THE AMERICAN ENCYCLOPEDIA AND DICTIONARY OF OPHTHALMOLOGY

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ASSISTED BY A LARGE STAFF OF COLLABORATORS

FULLY ILLUSTRATED

Volume X—Lenicet to Muscles, Ocular

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LIST OF LEADING SUBJECTS IN THIS VOLUME

Lenicet. Aluminum acetate. This is a basic aluminum acetate with the formula Al_2O_3 $(C_2H_4O_2)_2$, a very fine, voluminous, white powder very slightly soluble in any fluid.

Wolfberg has found a ten per cent. ointment with vaseline of great use in blennorrhea neonatorum, ulcerative blepharitis and burns. It is also a good basis for scopolamine and atropine ointments for the treatment of catarrhal corneal ulcers and ulcus serpens and for the combined use of dionine and atropine, as suggested by Arlt.

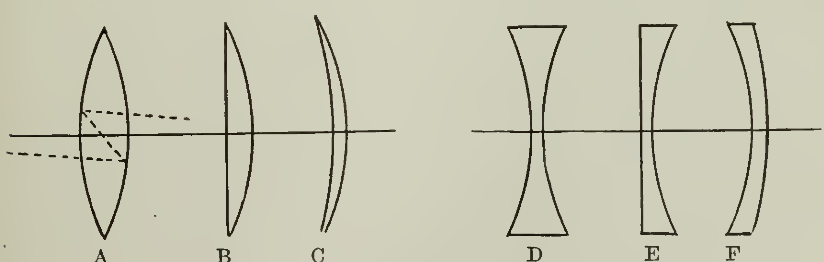
Fehr (*Centralbl. f. pkt. Augenheilk.*, July, 1914) advises this remedy in the treatment of gonorrheal ophthalmia. He approves of ice applications (as long as the cornea is clear), hourly lavage (day and night) with potassium permanganate lotion, vigorously painting the lids once daily with a 1 per cent. solution of silver nitrate, and afterwards inserting some atropine ointment and lenicet ointment.

Lenirenin. A mixture of lenicet, aluminum hydroxid, and suprarenal substances.

Lennox, Richmond. A Brooklyn, N. Y., ophthalmologist. Born in Brooklyn, June 28, 1861, he received his education in the arts and sciences at the Brooklyn Polytechnic Institute, and his medical degree at the College of Physicians and Surgeons in the City of New York. After a brief period of service in the Roosevelt Hospital, he studied ophthalmology and otology in Europe, and, on his return to America, settled as ophthalmologist and otologist in his native city. He died Nov. 14, 1895, aged thirty-four.—(T. H. S.)

Lens. In *biology*, an important organ of vision. See **Lens, Crystalline.**

In *optics*, a transparent refracting medium, usually glass, whose



Ophthalmic Lenses.

opposite surfaces, with respect to a common axis, are, in general, portions of intersecting spheric surfaces of like or unequal curvatures, resembling a lentil in form, and from which it first derived its name. It is a centered system of two refracting spheric surfaces which causes rays of light to converge or diverge systematically after passing through it. The spherical lenses in common use are divided into two classes; convex, or magnifying glasses, A, B, C, which are thickest in the center, and concave lenses, D, E, F, which are thinnest in the center. Each class has three varieties as follows:

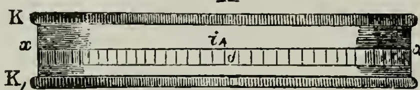
The convex lenses are A, double convex, or biconvex; B, plano-convex; and C, concavo-convex, the *meniscus,* deriving its name from the cusps (points) of the crescent moon. The concave lenses are D, double concave, or biconcave; E, plano-concave; and F, concavo-convex, the *contrameniscus,* sometimes *improperly* called concave meniscus. The terms concavo-convex and convexo-concave are correctly applied to the same lens, being separately chosen to indicate that the light is incident to the first stated surface. See also **Lenses and prisms, Ophthalmic,** embracing a variety of surface-combinations, one of which is the *cylindric lens* having a cylindric surface, which, when combined with a spheric surface is called a *sphero-cylindric* or *compound lens.* The straight line in the accompanying figure which passes through the center of curvature of the two surfaces is the *optical axis* of the lens, and the point on this axis, so located that every line drawn through it pierces parallel elements of the two surfaces, is its *optical center.* Incident rays of light that are parallel to the axis are rendered *convergent,* by a convex lens, toward a point, and by a concave lens, *divergent* from a point, its *principal focus* (See **Focus**), at a distance from the lens called its *focal length,* which is in inverse proportion to the *power of the lens.* See **Dioptry.** The distance from the optical center to the principal focus is the same on both sides of the lens, and depends upon the radii of its curved surfaces and the refractive index of the material of which it is made. Rays diverging from a point beyond the principal focus on either side of a convex lens are approximately collected in a *real focus* beyond the principal focus on the other side of the lens, but if the source of light is between the lens and its principal focus, the rays after emergence diverge as if they came from a so-called *virtual focus* behind the luminous point. The luminous point and its focus are interchangeable, and are called conjugate foci. See **Focus** and **Cardinal points of a lens.** A concave lens always renders rays divergent with respect to the direction of incidence, and so forms only virtual foci. If the source of light is an extended surface, then the pencil of rays from each of the points produces its own focus; and the collection of such foci constitute an *image* (q. v.), which is real and inverted if the foci are real, but virtual and erect if they are virtual. The relative sizes of the object and the image formed by a thin lens are sensibly proportional to their respective distances from the optical center; if the lens is thick, the distances must be counted from the so-called *principal points* (q. v.) of the lens, which lie on the axis on each side of the optical center. An image formed by a single lens is never perfectly distinct, on account of the spherical and chromatic aberrations of the lens. See **Aberration.** The former is due to the fact that a lens having spherical surfaces converges marginal rays to points nearer to the lens than the one in which the central rays are collected; the latter, to the fact that rays of different wave-lengths or color form their foci at different distances, the focal distance for violet rays being approximately one-seventh part shorter than that for the red rays refracted by a crown-glass lens. The spherical aberration can be corrected by making the surfaces of forms other than spherical, though preferably by combining two or more spherical lenses of properly proportioned curvature, the chromatic aberration (q. v.), only by combining two or more convex and concave lenses of different materials, usually a convex crown-glass with a concave flint-glass. *Achromatic lens,* see **Achromatic.** *Actinic lens* (q. v.). *Aplanatic lens,* a compound lens in which both chromatic and spherical aberrations are corrected. See also **Aplanatic.** *Apochromatic lens,* a microscope-objective made from certain peculiar kinds of glass, by means of which the aberrations can be more accurately corrected than in lenses made of ordinary crown- and flint-glass. See also **Apochromatic.** *Bifocal lens* (q. v.). *Bull's eye,* a plano-convex lens used with the microscope to concentrate rays of light upon an opaque microscopic object, or in a lantern to project a beam of light. *Burning lens,* a convex lens used to concentrate the heat of the sun at its focus. *Camera lens,* a lens used in a photographic camera or camera obscura. *Capsule of the lens,* the transparent, elastic, brittle, and structureless membrane inclosing the lens of the eye. *Cartesian lens* (q. v.). *Coddington lens* (q. v.). *Collimating lens* (q. v.). *Compound lens.* 1. A system of coaxially placed lenses. 2. A single lens whose opposite surfaces jointly produce sphero-cylindric refraction, one surface being spheric, the other cylindric, and producing the same effect as two combined cylindric surfaces or lenses with their axes at right angles to each other. *Concave lens,* a lens that is thinner at the center than at the edge. *Condensing lens,* or *condenser,* a convex lens or a combination of lenses used to concentrate a strong light upon some point or surface, as upon the slit of a spectroscope or a microscopic object, or a photographic negative in the process of making an enlarged picture. *Convex lens,* a lens that is thicker at the center than at the edge. *Copying lens,* a photographic lens specially designed for copying engravings, etc. *Crossed lens* (q. v.). *Crystalline lens,* in the eye, a double-convex body placed concentrically with the axis of vision behind the iris, between the aqueous humor and the vitreous humor, to focus rays of light upon the retina. See also **Eye.** *Cylindrical lens,* a lens which has one or both surfaces cylindrical; commonly used in spectacles to correct astigmatism of the eye. See **Lenses and prisms, Ophthalmic.** *Diamond lens,* a lens made from a diamond. *Doublet (lens),* a combination of two lenses separated by a small distance. Sometimes each of the two is itself a compound. *Engraver's lens,* a lens consisting of two plano-convex lenses whose spherical surfaces face each other within a cell. *Field lens* (q. v.). *Fluid lens,* a lens made by confining a liquid between two curved pieces of glass. *Fresnel lens* (q. v.). *Hyperbolic lens* (q. v.). *Immersion-lens,* a microscope-objective which requires a drop of water, oil or other liquid to be put between it and the cover-glass of the object under examination, in order to increase the angle of aperture and to obviate loss of light by reflection. *Kryptok lens,* see **Bifocal lens** and **Kryptok lens.** *Landscape lens,* a photographic lens specially adapted to landscape photography. *Magnifying lens,* a convex lens used to increase the apparent size of an object seen through it. The lens held near the eye produces this effect when the distance of the object from the lens is less than the principal focal length of the lens. *Minifying lens,* a concave lens used to decrease the apparent size of an object seen through it. Used by scenic artists and photoengravers. *Multiplying lens,* a plano-convex lens, the convex side of which has been worked into a number of plane facets, each of which presents a separate image (virtual, and not magnified) of the object viewed through it. *Orthoscopic lens* (q. v.). *Parabolic lens,* a lens having a surface ground to the curve of a hyperbola. *Pantoscopic lens,* the same as *bifocal lens* (q. v.). *Periscopic lens,* a concavo-convex lens, either of meniscus or contrameniscus (q. v.) form. The name is specially applied to spectacle-lenses, the concave surface being worn next the eye, and producing a wider field of view. *Photographic lens,* a lens or combination of lenses adapted to photography. Ordinarily the lens of the photographic camera is a combination of two achromatic lenses of peculiar curves, mounted in a tube with a considerable space between them. The photographic objective of a telescope is like an ordinary achromatic objective, except that its curves are adjusted to bring the blue and violet rays to the most accurate focus possible, rather than the yellow and green rays, which are most effective in vision. *Polyzonal lens,* the same as Fresnal lens. *Portrait lens,* a photographic lens specially adapted to the taking of portraits. *Rectilinear lens,* a photographic lens so constructed that straight lines in the object will be accurately reproduced in the picture, and not distorted into curved lines. See also **Orthoscopic lens,** and **Image.** *Side-condensing lens,* a condensing lens so attached to a microscope as to illuminate an opaque object by sidelight. *Stanhope lens,* a comparatively thick lens of small diameter with two convex faces of different radii, inclosed in a metallic tube. *Triplet lens,* a combination of three lenses, usually all achromatic. The ordinary form of microscope-objective is a triplet. *Toric lens,* a lens whose characteristic surface is generated through rotation, in the plane of its axis, of a semi-circular section having a radius that is shorter than the one prescribed by the rotation itself. See also **Lenses and prisms, Ophthalmic.** *Watchmaker's lens,* a plano —or double—convex lens used as a magnifying glass, mounted in a more or less conical tube capable of being held before the eye between the brow and cheek of the operator whose hands are employed in watchmaking, etc. *Wide-angle lens,* a photographic lens capable of making a distinct and undistorted picture of objects which subtend angles of 60° to 100° or more as seen from the camera; also, a microscope-objective which admits from each point of the object a pencil of rays of wide angle (often as much as 140° and upward); an objective of large angular aperture. See also **Aperture.**—(C. F. P.)

Lens, Absorption (spontaneous) of the. Although absorption of the lens is hardly to be expected after forty-five years of age, yet reports of the occurrence of this phenomenon are not uncommon, and in some cases account for an apparently miraculous return of vision in persons blind for years. Thus, A. E. Ewing (*Am. Jour. of Ophthal.,* p. 50, 1911) gives a history of complete, spontaneous absorption of the lens in a patient seventy years old. W. H. Dudley (*Ophthalmology,* Vol. IX, p. 493, 1913) reports absorption of the lens nucleus in a person sixty-six years of age.

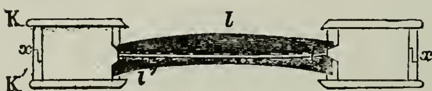
Lens, Arcus senilis of the. This is a term applied by Attias (*Ophthalmic Year-Book,* p. 400, 1912) to a ring opacity near the equator of the lens. Using Van Gieson's stain he found this zone colored by fuchsin. It was surrounded by a transparent zone, and the ring of opacity showed no punctiform, or radiate opacities, usually seen in incipient cataract. The capsule was normal. The changes giving rise to the opacity involved both the nuclei and the fibres. There were vacuoles in both, which contained numerous fatty droplets.

Lens, Astigmatic, of Stokes. A combination of lenses employed in determining the presence and the degree of ocular astigmatism. Donders (*Accommodation and Refraction of the Eye,* p. 485) describes it as consisting of two cylindrical lenses, the one plano-convex 1 of 1/10, the other plano-concave 1′ of —1/10. The first is fastened into a broad copper ring, the last into which rings at x are fitted to one another and can turn past one another around their axis. At the same time, therefore, the lenses 1 1′ also rotate past one another; they are turned with their flat surfaces towards each other, leaving a small interspace. The Figure A represents the instrument seen on the outer surface. It will be observed that on K an index i occurs, on K′ a graduated scale. If the index points to 0° or to 180°, the axes of the two cylindrical lenses are parallel; the section of the lenses appears as in B, so that when united, they may be regarded as a concavo-convex cylindrical lens, with equal radius of curvature of the two planes, whose action is about = 0. If the index points to 90° or to 270°, the axes of the cylindrical glasses stand perpendicular to one another. At the same time the system has its maximum m of astigmatic action; a plane of parallel rays of light, coinciding with the axis of 1, will

A



B



The Astigmatic Lens of Stokes.

undergo no deviation through 1, but through 1′, will be made convergent to its focus, situated at 10″; on the contrary, a plane of parallel rays, coinciding with the axis of 1′, are made divergent through 1, as if they came from a point, situated 10″ in front of the lens and through 1′, do not deviate further from this course. In the one meridian we thus obtain an astigmatism of 1/10, in the opposite of — 1/10, and the astigmatism m of rays, refracted in this position of the lenses, therefore amounts to 1/3. It thus appears, that by turning round from 0° to 90° the astigmatism ascends from 0 to 1/5, and by a simple formula, As $= m \sin a$, we can calculate the astigmatism for each angle a, which the axes of the lenses make with one another. For the sake of convenience definite degrees of astigmatism are directly given upon the instrument, rendering the calculation unnecessary.

It is easy to see the use which may be made of this instrument. If any one fails to obtain with the most satisfactory accommodation or reduction for distance, the normal acuteness of vision, and if we suspect the existence of astigmatism, we set the instrument about at the degree of astigmatism, which the disturbance of vision leads us to suspect (rather somewhat too weak than too strong), and cause it while the eye is steadily fixed upon the distant letters, to turn round before the eye. If improvement be now observed in a particular position the action of the astigmatic lens can be increased or diminished in the manner above described, until the maximum of distinctness is obtained; but this change requires again another position.

Biscuit-shaped Lens.

Lens, Bifocal. This important composite ophthalmic lens is, in its various ocular relations, fully discussed under a number of captions. See, for example, pp. 4919, 4958 and 4977, Vol. VII of this *Encyclopedia.* See, also, **Bifocal lens**; as well as under **Lenses and prisms.**

Lens, Biscuit-shaped. This rare congenital anomaly was described by Otto Becker in 1870. (See the figure.)

Lens-cap. A covering for the opening of the tube into which an optical lens is fitted.

Lens capsule. The transparent elastic envelope of the crystalline lens. See **Histology of the eye**; as well as **Anatomy of the eye.**

Lens, Cardinal points of a. See **Lenses and prisms, Ophthalmic.**

Lens, Cartisian. A lens so shaped that there is no spherical aberration. See **Cartisian lens.**

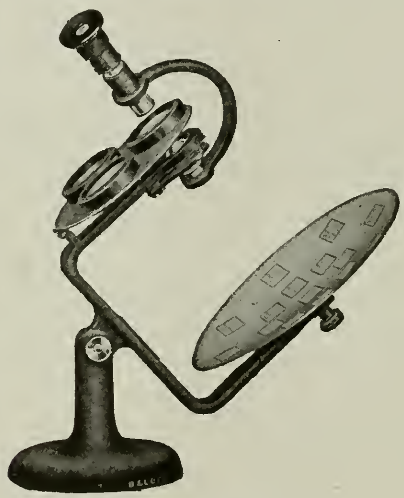
Lens centering. See **Lenses and prisms, Centering of**; also p. 1965, Vol. III of this *Encyclopedia.*

Lens, Coloboma of the. A congenital defect in the crystalline lens system, usually occurring at the lower margin of the lens and including the corresponding fibres of the zonula of Zinn. See p. 2884, Vol. IV of this *Encyclopedia;* also, **Coloboma.**

Lens, Colored. Dark glasses. Tinted glasses or lenses. See p. 2388, Vol. IV; as well as p. 3778, Vol. V, and p. 5122, Vol. VII, of this *Encyclopedia.*

Lens comparator. This is a trade name for a device intended to compare the optical characters of "punktal," toric, meniscus and other forms of curved lenses with the ordinary flat forms. The instrument is so designed that the lenses are tested under conditions similar to those that exist when they are in normal position before the eye, except that the course of the light is reversed. For a duplication of ocular conditions, there is provided an artificial eye with refractive elements of such power as to image a point of the retina on the far point sphere. This action is the same for all directions of the line of sight; therefore, for the sake of simplicity, both the retina and the refractive elements of the eye are eliminated, and only the far point sphere is considered, and represented by a concave disc provided with printed tablets. See the figure.

An observing telescope is mounted on a ball-and-socket joint, the center of which represents the center of rotation of the eye. The ball



The Lens Comparator.

is bored out to permit the passage of the light and contains a diaphragm which limits the diameter of the pencil of light to a value approximately equal to the aperture of the pupil of the eye. By means of this ball-and-socket joint, the telescope can be moved around the center of rotation in any direction within an angle of 60°, so that the lenses mounted for comparison on a revolving disc can be tested in succession for any line of sight within a solid angle of 60°. These lenses are situated between the diaphragm and the telescope at a distance of 25 mm. from the center of rotation. When testing the lenses in succession, the centering of each is accomplished by a spring catch, thus making possible a quick comparison between them.

The course of the light pencils is understood when we assume the ophthalmic lenses to be simple spheres. The center of the concave disc representing the far point sphere is situated in the focal point of the lenses to be tested; hence, a pencil of light coming from a point on the disc and passing through the diaphragm and the lens, is rendered parallel and the object point is, therefore, imaged at a great distance from the lens. The function of the observing telescope is to receive this parallel beam of light in order to render the object visible.

In the case of a compound lens the printed matter on the concave disc can be brought into the focus of only one meridian; therefore a compensating cylindrical element has been placed within the telescope. The tablets, or targets, fixed to the concave disc consist of printed text which serves as a test for definition and at the same time gives information as to what one may expect to see. In addition, each target states which meridian of the lens is under examination and the angle between the line of sight and the axis of the lens, when the telescope is pointed at the center of the target in question.

In manipulating the instrument, bring any one of the ophthalmic lenses mounted on the revolving disc into the proper position; the telescope is then moved to cover the target in the center of the concave disc and focused to suit the eye of the observer by rotating the eyepiece. The other lenses may then be brought into position successively by rotating the revolving disc, but care should be taken that the spring catch firmly secures the lens under observation in the correct center. The eyepiece should be readjusted, if necessary, for each lens.

With the telescope directed toward the target in the center of the concave disc, no astigmatism will be apparent through any of the lenses on the revolving disc. The telescope is now directed to any of the targets next to the central one, when (it is claimed) that through the punktal lens the test type is clear and distinct, while through the toric form a slight falling off in definition is noticeable and through the flat lens the definition is greatly impaired. Moving the telescope now to the extreme targets, situated at an angle of 30° from the center of the lens, the printed matter through the flat lens is unreadable. The same is the case with the small print when the toric lens is in position, while through the punktal lens the entire text of the printed matter on the target can easily be read. Thus proof is furnished of the high degree of correction for astigmatism in oblique pencils attained in the punktal lenses.

Lens, Crystalline. Descriptions of this important ocular organ are given on p. 377, Vol. I; p. 3387, Vol. V, and p. 5963, Vol. VIII of this *Encyclopedia.* The etiology, pathology and the treatment of lenticular abnormalities are described and pictured under various captions headed by **Cataract**; and to a large extent under **Congenital anomalies of the eye**; **Familial diseases of the eye**; **Heredity in ophthalmology**; and **Injuries of the eye.** A few additional remarks under various sub-headings are here appended.

Development of the lens. Carlini (*Ophthalmic Year-Book,* p. 210, 1914) regards the *zonule* as being developed from the anterior portion of the vitreous. In the hyaloid tissue between the ciliary body and lens, at the end of the fourth month of human fetal life, he traced the appearance of delicate fibers connecting the two structures. The true vitreous gradually became differentiated from the zonular space anteriorly; and later the hyaloid tissue and vessels were absorbed from the zonular space, leaving only the zonular fibers.

The *lens capsule* of the adult is thicker anteriorly than posteriorly, although in the embryo the capsule is first developed and is for some time thicker at the posterior pole. After the fourth month the central portion of the posterior capsule ceases to become thicker. The post-equatorial segment of the posterior capsule, however, continues to grow, and at birth is the thickest part of the capsule. But it afterwards becomes inferior in thickness to the anterior capsule, the growth of which continues throughout life. The continued growth of the anterior capsule is associated with the constant presence of a layer of epithelial cells in this situation.

It has been demonstrated by Lewis in *Rana sylvatica* that transplanting the optic vesicle, and placing it in contact with the ectoderm in some other portion of the body, will cause the development of a lens in this normally unrelated ectoderm. The lens is not self-originating, or self-differentiating, but depends for development upon contact of the ectoderm with the optic vesicle.

Weight of the lens. G. A. Clapp (*Archives of Ophthalm.,* p. 618, 1914) weighed the lenses of infants aged from two weeks to five months. The lenses were removed in capsule from one to twenty-four hours after death, immediately weighed, and then dried and re-weighed. The average weight was 0.0953 gm. Average weight of the solids was 0.0265 gm. There was a gradual increase in weight from birth until the fifth month. The average weight of the solids showed a proportionately greater increase with age.

Clausnizer weighed eighty-six lenses of adults extracted in the capsule. The average weight of thirty specimens of immature cataract was 0.236 grams; of thirty-six mature cataracts 0.213; of nineteen dislocated opaque lenses 0.183 and of twelve dislocated transparent lenses 0.227. The average weight of nineteen lenses from myopic eyes was

0.234, of ten lenses from hypermetropic eyes 0.218, and of fifty-six lenses from emmetropic eyes 0.216 grams.

Histology of the lens. Mawas believes that the great majority of the fibers of the muscle run in a longitudinal antero-posterior direction; true circular fibers do not exist. There are a few which run obliquely and it is these that have been taken for a sphincter. Neither does the muscle possess a true tendon. The effect of the contraction of the muscular fibers results in narrowing the smooth portion of the ciliary body with retraction of the iridocorneal angle on the one hand and a ''telescoping'' of the ciliary processes on the other.

This observer also finds a marked lenticular asymmetry the effect of which is an unequal action on the curvature of the crystalline. This asymmetry explains the correction or compensation of corneal astigmatism. A further effect is to displace the lens in the direction of greatest development of the ciliary body and to cause the former to execute somewhat of a turning movement. His anatomical studies show further that the contraction of the fibers of the muscle necessarily brings about a narrowing of the entire ciliary region, which entails as regards the zonula the relaxation of the posterior fibers and a traction backwards and outwards of the anterior ones; the latter are the most powerful and the most numerous. The results of this on the form of the crystalline are a flattening of the periphery with increase in the curvature of the center. These results confirm the statements of Tscherning; although the latter's explanation is based on an erroneous conception of the anatomical relations.

Refraction of the lens. Zeeman has examined the images furnished by the posterior surface of the human lens during accommodation, by means of a telescope, to determine whether the phenomenon obtained by Pflugk from freezing the accommodated lens of pigeons' eyes, namely the part near the equator becoming convex anteriorly—took place in man. In several instances he observed double images given by the peripheral portion of the posterior surface, though he was unable to determine whether either of the images was erect, as should be the case if it were furnished by a convex reflecting surface. In other instances where no doubling could be observed, the image was decidedly broadened in lower—rarely above 14 D. between 8 and 13 years.

The same observer points out that the radius of the anterior surface of the lens was found on the average to be greatest in myopes and least in hyperopes, i. e., inversely proportional to the refraction of the eye. The average thickness did not vary noticeably with the refraction. The radius of the posterior surface of the lens was least in hyperopia. The calculated refraction of the lens was greatest in hyperopia and least in myopia. The lens plays the determining part in emmetropization, for the length of the axes fluctuates within wide limits in emmetropia.

By the theory of a stratified dioptric system applied to the human crystalline lens, Monoyer finds that its dioptric power is 15.5 D.—a result which can be theoretically deduced from the hypothesis that its layers are concentric for each segment.

Fluorescence of the lens. See p. 5230, Vol. VII of this *Encyclopedia.*

Senile changes in the lens. Schanz calls attention to the observations of Jess, Chalupecky and himself which show that the effect of ordinary light causes chemical changes in the lens, which are similar to those in the lenses in old age. That is, the quantity of insoluble substances grows larger. His own observations show that this does not take place when the lens is protected by euphos glass. Another effect of ordinary light relates to diffusion. When a ray of sunlight enters a dark room, we can observe this; the fine suspended particles in the air split up the light. This splitting is noticeably stronger for violet than for red rays. The same effect takes place in the lens; in this way an action is produced on those parts of the lens which are covered by the iris. Van der Hoeve had called attention to the fact that light of short wave lengths can have an influence on the ciliary body also in the same way. An important question arises whether the hardening of the center of the lens, the related long sightedness and the cataracts of old age are caused by the invisible rays. Since we know that such rays cause changes in the lens similar to those we notice in advancing years, and we have an explanation of how short rays can affect the periphery, Schanz is convinced that these changes are cumulative effects of these short rays. See the introduction to **Cataract, Senile.**

Lens cutting. See **Lenses and prisms, Methods of manufacture.**

Lens, Dislocation of the. Ectopia lentis. Luxation or subluxation of the lens. Displacement of the lens. The ordinary, traumatic form of this anomaly has already been discussed and illustrated on p. 6320, Vol. VIII of this *Encyclopedia.* So, also, has been the congenital form; see p. 2871, Vol. IV.

Acquired lenticular displacements, i. e., not congenital and not due to injury, may occur if the zonula of Zinn has become weakened, or the lens is shrunken from any cause; it is probable, also, that a variety of conditions may cause slight forward displacement of the lens, especially changes in the constitution of the lymph in the vitreous, brought about by changes in the nutrition of the choroid, retina, or vitreous, of which little or nothing is known. Again, the condition of the circumlental space in old eyes is largely a matter of conjecture. It is probable that the ciliary muscle continues to contract during accommodation, though the lens remains impassive. Such contractions may be expected to slacken the zonule, so that the lens becomes more movable than during accommodation earlier in life (Parsons). An abnormal slackness of the zonule has also been ascribed by Snellen to degenerative changes. Atrophy of the zonula may also result from high myopia, or detachment of the retina, and is not infrequent in hypermature cataract. The zonula being weakened, a slight disturbance, such as coughing, sneezing, or bending over, will suffice to cause a dislocation. The lens may completely leave its bed (*luxation*); or it may remain partly in place and be tilted forward or backward (*subluxation*).

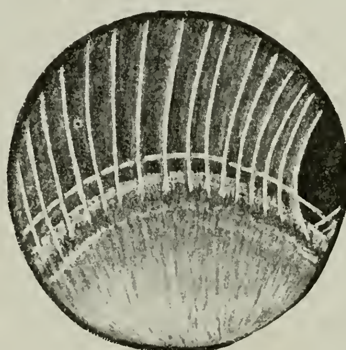
Dislocation into the vitreous humor is more frequent than into the anterior chamber. If the vitreous is softened, the lens can be seen bobbing about whenever the eye is moved. A misplaced lens becomes opaque, but in the vitreous it may retain its transparency for a long period. It acts as a foreign body and can cause serious trouble. The uveal tract becomes irritated, and such eyes often end in iridochoroiditis. If dislocated into the anterior chamber, the lens may block the drainage apparatus, causing pain, increase of tension, and destruction of vision.

In subluxation the patient is likely to be myopic. The zonula having lost its power over the lens, the latter by its elasticity gains greater curvature, thereby increasing the refraction.

This influence on the refraction was observed in a case reported by Possek (*Klin. Monatsbl. f. Augenheilk.*, p. 381, 1906) of a student who had received a blow on the right eye with a dull rapier. The lower part of the anterior chamber was deeper and the corresponding section of the iris receding, the upper part obliterated. The lower margin of the lens was raised. From the subsequent astigmatism the details of the fundus appeared larger in the horizontal meridian. This case is unusual, in that reposition of the lens had taken place the next day, after atropin and bandage. Probably some fibers of the zonula had been lacerated and, vitreous entering the gap without tearing, the hyaloid membrane had to hold the lens against gravity. After the vitreous had retreated the lens returned to its natural position. Vision and accommodation became normal. The right pupil, however, remained a little larger than the other.

Some displaced lenses rest on the pupillary margin. When partly or entirely in the anterior chamber, union is likely to occur between the lens and the cornea or iris.

Burk (v. Graefe's *Arch. f. Ophthal.,* Vol. 83, pt. 1, 1912; see the review in the *Ophthal. Review,* p. 148, May, 1913) gives the clinical histories and results of the microscopic examination of ten cases. These eyes were all fixed in 10 per cent. formalin solution and transferred direct to 96 per cent. alcohol, a hardly satisfactory method of preparation for the study of anatomical relations of fine structures.

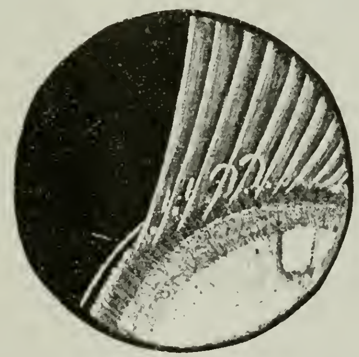


Spontaneous Dislocation of the Lens. (Würdemann.)

Enlarged 10 Diam. as shown by oblique illumination and loupe; dilated pupil. R. E. Showing partially cataractous lens dislocated down and inwards; a small clear space up and inwards; zonular fibers stretched and very distinct.

Burk is of the opinion that it is essential for the production of dislocation into the anterior chamber, whether spontaneous or acquired, that a complete separation of the zonular fibres should have taken place. In traumatic displacement, he has found numerous remains of fibres both on the anterior and posterior surfaces of the lens. These were too short to correspond with the whole fibres, part of which must, therefore, have remained attached to the ciliary processes. In two of his cases he found that the lens had made a complete revolution so that the lens epithelium was directed backwards, and in one of these the lens still remained connected on one side with the zonular fibres so that it hung suspended like a pendulum. He states that dislocation of the lens may occur with two different conditions of the zonular fibres. One in which they are partially or completely ruptured, and the other in which no such rupture has taken place. This latter form can only take place as a result of traction such as may be caused by scar formation in the neighborhood of the lens or through union with neighboring parts such as posterior synechiæ. That portion of the zonular fibres which runs between the ora serrata and the anterior limits of the ciliary processes was never found to be broken.

As regards the glaucoma that is so usual a result of lens dislocation Burk quotes v. Hippel's statement that in order to elucidate the pathology of glaucoma quite fresh cases are required for microscopical examination, and adds that he would go further, since once clinical symptoms of glaucoma have made their appearance secondary changes are already present to obscure the primary ones. He thinks that some of his cases in which glaucoma had not yet made its appearance throw some light on the way the dislocation of the lens starts the rise of tension. In these he found chronic inflammatory change in the angle



Spontaneous Dislocation of the Lens. (Würdemann.)

Enlarged 10 Diam. as shown by oblique illumination and loupe; dilated pupil. L. E. Showing cataractous lens dislocated down and outwards; a clear space about 1/3 area of pupil inwards; zonular fibers greatly stretched and four of them recently torn through; lens almost completely opaque; a quadrangular capsular opacity and spots at capsular attachment of zonule.

of the anterior chamber which would be likely to result in adhesions between the root of the iris and the ligamentum pectinatum. These inflammatory changes were not confined to that portion of the eye but tended to affect the whole uveal tract and even the retina. This inflammation the author thinks is due to the lens acting as a foreign body and starting cyclitis.

As a consequence of this Burk expresses himself as strongly of the opinion that every dislocated lens should be removed as early as possible. Theoretically he is doubtless right, but the dislocated lens is not always an easy thing to remove.

Six cases of congenital displacement of the lens have been studied by Beauvieux (*Arch. d'Opht.*, Vol. 33, p. 16, 1912) in Lagrange's clinic. After reviewing Stellwag and Becker's theory of zonular malformation during the closure of the fetal fissure, he accepts the hypothesis of Bedal and Lagrange which assumes an inheritance from highly myopic ancestors; in other words, the lens and the suspensory ligament are too small to fill the space allotted to them, and are therefore easily displaced. The evidence to be gleaned from present known facts, however, lends much more support to the Stellwag-Becker theory. In Van der Hoeve's case (*Arch. f. Augenh.*, Vol. 62, p. 145, 1912) the coloboma of the lens was unilateral and nasal with entire failure of the zonule fibers at this point. The defect embraced about one-fifth of the lens circumference.

Diagnosis.—If the lens is partly dislocated, and clear, there may be monocular diplopia. When the lens is in the vitreous humor, the iris is tremulous, the anterior chamber looks deep, the pupil usually is enlarged, accommodative power is lost, and often the dislocated lens can be seen by the naked eye. By ophthalmoscopic examination the eye is hypermetropic to a high degree, and the lens can be seen as a dark, grayish body, constantly shifting its position. When in the anterior chamber, the lens appears of a golden or amber color, under ordinary illumination. The lens may wander from the vitreous to the anterior chamber in response to the changed position of the eye.

Prognosis.—A dislocation of the lens into the vitreous, if recent, offers a good prognosis, provided the surgeon can succeed in getting the lens into the anterior part of the eye, from which it may be extracted. If there are no other lesions, an eye with its lens located in the anterior chamber offers a favorable prognosis. If glaucomatous symptoms have appeared, the outlook is not so favorable, yet some apparently desperate cases do surprisingly well after removal of the irritating body. An old dislocation, with a fluid vitreous, offers little encouragement.

Treatment.—Surgical interference is not always necessary or even justifiable in all forms of displacement of the lens. In the hereditary and congenital forms (*ectopia lentis*) where the lens is clear and the vision satisfactory for the patient's needs, nothing should be done other than correct the refractive error with sphero-cylinders. However, such lenses do sometimes become wholly luxated or so opaque as to need surgical relief.

In subluxation, where the rupture of the zonula fibres is slight, and the lens is but slightly tremulous, it may remain clear for years. If, however, the support is so slight that the lens moves like a door on hinges, trouble is likely to ensue. The free, unsupported part of the lens strikes the iris and sets up an irritation that usually results in glaucoma. An iridectomy done so as to include that part of the iris involved often gives relief.

When the lens exhibits little movement and causes no irritation, it is quite obvious that nothing is to be done. However, in the course of time, such lenses are apt to undergo changes, and the displacement may become complete, or the lens become entirely opaque, so as to call imperatively for its removal.

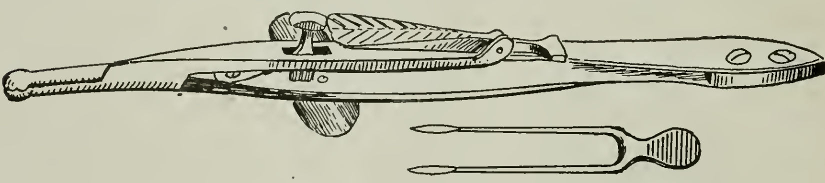
The extraction of a subluxated lens presents some difficulties which suggest themselves when considering the location and kind of corneal section, the cystotomy, the expulsion of the lens, or its removal with a wire loop or spoon. If the lens is in the anterior chamber, removal will be easy. A local anesthetic is to be used, and after introducing the speculum the first step is to anchor the lens. This is done by passing an ordinary straight saddler's needle, held in a Sand needle-holder, through the cornea. Then with a von Graefe knife the cornea is to be opened as in the ordinary extraction. A wire loop is to be passed behind the lens, which is then delivered. The use of the bident is not necessary. If the lens has caused great inflammation, or if the patient is a child, a general anesthetic will be necessary. It should be given with the patient placed face downward; otherwise, when the surgeon is ready to operate, he may find that the lens has passed into the vitreous humor. It may be advisable to anchor the lens under a local anesthetic and deliver it under a general anesthetic.

In the case of a 51 year old man who had congenital dislocation of both lenses, which were cataractous, Würdemann (*Ophthalmology*, Oct., 1913) operated in the following way: The usual cataract incision was made through the cornea, turning the knife, however, and not cutting through the conjunctiva at the upper part, leaving a bridge attached to the cornea and conjunctiva, as the lens sunk downwards and a bead of vitreous showed in the pupil. A very small peripheral iridectomy was made using the blunt hook for seizure of the iris, then the wire loop was inserted back of the lens and it lifted out, luckily without any loss of vitreous and without any bleeding. Atropine and 1:5000 sublimate ointment was applied, and a dressing of gauze and a cotton pad, held by adhesive strips, which was not changed in three days. Progress was uneventful until the sixteenth day, when some bleeding from the iris resulted in a small hyphema, which resorbed within a week.

Ewing (*Ophthalmic Record,* Nov., 1911) advocates the use of a broad, lance-shaped keratome, passing the blade behind the lens so as to fix the lens between the blade and the cornea. Pressure backwards is made by means of a Daviel spoon forcing the lens to follow through the wound on the anterior surface of the knife as it is withdrawn. The vitreous derives a certain amount of support from the broad blade of the keratome which thus minimizes its escape. The width of the keratome should not be less than 12.5 millimetres from one lateral angle to the other and the eye must be firmly fixed whilst the incision is being made.

In the same class of cases, Terson (*Arch. d'Opht.*, 31, p. 705, 1911) after using a miotic, fixes the lens nucleus by means of a long, delicate, sharp needle, which he then entrusts to an assistant. Then, after oblique linear incision at the infero-external limbus, the lens is extracted by combined movements of the needle and a curet or loop introduced into the anterior chamber.

If the lens is situated in the vitreous chamber, attempts to remove it are not justifiable unless its position can be changed. With the



Agnew's Bident for the Extraction of Dislocated Lenses.

pupil dilated, and the patient placed face downward, the lens may drop into the anterior chamber, in which event eserin should be instilled immediately, in the hope that the contracting iris will hold it in position until it can be anchored. In these cases owing to the great danger of loss of vitreous, it is advisable to make use of the Kalt suture. If an eye containing a lens located in the vitreous humor is blind and painful, an enucleation should be made, to prevent the occurrence of sympathetic ophthalmitis.

Various methods have been proposed for the extraction of lenses freely floating in the vitreous humor. Agnew (*Trans. Am. Ophthal. Soc.*, 1885, p. 69) used a *bident,* passed 6 mm. from the limbus through the sclera, with which he harpooned the lens. The latter was then pushed into the anterior chamber and extracted through a corneal section made below with a keratome.

Agnew's procedure was imitated successfully by Webster and Pomeroy (*Trans. Amer. Ophth. Soc.*, 1888, p. 168).

Noyes (*Diseases of the Eye,* New York, 1890) placed the patient on a table, resting on his chest and abdomen, face downward. He then passed a cataract needle through the sclera, transfixed the lens and extracted it.

Knapp's (*Arch. f. Augenheilk.*, 1883) method consisted in making the usual corneal section without iridectomy or capsulotomy, then, removing the eye speculum, he made use of the lower eye-lid to press on the sclera and expel the lens. If it did not present, he introduced into the eye a spoon or loop and completed the extraction.

Knapp's method is probably the best procedure for totally luxated lenses, free in the vitreous. As a rule, pressure on the lower eye-lid over the sclera, with counter-pressure by means of the upper lid, will bring success in most cases, and without great loss of vitreous.

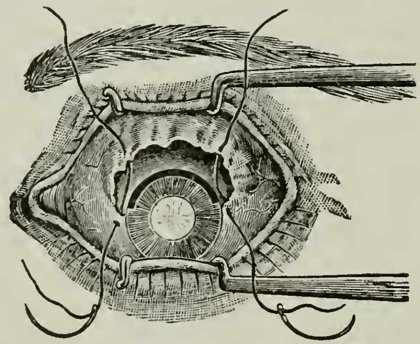
The writer has been fortunate in several cases to secure the lens without introduction of either spoon or loop, directing patient not to look downward, but rather slightly up, while the expulsive pressure is being made. The downward trend of the globe is apt to induce escape of vitreous by causing too great gaping of the corneal wound, owing to pressure of the globe on the orbital floor. Loss of vitreous should be met by injecting into the eye (to fill up the globe) a sufficiency of normal salt solution.

When it becomes necessary to introduce an instrument into the vitreous to extract a luxated lens, unless it be a small, calcareous one, the wire loop is much to be preferred. The spoon is likely to push the lens forward in front of it, owing to a layer of vitreous filling its concavity, but the wire loop permits the vitreous to pass through the open center and come in close contact with the lens; and thereby permits the cataract to be lifted out of the eye. The wire loop is sometimes serrated on its anterior surface, so that it has a better hold on the lens capsule.

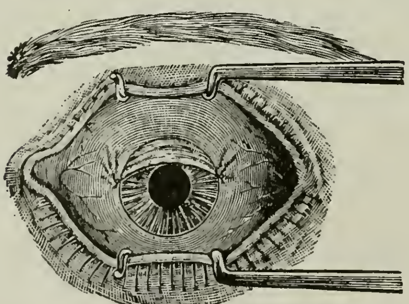
As a result of trauma, the lens is sometimes forced through a ruptured sclera *beneath the conjunctiva*. By making a suitable opening through the latter, the lens can be readily removed. No sutures are necessary. A pressure bandage suffices to bring the parts in apposition.

An interesting case of this sort was reported by Maynard (*Ophthalmology*, Jan., 1911). The patient, a Hindu, male, aged 48, while working in the railway workshops, was struck on the left eye by a piece of iron. The sight in that eye had previously been poor. An hour later, when first seen, the following conditions were found: In the right eye an immature cataract. In the left (the injured eye) the pupil was black and dilated, slightly irregular at its upper edge—due to a slight radiating laceration. The anterior chamber was deep. The iris was tremulous and there was a little blood on its anterior surface above and below the pupil. The lens was absent from its proper place. Vision=moving objects, and with a + 14 lens he saw figures at 15 inches. There was no external wound.

On raising the upper lid, which looked at first sight as if there were a chalazion in its center, there was found to be a globular swelling under the conjunctiva a bit larger than a pea, which was the cause of the projection in the lid. This swelling was caused by the lens which had been dislocated into this position by the blow. The swelling had a



Van Lint's Sliding Conjunctival Flap in Removal of a Dislocated Lens.



Van Lint's Sliding Conjunctival Flap in Removal of a Dislocated Lens.

yellowish color owing to the brown lens (cataractous) showing through the semi-transparent conjunctiva. Under cocain an incision was made across the swelling parallel to the corneal margin and about ¼ inch away from it. An overripe cataract in its capsule was taken out through the incision, which was then closed with two fine silk sutures. No vitreous escaped and healing occurred rapidly, with good vision.

Three months later the left lens was extracted with the loop; using the method of Van Lint (*La Clin. Ophtalmologique*, Vol. III, No. 7,

1911) as described by L. Webster Fox (*Ophthalmology,* Jan., 1912). A large sliding conjunctival flap was made, which was brought over the corneal wound by two sutures, this time likewise making a small peripheral iridectomy. No vitreous showed, but healing was extremely slow as one of the angles of the coloboma becoming impacted in the wound, ultimately formed a cyst, which was subsequently dealt with by a bridge incision of the conjunctiva and galvano-cautery, since which time the cyst has not returned and this eye, as well as the other, looks as if an ordinary and normal cataract extraction had been performed.

The final results were: With right $+9.00 \subset +5.00$ $25° = 6/xx$; left., $+9.00 \subset +5.00$ $160° = 6/xv$. He can read Snellen 0.30 at 30 cm. and can read the telephone book.

The extraction of totally displaced lenses is, as has been elsewhere stated, generally difficult, often impossible and rarely satisfactory. However H. S. Paine (*Annals of Ophthal.,* July, 1915) tells us that with a head illuminator, a 3 inch (focus as well as diameter) hand lens, the light from a frosted 20 candle power spiral filament electric bulb held 1½ to 2 feet above and one side of the eye (all diffuse light being excluded during the search and extraction) the operation can be successfully undertaken. Under asepsis, cocain and adrenalin, and a generous incision there may be made a broad conjunctival bridge at each end of which a stitch is inserted before its final cutting. If the iris is depressed, funnel-wise, it may be lifted with a fine hook or a delicate iris forceps, one blade of which is passed under it. A wide iridectomy is then made.

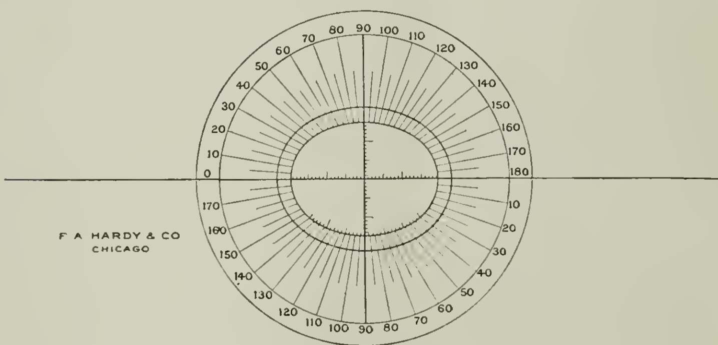
The fundamental part of this operation is to *see the lens during the time it is being extracted.* Of course all pressure by or through the lids must be obviated, hence the necessity of a skilled and attentive assistant to lift the lids from the eye-ball, either by gently lifting the speculum, or by using the Smith-Indian plan. And third, as this operation has been proven safe and successful, early operation is emphatically advisable.

Look for the lens until it is located (this is possible whether it is clear and transparent or opaque), *then with the lens constantly in view,* catch the lens or capsule with a Stevens traction hook, and slowly and carefully draw it toward the incision. When the lens approaches the anterior chamber, carefully pass behind it a Smith spatula, upon which it is to slide up and out. Now draw the lens out, if possible with the hook; if the hook tears out, deliver the lens by making gentle pressure with a blunt hook upon the cornea. This technique is also applicable for the partially dislocated hinged lens, which does not float up into the pupil upon completion of the incision, or one displaced into the vitreous during a cataract operation.

Lenses and prisms, Adjustment of. See **Lenses and prisms, Centering of**; and p. 4953, Vol. VII of this *Encyclopedia*.

Lenses and prisms, Centering of. In addition to the discussion of this subject on p. 1965, Vol. III, and on p. 4953, Vol. VII, of this *Encyclopedia*, it may be said here that of the numerous devices for determining the center of a simple, compound or prismatic lens the optician or ophthalmic surgeon who is in the habit of examining and adjusting the glasses he prescribes will find that the simple protractor is important.

Ophthalmic surgeons generally make use of a simple cardboard "protractor."



The Simple Protractor.

This device is used to determine the axis of lenses; whether they be in frames, broken lenses or uncut lenses about to be "edged" or finished. It is necessary, in each instance, to place 3 dots on the lens corresponding to its axis.

Before dotting a lens, it is safer to gain a clew as to the direction of the axis with the use of a lens measure, and keeping this in mind, always hold the lens with the axis toward the vertical line on the chart, otherwise there is a chance of dotting the axis in the opposite meridian to where it really is.

In the absence of a centering machine, one may determine the approximate axis by arranging a cross line in an upright position and holding the lens securely, dot it in the manner as described for the centering machine.

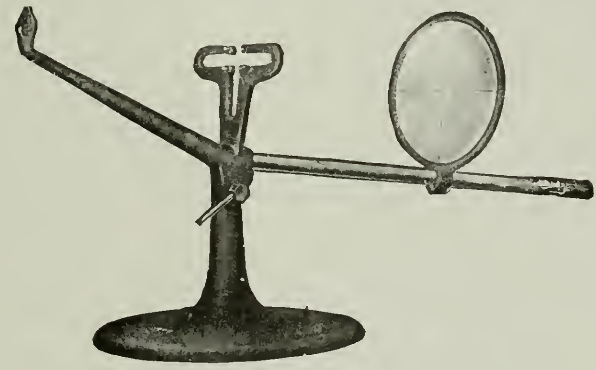
To obtain the center of a lens, hold lens before a cross line so that lines are unbroken. When such a position is found the center of the lens will be at the intersection of the cross lines.

Care must be taken to have one line of the cross perfectly vertical and the lens must be held perfectly still after the lines appear unbroken, else the results will be entirely wrong.

After dotting process is finished, place the lens on the oval on the card with the back surface of the lens up, and the center dot at the intersection of the cross, then the outside dots will indicate the axis of the lens.

If the lenses are decentered, the amount of their decentration may be easily measured. The meridian in which the axis of the cylinder lies may also be obtained by means of the protractor.

To measure the amount of decentration of a lens, dot its optical center and place it on the oval diagram so that its edges coincide with



Lens Centering Device.

It is extremely simple and efficient. The lens is held against hard rubber points and sighted against the cross lines of the target through a pin hole in the forward arm. When the center corresponds with the intersection of the principal cross lines, the lens is "dotted" with ink. To accommodate lenses of different focal lengths, the target is movable.

The rod supporting target is marked at the proper distance where target should be placed when decentering for prismatic power. At this point the principal vertical lines of the target represent power in prison dioptrics.

A wide base gives stability where it is not desirable to fasten to the bench, while the adjustment permits of sighting at any angle that is convenient.

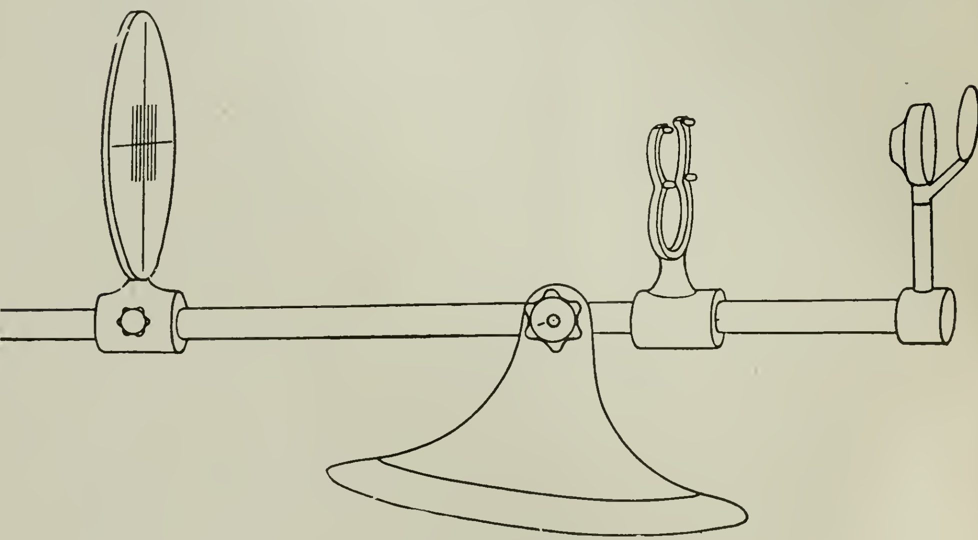
the diagram; then note the position of the dot. If it is at the point where the lines cross at the center of the diagram, the lens is centered. If the dot is not over the point where the lines cross, it is decentered, and the amount of the decentration either "in" or "out," "up" or "down," may be noted on the scale in millimeters.

The decentration of a plus or minus spherical lens 10 m/m produces as many prism diopters as the lens has refractive diopters. For instance:

If a 3.50 spherical lens be decentered 10 m/m, the lens has a 3½ degree prism incorporated in it, and the base of the prism will be in the meridian or in the direction of the dot if the lens be plus and in the opposite direction if it be minus.

The best and most accurate way is by the use of the improved centering machine which has a lens-holder, cross lines and eye-piece in perfect alignment. Holding the lens securely, move or turn the lens till the lines of the cross appear unbroken, then place one dot at each end of the lens exactly on the line and one dot exactly at the intersection of the cross.

Among the simpler machines for the purpose is one in which a bar is provided with two fixed and one sliding support. The first fixed sup-



Simple Centering Machine.

port has a pin-hole disc, the second a frame carrying four points on which the lens is rested, and the movable one with a white disc having a black cross. The lens to be tested is held against the four points, and adjusted while looking through the pin hole until the part of the cross seen through the lens coincides with the part seen around the lens. The intersection of the cross may be marked with an ink spot on the lens, and will be its center, while one of the lines will coincide with the axis of the cylinder and may be marked by two ink spots, one at either edge of the lens. See the accompanying figure.

A more complicated and patented device (Stoco) may be employed for the *centering of both lenses and prisms.* The following account of the instrument is furnished by the vendors.

To center or mark an uncut lens, place it in the adjustable lens holder A. The opening of the four points or jaws on the lens holder is accomplished by pressing on the lug L with the thumb or the forefinger whichever is most convenient for the operator. After the four points on the chuck have been opened and the lens has been placed between them, the lug L is released and the four points securely clamp the edge of the lens. The closing of the points on the lens chuck is controlled by a tension spring. The lens holder with the lens securely clamped in it can now be rotated or moved to either side to place the optical center and axis of the lens in alignment with the cross lines on the target. The operator now looks through the eye piece I, using either eye as the blinder will swing to either side. Grasp the lens rest A by the lugs on each side with both hands and move the lens holder A until the portion of the lines seen through the lens coincide with the lines on the target. The vertical and horizontal lines should pass through the lens without a break on either edge. After the lens is perfectly centered with the lines on the target, grasp the handle on the marking arm C and move it down until the marking points C strike the ink pad on the roller in the ink well. After the points have been supplied with ink move the arm forward until the points C strike the surface of the lens. The cutting line or major axis of the lens is marked and the lens is then released from the holder by pressing the lug L. The operator should always be careful not to move the lens holder A after the lens is centered, until the dots have been placed on the lens. The center dot denotes the optical center and the other dots on line denote the cutting line or major axis.

By watching the different movements of the lines when looking through concave and convex lenses the operator quickly becomes accustomed to the direction in which the lens should be moved to make the lines continuous. When moving a concave lens, the lines seen through the lens move in the same direction as the movement of the lens. When moving a convex lens the lines seen through the lens move in the opposite direction to the movement of the lens.

To center a spherical lens place the lens between the points in the lens holder A. Looking through the eye piece, move the lens until the lines seen through the lens are continuous with the lines on the target outside of the edge of the lens. The perpendicular and horizontal lines on the target should pass through the lens as straight lines without a break on either edge. After the lines are perfectly centered, swing the arm C forward and mark the optical center. The center dot denotes the optical center.

Before operating machine on each lens be sure indicating line on revolving head M is in its proper position on line with 90 degrees on graduated dial.

