of injury, may be operated in the following way. Both ends of a silk suture are armed with a needle. Each needle is carried into the external opening of the fistula, then brought out through the conjunctiva, one somewhat higher than the other. After removal of the needles the ends of the suture are tied and allowed to remain until they cut through (Hulke).

Among tumors of the lachrymal gland, cysts, sarcoma and carcinoma may be specially mentioned. When extirpation becomes necessary, the tumor may be grasped from the fornix after division of the outer commissure, or an entrance may be effected by separating the lid from the upper rim of the orbit. Extirpation of the healthy gland has also been performed in incurable epiphora (Laurence), but the symptoms will rarely justify such an operation.

2. Diseases of the Lachrymal Excretory Passages.

I. *Anomalies of the Lachrymal Puncta and Canaliculi.*

Reference has been made to the eversion of the lower lachrymal punctum in ectropium, and to the division of the canaliculus necessary in this condition. In stenosis of the canaliculus, which may be congenital, gradual dilatation should be attempted by the introduction of conical sounds. If the punctum is entirely occluded but still visible, a needle is entered at the point in question, the part dilated, and finally the canaliculus divided with Weber's knife. If the punctum is no longer visible, the canaliculus must be opened directly by an incision.

The canaliculus has been found plugged with fungous masses (streptothrix Foerster [F. Cohn] and micrococci); they are situated usually in the lower, sometimes in the upper canaliculus. Foreign bodies occasionally enter the ductus.

II. *Diseases of the Lachrymal Tube.*

Dacryocystitis (*Phlegmon of the Lachrymal Sac*).—When the lachrymal sac with its fibrous envelope is inflamed, the surrounding soft parts become implicated. The integument between the inner angle of the eye and the nose reddens and becomes œdematous; a prominence is usually found corresponding to the position of the lachrymal sac. There is an abundant flow of tears, the lids and conjunctiva may be injected and chemotic. There is violent pain, even fever. In a few days the diffuse redness and swelling subside, and finally the pus is usually evacuated at some part of the integument covering the lachrymal sac. More rarely the pus seeks a lower passage so that a reddish or bluish swelling, which contains the pus, is visible below. This may be mistaken for a simple abscess, inasmuch as the cutaneous inflammation over the lachrymal sac may have subsided. As a rule, evacuation of the secretion through the undivided canaliculus does not occur on pressure upon the region of the lachrymal sac in the acute stage.

When the pus perforates spontaneously, a fistula of the lachrymal sac usually develops, and through this the secretion of the mucous membrane of the sac oozes after the cure of the inflammation. The fistula gradually closes, more rarely a fine opening persists permanently.

In the majority of cases, an acute dacryocystitis only develops when disease of the mucous membrane of the sac has already existed or strictures of lachrymal duct have prevented the escape of tears. It also occurs after forced use of probes.

The treatment consists of lukewarm poultices which relieve the pains most quickly and check the process. In order to evacuate the secretion, we slit the upper canaliculus and the adjacent part of the wall of the lachrymal sac. If pronounced suppuration has occurred, an incision, about three-fourths centimetre long, should also be made through the anterior wall of the lachrymal sac and the latter irrigated daily with a two-per-cent solution of boracic acid. A tent of lint is placed in the wound in order to prevent its too rapid closure. If the inflammation is undergoing resolution, a Bowman's probe may be passed from the cutaneous wound into the lachrymal duct, in order to relieve any stricture which may be present. We may also attempt to bring about a return of the mucous membrane to the normal, by direct application of a one-per-cent solution of nitrate of silver, or, if necessary, of the mitigated stick. After the cutaneous wound has closed, the treatment must be continued against any remaining affection of the mucous membrane or a stricture.

In the treatment of fistula of the lachrymal sac, the normal excretory passages must first be made free. The fistula itself should be slit and its closure attempted by cauterization with nitrate of silver or the galvano-cautery. When the walls are hard, the fistulous canal should be excised and the adjacent edges of the skin united with sutures.

[No scar forms after a free incision in the early stages of a suppurating lachrymal sac. There is tissue enough in the region to prevent this. —St. J. R.]

Dacryocysto-Blennorrhœa. Strictures of the Lachrymal Duct.— When the mucous membrane of the lachrymal sac is diseased, there is increased secretion with stasis in the sac. The secretion may be vitreous or slightly opaque, mixed with small whitish flakes, or it is decidedly catarrhal or blennorrhœic, occasionally even purulent. In accordance with the character of the secretion, we speak of "old disease of the lachrymal sac," catarrh of the lachrymal sac, dacryocysto-blennorrhœa, and dacryocysto-pyorrhœa. Secondary changes are not uncommon. Dilatation (ectasia) of the lachrymal

sac may form, with distinct prominence of the anterior wall. In other cases, folds develop in the mucous membrane and give rise to small chambers and sacculations in the lachrymal sac; finally, polypoid proliferations and cheesy thickening of the secretion.

The lachrymal duct is very often narrowed. The stenosis results either from uniform or circumscribed swelling of the mucous membrane, from the formation of folds and valves, from fibrous strictures which occasionally traverse the entire canal or, finally, from bony exostoses which may result in incurable occlusion. Circumscribed stenoses are found chiefly at the beginning and end of the canal.

The diagnosis of chronic blennorrhœa of the lachrymal sac is made by pressing with the index finger upon the sac (*i.e.*, upon the inner angle of the eye) and noting whether secretion escapes from one of the puncta lachrymalia. If no secretion is discharged, the existence of the affection is not excluded, because there was perhaps no secretion present, at the time, that could be expressed or the entire amount may have passed into the nose. At all events the examination should be repeated. When the accumulation is pronounced, the region of the sac projects somewhat externally. This circumstance favors diagnosis of disease of the lachrymal sac, even when no secretion is discharged, on pressure, through the puncta lachrymalia.

The diagnosis of stricture of the lachrymal duct can only be made by injections into the lachrymal sac or the introduction of sounds.

When the canula of an Anel's syringe is very fine, it can pass through the upper lachrymal point into the canaliculus and can be pushed into the lachrymal sac. In order to do this, it should first be passed from below upward, in order to facilitate entrance into the puncta lachrymalia; it then receives a horizontal direction in order to pass through the canaliculus. If the syringe contains lukewarm water, gentle pressure on the piston rod will cause it to flow into the nose, provided the lachrymal duct is entirely permeable.



FIG. 180. Bowman's Probe.

We can convince ourselves directly by the introduction of Bowman's probes (Fig. 180) which are numbered from one to eight according to their varying thickness. We begin with one of the thinnest (about number two). In order to carry them readily into the lachrymal sac, the canaliculus is first slit with Weber's knife as far as the sac. The probe is now carried through the latter in a horizontal direction until it reaches the inner, bony wall. The end of the probe being pressed firmly against the wall, it is

moved upward ninety degrees so that it passes from a horizontal into a vertical position; it is then pushed slowly and cautiously through the lachrymal duct to the floor of the nasal cavity. As we have just mentioned, the end of the probe, when pressed firmly against the bony wall, is situated directly above the beginning of the lachrymal duct which it readily enters. Should difficulties arise in its further course, the probe is withdrawn somewhat and then pushed forward; obstructions are sometimes overcome by slight rotatory movements. Any obstructions or strictures which may be present are felt distinctly during the passage of the probe. Considerable force is sometimes required to push through a stricture, but this may only be done when we are sure that the sound is really in the nasal duct. When the floor of the nose is reached, the little plate in the middle of Bowman's double probe is usually situated in front of the upper rim of the orbit, in adults with the normal length of the face. The distance from the orbit to the floor of the nose may be previously measured upon the patient's face. As the canal is directed somewhat posteriorly (usually also somewhat to the outside) and the upper rim of the orbit projects, the probe, before being used, should be slightly bent with the concavity directed forward during introduction.