When marking plano cylinders or sphero cylinders the direction of the axis should be determined with a lens measure and the lenses should be placed in the lens holder A as follows: When marking the cylinders at 90 degrees, note the direction of the axis of the cylinder and place the lens in the holder with the axis in the direction of the

Lens Centering Machine.

vertical line on the target. After the lens is properly placed in the lens holder A, move the lens holder until the cross lines on the target are continuous within and without the edge of the lens, after which mark lens with points C. When the lens is marked in this position the line of dots will be the major axis or cutting line of the lens and should be placed on the line on the lens cutter pad which coincides with 0° and 180°. When the lens is cut the axis of the cylinder will be at 90°.

When marking cylinders at 180°, note the direction of the axis of the cylinder and place the lens in the holder A with axis in the direction of the horizontal line on the target. Move the lens holder until the cross lines on the target are continuous within and without the edge of the lens, the axis of the cylinder when cut will be 180°.

To mark cylinders for other axes than 180° or 90°. Place the lens in the lens holder and have the axis of the cylinder run in the direction of the vertical line on the target. Center the lens with the cross line on the target as before. Then with handle K rotate the revolving head M until the witness mark is opposite the degree desired, number of which is marked on the graduated dial. After the lens is marked the witness mark on revolving head M should be rotated back to its neutral position at 90°. There are two sets of numbers on the graduated dial. The inner set should be used when the side of the lens to be towards the eye in the mounting is placed towards the eye in the instrument. When the outside of the lens is placed towards the eye in the instrument, the outer circle of numbers on dial should be used. Example:

Suppose we have a prescription for a +.25 sphere combined with a .50 cylinder axis 75°. As the .25 sphere being the weaker focus is to be placed towards the eye in the mounting the +.25 sphere is placed towards the eye in the lens holder of the instrument. The axis of the cylinder is placed in alignment with the vertical line on the target. Rotate revolving head M until witness mark is opposite 75° mark on inner circle of numbers. When lens is marked and cut, the result will be the cylinder at axis 75°.

When mounting compound lenses having convex spheres, combined with convex cylinders, the weakest convex surface is placed towards the eye, when mounting compound lenses having concave sphere combined with concave cylinder, the strongest concave surface is placed towards the eye. When mounting lenses having convex spheres combined with concave cylinders, the cylinder side is placed next to the eye.

In centering lenses of different strength the protractor or dial with the lines and numbers representing the degrees can be moved toward or away from the operator according to the focus of the lens to be centered. Weak lenses require a longer range than strong lenses.

If the arms supporting the pads of the lens rest interfere with the view of the cross lines and protractor, revolve them in the frame. This enables the operator to set the cross lines at any required angle and still have a firm support for the lens and a clear view of the target.

Of course, there are exceptions to the above rule, as when making cement bifocals, and judgment must be used as to whether the spheres on the lenses are to be mounted towards the eye or away from the eye, because the segments must be cemented on the spheres. Lenses having strong convex spheres combined with weak cylinders are, of course, marked and cut with the spheres away from the eyes and the segments are cemented on the outside of the lenses. On weak foci lenses it is a matter of judgment which looks the best and wears the best. Care must be taken in marking pairs of lenses on cement bifocal prescriptions not to have the axis of one lens marked so as to cause the segment to be mounted toward the eye, and the other lens marked to cause the segment to be mounted away from the eye.

All kinds of prisms can also be marked on this instrument, by using the scale of lines on the target. The wide spaced lines indicate prism diopters when the target slide and lens rest are connected by the bar on the left side of the machine using the notch (F) at the end of the bar. Each wide space represents a prism diopter and a lens has as many prism diopters as the number of spaces the line is displaced. The narrow spaced lines indicate ½ prism diopters. These are also used when decentering strong foci lenses as the lines cannot be seen at the usual distance. When using the narrow spaces the target should be moved up to the notch (G) in the bar that is nearest to the lens rest. The wide spaces will then indicate 2, and the narrow spaces 1 prism diopter.

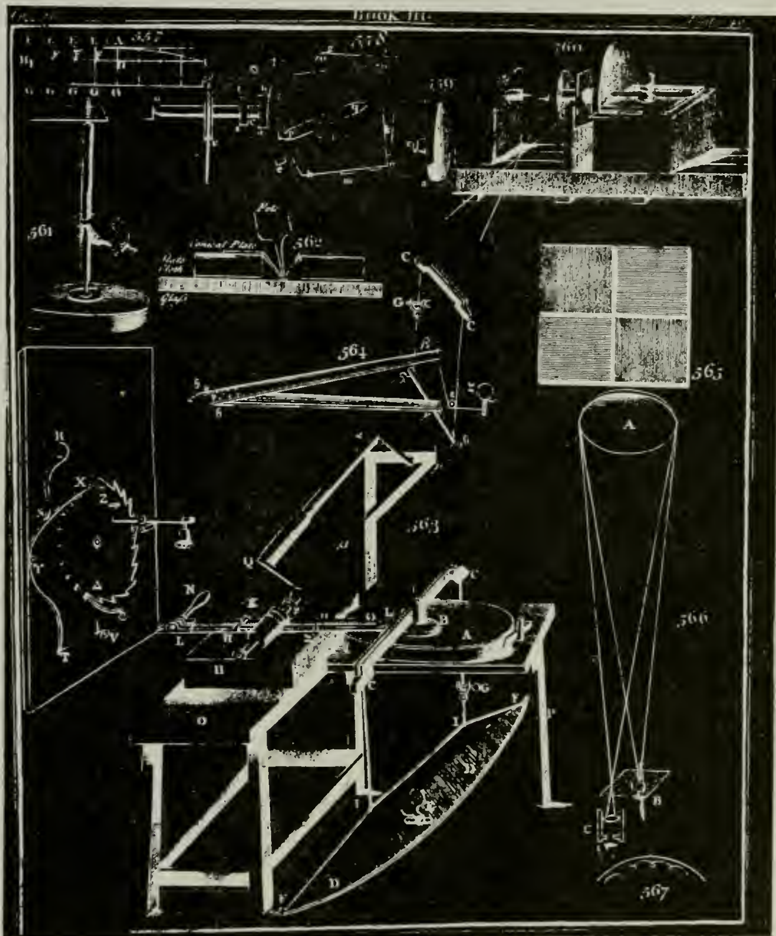
To mark a prism place it against the lens rest with the base in or out, up or down as the case may be, and revolve the target according to the axis of the prism so as to cause the lines and spaces to be moved in the direction of the apex or thin edge of the prism. When looking through the eye piece, the spaces seen through the lens are moved over past the line seen on the target. The number of spaces that the line on the target is offset determines the number of prism diopters.

One of the most important of the devices on this machine is the chuck H, for holding and testing edge ground lenses after they have been cut, edged or mounted. The chuck is fastened to the top of the revolving head M and is swung up out of the way when not in use. The chuck H geometrically centers a lens by the edges in perfect alignment with the eye piece and the center of the cross lines on the target. When in use it is swung down in front of the revolving head and the uncut lens holder A is removed. The lens is placed in the chuck H and the operator while looking through the eye piece revolves the revolving head M until the portion of the vertical line seen through the lens becomes continuous with the line outside without a break at its edges. If the lines on the target do not line up with the lens, the lens is decentered or off axis. When testing edge ground lenses, the outer circle of numbers on the index dial should be used, as the axis will register on the outer circle of numbers on the dial, when the inside of the lens is mounted towards the eye in the instrument.

In centering lenses of different strength the target with the cross lines can be moved toward or away from the operator, according to the focus of the lens to be centered. Weak lenses require a longer range than strong lenses.—(Chas. F. Hubbard.)

Lenses and prisms, Methods of manufacturing. Grinding and polishing lenses. The earliest method of manufacturing eyeglasses was undoubtedly very crude, and carried on laboriously by hand. We find, however, that a Dutch astronomer, Christian Huygens (1629-95) made use of machinery to construct a powerful telescope and became an authority on the grinding and polishing of lenses. See p. 6069, Vol. VIII of this *Encyclopedia*. A description of his methods, including an illustration of his mechanism, will be found in Smith's "*Optics*," Volume II, published in 1737; we quote the exact wording, with the original headings, as follows:

"At *CC* is represented a square beam of wood a little longer than the diameter of the tool, and about 1½ inch thick; the two extremities of it at *C* and *C* are bent downwards, and then are again directed parallel to the whole length, and serve for handles for the workman to lay hold upon. In the middle of this beam there is fixt an iron spike, so long that when the lower surfaces of the handles *C*, *C* are placed upon a plane, the point of the spike shall just touch the plane. This point presses upon the apex of the hollow cone, which descends through the hole in the slate, which by the interposition of a cloth was cemented to the glass *B* lying upon the tool *A*. To increase this pressure a sort of a bow *DED* is shaped out of a deal board, half an inch thick and 5 feet long, being 7 inches broad in the middle, and tapered narrower towards its extremities, so as to end almost in a sharp point. The middle of the bow is fixt to the floor by an iron staple at *E* driven cross it; and is bent into an arch by a rope *FIIF*; to which two other ropes are tied at *I* and *I;* the interval *II* being equal to the length of the beam *CC*. One of these ropes *ICCG* goes over the back of the beam *CC*, passing through a hole in each handle at *C* and *C*, and then is lapped round a cylindrical pegg at *G*, that passes through two wooden chaps, to the bottom of which the other rope is tied that comes from the other *I*. So that by turning the pegg *G*, to lap the rope about it, the bow *DD* may be bent as much as you please. The tool *A* is placed upon a strong square board fixt to the table *O* on one side, and supported on the other side by the post *P*. Then the workman sits down, and taking hold of the handles *CC*, he draws the glass to him and from him over the tool *A*, with a moderate motion. And after every 20 or



Huygens' Machines for Grinding and Polishing Lenses.

Figure No. 557—Brass Plate for Measuring or Gauging Surfacing Tools.
Figure No. 558—Machine for Turning Down Surfacing Blocks.
Figure No. 559—Concave Block.
Figure No. 560—Tool Truing Device.
Figure No. 561—Hand Surfacing Handle with Brass Block Cemented to Glass Blank Ready for Surfacing.
Figure No. 562—Glass Cemented to Stone Block Ready for Polishing.
Figure No. 563—Machine for Polishing.

24 strokes he turns the glass a little about its axis. This way of polishing took up two or three hours, and was very laborious as well as tedious, because the glass being so much pressed downwards was moved very slowly.

"Instead of the bow *DD*, afterwards I invented another spring, by sloping the flat ends of a couple of deal boards $\alpha\beta$, $\alpha\gamma$ and by nailing the flat slopes together very firmly that the boards might make an acute angle $\beta\alpha\gamma$. One of these boards so joined was laid upon the floor under the polishing table, the ends $\beta\gamma$ being under the middle of the tool *A*. So that they lay quite out of the way of the workman, who before was a little incommoded by the ends of the bow *DD*. The boards at the end α were 8 or 10 inches broad, and from thence went tapering almost to a point at β and γ. The board $\alpha\gamma$ lying upon the floor, the end β, of the upper board, was pulled downwards by a rope $\beta\epsilon\zeta$ that passed under a pully ϵ, fixt to the floor, and then was lapped round a strong pegg ζ that turned stiff in a hole in the floor. Under the end γ the middle of a strong stick $\delta\gamma\delta$ was fixt at right angles to the board $\alpha\gamma$, and cords were tied to each end of this stick at δ, δ, which went over the polishing beam *C*, *C* as in the former machine. This stick was lifted up but very little from the floor at the time of polishing; and by consequence the ropes δC, δC were long enough to give liberty of motion to the polishing beam *CC*. Two iron pins θ, θ passing through the ends of the boards at α, were skrewed into the floor, but the heads of the pins stood up above the boards, to give them liberty to rise up when the rope $\beta\epsilon\zeta$ was stretched.

Of grinding the glasses.

"The glass being planed and rounded as above, take away the plate with several cavities, and with some of the same cement fix on a smaller round piece of brass or rather steel, truly flat and turned about the bigness of a farthing but thicker, having first made in the center thereof, with a triangular steel punch, a hole about the bigness of a goose quill, and about the depth of $\frac{1}{12}$ of an inch; and at the very bottom of this triangular hole, a little small round hole must be punched somewhat deeper with a very fine small steel punch. A small steel point of about an inch long must be truly shaped and fitted to this triangular hole, and at the very apex to the small round deeper impression. Nevertheless it must not be fitted so exactly to the same but that it may have some liberty to move a little to and fro; the apex always continuing to touch and press upon the surface of the round hole below. This steel triangular point must be fixed to the end of a pole, to the other end of which another round iron point must be fixed, of about five or six inches long, to play freely up and down in a round hole in a piece of brass let into a board fixed against the ceiling for that purpose, perpendicular over the bench, and over the center of the tool, which must be strongly and truly fixed horizontally thereon.

"Now here it is to be noted that Mr. *Huygens* prescribes to fix his brass plate to the glass by the means of cement, and takes no notice of any other method whatever; though a very small experience in these affairs will convince any body that it is hardly possible, in this or any other case, to bring the cement to a fluidity sufficient to fix two plane surfaces exactly parallel one to the other, without heating the glass and the brass also to a great degree, and so as to endanger the figure of the glass considerably. To avoid this in fixing glasses to brass or wood or the like, some have done it with plaister of Paris: Mr. *Scarlet* does it by cementing another intermediate glass to the brass (or wood) and then fixing the glass, to be ground, to the outward surface of the cemented glass with common glew. Without all this trouble I have done it only with common Icthyocolla or fish glew, which will run very fluid, and will fix the glass and the brass it self strongly together; and round the edges of the brass I stick on some common soft red wax, such as is used for the privy seal, to keep the wet from getting to the glew.

"For grinding glasses truly plane, upon a plane tool, by this method, Mr. *Huygens* prescribes this pole to be about fifteen feet long; but in grinding upon a concave plate, the pole had best be made equal to the radius of the sphere of the tool; though I believe it would not be material if made considerably shorter, according as the height of the room will allow.

"It is necessary to have lying by one an ordinary piece of course glass, ground in the same tool, called a bruiser; whereby when any new emery is necessary to be laid on the tool in grinding your glass, the said emery is to be constantly first run over and smoothed, for fear any little course grains should remain and scratch the glass to be ground.

"Having these things prepared together with some pots of emery of various finenesses, take of your roughest sort a small half pugil, wetting the same and daubing it pretty equably on the tool; then lay on your glass and fix up your pole and continue to grind for a quarter of an hour, not pressing upon the pole, but barely carrying the glass round thereby; then take the like quantity of some finer emery and work another quarter of an hour therewith; then take the like quantity of emery still finer and work for the same time; last of all take a less quantity of some of the very finest you have, which will be sufficient for a glass of five inches diameter, and work therewith for an hour and a half, taking away by little and little some of the emery with a wet sponge. Do not keep it too wet nor too dry, but about the consistence of pap; for much depends on this. If it is too dry, your emery will clog and stick and incorporate, so as for the most part to cut little or not at all, unless here and there where its body chances to be broke, and there it will scratch and cut your glass irregularly; and if it is too wet, and too much diluted, it will from the irregular separation of its parts cut in some places more than others just as in the other case.

"But Mr. *Huygens* tells us this method of using various sorts of fresh emery is not good, finding by experience that the surfaces of large glasses are often scratched. And therefore he says it is best to take a large quantity of the first or second sort of emery, and so work with the same from the first to the last; taking away by little and little every half hour, or quarter of an hour, more and more of the emery with a wet sponge; by which means he could bring the glass extreamly smooth and fine, so as to see pretty distinctly a candle or the sash windows well defined through it; which is a mark when it is ground enough to be ready to receive a polish. But if the glass has not acquired this degree of transparency, it is certain, says Mr. *Huygens,* that too much emery remains; and therefore it must still be diminished and the operation continued. He found it best to make use of common well water in this grinding; and he took care to move the glass in circles, taking in an inch beyond the center of the tool and somewhat beyond the outside of the tool; and he found in a glass of two hundred feet whose diameter was 8 inches ¾, which he ground in a tool of 15 inches diameter, that the figure of the tool in grinding would alter considerably, unless he carried the glass round an inch beyond the center of the tool one way, and 3 inches ¼ beyond the skirts of it another way; but if he carried it no more than a straws breadth beyond the skirts of the tool, and accordingly farther beyond the center, the glass would always grind falsly, too much being taken off on the outsides so that he could never after bring the outsides of the glass to a true and fine polish.

"When you first begin to grind and the emery begins to be smooth, the glass will stick a little to the tool and run stiff; then fresh emery is to be added. When it afterwards comes to be polished it will, if large, require a considerable strength to move it, but this inconvenience will happen less in grinding by the pole than in grinding by hand. For the warmth of the hand makes the substance of the glass swell, and not only increases the sticking of the glass, but in some measure may also spoil the figure of it and also of the tool. When it is ground with the pole it never sticks very strongly, unless when you take the glass off from the tool and keep it from it for some time, and then apply it to the tool again; and this in large glasses; for by this means, says Mr. *Huygens,* the glass gets from the air a greater warmth than it had on the tool; and being again applyed to the tool, its lower surface is suddenly contracted by the coldness of the tool and so sticks to it. Wherefore saith he you must, in that case, wait till the glass and the tool come to be of one temper. The like effect is observeable in grinding large glasses when there is a fire in the room. Perhaps the cause of these effects may be more truly deduced from the attractive qualities of warm glass. But whatever is the cause, we may from hence perceive the great nicety of grinding large glasses, and the necessity there is of grinding them slowly, and with the greatest caution in the most minute circumstances.

"The method hitherto described of grinding with emery, is what is recommended by Mr. *Huygens.* Le Pere *Cherubin* prescribes another material, and it is the grit of a hard grind-stone well beaten into a fine powder and sifted pretty fine. And here in England the same thing was used to be performed by Mr. *Cox* with common clean fine white sand, taking away by little and little the said grit and sand as it ground finer and finer. Nay Mr. *Cox* was used to continue his grinding till the matter of the sand came to be so fine, and so little of it to remain in the tool, that he could, and frequently did use to polish off his glasses therein, without the use of any other material whatsoever; and I my self have been present, while Mr. *Scarlet* ground and polished, or dryed off, a glass of 16 feet in this manner. They call this way drying off on sand, because as the matter grows finer and finer, they wet it less and less, till for the last quarter of an hour (the whole work lasting near two hours) they only wet it by breathing upon it, and at the very last not at all.

"It seems this method is now quite disused: perhaps the violent labour requisite at the last may be a reason of it. A better reason may be the great improbability of grinding or polishing true by this method, by the uncertain and unequal force of the hand, and if this be the true reason of its disuse, I cannot well see but that this method of grinding and polishing out and out in the same tool, and with the same material, *viz.* white sand, might perhaps be again restored, and greatly improved by adding to the old way Mr. *Huygens's* method of grinding and polishing with a pole and spring to press down the pole; or some analogous contrivance. And in relation to grinding by all or any of the methods above described, this one general remark must be made, that the artist must allow time and patience to bring his glass by grinding to the smoothest and finest surface, that he possibly can, before he attempts to polish. For this and this only makes his glass polish truly smooth, well and easily: and the smoother you bring it in grinding, the less labour you will have in polishing; in which consists not only the greatest difficulty but the greatest danger too of spoiling all you have done before.

Of giving glasses the last and finest polish.

"Having removed the little brass plate from the glass, take says Mr. *Huygens* a very thick slate, or rather a block of blue or grey stone; let it be half an inch thick, and let it be ground true and round at the stonecutters; its diameter being somewhat smaller than the diameter of your glass, leaving a hole, quite through, in the center, of about an inch diameter. Then make some cement two parts rosin or hard pitch and one part wax; and taking a piece of thick kersey cloth, truly and equally wrought, cut this cloth round, and leave a like hole, one inch diameter, in the middle. Then warming the stone and also warming the glass, and spreading thinly and equably upon them some of this cement, lay on the cloth and thereupon lay on also the glass, having left in the middle a space the breadth of a shilling uncemented and blackt with a candle. Then provide an hollow conical plate of iron or steel (shaped like an high crowned hat) having the basis of the cone 1 inch diameter, and having round the basis a flat border about 2½ inches diameter, and having the depth or altitude of the cone exactly of the thickness of the slate, cloth and cement, to which the glass is fixt. The vertex of this cone must go down through the slate and cloth, so that being cemented on the slate, the said vertex may approach to the glass within a hair's breadth, and lye perpendicularly over the center of the lower surface of the glass: and this must be adjusted by the circular glass described above. Within the vertex of this hollow cone, the lower point of the pole is to be applyed in polishing; but it may be first proper to be observed, that perhaps fish glew and a brass plate, in lieu, and of the dimensions, of the abovesaid slate, may perhaps be better. Mr. *Huygens* observes also that the angle of the cone should be 80 or 90 degrees, and that the hollow vertex of it should be solid enough to receive a small impression from a round steel punch, to put the point of the pole into, which might otherwise have too much liberty and slip from the vertex. The design of the black spot in the middle of the glass, is to discover by the light of a candle obliquely reflected from your glass, after it has been polished some time, whether it be perfectly clear, and free from the appearance of any bluish colour like that of ashes.

"Before the work of polishing is begun, it is proper to stretch an even well wrought piece of linen over the tool, dusting thereupon some very fine tripoly. Then taking the glass in your hand, run it round 40 or 50 times thereupon; and this will chiefly take off the roughness of the glass about the border of it, which otherwise might too much wear away the lower parts of the tool, in which the glass is chiefly to obtain its last polish. If I understand Mr. *Huygens* right, this cloth is then to be removed, and the glass to be begun to be polished upon the very naked tool it self. But first there is to be prepared some very fine tripoly, and also some blue vitriol, otherwise called cyprion, english and hungarian vitriol finely powdered: mix four parts of tripoly with one of vitriol: 6 or 8 grains of this mixture (which is about the quantity of two large peas) is sufficient for a glass 5 inches broad. This compound powder must be wetted with about 8 or 10 drops of clear vinegar in the middle of the tool; and it must be mixed and softened thoroughly with a very fine small mullet. Then with a course painting brush take great care to spread it thinly and equably upon the tool, or at least upon a much larger space in the middle of it, than the glass shall run over in the polishing. This coat must be laid on very thin (but not too thin neither) otherwise it will waste away too much in the polishing, and the tool will be apt to be furrowed thereby, and to have its figure impaired; insomuch that sometimes a new daubing thereof must be laid on, which it is not easy to do so equably as at first. This daubing must be perfectly dryed by holding over it a hot clean frying pan, or a thin pan of iron, with lighted charcoal therein for that purpose; then leave all till the tool is perfectly cold. Then having some other very fine tripoly very well washed and ground with a mullet, and afterwards dryed and finely powdered, take some of the same and strow it thinly and equably on the tool so prepared; then take your course glass which lay by you, and smooth all the said tripoly, very equably and finely: then take your glass to be polished and wipe it thoroughly clean from all cement, grease or other filth which may stick to it, with a clean cloth dipped in water, a little tinged with tripoly and vitriol; then taking your glass in your hand apply it on the tool, and move it gently twice or thrice, in a straight line backwards and forwards; then take it off and observe whether the marks of the tripoly, sticking to the glass, seem to be equably spread over the whole surface thereof; if not, it is a sign that either the tool or the glass is too warm; then you must wait a little and try again till you find the glass takes the tripoly everywhere alike. Then you may begin boldly to polish, and there will be no great danger of spoiling the figure of the glass; which in the other case would infallibly happen. If the tool be warmer than the glass, it will touch the glass harder in the middle than towards its circumference; because the upper surface of the tool being swelled by heat will become too flat. On the contrary if the glass be warmer than the tool, it will bear harder towards its circumference than at the center; because the inferior surface of the glass is contracted by the coldness of the plate, more than the superior.

"Mr. *Huygens* says that if the work of polishing were to be performed by strength of hand only, it would be a work of very great labour, and even could not be performed in glasses of 5 or 6 feet focal distance: and he seems to think it absolutely necessary that an extraordinary great force or pressure should be applyed upon the glass. For this purpose he has therefore contrived and described two methods for sufficiently increasing the pressure; for the explanation of which, recourse must be had to the book it self and his figures[a]; it may suffice here to say that they chiefly consist in applying the force of a strong spring to press down the center of the glass upon the polisher.

"This operation of polishing, as it is one of the most difficult and nice points of the whole, hath been very variously attempted and described by various Authors. Sir *Isaac Newton,* Pere *Cherubin,* Mr. *Huygens* and the common glass grinders, have taken different methods in this matter. Sir *Isaac* is the only person who seems not to insist on the necessity of a very violent and strong pressure. In the english 8° edition of his Opticks page 95. he hath these words "An object-glass of a fourteen foot telescope, made by an artificer at *London,* I once mended considerably, by grinding it on pitch with putty, and leaning very easily on it in the grinding, lest the putty should scratch it. Whether this may not do well enough for polishing these reflecting glasses, I have not yet tried. But he that shall try either this or any other way of polishing which he may think better, may do well to make his glasses ready for polishing by grinding them without that violence, wherewith our *London* workmen press their glasses in grinding. For by such violent pressure, glasses are apt to bend a little in the grinding, and such bending will certainly spoil their figure.

"A glass 5 or 6 inches broad requires about 3000 strokes upon each surface, to bring it to perfection. And you must carefully examine the middle of the glass opposite to the blacking, whether any place appears darkish or of an ash-colour; or whether any small spots appear by an oblique reflection of the light of a candle or of a small beam of light let into a dark room. For the other parts of the glass will appear perfectly fine much sooner than the middle.

"After the glass has been sufficiently polished, let the stone, the cloth and the cement be warmed over a pan of charcoal, till the cement grows so soft that the glass may be separated from it by a side motion. Then whatever cement remains upon the glass must be wiped off with a hot cloth dipt in oil or tallow, and last of all with cleaner cloths. Then if it does not appear perfectly polished (for we are often deceived in this point) the work must be repeated again, by glewing the glass to the slate as before; then it must be wiped very clean and be made a little rough as we said before. We may also lay a new fund or coat upon the tool if the old one be spoiled; provided no other glass has been polished in the tool in the mean time. The old fund may be washed off from the tool with a little vinegar. Lastly take care always to choose the thickest and the clearest pieces of glass, to avoid a great many difficulties that arise from the unequal pressure in polishing.''

Strange to say, the methods of Huygens although clumsy give a very good idea of the apparatus employed and procedure followed in Europe for lens grinding from 1600 to the middle of the nineteenth century.

Lenses were manufactured in some quantity in the United States as early as 1883. Previous to that time most of the lenses used in this country were imported. At first only spherical lenses were ground; cylinder lenses were then so rare as to be a curiosity. About 1894 machinery for grinding cylinders was perfected and it is safe to say that today more cylinder lenses are worn than sphericals.

Later the meniscus and toric forms of lenses were manufactured. Their development commercially dates back only about 15 years and the change from the flat to the toric form in the last ten years has been so rapid as to tax the capacity of the manufacturers to the limit.

The glass for oval lenses comes in blanks, 45 x 35.5 mm. This size was adopted after much experimenting as most economical, since from these blanks it is possible to cut all the various sizes from the smallest to 000 eye.

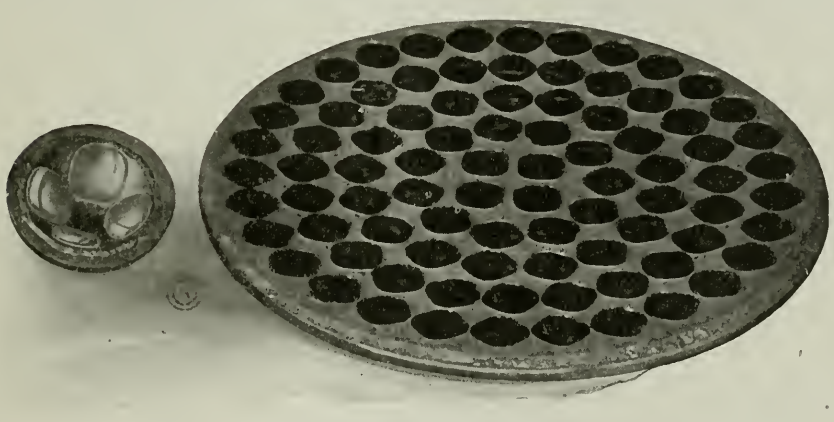
Glass for cylindrical lenses is 42 and 47 mm. square. When about three years ago there arose so great a demand for larger lenses it was found advisable to grind the axes of cylinders diagonal which made it possible to retain the standard already decided upon for the blanks, and to produce at the same time in most cases a much larger lens.

The blanks are first gauged for thickness by an automatic device, so arranged as to throw out the various thicknesses into receptacles arranged to receive them. So accurately is this done that the glasses are gauged to within a quarter of a millimeter.

The present day optician orders centered lenses without the slightest doubt of his order being accurately filled, and probably with no notion as to how it is done, but in the old days of foreign-made lenses it was often necessary to order many more than the required number to obtain a sufficient number with coincident optical and geometrical centers.

The tools required for the manufacture of lenses are primarily a block upon which the lens blanks are pitched while being ground and polished, a mould for shaping the pitch to the required form, for the lenses in question, a grinding tool also of required curvature, and a polishing tool for the final polishing.

The block upon which the lenses are to be pitched or blocked is in the form of a very much enlarged section of the lens surface to be ground and its diameter depends upon the radius of curvature of the



Grinding of Ophthalmic Lenses.
Block covered with pitch holding glass blanks ready for surfacing.

lens surface. If the lens required is weak, and therefore of relatively long radius of curvature, the block may be nearly two feet in diameter holding 100 or more lenses. If very strong and therefore of relatively short radius of curvature, the block may be so small as to contain only a single lens. The present tendency is altogether toward the use of lenses with strong curves.

This process is well illustrated in the figure, which shows two blocks carrying lenses of same power, one in the flat form and one in the toric. The combination is — 2.00 ○ — 2.00 cyl and calls for a — 2.00 spherical surface in the flat form and — 10. surface in the toric form. The former block holding 84 lenses, the latter only 4, the former being very easy to grind and polish, the latter very difficult.

The next operation consists in coating the block with pitch, this latter being a mixture of coal-tar and resin. A suitable quantity of melted pitch is poured into the cold mould of the required curvature and a hot block placed on the pitch in the mould. The pitch adheres to the hot block but does not adhere to the cold mould.

When block and pitch are nearly cold they are removed from the mould and lens blanks stuck on.

The lens blanks are first heated to about 250° F. and placed in position on the pitch. They are then pressed down upon the pitch, one at a time with the result that the pitch adheres very firmly to the heated glass blank. The block is then ready for grinding.

The grinding tool is made of cast iron turned to the proper form for the required lenses. The polishing tool consists of a cast iron disc lined with felt and of proper curvature for the lenses required. The grinding machines consist of an iron frame-work 110 feet in length carrying hundreds of grinding spindles and each machine is driven by a 55 horse-power motor. Each spindle carries a grinding tool and block of lenses when grinding, and a block of lenses and polishing tool when polishing.

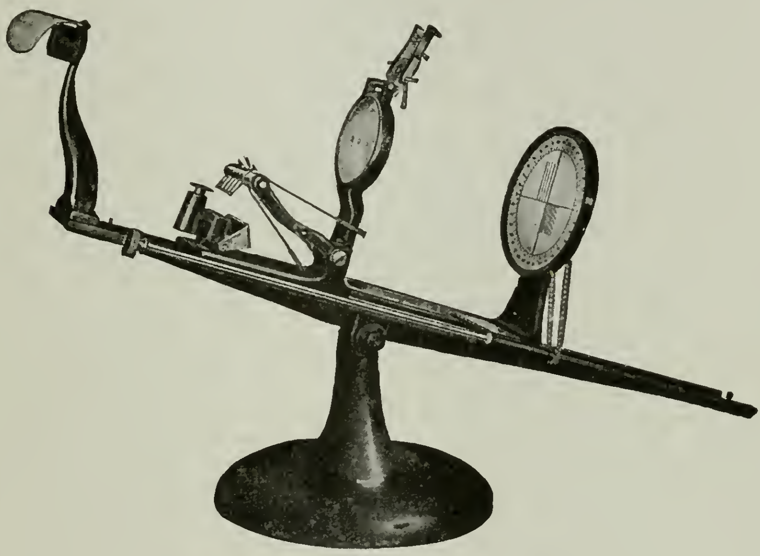
The grinding is done with emery and water, the block of lenses being rotated in the grinding tool by a crank on the end of the grinding spindle. The emery being between the glass and the iron embeds itself in the latter and the lenses are thus gradually ground to the shape of the emery-coated grinding tool. A coarse grade of emery is used for roughing to the required form. After washing both block and tool a smoothing emery is used. Last of all a finishing grade is used and completes the process, and the blocks of lenses are now ready for polishing.

The polishing material, commonly called rouge, is applied to the polishing tool which is lined with felt as stated. If the lens surfaces are examined with a microscope after the last grinding operation is finished they will appear to consist of an infinite number of little hills and hollows.

During the polishing operation due to the friction of the rouge and felt travelling over the lens surface there is probably an actual surface-flow so that the little hills mentioned are not only worn off but are also actually caused to flow into the hollows, thus giving us the polished surface required.

After polishing, the block of lenses is chilled in ice cold water thus causing the pitch to become brittle and allowing the lenses to be easily picked off. After both surfaces of the lenses are ground and polished they are inspected for quality, thickness, centering, etc.

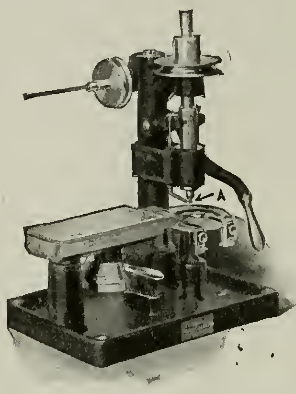
The lenses having been passed, the center and axis tests are carefully marked with a special ink by aid of a centering machine. See **Lenses and prisms, Centering of.** It is then placed upon the revolving plate "A" of a cutting machine (see the figure) with its axis in the proper position with regard to the former "B." The wheel C of the machine being revolved the lens is also revolved in contact with a diamond D, contact being made by the handle E. This diamond



Lens-Marking, Centering and Testing Instrument.

guided by the former, cuts the lens to shape and size. If the lens be intended for rimless work, it is clamped between two sections of a revolving spindle on an automatic edging machine. This revolving spindle is guided by suitable gearing in such a manner that the edge of the lens is brought into contact with a revolving corundum wheel, fed with a constant stream of water until it is reduced to the size and shape prescribed. Should the lens be intended for rimmed work, it is carefully edged by hand on a similar stone to that illustrated in the figure just referred to, without the automatic gear. The edging being completed the lens is again carefully tested for center and axis upon the centering machine, and if correct passed on to those whose duty it is to mount it. In rimmed work this is only a matter of screwing it into the eye wire, but in rimless work the lens must be drilled by means of a revolving diamond point A in a drilling machine. A visit to a workshop fitted with such machines and appliances as here described affords striking contrast to a workshop of an optician of the older school, with his coarse grindstone driven by a handle and other antiquated appliances.

Lenses to be *drilled* are inserted in the clip of the *power lens drilling machine,* which automatically centers the lens so that the hole will be



Power Driven Lens Drilling Machine Fitted with Diamond Drill and Steel Reamer.

either on center; above or below center, as previously set by moving one of the handles under the slide cover. The *melange,* or drilling fluid, is automatically fed on to the lens by a sliding valve which opens upon a downward movement of the drill spindle and allows the fluid

Fitted with Diamond Pointed Cutter.

to moisten the drill. A reamer is provided to finish the hole to desired diameter. See figure.

The *lens cutting machine* may be set to cut lenses of any size, shape or form and represents the highest type of the present lens cutter. The length and width of the lens is regulated by a very fine thumb screw arrangement. The shape is governed by a removable cam (see illustration). It has a rotary protractor base to enable the operator to cut any axis desired. In modern establishments the geometrical cutting line, as produced by the centering machine, is used, the cutting protractor being set at 0 or 180°.

Large and small tools for surfacing lenses. The illustration will explain the difficulty of producing deep curved lenses such as torics and strong concave lenses. The stronger the curve the fewer lens blanks can be cemented upon the grinding block.

Before the blanks are cemented to the blocks they are culled for thickness by a machine which selects them to differences of ¼ millimeter. After grinding and polishing the lenses are subjected to cold air, causing them to chill and loosen from the pitch combination used for cementing them. The lenses are then washed in a neutral soap solution and are ready for inspection.—(E. S. Craven.)

Lenses and prisms, Ophthalmic. For the convenience of the reader the following list of subheadings has been prepared for this important and extensive section. They occur in the order of their discussion: The Function of Ophthalmic Lenses—The Index of Refraction—Surface-Curvature—Typical Lenses—Cardinal Points of an Optical System—Cardinal Points of a Lens—Thin Lenses—Magnification—Equivalent Lenses—The Dioptry—Vertex-Refraction—Neutralization—Prisms—The Prism-Dioptry—Relation of the Prism-Dioptry to the Lens-Dioptry—Decentration—Relation of the Prism-Dioptry to the Meter-Angle—Applications of the Prism-Dioptry—Cylindric Lenses—Astigmatism—Compound Lenses—Toric Lenses—Wide-Aperture Lenses—Aspheric Lenses of Wide Aperture—Aberration—Ocular Aberration—Bifocal Lenses—The Fundamentals of Achromatism—Dioptric Formulæ for Combined Cylindric Lenses.

The Function of Ophthalmic Lenses.

The purpose of this essay is to describe the physical characteristics of ophthalmic lenses and prisms, and to lay before the student of ophthalmology at least those fundamental principles of their refraction with which every efficient eye-practitioner should be familiar; especially as the adaptation of lenses to vision is founded upon that commensurate knowledge of theoretic optics which embraces the measurable phenomena of light acted upon by mirrors, lenses and prisms. In other words, this unique branch of applied science is a special department of physics with which even the university student is not generally made familiar.

For this reason the various forms and properties of lenses used exclusively to counteract optical anomalies of vision are here dealt with, and whose function it is to change only the direction of rays of light so that they may, after passing through the artificial medium, enter the optically anomalous eye in the precise direction for which it is structurally adapted in a state of rest to produce a well-defined retinal image within the physiologically normal eye-ball.

Since, even without artificial aid, all symmetrically formed *healthy* eyes, in this state of repose, are capable of producing clearly defined retinal images of objects that under suitable conditions emit or reflect

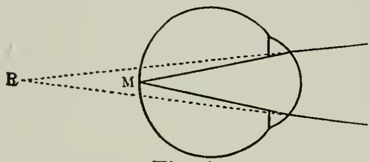


Fig. 1.
The Static Hyperopic Eye Adapted to Convergent Rays.

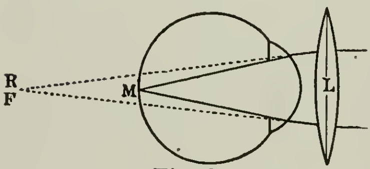


Fig. 2.
The Static Hyperopic Eye Lenticularly Corrected for Parallel Rays.

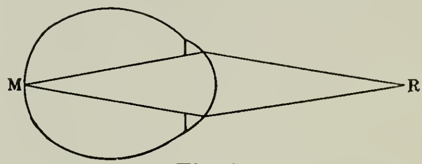


Fig. 3.
The Static Myopic Eye Adapted to Divergent Rays.

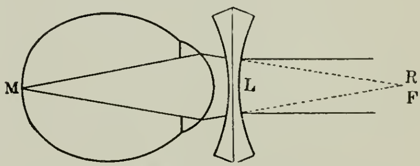


Fig. 4.
The Static Myopic Eye Lenticularly Corrected for Parallel Rays.

The Focus of the Artificial Lens is at the Farpoint of the Ametropic Eye.

either parallel, convergent or divergent rays, it has been found convenient to conventionally select the eye that is reposefully adapted to parallel rays as the normal or *emmetropic* eye; wherefore, eyes that are likewise statically adapted to convergent or divergent rays are merely considered optically anomalous or *ametropic* with respect to parallel incident rays of light. The difference between the refractive powers of the emmetropic and the ametropic eye is, therefore, equal to the power of the lens, L, required to cause parallel incident rays of light to assume convergence toward the farpoint *(punctum remotum)*, R, *behind* the hyperopic eye, Fig. 2, or apparent divergence from the farpoint, R, *in front* of the myopic eye, Fig. 4, because each of these unaided eyes, Fig. 1 and Fig. 3, respectively, is statically adapted to focus upon the retina (macular center), M, incident light converging toward or diverging from the same reciprocal point, R. In short, the punctum remotum, R, and the focus, F, of the lens, L, are coincident points.

Therefore, ophthalmic lenses are of two kinds, namely, those which bend or *refract* parallel incident rays through convergence to a *real focus,* F, behind the lens, or through divergence from an apparent or *virtual focus,* F, in front of the lens, L, which may be made of any refracting medium more dense than air, usually glass, whose opposite surfaces, with respect to a common axis, are, in general, portions of intersecting spheric surfaces of like or unequal curvatures, often resembling a lentil in form, and from which at least the convex lens appropriately derived its name.

In short, a lens is usually a centered system of two refracting spheric surfaces, which causes light-rays to converge or diverge systematically after passing through it. In fact, in order that a refracting medium shall be consistently called a lens it must have the property of producing either convergence or divergence of rays of light, toward a real or from a virtual focal point, F,—or focal line, as with the cylindric lens. The effect of convergence produced by a lens is to create a *real image* of the object, and of divergence, only to figuratively form an image, which is then called a *virtual image.*

For this reason a thin glass having either flat or slightly curved parallel surfaces, even though mounted in spectacles, is not a lens. Flat glasses are called plano-glasses; those with curved parallel surfaces being known by the French name, "Coquilles" (shells), which may be parts of a blown sphere of glass, or made of glass whose concentrically curved surfaces are more perfectly produced through grinding. Such vitreous agents are generally made of colored glass, being used to modify the intensity of the light entering the eye. In earlier times they were made of blue or green glass, later of *smoke* glass—which is neutral in its effect upon the natural color of objects seen through it—and more recently, in various shades of violet, green, yellow and orange glass. The two latter colors absorb, more or less, the irritating violet or chemical rays, though not as effectually as Crookes' glass, having a refractive index of 1.523, which is now produced in two shades, designated as Absorptions A (light) and B (dark). The former, A, is a very pale, neutral tint which is almost colorless to the observer seeing it worn by others. It is said to transmit 99 per cent. of visible light and to absorb the harmful ultra-violet rays and 40 per cent. of the red (heat) rays, while objects viewed through it retain their natural colors the same as shade B, which is equally as effective with respect to the harmful rays, but designed to transmit only 84 per cent. of visible light. Various kinds of greenish-yellow glass, also claimed to suppress the ultra-violet rays to a superior degree, are being exploited as Euphos, Noviol, Fieuzal, Chlorophyl and Hallour. Amber and Amethyst of various shades are also used.

Ophthalmic lenses are usually made of colorless glass, although the aforesaid colored glasses are sometimes advantageously applied; whereas, rock crystal, or so-called Brazilian pebble, has become almost obsolete for the purpose on account of its lack of homogeneity.

The Bausch & Lomb Optical Co. recently published some interesting information respecting the properties of optical glass from which, owing to its commendable brevity, the following is abstracted:

"Glass is an amorphous, transparent or translucent mixture of silicates by definite chemical formulæ. The essential materials for glass-making are silica, an alkali and lime or lead. Part of the lime or lead may be replaced by oxides of other metals, also by certain borates and phosphates to replace a part of the silica, especially in glass manufactured for optical purposes.

"Before the era of modern optical glass manufacture there were only two types of glass available to the optician, the one a lime glass with a low refraction and small dispersion (crown-glass), and the other a lead glass with a relatively high index and large dispersion (flint-glass). Although the terms "crown" and "flint" are still used, they have no definite meaning to the optician of today, as in late years the glass manufacturers, in answer to the demand of modern optics, have succeeded in putting upon the market so many new varieties that there is no longer the sharp division between the two kinds. It may be interesting to state here that in the last catalog of Schott & Genossen of Jena, Germany, there are listed *one hundred* different varieties of optical glass.

"The requirements demanded of the glass for ophthalmic lenses, while stringent, are not so many as those required for glass to be used in other optical instruments. Glass for ophthalmic lenses must be hard, durable, homogeneous, free from bubbles and striæ but also of a constant index of refraction. With the introduction of the deeper forms of lenses the moulding of glass has been introduced. This very materially shortens the subsequently applied process of grinding.

"Roentgen glass is a transparent glass which the Roentgen or X-ray can not penetrate. Lenses produced from this material offer protection to the patient, physician or operator while exposures with the X-ray are being made.

"Colored glass is produced by adding metal oxides to the mass of melted material: cobalt-oxide giving the blue, chrom-oxide, green; gold-oxide, ruby; silver-oxide, yellow, manganese-oxide, violet. Smoke glass is produced by using several of the above-mentioned oxides.

"Light when passing through glass will, generally speaking, suffer a reduction in intensity. The light lost in transmission is said to be absorbed, and the extent thereof is the intrinsic absorption of the glass. The volume of the light transmitted is said to be the intrinsic transmission of the glass. It has been satisfactorily proven that lost light is changed to heat.

"All glasses do not have the same absorption for the same color, nor does any one have the same absorption for all colors. Thus one specimen might pass a great deal of red and green and absorb nearly all blue light, while another might pass a great deal of green and blue and absorb nearly all the red light of the spectrum. Such absorption of particular colors or groups of colors is called *selective absorption.* A glass which absorbs equal proportions of colors of light is called a *neutral glass.* It serves the purpose of reducing the intensity of light without altering its color.

"Since absorbed light is entirely lost, the color of a piece of glass will be determined by the colors of light transmitted by it. If one looks at an object through a colored glass and the object gives off light only of the colors absorbed by the glass and in the proportions absorbed, the object will appear black. If the object gives off light only of colors transmitted by the glass and in the same proportions as transmitted, there will be no change in the color of the object. If the object gives off light, some of which is absorbed and some of which is transmitted by the glass, the object will seem to have only the colors transmitted by the glass.

"If for any reason it is desired to suppress any particular color or colors of light in proportions, it is necessary only to pass the light through a glass, the intrinsic absorption of which is in keeping with the requirements. We have prepared charts showing the relative intrinsic absorption of visible light of the colored glasses commonly used for ophthalmic lenses. The height of the rectangle represents 100 per cent., and the vertical lines indicate the various colors of the spectrum—red, yellow, green, blue and violet. The portions of the vertical lines below the curve indicate absorbed light, and those above indicate transmitted light. Thus, for example, the absorptions for Euphos A are:

	Per cent.		Per cent.		Per cent.
Red	32.4	Green	3.8	Violet	41.5
Yellow	8.8	Blue	25.0		

"The transmission of each color is, of course, 100 per cent., minus the per cent. of absorption for the color under consideration."

The Index of Refraction.

The amount and character of convergence or divergence obtainable in a lens depends upon the extent and nature of its surface-curvatures and the *index of refraction,* which is the ratio between the sine of the angle, i, of incidence and the sine of the angle, r, of refraction for a ray of light passing from one transparent medium into another, Fig. 5, which is the cross-section of a glass plate surrounded by air.

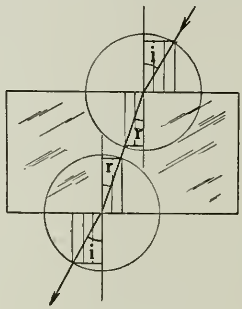


Fig. 5.

It is a *constant,* whose value depends on the nature of the two media separated by the refracting surface, provided the media have the same properties in all directions and the kind of light is specified. This, **Snell's law,** established by Willebrod Snellius, is expressed by the equation,

$$\sin i / \sin r = n, \quad \ldots\ldots\ldots\ldots\ldots \text{I.}$$

the index of refraction, or refractive index of a medium exposed to the incident light having a *specified* wave-length. When the light, before meeting the surface, has been travelling in a vacuum, the constant is termed the refractive index of the medium in which the refraction occurs. When light is incident in air upon a transparent medium, the index of the refraction is practically the same as if the light had been incident in a vacuum upon the same surface. Thus, the above ratio for a ray passing from air into water is about 4/3, or more exactly, 1.336. The index of ordinary crown-glass is approximately $3/2 = 1.5$. The indices more generally used in America are 1.507 and 1.523.

When n is greater than unity, it follows that the angle, r, is less than the angle, i, and the refracted ray makes an angle with the normal which is smaller than the angle of incidence. In fact, the incident rays at the point of impact upon the surface may be said to be bent toward the normal within the medium. This deflection generally occurs when light passes from a rarer to a denser medium; so that the latter is called the *optically denser medium,* whatever the mechanical densities of the media may be. Conversely, when light is deflected at the surface of separation of two media so as to be bent away from the normal, the index of refraction is less than unity, and the second medium is said to be *optically rarer,* or less dense, than the first.

When light is incident in a vacuum (or in air), on a transparent surface, it is nearly always deflected toward the normal, so that the refractive indices of nearly all transparent media are greater than unity. Light can also penetrate to a small depth into a metal, and in this case it is sometimes bent away from the normal (in the case of sodium, gold and silver), and sometimes toward the normal (in the case of platinum and iron).

Surface-Curvature.

Since the refractive index is a constant for any particular substance, it follows that the deviation incurred by a light-ray is wholly dependent upon the inclination of the refracting surface to the incident light, and in order that the deviation produced by a simple lens may be symmetric with respect to the axis of an incident pencil of light, the surface will require to be correspondingly curved in all of its meridians. Such a surface conveniently lends itself to the mechanical production of a lens, as it may be produced through rotation of an arc of any circle whose center is located upon the axis of revolution, thus producing a spheric surface of any desired radius.

A lens thus formed is called a spheric lens, and is universally used both in spectacles and other optical instruments. However, in a *thin* primitive lens one of the surfaces is either spheric or cylindric, the other surface being a plane, and when the lens thus formed is thickest in the center, it produces convergence and is called a convex, convergent, collective, or plus (+) lens; whereas, if the lens is thinnest in the center, it produces divergence and is called a concave, divergent, dispersive, or minus (—) lens. However, Mr. L. W. Bugbee, of Southbridge, Mass., has shown that the thickness of a lens may be sufficiently increased to reverse these properties.

The terms *plus* and *minus,* when used in this sense, correspond with the Continental Convention; an agreement among physicists of Continental Europe that all distances measured from a given point, such as the center of a thin lens, shall be counted positive when they agree in direction with the propagation of the incident light, and negative, if in the opposite direction. Therefore, convex lenses have positive (+) focal lengths, and concave lenses, negative (—) focal lengths;

this conception being now universal among ophthalmologists and opticians throughout the world. However, in many English works on geometric optics distances are counted positive when measured in a direction opposite to that of the incident light, so that the significance of the signs plus and minus is thereby reversed and tends to unnecessary confusion in the minds of students who may have recourse to differing text-books.

The six diagrams in Fig. 6 represent the principal sections of convex and concave lenses, whose surfaces may be either spheric or cylindric, classified in two groups as being typical in form to produce either convergence or divergence of light.

Typical Lenses.

I. (1) Plano-convex or convexo-plane, each of these terms, applied to the same lens, meaning that the first mentioned surface faces the

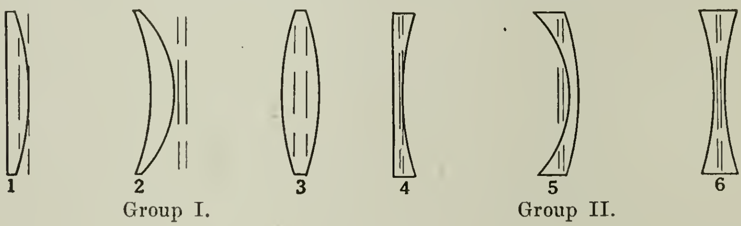


Fig. 6.

incident light. Similarly, (2) concavo-convex or convexo-concave lens, or *meniscus,* which term can properly only be applied to a *convex* lens whose section is a crescent, since it derives its name from the cusps (points) of the crescent moon. (3) Double convex or biconvex lens.

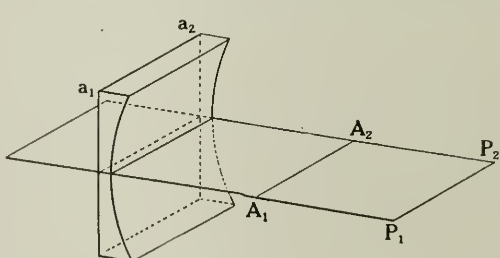


Fig. 7.

II. (4) Plano-concave or concavo-plane, each of these terms used for the same lens, meaning that the first mentioned surface faces the incident light. Similarly, (5) concavo-convex or convexo-concave lens, or *contrameniscus,* which is opposite in form and action to the crescentic lens. (6) Double concave or biconcave lens.

Spheric lenses produce either real or virtual *image-points,* whereas cylindric lenses produce similarly characterized *image-lines.*

In a cylindric lens, Fig. 7, the *maximum* refraction is strictly confined to those parallel principal sections, between a_1 and a_2, that are perpendicular to the rotary axis, A_1 A_2, through which the surface-curvature is generated, so that the image-points of contiguous sections establish an array of points to constitute the image-line, P_1 P_2, which is parallel to the cylinder's axis, A_1 A_2. Therefore, the image-line, P_1 P_2, and the axis, A_1 A_2, of the cylindric lens are located in a plane in which refraction does not occur; wherefore, linear dimensions that are located in it remain unchanged when viewed by the normal eye through the lens. For this reason cylindric lenses are used to counteract *simple astigmatism* of the human eye, which is then optically defective only in one plane or principal meridian that may have any angular inclination to the horizon. Hence, it is necessary to specify the position of the cylinder's axis with respect to the horizon, and which is usually counted *clock-wise* from it. As this position is generally read from the graduations on the outside of a trial-frame, they are engraved in the opposite direction.

In the optical trade the term *periscopic,* suggested by Wollaston, was formerly applied to the menisci and contramenisci originally recommended by Hertel, but it is now generally used merely to designate their shallower forms. The form of the lens greatly influences the definition of the image, it having been mathematically determined that the biconvex or biconcave lens producing the least aberration (*Principles of Geometrical Optics*, Southall) has a radius of curvature for the front surface 1/6th of the radius of the back surface. The plano-convex or plano-concave form is nearly as free from aberration; whereas the meniscus and contrameniscus, when given the proper proportions of surface-curvature, produce less aberration for obliquely incident pencils, and therefore give a wider field of distinct vision than lenses of any other form. See section on *Wide-Aperture Lenses.* The concave surfaces of the menisci, or the lesser curvature of biconvex lenses, in case a difference in the surfaces exists, should always be worn in proximity to the eye.

The term "meniscus" is much abused by opticians, through its incorrect application to a *concave* lens having pronounced counteracting curvatures (concavo-convex), and evidently from the desire to specify a more deeply curved periscopic lens, in distinction from the ordinary periscopic lens with lesser proportions of curvature. *Deep meniscus* would be a better term for the *crescentic lens* of accentuated curvature, which is always *convex;* whereas, *deep contrameniscus,* being counter-disposed in profile and effect to the crescentic lens, would be more correctly applied to a *concave* lens in which the concave and convex surfaces are of very pronounced curvature. Nor should the deep meniscus or deep contrameniscus be called a toric lens, as the latter must necessarily have a toric surface. Such errors give evidence of the need for more profound knowledge among persons engaged in a vocation requiring the proper use of technical terms.