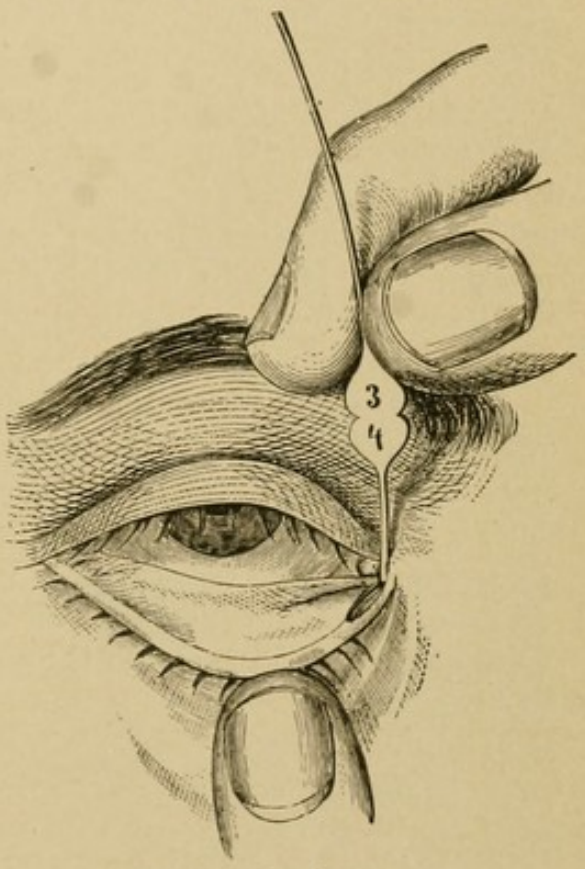


FIG. 181.—(From Stellwag.)

After dilatation with conical probes, the ordinary Bowman's probes may be introduced without slitting the canaliculus. But on account of the vertical position of the probe, which is necessary to its introduction into the lachrymal duct, the canaliculus is displaced and the resulting distortion interferes with the passage of fine probes.

But when epiphora is present, it is well to exclude other causes (such as conjunctivitis, etc.) before proceeding to the method of diagnosis just mentioned. The manipulation is always somewhat disagreeable to the patient. The introduction of the probe often causes pain which radiates into the upper teeth. This may be diminished by the preliminary injection of a few drops of a so-

lution of cocaine. [Not materially, however, in most cases.—St. J. R.]

The subjective symptoms are often trifling; epiphora is the chief complaint. The disease may be complicated with conjunctivitis, especially when the secretion of the lachrymal sac has reached the conjunctival sac. As the secretion is very infectious, any wounds or ulcerations of the cornea which come in contact with it, are apt to assume a serious character (see Hypopyon-keratitis).

The chronic diseases of the lachrymal duct, in the majority of cases, start from affections of the nasal mucous membrane. They are often found in chronic nasal catarrh and ozæna. In comparatively rare cases, they are due to chronic conjunctivitis and granulations. Primary disease of the bone occasionally implicates the tissue of the lachrymal duct, as in scrofula and syphilis. The structure of the bony canal also seems to exert an influence, as the affection is relatively frequent in individuals with flat noses. Blennorrhœa of the lachrymal sac is rare in childhood, but I have even observed it as a congenital condition.

The treatment should attempt to restore the escape of tears, which is prevented by stricture, and to relieve any affection of the mucous membrane (including the nose) which may be present.

To attain the former object, the best plan is the continued use of probes as just described. Weber's probes, which are thicker and more conical than those of Bowman, are also used. It is best to introduce them through the upper canaliculus. When employing Bowman's probes, it is immaterial whether the upper or lower canaliculus is used. The probes may sometimes be passed through one canaliculus and not through the other. After protracted use of the probes, stenosis of the opening of the canaliculus into the lachrymal sac is apt to take place; this must be again dilated with Weber's knife. The canaliculi themselves have less tendency to grow together, if they have been kept open for some time. Slitting the canal is unattended with any disadvantages so far as regards the escape of the tears.