A glass lens having two unequal spheric surfaces is shown in Fig. 8, with its surfaces symmetrically oblique to each other, except at two

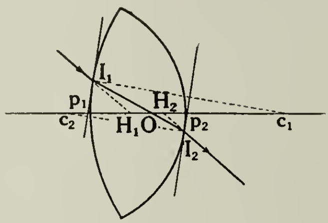


Fig. 8.

opposite points, p_1 p_2, defining the thickness of the lens upon a line, the principal axis, c_1 c_2, or *optic axis,* which also passes through the centers of curvature, c_1 and c_2.

The points, I_1 and I_2, upon the opposite surfaces lie in parallel planes that are perpendicular to the parallel radii, c_1 I_1 and c_2 I_2; hence, the emergent ray at I_2 is also parallel to the incident ray at I_1, and emerges from the lens without change in direction, the same as through a plate. The refracted ray, I_1 I_2, within the lens, cuts the optic axis at a point, 0, called the *optic center,* which is nearer to the surface having the shorter radius, though it is exactly in the middle of the lens when the curvatures are alike.

The prolongations of the incident and emergent rays also cut the axis, c_2 c_1, at two points, H_1 and H_2, called the *principal points.* In fact, all similar lines which are obliquely directed through these points are called *secondary axes,* and connect correlative points in the *object-space* and *image-space* on opposite sides of the convex lens.

Cardinal Points of an Optical System.

There are two distinguished pairs of conjugate axial points, introduced by Gauss, the most important of which are the principal points, and to which Listing has added another pair, the so-called nodal points. The six cardinal points are the two *principal foci,* the two *principal points* and the two *nodal points.* The *first principal focus,*

F_1, is the point on the principal axis where the incident rays intersect, or would intersect if produced, which emerge from the system parallel to the axis, Fig. 9, and in which the final medium has a different refractive index from the first medium, for instance, as in the human eye. See **Refraction of the eye.**

The second *principal focus,* F_2, is the point of axis-intersection of the emergent rays, whose incident direction has been parallel to the principal axis. The *principal points* on the axis are such that, when an incident ray (produced if necessary) passes through the first principal point, H_1, the corresponding emergent ray (produced if necessary) passes through the second principal point, H_2, but the incident and emergent rays are not necessarily parallel to each other. The *nodal points* are two points on the principal axis so disposed that the ray which before refraction is directed toward the first nodal point,

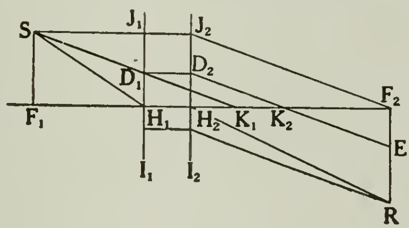


Fig. 9.

K_1, appears, after refraction, to come from the second nodal point, K_2, and follows a direction parallel to its incidence to the system. In each pair of principal points, and in each pair of nodal points, respectively, each point is the image of the other. The distance between the two nodal points is equal to the distance between the two principal points. The two planes drawn through F_1 and F_2, and H_1 and H_2, which are at right angles to the principal axis for axial pencils, are called the two focal planes and the two principal planes, respectively. The rays that originate, or appear to originate, from a point in the *first focal plane,* are, after refraction, parallel to each other and to the lines of direction, K_1 D_1 and K_2 D_2. The incident rays which are parallel to each other, intersect, after refraction, in some point on the *second focal plane.* This point is where the corresponding line of direction cuts the second focal plane. The two *principal planes* are so disposed that the directions of an incident ray and its corresponding emergent ray cut the two principal planes in two points, J_1 and J_2, on the same side and at the same distance from the principal axis. The second principal plane is the optical image of the first principal plane and vice-versa. The principal planes are called *planes of unit magnifica-*

tion, since an area of definite shape and size in the first principal plane produces a virtual image of precisely the same shape and size in the second principal plane. They are the only two conjugate images which have the same size and are situated on the same side of the principal axis. The *first principal focal distance,* F_1 H_1, is the distance between the first principal focus, F_1, and the first principal point, H_1; the *second principal focus distance,* F_2 H_2, being the distance between the second principal focus, F_2, and the second principal point, H_2.

Cardinal Points of a Lens.

Specifically, however, for a thick lens of any form, *in air,* the principal points and nodal points are synonymous, since they are both merged into one point, as, for instance, in the biconvex lens, Fig. 10,

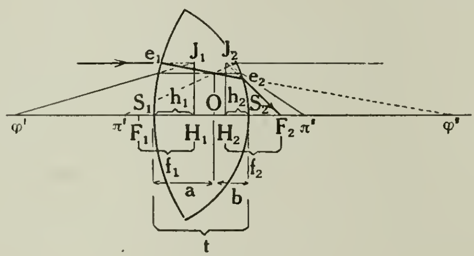


Fig. 10.

wherein the principal planes, H_1 J_1 and H_2 J_2, are conjugate images, of equal size, of the plane erected in the optic center, O. Hence, all rays which before refraction are directed toward a point, J_1, in the first principal plane, seem, after refraction, to come from a point, J_2, in the second principal plane, which is situated on the same side of the axis as the first, and equally distant from the axis.

The second principal focus, F_2, behind the lens, is the point at which are focused all incident parallel rays in front of the lens, since the refracted ray, e_1 e_2, within the lens, is again refracted at e_2 to produce the emergent ray, e_2 F_2, which appears to proceed from the point, J_2, of the second principal plane.

Similarly, parallel rays incident to the lens from the opposite direction have their focus at F_1, which is as far from H_1 as F_2 is from H_2. Consequently, the two principal focal distances, $H_1F_1 = f_1$, and $H_2F_2 = f_2$, of a lens, in air, are equal, irrespective of the surface-curvatures, and are designated simply by f. However, it is to be remembered that this distance, f, on either side of the lens, is always to be counted from its correlative principal point, H_1 or H_2. The following equations for a thick biconvex lens are obtained through suitable transformation of those given by Landolt (*The Refraction and Accommodation of the Eye.*—E. Landolt, Edinburgh, 1886), and through which it is found that the optic center, O, of the biconvex lens divides its thickness, t, in two parts, a and b, whose values are

$$a = \frac{tr_1}{r_1 + r_2}, \text{ and } b = \frac{tr_2}{r_1 + r_2}.$$

Therefore, when the radii, r_1 and r_2, of the surfaces, S_1 and S_2, are made equal to each other, a is equal to b, and consequently O is midway between the surfaces. When the radii are unequal, the optic center is nearer to the more convex surface.

The distances of the principal points, H_1 and H_2, from the surfaces, S_1 and S_2, are represented by h_1 and h_2, respectively, so that

$$h_1 = \frac{tr_1}{n(r_1 + r_2) - t(n - 1)}, \text{ and } h_2 = \frac{tr_2}{n(r_1 + r_2) - t(n - 1)},$$

these equations being derived from the corresponding general formulæ:

$$h_1 = \frac{tr_1}{n(r_1 - r_2) - t(n - 1)}, \text{ and } h_2 = \frac{tr_2}{n(r_1 - r_2) - t(n - 1)}, \ \ldots\text{II.}$$

which apply to a thick lens of any form, when r_1 and r_2 are given their proper signs. Thus, if $r_1 = r_2$, h_1 is also equal to h_2; wherefore, the principal points in an equiconvex lens are equally distant from its surfaces; and, in case the refractive index $n = 1.5$, and t is comparatively small, h_1 and h_2 are equal to one-third of the thickness.

The distances, a and h_1, are to be taken positively to the right and negatively to the left of the first surface, S_1; and b and h_2, positively to the left and negatively to the right of the second surface, S_2. Their dimensions, deduced from the preceding formulæ for a biconvex lens, become positive, so that the optic center and the principal points are inside of the lens. In the case of a meniscus, a and h_1 become negative, and b and h_2, positive, thus placing the optic center and the principal points outside of the lens, near its convex side. As the radii of the meniscus are both positive, the general formula, II., applies without change of signs.

The formula for the principal focal length of a thick biconvex lens whose radii differ is

$$f = \frac{r_1 \; r_2}{(n-1)\,(r_1 + r_2) - \dfrac{t(n-1)^2}{n}},$$

being derived from the general formula for a thick lens:

$$f = \frac{r_1 \; r_2}{(n-1)\,(r_2 - r_1) + \dfrac{t(n-1)^2}{n}}, \quad \ldots\ldots\ldots\ldots \text{III.}$$

after the proper signs for r_1 and r_2 have been introduced.

If, in the latter equation, the thickness, t, is reduced to nil, then

$$f = \frac{r_1 \; r_2}{(n-1)\,(r_2 - r_1)}.$$

Therefore,

$$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right), \ldots\ldots\ldots\ldots\ldots\ldots \text{IV.}$$

which is the general formula for the refraction of a very thin lens of any form whose focal length is f.

In the plano-convex and plano-concave lens, the first principal point is at the vertex of the curved surface; whereas, the second principal

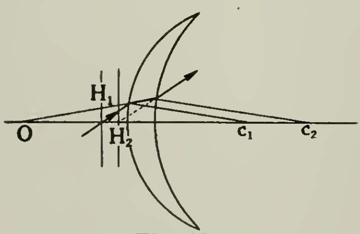


Fig. 11.

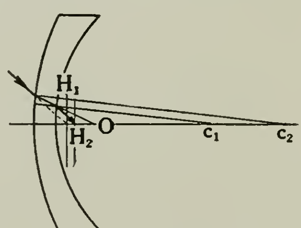


Fig. 12.

point is in the interior of the lens. In the meniscus and contrameniscus the principal points are not in the interior of either lens, but at definite distances on a particular side of it.

Thus, the meniscus, Fig. 11, has its principal points, H_1 and H_2, on the convex side; whereas for the contrameniscus, Fig. 12, they are on the concave side. In fact, this difference in the positions of the principal points, even in thin lenses of this kind, frequently affects the acuteness of vision when they are substituted as equivalents for thin biconvex or biconcave trial-lenses, respectively. This is due to the fact that their respective principal points, from which the focal lengths are measured, do not occupy the same positions with respect to the plane of the frame supporting either lens before the eye, so that the image of the lens can not in both cases coincide with the ocular far point.

This is more fully explained in the section on *Vertex-Refraction.*

Thin Lenses.

Ophthalmic lenses are usually very thin, so that the thickness may be considered a negligible dimension * with respect to the focal length, which is then counted from the optic center toward either focal point, F_1 or F_2, at the same distance, f, on either side of the lens. Either of these points may, therefore, be the principal focus, namely, the focus of rays that are incident to the lens parallel to its axis. For instance, an incident ray proceeding from the first principal focus (F_1 negative), or toward that point (F_1 positive) is rendered parallel to the axis after refraction through the lens; whereas an incident ray parallel to the axis gives rise to a refracted ray which virtually proceeds from the second principal focus (F_2 negative), or which actually passes through that point (F_2 positive).

As parallel incidence corresponds to the second principal focus, F_2, the latter is universally used to designate the *principal focal length,* f, of a convex or concave lens whose refractive index is n, and whose radii of curvature are r_1 and r_2. Their relation to each other is:

$$\frac{1}{f} = (n - 1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right).$$

The refraction, $\frac{1}{f}$, also expresses the *power of the lens,* which is proportional to the difference between the powers of the lens-surfaces (see section on the *Dioptry*). The means by which this equation is established, together with other general formulæ given in the text, may be found in any work on geometric optics.

However, great care should be exercised when numeric values are therein substituted for r_1 and r_2; it being necessary to remember that

* Excepting in convex lenses having a focal length shorter than 6 inches.

the optic center of the thin lens is the zero-point of the dimensions of curvature, and which are to be reckoned positive when their direction from the center agrees with the direction of the light's propagation. Of course, a direction opposite to this calls for a negative dimension. This is necessary, in order that convex lenses shall be considered positive, and concave lenses, negative. For instance, when the preceding equation is numerically applied to lenses whose front surface (the one exposed to incident light) has a radius r_1, the signs for the radii, r_1 and r_2, with respect to the optic center, are to be chosen as follows:

Biconvex type, $+ r_1$ and $- r_2$, which gives $+ f$, a positive lens.

Biconcave type, $- r_1$ and $+ r_2$, which gives $- f$, a negative lens.

Plano-convex type, $r_1 = o$, and $- r_2$, which gives $+ f$, a positive lens.

Plano-concave type, $r_1 = o$, and $+ r_2$, which gives $- f$, a negative lens.

Meniscus type, $+ r_1$ and $+ r_2$, as $r_1 < r_2$, which gives $+ f$, a positive lens.

Contrameniscus type, $+ r_1$ and $+ r_2$, as $r_1 > r_2$, which gives $- f$, a negative lens.

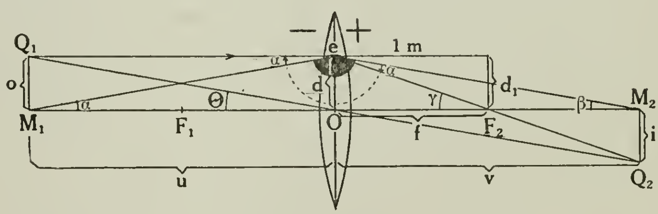


Fig. 13.

The *conjugate foci* of a lens are two points, M_1 and M_2, Fig. 13, so situated that the rays emitted from a luminous body or illuminated object at either point are refracted by the lens to the other. Therefore, the angle at e, shown densely shaded between the rays, M_1e and eM_2, is a *constant,* depending upon the curvature and the refractive index of the lens. For instance, if M_2 moves to F_2 (the second principal focus), M_1 moves in the same direction to infinity, because both sides of the dense angle simultaneously turn clockwise around e through the same angle, α, and thus establish the corresponding angle, γ at F_2. The angles at M_1, M_2 and F_2 are so related that $\alpha + \beta = \gamma$, as shown on the right side of the diagram; so that,

$$\tan \gamma = \tan (\alpha + \beta) = \frac{\tan \alpha + \tan \beta}{1 - \tan \alpha \tan \beta}.$$

However, instead of this, *for very small angles*, the tangent may be independently substituted for the arc of each angle; wherefore, $\tan \alpha + \tan \beta = \tan \gamma$, and whose linear dimensions in the diagram give:

$$\frac{d}{u} + \frac{d}{v} = \frac{d}{f},$$

in which d, for a radius of 1 meter, represents the tangent of the angle of the refracted ray's deviation from the axis, or from parallel incidence.

Moreover, in order to insure the angles being small, the decentration of e, represented by d, may be made equal to 1 centimeter,* hence

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}.$$

It will later be shown that the decentration, $d = d_1 = 1$ cm., in the principal focal plane of a lens, is also the measure of its prismatic power at the point of decentration, e.

As the dimensions of u and v are measured in opposite directions from the optic center O, it is necessary to make u negative, in case v and f are to be considered positive, or vice versa; wherefore, every type of lens will have a negative and a positive side with respect to the surrounding space.

As the Continental Convention is commonly applied to ophthalmic lenses, and the direction of u from the optic center is then *opposite* to the direction of the incident light, *u must always be taken negative.*

Consequently the preceding equation becomes

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{V.}$$

This is *the general formula for the conjugate foci*, wherein u is the object-distance and v is the image-distance from the optic center of the lens whose focal length is f.

While it is true that this formula is applicable to either the English or the Continental Convention, yet, when the latter is applied to *numeric values* of u and f, let it be emphasized that, *the dimension u*

* It is evident that the centimeter-value for d may be applied even to a lens of 5 centimeters focal length, as the tangent at the focus, F_2, is then $1/5 = 0.2$, which corresponds to the angle of 11° 18.6; so that all other inclinations of the paraxial incident and refracted rays to the axis will be considerably less than this.

must be given the minus sign for both concave and convex lenses, and that, *f must be given the minus sign for a concave lens,* in order to comply with the Continental conception of sign for direction.

Thus, for a concave lens: $$\frac{1}{v} - \frac{1}{-u} = \frac{1}{v} + \frac{1}{u} = -\frac{1}{f},$$

and for a convex lens: $$\frac{1}{v} - \frac{1}{-u} = \frac{1}{v} + \frac{1}{u} = \frac{1}{f}.$$

When numeric values are introduced in the formula V, for a convex lens it is found that the nearer the object is to the lens, the farther the proportionately increased image recedes from it.

Thus, if u is made infinitely great, v is equal to f, so that the incident rays are parallel, and a real, inverted and infinitely small image is formed at the second principal focus, F_2, of the lens. When u is equal to 2f, v is equal to 2f; in other words, when the object, o, is at twice the focal distance from the center of the lens, Fig. 13, the real

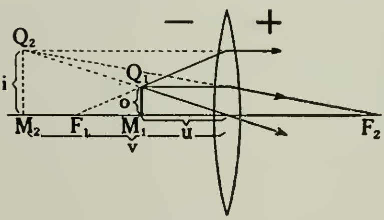


Fig. 14.

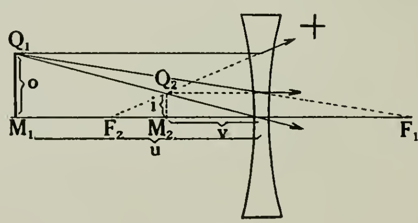


Fig. 15.

and inverted image, i, is also twice the focal distance from it. In case u = f, v is infinitely great, which means that the rays emerge from the lens as a beam of parallel rays directed toward an image that is infinitely large with respect to the object.

However, when the object approaches nearer to the lens than the first principal focus, F_1, say at a distance, u, equal to 2/3 f, then v = − 2f, the minus sign indicating that the image is on the same side of the lens as the object, and, therefore, is virtual and erect, as shown in Fig. 14.

Therefore, it may also be emphasized that, whenever a negative value for v is the result of introducing numeric values for u and f in the formula, V, for a convex lens, it signifies that the image-point, M_2, is on the incident side of the lens; that is to say, it is virtual and on the same side of the lens as M_1, this being the case when the object-point, M_1, is nearer than the first principal focus, F_1.

On the other hand, the formula, V, for a concave lens, will always give a negative value for v, whatever the numeric values of u and f may be, so that the image-point, M_2, is always virtual and on the same side of the lens as M_1. See Fig. 15.

Consequently, every thin lens that increases in thickness towards its periphery has virtual foci; and, vice versa, for the focus of a lens to be real, the lens must be thicker in the middle than at its edge. In other words, a concave lens always produces a virtual image, i, Fig. 15, and a convex lens, a real image, when the object is more remote than the focus, Fig. 13; or a virtual image, in case the object is nearer than the focus, Fig. 14. In fact, the object and the image are inseparably linked together, by means of the conjugate foci, in the so-called object-space and image-space, which, as shown in Figs. 14 and 15, may also occasionally occupy the same territory.

Magnification.

As the sizes of the object, o, and of the image, i, are reciprocal values depending upon the distances u and v, the so-called *lateral magnification*, M_l, is expressed by the equation:

$$M_l = \frac{i}{o} = \frac{v}{u} = \frac{f}{u + f} = \frac{f - v}{f}.$$

It may have any value, depending upon the position of the axial object-point, and is the measure of the actual magnification. When the semi-diameters of o and i, respectively, are projected to *opposite sides* of the *axis*, the image is *real* and *inverted;* whereas, if these dimensions are on the same side of the axis, the image is *virtual* and *erect.* In the latter case the image is not really formed, but only appears to be formed to the eye that sees it, therefore, the size of the virtual image is only apparent.

However, the apparent size of an object or its image, whether real or virtual, may be determined by the tangent of the visual angle under which it is seen, so that, in case the object is too distant or inaccessible to be measured, the equation above cited may be given the form:

$$M_o = \frac{i}{\tan \Theta} = f \text{ (approximately)}.$$

This is called the *objective magnifying power,* which is the ratio of the linear size of the image, i, Fig. 13, to the *apparent size of the* *object* expressed through the tangent of the slope-angle, Θ, of the chief ray that proceeds from the outermost object-point, Q_1. It differs from the so-called *subjective magnifying power,* M_s, which is applied to instruments designed to be used subjectively in conjunction with the eye for the purpose of amplifying vision, as for instance, in the case of the ordinary magnifying glass, or the microscope. In this event, it is the ratio of two individually considered visual angles subtended at the nodal point of the eye, namely, where one of the angles, Θ', corresponds to the image viewed in the instrument, and the other, η, to the object as seen by the naked eye at the distance of distinct vision.

Hence,

$$M_s = \frac{\tan \Theta'}{\tan \eta} = \frac{i}{v}\frac{a}{o} = \frac{a}{v}\frac{i}{o}.$$

This ratio involves the so-called "distance of distinct vision," a, which, being variable among different individuals, makes it necessary to conventionally adopt 25 centimeters or 10 inches as the standard distance of distinct vision for the normal eye. However, even where allowance is made for the different distances of distinct vision among far-sighted and near-sighted observers, "Abbe has pointed out that both observers, looking through the instrument, will, as a matter of fact, view the image of the same object under the same visual angle; so that whatever difference there may be in the magnifications is to be found, not in the instrument itself, but in the different organs of sight that are employed in conjunction with the apparatus." (*Principles of Geometrical Optics,* Southall.) Therefore, as the angle subtended at the ocular nodal point by the object seen by the naked eye has nothing to do with the instrument, it is convenient to substitute its value, $\tan \eta$, by its equivalent, namely, the linear dimension, o, of the object divided by the distance, a, of distinct vision, or o/a, when the ratio for the subjective magnifying power becomes $\frac{\tan \Theta' \, a}{o}$, the product of two factors, one of which (a) depends entirely on the eye of the observer. Consequently, Abbe ignores the variable factor, a, having shown that, from a strictly scientific point of view, his equation for the *intrinsic magnifying power,*

$$M_i = \frac{\tan \Theta'}{o} = \frac{1}{f} \text{ (approximately)},$$

is far superior, since it is strictly a constant of the instrument itself. In fact, in the special case, when the plane of the exit-pupil of the optic system coincides with the secondary focal plane, and the nodal point of the eye is situated at the secondary focal point of the system, Abbe's formula is strictly true for an instrument on the order of the microscope.

Equivalent Lenses.

When two lenses are separated upon a common axis by an appreciable distance, d, a thin single lens can be found, which, when placed at a suitable fixed point, will produce an *image of the same size, but not generally in the same position*, as that produced by the combination. This lens, with a focal length f, is said to be equivalent to the combined lenses whose focal lengths are f_1 and f_2, and is expressed by the equation:

$$\frac{1}{f} = \frac{f_2 + f_1 + d}{f_1 f_2} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{d}{f_1 f_2}, \quad \ldots\ldots\ldots\ldots \text{VI.}$$

which applies when either f_1 or f_2 is negative, or when both are negative. However, in ophthalmic practice, where lenses of moderate power are superposed in the trial-frame, the distance, d, between them may be neglected, so that their equivalence is expressed by

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{VII.}$$

In other words, the equivalent lens, whose focal length is f, when placed in the position occupied by two such lenses in the trial-frame, practically produces the same convergence or divergence from the same point as that produced by the combined lenses.

Moreover, for purposes of rapid calculation, it is convenient to use the reciprocals of the focal lengths rather than the focal lengths themselves. Thus, if D is used to represent the power, 1/f, of the lens whose focal length is f, and D_1 and D_2 are the powers of the lenses whose focal lengths are f_1 and f_2, respectively, the previous equation becomes

$$D = D_1 + D_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{VIII.}$$

Therefore, it is also apparent that, if D_1 and D_2 are equal powers of very thin lenses, the one being convex $(+ D_1)$ and the other concave $(- D_2)$, the refraction will be nil, or equivalent to a plane glass. Consequently, the combined effect of D_1 and D_2 is one of neutralization.

However, this principle does not apply to lenses of widely different form or of appreciable thickness, since the power or focal length of a lens depends upon three factors, the radius of curvature, the refractive index and the thickness of the glass; hence the latter must be taken into consideration as soon as it becomes an appreciable percentage of the focal length. This will be more fully explained in the sections on *Vertex-Refraction and Neutralization.*

A pair of lenses is said to be *congeneric* when both lenses are either convex or concave, and *contra-generic* when one lens is convex and the other, concave. Thus, a pair of superposed contra-generic lenses of the same convergent and divergent power, are, within certain limits mentioned in said sections, capable of neutralizing each other; from which it follows that a convex lens, say + 2 D., will counteract the effect of a concave lens, — 2 D.

The Dioptry.

The abbreviation "D." signifies the unit of refractive power, originally in French called dioptrie and since Anglicised to dioptry. It represents the power of a lens whose focal length is one meter = 100 centimeters, or 39.37 U. S. standard inches. As the power of a lens increases, its focal length decreases, and vice versa; or in other words, the power of a lens is in inverse proportion to its focal length. Therefore, in the inch-system the power of a lens is *approximately* expressed through the fractions 1/40, 1/20, or 1/10 for a lens whose focal length is 40, 20 or 10 inches; whereas, in the metric system, for a lens whose focal length is 10, 25 or 50 centimeters, the dioptral power is expressed by 100/10 = 10 D., 100/25 = 4 D., or 100/50 = 2 D., respectively. The metric or *dioptral* system is far more convenient, since the superposition of low powered lenses so frequently resorted to in ophthalmic practice renders it easier to add their powers in dioptrics than to add fractions representing their powers in the inch-system, which, therefore, is now less frequently used. The adjective dioptral refers specifically to lenses and prisms numbered in dioptries, and is thus used in distinction to *dioptric*, a term which applies to refraction in general and without reference to any specific unit of measurement. The focal length of any dioptral lens is readily found through dividing 100 cm. or 40 inches by its given dioptral power. For instance, 100 cm. divided by 2 D. = 50 cm. focal length; or 40 in.

divided by 2 D. = 20 in. focal length. Similarly, 100 cm. divided by 0.25 D. = 400 cm.; or 40 in. divided by 0.25 D. = 160 in. focal length. On the other hand, the power of a lens whose focal length is given, say 50 centimeters or 20 inches, is found through dividing 100 cm. by its given focal length in centimeters, or 40 in. by its given focal length in inches; thus, 100 cm./50 cm. = 2 D., or 40 in./20 in. = 2 D.

It may be repeated that it is misleading to apply the term *"lens"* (which implies a focus) to a plane glass or to one whose curved surfaces are parallel, or the term *"diopter"* to lenses of the dioptral system. "Diopter," is not sufficiently specific, because it may be any one of several instruments used by engineers or surgeons. Therefore, the preference should be given to dioptry, which is certainly unequivocal in its meaning. Moreover, it should be remembered that all lenses, no matter which system of numbering is used, have dioptric (refractive) power, whereas, those of the metric system have specifically *dioptral* power.

As a spheric surface may be thought to be generated through rotation of a circular curve upon its radius, which axis of revolution for a lens is the optic axis, the refraction of a spheric lens is uniformly the same in every *principal section*—a plane in any meridian containing the axis. However, this refraction depends upon the refractive powers contributed by the two opposite surfaces of the lens, and which are often separately considered in the construction of ophthalmic lenses. For instance, in a thin meniscus having a + 3 D. spheric surface on one side, and a − 1.25 D. spheric surface on the other, the total refraction is + 1.75 D. Commercial periscopic lenses are uniformly made with one concave surface, − 1.25 D.; whereas, deep menisci and contramenisci are usually, − 6 D., and, in special instances, − 9 D. The former uniformity facilitates the addition of reading segments from stock for bifocal lenses.

In any event, the power of a thin lens is equal to the algebraic sum of the refractive powers of its opposite surfaces.

Landolt's table, in which the dioptral and the inch systems are compared, is here given.

INCH-SYSTEM AND DIOPTRAL EQUIVALENTS.

Computed by E. Landolt.

OLD SYSTEM.				NEW SYSTEM.			
I. Number of the Lens, Old System.	II. f = Focal Distance in Engl. in. for n = 1.53.	III. f = Focal Distance in Millimeters.	IV. D. Equivalent in Dioptries.	V. Number of the Lens, New System.	VI. f = Focal Distance in Millimeters.	VII. f = Focal Distance in Engl. inches.	VIII. Corresponding Number of the Old System.
72	67.9	1724	0.58	0.25	4000	157.48	166.94
60	56.6	1437	0.695	0.5	2000	78.74	83.46
48	45.3	1150	0.87	0.75	1333	52.5	55.63
42	39.6	1005	0.99	1	1000	39.37	41.73
36	34	863	1.16	1.25	800	31.5	33.39
30	28.3	718	1.39	1.5	666	26.22	27.79
24	22.6	574	1.74	1.75	571	22.48	23.83
20	18.8	477	2.09	2	500	19.69	20.87
18	17	431	2.31	2.25	444	17.48	18.53
16	15	381	2.6	2.5	400	15.75	16.69
15	14.1	358	2.79	3	333	13.17	13.9
14	13.2	335	2.98	3.5	286	11.26	11.94
13	12.2	312	3.20	4	250	9.84	10.43
12	11.3	287	3.48	4.5	222	8.74	9.26
11	10.3	261	3.82	5	200	7.87	8.35
10	9.4	239	4.18	5.5	182	7.16	7.6
9	8.5	216	4.63	6	166	6.54	6.93
8	7.5	190	5.25	7	143	5.63	5.97
7	6.6	167	5.96	8	125	4.92	5.22
6½	6.13	155	6.42	9	111	4.37	4.63
6	5.6	142	7	10	100	3.94	4.17
5½	5.2	132	7.57	11	91	3.58	3.8
5	4.7	119	8.4	12	83	3.27	3.46
4½	4.2	106	9.4	13	77	3.03	3.21
4	3.8	96	10.4	14	71	2.8	2.96
3½	3.3	84	11.9	15	67	2.64	2.8
3¼	3.1	79	12.7	16	62	2.44	2.59
3	2.8	71	14	17	59	2.32	2.46
2¾	2.6	66	15.1	18	55	2.17	2.29
2½	2.36	60	16.7	20	50	1.97	2.09
2¼	2.1	53	18.7				
2	1.88	48	20.94				

Vertex-Refraction.

The need for a fixed point of orientation from which to measure the focal length of a lens of any form placed before the eye was first recognized by Dr. Moritz von Rohr, physicist, of the firm of Carl Zeiss, Jena, Germany, who suggested that it shall be the pole or vertex of the lens-surface facing the cornea; this being in precise agreement with the measurement of prisms suggested by the writer in 1890. In other words, the reciprocal of the distance between the vertex of this surface and the true focus of the lens shall represent its power or so-called vertex-refraction, designated by the symbol D_v. In fact, through such means only is it possible to accurately substitute a deeply curved lens for one of plano or equibispheric form, the increasing popularity of the former having encouraged Dr. von Rohr's investigations with this purpose in view. To the Bausch & Lomb Optical Co. is due the credit for having introduced the vertex system in America.

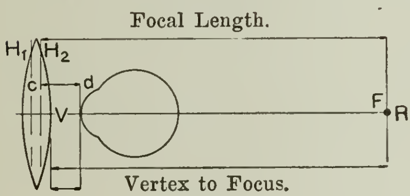


Fig. 16.

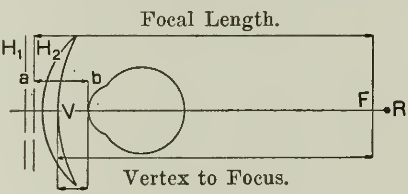


Fig. 17.

In the accompanying figures, 16 and 17, a biconvex lens and a meniscus of equal focal lengths are placed at the same interpolar distance from the eye, but, owing to the second principal plane, H_2, of the meniscus being farther (ab) from the cornea than that (cd) of the biconvex lens, the focal point, F, of the meniscus is correspondingly nearer than the *punctum remotum*, R, of the eye, which demonstrates that the meniscus will require to have a greater focal length, if its focus is to coincide with the ocular far point. Otherwise, as shown in the diagrams, the meniscus of the same focal length over-corrects the hyperopia.

This clearly shows that lenses of the same refractive power are not interchangeable as ophthalmic corrections when they are of materially different forms. In fact, this is especially true when the power exceeds 3.5 dioptries.

Since the positions of the principal points, with respect to the lens itself, are dependent upon both the form and the thickness of the lens, it follows that its focal length is dependent upon two variables unknown to and neglected by the practitioner who measures ocular refraction.

Up to within a comparatively short time the refractive power of the lens and its distance from the eye have constituted the only data thought to be of moment in such practice, and which, indeed, is still true, provided the focal length of the lens is measured from the vertex of the lens proximate to the eye, instead of from the ever shifting principal points. See end of section on *Cardinal Points of a Lens.* In other words, when the vertex-refraction is substituted for the refractive power, the form and thickness may still be practically ignored, so long as means are provided to measure the vertex-refraction and the distance between the pole of the lens and the cornea.

By vertex-refraction is meant the reciprocal of the distance between the vertex of the lens and its focus, this distance for an equibiconvex (or biconcave) lens, being about ⅓ of the lens-thickness shorter (or longer) than the true focal length; that is to say, the vertex-refraction is correspondingly greater for the convex lens, Fig. 16, than its refractive power. But, as the thickness of ophthalmic lenses below 7D. is a negligible dimension, there is practically not any difference between the refractive power and the vertex-refraction, so that the latter's practical utility is really confined to biconvex lenses of greater power than 7 dioptries and to the thin menisci and contramenisci above 3.5 dioptries.

It is only above these powers, respectively, that the displaced principal points produce a material difference between vertex-refraction and refractive power.

The following tabulation, determined through the subscribed formulæ, sufficiently shows to what extent a difference in the thickness of bispheric lenses affects these values.

COMPARATIVE VALUES OF REFRACTING POWER AND VERTEX-REFRACTION IN STRONG LENSES.

	Ref'g Power in Diop-tries.	Vertex-Ref'n in Diop-tries.		Neg'ble Differences in Vertex-Ref'n.
1. Equiconcave Lens, 10 D. surfaces, 0.6 mm. thick........	— 20.04	— 19.96	No thickness, — 20 D.	0.04 diop.
2. Equiconvex Lens, 10 D. surfaces, 7.8 mm. thick........	+ 19.48	+ 20.55	Don't neutralize — 20 D.	
3. Biconvex Lens, unequal surfaces, 7.8 mm. thick........	+ 18.98	+ 19.96	from 9.47 D. surface	0.04 diop.
whose surfaces are indicated in column 3..........	+ 18.98	+ 20.02	from 10 D. surface	0.02 diop.

The surfaces of the lens, 3, have been thus chosen in order that its refractive power, + 18.98, shall neutralize with — 20.04 when the 10 D. surfaces of both lenses are in contact. The vertex-refraction of the lenses, 1 and 3, whose refractive powers neutralize with 20.04, are both practically 20 dioptries in vertex-refraction, since hundredths of a dioptry in the last column are negligible values.

Here it is shown that increased thickness of the convex lenses, while reducing the refractive powers, correspondingly increases their vertex-refractions. The reverse is true of the concave lens. Incidentally, when a meniscus exceeds 4.25 D. it is thicker than a biconvex lens of the same power, but if it is a Punktal lens it is proportionately even still thicker among all powers. This lens is described in the section on *Wide-Aperture Lenses.*

When the thickness of a lens exceeds 0.001 of the focal length, it is no longer permissible to compute its power by adding the refractive powers of its surfaces, so that it becomes necessary to incorporate its thickness in the formula:

$$D = D_1 + D_2 - D_1 D_2 \frac{t}{n}, \ldots\ldots\ldots\ldots\ldots\ldots \text{IX.}$$

in which D is the dioptral power of the lens, D_1 and D_2, the powers of its surfaces, t, the thickness, and n, the refractive index of the glass.

The vertex-refraction (D_v) is obtained through the equation:

$$D_v = D.\frac{1}{1 - D_1 \frac{t}{n}}, \quad \ldots\ldots\ldots\ldots\ldots\ldots X.$$

when the surface corresponding to D_1 is remote from the eye. In case the other side of the lens is to occupy this position, the numeric value of D_2 is therein to be substituted for D_1.

Through these formulæ it may be easily shown that the thickness and the distance between two or more superposed lenses have considerable influence upon the refractive power and the vertex-refraction, so that it is also inaccurate to ignore the distance between lenses in the trial-frame as is commonly done, especially if the lenses are of appreciable power. In fact, it is absolutely necessary that the prescribed ophthalmic lens shall have the same vertex-refraction as the lenses combined in the trial-frame. As the disclosures which may be made through these formulæ are of special interest, the first one is here

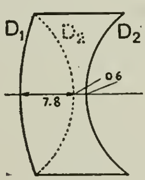


Fig. 18.

Focal length, convex lens.

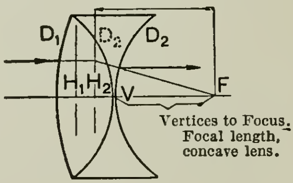


Fig. 19.

applied to determine the refraction of a spherically curved medium, Fig. 18, 8.4 mm. thick, having a concave surface, D_2, corresponding to 10 dioptries of refraction. The refractive index of the glass is 1.507. Now, let it be desired to know what curvature shall be given to the surface, D_1, in order that the refractive power of this medium shall be *nil.* In this instance,

$$D = 0,\ D_2 = -10, \text{ and } \frac{t}{n} = \frac{0.0084}{1.507} = 0.005573 \text{ meters},$$

$$\text{wherefore, } 0 = D_1 - 10 + D_1 \times 0.05573.$$

$$D = 9.472,$$

the refraction of the first surface of the medium, and which, being less than $D_2 = 10$, demonstrates that the surfaces are not parallel, but actually bound a *contrameniscus without power,* its thickness being

8.4 mm. In order to make this apparent, the curvatures of D_1 and D_2 have been drawn disproportionate to each other. Furthermore, it is quite evident that this absence of refractive power will not be affected if, for convenience of further illustration, a spheric surface of 10 dioptries, corresponding to the dotted line in Fig. 18, is interpolated so as to virtually constitute two contiguous lenses of the thickness, 7.8 mm. and 0.6 mm., respectively. The power, D, of the convex lens thus constituted, when freed in the air, is therefore,

$$D = D_1 + D_2 - D_1 D_2 \frac{t}{n}, \text{ in which case } \frac{t}{n} = \frac{0.0078}{1.507} = 0.0051758.$$

$$D = 9.472 + 10 - 94.72 \times 0.0051758 = 19.472 - 0.4902.$$

$$\therefore D = 18.982,$$

which is the refractive power of the convex lens. The power of the concave lens, 0.6 mm. thick, having 10-dioptry surfaces is similarly obtained through giving the negative sign to the surfaces, D_1 and D_2, so that $-D = -20.04$ is the power which neutralizes $+18.982$, the power of the contiguous convex lens.

As the surfaces of this convex lens are of different powers, it is necessary, in determining its vertex-refraction, to apply the formula, X to each side of the lens, since it will depend upon which side of the lens is to be proximate to the eye. Hence, if the weaker side, 9.472, is placed near the eye, and which would be the case with a lens of this form, the stronger side, 10, is to be substituted for D_1 in the formula:

$$D_v = D \frac{1}{1 - D_1 \frac{t}{n}}, \text{ and since } \frac{t}{n} = 0.0051758,$$

$$D_v = 18.982 \frac{1}{1 - 10 \times 0.0051758} = \frac{18.982}{0.94824}.$$

$$\therefore D_v = 20.02, \text{ or practically } 20\ D_v.$$

Similarly, if the stronger side of the convex lens is proximate to the eye, then 9.472 is the front surface, D_1, so that the vertex-refraction is found to be

$$D_v = \frac{18.982}{0.9509}$$

$$\therefore D_v = 19.962,$$

therefore, also practically 20 D_v., and which is the highest lens-power used in ophthalmic practice.

This conclusively proves that:

Two superposed contra-generic lenses of minimum thickness, having two surfaces in absolute contact and whose dioptral powers effectually neutralize each other, have the same vertex-refraction, even though their refractive powers are actually and unavoidably different.

Conversely, two contra-generic lenses of least thickness and of the same vertex-refraction, whose surfaces are brought into absolute contact, neutralize each other's unequal refractive powers.

Surprising as this may prove to be, it also demonstrates that the vertex-system does not defeat the advantages of the principle advocated by the author and adopted twenty years ago by all but one of the leading lens manufacturers in America, namely, that the stronger biconvex lenses shall be made weaker than standard biconcave lenses of least polar thickness, in order to extend neutralization to all accurately contiguous bispheric lenses, and whose vertex-refractions, for this very reason, are now found to be the same as the dioptral numbers they conventionally bear, and which may be readily verified through measurement by the vertex-dioptrometer made by the Bausch & Lomb Optical Co. Of course, it is to be understood that, among convex lenses of high power their surfaces shall so differ that the stronger side may be brought into effectual contact with the standard concave lens of minimum thickness.

Quite apart from this demonstration, in which provision is actually made for a concave lens-thickness of 0.6 mm., it is self-evident that, if the concave lens, Fig. 19, is made infinitely thin and the closely fitted contiguous lenses of different powers neutralize each other, their focal points must be in the same place, while their vertices likewise coincide. Therefore, the distances between the vertices and the focus are practically equal, so that the vertex-refraction is the same for each lens. It is, of course, to be understood that the aforesaid law applies only to ophthalmic lenses whose surfaces are in close contact and whose apertures are comparatively small. American lens manufacturers have in the past assumed quite different attitudes with respect to the numbering of their biconvex lenses ranging between 7 and 20 dioptries; one optical company having ignored in them the admissibility of neutralization, the other companies having jointly conceded and attempted to provide for it, so that the actual powers of such biconvex lenses have not been uniformly the same for all lenses bearing the same number. This discrepancy has for years been a source of misconception and inconvenience to most opticians, but, fortunately, will no longer exist after the vertex system becomes the standard of comparison to be verified by the vertex dioptrometer.

For instance, it is well known that a + 20 D. biconvex lens of appreciable thickness can not be neutralized by — 20 D., even though each lens actually measures 20 D. upon the optical bench, or an equivalent instrument. See lens, 2, in the preceding tabulation. On the other hand, if the principle of neutralization, for a refractive index of 1.507, is made to apply to a bispheric lens of the therein indicated curvatures and power, a standard biconcave lens (0.6 mm. thick) of — 20.04 D. will be neutralized by a + 18.98 D. biconvex lens (7.8 mm. thick), which, being conventionally numbered + 20 D., will now by the instrument actually measure + 19.96 D_v. and, therefore, practically + 20 D_v. Hence, the + 18.98 D. lens, which neutralizes the — 20.04 D. lens also has, within the negligible error of 4/100ths of a dioptry, the same vertex-refraction, 20 D_v. In short, the dioptral values of all lenses made by manufacturers who originally adopted the author's suggestion, within the limitations herein set forth, are at present actually the equivalents of vertex-refraction.

In fact, the trial-sets made by one of the American manufacturing companies are claimed for this reason to have been numbered, during the past twenty years, to signify either dioptries or vertex-refraction, though the latter was, of course, not to have been anticipated, since Dr. von Rohr has only recently and probably quite unconsciously proven the wisdom of the author's original suggestion. Let it be well understood that there is not any difference between dioptries and vertex-refraction when they are applied exclusively to biconvex and biconcave lenses of really *negligible thickness, or to convex lenses, regardless of power, that are effectually neutralized through actual contact with concave lenses of least thickness,* and only in case they do not thus neutralize is there any discoverable difference in these values among *biconvex lenses* stronger than 7 D. Therefore, in any case where effectual neutralization is in doubt, the vertex-refraction is to be determined by means of the vertex-dioptrometer. In fact, this instrument may be relied upon to secure absolute precision with respect to the measurement and duplication of any lens or combination of lenses in the trial-frame, in terms of vertex-refraction. Moreover, this system of measurement supplies a long felt need in making it possible to more accurately substitute the menisci and contramenisci for lenses of the flatter types or their combinations, besides obviating recourse to neutralization among deeply curved lenses, and which never did apply to them with any reliable degree of accuracy.

Should these lenses eventually take the place of all other ophthalmic lenses, excepting those in the trial-set, then certainly will vertex-refraction, the vertex-dioptrometer and the instrument for measuring the distance between the poles of the cornea and trial-lens constitute absolutely indispensable accessories to ophthalmic practice. However, in the interim the progressive practitioner will recognize the desirability of having his trial-lenses rated in vertex-refraction, provided they do not accurately neutralize each other throughout the entire range of their powers, and of using a trial-frame in which the distance between the cells is reduced to a minimum, so as to secure the true vertex-refraction of superposed spheric and cylindric lenses when they are to be substituted by menisci or contramenisci. In order to avoid the influence of thickness it is now proposed to materially reduce the diameter of our trial-lenses, which are to be numbered in vertex-refraction and made flat on one side so as to minimize the extent of their separation in the trial-frame. With this change, the principle of neutralization will, of course, all the more readily apply among all powers of paired contra-generic trial-lenses whose curved surfaces may be effectually brought into contact.

The facts disclosed in this discussion justify the conclusion that, from a strictly practical point of view the vertex-system is a reliable monitor to insure the righteous performance of convex lenses, especially those which are stronger than 7 dioptries, and a subtle guide to the correct substitution of a deeply curved lens, either spheric or toric, for any lens or combination of lenses that may be mounted in the trial-frame at a definite distance from the eye.

While it is true that the vertex-system of measurement and the method of neutralization are equally inefficient with respect to disclosing the *true refracting power* of a strong convex lens, yet the present practice of neutralization may be perpetuated as an eminently convenient means of verifying the fact that:

When two bispheric contra-generic lenses in close *surface-contact*, of any power and of minimum thickness, effectually neutralize each other, they are of the same vertex-refraction.

Neutralization.

The thickness of a lens whose power is not restricted can only be considered a negligible dimension in a *standard concave lens* of minimum thickness, since all concave lenses between 0.25 D. and 20 D. can be made of the same infinite thinness in the center. In convex lenses, however, there is an unavoidable increase in thickness, which becomes of sufficient magnitude in lenses above 7 D. to conflict with the assumption of negligible thickness. This was explained in the preceding section, though it will here be discussed from a somewhat different view-point.

When the element of thickness is considered, we have the formula for bispheric lenses of equal curvatures:

$$r = f(n-1) + \sqrt{\frac{(nf-t)\,f(n-1)^2}{n}}, \quad \ldots\ldots\ldots \text{XI.}$$

wherein r is the radius of curvature, n, the index of refraction, f, the focal length, and t, the thickness, in contra-distinction to the formula for neglected thickness, wherein $r = 2f(n-1)$ ....XII.

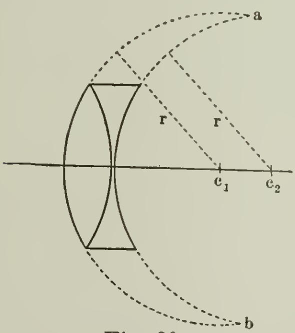


Fig. 20.

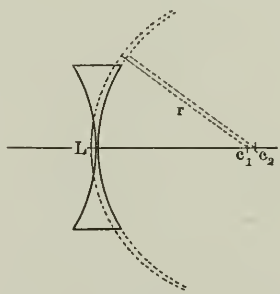


Fig. 21.

Therefore, it is evident that the radius of curvature will be a different one for equibiconvex lenses, in which thickness is considered, from that of biconcave lenses, of the same power, having no appreciable thickness.

The accompanying diagram, Fig. 20, representing a biconvex lens in contact with a biconcave lens of *identical* curvatures, clearly shows that they can not optically neutralize each other, as they really constitute only the central portion of a much larger periscopic *convex* lens or meniscus, and which our imagination can construct upon the dotted lines that are continued to their intersections at a and b.

The diagram also shows that the power of the imaginary meniscus must *increase* with an increase in the thickness of the biconvex lens, because the anterior and posterior surfaces of the meniscus will be rendered more oblique to each other as their respective centers of curvature, c_1 and c_2, are separated to provide for an increased thickness. The nearest approach to neutralization will, therefore, be secured when the centers of curvature, c_1 and c_2, are as close together as possible, thus making the biconvex lens, L, exceedingly small and thin, as shown in Fig. 21.

However, the lenses in our trial-cases are too large to secure even this *approximate* neutralization. Their diameter of necessity determines the thickness, which must increase with the power. For instance, in a 20 D. equibiconvex trial-case lens of 3.5 centimeters diameter we find the minimum thickness to be 0.75 centimeters. If, therefore, in formula XI, we place, $t = 0.75$, $n = 1.5$, and $f = 5$

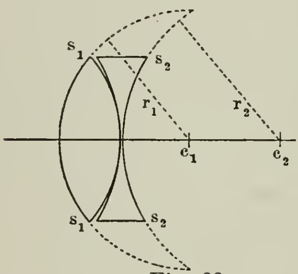


Fig. 22.

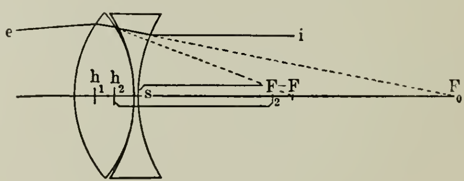


Fig. 23.

centimeters, we obtain 4.87 centimeters as the value of r; whereas, for a 20 D. concave lens, according to formula XII, we find $r = 5$ centimeters.

As the radius is shorter for the convex lens than for the concave lens of the same power, it is evident that their surfaces will actually touch each other only in the center, as exaggeratedly shown in Fig. 22.

Besides, the outer surface, s_1s_1, of the convex lens will be even more oblique relatively to the outer one, s_2s_2, of the concave lens, so that these lenses actually form the center of a stronger convex meniscus than is shown in Fig. 20. Or, viewing it in another light: Parallel rays, i, in Fig. 23, that are incident to the concave lens, are refracted by it as if emanating from the virtual focal point, F, of the concave lens, which is outside of the focal point, F_2, of the convex lens. Such rays, e, will therefore be rendered convergent, instead of parallel, in passing out of the convex lens, showing that neutralization does not exist.

The focal distance, sF, of the concave lens, one therefore capable of being made infinitely thin, is counted from a single point, s, on the optic axis in the center of the lens; whereas, in convex lenses of appreciable thickness, it is counted from the *posterior principal point*, h_2, within the lens. In a biconvex lens of equal curvatures, made of glass with an index of refraction $n = 1.5$, it has been demonstrated that the principal points, h_1 and h_2, are separated by a distance equal to one-third of the lens-thickness. (Müller-Pouillet's *Lehrbuch der Physik*, page 160, Braunschweig, 1894.) Therefore, it is obvious that the focal distance of the convex lens will have to be increased by at least one-third of the lens-thickness, so as to have F_2 and F *coincide* for the purpose of effecting neutralization.

With a minimum thickness equal to 0.75 cm., we must consequently add 0.25 to the focal distance, 5, making 5.25 cm. the focal distance of the convex lens. This corresponds to a refraction of 19.047 dioptries. Consequently, *a 19.047 equibiconvex lens of 0.75 cm. thickness neutralizes a 20 D. concave lens of infinite thinness.* To be more accurate, we should actually allow for 0.06 cm. thickness of the concave lens. This would result in the convex lens being even somewhat weaker than 19.047 dioptries.

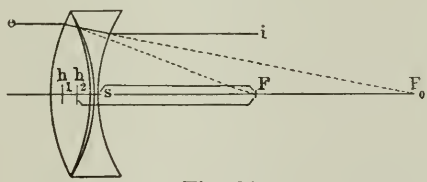


Fig. 24.

However, according to formula XI, a 19.047 D. equibiconvex lens of 0.75 cm. thickness should have a radius $r = 5.121$ cm., so that the superposed neutralizing lenses would actually touch each other at their edges, instead of at the center, as exaggeratedly shown in Fig. 24.

Furthermore, any additional increase in the thickness of the convex lens will be associated with an increase in the distance, h_2F, and will, therefore, call for a corresponding decrease in the power of the convex lens to produce neutralization.

Thus, the tendency will invariably be to over-estimate the power of the convex lens, when an effort is made to determine its power by that of the concave lens which neutralizes it.

Calculation shows that the discrepancies in neutralization of lenses of this kind, varying between 0.25 D. and 1 D., exist in the entire series of convex lenses between 7 D. and 20 D. Consequently, it also follows that the indiscriminate superposition of lenses, so frequently practised during the subjective method of examination of ocular refraction, is not permissible with lenses of high power.

In other words, lenses of high power are no more capable of being algebraically combined than prisms of high power; a supposed fault for which the practicability of the prism-dioptry was so severely criticized without heed of the injunction that, the desire to multiply any *unit in optics* should be curbed by a knowledge of the fact that all the fundamental optical laws are based upon the assumption and acceptance of *values of limited magnitude,* and that there is, therefore, apt to be a point where *unreasonable* multiplication of an optical unit will contradict the actually existing optical phenomenon.

The general, though erroneous, belief that the entire series of corresponding contra-generic lenses of equal power should neutralize each other has gained such general credence that lens manufacturers have allowed themselves to be swayed by this popular opinion, and

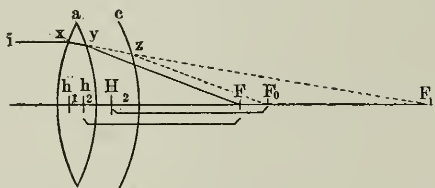


Fig. 25.

as a result have justifiably adopted the principle of making the strong convex lenses weaker than the standard concave lenses, so as to meet the demand for neutralization, and which, under stipulated conditions mentioned later, conforms to the vertex-system of measurement. As has been shown, a 20 D. equibiconvex lens should have a shorter radius than a concave one of the *same* power, yet examination of many of the older trial-cases will reveal the fact that such is not the case, when the surfaces are measured by a suitable gauge. We can, however, gain no reliable information regarding the power of a *strong* convex lens through measurement of its surfaces by means of the spherometer or modern lens-measure, since two lenses of the same curvature, but of different thickness, will not be of the same power. As the thickness increases, the power will diminish for one and the same curvature. This is shown in Fig. 25.

The so-called lens-measure is indeed practicable *only for concave* lenses, since they alone are of negligible thickness, but for thick convex lenses above 7 dioptries this instrument is absolutely unreliable; nor can it be used on any other lenses than those having a refractive index of 1.5.

The incident ray, i, Fig. 25, is refracted by the anterior surface, ab, of the lens in the direction xF_1, and by the posterior surface at y to the focus, F. If the thickness be increased, so as to place the posterior surface at cd, then xF_1 will be refracted by the posterior surface at z to F_0, parallel to yF, since the surface, cd, is of the same radius as ab.

The focal distance, H_2F_0, of the thicker lens, is not appreciably different from h_2F of the thinner lens; in fact, the difference between these distances scarcely amounts to 0.05 cm., for a curvature of 5 cm., in lenses of 0.75 cm. or 1 cm. thickness. Nevertheless, such a difference would be appreciated by the eye in neutralizing the lenses.

This investigation, originally made in 1895, led the author to suggest that all biconvex lenses shall be made weak enough to neutralize with corresponding concave lenses of standard minimum thickness, even though this caused the weaker convex lenses to be numbered higher than their actual dioptral powers, which are, of course, the reciprocals of the distances between the principal points of the lenses and their focal points. However, with the recent introduction of the vertex-system, which substitutes the vertex of the lens for its principal point, the actual dioptral power of the convex lens is equally weaker and similarly ignored, with the fortunate result that the author's suggested weaker convex neutralizing lens is the one whose power is expressed in vertex-dioptries, provided that the biconvex lenses among the higher powers have such unequal curvatures of their surfaces as to permit one of the latter to be brought into close contact with the corresponding surface of the neutralizing equibiconcave lens. In fact, this principle is claimed to have been applied by one of the optical companies in this country. See section on *Vertex-Refraction*.

When convex lenses stronger than 7 dioptries are prescribed, and they are measured by neutralization with concave lenses, we should simply remember that the actual dioptral powers of the stronger convex lenses are always weaker than the dioptral powers indicated by the numbers upon the concave lenses.