In the beginning the probe must be introduced daily. After each introduction it is allowed to remain in the canal for some time (five to fifteen minutes). In fibrous strictures, success is rarely obtained in less than four to eight weeks, and even then the probe must again be introduced from time to time. The size of the probe is gradually increased, but very large ones need not be inserted. We need hardly ever exceed No. 6 Bowman. As Arlt emphasizes, a comparatively narrow canal suffices for the escape of the tears. Sounds that are too thick produce fissures in the mucous membrane

and perhaps separate it from the bones—an accident that may also occur with ordinary sizes. In such cases the probing must be discontinued for some days; if the introduction does not succeed occasionally, it should not be forced. If the patient cannot visit the physician, the former can usually learn to introduce the probe, when the canal has become sufficiently permeable. Small probes have been constructed with a horizontal projection which rests upon the margin of the lid and which, when introduced, may remain in the canal for several days. This plan is not to be recommended on account of the excessive irritation.

Tight strictures may be cut with a small knife, and the part then kept open by means of sounds (Jaesche). Stilling proposes simple incision of the stricture with a wedge-shaped knife, after which the sounds are not inserted. As a rule, the stricture then becomes narrower after a while than before. But the hemorrhage which follows the incision often relieves the coexisting swelling of the mucous membrane.

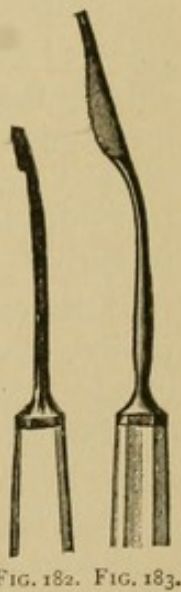


Fig. 182. Fig. 183.

When the passage is very narrow and constantly exhibits a tendency to close despite persistent probing, and particularly when caries is present, it is better to abstain entirely from the introduction of the probe. We should then content ourselves with the treatment of the blennorrhœa by injections of an antiseptic solution (four-per-cent solution of boracic acid) or astringents. Among the latter I prefer a one-per-cent solution of sulphate of zinc. The injection of iodoform powder or salve is also very useful. The injections are made once a day with Anel's syringe. Excessive pressure with the piston must be avoided because the fluid is then apt to enter the surrounding tissue through wounds in the mucous membrane and may produce quite considerable inflammatory œdema. For this reason injections must be avoided immediately after the passage of the probe.

In suitable cases, the use of probes is combined with injections; but blennorrhœas also occur without strictures. The air douche (by means of a bulb or syringe) has also been recommended for the removal of the secretion (v. Graefe).

Thorough scarification of the entire lachrymal duct is very useful when there is marked secretion and swelling of the mucous membrane. The small knives devised by me (Figs. 182 and 183) may be used to incise the lachrymal sac and duct. In the lachrymal sac we often incise membranes in which fluid or thickened masses of secretion have been encapsulated or retained. A single scarification sometimes suffices to cure the disease of the mucous

membrane (during the next few days neither sounds nor injections are used). Deep, frequently repeated scarifications are also useful in ectasia of the lachrymal sac, inasmuch as the formation of cicatrices causes contraction of the sac.

If all these measures fail to make the strictures permeable or, at least, to relieve the blennorrhœa, the destruction or extirpation of the lachrymal sac comes into question. As a matter of course, this permanently abolishes the flow of tears into the nose, but the patient's complaints are diminished, because the irritation of the conjunctiva by the secretion of the lachrymal sac ceases. The sac may be destroyed by first slitting the upper and lower lachrymal points, then dividing the intervening portion of the inner wall of the lachrymal sac; a piece of chloride of zinc paste (1 : 3), wrapped in cotton, is now pushed deep into the lower part of the lachrymal sac and upon this more cotton is packed (Pagenstecher). The mucous membrane is destroyed by the gradual oozing of the dissolved caustic; the paste is removed at the end of a few hours. The most certain method is the opening of the entire lachrymal sac from the integument, through a long vertical incision. After the sac has been dilated and exposed still further by the introduction of laminaria or compressed sponge, the entire surface of the mucous membrane is cauterized with the galvano-cautery. Special care must be taken that the openings of the canaliculi are first occluded. The use of caustic pastes or the solid stick, which must be repeated, is less certain.

The extirpation of the entire sac has been recently recommended anew by Alf. Graefe. After making a cutaneous incision, the sac is removed in its entirety as far as possible, and any remains are removed from the bones with the sharp spoon. Under strict antisepsis, the union of the edges of the cutaneous wound takes place by first intention.

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