On the other hand, if the numbers are intended by the makers to indicate that corresponding contra-generic lenses in the trial-case neutralize each other by actual contact of, at least one pair of, their surfaces, then the numbers also signify vertex refraction.

Prisms.

As the convergence or divergence of light produced by a lens necessarily involves variable degrees of deviation, we shall first consider the simple deviation produced by a prism, which is the inheritent deviating element at each point of curvature of any lens. In fact, every principal section of a lens may be considered to be composed of prisms whose angles vary at successive points of curvature of its surface, or in other words, every meridian of a lens, between its center and its edge, consists of a pyramidal aggregation of prisms,

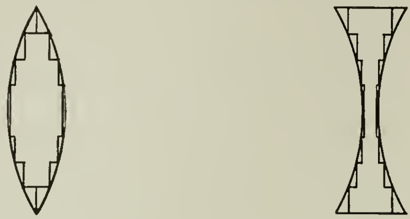


Fig. 26. Fig. 27.

Fig. 26 and Fig. 27, which vary in angle, and consequently in deviating power, at each succeeding point upon the line of surface-curvature, and at which point a single ray of light is deviated from its incident direction. This deviation or refraction occurs whenever a ray ot light is obliquely incident to a transparent medium, or passes through one whose opposite sides embrace an angle.

Therefore, the prism is the simplest form that can be given to a medium which will positively insure the necessary oblique incidence

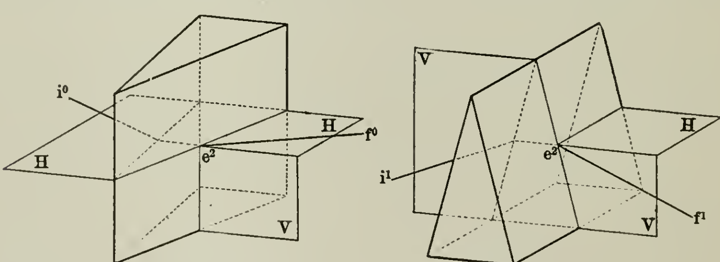


Fig. 28. Fig. 29.

to produce angular deviation of a refracted ray of light. In fact, any refracting medium included between two plane surfaces that embrace an angle between them is called a prism, and the line where the two surfaces meet, or would meet, if produced to form the refracting angle or *apex-angle,* is called the edge. The base is the side opposite to this apical angle. The refracted ray always lies in the same plane with the incident ray. Hence, the incident ray, i, and refracted ray, f, are shown in the horizontal plane, H, Fig. 28, and in the vertical plane, V, Fig. 29; each of these planes being coincident with the principal section in which the greatest refraction is produced.

All principal sections of the prism are equal in every respect and parallel, and a line connecting the base with the apex in a principal section is called the *base-apex line.*

These figures illustrate that the refraction is strictly confined to the plane whose intersection with the medium defines the obliquity of

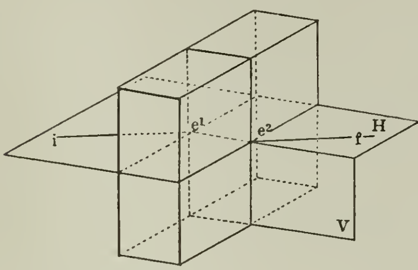


Fig. 30.

its surfaces; whereas, in the right-angled coordinate plane the refraction is passive or nil, because the direction of the ray remains unchanged in passing through opposite parallel surfaces, even though an obliquely incident ray, i, is deviated within a plate, Fig. 30, and from whence it again emerges as a refracted ray, f, parallel to the incident ray.

It is evident that the refraction is active in one and passive in the other plane for a medium whose surfaces are oblique in but *one* plane,

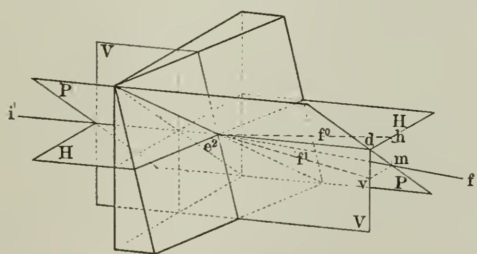


Fig. 31.

so that, to obtain the refraction active in both fixed planes, an obliquity of the surfaces relative to each plane is necessary. In such a medium, Fig. 31, if the refraction is considered merely with regard to the horizontal obliquity of the surface, the refracted ray will assume the direction e_2h, and, if it is considered independently for the vertical obliquity, the refracted ray will assume the direction e_2v. Therefore, with due regard to the obliquity in both planes, the refraction must include both properties of deflection and result in a refracted ray, f, which is directed to a point, m, defined by projection of the apportioned horizontal and vertical displacements, dh and dv. As this is a prism whose base is really set diagonally to the fixed right-angled coordinate system, the ray, f, must naturally be refracted in the direction of the greatest distance apart of the surfaces, through the point, m, within the diagonally bisecting or oblique plane, P. Consequently, the deviating power of the prism is proportional to the line, dm, which is the hypothenuse of the triangle formed by the forces, dh and dv; hence the equation:

$$dm = \sqrt{(dh)^2 + (dv)^2}.$$

When light passes through a prism that is more dense than air, its emergent pencil at e_2, Fig. 32, is always deviated from the direction of incidence at e_1, toward the base of the prism, while the deviation, δ, also increases with the apical angle. In other words, the axis of the emergent pencil will either really (as in diagrams a and b) or virtually (as in c and d) intersect the plane of the base. In fact,

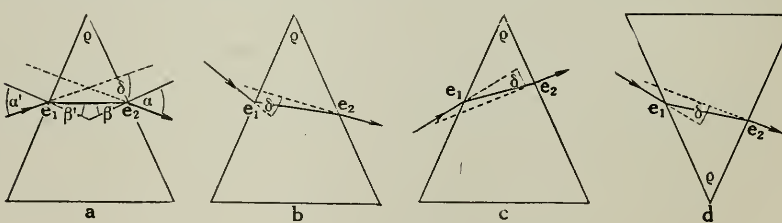


Fig. 32.

the direction of the final deviation, with respect to the base of a prism of any material, depends upon whether the refractive index is greater or less than unity. Thus, for instance, in a very thin prism of gold, whose refractive index is 0.58, the deviation is away from the plane of the base. Therefore, with respect to the transmission of light, gold is less dense than air. The total deviation, δ, is equal to the sum of the angles of incidence, α', and emergence, α, less the refracting angle, ς, of the prism. Hence, in Fig. 32 (a), $\delta = \alpha' + \alpha - \varsigma$; also $\varsigma = \beta' + \beta$, $\sin \alpha' = n \sin \beta'$ and $\sin \alpha = n \sin \beta$, the two latter equations expressing Snell's law of refraction through the refractive index, n. The relation existing between the angle of incidence, α', the angle of emergence, α, the refracting angle, ς, and the refractive index, n, of a prism is expressed by the equation:

$$\sin \alpha = \sin \varsigma \sqrt{n - \sin^2 \alpha'} - \cos \varsigma \sin \alpha',$$

so that the value of any of these factors may be determined when at least three of them are known.

Therefore, the produced deviation, δ, is dependent upon three factors, namely, the angle of incidence, the index of refraction and the angle of the prism, and, as both the index and the angle are constants for any given prism, the deviation may be rendered variable through merely increasing or decreasing the angle of incidence. Consequently, there is a position of the prism, with respect to the incident ray, which will produce the *least* deviation, the so-called *minimum deviation.* In order that a ray shall suffer minimum deviation, the angle of incidence, α', and the angle of emergence, α, must be equal; wherefore, the ray within the prism is also equally inclined to the two faces, Fig. 33; that is to say, the prism must be symmetrically placed with respect to both the incident and the emergent ray.

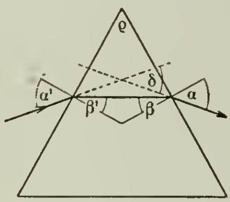


Fig. 33.

When the refracting angle, ς, of a prism is known, and the minimum deviation, δ, has been determined by means of a spectrometer, the refractive index, n, of the substance composing the prism may be calculated by means of the equation:

$$n = \frac{\sin 1/2\ (\delta + \varsigma)}{\sin \varsigma/2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{XIII.}$$

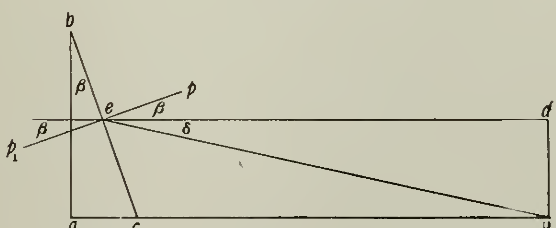


Fig. 34.

In case the incident ray is perpendicular to the front face of the prism, the refracting angle, ς, becomes equal to β, Fig. 34, so that the equation is simplified to:

$$n = \frac{\sin(\delta + \beta)}{\sin \beta}$$ and may be given the form:

$$\tan \beta = \frac{\sin \delta}{n - \cos \delta}, \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{XIV.}$$

when it is desired to determine the angle of the prism for any known value of the angle of deviation. If the refracting angle, ς, of a prism is very small, and the prism is placed in the position of minimum deviation, Fig. 33, then $\delta = (n - 1)\varsigma$. In other words, when $n = 1.5$, $\delta = \varsigma/2$.

However, this useful equation is frequently misapplied in ophthalmic literature, through neglect of its restrictions, and even though the deviation produced by a weak prism is about one-half of the apical angle for a prism that is *not exactly* exposed to minimum deviation, the equation is not applicable to *oblique* incident pencils of light. Ophthalmic prisms were originally numbered by the values of their refracting angles in degrees, and Dr. Edward Jackson was the first ophthalmologist to suggest that prisms should be designated according to their minimum deviation. However, as this would have entailed a very tedious and difficult method of measurement, by means of an expensive instrument, the spectrometer, requiring a degree of accuracy in manipulation and a knowledge in the reading of verniers with which opticians could not readily be made familiar, the writer, in 1890, suggested a novel nomenclature, based upon the tangent-deflection, dv, of 1 centimeter at the distance of one meter from the prism, Fig. 34, and which was subsequently adopted by the Ophthalmological Section of the American Medical Association in 1891. It seemed desirable to designate prisms according to their refractive powers, in order to bring them into harmony with the lenses used in ophthalmic practice; in fact, both lenses and prisms are now known by the work they perform, regardless of the refractive index and dimensions of the material used in their production. Therefore, the prism which produces a tangent-deflection of 1 cm. at one meter's distance was chosen as the unit of prismatic power.

In Fig. 35, for convenience of comparison, two overlapping principal sections of the prisms, ABC and abc, are shown with a common point of refraction at c. The prism, abc, by itself, produces a deflection, $dv = \delta$, in the meter-plane, PP_1; whereas, the prism, ABC, produces the same unit-deflection, $d_1v_1 = dv = \delta$, at one-half the distance, ½ meter, and therefore effects twice the unit-deflection at the meter-plane, PP_1, *provided the incident rays of light are parallel.* Hence, the deflection produced by the refractive power is in inverse proportion to the distance at which the unit-deflection is produced, being fully in harmony with the refraction of a lens, which is in inverse proportion to the distance at which its image is formed. Thus, prisms, that effect say, two, three, or four times the unit-deflection in the meter-plane, will produce the same unit-deflection at one-half, one-third, or one-quarter of a meter, respectively. As prismatic refraction is a basic and inseparable part of lenticular refraction, the characteristic form and dimensions of the medium producing the former may be utterly ignored, so that it is merely necessary to specify the extent

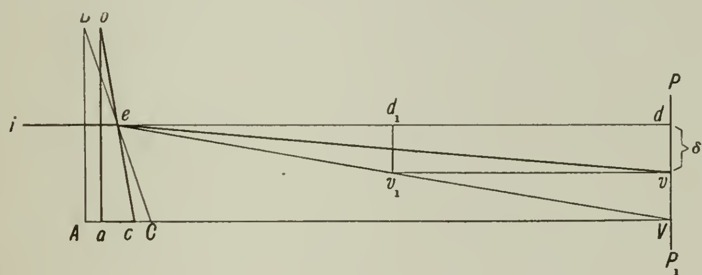


Fig. 35.

of the produced prismatic power. Regardless of the exceptions to be mentioned later, when the incident light proceeds from infinity, each ray that is incident upon the surface of a one-dioptry lens, one centimeter from its optic center, suffers the same centimeter-deflection toward its focus in the focal plane as that produced by the prismatic unit in the tangent-plane at the focal distance of the lens, one meter.

The Prism-Dioptry.

As prisms notably possess the property of apparently changing the position of objects seen through them, it was proposed in the new system that the apparent distance between the object and its *virtual* image, measured in a plane at right angles to the line of vision, should form the basis of comparison between the relative strengths of prisms. The tangent-deflection of one centimeter, *figuratively* located in a plane one meter from the prism, was, therefore, arbitrarily though befittingly chosen as the new unit of prismatic power, and was named the prism-dioptry. Moreover, as this *theoretic* tangent-deflection is based upon the assumption that *parallel* incident rays are to proceed from the object, it is necessary in practice to place the tangent-plane at a distance of 6 meters, and to correspondingly increase the unit-deflection to 6 centimeters, when estimating the deviation produced by a prism while sighting through it at a suitable scale of equal parts, the primometric scale. Therefore, in practice the *virtual* deflection is indirectly ascertained, through projection outward of the object's

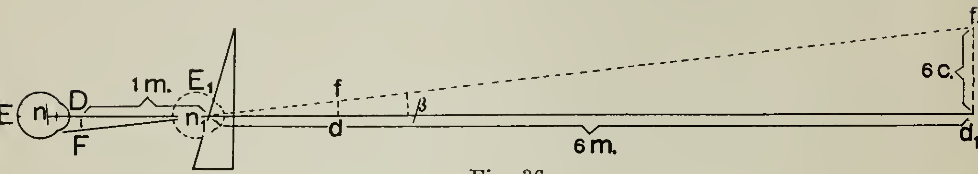


Fig. 36.

image within the eye, by looking through the prism, and noting the measurable apparent deflection of the image, f_1, from the object, d_1, *in the plane of the object six meters from the prism,* as shown in Fig. 36, where the actual deflection, DF, behind the prism, is equal to the virtual deflection, df, one meter in front of it.

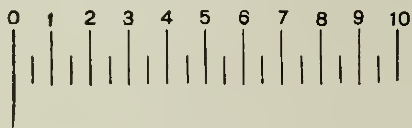


Fig. 37.

The prismometric scale, Fig. 37, as devised by the author for the purpose of conveniently measuring the powers of prisms, consists of a series of parallel lines, separated by six-centimeter distances, successively marked from 0 to 10, with the line at zero longer than the rest, so that it may serve as the object to be viewed through the prism.

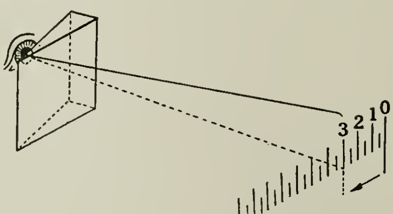


Fig. 38.

Commensurate subdivision of the scale facilitates readings to ½ or even ¼ prism-dioptrics. In order to measure a prism, its base-apex line must occupy a horizontal position, with its anterior face parallel to and six meters from the plane of the scale. The upper edge of the prism should be on a level with the lower extremities of the scale-graduations, and the perpendicular apex-edge of the prism should be directly opposite to the elongated index-line at zero, as illustrated in Fig. 38.

The observer places the pupil of his eye (its mate being closed) near the upper end of the apex-edge, so that the upper naked half of the pupil is exposed to the scale, while the ocular image of the index-line is seen through the prism and the lower half of the pupil. The observed apparent displacement of the index-line, as read from its apparent coincidence with one of the lines of the scale, determines the power of the prism in prism-dioptries, which, in Fig. 38, is shown to be 3 prism-dioptries.

In order that an object, d_1, Fig. 36, may be monocularly seen in its true position, the impulse to fixation so directs the visual axis that the object and the nodal point of the reduced eye, E, are in line, as drawn between n and d_1. As soon as a prism is interposed, the refraction at n_1 causes the pencil $d_1 n_1$ to assume the direction n_1F, which, with respect to the eye, E, does not enter its pupil, so that the eye will not only require to be brought nearer to admit the pencil n_1F, but also so close that its nodal point shall coincide with the point of refraction at n_1, if, indeed, the most accurate estimate of the deflection, $d_1 f_1$, is to be made. This, however, is practically impossible, wherefore, a slight error, due to parallax, will always be committed in reading the apparent deflection. Furthermore, readings should be taken as near the apex-edge as possible, in order to avoid another error that is due to increased thickness near the base, and which is explained in the section on *Astigmatism*.

The measurement of prisms, especially those of high power, should, therefore, be made with extreme care, by placing the pupil of the eye as closely as possible to the perpendicular apex-edge of the prism, Fig. 38. Prisms of high power, however, are not used as spectacle glasses, so that errors of a few prism-dioptries, more or less, are quite immaterial, when they are used merely to measure adduction and abduction, for instance. Measurement of the *theoretic* centimeter-deflection at the meter-distance is only justifiable when the rays proceeding from the observed index-line, at a distance of one meter, are rendered parallel by a carefully centered lens used as an eye-piece, or when the centimeter-deflection for incident parallel rays is projected upon a screen placed one meter from the prism. Both of these methods are, of course, less convenient. While it is true that a prism of 10 prism-dioptries produces a deflection that is 10 times greater than that produced by 1 prism-dioptry, yet two superposed 5-dioptral prisms will not produce a deflection exactly equal to 10 cm.; this being equally true of the resultant focal length of two superposed

5-dioptry lenses, which is not exactly 10 cm. In the former instance the discrepancy is due to the fact that twice the deflection is not produced by double the refracting angle; and in the second case, the increased thickness of the combined lenses is not a negligible dimension with respect to their resultant focal distance. Ever since 1894, American manufacturers have adopted the prism-dioptral system, and use the figure of a triangle as the symbolic sign for the prism-dioptry. Thus, one prism-dioptry ($1^{\triangle}$) is readily distinguished from the prism of one degree (1°) refracting angle, and, in fact, from prisms of any other system.*

As an exponent to the numerals of prismatic power the triangle originated with, and rightfully belongs to the prism-dioptry; and,

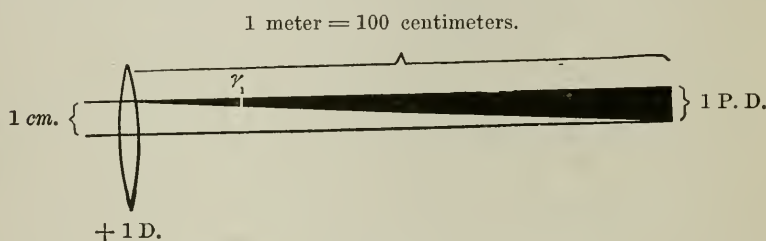


Fig. 39.

since this triangle represents both the principal section of a prism and the letter D of the old Greek alphabet, it is to be construed as an abbreviation symbolic of the words "prism" and "dioptry."

Moreover, ophthalmic prisms being frequently prescribed to counteract faulty deviations of the visual lines due to muscular imbalance, there is certainly need for an unequivocal symbol being punctiliously used by both ophthalmic practitioners and opticians.

Since lenses are a mere fusion of prisms of varying angles, the prism-dioptry may also be said to be the linear deflection which the emergent ray sustains at the focus of a meter-lens when the incident ray, parallel to the axis of the lens, impinges upon a peripheral part of the lens one centimeter from its optical center, Fig. 39.

* In order to be thoroughly consistent, in the interest of distinction the centrad should be designated by a figure containing an arc between two radii (1 ◁), since prisms made in America are marked (△) in prism-dioptries. Besides, Dr. W. S. Dennett, who suggested the centrad, had failed to disclose its possibilities with respect to the decentration of lenses or the meter-angle, nor had he originally suggested a sign to designate it. The centrad is equal to 0.01 of the radian, which is the angle subtended at the center of a circle by an arc equal in length to the radius. Therefore, the centrad is 1/100th part of the arc of 57° 17′ 44,80625″, and, in the smaller arc-values, is only approximately equal to the prism-dioptry.

Therefore, the prism-dioptry also represents the measure of the angle of deviation, γ_1, for an eccentricity or decentration of one centimeter.

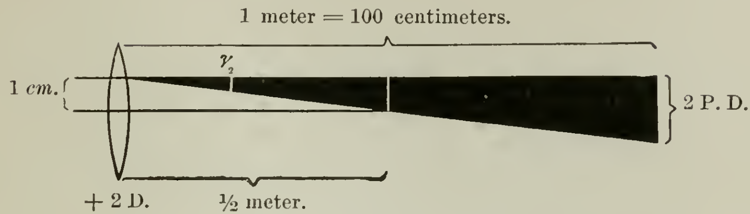


Fig. 40.

A ray impinging upon the same point of a 2-dioptry lens, Fig. 40, sustains the same unit-deflection at its focal distance, ½ meter, so that the measure of its angle of deviation, γ_2, is expressed by twice the deflection at the meter-plane, or 2 prism-dioptries. It will be later shown that a lens decentered twice or half as much will produce twice or half as many prism-dioptries as the lens possesses dioptries of lenticular refraction. The prism-dioptry is, therefore, but a sequence of the lens-dioptry, and, being based upon the proportion of 1:100, expresses a grade of angular inclination in daily use by engineers and scientists the world over. In order to reduce prism-dioptries to degrees of angular deviation, it is merely necessary to divide the prism-dioptries by 100, when the result will represent the tangents to correlative angles in degrees, and which are to be readily found in any table of natural tangents. Therefore, the prism-dioptry is virtually also a goniometric function, expressing the angle subtended by the tangent; and since different lenses, through varying decentrations, will produce different values of the angles of deviation, γ_1, γ_2, etc., it is possible, through the prism-dioptry, to determine the values of these angles in degrees, minutes, and seconds. Herein lies the unique simplicity and advantage of the prism-dioptry, especially when it is desired to know the exact angle of deviation produced by a prism of known dioptral power, or, conversely, when it is desired to ascertain the dioptral power of the prism that shall produce a given angle of deviation. The following examples will suffice to make this clear:

1. In the accompanying table, I, which has been abbreviatedly transcribed from a table of natural tangents, we find the tangent of 6°30′ to be 0.11394, for a radius of 1.

Table I.
Natural Tangents.

A.	Tangents.	D.1′
5°	0.08749	
		2.93
10′	0.09042	
		2.93
20′	0.09335	
		2.94
30′	0.09629	
		2.94
40′	0.09923	
		2.94
50′	0.10216	
		2.94
6°	0.10510	
		2.94
10′	0.10805	
		2.94
20′	0.11099	
		2.94
30′	0.11394	
		2.94
40′	0.11688	
		2.95
50′	0.11983	

Table II.
Angles of Deviation and Prism-Dioptries.

A.	
5°	8.749 = 100 × N.TG.
10′	9.042 = 100 × N.TG.
20′	9.335 = 100 × N.TG.
30′	9.629 = 100 × N.TG.
40′	9.923 = 100 × N.TG.
50′	10.216 = 100 × N.TG.
6°	10.510 = 100 × N.TG.
10′	10.805 = 100 × N.TG.
20′	11.099 = 100 × N.TG.
30′	11.394 = 100 × N.TG.
40′	11.688 = 100 × N.TG.
50′	11.983 = 100 × N.TG.

As the prism-dioptry is computed for a radius of 100 cm., we merely have to multiply the tangent given in this table by 100 to obtain 11.394^Δ as the prism that produces the desired angle of deviation, 6°30′. Hence, it is only necessary to displace the decimal points in the table, I, two points to the right in order to convert all of its tangent-values into prism-dioptries, when corresponding angles in the table will represent the angles of deviation produced by correlated prisms of the dioptral system, as shown in Table II.

Let us consider the following example, which differs only slightly from the preceding one:

2. Light being perpendicularly incident to one face of a prism, give the prism-dioptral power that produces a deviation of 6° 35′ 30″. It is apparent that the deviation in this case is only 5′ 30″, or 5.5′ greater than in the first example.

In the table, I, the tangent of 6°30′ = 0.11394, so that the tangent sought must be one having a value between this and the tangent given in the table for 6°40′. In the table is given:

$$\tan 6° 40' = 0.11688$$
$$\tan 6° 30' = 0.11394$$

Hence, the difference for $10' = 0.00294$

Therefore, the difference for 1′ will be 1/10th of this, or 0.000294, and for 5.5′ must be multiplied by 5.5, which gives

	0.001617,	the difference for 5.5′.
This, added to	0.11394 ,	the tan 6° 30′,
gives:	0.11555	= tan 6° 35.5′ for a radius of 1.

The prism-dioptry radius being 100, we multiply this by 100, and obtain 11.555$^{\Delta}$ as the prism producing a deviation of 6° 35′ 30″. In some tables of natural tangents the differences of the tangent-values for 1′ are given in a separate column, as shown on the right in Table I, and which obviate the need for computation through subtraction of the tangent-values in the table in order to first ascertain the difference for 10′, and then for 1′.

This abbreviation is used in the following example:

3. Give the angle of deviation in degrees, minutes and seconds that is produced by a prism of 9 prism-dioptries when exposed to perpendicular incidence. We know that 9$^{\Delta}$ corresponds to a tangent-deflection of 9 cm. at 100 cm., or a tangent-value = 0.09.

The nearest tangent-value in the table is 0.08749, so that	0.09000
less the tan 5° =	0.08749
gives a difference in the tangent-value =	251.

In the table, I, between the tangents for 5° and 5° 10′, we find a difference of 29.3 is produced by 1′. Hence, we divide 251 by 29.3 in order to ascertain the number of minutes contained in the tangent-difference of 251, and find 8.56′. This must be added to 5°. Hence, $5° 8.56' = 5° 8' + 0.56 \times 60'' = 5° 8' 33.6''$.

Consequently 9$^{\Delta}$ produce an angular deviation of 5° 8′ 33″ +.

Therefore, it is evident that the mathematical accuracy of the prism-dioptry far exceeds the requirements of ophthalmic practice. Attention is also directed to the differences for 1′ shown in the table, I, and which do not in every instance exactly correspond with the differences that would be obtained by subtracting the lesser from the next greater given tangent-value. This is due to the fact that the underscored figures in the fifth decimal place are one figure higher in this table than they would be in a table giving the tangent-values to the sixth or seventh decimal place, and from which the indicated differences for 1′ are taken and here given as an addendum to the table.

Incidentally, it may be stated that it is a scientific error to speak of prism-dioptries as degrees or centrads, for the reason that prism-dioptries are tangent-values and not degrees or parts of the radian. Carelessness of this kind leads only to bad habits of expression not usual among scientific men wishing to be technically understood. The student should bear in mind that optics is an exact science that is based upon a mathematical precision which does not admit of ambiguity of any kind.

The Relation of the Prism-Dioptry to the Lens-Dioptry.

As prisms are frequently combined with spheric lenses, it is here proposed to consider the relations of the prism-dioptry to such combinations, as well as to the equivalents which are to be obtained by a mere decentration of the spheric lenses themselves.

In the accompanying figure, 41, a thin lens is shown with its principal anterior and posterior foci, F_1 and F_2, equidistant from O, upon the optic axis, F_1OF_2.

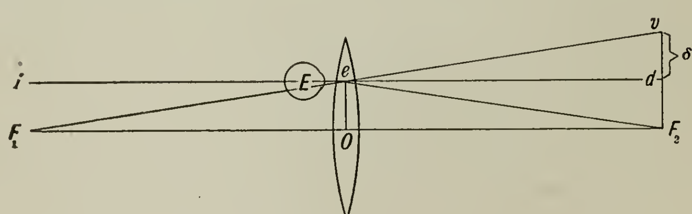


Fig. 41.

The ray, ie, which is parallel to the optic axis and incident at an eccentric point, e, of the lens, being refracted to the focal point, F_2, sustains a deflection, dF_2, *in the focal plane,* which is always equal to the decentration, Oe.

A ray, de, which is parallel to the optic axis and incident from the opposite direction, is refracted to the focal point, F_1, and, if received by the eye at E, is projected by it in the prolongation of F_1e to v.

Consequently, $dv = \delta$ is the measure of the apparent displacement of the point, d, resulting from the prismatic action inherent at e. From the congruent triangles, OeF_1, OeF_2, and dve, it follows that: $\delta = dF_2 = Oe$.

Therefore, the tangent-deflection, δ, *at the focal plane of the lens,* is always equal to the amount of decentration, Oe, and is consequently in direct proportion to it. Augmented decentration of the lens will be associated with an increase in the prismatic action, resulting from a growing inclination of the tangents, $t_1 t_2 \ldots$, determining the obliquity of the spheric surface at corresponding opposite points of eccentricity, as shown in Fig. 42.

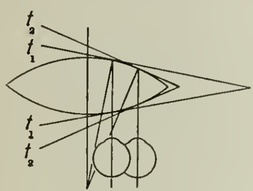


Fig. 42.

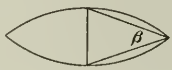


Fig. 43.

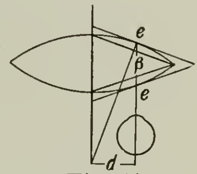


Fig. 44.

The inclination of these tangents, relatively to each other, becomes a maximum when the angle between them reaches 180°, that is to say, when they both coincide and so form the tangent to the lens which must then have become a perfect sphere. The amount of prismatic action it will be possible to obtain consequently depends only upon the diameter of the lens, yet, it will be shown that this has its limitations.

It is further obvious that a *virtual* prism of *constant* angle can not exist within the lens to produce the aforesaid variable results. The Fig. 43 is, therefore, apt to prove misleading, as there is but one fixed amount of decentration, d, Fig. 44, which corresponds to a prism of the angle, β, and which is determined by the tangents to the lens surfaces at e, there drawn parallel to the sides of the inscribed prism.

The principal focus of a spheric convex lens is known to be the point to which incident parallel pencils of light are made to converge after their passage through the lens. However, this is only true for pencils of light that are incident within a comparatively small area surrounding the pole upon the optic axis. Light that is incident outside of this limit does not reach the common focus, and produces what is termed spheric aberration; wherefore, the eye is provided with its iris, and every compound optical instrument with its diaphragm, in order to prevent entrance of the aberrative pencils that would otherwise interfere with a clear definition of the retinal image received through the comparatively small pupil.

In Fig. 45 a vertical section of a thin lens is shown, and upon which parallel rays, between o and b, are incident near the center of the lens, with its principal focus, F, in the focal plane, DF, at a distance of one meter. The extreme pencil, AB, is shown *not* to reach the focus, F, therefore, produces aberration, and does not fall subject to the law of decentration hereinafter discussed. The outermost useful ray, ab, through refraction at b, suffers deflection in its original course from D to F; in other words, this tangent-deflection, DF, in the focal plane of any lens, can only be equal to the decentration, ob, when it is confined within the circumscribed non-aberrative area, ob, of the lens.

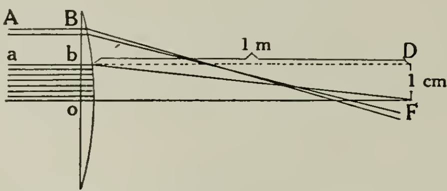


Fig. 45.

However, this limit is scarcely ever reached in the decentration of spectacle-lenses, whose size rarely admits of even a decentration of 5 millimeters; and yet, this is another instance in which the injunction respecting the practical application of the fundamental laws of optics must be respected, since the stronger the lens, the more restricted will be the area of decentration. Similarly, the generally accepted negligible thickness of lenses is known to assume such appreciable proportions in convex lenses of high power as to preclude their indiscriminate superposition, and for which reason their neutralization by concave lenses of equal power is not attainable.

Decentration.

Since the prism-dioptry is a deflection of 1 centimeter at one meter's distance, irrespective of the character of the refracting medium that

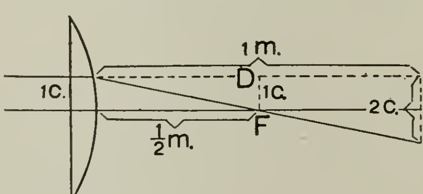


Fig. 46.

produces it, it follows that a decentration of one centimeter on a one-dioptry lens, Fig. 45, will produce a deflection, DF, in the focal plane at one meter, which is also equal to one centimeter and, therefore, one prism-dioptry.

Similarly, a two-dioptry lens, Fig. 46, decentered the same amount, produces a tangent-deflection equal to 1 centimeter *at its focus, half a meter,* which is equivalent to 2 centimeters in the meter-plane, or 2 prism-dioptries. Therefore, within the limitations of decentration above mentioned, the prismatic refraction of a decentered lens is also in inverse proportion to the distance at which the unit-deflection is produced. The following tabulation serves to make this clear:

Lens.	Decentration.	Tangent Deflection at the Focus.	Tangent Deflections in the Meter-plane.
1 D.	1 cm.	1 cm. at 1 meter	1 cm. = 1^{Δ}
2 D.	1 cm.	1 cm. at ½ meter	2 cm. = 2^{Δ}
3 D.	1 cm.	1 cm. at ⅓ meter	3 cm. = 3^{Δ}

This table also reveals the author's unique law:

Any lens is capable of producing as many prism-dioptries as the lens possesses dioptries of refraction, provided it is decentered one centimeter.

On the other hand, the prism-dioptries will change as the decentration becomes greater or less, as shown in the following tabulation:

Lens.	Decentration in Centimeters.			Decentration in Millimeters.		
	1 cm.	2 cm.		1 mm.	3 mm.	6 mm.
0.25 D.	0.25	0.5	—Prism-Dioptries—	0.025	0.075	0.15
0.5 D.	0.5	1	" "	0.05	0.15	0.3
0.75 D.	0.75	1.5	" "	0.075	0.225	0.45
1 D.	1	2	" "	0.1	0.3	0.6
2 D.	2	4	" "	0.2	0.6	1.2

A lens of 2 D., limited by its size to a decentration of 3 mm., will afford 0.6^{Δ}; whereas, a lens of 1 D., capable of a decentration of 6 mm., will produce the same prismatic effect, as shown above. In other words, a lens of one-half or one-third the power will require to be decentered twice or three times as much to secure the same number of prism-dioptries.

Therefore, it is only the size of the available lens which will, within the usual requirements of practice, set a limit to its prismatic power.

In Fig. 47, abc represents a vertical section of a 1 D. plano-convex lens, with three parallel rays, i_1, i_2, i_3, separated by one-centimeter distances, which are incident upon its plane side. These rays, after refraction, are collectively directed to the focal point, v, and therefore suffer perpendicular deflections in the focal plane *, dv, which are equal to the correlative decentrations of the rays, i_1, i_2, i_3, at their respective points of refraction.

As the spheric surface may be considered to be built up of an unbroken succession of infinitely small prisms of slightly varying angles, it is to be noted that the three chosen prisms, shown in their order of 1^{Δ}, 2^{Δ}, and 3^{Δ}, correspond to the respective decentrations of 1, 2 and 3 centimeters, and, therefore, produce correlative deflections in the focal plane, dv, *exactly* the same as the spheric surface at the same points of refraction. Some recent authors have failed to comprehend this unequivocal precision, wherefore, illustration of the principle is repeated in this form.

In Fig. 48 three concentric curvatures are shown to represent, respectively, the spheric or cylindric surfaces of 1, 2 and 4-dioptry

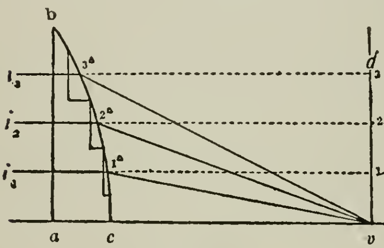


Fig. 47.

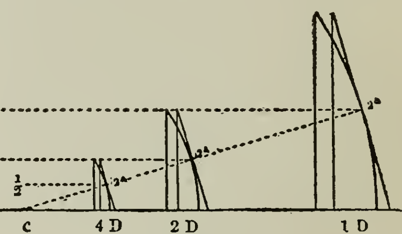


Fig. 48.

lenses, in which the same prism of 2^{Δ} occupies a different position (decentration), relatively to the optic axis, on each of the lenses.

Beneath each section is given the dioptral power of the lens, which, being multiplied by the decentration in centimeters, shows the same prismatic power of 2^{Δ} to exist at a different though definite point on the surface of each lens.

Thus it is seen that every lens, whatever its dioptral power, contains all possible values of the prism-dioptry, which means that the prism-dioptry itself must constitute a distinct part of every lens of the dioptral system.

This is graphically demonstrated in the accompanying figures, in which the dimensions of decentration and lens-curvatures are materially exaggerated.

* "The great and enduring work of Gauss on the elucidation and simplification of optical laws has among its cardinal elements four planes—the anterior and posterior focal planes and the two principal planes (Hauptebenen); and the proportion of the size of image to object, as elucidated by the formula of Helmholtz, is calculated on the tangent plane. * * * This plane can, in the case of prism-deflection, be regarded in the same light as the focal plane of the standard lens."—*The Ophthalmic Review*, London, England, January, 1891.

In Fig. 49 the lens of 2 D., with a decentration $d_1 = 3$ mm., produces a deflection of $0.6^{\triangle}$ *at the meter plane,* by reason of the obliquity of the lens-surfaces determined by the tangents at e_1, constituting a *virtual* prism of the angle, β, with its apex at a_1.

In Fig. 50 the lens of 1 D., whose radius $r_2 = 2r_1$, is decentered by the amount, $d_2 = 2d_1 = 6$ mm., to produce $0.6^{\triangle}$ *at the meter plane*

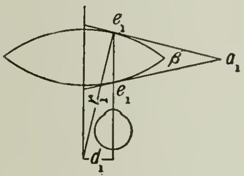


Fig. 49.

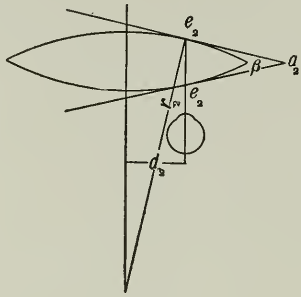


Fig. 50.

by a virtual prism of exactly the same angle, β, with its base at e_2e_2 and apex at a_2.

Consequently, it is only necessary to remember that:

The prism dioptries in decentered lenses are in direct proportion to their refraction and decentration.

Moreover, it is actually possible through decentration to determine the dioptral power of any pair of contra-generic lenses that effectually neutralize each other, and whose power may be *unknown.* All that is

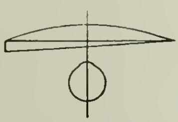


Fig. 51.

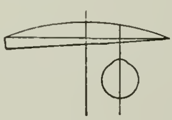


Fig. 52.

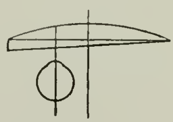


Fig. 53.

necessary is to place the lenses over each other, and to separate their optic centers exactly one centimeter, when the prism-dioptral power, as read from the prismometric scale, will be equal to the dioptral power of the lenses.

In cases where inadequate size of the lens prevents decentration, it becomes necessary to add to it a constant prism. Since the slightest decentration of a simple lens is certain to produce a corresponding prismatic effect, it is evident that the *constant* value of any prism. upon one of whose surfaces a spheric lens has been ground, will only be retained when the optic axis of the lens-surface strictly coincides with the visual axis. See Fig. 51.

The effect of decentration will naturally be to increase or diminish the prismatic action of the constant prism which has been combined with the lens-surface.

Thus, the prism in Fig. 52 is increased by the prismatic action due to decentration of the lens, as the visual axis has been shifted toward its edge and the apex of the constant prism; whereas, in Fig. 53 it is decreased through decentration in the opposite direction.

Supposing a 5 D. lens to be combined with a prism of 2^{Δ}, the former being decentered 2 mm., through shifting the visual axis toward the apex of the prism. We know that a 5 D. lens produces 5^{Δ} when the decentered 1 cm., and, therefore, will produce 0.2 of 5^{Δ} when decentered 2 millimeters, which is equal to 1^{Δ}. Therefore, the constant prism of 2^{Δ} has been increased by 1^{Δ}, making it 3^{Δ}. A decentration of the lens to an equal amount in the opposite direction will leave but 1^{Δ} for the entire combination. Two millimeters have in this case affected the value of the constant prism by 50 per cent. of its active function, and which forcefully emphasizes the need for precision in centering lenses that are mounted in spectacles, especially when they are of considerable power.

The prism-dioptry and the meter-angle being directly dependent upon the inter-pupillary distance, it behooves us, in any endeavor to secure accurate results, to be exceedingly particular as to its measurement.

The Relation of the Prism-Dioptry to the Meter-Angle.

The unit-angle of convergence has been designated, by Nagel, the meter-angle; being the angle through which each eye turns when it abandons parallelism of the binocular lines of fixation in order to see an object situated upon the median line one meter from the eye.

Therefore, in Fig. 54 it is the arc embraced between the median line, MO, and the line of fixation, OE_1, whose length is one meter, so that

$$\sin \gamma_1 = \frac{b}{OE_1} = \frac{b}{C_1}$$

As the base-line, b, is a constant, one-half of the inter-pupillary distance of any individual, it follows that different values of the meter-angle (ma) are rendered solely dependent upon correspondingly varying values of C_1. Hence, if $C_1 = 1$ meter,

$$1\ \text{ma} = \text{arc sin}\,\frac{b}{C_1} = \text{arc sin}\,\frac{b}{1M} = b,$$

$$2\ \text{ma} = \text{arc sin}\,\frac{b}{C_2} = \text{arc sin}\,\frac{b}{\frac{1}{2}M} = 2\ b, \text{ and so on.}$$

However, the prism-dioptry differs from the meter-angle in that the distance of one meter is chosen parallel to the median line * instead

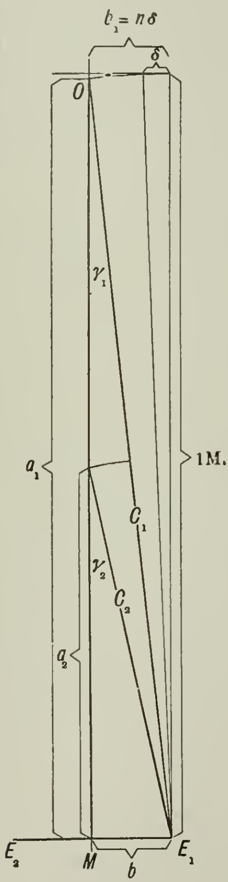


Fig. 54.

* Such substitution is admissible up to 5 meter-angles, as the difference between the tangent-deviation produced by the prism and the sine-value of five meter-angles amounts only to 4′ 42.7″.—A Metric System of Numbering and Measuring Prisms, Charles F. Prentice, *Archives of Ophthalmology*, Vol. XIX, 1890.

of upon the visual line, so that the definite dimension of one centimeter becomes the unit of comparison with respect to the base-line, which is known to be variable for different individuals. This is indicated in the diagram, Fig. 54, wherein $\delta = 1$ cm., the unit for the prism-dioptry; whereas, one meter-angle is indicated by $b = b_1 = n\,\delta$. Consequently, the meter-angle is n times greater than the prism-dioptry; or, the number of prism-dioptries,

$$n = \frac{b}{1 \text{ cm.}}.$$

Therefore, it is evident that the meter-angle contains as many prism-dioptries as there are centimeters in the base-lines. Thus, for instance, for an inter-pupillary distance of 6 cm., the base-line will be 3 cm., so that

$$1 \text{ ma} = \frac{3 \text{ cm.}}{1 \text{ cm.}} = 3^{\Delta}.$$

Similarly, for an inter-pupillary distance of 5 centimeters, the base-line being equal to 2.5 centimeters, the meter-angle is equal to 2.5^{Δ}.

Therefore, for each inter-pupillary distance, a different prism is found necessary to substitute the meter-angle. This is quite natural, since greater demands for convergence are made necessary in wide than in narrow inter-pupillary distances. It is consequently only necessary to memorize the author's simple rule:

Read the subject's inter-pupillary distance in centimeters, when half of it will indicate the prism-dioptries required to substitute one meter-angle of convergence for each eye.

Or, to put it more uniquely:

Every individual carries his own meter-angle expressed in prism-dioptries between the centers of his ocular pupils and the crest of his nose.

Applications of the Prism-Dioptry.

The practical advantages of the prism-dioptry are best illustrated through citation of a few instances in which it is successfully applied. For instance:

1. What refracting medium should be placed before each of a pair of normal eyes having an inter-pupillary distance of 6 centimeters, in order that their powers of accommodation and convergence may *not*

be exercised in obtaining a distinct view of an object placed on the median line at ⅓ of a meter from the eyes?

Reference being had to Fig. 55, it is evident that a + 3 D. spheric lens will project parallel pencils into each eye from a point, D, ⅓ of a meter directly in front of it, thus obviating accommodation for the point, D, at this distance.

To suspend convergence, however, it will be necessary also to simultaneously project parallel pencils into both eyes from the single point, F. In order that rays divergent from F may be rendered parallel in passing out of the lens immediately in front of each eye, they must suffer a deflection, DF, equal to one-half of the inter-pupillary distance, 3 cm., in the plane, DD, at ⅓ of a meter, and therefore 9 centimeters in the meter-plane, which is 9^{Δ}. Consequently, a + 3 D. spheric lens combined with a prism of 9^{Δ}, with its base in before each eye, fulfills the requirements.

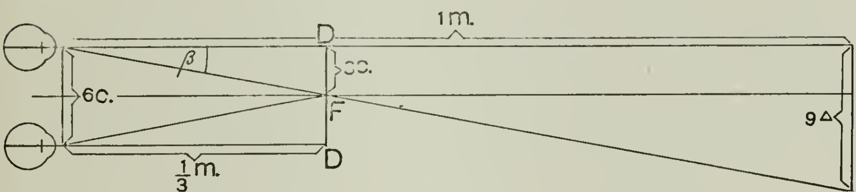


Fig. 55.

2. Two + 2 D. lenses in spectacles are found to be vertically decentered in opposite directions, one center being 5 mm. above, and the other 5 mm. below the inter-pupillary plane. The lenses are worn for both distance and reading by a young person known to have perfect balance of the extrinsic ocular muscles. What is the effect produced, and its extent?

A 5 mm. decentration of each lens is equivalent to a one-centimeter decentration of one of the lenses, provided its mate were properly centered, so that vertical diplopia would be produced through the decentered lens projecting the image within the eye at a different elevation with respect to the other.

The centimeter-decentration of a 2 D. lens produces a deviation corresponding to 2^{Δ} at the meter-plane, and, therefore, a vertical displacement of 12 cm. at 6 meters. Consequently, the object seen binocularly at this distance will appear as two objects whose centers are 12 cm. apart; whereas, in reading at ⅓ of a meter, 2^{Δ} produce a displacement equal to ⅓ of 2 cm., or 6⅔ mm., so that a line of type will appear as two lines of type separated by this distance.

3. A person claims to see an object placed at 6 meters' distance

as two objects, and indicates that their measured distance apart is 40.2 centimeters. What is the angular deviation between his visual axes?

40.2 cm. at 6 meters is equivalent to 1/6 of 40.2 cm. at one meter, or 6.7 cm. Therefore, 6.7/100 or 0.067 is the tangent of the angle of deviation. In the table of natural tangents this value corresponds to 3° 50′.

4. Being given two thin contra-generic lenses that are found to *exactly* neutralize each other, yet, whose power is unknown, it is required to determine their power by the prismometric scale as the only implement at hand.

This is accomplished by accurately locating the optic center of each lens with an ink-dot, and upon one of them locating another similarly marked point exactly one centimeter from the center. Then, by superposing the lenses so that the center of one lens accurately covers the decentered centimeter-point of the other, and holding the combined lenses before the eye, we read, through the contiguous upper edges of them, the prism-dioptral power upon the scale. The law of decentration teaches that the lens-dioptral power is equal to the prism-dioptral power when a lens is decentered one centimeter, so that, if the lenses in question produced, for instance, a five prism-dioptry deflection, the lenses must then also have five dioptries of lenticular refraction. Subsequent neutralization would prove this to be the case and would, therefore, also substantiate the author's law of decentration. The higher the power of the lenses, the more subtle becomes the experiment.

Whenever the prismometric scale is used to measure the prism-dioptral power of any lens, it is obvious that a contra-generic lens must be used to counteract the lens-dioptral power of the lens whose prismatic power alone it is sought to measure. In fact, this is now the only reliable method by which the prismatic power of any compound lens involving prescribed power of this kind can be determined. Instances frequently arise in ophthalmic practice in which it becomes necessary to add more prismatic power to a lens than can be conveniently obtained through decentration alone, this being accomplished through grinding either one or both lenticular surfaces upon one or both faces of a prism and, therefore, making a variety of such combinations possible. Combinations of spheric surfaces with prisms are called *sphero-prismatic lenses,* or *prismo-spheres,* and, being less complicated than some others, are here chosen to explain the procedure necessary to measure their prism-dioptral power. For instance:

5. In order to measure the prismo-sphere, $+ 3$ D. sph. $\supset 2^{\Delta}$, it is first

necessary to carefully locate the optic center of a concave spheric lens of 3 dioptries, by marking it with an accurately placed and very small ink-dot, which, when perfectly dry, should be placed in contact with the spheric side of the prismo-sphere, as shown in figures 56 and 57. The operator next places the entire combination before one eye at exactly six meters from the scale, taking the usual precaution to have the base-apex line of the prismo-sphere horizontal, with its base to the left, and in such manner that the upper edge of the entire combination covers the lower half of the pupil. The index-line observed through the lenses will then appear to be displaced towards the right, relatively to the graduations seen through the uncovered upper half of the pupil, while that of the other eye is occluded. In the event of the index-line appearing to be displaced more or less than the required graduation marked "2," the operator needs only to shift the neutralizing lens carefully to the left or right, until the index-line exactly coincides with the second graduation. Care should be exercised not to change the position of the prismo-sphere in any way during this act, and, while in this position, an ink-dot should be placed upon the face of the prismo-sphere next to the eye, and precisely opposite to the dot on the neutralizing lens. The dot on the prismo-sphere then indicates the point which should become the center of the glass in the spectacle-frame.

The reason for this will be obvious from the following considerations:

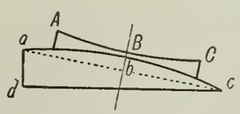


Fig. 56.

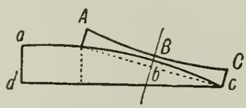


Fig. 57.

The concave lens, ABC, in Fig. 56, with its center at B, merely neutralizes the spheric power of the plano-convex lens, abc, thus leaving only the measurable effect of a prism, acd, just at the opposite points, Bb. By shifting the neutralizing lens laterally, as indicated in Fig. 57, the effect of a prism of greater angle is obtained.

Consequently, it is possible, within reasonable limits, by this means to correct any inaccuracy that may have been produced in the practical operation of grinding. The method is also applicable to *cylindro-prismatic* and *sphero-cylindro-prismatic lenses,* and in these cases, through neutralizing the cylindric element by an additional and carefully adjusted contra-generic cylinder, although this is naturally a little more difficult. Opticians who keep sphero-cylindric lenses in stock will generally find it more convenient to use these in neutralizing compound lenses involving both cylindric and prismatic power. It is obvious that it will be much easier to hold and shift a neutralizing lens consisting of only one piece of glass; besides, it will lessen liability to error. In shifting compound neutralizing lenses, great care should be exercised to keep the cylindric axis of the neutralizing lens parallel to the cylindric axis of the lens whose prismatic power is to be measured, in case displacement of the lens-centers becomes necessary.

6. While it is not strictly within the province of an essay on ophthalmic lenses to include a discourse on the various methods employed in applying them to anomalies of vision, yet, in this instance an exception is thought to be fully justified in behalf of the prism-dioptry, especially as its useful applications by the ophthalmic practitioner are not published in other works.

For instance, in making a test for hyperphoria in the consultation room, the author's phorometric chart has been devised to enable the patient to exactly indicate the vertical distance apart of the dual lights, of a single light in the object-space, which he thus conceives through the two ocular images produced by any manifest deviation between his visual axes.

Admitting, by way of illustration, that the patient has decided them to be vertically six centimeters apart, which, being equivalent to 1 cm. at 1 meter's distance, indicates that the manifest vertical deviation between the visual axes is equal to 1^{Δ}. Therefore, the diagnostician is enabled promptly to decide that a prism of 1^{Δ}, placed with its base-apex line vertical, should correct the patient's *manifest* hyperphoria. Should further deviation persist, after this prism is introduced, it would merely suggest that there is more hyperphoria latent. However, the author's experience leads to the conclusion that an attempt should at first be made to correct *only the manifest hyperphoria.*

In connection with the chart the author preferably uses a + 12 D. cylindric lens, which produces a much heavier and more readily recognized line of light than that observed through the Maddox rod.

The chart is shown in Fig. 58 as a blackboard 20 inches square, having upon its surface eight vertically and eight horizontally arranged dots, which are separated by 6-centimeter distances, so that each interval of space between the dots represents 1^{Δ} at 6 meters' distance from the eye. Charts designed to be used at a lesser distance than 6 meters are unreliable and incorrect from a scientific point of view. See sections on *The Prism-dioptry* and *Astigmatism.* A light is placed behind a piece of red glass in a circular opening in the center of the board.

The patient being directed to look through his *distance* glasses at the central light with both eyes—while the cylindric lens is placed by the operator, first vertically and then horizontally before one eye—will be able to promptly indicate any displacement of the red line of light from the center, by stating through which of the dots the red line seems to pass.

For instance, should the red line of light appear to pass horizontally through the second dot above the center, when the cylindric lens is properly placed before the patient's right eye, the operator will at once decide that a prism of 2^{Δ}, placed with its base up before the patient's right eye, should cause the red line to drop two points to the

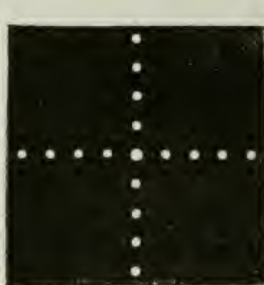


Fig. 58.

center, thus counteracting the manifest vertical deviation of his visual axes.

It is, of course, of the utmost importance that the centers of the distance glasses worn during the test should be carefully adjusted in respect to their inter-pupillary distance and elevation. When the vertical deviation of the visual axes exceeds the amount provided for by the chart (4^{Δ}), correction by prisms is more or less uncertain, owing to the phenomena of internal reflection and spectral color more or less apparent in prisms of higher power.

Lateral deviations of the visual axes are to be similarly determined by means of the horizontal dots on the board, though great caution should be exercised in reaching conclusions respecting them. Besides, in such cases prismatic corrections of sufficient power to be effective are both cumbersome and generally unsatisfactory.

The chart with its rod-image is unquestionably more reliable than any method in which a prism, producing either intended vertical or lateral displacement of the ocular image, is substituted for the rod in an attempt to determine the *actual* direction of the visual lines at right angles to the artificial displacement first induced by such prism. It is evident that the direction of the visual line, whatever it may be, is due to a force, the *resultant of a system of component forces* (Ganot's "*Physics*," or any book of engineering formulæ) exercised by the muscles attached to each eye-ball. Consequently, in accordance with the established physical law, to apply a prism that shall induce diplopia in any direction is equivalent to adding another force to the system which must then have a different resultant. In any event, the reliability of this sort of test certainly depends upon whether or not the relative strengths of the muscles remain unchanged by the addition of the prism. That a prism does stimulate a force foreign to the normal action of a muscle is a fact supported by long established experience. For instance, it is well known that the powers of adduction and abduction are to be measured by a prism placed with its apex toward the muscle to be taxed, and which shows that a limit of endurance, with respect to the power of the prism, can be reached. Furthermore, where muscular imbalance really exists, it is logical to suppose that a prism of sufficient power to produce manifest diplopia will be more apt to cause a change from the true direction of the visual lines than if such an anomaly did not exist.

Therefore, the conclusion is justified that the *actual* directions of the visual lines that are sought to be determined are not the same as the directions that are made apparent by use of the diplopia-producing prism, so that reliable information respecting the *phorias* is not to be secured through this means.

7. As a matter of further interest to the diagnostician it may be stated that the author quite recently established the law:

In manifest hyperphoria of one prism-dioptry the distance between the chiasmal image-centers is equal to one hundredth part of the distance between the nodal point and the retina in the deviating eye (*Ophthalmic Record,* Chicago, Ill., February, 1914). See definition, **Chiasmal image.**

In fact, for Donders' reduced eye, whose first focal length $F' = 15$ mm., it was demonstrated that a deviation of 1^{Δ} between the visual axes produced a foveal displacement in the deviating eye equal to 0.15 mm., this also being equal to the binocularly produced separation of the chiasmal image centers in case either contiguous or overlapping images exist.

Moreover, it was shown that the figurative chiasmal images are vertically *separated* when the diameter of the object viewed binocularly is less than the prism-dioptral deviation, and that they overlap when the diameter of the object is greater than the prism-dioptral deviation between the visual axes. The limits between which *overlapped* images are produced are made apparent in the following necessarily exaggerated diagrams, Figures 59, 60 and 61, and in which the dimensions of the various retinal images have been calculated for white square targets of different sizes placed at 6 meters' distance from the eyes.

DEVIATION BETWEEN THE VISUAL AXES = 1 PRISM-DIOPTRY.

Foveal Displacement, Separation of the Chiasmal Image-Centers and the Image-Extension = d = 0.15 mm. for Donders' Reduced Eye.

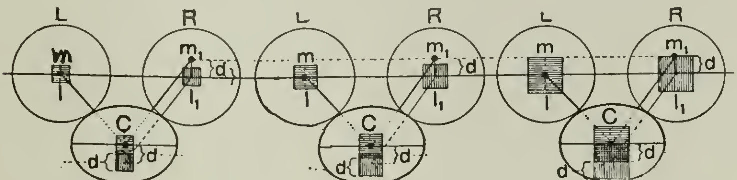


Fig. 59. Object, 60 mm. square. Image, 0.15 mm. square.

Fig. 60. Object, 87.3 mm. square. Image, 0.2185 mm. square.

Fig. 61. Object, 120 mm. square. Image, 0.3 mm. square.

This is of special interest, because it familiarizes the ophthalmic practitioner with the fact that all of the letters of the visual test-card that are smaller than 60 mm. square, at 6 meters from the reduced eye, produce separated chiasmal images for a deviation of 1^{Δ} between the visual axes; whereas, larger letters produce overlapped images.

Of course, with increased deviation between the visual axes, or increased distance (F′) between the nodal point and the fovea of the deviating eye, there will be a proportionate increase in the separation of the chiasmal image-centers.

Thus: 1^{Δ}, 2^{Δ}, 3^{Δ}, 4^{Δ} of deviation between the visual axes, produce 0.15, 0.3, 0.45, 0.6 mm. separation of the chiasmal image-centers, when $F' = 15$ mm., or 0.16, 0.32, 0.48, 0.64 mm. separation of the chiasmal image-centers, when $F' = 16$ mm.

In short, when the diameter of the object at 6 meters' distance is exactly equal to the prism-dioptral deviation between the visual axes, contiguous chiasmal images are formed whose line of contact is the boundary between separated and overlapped images.

Familiarity with the principles herein set forth should not only impress the ophthalmic surgeon with the extreme delicacy of the muscular balance necessary to maintain orthoscopic binocular vision, but also encourage him to make effort to counteract minor degrees of hyperphoria through optical rather than by surgical means; especially when it is emphasized that the displacement of the fovea in the deviating eye amounts only to 0.6 of a millimeter for a deviation between the visual axes of 4 prism-dioptries, commonly thought to be effectually corrigible through the application of surgical skill, and which it is conceded bespeaks marvelous dexterity where it has been successfully applied in cases of this kind.

However, in order to avoid misconception, it is emphasized that the chiasmal image is not to be construed as an actual image, but that "it shall signify (figuratively, of course) that orderly assemblage of the optic nerve-fibrils which receive their individual stimuli from corresponding points in each retinal image" (*Ophthalmic Record,* Chicago, Ill., July, 1914); this figure of speech being used to make it clear that the drawings are produced through projection of corresponding points within the retinal image-areas into the chiasmal field, notwithstanding the well known fact that the latter's diameter is inadequate to accommodate the implied arrangement of the nerve-fibrils that are supposed to transmit, in one way or another, conjecturally or otherwise, the ocular images themselves. In fact, the diagrams show the needful exaggeration of the chiasmal field, which is used merely as an imaginary transverse plane in which to actually picture the retinal images as they are mentally conceived, and which, in this supposed state of perception, are *figuratively* called chiasmal images, in order to distinguish them from the actual retinal images that occupy differently located areas. In fact, this and the advantage the chiasmal image offers to the draftsman in producing lucid diagrams constitute the only excuse offered for its use.

Moreover, the precedent established by Professors Hall and Hartwell, with respect to *corresponding points,* is accepted by assuming that the axial image-point of each eye at the fovea is conveyed by its corresponding optic nerve-fibril to the center of the chiasmal field; an assumption actually made necessary to reconcile mental orientation of the image with respect to a common center of visual perception of an object centered upon the median line, as well as the construction of the diagrams portraying them. Consequently, it may be safely conceded that, if both macular centers were not transmitted by their own nerve-fibrils so as to produce superposed images of themselves at the center of the optic commissure, there not being any substantiated evidence to the contrary, and a similar coalition of them did not exist somewhere in the brain itself, the images in both eyes would necessarily be conceived by the brain as dual images, so that diplopia would exist under all circumstances. It is, therefore, obvious that, in orthophoria the centers of the ocular images must be so projected, at least in a drawing, as to exactly cover each other at the center of the figurative chiasmal field; or, expressed in terms of the printer, they must be in perfect register, thus requiring their point-to-point projection to this center * in the diagram in order to correspond to the supposed center of orientation for the orthoscopically conceived brain-image itself. Such a point of orientation is quite as necessary to pictorial illustration in ophthalmology as the prime meridian at Green-

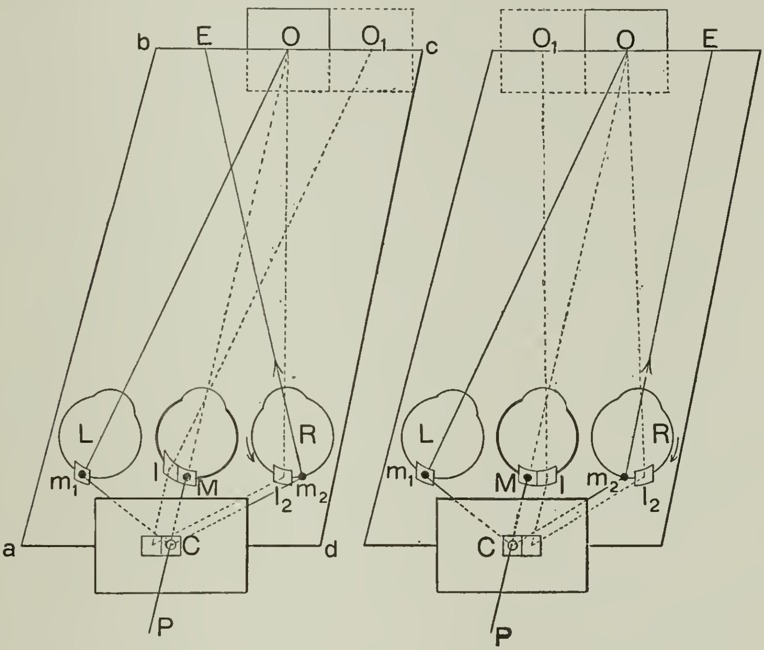


Fig. 62. Homonymous Projection.

Fig. 63. Heteronymous Projection.

Contiguous Mean Cyclopean Images derived from Figurative Chiasmal Images.

wich is to navigation, or the pole star is to astronomy, for without it one could not definitely interpret the difference between right and left, or up and down, in constructing a diagram in accordance with the rules of projection that apply to mechanical drawing. Consequently, so far as pictorial illustration is concerned, it is necessary to accept this point-to-point correspondence, even though the most recent investigations may have proven that this is not punctiliously correct for certain peripheral extensions of the object from its center on the median line, or for points of binocular fixation not located upon it.

* This correspondence of macular points in the superposed retinæ is accepted by Hall, Hartwell and Titchener.

These considerations make it evident that an image to be *orthoscopically* conceived by the brain must be produced through fusion into a single image, somewhere and by some means, of two similarly conceived ocular images of the same size. This being the fact, the single image, located at the visual center of the brain, is produced quite the same as if it were transmitted from a single image whose center is the *point of orientation* at the fovea in a single *mean eye* (cyclops),* situated on the median line, exactly between the eyes. See Fig. 62. Therefore, *a figurative cyclopean fovea,* in addition to the *center of the chiasmal field,* may be made to serve as another point of orientation in comparing the relative positions of the retinal images in the phorias.

In order to demonstrate the purpose and need of at least one point of orientation, although two different ones will be herr jointly applied, let it be supposed that the diagram, Fig. 62, represents a horizontal plane, abcd, in which the corresponding sections of the right eye, R, and the left eye, L, are located to view the object, O, upon the median line, MO. It is also assumed that the visual axis of the right eye, R, is faultily directed towards E, as in esophoria, so that its macula, m_2, is turned to the right; whereas, the macula m_1, of the left eye, L, retains its normal position with respect to the object, O; and, therefore, also with respect to the center, C, of the chiasmal field and the macula, M, of the *mean eye* on the median line, and to which points of orientation the *macular center,* m_2, in the right eye is also projected. Consequently, the macular centers, m_1, and m_2, in both eyes have the same points of orientation, C and M, in common, while the

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* "It makes a difference in apparent projection-distance whether an object be seen with the right or the left eye, so that we ought not to say identical points with reference to an object, but *coincident points,* as if the retinæ were *laid one within the other like two cups;* etc., etc.; that the error in putting the finger through a ring is greater when the right than when the left eye is closed, so that a *true, mean, cyclopean eye* would be slightly to the right of the median line." Bilateral Asymmetry of Function. By G. Stanley Hall and E. M. Hartwell. The Psychophysical Laboratory, Johns Hopkins University, Baltimore, Md.—*Mind,* Vol. IX, p. 93, London, 1884.

The following extract from Titchener's *Textbook of Psychology* (1911, p. 309) corroborates the character of a mean eye, in which "a pin" is substituted for the median line: "Think of the two retinas as slipped, the one over the other, and as held together by a pin driven through the superimposed foveas. *The two pin-holes then represent corresponding points,* the retinal points *stimulated by the point in objective space which the eyes,* at any given moment, *are fixating.* Let other pins be driven vertically through the two retinas, at any points round about the fovea: in the rough, every pair of holes will represent a pair of corresponding points. Now, it is clear, if you work the matter out by help of diagrams, that when the eyes are in a certain fixed position, only a certain number of the points in objective space can be imaged upon corresponding points."

The italics have been introduced by the writer in order to emphasize evident corroboration of his contention.

image-center, m_1, *of the left eye alone* is transmitted to these points.

But, the center of the image, I_2, projected from O into the right eye, is situated on the left side of its macula, m_2, and is, therefore, transmitted with equal displacement so as to be located on the left side of the centers of orientation, C and M, in the chiasmal field and mean eye, respectively. Therefore, the displaced image, I_2, in the *right eye,* is transmitted to and located on the *left side* of the mean eye as the false cyclopean image, I; and it is this image, belonging to the right eye, that is homonymously projected to O_1, on the right side of and at the same prism-dioptral distance, EO, from the object O.

The points m_1, m_2, C and M are corresponding points with reference to the axis, PCM, of bilateral symmetry within the cranium, which coincides with the median line, MO, in the object-space and is directed to the supposed center, P, of image-perception in the brain.

In Fig. 63, heteronymous projection of the ocular images is illustrated. Both diagrams show that the chiasmal and mean cyclopean images, respectively, are contiguous, because the horizontal diameter of the object is made equal to the prism-dioptral deflection EO, so that the real object, O, and the mentally conceived *apparent object,* O_1, are also in contact.

The figurative mean cyclopean images, I and M, are graphically projected from their corresponding chiasmal images, so that *conjointly* they make it possible to pictorially illustrate either honomymous or heteronymous diplopia in a manner not hitherto lucidly accomplished.

Consequently, the *nodal point* of the "mean cyclopean eye," mentioned in 1884 by Hall and Hartwell (who more consistently used the median line instead of "the pin driven through the superimposed foveas" mentioned by Titchener) serves, in the writer's drawings, as the pole for the orientation, in any meridian, of the *directions of image-projection into the object-space;* whereas, the *chiasmal center* is the point for the orientation of the *distance between the transmitted dual ocular images,* in case separation or overlapping of them exists. Therefore, it is obvious that both of these imaginary points of orientation may be made to serve as a useful *working hypothesis* in making a lucid drawing in physiologic optics, while the *chiasmal image* specifically commends itself as a *figure of speech,* when it is desired to differentiate between the ocular images and their corresponding brain-images, whose actual locations and physical existence have not yet been definitely determined. In fact, "brain-image" is also only a figure of speech, since it is just as imaginary as its correlative chiasmal image, which, at least figuratively, occupies a definite location.

In view of the indeterminate psychophysical character of these images, and an effort being made to picture them in a drawing, the delineator will at least need to assume that the center, P, of the so-called brain-image is the center of image-perception; that it is located in the horizontal plane, in juxtaposition to the center, M, of the centered cyclopean image of the object on the median line and, therefore, coincident with the center of the chiasmal image; said line, PCM, *within the cranium,* being considered the axis of visual orientation, or the directrix of bilateral symmetry of vision in the mind of the draftsman at least, if not in that of the psychologist.

Thus the interdependence of the chiasmal center and the nodal point of the mean eye have been disclosed, and which, for the purpose of making a lucid and mathematically serviceable drawing in accordance with the rules of projection, must be considered as being located in planes that are at right angles to each other.

8. It being within the province of the ophthalmic practitioner to discriminate in his choice of the means that shall be employed by the optician in practically executing prescriptions for glasses, a few instances are here given in which such discrimination is both convenient and profitable. The following examples are confined to hyperphoria, because it may be more effectually counteracted through the use of prisms than any other muscular imbalance.

Assuming that the diagnosis has resulted in the prescription:

O.D. + 3 D. sph. ⌢⌣ 2^{Δ} base up,
O.S. + 3 D. sph.

The optician would execute this prescription literally, and, therefore, grind a + 3 D. spheric surface upon a prism of 2^{Δ} at objectionably increased cost, because the prism-dioptries required in the right lens are in excess of the prismatic power attainable through decentration of a stock-lens.

However, the discriminating practitioner will convert his office-data so as to read: O.D. + 3 D. sph. ⌢⌣ 1^{Δ} base up, and O.S. + 3 D. sph. ⌢⌣ 1^{Δ} base down, but, in writing the prescription, will take advantage of the law of decentration applied to a + 3 D. lens. In accordance with this law, 3 D. decentered 1 cm. gives 3^{Δ}, yet, as only 1^{Δ} is needed, a decentration of ⅓ cm. for each lens will satisfy the requirements. Therefore, the prescription should be written:

O.D. + 3 D. sph., decentered ⅓ cm. up,
O.S. + 3 D. sph., decentered ⅓ cm. down,

and by which it is understood that the optic center of the convex lens is above the visual axis of the right eye, and below it before the left eye. Fig. 64 indicates the position of the lens with respect to the right eye.

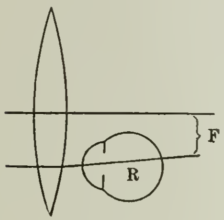


Fig. 64.

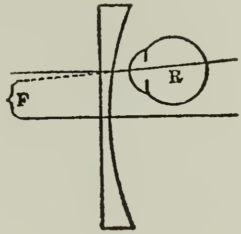


Fig. 65.

As the term "decentration" always signifies displacement of the lens relatively to the visual axis, it is to be remembered that the upturned base of a prism combined with a concave lens calls for the thick edge of the lens being placed upward, so that in such cases attempted decentration must be downward, Fig. 65. In other words, the decentration of concave lenses must be in the opposite direction to that of the specified base of the prism. For instance, as cylindric refraction is always perpendicular to the indicated axis:

9. When O.D. — 2 D. cyl., axis 180° ⊂ 2$^{\Delta}$ up, and O.S. — 2 D. cyl., axis 180° are written to call for decentration, the prescription should be:

O.D. — 2 D. cyl., axis 180°, decentered ½ cm. down,
O.S. — 2 D. cyl., axis 180°, decentered ½ cm. up.

The optician's ability to apply the law of decentration is governed entirely by the size of the lenses furnished by the manufacturers, who nevertheless now make extra large lenses at a slightly increased cost, and which admit of a 5 mm. decentration vertically, or 3 mm. horizontally, provided the corresponding diameters of the oval shapes required for the lenses are not too great.

10. As another example let us cite a case in which the examination results in O.D. + 2.75 D. sph. ⊂ + 1.25 cyl., axis 180° ⊂ 2$^{\Delta}$ base up, and O.S. + 4 D. sph.

In case the mounted lenses are to be of average size, the prescription may be written:

O.D. + 2.75 D. sph. ⊂ + 1.25 D. cyl., axis 180°, decentered 5 mm. up,
O.S. + 4 D. sph.;

or, if the mounted lenses are to be of large size:

O.D. + 2.75 D. sph. ⊂ + 1.25 D. cyl., axis 180°, decentered 2½ mm. up,
O.S. + 4 D. sph., decentered 2½ mm. down.

The above examples suffice to show how easily and with what absolute accuracy these prescriptions may be executed without incurring the additional expense of grinding prismatic combinations. In fact, this expense should only be incurred in those cases where decentration is impossible on account of an insufficient size of the lenses. A glance at the prescription will determine at once which of the methods to apply. Take, for example, a case like:

11. O.D. + 1 D. sph. ⊂ 1^{Δ} base up, and
O.S. + 1 D. cyl., axis 90° ⊂ 1^{Δ} base down.

In this case, as our commercial lenses are too small to bear a decentration of 1 cm., it would be necessary to grind the lenses as the prescription is written, though even here, to lessen the expense of the left lens, it is preferable to write:

O.D. + 1 D. sph. ⊂ 2^{Δ} base up,
O.S. + 1 D. cyl., axis 90°.

If these lenses are to be rimless eye glasses, effort should be made to match the lenses as nearly as possible in thickness, in order to avoid a preponderance of weight that would otherwise result in the right lens. Whenever prismatic corrections in the vertical direction are necessary, a preference should be given to place the base up before one eye rather than base down before the other, especially where the prism is stronger than 2^{Δ}. This is explained in the fact that the eyes are much more frequently turned downward than upward, and are, therefore, more exposed to the annoying internal reflections that are noticeable near the base of the prism when it is down. This, in part, also explains why strong prisms with their bases towards the nose are not satisfactory. See section on *Astigmatism.*

12. It is intended here to illustrate the principal defect which so frequently leads to disappointment in the use of cemented bifocal lenses (more specifically described in a subsequent section), as well as to explain how it may be obviated through application of the prism-dioptry. When occasion demands, it is common practice among ophthalmologists to prescribe glasses for "reading" and "distance," and occasionally with rather vague instructions to the optician to provide the necessary lenticular corrections in the form of bifocal lenses. These, in the event of their being of the so-called "cemented" variety,

the optician executes by cementing two thin lenticular segments to the lower surfaces of the lenses whose upper fields are used for distant vision; both of the segments being cut from the peripheral parts of that lens which produces the requisite amplifying or reducing power in the lenticular combination. The principal effort of the optician, at present, is to make this lens as thin as possible, and to reduce its diameter so as to enable him to secure at least two segments of sufficient size for the ocular fields required.

Economy and extreme thinness of the segment are doubtless desirable, but these are only of minor importance. Spectacles as now constructed, exclusively with this in view, are rarely ever free from a prismatic action, operative vertically, which renders them very uncomfortable to wear, and frequently useless. This is especially true in lenses of high power, *and in cases involving cylindric combinations,* where the spheric refraction is obtained by spheric curvature of *one*

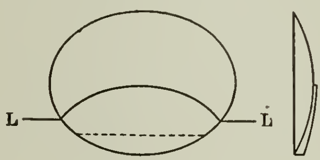


Fig. 66.

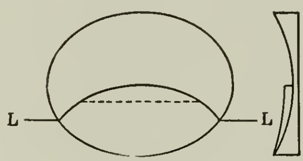


Fig. 67.

surface only. With a view to brevity, only the latter type of correction will be discussed.

The accompanying diagrams, Fig. 66 and Fig. 67, will serve to illustrate the defect referred to.

In each of these figures the line, LL, is drawn upon the paper, which is supposed to be placed several inches behind the bifocal sphero-cylindric lens. The line viewed through the lower segmental field appears disconnected, being deflected by the prismatic action resulting from decentration of the "distance" and "reading" lenses relatively to each other. It is, of course, customary to have the lower smaller field for reading, as shown above, but, for convenience of easier demonstration, the reader may make the interesting experiment of superposing two concave lenses, say, — 4.5 D. and — 2.5 D., on which the optic centers have been previously marked with ink-dots, and allowing them to occupy the positions shown in Fig. 68, in which the overlapping parts are in the smaller field for distance.

By more widely separating the lens-centers (designated by +), it will be observed that the disconnected portion of the line, LL, as seen through the lenses, will appear displaced to a lesser degree, and, if the upper concave lens, — 2.5 D., is chosen of sufficient diameter, it will be possible to secure a distance between the lens-centers which will exhibit the line, LL, unbroken, as in Fig. 69. This shows that the prismatic action depends only upon the distance separating the lens-centers and, therefore, also that *the lens,* specifically in this case the upper one, from which the segmental wafers should be cut, *must have a definite diameter for every combination,* if the prismatic action is to be eliminated. We shall cite an example in which we have for distant vision: — 7 D. sph. ⊃ — 2 D. cyl., ax. 180, and for reading: — 4.5 D. sph. ⊃ — 2 D. cyl., ax. 180, which, executed as a cemented bifocal lens, calls for a + 2.5 D. periscopic segment. This leads us to the proposition:

What peripheral part of a 2.5 D. periscopic convex lens should be used as a segment to insure freedom from prismatic action in the center

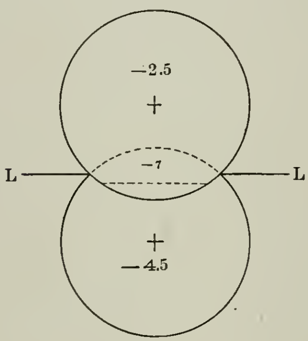


Fig. 68.

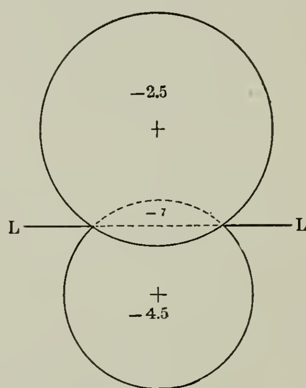


Fig. 69.

of the segment 7 millimeters below the center of the distance lens, — 7 D. sph. ⊃ — 2 D. cyl., ax. 180?

The key to its solution is to be found in the law that "a lens decentered one centimeter will produce as many prism-dioptries as the lens has dioptries of refraction."

The center of the segment being 7 millimeters (0.7 cm.) below the center of the distance lens, makes it obvious that we have a prismatic action at this point acting vertically, on account of the — 7 D. sph. and — 2 D. cyl., ax. 180, which is equivalent to a decentration of 0.7 cm. on 9 D. to be neutralized by the segment. Reverting to the stated law we find that 9 D. decentered 1 cm. affords 9^{Δ}, therefore, 0.7 cm. will give 0.7 of 9, or 6.3^{Δ} as the prismatic action to be overcome.

The segment of + 2.5 D. decentrated 1 cm. gives only 2.5^{Δ}, so that it takes a decentration of 2.5 cm. to produce $2.5 \times 2.5 = 6.25^{\Delta}$. Therefore, this segment, when placed with its thin edge at the lower edge of the concave distance lens, will neutralize the existing 6.3$^\Delta$ with an error of only 0.05$^\Delta$. As will be later shown, the + 2.5 D. lens, in order to be large enough for so great a decentration, must be at least 64 millimeters in diameter, and should be ground to a knife-edge to insure extreme thinness. As this example came to the author's notice, the instructions given to the mechanic, who successfully executed the lenses, are here repeated as follows:

"Make a 2.5 D. periscopic convex lens (+ 7 D. on — 4.5 D.) 64 millimeters in diameter, worked to a knife-edge at the periphery, and, after marking its optic center, lay off four points, p, p, p, p, 25 millimeters from the center, as shown in the diagram, Fig. 70."

"Replace the lens on the *convex* grinding tool, and cut the lens through the indicated dotted transverse diameters into four equal

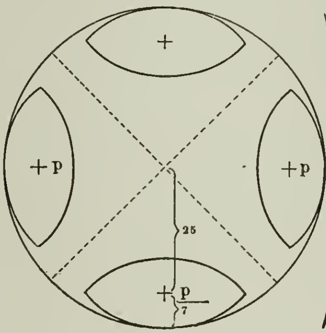


Fig. 70.

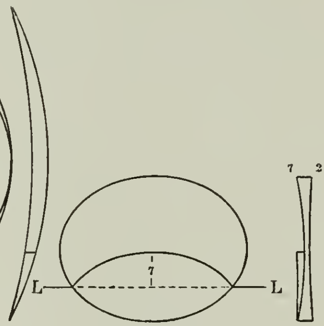


Fig. 71.

parts. This will secure four quadrants, with ample provision against accident. Select for both eyes two of the most perfect quadrants, and cut from them the peripheral segments to the shape indicated, and cement the segments into the concave 7 D. spheric surface of the sphero-cylindric lens, with their thin edges down, when a line, LL, viewed through the reading lenses, will appear continuous as in Fig. 71."

It is obvious that the diameter of the lens is determined by adding twice the decentration (25 × 2) to one full width of the wafer (7 × 2), which gives 64 millimeters.

In conclusion, it is believed to have been demonstrated that applications of the prism-dioptry do not call for profound mathematical knowledge, even though this optical unit is based upon accurate mathematical deductions that involve a principle which is easily understood and capable of being applied within the confining limits set by the fundamental laws of optical science. What could be more simple than to remember the centimeter in its connection with the prism-dioptry, as we do the meter in its relation to the lens-dioptry?

The prism-dioptry commends itself because every lens, whatever its dioptral power, contains all possible values of the prism-dioptry, which means that it unavoidably constitutes a distinct part of every lens of the dioptral system. Therefore, the prism-dioptry stands unchallenged in its unique ability to harmonize all of the refracting elements in the ophthalmic lens-case, through establishing a scientifically accurate, direct and inseparable relationship between prisms and lenses, and which cannot be accomplished by any other advocated system without appropriating the laurels of the prism-dioptry.

Cylindric Lenses.

A cylindric surface is generated through rotation of a straight line that is parallel to the axis of revolution, Fig. 72, wherefore, the center of curvature of any principal section is on the axis, AA, the so-called axis of the cylindric lens.

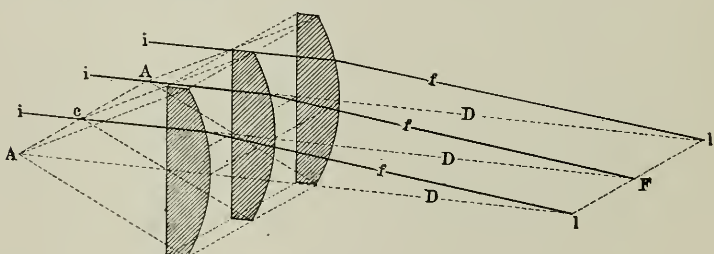


Fig. 72.

Moreover, the principal sections, Fig. 72, of the lens are parallel and have their corresponding focal points at the same distance, D, from the lens, thus producing a succession of adjacent points, resulting in the so-called focal line, lFl, which is parallel to and in the same plane with the axis, AcA, of the cylinder.

The diagrams, figures 73, 74, 75 and 76, are presented in order to more forcefully impress upon the mind the property of refraction with respect to the principal meridians of cylindric lenses. In fact, dexterity in the practice of adapting lenses to vision largely depends upon a clear conception of the principal planes of refraction, both in the human eye and in the lenses used to correct its various anomalies. Therefore, elementary as the accompanying discussion may appear, it nevertheless has its value as a mental drill in the acquirement of such knowledge.

As simple cylindric lenses have their surfaces of greatest obliquity in the plane which is perpendicular to the axis, we here also find the refraction active in this plane, and passive in the axial or right-angled coordinate plane, wherein, the same as in the illustration of prisms, i_0 and f_0 are associated with refraction in the horizontal, and i_1 and f_1 with refraction in the vertical plane.

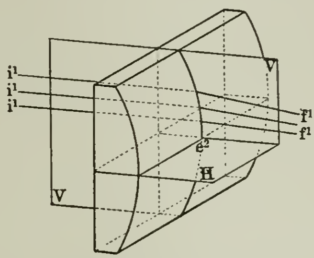


Fig. 73.

Axis, horizontal. Refraction, vertical.

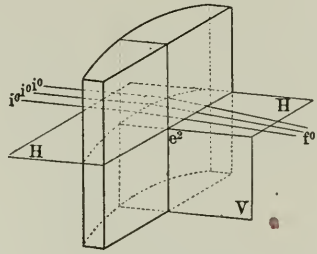


Fig. 74.

Axis, vertical. Refraction, horizontal.

Plano-convex Cylindric Lenses.

Furthermore, it is evident that the refraction in any plane that is placed diagonally between the passive and active planes of the cylinder will be equal to an amount varying between nil and its maximum refraction; and in case the cylinder is placed diagonally to a pair of right-angled coordinate planes, V and H, the sum of the dioptral

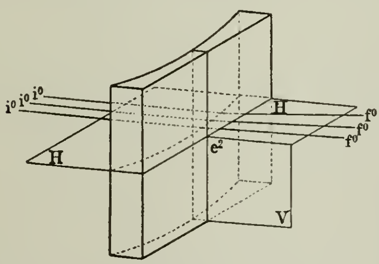


Fig. 75.

Axis, vertical. Refraction, horizontal.

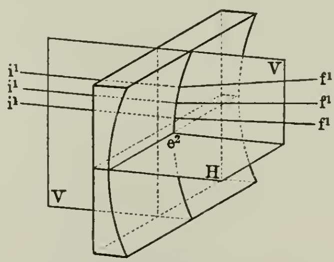


Fig. 76.

Axis, horizontal. Refraction, vertical.

Plano-concave Cylindric Lenses.

powers of the cylinder in these planes is always equal to the maximum dioptral power, D, of the cylinder. Thus, if β is the angle between the axis and the horizontal plane, H, the powers, D_V and D_H, in the planes, V and H, respectively, are related to each other as follows:

$$D_V \cos^2\beta + D_H \sin^2\beta = D, \quad \ldots\ldots\ldots\ldots\ldots \text{XXI.}$$

wherein D_V and D_H merely designate the same dioptral factor, D, in the planes, V and H.

In a practical experiment in which the lens is held at some distance from the normal eye, convex cylindric refraction manifests itself by an apparent *increase,* and concave cylindric refraction by an apparent *decrease* in the dimensions of an observed object in that plane which is at right angles to the axis. In the axial plane, the refraction being passive, corresponding dimensions remain unchanged.

To obtain cylindric refraction of equal amount in both planes, thereby reducing the focal line to a focal point, it is necessary to com-

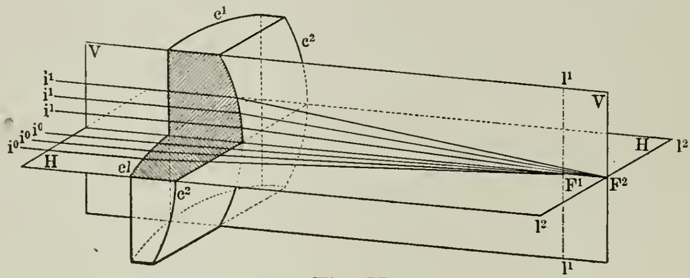


Fig. 77.
Double or Bicylindric Lens.

bine two identical cylinders, or, to create a single lens whose opposite surfaces are right-angled coordinate cylindric elements as shown in Fig. 77.

Under such circumstances, however, the focal line, $l_1F_1l_1$, for the front surface, c_1, is slightly closer to the face of the lens than the focal line, $l_2F_2l_2$, for the back surface, c_2. Aside from this, in making a

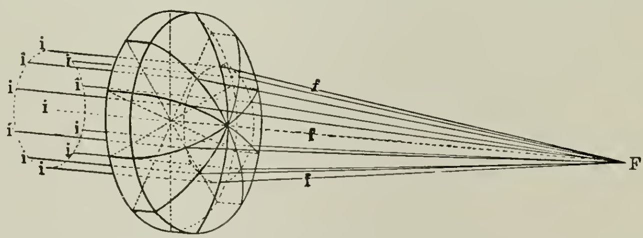


Fig. 78.
Plano-convex Spheric Lens.

bicylindric lens it is difficult to insure its chief planes of refraction being strictly at right-angles to each other, and which, if not the case, not only alters the maximum and minimum refractions, but also the positions of the principal planes in which they occur.

The greater the distance apart of the surfaces, c_1 and c_2, the greater will be the aberrative distance, F_1 to F_2; yet, as the thickness of the lens may generally be accepted as a vanishing dimension in proportion to the focal distance, we may consider a common focal point to exist for both refracting surfaces.

However, it is far less difficult to create a *single* surface capable of producing this equal amount of refraction in both the vertical and horizontal planes.

In fact, such a surface is obtained through rotation upon the optic axis of the plano-convex section, 1, Fig. 6, whereby a plano-convex spheric lens, Fig. 78, is produced. Similar rotation of the remaining sections in Fig. 6 would produce the spheric lenses mentioned in connection therewith.

It is evident that the incident and final rays will retain their relative obliquity during the rotation, so that all incident parallel rays have their corresponding final rays in the resulting cone whose apex is at the focal point, F.

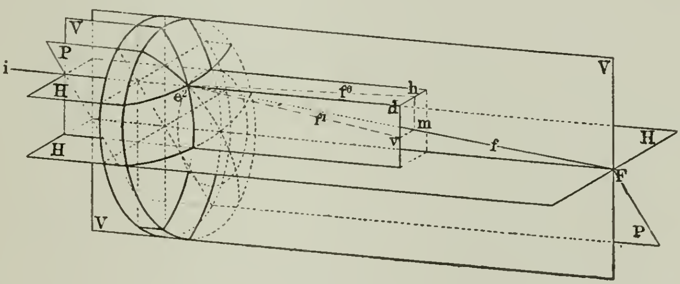


Fig. 79.

In order to further illustrate this, the principle previously utilized for the prism, Fig. 31, may also be applied to a lens having only one spheric surface, and which is consequently oblique with respect to both right-angled coordinate planes.

In the plano-convex spheric lens, Fig. 79, if we consider the refraction at e_2 of the ray, i, merely with regard to the horizontal refraction, the final ray would take the direction f_0 to h, and, if independently for the vertical refraction, the final ray would assume the direction f_1 to v. Therefore, with due consideration to the refraction in both planes, the refracted ray must include both properties of deflection, and result in a final ray, f, which is directed to the focal point, F, through a point, m, of the oblique plane, P, as defined by projection of the apportioned horizontal and vertical displacements, dh and dv.

Finally, we may, therefore, conclude that spheric refraction is equivalent to the refraction of right-angled crossed cylinders of identical curvatures.

As in spheric lenses the refraction is equally active in any pair of diametrically-opposed meridians, it follows that both the lateral and vertical dimensions of objects seen through them will appear to be enlarged by convex lenses and diminished by concave lenses, when these are held at some distance from the normal eye. In fact, persons who are expert have been known in this manner to accurately estimate the power of a lens by its associated apparent degree of magnification or minification of the distant object.

Moreover, on viewing a fixed distant object through a convex lens, held at about 12 inches from the normal eye, that is being shifted either vertically or horizontally across the visual line, the object will appear to move contrary to the motion of the lens; whereas, when a concave lens is used the motion of the object will agree with that of the lens. This principle is commonly utilized to ascertain the powers of ophthalmic lenses, through successively covering the lens, whose power it is desired to determine, by a contra-generic lens of known power, until the lens is found that neutralizes or arrests the apparent motion of the object. As a rule few lenses are required to be used before attaining neutralization, as the operator is generally able to at least closely approximate the power of the lens through having first applied the less accurate visual estimate.

Cylindric lenses are used to counteract astigmatism in the human eye, which, in other respects, may be either normal, farsighted or near-sighted. In the first mentioned instance a plano-cylindric lens is used to neutralize the astigmia; whereas, in hyperopia or myopia, the cylindric surface is necessarily combined with the required spheric surface, such combinations being called *sphero-cylindric lenses.* When a prism is combined with a cylinder, it constitutes a *cylindro-prismatic lens,* and in case a spheric surface is also incorporated, it is called a *sphero-cylindro-prismatic lens;* these terms being used to distinguish them among the great variety of *compound lenses* in general use to counteract astigmatism of the eye.

Astigmatism.

In *optics,* astigmatism is the failure of rays that are refracted or reflected at a surface to converge to a single point, and occurs when the *axis* of the incident pencil is *oblique* to one or both surfaces of a prism, lens, or mirror. For instance, in the case of refraction of an oblique bundle of rays near the periphery of a spheric surface, Fig. 80, the meridian-rays, of which the chief ray, ie, is the axis, come to a focus sooner upon the refracted chief ray, ef_2, than the sagittal rays, which suffer refraction to a lesser degree in a plane, pe, at right angles to the meridian-plane, ec, at the same point, e. The point, f_1, which is the vertex of the meridian rays, is called the *primary image-point;* and the point, f_2, which is the vertex of the sagittal rays in the plane at right-angles to the meridian-plane, is called the *secondary image-point.* The lines, $d_1\,f_1\,d_1$ and $d_2\,f_2\,d_2$, through both of which all the rays of the refracted bundle pass, and which may be regarded as straight lines in their respective coordinate planes, are, in general, called the two image-lines of the narrow refracted bundle. In other words, the primary image-line lies in the primary principal section, and the secondary image-line lies in the secondary principal section, both of which are at right-angles to each other and perpendicular to

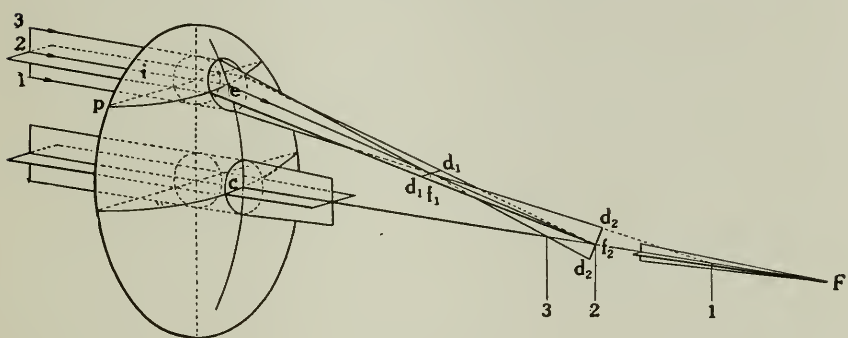


Fig. 80.
Astigmatic Refraction by a Plano-convex Lens.

the chief ray, ef_2, of the astigmatic bundle. This principle was established by Sturm, the originator of the theory of astigmatism. Matthiessen contends that the image-lines may not be, and, generally, will not be, perpendicular to the chief ray, ef_2, but it is more convenient and quite permissible to consider both of the image-lines, according to Sturm's definition, "perpendicular to the chief ray of the astigmatic bundle." In fact, they are so located for the cornea of the eye having regular astigmatism, and whose surface at the point of incidence, the vertex of the cornea, may be considered to be asymmetrical, owing to the difference of curvature in the principal sections or meridians exposed to *homocentric rays* (those that emanate from one and the same point on the axis) as well as *paraxial rays* (those that are incident within a very small area around the vertex of the surface). All other rays which do not lie in the principal sections will be refracted so as to intersect corresponding points within the limitations of the image-lines, as shown in Fig. 89A. In 1825, Airy was the first to apply a lens to correct the astigmatism in his own eye. As the refracted bundle of rays thus formed does not anywhere pass through a point, it is called an astigmatic bundle or pencil. The same principle applies to a normally incident homocentric bundle of rays, provided the bundle is refracted or reflected by a toric surface; that is to say, a rotary surface in which the meridians of greatest and least curvature are at right-angles to each other. The toric surface, Fig. 98, is well illustrated through its comparison with the peripheral surface of an inflated rubber tire, which has a greater curvature along the circumference of the wheel than in the transverse plane of a spoke. In fact, the astigmatic cornea is such a surface. When incident paraxial and homocentric rays proceed from *infinity* and are refracted by a toric surface, or its equivalent, a sphero-cylindric lens, the image-points and image-lines are called *focal points* and *focal lines,* respectively. Hence, the primary and secondary focal points on the axis are in their corresponding *primary* and *secondary focal lines,* these being located in their correlated *primary* and *secondary focal planes,* which are perpendicular to the axis. The distance between the focal lines or planes at F_1 and F_2, Fig. 89A, is known as the "focal interval" of Sturm; and a third plane, situated between and parallel to the focal planes, contains a circle, defined by the outermost rays of the astigmatic bundle, which has been somewhat misleadingly called the circle of least confusion, although here perhaps is obtained the image-point having least distortion. The locus of this circle, if named the region of transition, would more definitely define its characteristic property and position, since it is that place between the focal planes, where the constantly varying elliptic cross sections of the refracted bundle, on the side of the approaching light-wave in front of the circle, are again converted into successive and similarly inconstant elliptic cross-sections whose diameters are reversed behind the circle, T, Fig. 89, which is, therefore, a characteristic cross-section of the astigmatic bundle. The theory of astigmatism for oblique incidence also applies to any spheroid surface, that is to say, to any rotary surface approaching a spheric form and that may be generated through rotation of one of the conic sections, such as the ellipse, the parabola or the hyperbola, and which are known as ellipsoids, paraboloids, and hyperboloids, respectively. For instance, a lens of the latter type is called a hyperbolic lens (rather difficult of production), and is occasionally used, with more or less success, to correct conical cornea. which has an acute curvature near its apex that flattens out and steeply approaches the limbus. This shape of the cornea suggested the possibility of correcting the defect by means of a hyperbolic lens, which also has this characteristic form. In practice, however, a difficulty is encountered through the necessary movements of the eye in its orbit, causing the apex of the cornea to wander from the center of the lens, which should at all times be in collimation with the apex of the cornea, in order to make the lenticular correction efficient at the fovea centralis. For this reason hyperbolic lenses can only achieve their greatest efficiency when the apices of both the cornea and the lens are coincident with the line of fixation.

The astigmatism near the periphery of the conical cornea may, therefore, be said to be the dividing line between corrigible *regular* and *irregular astigmatism;* the latter comprising a variety of malformations of the corneal surface, or of the lens itself, that precludes satisfactory correction by lenses. Regular astigmatism is counteracted by means of cylindric or toric surfaces, such as are described under compound and toric lenses.

Corrigible astigmia of the eye implies that the visual line shall coincide with the optic axis of the corrective lens whose meridians of greatest and least refraction shall also correlatively coincide with the meridians of least and greatest refraction of the eye, in order to produce at its fovea an axial image-point instead of the diffusion produced by the refracted astigmatic bundle. Therefore, in ophthalmic lens-corrections only *direct pencils* of light are involved, namely those that are emitted from a luminous point upon the optic axis, and which, upon being refracted, are directed to a conjugate point upon the same axis.

It is nevertheless important that some consideration should also be given to the refraction of *oblique pencils,* on account of the aberration they so often produce when the visual axis of the eye and the axis of the corrective lens do *not* coincide. In fact, such distortion, detrimental to clear vision, may be produced through extreme excursions of the visual line from the center of any corrective lens, or by an abnormally tilted position of the lens itself before the eye. Incidentally, it may be mentioned that even moderately strong cylindric lenses, whose axes are *horizontal,* on being tilted before the visual line directed for distance, produce aberration; or, in case such lenses are properly placed for viewing remote objects, the downward direction of the visual line, incident to reading, produces the same effect. Therefore, when the axes of such cylindric lenses are *horizontal,* it is advisable to slightly decrease their power in case they are to be used for both reading and distance. Moreover, even a spheric lens that is tilted upon its optic axis produces an astigmatic pencil whose image-lines are closer to the lens than its true focus.

In fact, in any case where the axis of the incident cone of light does not coincide with the normals to both opposite surfaces of the refracting medium, whether it be a lens, prism or plate, the refracted pencil will no longer be a circular cone of light; but, it will be a pencil bounded by a surface that penetrates and defines the illuminated area of the medium and two image-lines, which are at right angles to each other and the axis of the refracted pencil, Fig. 83.

The same law applies to obliquely incident pencils of light that are *reflected* by spheric surfaces. Its mathematical elucidation may be found in most works on geometric optics.

In illustration of the difference between refracted direct and oblique

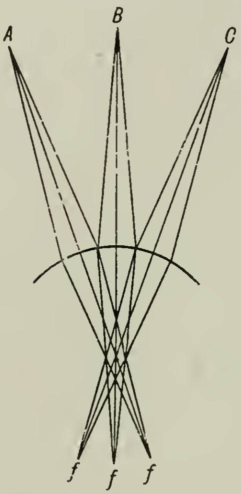


Fig. 81.

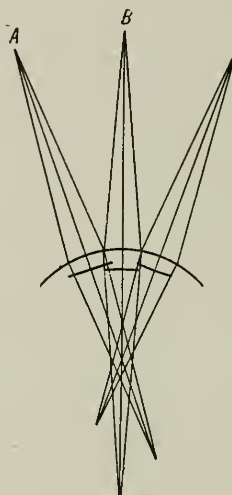


Fig. 82.

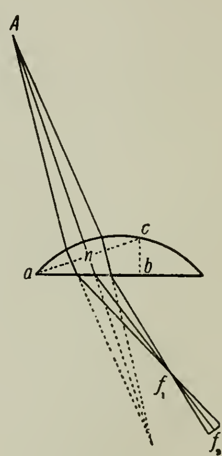


Fig. 83.

pencils, let the curved line in Fig. 81 represent the spheric surface of a medium whose density is greater than air, when perpendicularly incident conic pencils of light, projected upon it from successive points, A, B, C, will have their respective conjugate foci, f, upon the correlative radii with which the axes of the incident pencils coincide.

If the refracted pencils, within the medium, are to have *focal points outside* of the medium, the axes of these pencils will have to be *perpendicularly* intersected by the second surfaces, as shown by the heavy lines in Fig. 82; and in the event of the second surface occupying an oblique position, ab, Fig. 83, with respect to the pencil, A, the medium must be considered as a lens, having its optic center upon the axis, A n, of the incident pencil, with the prism, abc, added to it.

The circular cone of light, *within* the medium, will then project an elliptic area of illumination, E, Fig. 84, upon the second surface, as the *axis* of the pencil is here *oblique,* so that the refracted pencil ceases to be a circular cone, projecting itself outside of the medium as an *astigmatic pencil,* of which f_1 and f_2 are the image-lines at right angles to the axis, which is deflected toward the base of the inherent prism, P.

This optical phenomenon, which is sphero-cylindro-prismatic in effect, has been known to physicists ever since Kummer, in 1860, first called attention to the theory by which it was mathematically proven.

It may be experimentally, though crudely, demonstrated by placing

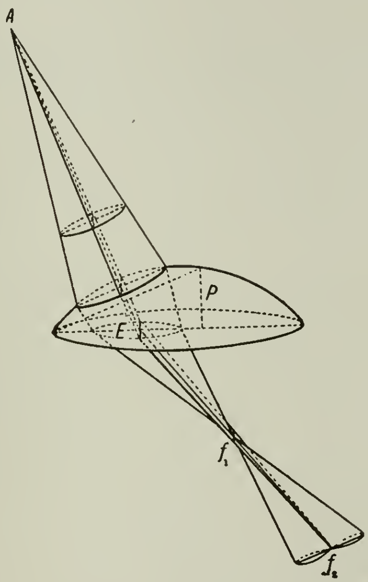


Fig. 84.

a plano-convex lens of 8 D. directly between a light at 20 feet, and a screen receiving its image. On interposing a prism of 20^{Δ}, for example, with its base downward, and in a manner to insure contact of the plane faces of the glasses, the image will be observed to change both its form and position upon the screen. By drawing the screen slightly nearer to the lens, a horizontal though imperfectly defined line, corresponding to f_1, will become manifest, and by increasing the distance between lens and screen, a vertically elongated looped figure involving "coma-aberration," * closely resembling a line, at f_2, will appear.

When a circular cone of light, C, Fig. 85, from a short finite distance, falls obliquely upon the face of a prism, we again have an

* Some excellent drawings exhibiting these appearances are to be found in H. Dennis Taylor's *A System of Applied Optics* (London, 1906).

elliptic area of illumination, and the refracted rays, *within* the medium, will assume a direction as if emitted from the image-lines, v_1 and v_2, reaching the second surface of the prism, and being refracted by it to the eye at E, as if projected from the lines, V_1 and V_2, on the opposite side of the prism.

There is one exception to this result, and that is when the axis of the incident pencil assumes the direction which is subject to minimum

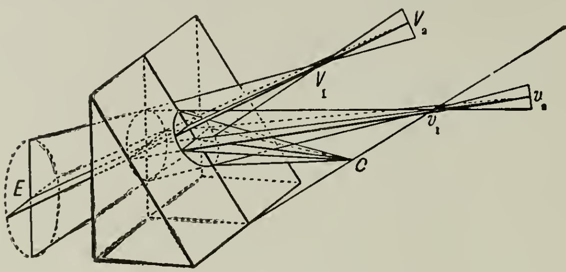


Fig. 85.

deviation, and in which event the emergent pencil will appear to diverge from a *point,* at the same distance from the anterior surface as the original source of light, C. In the case of a plate, the emergent rays will also constitute an astigmatic pencil, with the difference that its rays will appear to proceed from a pair of image-lines located upon an axis *parallel* to the axis of the incident pencil.

This sphero-cylindro-prismatic action, on the part of a simple prism,

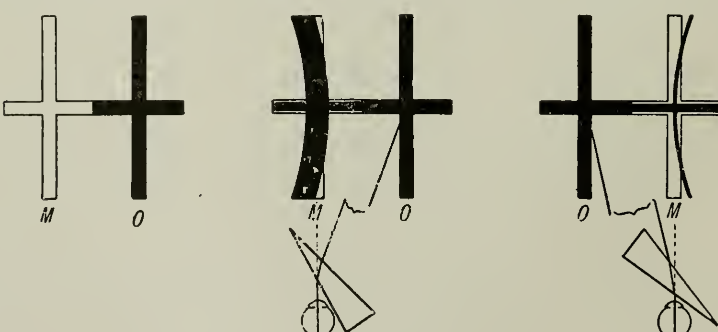


Fig. 86.

may be experimentally demonstrated in the following manner: Construct the figure MO (to the left in Fig. 86, in which the width of the principal bars is, say, 2 inches, and the distance apart of the perpendiculars is about 24 inches), and place it at right-angles to the line of sight, at a distance of about 6 feet from the eye, before which a prism of 10^{Δ} is given considerable inclination to the visual axis, with its base in or out, as shown in the two right-hand diagrams, Fig. 86. The eye in each instance is to be placed directly opposite to the figure, M. In both cases the prism is shown not only to have changed the position of the solid cross, O, but also to have altered the dimensions of its vertical and horizontal bars in comparison with M.

With this knowledge of the refraction of oblique pencils, it is easy to comprehend the error committed in attempting to measure the true power of prisms by their apparent tangent-deflections observed at the distance of one meter, and why prisms, even of moderate power, produce aberration when used for reading at a lesser finite distance.

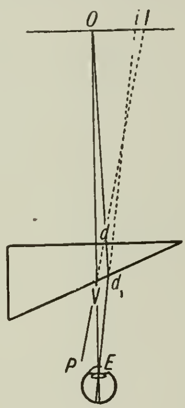


Fig. 87.

In Fig. 87 the relative positions of the object of fixation, O, at one meter's distance, the prism of exaggerated dimensions and the eye are shown. It is evident that the perpendicularly incident axis, OV, of the conic pencil of rays emitted by the object, O, coincides with the visual axis, and that the axis of the refracted pencil, VP, *does not* enter the eye, although it *does* define the deflection, OI, which it is desired to measure. However, the axis of the refracted pencil, d_1E, which *does* enter the eye, results from that incident pencil whose axis is *oblique* relatively to the normal at d, so that it is a ray approaching the direction for minimum deviation and must consequently suffer less deflection, Oi, than the refracted pencil whose axis is VP.

Therefore, it is evident that the observed deflection, Oi, is less than the actual deflection, OI, whose extent is really sought.

Even *thickness,* a dimension which we are taught to neglect with respect to ophthalmic lenses, becomes an appreciable and misleading factor in prisms above 8^{Δ}, when the unjustifiable attempt is made to measure their deflection at short finite distance. This will be apparent from the following considerations.

It has been shown that the ray, which in the nearest limit reaches the eye, is the axis, Od, Fig. 87, of an *oblique* pencil, being refracted within the prism, ABC, from d to d_1, and thence in air to the eye, E, which projects it to i, upon the scale, OI. For a given thickness of prism, this is the only pencil which will be received by the eye, since, if we increase the thickness, as in Fig. 88, by allowing the plane, A_1B_1, to represent the anterior surface of the prism, the original incident axis, Od, will be refracted at v instead of d, when the axis of the refracted pencil will traverse the path, vv_1P_1, to the left of the eye,

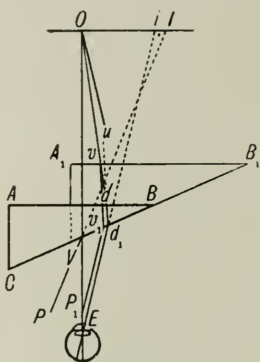


Fig. 88.

and parallel to dd_1E. The refracted pencil which would enter the eye, for the indicated *increased* thickness, could only accrue from an increased obliquity of the incident axis, Ou. The latter would, therefore, even more closely approach the direction for minimum deviation, and from which we are to conclude that the deflection noted upon the scale, OI, by the eye will be *least near the base* and consequently greatest near the apex of the prism.

In fact, this was proven by actual experiment with a prism 1¼ inches square, whose apical angle was 22°, and which, by an observation taken near the base, indicated 17.9^{Δ}; whereas, through the feather-edged apex it measured 18.9^{Δ}. The same prism placed 6 meters from the scale measured 20^{Δ}. Therefore, the error committed by measurement through the apex was 1.1^{Δ}, while the increased thickness at the base still further increased the error by 1^{Δ}. Consequently, the conclusion is justified that *the error will be least in prisms of high degree*, when readings at finite distance are taken at the apex of the prism, and that it will be reduced to a minimum, *throughout the principal refract-*

ing plane, when the deflection is measured for pencils which are *perpendicularly incident to all points of the prism-surface,* that is to say, when the pencils of light are *cylindric,* and which will practically be the case when the object of fixation, *a line, is situated at 6 meters' distance.* Thus, it has been conclusively demonstrated that, the power of a prism can not be accurately determined, through observation of the apparent tangent displacement of an object seen through it, at any shorter distance than 6 meters.

Compound Lenses.

I. Congeneric Meridians (Convex).

Among ophthalmic lenses an astigmatic lens is one in which the diametrically opposed principal sections include different degrees of refraction. in contradistinction to those hitherto mentioned, in which

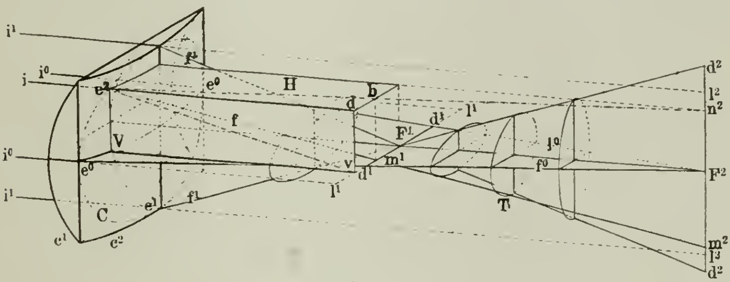


Fig. 89.

Convex Bicylindric Lens ($+ c_1$, axis 180° $\bigcirc$ $+ c_2$, axis 90°).

uniform refraction took place either exclusively in one meridian, or equally in both principal meridians.

Referring to Fig. 77, it is evident that the aberrative distance, F_1 to F_2, may also be definitely increased through assigning different amounts of refraction to the active planes or sections of the combined cylinders. In this event the focal point ascribed to the equally curved bicylindric lens will be effaced, though substituted by a pair of focal lines whose distance apart will be equal to the difference between the focal distances of the crossed *unequal* cylinders. Thus, in the bicylindric lens, Fig. 89, consisting of two crossed convex cylinders, c_1 and c_2, of unequal curvatures, $l_1F_1l_1$ and $l_2F_2l_2$ will be the corresponding *elementary* focal lines. The distance between them, F_1 to F_2, is the "focal interval" of Sturm.

As the cylinders are of equal length, the focal lines, $l_1F_1l_1$ and $l_2F_2l_2$, would also be identical in this respect, if the apportioned refractions of the cylinders were considered *independently* of each other.

The combined refraction of the cylinders, however, definitely modifies this hypothesis, and in the following manner:

The outermost incident rays, i_o, in the central horizontal plane, which would have been directed to the points l_1 and l_1, for the cylinder c_1, will suffer horizontal displacement toward the point, F_2, owing to the activity of the refraction in this plane for the cylinder, c_2, and so establish points d_1 and d_1, of the focal line, $l_1F_1l_1$, for the combined action of the cylinders, c_1 and c_2, in the *horizontal* plane.

Similarly, the outermost incident rays, i_1, in the central vertical plane, which would have been directed to the points l_2 and l_2, for the cylinder, c_2, will suffer vertical refraction in this plane by the cylinder, c_1, which causes the final rays to cross each other at F_1 and to intersect the focal line, $l_2F_2l_2$, at the points d_2 and d_2, for the combined action of the cylinders, c_1 and c_2, in the *vertical* plane.

If we consider the refraction at the point e_2 of the circle, C, for the ray, i, merely with regard to the horizontal refraction of the surfaces, or the cylinder, c_2, the final ray would take the direction e_2h, intersecting the focal line of the cylinder, c_2, at a correlative point, n_2; but, as all final rays for the cylinder, c_1, above the central horizontal plane, intersect the focal line, $d_1F_1d_1$, it follows, through presence of the cylinder, c_1, that the ray, e_2h, must fall subject to the influence of c_1 for the combined action of the cylinders, thus depressing the ray, e_2h, from the point h, perpendicularly to m_1, and consequently also the point n_2 to m_2, within the focal line, $d_2F_2d_2$.

Therefore, by means of the same reasoning that was applied to the refraction of a rotated prism, Fig. 31, it is found that the direction of the final ray, f, has, in this instance, also been determined by projection of the apportioned horizontal and vertical displacements, dh and dv, which are solely dependent upon the active meridians of the cylinders, c_1 and c_2.

Increased proximity of the point e_2 to e_o, upon the circle, C, will be associated with an increased distance between m_1 and F_1, and with an approach of m_2 toward F_2 for these points of intersection of the final ray, f, within the respective focal lines, F_1d_1 and F_2d_2. The reverse is evident for an advancement of e_2 toward e_1.

The total refraction for all incident parallel rays within the area of the circle, C, Fig. 89A, will, therefore, result in an astigmatic pencil whose focal lines, $d_1F_1d_1$ and $d_2F_2d_2$, are limited as to position and magnitude. This astigmatic pencil, if intercepted at intervals by a transverse perpendicular screen, will thereon project elliptic areas of light whose longest and shortest diameters correspond to the principal meridians of refraction. In the immediate vicinity of F_1, for instance, the ellipses have their longest diameters horizontal; whereas, in the vicinity of F_2 their longest diameters are vertical.

This naturally effects a reversal of the ellipses, respecting their diameters, at some point within the focal interval, F_1F_2; such point being determined where the vertical and horizontal displacements are alike, and the section, T, Fig. 89, is a circle whose locus is the region of transition.

Astigmatic refraction in a lens is, however, preferably attained by combining a spheric with a cylindric surface; the requisite conditions being fulfilled through that increase or decrease of the spheric refraction which is produced by and in the active meridian of the cylinder. To increase the refraction of a positive or negative spheric lens in

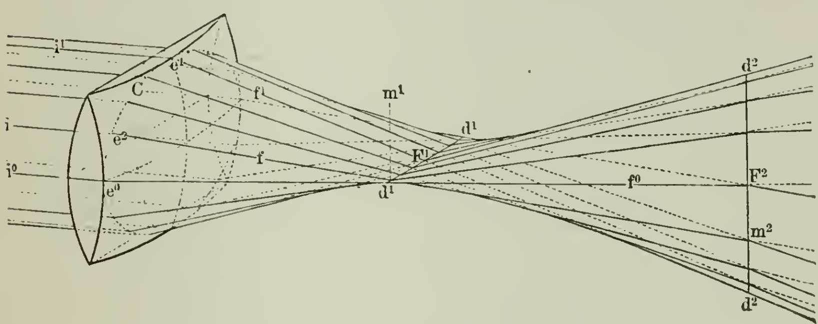


Fig. 89A.

one meridian, we may add to it the active meridian of the cylinder bearing the same sign; and to decrease it in the same meridian we may combine it with the active meridian of a cylinder bearing the opposite sign. For instance:

1. The combination of a positive spheric with a positive cylindric surface results in the section of *greatest* refraction being double convex; and,

2. The combination of a positive spheric with a weaker or less acutely curved negative cylindric surface results in the section of *least* refraction being *periscopic* convex.

Where the aforesaid combinations are spoken of, we shall, for convenience, apply to them the terms double and periscopic form, respectively.

As the combination of crossed convex cylinders of unequal curvatures gave rise to a pair of focal lines, to the novice it may appear requisite that a focal point and a focal line should exist for the combination of a spheric with a cylindric surface. However, the following analysis will avert this possible though erroneous impression:

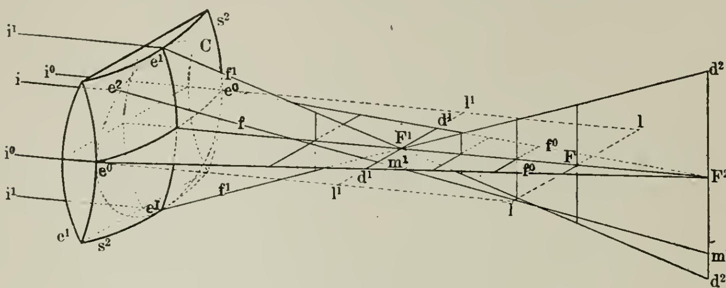


Fig. 90.
Convex Sphero-cylindric Lens ($+ s_2 \frown + c_1$, axis 180°).—Double Form.

In the convex sphero-cylindric lens of double form, Fig. 90, if we considered the refraction for each surface independently of the other, we should find a focal point at F_2 for the convex spheric surface, s_2, and a focal line, say at l F l, for the cylindric surface, c_1. Their combination giving rise to augmented refraction in the vertical plane, however, occasions a displacement of the focal line, lFl, to the position of $l_1F_1l_1$.

The final rays from the outermost points, e_o, in the horizontal plane, being directed to the focal point, F_2, it is evident that the focal line, $l_1F_1l_1$, must become subject to the influence of the spheric refraction in

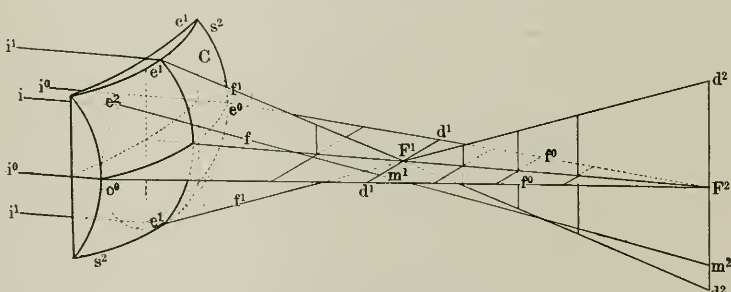


Fig. 91.
Convex Sphero-cylindric Lens ($+ s_2 \frown - c_1$, axis 90°).—Periscopic Form.

this plane, thereby establishing the points d_1 and d_1, and restricting the magnitude of the focal line to $d_1F_1d_1$.

The final rays from the outermost points, e_1, in the vertical plane, which in absence of the cylinder would have been directed to the focal point, F_2, now cross each other at F_1. Their extremities are, therefore, displaced from F_2 to d_2 and d_2, thus resulting in the destruction of the focal point, F_2, and establishing a limitation of the rays to a *created* focal line, $d_2F_2d_2$.

The convex sphero-cylindric lens of periscopic form, Fig. 91, is constructed by combining a *weaker* concave cylinder, c_1, with a convex spheric surface, s_2; the axis of the cylinder here being placed in the vertical instead of the horizontal plane for the purpose of future comparison.

In this case we have given to the spheric surface, s_2, a curvature corresponding to the focal point, F_1, and to the cylindric surface, c_1, a curvature which, acting in combination with its associated horizontal meridian of the spheric surface, causes the rays to unite at the focal line, $d_2F_2d_2$. The reason given for the destruction of the focal point F_2, in the lens, Fig. 90, may in this instance be similarly applied to explain the creation of the primary focal line, $d_1F_1d_1$, as well as the limitation of the secondary focal line to the magnitude of $d_2F_2d_2$.

A characteristic difference between the double and the periscopic form of astigmatic lens consists in the fact that the positions of the focal lines are interchanged with respect to their correlative elements of creation. Thus, in Fig. 90 the focal line, $d_2F_2d_2$, corresponds to the initial effect of the spheric surface; whereas, in Fig. 91 the primary focal line, $d_1F_1d_1$, corresponds to it.

This difference, however, is not material, as it is evident that the magnitude of the focal lines and their distances from the lens are dependent upon the refraction ascribed to its two principal sections; and, since any two given points (d_1 and F_2, F_1 and d_2, m_1 and m_2) definitely fix the position of a line or ray in space, it is further obvious that the direction of all final rays will be identical for any thin lens in which the right-angled coordinate meridians of greatest and least refraction are allotted the same, and upon whose surface the rays are incident in the immediate vicinity of the optic axis.

To demonstrate the analysis of formulæ for these equivalents, we shall, in the respective figures, designate the refraction as being expressed by:

Ia.	+ 3.5 D. cyl., axis 180°	⊃ + 1.5 D. cyl., axis 90°.	(Fig. 89.)
IIa.	+ 1.5 D. spheric	⊃ + 2.0 D. cyl., axis 180°.	(Fig. 90.)
IIIa.	+ 3.5 D. spheric	⊃ − 2.0 D. cyl., axis 90°.	(Fig. 91.)

It being necessary to become thoroughly familiar with the meridians of greatest and least refraction, it is considered expedient to picture these in their respective planes of activity, V and H, as shown in their correlative sectional diagrams, Fig. 89a, Fig. 90a, Fig. 91a, and to refer to them as follows:

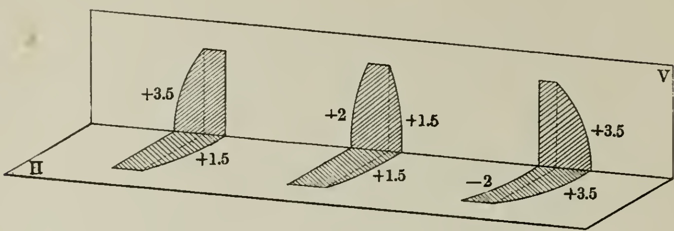


Fig. 89a. Fig. 90a. Fig 91a.

Formula Ia. + 3.5 D. cyl., ax. 180° ⊃ + 1.5 D. cyl., ax. 90°. (Fig. 89.)
Refraction: + 3.5 D., vertical ⊃ + 1.5 D., horizontal, = + 3.5 V ⊃ + 1.5 H. Fig. 89a.

Formula IIa. + 1.5 D. spheric ⊃ + 2 D. cyl., axis 180°. (Fig. 90.)
Refraction: + 2 D. + 1.5 D., vertical ⊃ + 1.5 D., horizontal, = + 3.5V ⊃ + 1.5 H. Fig. 90a.

Formula IIIa. + 3.5 D. spheric ⊃ − 2 D. cyl., axis 90°. (Fig. 91.)
Refraction: + 3.5 D., vertical ⊃ − 2 D. + 3.5 D., horizontal, = + 3.5V ⊃ + 1.5 H. Fig. 91a.

Therefore, the lenses Ia, IIa, and IIIa are asymmetrically-refracting equivalents.

As the preference is generally given to the double form (Formula IIa), and, under certain circumstances, occasionally to the periscopic form (Formula IIIa), the rules applicable to the conversion of the one into the other formula alone are given.

To convert the double into the periscopic form:

Rule 1. *Place the sum of both numerals of refraction as the numeral for the newly created spheric element,* and combine with the same cylindric element having its sign and axis reversed.*

To convert the periscopic into the double form:

Rule 2. *Place the difference of both numerals of refraction as the numeral for the newly created spheric element,* and combine with the same cylindric element having its sign and axis reversed.*

As these lenses are practically only used for the correction of anomalies of ocular refraction, it is customary, when adapting them, to note the positions of the cylindric axes by means of the graduations

* The sign of the original spheric surface remaining unchanged.

upon the trial-frame. This, however, does not change the inherent properties of the lenses, whose meridians of greatest and least refraction are always 90° apart for all possible axial positions between 0° and 180°.

Thus, in the instance of the formula:

+ 1.5 D. sph. ⊃ + 0.50 D. cyl., axis 130°,

the periscopic form would be expressed, according to Rule 1, by

+ 2 D. sph. ⊃ — 0.50 D. cyl., axis 40°.

Inversely, the former may be made the result of the latter through application of Rule 2.

2. *Congeneric Meridians (Concave).*

The preceding analytic treatment is alike applicable to the similarly planned † concave compound lenses, Figs. 92, 93, 94, in each of which the focal lines, and consequently also the focal interval and region of transition are virtual and in the negative region before the lens.

All parallel rays incident upon and within the periphery of the circle, C, in any of the figures, will, therefore, result in final rays, behind the lens, which appear to emanate from correlatively established virtual points (d_1 and F_2, F_1 and d_2, m_1 and m_2) of and within the limits of the focal lines in front of the lens. For these lenses, respectively, the refraction has been allotted as follows:

Ib. — 1.5 D. cyl., axis 180° ⊃ — 3.5 D. cyl., axis 90°. (Fig. 92.)
IIb. — 1.5 D. spheric ⊃ — 2 D. cyl., axis 90°. (Fig. 93.)
IIIb. — 3.5 D. spheric ⊃ + 2 D. cyl., axis 180°. (Fig. 94.)

and which, through similar use of sectional planes, such as applied to Fig. 89a, etc., will be found to be asymmetrically-refracting equivalents.

According to Rule 1, for instance, the concave sphero-cylindric lens,

— 1.25 D. sph. ⊃ — 0.75 D. cyl., axis 160°,

may be converted into the periscopic form:

— 2 D. sph. ⊃ + 0.75 D. cyl., axis 70°,

and *vice versa,* according to Rule 2.

† The meridian of greatest refraction is here placed in the horizontal instead of the vertical plane.

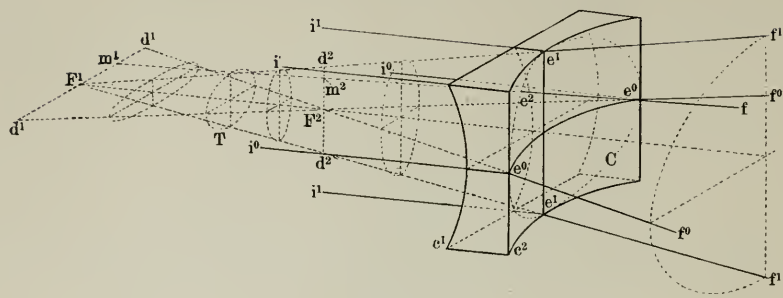


Fig. 92.

Concave Cylindro-cylindric Lens ($-c_1$, axis 180° ⌒ $-c_2$, axis 90°).

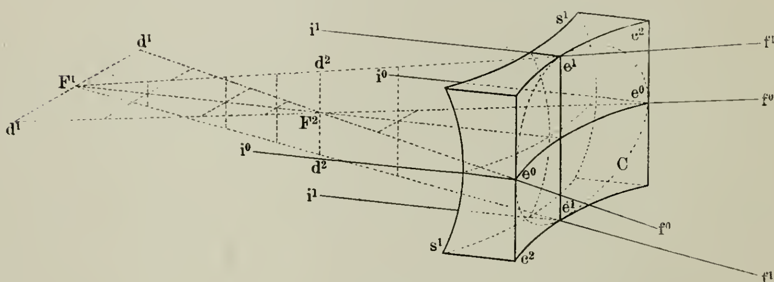


Fig. 93.

Concave Sphero-cylindric Lens ($-s_1$ ⌒ $-c_2$, axis 90°).—Double Form.

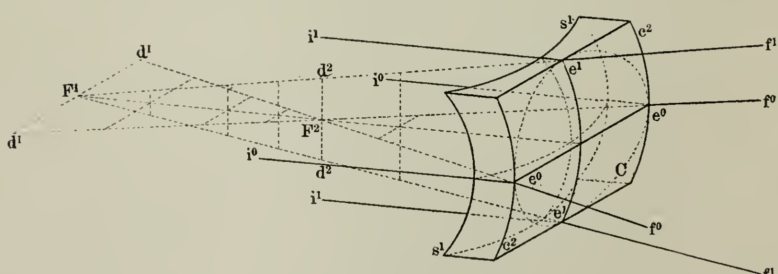


Fig. 94.

Concave Sphero-cylindric Lens ($-s_1$ ⌒ $+c_2$, axis 180°).—Periscopic Form.

In the above figures, i_o, e_o and f_o are associated with horizontal refraction, and i_1, e_1 and f_1 with vertical refraction.

3. *Contra-generic Meridians (Convex and Concave).*

As a final complication, different or even like degrees of positive and negative refraction may be ascribed to the diametrically opposed principal sections of a lens; this being achieved in the lens, Fig. 95, through combining a concave cylinder, c_1, with a convex cylinder, c_2, so that their contra-generic active meridians are at right-angles to each other.

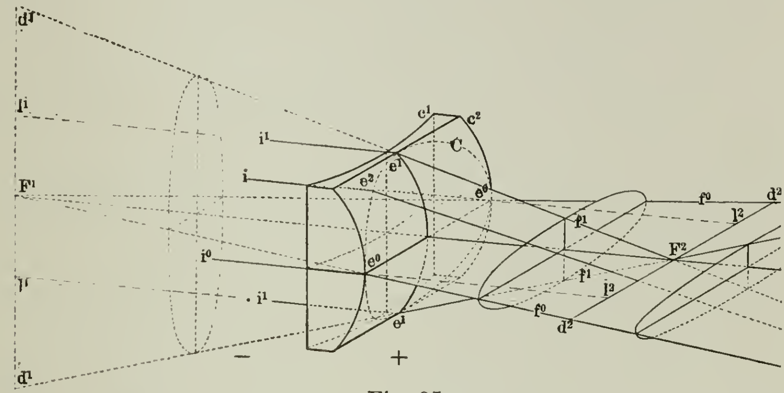


Fig. 95.

Concavo-convex Cylindro-cylindric Lens (— c_1, axis 90° ⌒ + c_2, axis 180°).

Independently considered, each cylinder, c_1 and c_2, would have its focal line, $l_1F_1l_1$ and $l_2F_2l_2$, of original magnitude in the region of its sign, — and +, respectively, and consequently on opposite sides of the lens.

When the cylinders are associated, however, the final rays, which would have been restricted to the limits of the focal line, $l_2F_2l_2$, for the cylinder, c_2, will, by virtue of the dispersive effect of the cylinder, c_1, in the horizontal plane, be confined to an augmented focal line, $d_2F_2d_2$, within the limits d_2 and d_2, for the outermost rays emanating from the point, F_1, of the virtual focal line, $l_1F_1l_1$.

Therefore, all final rays within the limits of the circle, C, will be accorded associated vertical and horizontal refraction, culminating in their united intersection of a line, $d_2F_2d_2$, in the horizontal plane and in the positive region behind the lens. Interception of these rays, by successive transverse vertical planes, will make manifest similarly arranged ellipses respecting their greatest and least diameters, before and behind the focal line, $d_2F_2d_2$. By projecting the final rays into the region of their apparent emanation from before the lens, the virtual focal line, $l_1F_1l_1$, is increased in magnitude to $d_1F_1d_1$, so that the so-defined ellipses are reversed respecting their greatest and least diameters, as shown by the dotted lines in the negative region, Fig. 95. Here the circle of transition is within the plane of the lens itself.

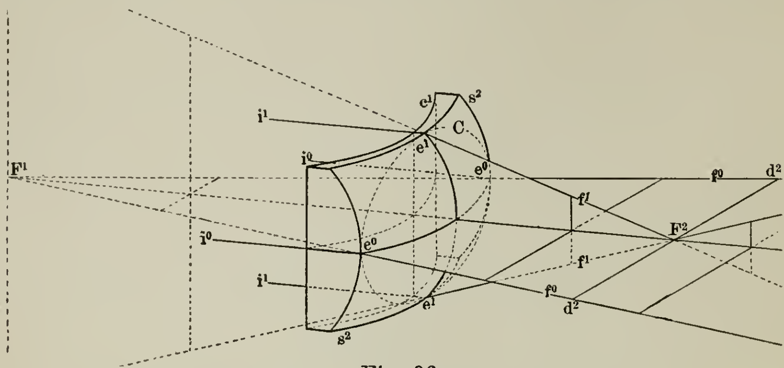


Fig. 96.

Concavo-convex Sphero-cylindric Lens ($+ s_2 \frown\!\!\!\smile - c_1$, axis 90°).

Identical refraction is also preferably obtained in this instance by combinations of spheric with cylindric surfaces.

The combination of a convex spheric surface with the active meridian of a stronger concave cylinder creates a periscopic section which is concave; whereas, the combination of a concave spheric surface with

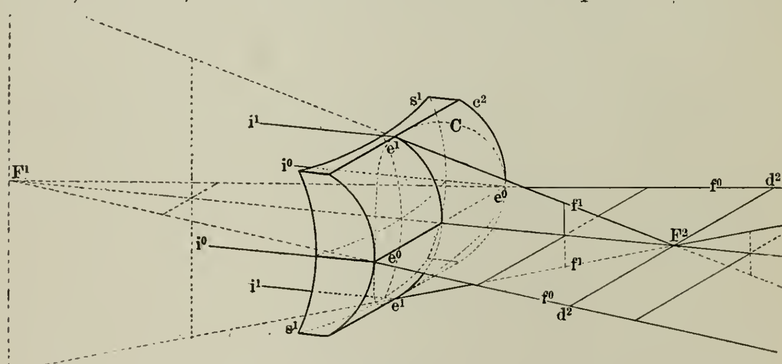


Fig. 97.

Concavo-convex Sphero-cylindric Lens ($- s_1 \frown\!\!\!\smile + c_2$, axis 180°).

the active meridian of a stronger convex cylinder results in a periscopic section which is convex. The identity of the refraction for these combinations becomes apparent by reference to the concavo-convex sphero-cylindric lenses, Figs. 96 and 97, in which, through a judicious selection of the respective spheric and cylindric curvatures, the required positive and negative elements of refraction for the principal meridians of the crossed cylindric lens, Fig. 95, are fulfilled.

To illustrate the equality of formulæ characterizing these equivalents, we refer to their correlative sectional diagrams, Figs. 95c, 96c, 97c, in the following order:

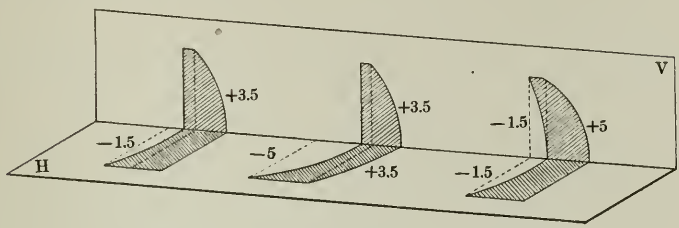


Fig. 95c. Fig. 96c. Fig. 97c.

Formula Ic. — 1.5 D. cyl., ax. 90° ⊃ +3.5 D. cyl., ax. 180°. (Fig. 95.)
Refraction: — 1.5 D., horizontal ⊃ + 3.5 D., vertical = — 1.5 H ⊃ + 3.5 V. Fig. 95c.

Formula IIc. + 3.5 D. spheric ⊃ — 5 D. cyl., axis 90°. (Fig. 96.)
Refraction: — 5 D. + 3.5 D., horizontal ⊃ + 3.5 D., vertical = — 1.5 H ⊃ + 3.5 V. Fig. 96c.

Formula IIIc. — 1.5 D. spheric ⊃ + 5 D. cyl., axis 180°. (Fig. 97.)
Refraction: — 1.5 D., horizontal ⊃ — 1.5 D. + 5 D., vertical = — 1.5 H ⊃ + 3.5 V. Fig. 97c.

These lenses being equivalents, the rule is given only for converting the cylindro-cylindric lens (Formula Ic) into the concavo-convex sphero-cylindric lenses (Formula IIc and IIIc).

Rule 3. *Place the sum of both numerals of refraction as the numeral of the newly-created cylindric element, giving to it both the sign and axis of either cylinder, and combine with the neglected cylindric numeral and its associated sign as the spheric element.*

Comparison of the periscopic lenses, Figs. 91 and 94 with the Figs. 96 and 97, respectively, exhibits a striking similarity in their construction. The characteristic difference between them is that in the latter the cylindric refraction exceeds the spheric refraction, whereas, in the former the reverse is the case.

In the first edition of the author's work, *Ophthalmic Lenses,* 1886, tables were published which showed the combinations available, between 0.25 and 3.25 dioptries, for crossed cylindric lenses, together with their sphero-cylindric equivalents. In the accompanying abbreviated tabulation, Table I, the diagonal line of spheric lenses divides the table into two sets of compound lenses that are duplicates in refraction, even though there is a difference in the positions of the cylindric axes. Thus, all lenses in the vertical columns *beneath* the spheric lenses are correlative duplicates of the lenses in the horizontal columns to the *right* of them. For instance, $A_1 = a_1$, $A_2 = a_2$; $B_1 = b_1$, $B_2 = b_2$, etc.

I. TABLE OF CROSSED CYLINDERS AND THEIR SPHERO-CYLINDRIC EQUIVALENTS.

Congeneric Meridians (Convex).

DIOPTRIES.	+0.25 C. 180°	+0.50 C. 180°	+0.75 C. 180°	+1.00 C. 180°	+1.25 C. 180°
+0.25 C. 90°	(+0.25)	a^1 +0.25⊂+0.25⊖ +0.50⊂−0.25⦶	a^2 +0.25⊂+0.50⊖ +0.75⊂−0.50⦶	a^3 +0.25⊂+0.75⊖ +1.00⊂−0.75⦶	+0.25⊂+1.00⊖ +1.25⊂−1.00⦶
+0.50 C. 90°	A^1 +0.25⊂+0.25⦶ +0.50⊂−0.25⊖	(+0.50)	b^1 +0.50⊂+0.25⊖ +0.75⊂−0.25⦶	b^2 +0.50⊂+0.50⊖ +1.00⊂−0.50⦶	b^3 +0.50⊂+0.75⊖ +1.25⊂−0.75⦶
+0.75 C. 90°	A^2 +0.25⊂+0.50⦶ +0.75⊂−0.50⊖	B^1 +0.50⊂+0.25⦶ +0.75⊂−0.25⊖	(+0.75)	+0.75⊂+0.25⊖ +1.00⊂−0.25⦶	+0.75⊂+0.50⊖ +1.25⊂−0.50⦶
+1.00 C. 90°	A^3 +0.25⊂+0.75⦶ +1.00⊂−0.75⊖	B^2 +0.50⊂+0.50⦶ +1.00⊂−0.50⊖	+0.75⊂+0.25⦶ +1.00⊂−0.25⊖	(+1.00)	+1.00⊂+0.25⊖ +1.25⊂−0.25⦶
+1.25 C. 90°	+0.25⊂+1.00⦶ +1.25⊂−1.00⊖	B^3 +0.50⊂+0.75⦶ +1.25⊂−0.75⊖	+0.75⊂+0.50⦶ +1.25⊂−0.50⊖	+1.00⊂+0.25⦶ +1.25⊂−0.25⊖	(+1.25)

In the above formulæ the first numerals apply to spheric refraction, and the second numerals to the cylindric refraction. In the associated signs for axial position, the upright and horizontal diameters (| and —) of the circles denote the axes, 90° and 180°, respectively. With the exception of the diagonal line of spheric equivalents, each field contains both the double and periscopic forms of the convex sphero-cylindric equivalent. For crossed concave cylinders it is merely necessary to reverse the signs, + and —, wherever they occur.

II. TABLE OF CROSSED CYLINDERS AND THEIR SPHERO-CYLINDRIC EQUIVALENTS.

Contra-generic Meridians (Convex and Concave).

DIOPTRIES	+0.25 C. 180°	+0.50 C. 180°	+0.75 C. 180°	+1.00 C. 180°	+1.25 C. 180°
−0.25 C. 90°	+0.25⊂−0.50⦶ −0.25⊂+0.50⊖	+0.50⊂−0.75⦶ −0.25⊂+0.75⊖	+0.75⊂−1.00⦶ −0.25⊂+1.00⊖	+1.00⊂−1.25⦶ −0.25⊂+1.25⊖	+1.25⊂−1.50⦶ −0.25⊂+1.50⊖
−0.50 C. 90°	+0.25⊂−0.75⦶ −0.50⊂+0.75⊖	+0.50⊂−1.00⦶ −0.50⊂+1.00⊖	+0.75⊂−1.25⦶ −0.50⊂+1.25⊖	+1.00⊂−1.50⦶ −0.50⊂+1.50⊖	+1.25⊂−1.75⦶ −0.50⊂+1.75⊖
−0.75 C. 90°	+0.25⊂−1.00⦶ −0.75⊂+1.00⊖	+0.50⊂−1.25⦶ −0.75⊂+1.25⊖	+0.75⊂−1.50⦶ −0.75⊂+1.50⊖	+1.00⊂−1.75⦶ −0.75⊂+1.75⊖	+1.25⊂−2.00⦶ −0.75⊂+2.00⊖
−1.00 C. 90°	+0.25⊂−1.25⦶ −1.00⊂+1.25⊖	+0.50⊂−1.50⦶ −1.00⊂+1.50⊖	+0.75⊂−1.75⦶ −1.00⊂+1.75⊖	+1.00⊂−2.00⦶ −1.00⊂+2.00⊖	+1.25⊂−2.25⦶ −1.00⊂+2.25⊖
−1.25 C. 90°	+0.25⊂−1.50⦶ −1.25⊂+1.50⊖	+0.50⊂−1.75⦶ −1.25⊂+1.75⊖	+0.75⊂−2.00⦶ −1.25⊂+2.00⊖	+1.00⊂−2.25⦶ −1.25⊂+2.25⊖	+1.25⊂−2.50⦶ −1.25⊂+2.50⊖

In the above formulæ the numerals and signs have the same significance as in the preceding table, but for crossed cylinders having the axis of the concave cylinder at 180° and the axis of the convex cylinder at 90°, it is necessary to *reverse the axes* throughout.

Toric Lenses.

I. *Congeneric Meridians.*

The properties of astigmatic refraction are also fulfilled in a lens by creating for it, opposite to its plane side, a single surface whose diametrically-opposed principal meridians are of unequal refraction.

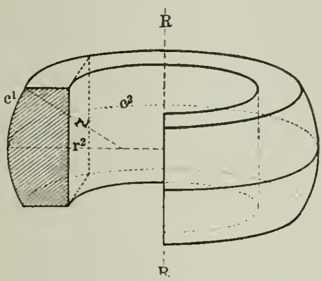


Fig. 98.

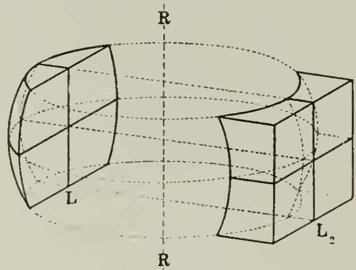


Fig. 99.

Such a surface, called a *torus,* is shown in Fig. 98, wherein the curvature, c_1, whose radius is r_1 and refraction is 3 D., is rotated upon a vertical axis, R, so as to create the curvature, c_2, whose radius, r_2, is chosen to produce 2 D.

In Fig. 99 two lenses are shown to be included within the surface so developed and an opposite plane side, the one being a plano-convex toric lens, L_1, the other a plano-concave toric lens, L_2.

From the construction it follows that these lenses are each possessed of 3 D. of refraction in the vertical meridian, and 2 D. of refraction in the horizontal meridian, so that the formulæ for the same may be expressed by:

(A_1) [+ 3 D., Ref. 90° ⌢ + 2 D., Ref. 180°] Tor. . . . . (L_1)
(B_1) [— 3 D., Ref. 90° ⌢ — 2 D., Ref. 180°] Tor. . . . . (L_2)

as a distinction from the correlative formulæ, A_2 and B_2, for a pair of crossed cylinders of identical refraction:

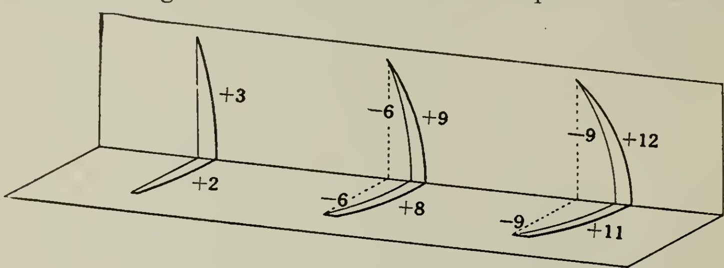
(A_2) + 3 D. cyl., axis 180° ⌢ + 2 D. cyl., axis 90°.
(B_2) — 3 D. cyl., axis 180° ⌢ — 2 D. cyl., axis 90°.

and their corresponding equivalents:

(A_3) { + 2 D. sph. ⌢ + 1 D. cyl., axis 180° (Double form).
+ 3 D. sph. ⌢ — 1 D. cyl., axis 90° (Periscopic form).

(B_3) { — 2 D. sph. ⌢ — 1 D. cyl., axis 180° (Double form).
— 3 D. sph. ⌢ + 1 D. cyl., axis 90° (Periscopic form).

The plano-toric lens, L_1 or L_2, does not generally possess any advantage over its corresponding sphero-cylindric equivalent, so that the latter combination is preferably used. However, as the convex toric surface is especially well adapted to lenses of the deep meniscus and contra-meniscus types, it is usually combined with a concave spheric surface of more or less variable curvature, due to the fact that American manufacturers, in this instance, call the weaker curvature of the toric surface the "base-curve" of the sphero-toric lens. In this respect, the meaning of the term differs from that applied by them to the spheric menisci, whose inner concave surfaces are uniformly 6 dioptries. With this understanding American manufacturers require that all orders



Plano-toric. Toric Meniscus. Base-curve, 8. Toric Meniscus. Base-curve, 11.

Fig. 100.
Congeneric Meridians.

for toric lenses shall be written the same as for sphero-cylinders, except that the desired base-curve of the toric surface must also be specified; otherwise, toric surfaces with the 6-dioptry curve are usually supplied. In case this choice should result in the lens being comparatively shallow in depth, it is advisable to select a 9-dioptry curvature for the toric surface. Incidentally, a concave toric surface is rarely used in combination with a convex spheric surface.

The object of the toric surface is to provide a definite focal interval that may be utilized in combination with any spheric surface, in order to produce the same interval between the resultant meridians of greatest and least refraction of the so-called *sphero-toric lens.*

This is made clear through comparison of the principal sections in different lenses of the same power, pictured in Fig. 100, and in which the convex *toric* surfaces are drawn with *heavier* lines, in order to distinguish them from their associated concave spheric surfaces.

Each of these lenses has + 3 D. of refraction in the vertical plane and + 2 D. of refraction in the horizontal plane, and therefore corresponds to the sphero-cylindric lens, + 2 D. sph. ⊃ + 1 D. cyl., axis 180°.

The toric meniscus or contrameniscus usually affords the advantage of allowing its peripheral area to be brought nearer to and more concentric with the eye-ball than is possible with the sphero-cylindric equivalent; so that, for all ordinary movements of the eye-ball the visual axis will be less oblique to the inner surface of the lens. This and the consequent absence of reflection from the inner concave surface also give this form of sphero-toric lens a wider and more comfortable field of vision than is obtained by the ordinary sphero-cylindric equivalent. These lenses, even in the weaker powers, are decidedly advantageous where cemented bifocal lenses are required, since the segments placed upon them for reading are inclined at an angle more closely approaching a position for perpendicular incidence of the visual axes when looking downward.

However, it frequently occurs that a toric meniscus or contrameniscus does not afford the same acuity of vision as its sphero-cylindric equivalent, owing to the fact that their respective principal points do not occupy the same positions before the eye (see description of Figs. 11 and 12). This detriment may, at times, be overcome by slightly modifying the concave spheric surface, the amount being determined by placing a weak spheric lens, between 0.12 and 0.5 (+ or −), in front of the sphero-toric lens while it is being actually used in the test for an improvement of vision.

Heretofore this procedure was unavoidable, and could not be met in any other way, because the spheric and cylindric surfaces of the lenses superposed in the trial-frame and their positions before the eye are not the same as those of the substituted sphero-toric lens. See section on *Vertex-Refraction*.

The focal interval of the toric surface may also be used to advantage in making sphero-toric lenses of the *biconvex form*, more especially in cases where the power of the spheric surface is very considerable, such as required to counteract an aphakia that is associated with astigmatism. An instance in which this type of lens is applied will best serve to illustrate its various advantages.

In examining the refraction in aphakia, it is customary, as in other cases, to place the spheric lens in the groove at the back of the trial-frame, and therefore, nearer to the eye, with the cylinder in front. For example, in a case involving

$$+ 9 \text{ D. sph.} \bigcirc + 3.5 \text{ D. cyl., axis } 160°,$$

the correction is obtained by placing a biconvex spheric lens of + 9 D. in the trial-frame behind the cylinder, + 3.5 D.

The optician would ordinarily execute this prescription *literally,* by making the lens + 9 D. spheric on one side, and + 3.5 D. cylindric on the other, thereby substituting a *plano-convex* spheric element for the biconvex one used in the trial-frame. Furthermore, in mounting the lens, he would place the spheric surface farther from the eye, with the cylinder inside, thus causing the spectacles to be worn with the surfaces of the lens *reversed* with respect to their positions before the eye in the trial-frame.

It is, therefore, obvious that the serious error is committed of substituting a lens which involves a change in the relative positions of its principal points, thus changing the position of the focus within the eye and to a degree impairing the visual acuity obtained by the spectacles, as compared with that secured by the test in the trial-frame. Aside from this we have, in the aforesaid sphero-cylindric lens, the detrimental phenomenon of *internal reflection,* caused by the extreme bulging forward of the convex element, whose surface is ex-

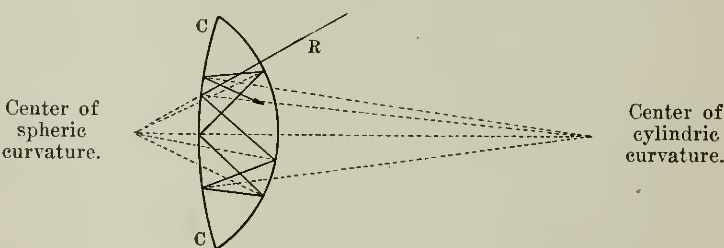


Fig. 101.

posed to light coming from other directions than that of the desired centrally incident beam.

Every ray of light, R, Fig. 101, entering the convex spheric surface in a direction coincident with its radius of curvature, will enter the lens *unrefracted*, and fall upon the inner surface, C, of the cylinder on the other side.

Under favorable conditions such a ray will be reflected from C back to the inner anterior surface of the lens, there again undergoing reflection, and so on, until it becomes dissipated within the lens as diffused light. The dotted lines in the diagram represent the radii of curvature as dividing the angle of incidence and reflection equally at the points of impact on the surfaces within the lens.

Therefore, the person wearing such spectacles is compelled to look, as it were, through a self-luminous medium that tends to interfere with the direct central incident beam of light passing through it to his pupil. Again, in this form of lens the aberration is greater for all excursions of the eye where the visual axis is directed through the lens at points not coinciding exactly with the optic axis of the lens.

These facts were clearly exemplified in a case which came to the author's notice in 1889. The lens had been made of the sphero-cylindric form and power as above stated. The patient complained of inability to correctly judge distances in looking downward, and of an annoying glare of light which he felt was within the lens itself when worn out of doors, or in a strong light. He thought, if the glare could be removed he would be enabled to see better. In fact, he had made the experiment of shading the lens by sighting through the partially closed hand held closely before it, and had noticed less disturbance from the glare.

The sphero-cylindric correction, then worn by him, gave him scarcely better than 6/9 of vision, whereas the test lenses in the trial-frame gave him the somewhat unusual acuteness of 6/6.

It occurred to the author that the interior reflections could be avoided by constructing the lens with less curvature on the anterior surface. Therefore, a lens having a toric surface on the anterior side, and a spheric surface on the other was suggested as follows: + 6 D. sph. combined with a toric surface of + 6.5 D., axis 160° by + 3 D., axis 70°, in place of 9 D. sph. ⌢ + 3.5 D. cyl., axis 160°.

Before proceeding to consider the equivalence of these lenses, it is suggested that all thought of a simple cylindric form should be dispelled from the mind when the toric surface is referred to. The subject will be more easily understood by dealing only with the principal refracting meridians, without regard to the other meridians of curvature that give form to the toric surface.

Referring to the lens, + 9 D. sph. ⌢ + 3.5 D. cyl., it is evident that the meridian of least refraction is 9 D., and the meridian of greatest refraction is 12.5 D., as indicated by m and M in the rectangular planes of Fig. 102.

The extreme spheric curvature, 9 D., on the anterior surface may be lessened to any desired degree, provided the loss of refraction is compensated for by adding it to the opposite cylindric side of the lens, in which case the simple cylindric surface would necessarily be *replaced* by a surface of astigmatic refraction, a toric surface, having the required focal interval of 3.5 D. To obtain such an equivalent lens of *thinnest biconvex form,* it is only necessary to divide the original meridian of greatest refraction, M = 12.5 D., in two parts, as nearly equal as possible; say 6 D., for the back surface, and 6.5 D. for the front surface, which, together, give 12.5 D. for the newly-created *biconvex* meridian of greatest refraction, M_1, Fig. 102, in the desired equivalent lens.

Taking 6 D. as the posterior spheric surface, it is necessary to combine it with 3 D. on the anterior surface to secure 9 D. as the meridian of least refraction, m_1, in the new lens. Consequently, 6.5 D. and 3 D., respectively, represent the refraction of each of the principal meridians of the anterior toric surface, which, when combined with the 6 D. posterior spheric surface, fulfills all the requirements of equivalence, as shown in the sections delineated in Fig. 102.

The sphero-toric lens referred to was set in a spectacle-frame, with the toric surface outward, and its meridian of least refraction at 160°, so that the refracting elements occupied the same positions as the lenses in the trial-frame.

The spectacles were worn by the patient for nine years prior to his death, with complete relief from all the disagreeable phenomena men-

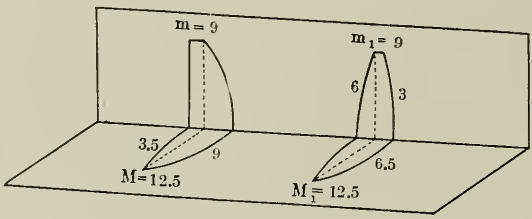


Fig. 102.

tioned. It may also be stated that his visual acuteness with the new lens was slightly better than 6/6.

For reading, the patient required + 12 D. sph. ⊃ + 3.5 D. cyl., axis 160° in the trial-frame, which was given him in the form of a sphero-toric lens: + 8 D. sph. ⊃ toric surface of + 7.5 D., axis 160° by + 4 D., axis 70°.

In addition to the advantages mentioned, the patient was saved the annoyance of wearing uncomfortably heavy lenses that would also attract attention. In every similar instance where the author has applied the sphero-toric lens it has given satisfaction, though in only two other cases has the visual acuteness been so perfect as in the one just cited.

The use of the sphero-toric lens is by no means confined to cases of aphakia, since equally good results can be secured by its use in high degrees of compound myopic astigmatism, especially where the cylindric corrections are weak in comparison with the high spheric curvatures involved. Still greater advantages are to be secured through making one surface of the lens *aspheric*. See section on *Aspheric Lenses of Wide Aperture*.

II. *Contra-generic Meridians.*

While it is also possible to produce a toric surface with *contra-generic* meridians, such as indicated in Fig. 103 and Fig. 104, yet it is not used either separately or in combination with a spheric surface, because its focal interval may be more conveniently utilized through

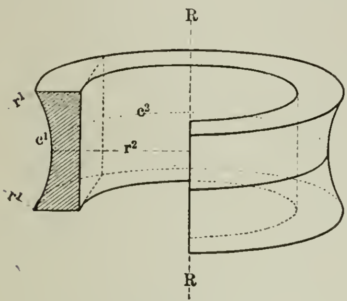


Fig. 103.

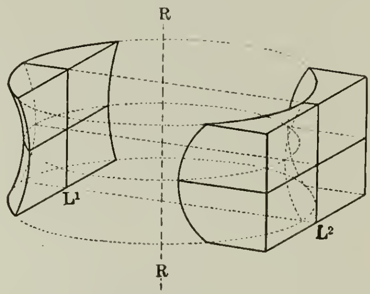


Fig. 104.

combining the usual convex or concave toric surface, shown in Fig. 99, with a suitable spheric surface. The diametrically opposed principal meridians in each of the lenses in Fig. 104 are convex and concave, so that their correlated refractions may, for convenience of illustration, be expressed by:

(C_1) [— 3 D. Ref. 90° ⌒ + 2 D. Ref. 180°] Tor. .... (L_1)
(D_1) [+ 3 D. Ref. 90° ⌒ — 2 D. Ref. 180°] Tor. .... (L_2)

so as to distinguish them from the corresponding formulæ for crossed cylinders of identical refraction:

(C_2) — 3 D. cyl., axis 180° ⌒ + 2 D. cyl., axis 90°
(D_2) + 3 D. cyl., axis 180° ⌒ — 2 D. cyl., axis 90°

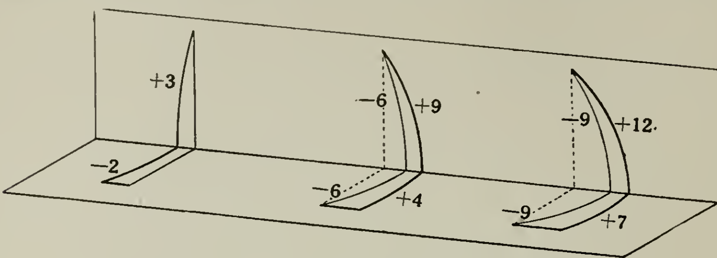
and their sphero-cylindric equivalents, which are, respectively:

(C_3) { + 2 D. sph. ⌒ — 5 D. cyl., axis 180°
— 3 D. sph. ⌒ + 5 D. cyl., axis 90°

(D_3) { — 2 D. sph. ⌒ + 5 D. cyl., axis 180°
+ 3 D. sph. ⌒ — 5 D. cyl., axis 90°.

The last mentioned lens is pictured to be equivalent in refraction to the principal sections in Fig. 105, and in which the focal interval of 5 D. is also the numeric difference between the principal meridians of the toric surfaces.

It is sometimes preferable to select a *toric surface* for the deeper and *inner concave surface* of a lens having contra-generic meridians,



Plano-toric. Toric Meniscus. Base-curve, 4. Toric Meniscus. Base-curve, 7.

Fig. 105.

Contra-generic Meridians.

the choice being usually governed by the nature of the visual defect that it is intended to counteract. In other words, the curvatures of the toric lens should as closely as possible harmonize in kind and position before the eye with those occupied by the sphero-cylindric lens in the trial-frame.

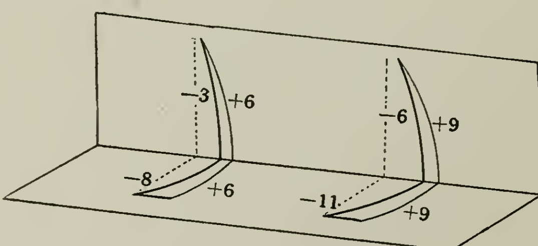


Fig. 106.

Concave Toric Surfaces.

For instance, the sections in Fig. 106 make it clear that the 6 D. and 9 D. spheric curvatures may be made convex instead of concave, through combining them with *concave* toric surfaces that should be placed next to the eye, the same as would be the case if a lens + 3 D. sph. ⊂ — 5 D. cyl. were used, and in which the concave cylindric element is worn near the eye.

Wide-Aperture Lenses.

In order to satisfy the stipulation that the focus of an ophthalmic lens shall coincide exactly with the far point of the ametropic eye, it is evident that two lenses of materially different forms (bispheric and meniscus or contrameniscus), placed alternately at the same distance from the eye, must differ in power, because the distance between their respective focal and principal points is then not the same dimension. For instance, the thin meniscus, whose principal points are slightly beyond the outer surface of the lens, and therefore farther from the far point of the hyperopic eye, should be correspondingly weaker than the biconvex trial-lens; whereas, the thin contrameniscus, having its principal points somewhat nearer than the inner surface of the lens and closer to the far point of the myopic eye, must be a little stronger than the biconcave trial-lens. See section on *Vertex-Refraction.*

For this reason the representatives of Carl Zeiss in Jena, Germany, the Bausch & Lomb Optical Co., have in America introduced a more exact system, devised by Prof. Moritz von Rohr, through which the dioptral powers of ophthalmic lenses are expressed in vertex-refraction (D_v), as reciprocals of their focal lengths, which are counted from the vertices of their back surfaces, irrespective of typical lens-form. This principle applies advantageously to all lenses of wide aperture and especially to the so-called Punktal lens, which is numbered in vertex-refraction and designed to eliminate the astigmatism due to oblique light-incidence and to render available a field of view of about 60°, in order that objects viewed through the extreme marginal zone of the lens may be seen as distinctly as through its center. In other words, each point of the object is faithfully reproduced as a distinct point in the image formed by the Punktal lens, which is either a meniscus or contrameniscus, whose concave surface is different for each power between 0.25 D_v and 20 D_v, the other surface being either spheric or toric. However, there is a notable exception, namely, when the power of the *convex* Punktal lens exceeds 7 D_v it is called a Katral lens, in which the concave surface is made *aspheric,* in order to correct the aberration for the full aperture of a meniscus of high power. Punktal inner curves vary by 0.0012 meters and sometimes less, being ground and polished with the same care as a photographic objective, so that, if bifocal lenses are desired, they can only be made in the fused type. Similarly devised lenses are being exploited in Germany, by different makers, under the names, Rectaviz and Isokryster, respectively.

Punctilious application of vertex-refraction entails provision being made for determining the exact distance between the cornea of the eye and the back surface of the trial-lens in a trial-frame of special construction; this being supplemented by an instrument, vertex dioptrometer, which accurately measures the lens of any type that may be subsequently used to substitute the lens or lenses in the trial-frame. To facilitate this substitution without the measuring instrument tables are supplied through which may be ascertained the vertex-refraction of the ophthalmic lens that is required to be worn at a prescribed distance from either the myopic or hyperopic eye, because such indicated powers are dependent upon the distance between the cornea and the proximate vertex of the accurately adjusted trial-lens. As this interpolar distance naturally varies with the facial anatomy peculiar to different individuals, it is necessary in the tables to give it specifically different values from 4 mm. to 20 mm. If the correcting lens is to be a meniscus or contrameniscus, allowance must also be made for the vertex-depth of its concave surface, since the pole of this lens, with respect to the interpupillary plane of the frame, will be farther from the eye than the pole of the lens used in the trial-frame, and from whose vertex the interpolar distance is measured.

Therefore, still another table of corrections is supplied, in which the vertex-depths, in millimeters, are given for a series of concave surfaces, varying in power between — 1 D. and — 20 D., upon lenses whose diameters vary by millimeters between 34 mm. and 46 mm. In fact, strict compliance with this table is of greatest moment when prescribing menisci and contramenisci or Punktal and Katral lenses whose powers exceed 3.5 D_v. None of these lenses admit of being neutralized by each other, or by lenses of other types.

Reverting to the first mentioned tables we find 17 different dioptral powers (D_v) of vertex-refraction are introduced as equivalents for each of the powers of the ordinary dioptral lenses that are placed at the same number of distances from the cornea.

TABLE I

Myopic Eyes

Axial Refraction in Diopt.	Vertex Refraction of Correcting Lens for a Distance in Millimeters between Vertex of Lens and Vertex of Cornea Equal to																
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
— 3.00	3.05	3.05	3.05	3.10	3.10	3.10	3.10	3.10	3.10	3.15	3.15	3.15	3.20	3.20	3.20	3.20	3.20
— 3.25	3.30	3.30	3.30	3.35	3.35	3.35	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.45	3.50	3.55	3.60
— 3.50	3.55	3.60	3.60	3.60	3.60	3.65	3.65	3.65	3.70	3.70	3.70	3.70	3.70	3.75	3.75	3.80	3.80
— 3.75	3.85	3.85	3.85	3.85	3.90	3.90	3.90	3.95	3.95	3.95	3.95	4.00	4.00	4.00	4.05	4.05	4.05
— 4.00	4.10	4.10	4.10	4.10	4.15	4.15	4.20	4.20	4.20	4.25	4.25	4.25	4.30	4.30	4.35	4.35	4.35
— 4.25	4.35	4.35	4.40	4.40	4.45	4.45	4.45	4.50	4.50	4.50	4.55	4.55	4.60	4 60	4.60	4.65	4.70
— 4.50	4.60	4.65	4.65	4.70	4.70	4.75	4.75	4.75	4.80	4.80	4.85	4.85	4.90	4.90	4.90	4.95	5.00
— 4.75	4.90	4.90	4.95	4.95	5.00	5.00	5.00	5.00	5.10	5.10	5.10	5.15	5.20	5.20	5.25	5.30	5.30

TABLE II

Hyperopic Eyes

Axial Refraction in Diopt.	Vertex Refraction of Correcting Lens for a Distance in Millimeters between Vertex of Lens and Vertex of Cornea Equal to																
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
+ 3.00	2.95	2.95	2.95	2.95	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.85	2.85	2.85	2.85	2.85	2.80
+ 3.25	3.20	3.20	3.20	3.15	3.15	3.15	3.15	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.05	3.05	3.05
+ 3.50	3.40	3.40	3.40	3.40	3.35	3.35	3.35	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.25	3.25	3.25
+ 3.75	3.70	3.65	3.65	3.65	3.60	3.60	3.60	3.60	3.55	3.55	3.55	3.55	3.50	3.50	3.50	3.50	3.50
+ 4.00	3.90	3.90	3.90	3.90	3.85	3.85	3.80	3.80	3.75	3.75	3.75	3.75	3.75	3.70	3.70	3.70	3.70
+ 4.25	4.15	4.15	4.10	4.10	4.10	4.10	4.05	4.05	4.05	4.00	4.00	4.00	4.00	4.00	3.95	3.90	3.90
+ 4.50	4.40	4.40	4.35	4.35	4.30	4.30	4.30	4.25	4.25	4.25	4.20	4.20	4.20	4.15	4.15	4.15	4.10
+ 4.75	4.65	4.65	4.65	4.60	4.55	4.55	4.50	4.50	4.50	4.50	4.50	4.40	4.40	4.40	4.35	4.35	4.35

TABLE III

Vertex-Depths of Ophthalmic Lenses

Curvature of the Hollow Surface of Lens	For Diameters in Millimeters Equal to												
	34	35	36	37	38	39	40	41	42	43	44	45	46
– 3.00	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.5
– 3.25	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.6	1.6	1.7
– 3.50	1.1	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.7	1.7	1.8	1.8
– 3.75	1.1	1.4	1.4	1.3	1.4	1.5	1.6	1.6	1.7	1.8	1.9	1.9	2.0
– 4.00	1.2	1.2	1.4	1.4	1.5	1.6	1.6	1.7	1.7	1.8	1.9	2.0	2.1
– 4.25	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.7	1.8	1.9	2.0	2.1	2.2
– 4.50	1.3	1.4	1.5	1.5	1.6	1.7	1.8	1.8	1.9	2.0	2.1	2.2	2.3
– 4.75	1.4	1.5	1.6	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5

These tables are abbreviations of the originals covering the full range of powers between 0.25 and 20 dioptries, as published by the Bausch & Lomb Optical Co.

For instance, the regular trial-lens of + 4 D., whose pole is 4 mm. from the cornea, is equivalent to + 3.9 D_v, whereas, if placed at 12 mm., it is + 3.75 D_v, or, if at 20 mm., it is + 3.7 D_v. Consequently, in order to secure the full benefit of this exploited precision, accurate measurement of the actual interpolar distance is of the utmost importance, if indeed the lens that precisely corresponds to it can be supplied within the range of dioptral values given in the tables as equivalents and needful substitutions in vertex-refraction, and which would, of course, represent an unprecedented degree of precision among ophthalmic lenses.

However, for the present the range of powers in vertex-refraction for Punktal lenses is being confined to quarter-dioptry intervals, so that the actual vertex-refraction of the ordinary trial-lens of a given number will in practice have to be substituted by the nearest available power of a Punktal lens that is to occupy the same position given in the tables, I and II. Still, this *method* of substitution may be conveniently avoided through the use of the vertex-dioptrometer, which measures the dioptral refraction from the vertex of the lens instead of from the principal point.

Both surfaces of the Punktal lens are mathematically calculated upon the assumptions that the back surface of the lens is 25 mm. from the center of rotation of the eye-ball, and that the lens and the refractive media of the eye together constitute an optical system in which the cross-section of the refracted pencil of light at this center of rotation is the exit-pupil of the system. This motive being strictly complied with makes it evident that the relative proportions to each other of the front and back surface-curvatures necessary to provide a range of powers in Punktal lenses can only in very exceptional instances, if any, be the same as those of the ordinary menisci and contramenisci having standard base-curves of 6 D. or 9 D. and which, "because of their similar correction of astigmatism in the marginal parts, have a useful field of view of 52°." Therefore, it remains to be seen whether a greater variety of well chosen base-curves applied to the latter may not after all in some instances, by way of substitution, suffice to produce an inappreciable difference when such improved wide-angled lenses are practically applied, especially as the fields of view of similar lenses are now only 4° less at the margin than in Punktal lenses. In fact, this proposition would merely involve "bending the lens" in strict accordance with the formulæ known to physicists (*Principles of Geometrical Optics.*—Southall) long before the successful attempt was made by Dr. M. von Rohr to correct the aberration in lenses of high power by means of the *aspheric* surface, and which is now exclusively applied to and admitted to be necessary only in menisci and contramenisci above 7 D_V. See section on *Aspheric Lenses of Wide Aperture.*

In order to meet this emergency the Bausch & Lomb Optical Co. has engraved its trade-mark upon each Punktal lens, and, indeed, so faintly that it requires a special instrument to detect it. Although in a few typical forms and powers the Punktal lens may be objectionably thick, it is unquestionably the most scientifically devised ophthalmic lens as yet produced.

Aspheric Lenses of Wide Aperture.

Dr. Moritz von Rohr, physicist, of the firm of Carl Zeiss, Jena, Germany, at the suggestion of the ophthalmologist, Dr. A. Gullstrand, Upsala, Sweden, mathematically determined the curvatures of the so-called Gullstrand cataract lens, which is provided with a concave surface that is more acutely curved near its periphery, a spheroid surface, which Dr. von Rohr calls an *aspheric surface,* whose function it is to counteract the astigmatism produced by the oblique ray-bundles that would otherwise enter the eye when the visual axis is directed through the peripheral parts of a spheric lens of high power, and such as is required to correct the refraction in aphakia, whether paraxial astigmatism is present, or not.

Lenses of this type, from $+ 8\ D_v$ upward, being designed for surgically operated cataract cases, are now being sold by the Bausch & Lomb Optical Co. as Katral lenses, which have the same optical properties as Punktal lenses. Either of these lenses provides an unrestricted field of 60°, permitting the wearer to rotate the eyes in a normal manner and to secure distinct vision even through the margins of the lens.

In a Katral lens of $12\ D_v$ the radius of the osculating sphere is actually 140 mm., and the difference of the aspheric surface is only 0.16 mm., which shows the extreme precision applied in their manufacture.

At a meeting of the Ophthalmological Society in Heidelberg, 1910, von Rohr exhibited photographic plates which demonstrate that Gullstrand's cataract lens, in this instance an *asphero-toric meniscus,* permits excursions of the visual axis from the pole of the lens toward its periphery to the extent of 30° in one of its principal sections, and 36° in the other, with greater freedom from aberration than is obtained for a similar excursion of 12° behind a sphero-cylindric lens intended to correct 13 D. and 7 D. of refraction in the principal sections of the eye that are inclined to each other at an angle at 45°.

However, applications of the Katral lens involve intricate calculation being made for its construction, the same being based upon definite information respecting the distance between the cornea of the eye and the proximate surface-vertex of the inner trial-lens in the trial-frame, either in case a spheric or sphero-cylindric lens is used in it for distant vision, or for reading at a specified distance. Similar specifications are required in order to calculate the curvatures of a contrameniscus for extreme myopia. The cost of each Katral lens is listed between $20.00 and $55.00, the price depending upon its typical form and power.

Incidentally, it may be mentioned that aspheric surfaces have been produced at the Zeiss works ever since 1899, yet their applications were later confined chiefly to the finer wide-angled condensers for the substage of the compound microscope, and in 1910 von Rohr incorporated the aspheric surface in the aplanatic lens used in Gullstrand's ophthalmoscope, which is constructed especially to obviate the extraneous light-reflections from the observed eye. In 1908 von Rohr gave credit to his colleague, O. Henker, for having perfected the mechanical agents through which Gullstrand lenses were produced and photographically tested to prove their efficiency.*

Aberration.

The desired deviation which rays of light sustain in their passage through a lens is exposed to two principal faults that prevent the refracted rays from meeting in a common focus, thus producing a distorted or indistinct image that is also associated with more or less color. The latter phenomenon is called *chromatic aberration*, and is due to the decomposition of white light produced by the inherent variable prismatic power of the lens, which is greater near its edge.

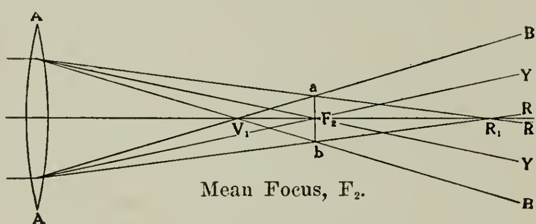


Fig. 107.
Circle of Chromatic Aberration, ab.

The violet rays of the spectrum, being more refrangible than the red rays, cause the former to cross the optic axis nearer to the lens, so that the more remote focussed image is fringed with color, usually blue.

The focal length of the lens is shorter for blue rays than for red rays, or the two principal foci, F_1 and F_2, for blue rays, B, are nearer to the lens than those for red rays, R, Fig. 107. Nevertheless, a lens may be constructed so as to be tolerably free from this defect, when it is called an *achromatic lens* (see *The Fundamentals of Achromatism*). It commonly consists of two superposed spheric convex and concave lenses, usually united through balsam, and respectively made of glass

* Die Theorie anastigmatischer Starbrillen, M. von Rohr.—Bericht ueber die XXXV Versammlung der Ophthalmologischen Gesellschaft, Heidelberg, 1908.
Ueber Gullstrandsche Starbrillen mit besonderer Beruecksichtigung der Korrektion von postoperativem Astigmatismus, M. von Rohr.—Bericht ueber die XXXVI Versammlung der Ophthalmologischen Gesellschaft, Heidelberg, 1910.
Ueber neuere Bestrebungen in der Konstruktion ophthalmologischer Instrumente, M. von Rohr.—Bericht der XXXVII Versammlung der Ophthalmologischen Gesellschaft, Heidelberg, 1911.

having different refractive and dispersive powers, such as crown-glass and flint-glass, with their curvatures so accurately proportioned that the chromatic aberration produced by one lens is counteracted by that of the other lens. However, in ophthalmic lenses, chromatic aberration is not so manifest as *spheric aberration,* which consists of both *longitudinal* and *lateral aberration,* due to a curvature of the lens which causes those rays that are refracted near its edge to cross each other before reaching the more or less sharply defined focal point, F_2, Fig. 108, of the central rays. These consecutive points of intersection, p_1, p_2, etc., generate in any principal axial plane a caustic curve whose cusp is at the focus, F_2. Consequently, the entire bundle of refracted rays is enveloped by a surface called the *caustic,* which is the evolute of the refracted wave. Even actual point-images which are necessarily

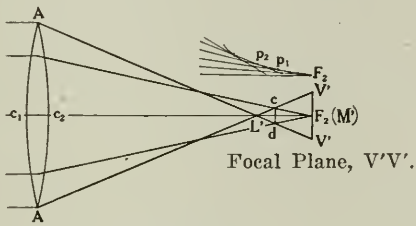


Fig. 108.
Least Circle of Spheric Aberration, cd.

formed by bundles of rays of finite aperture (a narrow zone immediately surrounding the optic axis) are, in general, more or less associated with longitudinal aberration that is not discovered by the eye, owing to its comparatively poor resolving power. Furthermore, the rays of an isolated bundle, obliquely incident upon a very small surface-element at the peripheral part of the lens, are transformed by refraction, at a surface of any form, into a non-homocentric or astigmatic bundle of rays, all the rays of which, at least to a first approximation, intersect two definitely short lines, the so-called image-lines of the bundle. This phenomenon was referred to under *Astigmatism,* and which, under suitable conditions, was also shown to be inherent in any simple lens. The longitudinal aberration is measured along the optic axis, being the distance between the focus, F_2, of the paraxial rays and the nearer point of axis-intersection, L′, of the rays that emerge from the periphery of the aperture, and upon whose magnitude, $L' F_2$, the aberration depends. The longitudinal aberration in thin lenses of the same focal length varies with their form; in other words, it depends upon the curvatures, c_1 and c_2, given to the lens. Since it is not practically feasible to entirely abolish longitudinal aberration in an infinitely thin lens that is exposed to an object-point situated at infinity, and in order to secure at least the minimum aberration in a thin lens so exposed, the curvatures c_1 and c_2 must bear the following relation (*Principles of Geometric Optics,* Southall) to each other:

$$c_1 : c_2 = \frac{n(2n+1)}{2n^2 - n - 4} \quad \text{XV.}$$

$$\text{when } c_1 = \frac{n(2n+1)}{2(n-1)(n+2)} f, \text{ and } c_2 = \frac{2n^2 - n - 4}{2(n-1)(n+2)} f, \quad \text{XVI.}$$

wherein n is the refractive index, f is the focal length, and $c_1 = \frac{1}{r_1}$ and $c_2 = \frac{1}{r_2}$ are the curvatures of the bounding lens-surfaces whose radii are r_1 and r_2. Within certain rational limits it is also feasible to vary the curvatures of the opposite surfaces of a lens without altering its focal length; this procedure being called "bending the lens." For instance, it is "bending the lens" to give a lens of given focal length such typical form as shall correct spheric aberration throughout its entire field, as in the Punktal lens. Through the above equations, and the choice of an index $= 3/2$ it can be shown that a biconvex or biconcave lens has the least longitudinal aberration when the curvature of its front surface, c_1, is six times as great as the curvature, c_2, of its back surface (the greater curvature having the shorter radius). This lens is called a "crossed lens."

The plano-convex lens is nearly as good as the crossed lens whose aberration is only 2 or 3 per cent. less than the former, is easier to make, and therefore, more commonly used in eye-pieces, etc. The crossed lens of flint-glass, with a refractive index of 1.6, is a plano-convex lens. The *least circle of aberration* is perpendicular to the axis and located within the amplitude of the longitudinal aberration. Its diameter is determined by the intersections of the edge-rays with the caustic surface after these rays have crossed the axis. The distance of the least circle of aberration, cd, from the image-point is approximately equal to ¾ of the longitudinal aberration of the extreme outside ray.

The radius, M′ V′, of that circle inside of which all the rays of the bundle cross the perpendicular image-plane at the cusp, and which is produced by intersections of the extreme edge-rays with the image-plane, is called the *lateral aberration*.

Spheric aberration may also be more or less obviated by means of an aperture-stop placed in close proximity to the lens so as to exclude the peripheral rays that would otherwise interfere with the central rays in their production of a distinct image. In fact, this is accomplished in the construction of every compound lens-system through introducing an annular disk of *calculated* diameter, known as the *diaphragm* or stop, which is suitably placed between the lenses to effectually exclude the peripheral rays. If the proper diaphragm be replaced by one of smaller aperture, we increase the definition, but diminish the extent of field and illumination. A larger aperture will increase illumination and field, but definition will be impaired, on account of the aberration thus allowed.

The aperture of the diaphragm must, therefore, have a definite and specific diameter in every optical instrument, if we are to secure *maximum* definition and illumination, *without aberration*. The proper diaphragm is, therefore, one of the most important and indispensable parts of every compound dioptric system.

The following description of ocular aberration is given, because the aberration of the eye itself should be explained in an essay which aims to describe the lenses used to remedy its various optical defects.

Ocular Aberration.

The human eye, being a compound dioptric system, is provided with its diaphragm—the iris. In the eye, which is a dynamic apparatus given to variations of power, a fixed diameter of pupil would fail to theoretically fulfill the requirements. When the eye is in a state of accommodation, it becomes a stronger refracting system, and therefore needs a smaller aperture of diaphragm, hence the pupil contracts.[1] Yet, Helmholtz [2] says: "A. von Graefe observed in an eye from which he had removed the iris by operation that the normal range of accommodation was still present, and also that the changes in the anterior curvature of the lens could still be observed." He concludes: "The iris, therefore, does not play an important rôle in accommodation" (lit. trans.). Landolt [3] expresses the same opinion. While the measurements referred to are undoubtedly correct, yet, if the conclusion

1. In fact, it was at one time supposed that contraction of the pupil was the only means by which the eye adapted itself for near vision. Helmholtz, *Physiologische Optik*, page 151, Hamburg and Leipzig, 1886.
2. Helmholtz, *Physiologische Optik*, page 138.
3. Landolt, *Refraction and Accommodation of the Eye*, page 164, Philadelphia, 1886.

reached is construed in its broadest sense, it discountenances the value of the iris as a diaphragm entirely.

It is, nevertheless, universally admitted that the iris does act independently of, yet simultaneously with, accommodation.[4] When acting independently of accommodation, the iris is known to behave as a highly sensitive photostat,[5] through regulating the volume of light upon the retina to such a degree as shall be most agreeable to the light-perceptive sense.

A most subtle and synchronous balance, between retinal perception, uveal stimulus and iritic response, must, therefore, exist, if the iris is to perform its functions simultaneously as diaphragm and photostat.

An endeavor is here made to support the hypothesis that *a disturbed equilibrium of these functions is probably the cause of asthenopia in low degrees of ametropia.* From a strictly optical point of view every eye of the same refraction, other things being equal, should have a pupil of the same diameter—one suited, by *calculation,* to exclude peripheral aberration, while securing the greatest tolerable illumination. This, however, is not known to be the case, nor has the author found that any one has ever calculated what the diameter of the pupil should be for any given schematic eye. Listing has calculated a table showing the changes in diameter of the diffusion circles upon the retina which arise through efforts of accommodation in a schematic eye having a pupil of 4 mm. (Helmholtz, *Physiologische Optik,* page 127.)

We have thus far been content to know that pupils differ in size in different persons. There must, however, be a *limit* to the maximum diameter of the pupil, if aberration is to be excluded, and if, *for any reason,* the pupil is prevented from contracting to at least this limit, we shall have aberration and an associated impairment of vision, even in the emmetropic eye.

This is exaggeratedly shown in Fig. 109, in which the central incident rays, cc, focus at f upon the retina, while the peripheral rays, pp, produce thereon an area of diffusion,† ab, and which, to all practical purposes, would be equally as effective in impairing vision as a low degree of myopia, having its intra-ocular focus anywhere between the

4. "Movements of the iris are nevertheless associated with accommodation; they are governed by the same nerves as the latter, so that, until the mechanism of accommodation is better understood, a direct relation between them may not be looked upon as being improbable" (lit. trans.).—Donders, *Refraction and Accommodation,* page 485, Wien, 1866.

5. Photostat, Greek Φῶς (Φωτ-) light, + ατατός, verbal adjective of ἱστάναι, stand—an automatic light regulator, suggested by the author in "The Iris, as Diaphragm and Photostat."—*Annals of Ophthalmology and Otology,* October, 1895.

† For purposes of lucid illustration, the diffusion areas in all of the diagrams are greatly exaggerated.

retina and f_1. Therefore, *it is evident that the instillation of a mydriatic, even in the emmetropic eye, also produces a defect which is not to be mistaken for a lenticularly corrigible ametropia.* In fact, it is questionable whether the eye can discriminate between images which are impaired by peripheral aberration and those that are illy defined through slight errors of refraction. The following experiment will serve to illustrate this. By placing a 1 D. convex lens before the emmetropic eye, it is practically rendered myopic for distance, the letters of the test-card at 6 m. becoming indistinct, with a probable reduction in the visual acuteness to, say, 6/9. If the lens be now covered with a pin-hole disk, normal acuteness of vision will be re-

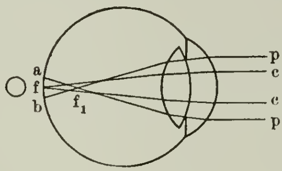


Fig. 109.

established, with no other appreciable difference than that the field and illumination are less. We may, therefore, consider the peripheral rays, here accompanying the increased refraction, as aberrative rays with respect to the enclosed central incident beam, so that an eye capable of contracting its pupil to the same extent would, in part. similarly correct its error of refraction.

This is undoubtedly one reason why errors of refraction of the same degree are not accompanied by the same diminution of visual acuteness in different individuals. The myope of 1 D., with small pupils, *without* glasses, will probably have better vision than the myope of 1 D. with much larger pupils. Within certain limits, peripheral aberration and anomalies of refraction are analogous in destroying definition of the image. A slight error of refraction, with large pupils. may produce diffusion circles equally as pronounced as a considerable refractive error with small pupils.

Asthenopia is, therefore, quite as apt to be experienced on account of the size of the pupil as it is on account of the error of refraction.

This should explain why it is that many persons, having small pupils, endure a considerable error of refraction without inconvenience, whereas others, with large pupils and small errors of refraction, are afflicted with asthenopia. Again referring to Fig. 109, the larger the pupil the greater will be the zone of peripheral aberration and its correlated diffusion-area, ab. In fact "the peripheral aberration upon the optic axis is known to increase, not only in proportion to the square of the aperture, but, also *pari passu* with the refraction'' (physical law), so that we should have greater diffusion circles upon the retina, when the ciliary muscle is brought into action, even in emmetropia, to correct the peripheral aberration that impairs the sharp definition at f. The only stimulus that could assist in correcting the aberration in this case would be that which, imparted to the

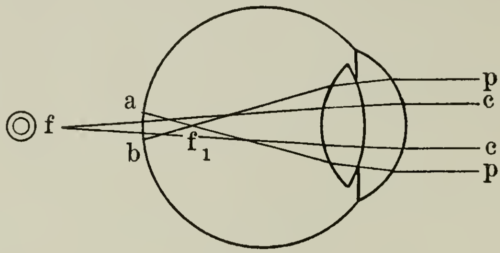


Fig. 110.

iris from the retina, would cause the pupil to contract sufficiently to exclude peripheral rays. In here speaking of the retina, we of course take for granted its highest state of physiologic development. The question then arises: In low degrees of ametropia, is such stimulus imparted to the iris *independently of accommodation, without increased light intensity?* If there is such independent action on the part of the iris, ineffectual efforts of the ciliary muscle to correct

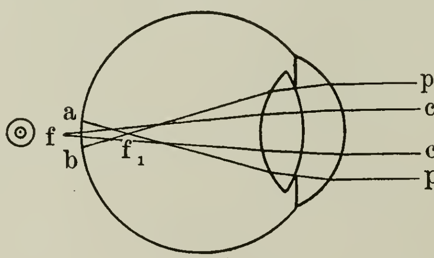


Fig. 111.

impaired vision may be followed by a contraction of the pupil necessary to shut out the peripheral rays. As to this, let us investigate the relation that should exist between the iris and accommodation in the slightly hyperopic eye.

In this case, Fig. 110, the central rays, cc, are focused behind the retina at f, the peripheral rays crossing at f_1 to produce the diffusion-area, ab. In *facultative hyperopia* there will be accommodation sufficient to bring f forward to the retina. With this increased refraction, however, the pupil remaining the same, f_1 will recede from the retina, with a corresponding increase in the size of the diffusion-area, ab.* It is, therefore, evident that, if *increased* aberration is to be avoided, a *normal* pupil must contract concurrently with the accommodation. This, generally speaking, is known to be the case. If, as in Fig. 111, the hyperopia is of low degree, with an *excessively* large pupil, we shall have a comparatively small central area of diffusion, due to the refractive error, covered by a much larger area of diffusion and illumination, ab. The slightest effort of accommodation would tend to sustain or increase this discrepancy. Therefore, it follows that, if the aberration is to be abolished, the iris must receive an increased stimulus to bring about a contraction of the pupil *in excess of that which is concurrently associated with accommodation, and that, too, for every change in light intensity.* Were this not the case, vision

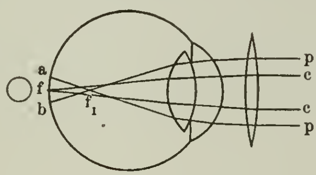


Fig. 112.

for distance,† with excessively large pupils, would be impaired by aberration under all circumstances.

The additional stimulus to contraction is undoubtedly due to the *increased area of illumination* above mentioned. This would seem to imply that the contraction of the pupil not only responds to the light intensity (quality), but also to its area (quantity) upon the retina.

It is also evident that the impairment of vision should be ascribed to that factor causing the greater area of diffusion upon the retina. The larger the pupil, the more will the peripheral aberration predominate over that which is produced in the center by a low degree of refractive error.

By placing the correcting lens before the eye in hyperopia we increase the refraction, thus eliminating the diffused central image while at the same time increasing the peripheral aberration, and,

* Listing's table shows that the diffusion circles upon the retina increase more rapidly as the object approaches the eye at short range.—Helmholtz, *Physiologische Optik*, page 128.

† In accommodation, with a standard light placed behind the plane of the eyes, and an approach to them of the paper upon which the test-type is printed, the illumination upon the paper increases in the inverse proportion to the square of the reduced distance between the light-source and the test-object. The illumination also varies directly as the cosine of the angle of incidence upon the illuminated surface.—Physical law of photometry.

therefore, also the *area of illumination,* Fig. 112. If the pupil contracted only in *proportion* to the consequent increased light-stimulus, there would still remain the original diameter of diffusion area. As, however, correction of the refractive error by the lens improves vision and relieves asthenopia—being *tacit proof* that the aberration is dispelled—it is evident that the pupil must contract *more* than in proportion to the aforesaid light-stimulus. Is it not then probable that the pupil contracts *more freely* when accommodation is relaxed?

In controverting this, it would be necessary to refute the following fact pertaining to combined kinetic energies:

When accommodation is in force, the iris is known to be carried forward (Helmholtz, *Physiologische Optik,* page 131, Wien, 1886) by pressure from the anterior surface of the lens, which has become more strongly curved. Such lens-pressure, *the iris remaining inactive,* would tend to incease the diameter of the pupil. On this account, greater efforts of the sphincter will be necessary to counteract this action of the lens-surface when accommodation is present, Fig. 113, than it would with relaxed accommodation, Fig. 114.

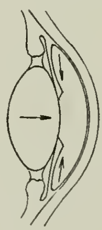


Fig. 113.

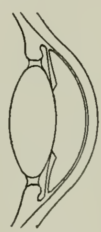


Fig. 114.

However, for normal conditions of innervation the sphincter is known to more than overcome such action on the part of the lens in accommodation, Fig. 113. If, therefore, our hypothesis is correct, we have found a reason why low-degree lenses are of so much benefit in slight hyperopia and congeneric astigmatism. Furthermore, we are justified in assuming that the sphincter in large pupils does not always adequately respond, *while accommodation is in force,* especially in cases where the optical error is so slight as a quarter-dioptry, from the fact that, in the majority of such cases the patients are young and often possesses amplitudes of accommodation varying between 6 and 14 dioptries.

Patients with such accommodation have so much of it in reserve, even when using the eyes in proximity, that their asthenopia can scarcely be ascribed to an overtaxed ciliary muscle. Are we not then justified in attributing it to possible fatigue of the iris, resulting from its involuntarily prompted, though futile, efforts to exclude peripheral aberration, on account of the sphincter's inability, *for some reason,* to contract sufficiently?

It is not recorded that a disproportion of the pupils to the dioptric system of the eyes does ever exist physiologically, but there are many conditions of the nervous system which produce immoderate dilatation of the pupils. Such dilatation, *while it lasted,* would tend to oppose the normal association between refraction and the correlated size of the pupil.

In those cases of *normal* pupil, where the perceptive function of the retina is keen and the error of refraction is slight, retinal stimulus will prompt contraction of the pupil sufficiently to exclude aberration. Is it not probable that, in some cases with *large* pupils, protracted efforts of this kind would result in fatigue of the iris? Might not prolonged ineffectual efforts of the iris to regain equilibrium between its functions, as diaphragm and photostat, account for asthenopia? Or, to put it in another way: Could not that prolonged effort of the sphincter, which would have to be *in excess* of the normal qualitative and quantitative light-stimulus to correct aberration, produce asthenopia?

It need not follow that the iris is incapable of temporarily contracting even to a greater extent than is necessary for the above purpose. This is demonstrated by the extreme contraction of which the pupil is generally capable when exposed to intense light, and the eye is in its static state of refraction.

In hyperopes, we generally ascribe the cause of asthenopia to fatigue of the ciliary muscle, owing to its efforts to exclude the error of refraction by accommodation. The same can not be said of myopes, whose use of accommodation for such purpose would only render them deplorably more myopic. Their asthenopia can certainly not be ascribed to ciliary fatigue. Some myopes, however, endeavor to improve their vision by compressing the eyelids, which means that they thereby *modify the pupils* to exclude peripheral rays and the aberration which is heightened by the myopia. In low degrees of myopia and congeneric astigmatism, however, modification of the pupils, by compression of the eyelids, is not sufficiently *delicate* to exclude aberration, *without too great a sacrifice of illumination.* Such patients are, therefore, more apt to apply for relief from glasses than those who help themselves by compression of the eyelids, provided this is unaccompanied by asthenopia. In the former cases, we are to suspect that the relief sought is *freedom from peripheral aberration.* This aberration also aggravates photophobia, which is a symptom frequently complained of in such instances.

The improvement in vision which the myope, of low degree, with large pupils, secures by the lenticular correction, is practically due to the fact that the peripheral aberration is decreased, through the reduced refraction obtained by the concave lens in front of the eye, Fig. 115.

The rays emitted from the concave lens enter the pupil with a divergence counteracting the excessive convergence of the rays which are imperfectly focused by the crystalline on the retina behind f. The peripheral diffusion-area, ab, may not, however, always be in such proportion to the central diffusion-area as to be fully corrected by the lens which corrects the refractive error in the center. Should it, in the case of a larger pupil, be greater, the patient would merely then

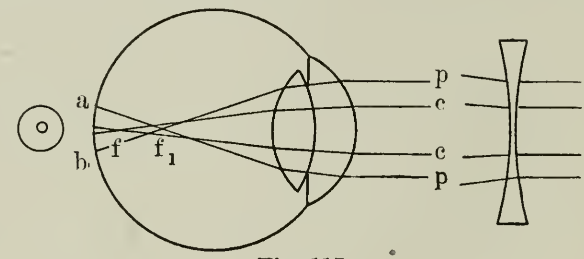


Fig. 115.

select a stronger lens having its proper effect upon peripheral rays, while its tendency would also be to overcorrect the myopia. For a low degree of myopia this would scarcely be appreciable, since very little difference in refraction is experienced in the actual centers between lenses of a quarter and a half-dioptry.

In those cases where the quarter-dioptry lens seems to relieve asthenopia it will generally be found that the pupils are comparatively large. This is especially noteworthy in those cases where myopes with lenses of trivial power are benefited by wearing their distance corrections for *reading,* and which can serve no other *needful* purpose than to eliminate peripheral aberration.

So far, we have no means of ascertaining the size of the pupil, or that variation of it, which is necessary to establish the proper harmony between refraction, accommodation, illumination and freedom from aberration. The intuitive discrimination, which accompanies experience, is at present our only guide.

In refractive errors of low degree, which are relieved by lenticular correction, the retinal perception is usually also very keen, thus increasing stimulus to contraction of the sphincter, while the correction in such cases frequently improves vision to 6/3, which is far above the conventionally accepted normal acuteness of vision.

The larger the pupil, the more pronounced will be the improvement in visual acuteness obtained by low-degree corrections. The quarter-dioptry lens rarely proves of benefit when the pupils are small.

Again, patients frequently wear such glasses, which for a time relieve the asthenopia, and ultimately lay them aside, without feeling the necessity of their further use. Examination will nevertheless reveal the fact that *the optical error has not changed.* Why then should asthenopia exist at one time, and not another, for an *invariable hypermetropic astigmatism,* for instance, if the fatigue in the first instance had only been due to that of the ciliary muscle?

Closer examination, however, will frequently show that the pupils appear to be smaller at the time the patient has discarded his glasses than when they were prescribed. The pupil being the only member seeming to have undergone a change, are we not justified in suspecting the iris, by reason of disturbed innervation, as having been at least implicated in the cause of asthenopia?

It is commonly understood that visual acuteness depends upon the perceptive functions of the retina, as well as upon the size of the image projected upon it, and which is limited by the visual angle subtended by the object at the ocular nodal point. Therefore, to the exclusion of all other considerations, the ability to discern objects primarily depends, first, upon contrast between light and shade, involving also the color sense; and, second, upon the size of the object viewed. Hence, the greater the contrast between the color of the object and the background, the more readily will an object of any given size be distinguished. Thus, it is frequently observed that a visual acuteness of 6/9, with diminished illumination, is raised to 6/6 with a maximum illumination, as a result of heightened contrast between the type and its background. In cases of ametropia and amblyopia it is, however, also frequent that increased illumination reduces the definition, owing to a superabundance of extraneous light, which serves to reduce the contrast within the polar field of fixation. In optical instruments it is found practicable to exclude peripheral extraneous light by means of a diaphragm of suitable aperture, and it is even possible to increase the definition, through limiting the field in an inferior instrument by further reducing the size of this aperture. Thus it is that the pin-hole disk heightens the visual acuteness in ametropes who view distant objects through it, and even though the same proportionate improvement can be obtained in a similar manner at finite distance, yet, it would be exceedingly difficult to accurately place the pin-holes centrally before the pupils of both eyes for reading. To obviate this impracticability, while still securing an unimpaired field of fixation, the typoscope,* devised by the author, seems in many instances to effectively serve its purpose. It consists of a rectangular plate of hard rubber, or black card-board, 7 by 2¼ inches, provided with an aperture 4¼ by ⅜ inches, centrally located, though laterally displaced so as to leave sufficient of the plate, two inches, to be conveniently held between the thumb and fingers, when it is placed upon the book or paper, and while it is being slid down over the column in reading. The central aperture is just broad enough to allow two lines of brevier type to be viewed at a time, and long enough to take in the width of an average column of type. The author has found it to be especially serviceable to persons afflicted with incipient cataract and amblyopes wearing high corrections. The former, who notably suffer greater impairment of vision from extraneous light, are invariably enabled with their glasses to read the smallest type through supplementary aid of the typoscope, which excludes all light reflected from the surface of the paper, except that which actually affords them the necessary contrast between it and the type within the slot. The device is exceedingly simple, inexpensive, and easily carried in the pocket. Its utility is easily demonstrated by first ascertaining the size of the smallest type which the patient reads with glasses, and then allowing the patient to use the typoscope in addition to them, for the purpose of ascertaining whether smaller type can be read, or not.

Bifocal Lenses.

The bifocal lens is provided with two adjoining upper and lower fields of view, differing in refractive power, and so proportioned that each field may be separately used in spectacles to correct optically imperfect vision for either near or distant objects. Its conception is ascribed to Benjamin Franklin, whose spectacles contained two lenses before each eye; one lens being effective above, the other below their centrally located and abutting straight-lined edges within the frame. The so-called solid bifocal lens is a subsequent improvement in which the adjoining fields are integral parts of a single lens, one of whose surfaces is prescribed by two intersecting spheric curvatures of different radii to produce the required difference in power. In the higher powers, this lens is inefficient on account of its prismatic action and

* "I am delighted with the typoscope. It rests on sound physiologic principles, and will benefit many people."—H. Knapp, New York, 1897.

the limited area of its upper field, wherefore, it has been supplanted by the so-called cemented bifocal lens invented by Morck, Fig. 71, in which the amplified power of its lower field is secured through attachment to the major lens, by balsam, of a smaller lens or segment of any desirable size or contour. When the segment is round and ground to a "knife-edge" it is known as the *Opifex* bifocal lens. By this means it is possible to place the optic center of the upper or lower lens in line with the visual axis of the eye when either field is used. See section on *Applications of the Prism-dioptry.* However, recently a solid bifocal lens has been exploited in which the lower field is obtained through intersection of two concave surfaces on the concave side of a meniscus, thereby producing an upper field that is greater than the lower field and generally obviating the prismatic action so manifest in the original, solid bifocal lens.

The patentees furnish so-called blanks, in which the segmental reading portion in the concave side of the blank is weaker, by quarter-dioptry intervals, between 1 and 3.5 dioptries, than the distance portion of the blank, which is given either a —4 D. or —6 D. surface. For instance, through grinding the opposite side of the blank to a convex spheric or toric surface, the residual positive power in the lower field is greater than the upper field in the resultant lens, which is a deep meniscus, this being the only form in which the blanks are now being supplied. Still, other unrevealed methods have lately been employed to produce equally efficient solid bifocal lenses. In Borsch's fused bifocal lens the lower field is obtained through fusing a small lens of flint-glass into a corresponding cavity placed eccentrically in the major lens of crown-glass, and this lens is subsequently finished so that the surfaces of both the upper and lower fields constitute a uniformly continuous surface, thereby obviating the dust-collecting raised edge of the segment common to ordinary cemented bifocal lenses, while also making the integral segment almost invisible. Borsch's fused lens is now commercially known as the Kryptok lens, which probably derives its name from the hidden recess or crypt into which the flint-glass lens is fused. Flint-glass, on account of its higher refractive index, is here used to produce increased power, and not to effect *achromatism* (freedom from color), which, in fact, is not a possibility under the prescribed conditions, since the unequal dispersive powers of the crown-glass and flint-glass and the proportions to each other of their surface-curvatures, as required in achromatism, are not taken into consideration. See section on the *Fundamentals of Achromatism.*

In order that a lens shall be achromatic, its component superposed contra-generic lenses of crown-glass and flint-glass, of unequal refractive powers and dispersions, must have their curvatures so accurately proportioned to each other that the chromatic (color) aberration produced by one lens is counteracted by that of the other. In fact, it is the same principle that applies to the achromatic prism, wherein the two component prisms of unequal refractions and dispersions are placed with their bases in reversed positions, and their angles are so relatively proportioned as to still effect ray-deviation without any appreciable amount of dispersion or decomposition of white light into its spectral colors. Consequently, fused bifocal lenses are not designed to be achromatic, since their construction is directly opposite to this requirement, so that they are frequently even less free from perceptible color than ordinary cemented bifocal lenses of crown-glass.

Although the various types of ophthalmic lenses are not generally made to insure achromatism, its fundamental principle as well as the color-phenomenon so frequently observed in them are nevertheless thought to merit at least the following elementary description in an essay of this kind.

The Fundamentals of Achromatism.

Dispersion.*

In the year 1672 Sir Isaac Newton communicated to the Royal Society his discovery that refraction by a prism resolves white light into its component elementary color-rays to produce the solar spectrum, and that these dispersed rays of different wave-lengths may be again refracted by a suitably placed duplicate prism to produce white light. Although Newton thus laid the foundation for achromatism, and incidentally also substantiated the law that light of any wave-length is propagated either forward or backward over the same rectilinear course, he was nevertheless of the opinion that the color-deviation could not be corrected in a prism or lens without annulment of the ray-deviation. Seventy-five years later Euler, who had based his argument upon the erroneous assumption that the human eye is an achromatic combination of lenses, mathematically demonstrated that achromatism is achievable. Ten years thereafter Dolland, though having failed to experimentally verify Euler's calculations, yet encouraged by the example of Klingensticrna's experiments, successfully produced an achromatic telescope-objective in which a convex

* This introduction to achromatism is abstracted chiefly from Prof. Southall's *Principles of Geometrical Optics.*

lens of crown-glass was combined with a concave lens of flint-glass; the chromatic dispersion of the former being counteracted by the latter through an equal amount of chromatic dispersion in the opposite direction.

Newton had concluded that sun-light is not homogeneous, but is composed of rays of different colors, some of which are more refrangible than others; the red rays being refracted least, and the violet rays most, in the spectrum whose colors are arranged in the order of red, orange, yellow, green, blue, indigo and violet. Moreover, he supposed the solar spectrum to be continuous with respect to the gradual transmutation of its colors. However, Wollaston, in 1802, discovered that the solar spectrum is crossed by a number of dark bands, which were later explained by Kirchhoff to be due to the light-waves from each incandescent element within the nucleus of the sun being absorbed by its own cooler gas within the sun's vaporous envelop. In fact, the absence of any particular color or light-wave in the solar spectrum, as exhibited by the presence of these bands, indicates that the corresponding wave is either not emitted by the sun, or else that it is lost through absorption or otherwise before it reaches the observer's eye.

After all, it was not until Fraunhofer, in 1814, independently rediscovered these bands as lines irregularly distributed over the entire extent of the solar spectrum, and that only their relative distances apart and their associated color-areas are altered in the same sequence by using a prism of different material, that their true significance and value were recognized by him. As Fraunhofer found each of these lines, at that time 576 in number, to correspond to a definite wave-length of light, he employed them to determine the different refractive indices of a substance, and designated the more conspicuous lines in the different parts of the spectrum by the capital letters of the Roman alphabet from A to H; the line in the violet end of the spectrum, as nearly as he could locate it, being designated by the letter J. Therefore, it is obvious that the so-called refractive index of a substance is ambiguous, unless the particular line of the spectrum for which the refractive index has been determined is specified, since a medium has just as many indices of refraction as there are lines in the different color-areas of the spectrum. Hence, the line, D, located in the brightest yellow part of the spectrum, is commonly used to determine the refractive indices of the various kinds of glass, so that the refractive index for this line, indicated by n_D, identifies the so-called *mean ray,* situated about midway between the lines, C and F, in their respective red and blue parts of the spectrum. As the interval between these lines defines the chosen extent of the dispersions of two media that may become subjects of comparison, the difference between them, $n_F - n_C$, called the *mean dispersion,* serves for all practical purposes to sufficiently characterize the dispersions of different substances; and the ratio of this value to the difference, $n_D - 1$ (the index for the line, D, less the index of air, whose value is 1), provides an appropriate expression for the so-called *relative dispersion* or *dispersive power,* $\frac{n_F - n_C}{n_D - 1}$*, of a substance. This value, when applied to a definite material, such as crown-glass, may be written, $\frac{n_F' - n_C'}{n_D' - 1}$, so as to distinguish it from the corresponding value, $\frac{n_F'' - n_C''}{n_D'' - 1}$, for flint-glass.

Achromatism, as will be later shown, depends (1) upon the joining together of at least two kinds of glass of different refractive powers and unequal dispersions, as identified by the lines of the spectrum, and (2) upon a definite choice of the inclination of their contiguous surfaces to their exposed bounding surfaces, since the latter are usually prescribed. Although Fraunhofer and others had tried to produce new kinds of glass, it was not until Abbe and Schott, of Jena, Germany, succeeded in making a variety of pairs of different kinds of crown-glass and flint-glass, in which the dispersion in the various parts of the spectrum is as nearly as possible proportional in each pair, that it has been possible to take the fullest advantage of Fraunhofer's discovery. Encouraged by these experiments, Schott and Genossen, in 1884, established the "Glasstechnisches Laboratorium" at Jena, where the world renowned Jena glass is produced to supply skilled opticians with glass having the properties necessary to fulfil, as closely as possible, the theoretic requirements in perfected optical instruments.

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* The reciprocal of this value, which is $\frac{n_d - 1}{n_f - n_c}$, is designated by $\dot{v}$, and the differences between the refractive indices of n_d, or n_f and the indices for other spectral lines are given under "Partial Dispersions" in the stock-and price-lists of Jena glass.—*Principles of Geometrical Optics,* Southall.

Achromatism.

In order to explain the principle of achromatism, license is here taken to depart from the usual method, by substituting an original, analytic and more or less elementary one, in which, for the sake of greater clearness in the accompanying drawings, the delineations of dispersion are greatly exaggerated. Moreover, the Fraunhofer D-line in the brightest yellow part of the spectrum is chosen for the refracted mean ray (Y), about midway between the red (R) and blue (B) rays; wherefore this demonstration also strictly applies only to the behavior of the color-rays confined between these limitations of the spectrum, commonly designated by the Fraunhofer lines C and F, respectively, for incident white light proceeding from infinity. As the indigo and violet rays, though necessarily constituent parts of white light, are thus ignored, it is to be understood that, wherever emergent white light is later mentioned it is supposed to be only approximately colorless.

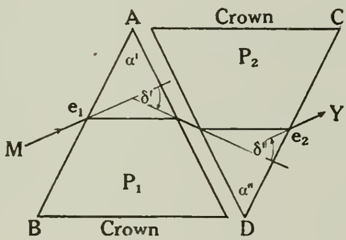


Fig. 116.

In geometric optics the laws of refraction are ordinarily applied to white light as if it were homogeneous or monochromatic and traversed successive media as though each medium had only one index of refraction, usually the index, n_D, corresponding to the D-line of the spectrum.

Thus, for instance, when the axes (mean rays) of the incident and emergent beams are inclined at equal angles to the surfaces of a prism, P_1, in Fig. 116, the prism is said to be in position to produce the "minimum deviation" of the emergent beam, as expressed by

$$\delta' = (n'_D - 1)\alpha', \qquad \text{XVII.}$$

regardless of the fact that it is composed of a number of constituent color-rays. Therefore, strictly speaking the prism can not be placed in position of minimum deviation for all color-rays at the same time, but for limited extents of dispersion, such as between the red and blue rays inclined at slight angles to the surfaces of a prism of very small angle, it may be considered to be very nearly so.

Since achromatism involves the deviations as well as the dispersions produced by at least two media of different optical density, only the deviation of a monochromatic ray, the mean yellow ray, will first be considered with reference to two adjacent prisms, P_1 and P_2, Fig. 116, of the same crown-glass. In this case the incident mean ray, M, to the prism, P_1, suffers the minimum deviation, δ', in its progress toward the second prism, P_2, where it again suffers the minimum

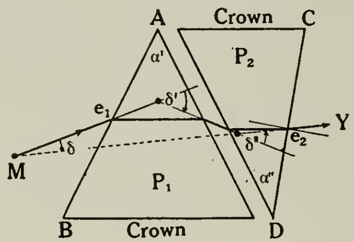


Fig. 117.

deviation, $\delta'' = \delta'$, in its passage through the second prism, since both prisms have the same refracting angle, $\alpha' = \alpha''$. As these equal deviations occur in opposite directions, there is not any actual deviation from the direction of the incident ray, M, so that the emergent ray, Y, is parallel to it, and the prisms jointly act as a plate, even though their faces are not in contact.

However, deviation from the direction of incidence may be secured

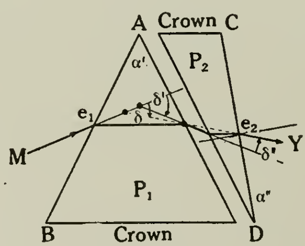


Fig. 118.

through changing the inclination of the posterior surface of the second prism; in other words, through decreasing its refracting angle, α'', as shown in Fig. 117, where the emergent ray, Y, has a lesser upward direction than in Fig. 116. In Fig. 118 the angle, α'', is even still smaller, and therefore produces a downward direction of the emergent ray Y.

It is obvious that these changes in the direction of the emergent ray, Y, depend upon whether the refracted ray within the second prism approaches the point, e_2, of emergence from below or from above the perpendicular at this point of the surface, CD, as shown in figures 117 and 118, this also being true of the same mean ray, if considered as the axis of the dispersed color-rays, when the incident light is a beam of white light. In any event, the resultant deviation is $\delta' - \delta'' = \delta$; this being the same deviation as would be produced

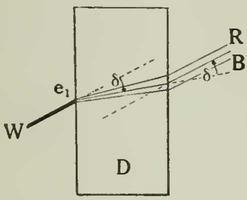


Fig. 119.

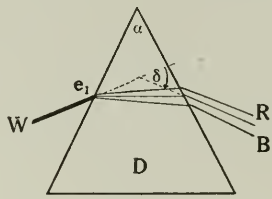


Fig. 120.

by a single prism whose angle between the faces, AB and CD, is $a = a' - a''$.

However, in associating deviation with dispersion it is necessary to consider also the individual directions of the color-rays. Thus, for instance, in the figures 119 and 120, representing the principal sections of a plate and a prism, respectively, the narrow beam of white light, W, incident at e_1, upon the denser medium, D, is refracted by it so as to produce a slightly wider beam composed of emergent

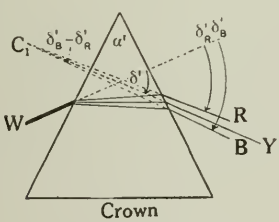


Fig. 121.

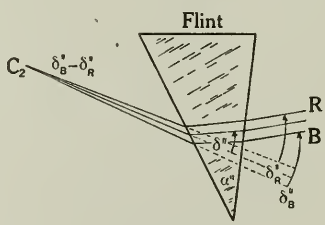


Fig. 122.

color-rays between red (R) and blue (B). However, to render this color-effect at the margins of the emergent light from a plate at all visible, even through a carefully adjusted narrow opening, the plate would require to be very thick, and the incident light would also have to pass through a very narrow slit; but, under normal conditions of exposure, the incident light may be thought to consist of an infinite number of contiguous beams, W, whose constituent and emergent parallel color-rays so overlap each other as to be perceived by the eye as white light. Still, in each of the indicated media the color-rays are divergent at e_1, when the light is propagated from left to right, but, in accordance with the law of reversibility, when the color-rays between R and B are propagated in the opposite direction, they also internally converge toward e_1, and there produce emergent white light. Hence, in either case, white light is manifest whenever its constituent color-rays are at least parallel; whereas, an actual evidence of color is confined to the absence of such parallelism after refraction.

To the degree of approximation previously stated, the prism, Fig. 121, is placed in position of minimum deviation, so that the angular deviation of the refracted blue ray, B, from the direction of incidence is $\delta'_B = (n'_B - 1)\alpha'$. Similarly, for the red ray, R, the deviation is $\delta'_R = (n'_R - 1)\alpha'$.

When α' is herein substituted by $\frac{\delta'}{n'_D - 1}$, from the equation XVII, the angular difference between the blue and red rays is

$$\delta'_B - \delta'_R = \frac{n'_B - 1}{n'_D - 1}\delta' - \frac{n'_R - 1}{n'_D - 1}\delta' = \frac{n'_B - n'_R}{n'_D - 1}\delta',$$

or, the angle of dispersion, $\delta'_B - \delta'_R$, is equal to the dispersive power $\frac{n'_B - n'_R}{n'_D - 1}$, multiplied by the angular deviation, δ', of the refracted mean ray, Y. Therefore, not only is deviation and dispersion produced, but experience also teaches that different substances produce different dispersions. For instance, flint-glass has a greater dispersive power than crown-glass, so that an inverted flint prism may be found to produce the same, though oppositely directed, dispersion as a crown prism of greater angle. This is made clear through the reversed arrows ascribed to the rays emerging from the flint prism, of lesser angle, Fig. 122, which also shows the angular dispersion, $\delta''_B - \delta''_R$, for the color-rays *diverging* from C_2 in their incidence from the left, since the refracted parallel rays R and B, if propagated from the opposite direction, actually incur the same dispersions, δ''_R and δ''_B, respectively.

Therefore, it is obvious that two prisms having different angles of *deviation*, δ' and δ'', respectively for crown-glass and for flint-glass, yet producing the same angles of dispersion, $\delta'_B - \delta'_R = \delta''_B - \delta''_R$, may be combined with their bases reversed so as to insure the emergent color rays being made parallel to constitute white light, and that the choice of their refracting angles will require to be such that, the divergent color-rays, emergent from the crown-glass prism, shall be those rays, incident to the flint-glass prism, which appear also to proceed from the common point C_1, the vertex of the coincident equal angles of dispersion in Fig. 123 and Fig. 124.

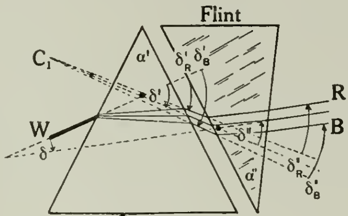


Fig. 123.

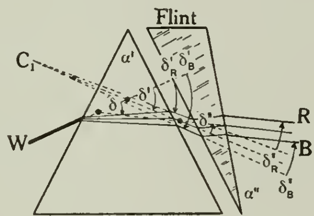


Fig. 124.

Since this principle also applies when the space between the parallel faces of the prisms is eliminated, it is usual to join them together by means of Canada balsam, thus creating a composite prism which is said to be achromatic only for the two colors red and blue. As the direction of each color-ray depends upon its own refractive index for each different medium, it follows that the angle of dispersion, $\delta'_B - \delta'_R = (n'_B - n'_R)\alpha'$, for the crown prism, and similarly, $\delta''_B - \delta''_R = (n''_B - n''_R)\alpha''$, for the flint prism.

Moreover, as these angles of dispersion must be equal to insure achromatism for the red and blue rays, it follows that:

$$(n'_B - n'_R)\alpha' = (n''_B - n''_R)\alpha'', \quad \ldots\ldots\ldots\ldots \text{XVIII.}$$

which determines the angles α' and α'' of the superposed prisms, in order that the emergent light shall be approximately free from color.

The deviation of the emergent light from the direction of incidence is equal to $\delta' - \delta'' = (n'_D - 1)\alpha' - (n''_D - 1)\alpha''$.

Thus, by making $\delta' = \delta''$, the angles of two prisms of different substances may also be so chosen as to avoid deviation of the refracted mean ray, while still permitting the dispersion of all other color-rays, and as required in the construction of direct vision spectroscopes.

Incidentally it is to be noted that, the position of minimum deviation is not also the position of minimum dispersion, since the dispersion may be indefinitely increased by adjusting the prism with respect to the incident beam. Therefore, it is always possible to adjust the refracting angles, α' and α'' of two contiguous prisms of different glass so that the dispersion for two colors produced by the first prism may be sufficiently counteracted by the second prism to effect approximate freedom from color in the emergent beam. In this case, the residual dispersion, called the *secondary spectrum,* is due to the fact that different substances disperse corresponding parts of the spectrum to widely different extents. For instance, one medium may separate the blue and the orange light very much, while the other medium separates these colors very little, so that the areas of color in both spectra are not precisely alike. This so-called *irrationality of dispersion* prevents reliable comparisons of the spectra of prisms being made, since the spectrum obtained with one prism is not the same as that produced by another. Besides, the projected spectrum produced by a prism is impure, because each point in the spectrum is not illuminated exclusively by one of the constituent colors of white light, so that there is more or less overlapping of them. However, if the virtual spectrum is viewed through a prism in position for minimum deviation, there is not any sensible overlapping of this kind, hence the *virtual* spectrum is pure. On the other hand, spectra which are produced by *reflection* from ruled gratings are all pure and exactly alike, so that the data secured by different observers are always the same, and for which reason the diffraction spectrum is chosen as the standard in the physical laboratory.

However, reverting to the *refracted* spectrum, it is possible in an achromatic combination of two prisms to correct its successive residual colors through adding another prism for each color. When three prisms are used to correct three colors the remaining smaller dispersion is called the *tertiary spectrum.* Therefore, it is impossible to obtain perfect achromatism without the use of a very large number of different media, but, as the successive uncorrected spectra rapidly grow fainter they are negligible. Hence it is seldom deemed necessary to correct more than two colors.

The preceding principles are also well adapted to explain achromatism of a lens, especially when the component lens-thicknesses are exaggerated for the purpose only of lucid illustration, With this understanding, all parallel rays of white light incident from the left upon the convex lens, Fig. 125, result in divergent pencils of color-rays within the lens, which upon emergence intersect the optic axis at different points, so that the red and blue rays are separately focused at R_1 and B_1, respectively. In other words, the convex lens is more strongly convergent toward the axis for blue rays than for red

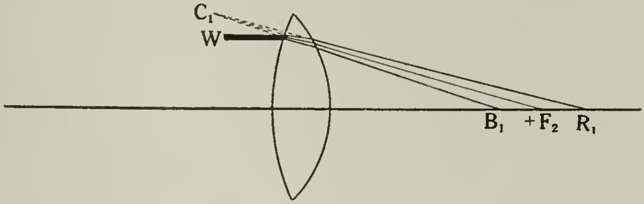


Fig. 125.

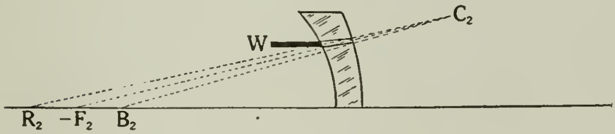


Fig. 126.

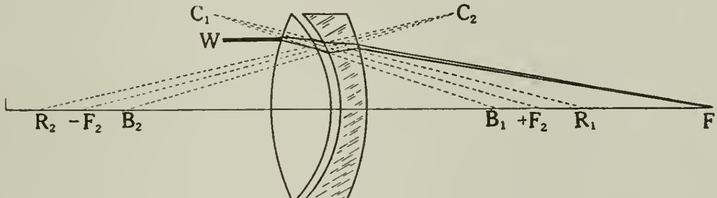


Fig. 127.

rays, or the emergent light is a divergent pencil of color-rays appearing to proceed from C_1; whereas, the weaker concave lens, Fig. 126, is more strongly divergent for blue rays than for red rays, so that the emergent light is a convergent pencil of color-rays whose vertex is C_2. Now, as the dispersion of flint-glass is greater than that of crown-glass, it is obvious that the same amount of dispersion, though in the opposite direction, may be produced through choice of a weaker concave flint lens whose focal length is, therefore, greater than that of the convex crown lens.

Hence, when two such properly proportioned lenses, Fig. 127, are very slightly separated upon a common axis, their *equal dispersions* in opposite directions counteract each other, thus producing an achromatic combination corrected for two colors. However, in this case the rays emitted from the convex lens are *incident* upon the concave lens as a divergent pencil of color-rays which individually converge toward R_1 and B_1 upon the axis, so that the divergent color-rays from the convex lens, which appear to proceed from C_1, are no longer, after refraction by the concave lens, directed to the point C_2, but assume a lesser convergence toward the more remote point, F, the focus of the combination. Therefore, in order to make a lens approximately achromatic for parallel incident rays it is necessary that it shall be so constructed as to effect a fusion of the points B_1 and R_1 of the convex lens into a single point, F, the positive focus of the combination. This means that the emergent color-rays are not parallel, and, therefore, do not constitute white light until they have collectively merged into the focal point, F, where they are superposed to produce it; whereas, with two prisms the emergent light is achromatised through immediate parallelism of the color-rays at the surface of emergence, and in front of which a continued divergence of the internal color-rays has been shown to exist. On the other hand, in a combination of two contra-generic lenses continued divergence of the color-rays within both lenses does not exist, since their divergence within the crown lens is approximately counteracted by their convergence within the adjoining flint lens, Fig. 127. Consequently, it is evident that white light does not traverse the interior of a refracting medium, even if it is achromatic. Since the convex crown lens has a shorter focal length, it dominates the refractive power; whereas, the weaker concave flint lens prevails only as the color-correcting element in the combination, which in practice is made integrate through Canada balsam, in order to avoid reflection from the contiguous surfaces.

Moreover, as the angles of dispersion are proportionate to their corresponding relative dispersions and may be expressed through them, it is also obvious that the relative dispersion of the convex *crown* lens must bear the same proportion to its mean focal length, $+ f'$, as the relative dispersion of the concave *flint* lens to its mean focal length, $- f''$; that is to say,

$$\frac{n'_F - n'_C}{n'_D - 1} : f' = \frac{n''_F - n''_C}{n''_D - 1} : - f''.$$

This equation, when transformed to

$$\frac{n'_F - n'_C}{n'_D - 1}\,\frac{1}{f'} + \frac{n''_F - n''_C}{n''_D - 1}\,\frac{1}{f''} = 0. \quad \ldots\ldots\ldots\ldots \text{XIX.}$$

prescribes the condition of achromatism of two superposed contra-generic thin lenses made of crown-glass and flint-glass, and involves the stipulation that the sum of the products of the relative dispersions of the substances used and the refractive powers of the lenses shall be zero.

As n'_F is greater than n'_C, and n''_F is greater than n''_C, while n'_D and n''_D are both greater than unity, it follows that f' and f'' must have opposite signs, so that, if the combination is to be a positive or convergent lens, the component convex lens, whose focal length is f', will require to be stronger than the concave lens whose greater focal length is f''; wherefore, the relative dispersion of the convex material will have to be less than that of the concave material, in order to satisfy the equation XIX. This equation also applies to a *concave* achromatic lens, but in which the stronger concave element is made of crown-glass and the other of flint-glass.

However, as the achromatic combination under discussion is convex, its refraction is $1/f$, while the refractions of its component convex and concave lenses are $1/f'$ and $-1/f''$, respectively, so that,

$\frac{1}{f'} - \frac{1}{f''} = \frac{1}{f}$, from the general formula,

$$\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{f} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{XX.}$$

Therefore, so long as the focal distances, f' and f'', which satisfy this equation, are also so proportioned to each other as to satisfy the equation, XIX, the convex lens will be achromatic with respect to the two colors, red and blue.

The exposed surface-curvatures of a lens of any form, whose focal length is f, are determined by the general formula,

$$\frac{1}{f} = (n_D - 1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right), \ldots\ldots\ldots\ldots \text{XXI.}$$

so that even the achromatic lens may be of any type commensurate with the more or less empiric choice of the radii, r_1 and r_2, if it is to satisfy only the condition of achromatism for paraxial rays. But, as the image-distortion due to spheric aberration is nearly as pernicious as chromatic aberration, the former must also be corrected, especially in lenses of wide aperture.

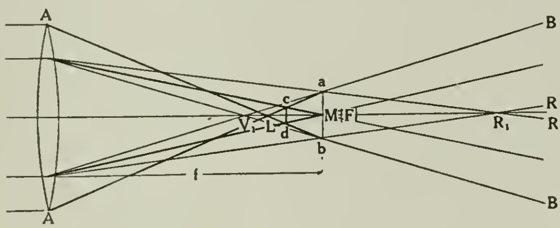
A lens in which both the chromatic and spheric aberrations are corrected is called an *aplanatic lens,* yet its construction also involves compliance with the so-called sine condition (*Principles of Geometrical Optics,* Southall). However, ordinarily the radii, r_1 and r_2, of the outer surfaces of an archromatic lens are selected so as to give the lens that form which produces the least spheric aberration. In order to simplify the cumbersome calculations necessary to provide the requirements to avoid both kinds of aberration in thin lenses, Herschel, in 1821, established a simple rule, which, with sufficient practical accuracy, applies to lenses of no greater aperture than 1½ inches. Professor Prechtl of Vienna, in 1828, stated it as follows:

"An object-glass consisting of two thin lenses is practically free from aberration when the radius of the exposed surface of the crown-glass = 6.72 and that of the flint-glass = 14.2, provided the mean focal length, f, of the objective is made = 10, and the radii of the two contiguous inner surfaces are so calculated that the focal lengths of the component lenses are in proportion to their dispersive powers." However, this applies only in case the crown-glass index is 1.528 and the flint-glass index is 1.601, when it is merely necessary to make the radius of the exposed surface of the crown-glass, $r_1 = 0.672 \times f$, and the radius of the exposed surface of the flint-glass, $r_2 = 14.2 \times f$, in order, through the formula, XXI, to determine the radii of the contiguous surfaces of the lenses whose focal lengths, f' and f'', must be made to satisfy the equations, XIX and XX, for an achromatic lens whose focal length is f. Moreover, even though Herschel's rule to obviate spheric aberration is not complied with, the formulæ, XIX, XX and XXI, provide for at least approximate achromatism of a lens of any form for which at least one radius of surface-curvature and the focal length are known. However, when achromatic lenses are required to be of wide aperture, it is necessary to use formulæ of a higher order of approximation.

Through superposing the diagrams illustrating spheric and chromatic aberration, figures 107 and 108, to produce the Fig. 128, the distinction between the achromatic and the aplanatic lens may be lucidly shown, since all of the color-rays of the simple lens that intersect the optic axis, between V_1 and R_1, are made to merge into the focal point, M, by the achromatic lens, which, if also aplanatic, eliminates both the longitudinal spheric aberration, LM, and the chromatic aberration, $V_1 R_1$.

Incidentally it is also to be noted that the detrimental effect of chromatic aberration is greater than that of spheric aberration, because the circle of chromatic aberration, ab, is considerably greater than the least circle of spheric aberration, cd.

However, as in the latter the light intensity is correspondingly greater, its effect is not to be estimated by the proportions of these circles of aberration to each other. The diagram makes it apparent that the *longitudinal chromatic aberration*, $V_1 R_1$, will increase for a greater focal length, f, of a lens made of the same kind of glass, and that it does not depend upon the aperture of the lens, but that it will remain the same constant for different apertures of a lens having the same focal length. Therefore, it is the reverse of the condition that applies to the *longitudinal spheric aberration*, LM, which increases with the square of the aperture, AA, and in inverse proportion to the focal distance. On the other hand, the *lateral chromatic aberration*, measured by the diameter, ab, of the circle of chromatic aberration, depends upon the diameter of the aperture of the lens, and is proportional to it, as may be seen in the diagram. Therefore, in an



Circle of Chromatic Aberration, ab, in Focal Plane.
Least Circle of Spheric Aberration, cd.

Fig. 128.

achromatic convex lens it is evident that the weaker concave lens must supply a circle of chromatic aberration of the same size as that produced by the stronger convex lens; wherefore, the dispersive power of the concave lens must be greater in proportion to its refractive power, and for which reason, as previously shown, flint-glass having a greater dispersive power is used. Moreover, the greater the dispersive power of the flint-glass is in proportion to that of the crown-glass, and the smaller the difference between their respective dispersions, the flatter the curvature of the concave lens will require to be, and therefore also the greater will be the preponderance of the refraction of the convex lens over that of the concave lens.

Dioptric Formulæ for Combined Cylindric Lenses.

Shortly after publication of the author's "*Treatise on Ophthalmic Lenses,*" the late Dr. Swan M. Burnett kindly suggested the execution of plastic models of combined cylindric lenses, by placing a set of these, conceived and hastily prepared by himself, in the writer's hands for further elaboration; with the request, if possible, also to produce two additional combinations in which the cylinders were to be united at angles other than right angles. As a result of the writer's research during the time devoted to the construction of the latter more especially, and with a view to establish confidence in the precision of these models, the following mathematical demonstration was first presented in 1888. The subject has been divided into two theorems; one covering congeneric cylinders, the other, contra-generic cylinders, and in which the diagrams are intentionally drawn at variance with the laws of true perspective, in order to strictly preserve all important circles and right angles referred to in the text. The final transformations of the formulæ, as adapted to the requirements of the *dioptral* system, are included so as to render complete the proof that two superposed cylindric lenses, crossed at any angle, are equivalent to a sphero-cylindric lens, thus actually nullifying the need for employment of the formulæ in ordinary ophthalmic practice. However, the importance of the demonstration is made evident in the *sixteen laws* originally disclosed by the author, through simple formulæ based upon *first approximation,* and which ordinarily apply to thin lenses that are commonly used to counteract optical anomalies of vision.

I. Congeneric Cylinders.

1. *Relative Positions of the Primary and Secondary Planes of Refraction.*

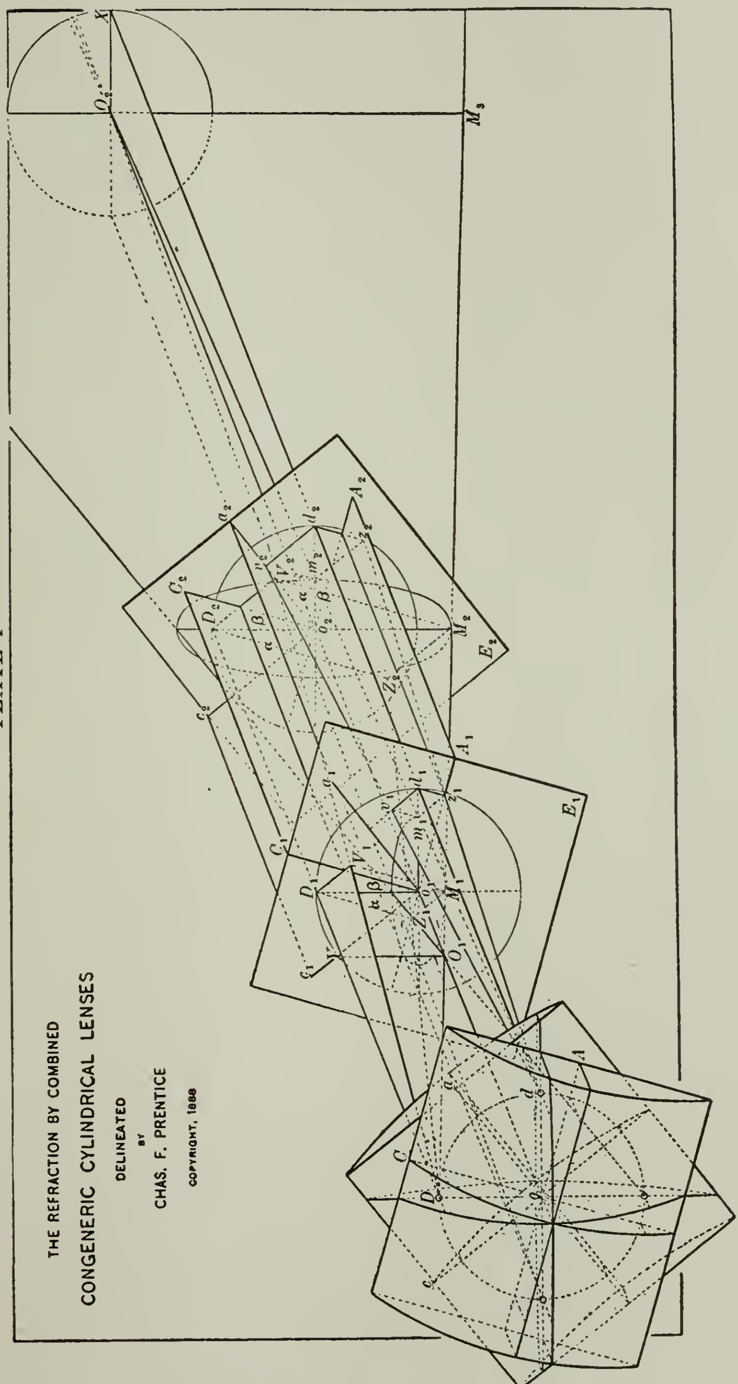
As in most cases the total thickness of the combined cylinders is a very small dimension compared with their resultant focal lengths, the cylinders may be considered to be so thin that their individual optic centers coincide in one point, within a plane perpendicular to the optic axis, this point being taken as the optic center of the superposed lenses.

In Plate I, two combined convex cylindric lenses are shown, which, though somewhat at variance with the prescribed conditions of thickness, will, however, better serve to make our subject clear.

The dotted circle shown within the lenses, with its center at the optic center, o, shall represent the plane above alluded to.

The *passive* or axial planes of the cylinders are shown by dotted parallelograms at A and a, bisecting each other under the angle Aoa $= \gamma$ in the optic axis at o; and their *active* planes of refraction, C and c, which are of necessity at right angles to their correlative axial planes, similarly bisect each other at the same point. Hence, $\sphericalangle$ Coc $= \sphericalangle$ Aoa $= \gamma$.

PLATE I


THE REFRACTION BY COMBINED
CONGENERIC CYLINDRICAL LENSES
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The compound lens thus presented consists of two congeneric cylindric elements, each of which, *independently considered,* will have its corresponding focal plane, which, for convenience, we may term an *elementary* focal plane of the combination. Thus, E_1 and E_2, at the focal distances, f_1 and f_2, are the elementary focal planes for the cylinders, C and c, respectively. The cylinder, C, will consequently have the property of deflecting a ray, incident at D, perpendicularly from D_1, in the plane E_1, to the point Z_1 of the axial plane, $A_1 Z_1$; whereas, the cylinder c will have the property of deflecting a ray, incident at the same point, perpendicularly from D_2, in the plane E_2, to the point, V_2, of the axial plane, a_2o_2.

The greatest amplitude of deflection for C will therefore be D_1Z_1 in the plane E_1, and for c will be D_2V_2 in the plane E_2. It is further manifest that the refracted ray, DV_1V_2, contributed by c only, in attaining its greatest deflection D_2V_2, in the plane E_2, will penetrate the plane E_1 at V_1, and in it present a proportionate deflection D_1V_1.

D_1Z_1 and D_1V_1, being amplitudes of deflection *reduced to the same plane,* E_1, will then bear the same relation to each other as their corresponding refractions. Thus

$$D_1Z_1 : \frac{1}{f_1} = D_1V_1 : \frac{1}{f_2};$$

or,

$$D_1Z_1 = \frac{1}{f_1}, \text{ when } D_1V_1 = \frac{1}{f_2},$$

and which may easily be shown to be the case when the deflections are measured in a plane one inch from the lens (*Refraction and Accommodation of the Eye,* by E. Landolt, M. D., Paris, translated by C. M. Culver, M. A., M. D., Philadelphia, 1886, see page 58).

Provided, therefore, that the deflections are measured, within the same plane, from a point D_1 of the same line of incidence, DD_1, we may determine the resultant of two deflections, D_1Z_1 and D_1V_1, for any angular deviation existing between them at D_1, by the physical law governing similarly united forces. D_1M_1, as the diagonal of the parallelogram, $D_1V_1M_1Z_1$, will consequently be the resultant deflection accruing from a combination of the cylinders, C and c.

As each cylinder contributes a plane of active and one of passive refraction, we shall evidently obtain two resultant principal planes for their combination, the one of greatest refraction, commonly called the *primary* plane, DD_1o_1o, intersecting the angle, $Coc = \gamma$, between the active planes of refraction, C and c, and one of least refraction, termed the *secondary* plane, dd_2o_2o, intersecting the angle, $Aoa = \gamma$, between the passive or axial planes, A and a.

The primary plane, in penetrating the plane E_1, will consequently divide the angle $C_1o_1c_1 = Coc = \gamma$ into $D_1o_1c_1 = \alpha$ and $D_1o_1C_1 = \beta$. In the plane E_1 we shall then find the angles α and β to be directly dependent upon the associated deflections D_1Z_1 and D_1V_1 for the point D_1. In the plane E_2 a similar division of the angle, $A_2o_2a_2$, by the secondary plane, will be rendered dependent upon d_2v_2 and d_2z_2 for the point d_2. As to this, the diagram is believed to be sufficiently clear, without further reference.

Since the resultants D_1M_1 and d_2m_2 define the directions of the refracted rays DM_1 and dm_2, it is further evident that for D and d to be points of the primary and secondary planes, respectively, they will have to be so chosen that D_1M_1 and d_2m_2 shall be directed *towards* the optic axis oo_1o_2; and, as we shall later learn, this is but one of the restrictions which renders a diagram somewhat difficult of construction. The resultant deflections D_1M_1 and d_2m_2 are, therefore, shown in the primary plane, *coincident* with D_1o_1, and in the secondary plane *coincident* with d_2o_2, respectively.

For all intermediate points of the circle, the resultant deflections deviate *from* the optic axis. This has been taken advantage of in constructing Dr. Burnett's models, and in determining the directions of twelve refracted rays in each of the figures 2, Plates II and IV.

The position of the primary plane DD_1o_1o, shown as dividing the angle, $C_1o_1c_1 = \gamma$, so that

$$\gamma = \alpha + \beta, \qquad (1)$$

will then be determined by fixing the relations existing between α and β.

In the plane E_1, from the triangle $D_1Z_1M_1$, we have

$$D_1Z_1 : Z_1M_1 = \sin \sphericalangle Z_1M_1D_1 : \sin \sphericalangle Z_1D_1M_1,$$

$$\sphericalangle Z_1M_1D_1 = \sphericalangle D_1o_1c_1 = \alpha,$$

by parallelism of Z_1M_1 and c_1o_1; and, for similar reasons,

$$\sphericalangle Z_1D_1M_1 = \sphericalangle D_1M_1V_1 = D_1o_1C_1 = \beta.$$

$$\therefore D_1Z_1 : Z_1M_1 = \sin \alpha : \sin \beta,$$

$$Z_1M_1 = D_1V_1.$$

$$\therefore D_1Z_1 : D_1V_1 = \sin \alpha : \sin \beta. \qquad (2)$$

In the oblique plane DD_2V_2 we find

$$D_1V_1 : D_2V_2 = DD_1 : DD_2;$$

or, as DD_1 and DD_2 are the focal distances, f_1 and f_2, of the cylinders, C and c, respectively,

$$D_1V_1 : D_2V_2 = f_1 : f_2. \quad \text{.................. (3)}$$

Multiplying the equations (2) and (3), we obtain

$$\frac{D_1Z_1}{D_2V_2} = \frac{\sin\alpha}{\sin\beta}\frac{f_1}{f_2}. \quad \text{.................. (4)}$$

Since D_1o_1 is the radius of the circle indicated, we may, for convenience, ascribe to it the value 1. We shall then have

$$D_1Z_1 = \sin \sphericalangle D_1o_1Z_1,$$

$$\sphericalangle D_1o_1Z_1 = C_1o_1Z_1 - \sphericalangle D_1o_1C_1.$$

$$\therefore \sphericalangle D_1o_1Z_1 = 90^\circ - \beta.$$

$$\therefore D_1Z_1 = \sin(90^\circ - \beta) = \cos\beta. \quad \text{............ (5)}$$

In the plane E_2 we similarly find

$$D_2V_2 = \sin \sphericalangle D_2o_2V_2,$$

$$\sphericalangle D_2o_2V_2 = \sphericalangle V_2o_2c_2 - \sphericalangle D_2o_2c_2.$$

$$\therefore \sphericalangle D_2o_2V_2 = 90^\circ - \alpha.$$

$$\therefore D_2V_2 = \sin(90^\circ - \alpha) = \cos\alpha. \quad \text{............ (6)}$$

Substituting the values for D_1Z_1 and D_2V_2 from (5) and (6) in the equation (4), we obtain,

$$\frac{\cos\beta}{\cos\alpha} = \frac{\sin\alpha}{\sin\beta}\frac{f_1}{f_2};$$

or, by multiplying both members of equation by 2 and transposing,

$$2\cos\beta\sin\beta = 2\cos\alpha\sin\alpha\frac{f_1}{f_2}$$

$$\therefore \sin 2\beta = \sin 2\alpha\frac{f_1}{f_2}. \quad \text{.................. (7)}$$

The position of the secondary plane dd_2o_2o, shown as dividing the angle $A_2o_2a_2 = \gamma$ into $d_2o_2a_2 = \alpha$ and $d_2o_2A_2 = \beta$, *provided* d_2o_2 *is perpendicular to* D_2o_2, will be determined by similarly fixing the relations between α and β. Here it can also be shown that

$$d_2z_2 : d_2v_2 = \cos\alpha : \cos\beta \quad (8)$$

$$d_1z_1 : d_2z_2 = f_1 : f_2 \quad (9)$$

$$d_1z_1 = \sin\beta \quad (11)$$

$$d_2v_2 = \sin\alpha \quad (12)$$

whereby, as before, $\sin 2\beta = \sin 2\alpha \dfrac{f_1}{f_2}$.

We therefore conclude that:

1. *The primary and secondary planes of refraction are at right angles to each other for any angular deviation of the axes of two combined congeneric cylindric lenses.*

In a further consideration of the relation (7), $\sin 2\beta = \sin 2\alpha \dfrac{f_1}{f_2}$, we observe that the sines of the angles 2α and 2β, which are each always less than 90°, merely differ by the co-efficient $\dfrac{f_1}{f_2}$.

If, therefore, $f_2 = f_1$, which is the case when the cylinders are of equal refraction, the $\sin 2\beta$ will be equal to the $\sin 2\alpha$, and which can only be the case when $\alpha = \beta$, or, as $\alpha + \beta = \gamma$, when $\alpha = \beta = \dfrac{\gamma}{2}$; hence:

2. *For combined congeneric cylinders of equal refraction, the primary plane equally divides the angle between the active planes of the cylinders, and the secondary plane similarly divides the angle between the axial planes of the cylinders.*

In case, however, $f_2 > f_1$, which is the case when the refraction of the cylinder C is greater than c, then $\sin 2\alpha > \sin 2\beta$, or, when $\alpha > \beta$, so that

3. *For combined congeneric cylinders of unequal refraction, the primary plane, in dividing the angle between the active planes of the*

cylinders, will be nearer to the active plane of the stronger cylinder, and the secondary plane consequently nearer to the axial plane of the same cylinder.

This is also demonstrated in the diagram.

As, for a combination of two cylinders, C and c, under given angular deviation of their axes, the only known quantities will be f_1, f_2 and γ, it will be necessary to express α and β in terms of f_1, f_2 and γ.

This is accomplished through the equations (1) and (7):

$$\gamma = \alpha + \beta$$

$$\sin 2\beta = \sin 2\alpha \frac{f_1}{f_2},$$

when, after proper substitution and reduction, we obtain:

$$\cos \alpha = \sqrt{\frac{1}{2} + \frac{1}{2} \frac{f_1 + f_2 \cos 2\gamma}{\sqrt{f_1^2 + 2f_1 f_2 \cos 2\gamma + f_2^2}}} \quad \ldots\ldots\ldots (I)$$

It will be unnecessary to seek β in the same manner, since, through (1), we find $\beta = \gamma - \alpha$.

When reducing this formula, for any given value of γ, pursuant to reasons later given, it should be observed that $f_2 > f_1$, in which case α, within the angle γ, is to be counted from the axis of the *weaker* cylinder.

2. *Positions of the Primary and Secondary Focal Planes.*

As the plane DD_1o_1o is the primary plane, it follows that all parallel rays incident in it between D and o will, after refraction, intersect the optic axis oo_1 at some point, which will be a point of the primary focal line. Therefore the resultant ray DM_1M_2, in attaining its greatest deflection D_1M_1 in the elementary plane, E_1, will establish the position of the primary focal line, through its previous intersection of the optic axis, oo_1, at the point, O_1.

In the secondary plane, dd_1o_1o, for similar reasons O_2 will be a point of the secondary focal line, though this point of intersection of the final ray dm_1m_2 with the optic axis is more distant, in consequence of the inferior deflection d_2m_2 in the plane, E_2.

Similar resultant deflections, at opposite cardinal points of the circle within the lens, define the directions of their corresponding refracted rays. These rays not only limit the major and minor axes of the ellipses shown in the planes, E_1 and E_2, but also determine the lengths of the focal lines at O_1 and O_2. Thus O_2M_3 represents one-half of the secondary focal line at O_2. The primary focal line, in the secondary plane, perpendicular to YO_1 at O_1, has been omitted, to avoid possible misinterpretation of more important points of reference in the diagram. All rays parallel to the optic axis, incident at intermediate points of the circle within the lens, will, upon refraction, intersect the planes E_1 and E_2 at correlative points of the ellipses drawn thereon.

The circle of least confusion, T, will lie between the planes E_1 and E_2. (See Plate II, Fig. 2.) Its position may be determined through a simple formula given by Prof. W. Steadman Aldis in his discussion of the focal interval resulting from rays obliquely incident upon a spherical lens. (*Elementary Treatise on Geometrical Optics,* W. S. Aldis, M. A., Cambridge, 1886, see page 39.)

Our object being to determine the distances of the primary and secondary focal lines, or planes, from the principal plane within the combined cylinders, we shall proceed as follows:

In the primary plane DD_1M_1, we have

$$DY : DD_1 = YO_1 : D_1M_1.$$

Substituting, $DY = O_1o = F_1$, as the primary focal distance;

$$DD_1 = f_1;$$

$$YO_1 = D_1o_1 = \text{radius} = 1.$$

$$\therefore F_1 = \frac{f_1}{D_1M_1}. \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (26)$$

In the parallelogram $D_1V_1M_1Z_1$, the angle between the forces, D_1V_1 and D_1Z_1, being equal to $\sphericalangle C_1o_1c_1 = \gamma$, we have, as the resultant deflection,

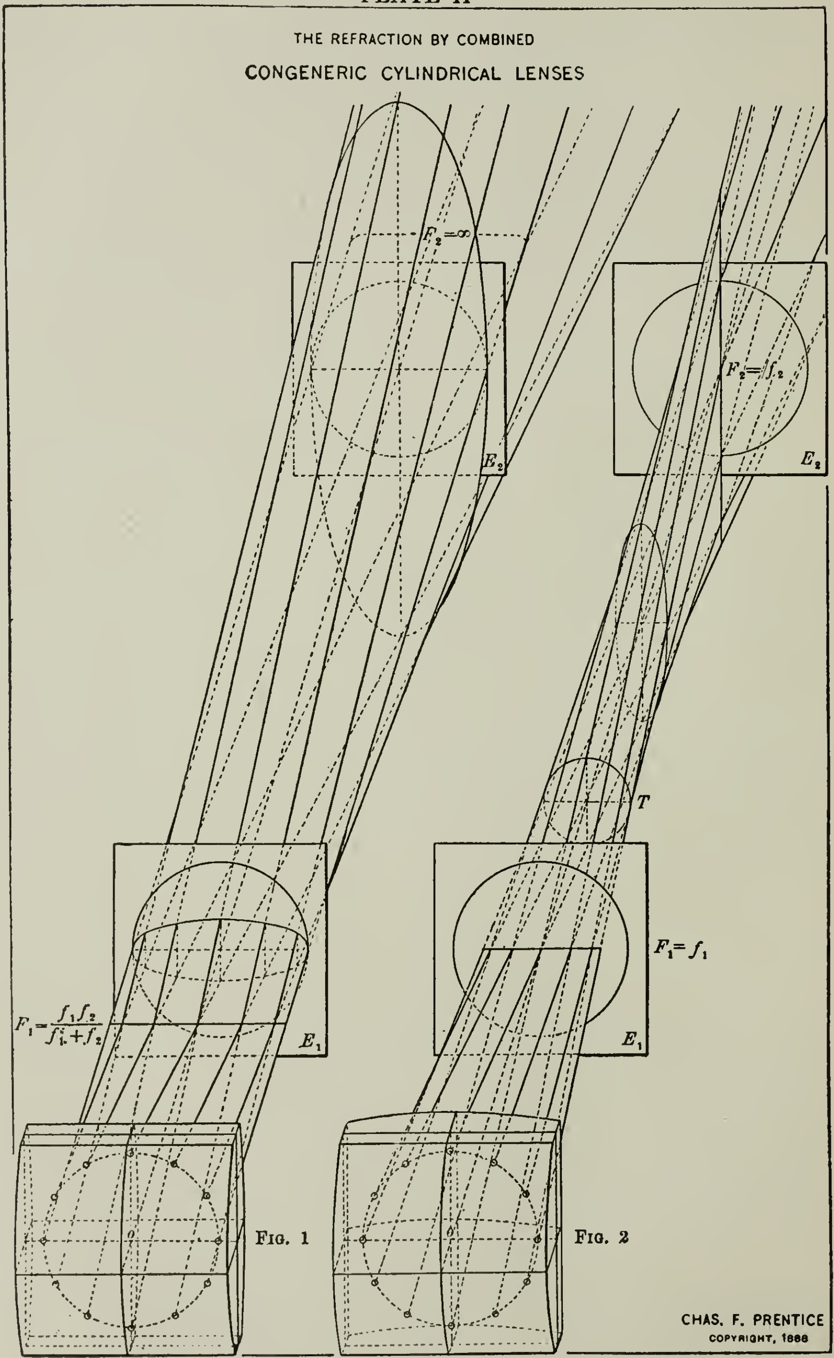
$$D_1M_1 = \sqrt{(D_1Z_1)^2 + (D_1V_1)^2 + 2(D_1V_1)\,(D_1Z_1)\cos\gamma}, \quad (27)$$

in conformity with the statical formula,

$$R = \sqrt{P^2 + Q^2 + 2PQ\cos\gamma},$$

for forces, P and Q, acting at the same point, within the same plane, under the angle γ.

PLATE II


THE REFRACTION BY COMBINED
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F2=∞
E2
F2=f2
E2
T
F1=f1
F1=f1f2/(f1+f2)
E1
E1
FIG. 1
FIG. 2
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Substituting in (27) the value of $D_1Z_1 = \cos\beta$, from (5); and of

$$D_1V_1 = \frac{f_1}{f_2} D_2V_2, \text{ from (3)}, = \frac{f_1}{f_2} \cos\alpha, \text{ from (6), we obtain,}$$

$$D_1M_1 = \sqrt{\cos^2\beta + \left(\frac{f_1}{f_2}\right)^2 \cos^2\alpha + 2\frac{f_1}{f_2}\cos\alpha\cos\beta\cos\gamma}.$$

Introducing this value for D_1M_1 in (26),

$$F_1 = \frac{f_1}{\sqrt{\cos^2\beta + \left(\frac{f_1}{f_2}\right)^2 \cos^2\alpha + 2\frac{f_1}{f_2}\cos\alpha\cos\beta\cos\gamma}} \quad \ldots (28)$$

By substituting the proper values for α and β, from equation (1), after adequate reduction we obtain

$$F_1 = \frac{f_1f_2}{\sqrt{\tfrac{1}{2}\left[f_1(f_1+f_2\cos 2\gamma)+(f_1+f_2)(f_2+\sqrt{f_1^2+2f_1f_2\cos 2\gamma+f_2^2})\right]}}. \quad \ldots\ldots\ldots\ldots (30)$$

Transforming, and substituting $1 - 2\sin^2\gamma$ for $\cos 2\gamma$, we may, for convenience in calculating, preferably write

$$F_1 = \frac{f_1f_2}{\sqrt{\frac{(f_1+f_2)^2}{2} - f_1f_2\sin^2\gamma + (f_1+f_2)\sqrt{\frac{(f_1+f_2)^2}{4} - f_1f_2\sin^2\gamma}}} . \text{(II)}$$

When the cylinders are of equal refraction, f_1 being equal to $f_2 = f$, the above assumes the simple form,

$$F_1 = \frac{f}{1+\cos\gamma} \quad \ldots\ldots\ldots\ldots \text{(IV)}$$

In the secondary plane dd_2XO_2, we have

$$dX : dd_2 = XO_2 : d_2m_2.$$

Substituting, $dX = O_2o = F_2$ as the secondary focal distance;

$$dd_2 = f_2;$$

$$XO_2 = \text{radius} = 1.$$

$$\therefore F_2 = \frac{f_2}{d_2m_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (31)$$

In the parallelogram $d_2v_2m_2z_2$, the angle between the forces, d_2v_2 and d_2z_2, being equal to $\sphericalangle\, v_2d_2z_2 = 180° - \sphericalangle\, A_2o_2a_2 = 180° - \gamma$,

$$\therefore d_2m_2 = \sqrt{(d_2z_2)^2 + (d_2v_2)^2 + 2\,(d_2v_2)\,(d_2z_2)\cos(180° - \gamma)}.$$

Substituting the value for $d_2z_2 = \frac{f_2}{f_1}\, d_1z_1$, from (9), $= \frac{f_2}{f_1} \sin\beta$, from (11); and for $d_2v_2 = \sin\alpha$, from (12), we obtain,

$$d_2m_2 = \sqrt{\left(\frac{f_2}{f_1}\right)^2 \sin^2\beta + \sin^2\alpha - 2\,\frac{f_2}{f_1}\sin\alpha\sin\beta\cos\gamma};$$

which, introduced in (31) and being multiplied in the numerator and denominator by $\frac{f_1}{f_2}$, gives

$$F_2 = \frac{f_1}{\sqrt{\sin^2\beta + \left(\frac{f_1}{f_2}\right)^2 \sin^2\alpha - 2\,\frac{f_1}{f_2}\sin\alpha\sin\beta\cos\gamma}}.$$

Through substitution of the proper values for α and β, from equation (1), after suitable reduction we find

$$F_2 = \frac{f_1f_2}{\sqrt{\tfrac{1}{2}\left[f_1(f_1+f_2\cos 2\gamma) + (f_1+f_2)(f_2 - \sqrt{f_1^2+2f_1f_2\cos 2\gamma+f_2^2})\right]}} \quad \ldots\ldots\ldots\ldots (33)$$

Substituting, $\cos 2\gamma = 1 - \sin^2 \gamma$,

$$F_2 = \frac{f_1 f_2}{\sqrt{\frac{(f_1 + f_2)^2}{2} - f_1 f_2 \sin^2 \gamma - (f_1 + f_2)\sqrt{\frac{(f_1 + f_2)^2}{4} - f_1 f_2 \sin^2 \gamma}}} \qquad \text{............(III)}$$

This formula, reduced for cylinders of equal refraction, f_1 being equal to $f_2 = f$, becomes

$$F_2 = \frac{f}{1 - \cos \gamma} \qquad \text{....................(V)}$$

It may be of interest to note that these formulæ differ from those given for F_1 merely by the minus sign in the denominator.

The preceding formulæ being alike applicable for combinations of convex or concave cylinders, the foci, f_1 and f_2, are to be introduced as positive values, merely with the restriction that f_2 be greater than or equal to f_1, in either case.

3. *Relations Between the Primary and Secondary Focal Planes.*

Since F_1 and F_2 have been shown to be dependent upon f_1, f_2, and γ, it is evident that, for fixed values of f_1 and f_2, the resultant foci will be rendered dependent entirely upon whatever value may be given to the angle, γ.

It is further obvious that the refraction of one cylinder will be affected most by the other when their axes coincide, or when $\gamma = 0°$, and least when their axes are at right angles to each other, or when $\gamma = 90°$.

We shall, consequently, fix upon the limits of F_1 and F_2 for these extremes of γ.

Introducing $\gamma = 0°$, and consequently $\cos 2\gamma = +1$, into the formulæ (30) and (33), we obtain, for $f_2 > f_1$,

$$F_1 = \frac{f_1 f_2}{\sqrt{\frac{1}{2}[f_1 (f_1 + f_2) + (f_1 + f_2)(f_2 + f_1 + f_2)]}} = \frac{f_1 f_2}{f_1 + f_2}.$$

$$F_2 = \frac{f_1 f_2}{\sqrt{\frac{1}{2}[f_1 (f_1 + f_2) + (f_1 + f_2)(f_2 - f_1 - f_2)]}} = \frac{f_1 f_2}{0} = \infty.*$$

* The sign for infinity.

$$\therefore F_1 : F_2 = \frac{f_1 f_2}{f_1 + f_2} : \infty. \quad \ldots\ldots\ldots\ldots\ldots (34)$$

For $F_1 = \dfrac{f_1 f_2}{f_1 + f_2}$, we shall have as the refraction

$$\frac{1}{F_1} = \frac{1}{f_1} + \frac{1}{f_2}; \text{ consequently,}$$

4. *When the axes of the congeneric cylinders coincide, the primary focal plane will correspond to that focal plane which is defined by the sum of the refractions of the cylinders, whereas the secondary focal plane will be at infinity.*

This is shown in Plate II, Fig. 1.

Introducing $\gamma = 90°$, and consequently $\cos 2\gamma = \cos 180° = -1$, into (30) and (33), we have, for $f_2 > f_1$,

$$F_1 = \frac{f_1 f_2}{\sqrt{\frac{1}{2}[-f_1(f_2 - f_1) + (f_1 + f_2)(f_2 + f_2 - f_1)]}} = \frac{f_1 f_2}{f_2} = f_1.$$

$$F_2 = \frac{f_1 f_2}{\sqrt{\frac{1}{2}[-f_1(f_2 - f_1) + (f_1 + f_2)(f_2 - f_2 + f_1)]}} = \frac{f_1 f_2}{f_1} = f_2.$$

$$\therefore F_1 : F_2 = f_1 : f_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (35)$$

As f_1 and f_2 correspond to the positions of the elementary planes, E_1 and E_2, it follows that

5. *The primary and secondary focal planes coincide with their correlative elementary focal planes, when the axes of the congeneric cylinders of unequal refraction are at right angles to each other.*

This is demonstrated in Plate II, Fig. 2.

In the same relation (35), if $f_1 = f_2$, then $F_1 = F_2$, or

6. *The primary, secondary, and elementary focal planes all merge into one plane, when the axes of the congeneric cylinders of equal refraction are at right angles to each other.*

As in this case we have but one focal plane, the refraction corresponds to that of a spherical lens.

F_1 being chosen to signify the primary focal distance, it will have to be less than F_2, yet if $f_1 > f_2$, we should find, in consequence of the relation (35), that $F_1 > F_2$. To retain the significances of F_1 and F_2, it will therefore be necessary to substitute f_2 by the greater given value of cylindric focus, and f_1 by the lesser, as stated under the formula (v).

Owing to the previous considerations, between the limits of 0° and 90° for γ, we are then to conclude that F_1 will vary between $\dfrac{f_1 f_2}{f_1 + f_2}$ and f_1, while F_2 varies between ∞ and f_2, as the nearest and most remote limits of focal distance for F_1 and F_2, respectively.

As an illustration, let Fig. 1, Plate II, represent two combined convex cylinders of unequal refraction, with their axes coincident, and so united as to permit of the rotation of one of the cylinders upon the true planes of their faces, about the optic center, o.

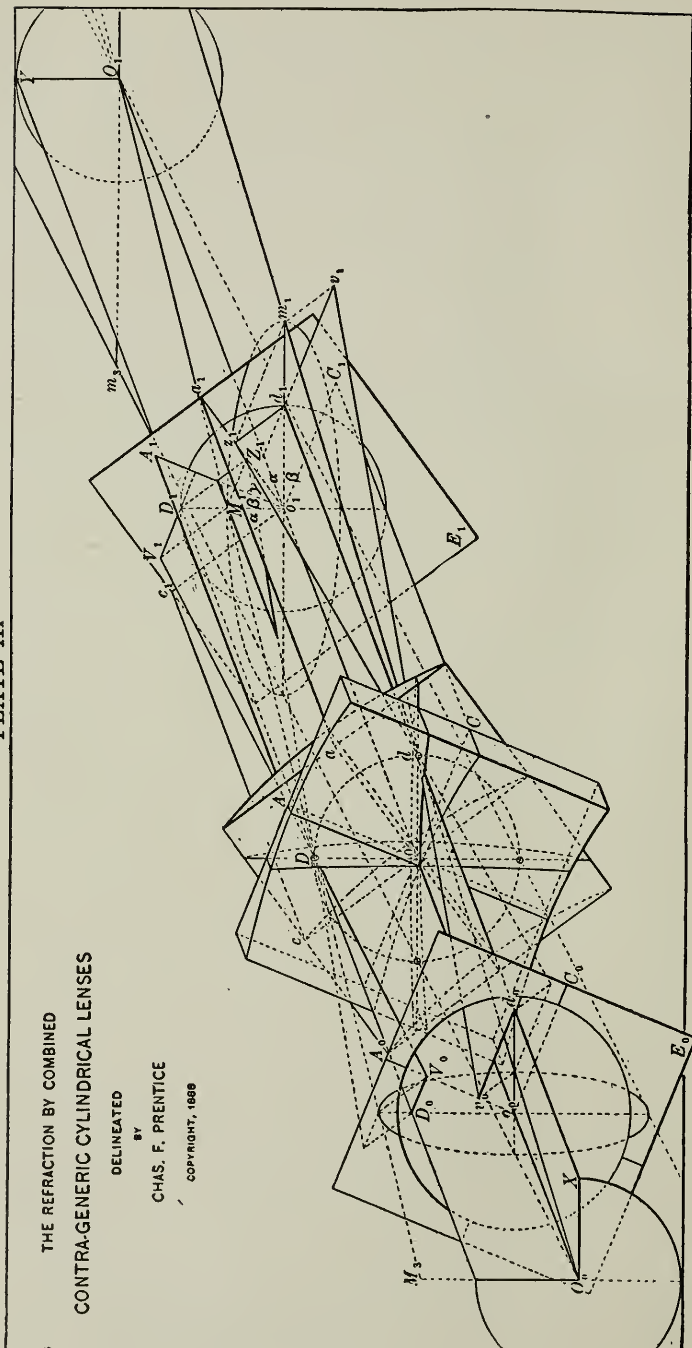
In the position shown ($\gamma = 0°$), the shortest possible focal distance F_1 of the primary focal line will be $\dfrac{f_1 f_2}{f_1 + f_2}$, which corresponds to the combined refraction, $\dfrac{1}{f_1} + \dfrac{1}{f_2}$, of the cylinders in the active plane. In the secondary plane, $F_2 = \infty$; consequently, $\dfrac{1}{F_2} = \dfrac{1}{\infty} = 0$, which corresponds to the refraction in the axial or passive plane of the cylinders.

The slightest change in the position of one of the cylindric axes will give rise to a definite value of the angle γ in the Formula III, thereby bringing F_2 within the limits of finite distance, while decreasing the value of F_1 in the Formula II.

For each successive increase in the angle γ, the primary focal plane corresponding to F_1, will recede farther and farther from the combined lenses towards E_1, while the secondary focal plane, corresponding to F_2, approaches nearer and nearer from ∞ to E_2, until $\gamma = 90°$, when F_1 will have reached E_1 on the moment that F_2 merges into E_2, as shown in Plate II, Fig. 2.

Rotation of one of the cylinders is thus associated with corresponding changes in the distances F_1 and F_2, while the movements of their

PLATE III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correlative focal planes will be in opposite directions to each other; which proves that:

7. *The primary and secondary focal planes are conjugate planes, subject to variations of the angle between the axes of the congeneric cylinders.*

In order to comply with this law, in constructing the Plate I, it has been necessary to select elementary foci in marked disproportion to the curvatures of the cylinders; otherwise the secondary focus F_2 could not be brought within the space allotted for the diagram.

II. Contra-generic Cylinders.

1. *Relative Positions of the Principal Positive and Negative Planes of Refraction.*

In a combination of convex and concave cylinders, we can no longer have the primary and secondary planes, which we have learned to consider as planes of greatest and least refraction, but, instead, we shall have a plane of greatest positive and one of greatest negative refraction, synonymously with the generally-adopted distinction between convex and concave lenses, as designated by the signs + (plus) and — (minus), respectively. As the refractions of the convex and concave elements in the combination are opposing forces, the plane of greatest positive refraction will evidently lie between the active plane of the convex cylinder and the axial plane of the concave cylinder, whereas the plane of greatest negative refraction will be between the active plane of the concave cylinder and the axial plane of the convex cylinder.

In Plate III, therefore, the plane, DD_1o_1o, of greatest positive refraction is shown between c and A, and the plane, dd_1o_1o, of greatest negative refraction between C and a. These planes, being at right angles to each other, divide each of the angles, $A_1o_1c_1$ and $C_1o_1a_1$, into α and β.

To establish the formulæ for combined contra-generic cylinders, we shall, therefore, have to ascribe another significance to the angles α and β.

The deviation of the axes, Aa, is equal to angle $A_1o_1a_1 = \gamma$, and, since c_1o_1 is perpendicular to a_1o_1, $\alpha + \beta + \gamma$ is equal to 90°; consequently,

$$\alpha + \beta = 90° - \gamma \quad \ldots\ldots\ldots\ldots (36)$$

The elementary focal planes, E_0 and E_1, corresponding to the focal distances f_0 and f_1, respectively, are exhibited on opposite sides of the combined cylinders; since E_0, for the concave cylinder, is virtual and in the negative region before the lens; whereas, E_1, for the convex cylinder, is in the positive region behind the lens. Consequently, for the point D, the convex cylinder, c, contributes as its greatest amplitude of deflection D_1Z_1, perpendicular to a_1o_1 in the plane E_1. The greatest amplitude of deflection for the concave cylinder C is D_0V_0, perpendicular to A_0o_0 in the virtual plane E_0. As the incident ray at D will be refracted by the concave cylinder as if emanating from a correlative point V_0 of the virtual axial line V_0o_0, it is evident that the direction of the ray refracted by it will be V_0DV_1. The proportionate deflection contributed by the concave cylinder, measured in the plane E_1, will consequently be D_1V_1.

Provided the point D is properly chosen, it will be a point of the plane of greatest positive refraction, that is to say, when the resultant deflection D_1M_1, accruing from the associated deflections D_1V_1 and D_1Z_1 in the parallelogram of forces $D_1V_1M_1Z_1$, is directed *toward* the optic axis.

To insure D_1M_1 being so directed, it is obvious that the associated deflections, D_1Z_1 and D_1V_1, must also be measured in the plane E_1, in the positive region behind the lens.

Similar reasoning will apply to the point d as being in the plane, dd_1o_1o, of greatest negative refraction. In this instance d_1m_1, being a force directed *from* the optic axis, in the plane E_1, is to be taken negative, synonymously with the plane of greatest negative refraction.

The relations between α and β are to be determined by an analogous method to the one given for congeneric cylinders, whereby we obtain

$$\sin 2\alpha = \sin 2\beta \frac{f_1}{f_0}, \qquad (37)$$

as defining the positions of the planes of greatest positive and negative refraction, which are again at right angles to each other.

We here also find the sines of the angles, 2α and 2β, to differ by the co-efficient $\frac{f_1}{f_0}$. Hence, when $f_0 = f_1$, we shall have $\alpha = \beta = \frac{90° - \gamma}{2}$, or,

8. *For combined contra-generic cylinders of equal refraction, the plane of greatest positive refraction equally divides the angle between the active plane of the convex cylinder and the axial plane of the concave cylinder; and the plane of greatest negative refraction similarly*

divides the angle between the active plane of the concave cylinder and the axial plane of the convex cylinder.

In case $f_0 > f_1$, then $\beta > \alpha$; or,

9. *When the convex cylinder is stronger than the concave cylinder, the plane of greatest positive refraction will be nearer to the active plane of the convex cylinder, while the plane of greatest negative refraction will be proportionately farther from the active plane of the concave cylinder.*

In case $f_1 > f_0$, then $\alpha > \beta$; or,

10. *When the concave cylinder is stronger than the convex cylinder, the plane of greatest negative refraction will be nearer to the active plane of the concave cylinder, while the plane of greatest positive refraction will be proportionately farther from the active plane of the convex cylinder.*

This is manifest in the diagram.

The values of α and β may be expressed in terms of f_1 f_0 and γ in a similar manner to that shown in the previous theorem, when it can be shown that,

$$\cos \alpha = \sqrt{\frac{1}{2} + \frac{1}{2} \frac{f_0 - f_1 \cos 2\gamma}{\sqrt{f_0^2 - 2f_0f_1 \cos 2\gamma + f_1^2}}} \quad \ldots . (\text{VI})$$

This and the transposed equation (36), $\beta = 90° - (\gamma + \alpha)$, suffice to locate the positions of the principal planes of refraction; the angle α being counted from the axis of the *convex* cylinder.

2. *Positions of the Positive and Negative Focal Planes.*

The positions of the positive and negative focal planes will evidently here also be determined by the resultant rays, DM_1 and dm_1, and their correlative intersections with the optic axis at O_1 and O_0.

O_1m_3 will therefore represent one-half the focal line in the positive region behind the lenses, and O_0M_3 one-half the virtual focal line in the negative region before the same.

The ellipses shown in the planes E_1 and E_0 are of the same significance in this as in the preceding combination.

In the plane of greatest positive refraction, DD_1YO_1, we have

$$DY : DD_1 = YO_1 : D_1M_1.$$

Substituting, $DY = O_1o = F_1$ as the positive focal distance,

$$DD_1 = f_1;$$

$$YO_1 = Do = \text{radius} = 1.$$

$$\therefore F_1 = \frac{f_1}{D_1M_1} \qquad \text{.....................(47)}$$

In the parallelogram $D_1V_1M_1Z_1$, the angle between the forces, D_1V_1 and D_1Z_1, is equal to $180° - \gamma$, since $D_1Z_1 \perp Z_1o_1$, and $D_1V_1 \perp A_1o_1$.

$$\therefore D_1M_1 = \sqrt{(D_1Z_1)^2 + (D_1V_1)^2 + 2(D_1Z_1)(D_1V_1)\cos(180° - \gamma)}.$$

In the oblique plane $D_0V_0DV_1D_1$, we find,

$$D_1V_1 : DD_1 = D_0V_0 : DD_0.$$

$$D_0V_0 = \sin \sphericalangle D_0o_0A_0 = \sin \sphericalangle D_1o_1A_1 = \sin \beta.$$

$$DD_0 = f_0.$$

$$\therefore D_1V_1 = \frac{f_1}{f_0} \sin \beta.$$

$$D_1Z_1 = \sin(\sphericalangle Z_1o_1c_1 - \sphericalangle D_1o_1c_1) = \sin(90° - \alpha) = \cos \alpha.$$

Substituting these values in the equation for D_1M_1, equation (47) becomes,

$$F_1 = \frac{f_1}{\sqrt{\cos^2 \alpha + \left(\dfrac{f_1}{f_0}\right)^2 \sin^2 \beta - 2\dfrac{f_1}{f_0} \sin \beta \cos \alpha \cos \gamma}},$$

and which, through equation (36), may be given the form:

$$F_1 = \frac{f_1 f_0}{\sqrt{\tfrac{1}{2}\left[f_1(f_1 - f_0 \cos 2\gamma) + (f_0 - f_1)\left(f_0 + \sqrt{f_0^2 - 2f_0f_1 \cos 2\gamma + f_1^2}\right)\right]}}.$$

$$\text{.............................(48)}$$

Substituting, $\cos 2\gamma = 1 - 2\sin^2 \gamma$,

$$F_1 = \frac{f_1 f_0}{\sqrt{\dfrac{(f_0 - f_1)^2}{2} + f_0f_1 \sin^2 \gamma + (f_0 - f_1)\sqrt{\dfrac{(f_0 - f_1)^2}{4} + f_0f_1 \sin^2 \gamma}}} \quad \text{(VII)}$$

This formula, when reduced for cylinders of equal positive and negative refraction, f_0 being equal to $f_1 = f$, assumes the simple form

$$F_1 = \frac{f}{\sin\gamma} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(IX)}$$

In the plane of greatest negative refraction, $d_1m_1dO_0X$, we obtain,

$$dX : dd_1 = XO_0 : d_1m_1.$$

Substituting, $dX = O_0o = -F_0$ as the negative focal distance;

$$dd_1 = f_1;$$

$$XO_0 = do = \text{radius} = 1.$$

$$\therefore -F_0 = -\frac{f_1}{d_1m_1}; \quad \ldots\ldots\ldots\ldots\ldots\ldots (49)$$

since d_1m_1 is to be taken negative.

In the parallelogram $d_1v_1m_1z_1$, the angle between the forces, d_1v_1 and d_1z_1, is again $180° - \gamma$; hence,

$$d_1m_1 = \sqrt{(d_1z_1)^2 + (d_1v_1)^2 + 2\,(d_1z_1)\,(d_1v_1)\cos(180° - \gamma)}.$$

In the oblique plane $d_0v_0dv_1d_1$, we find,

$$d_1v_1 : dd_1 = d_0v_0 : dd_0.$$

$$d_0v_0 = \sin(\sphericalangle D_0o_0d_0 - \sphericalangle D_0o_0A_0) = \sin(90° - \sphericalangle D_1o_1A_1)$$

$$= \sin(90° - \beta) = \cos\beta.$$

$$dd_0 = f_0.$$

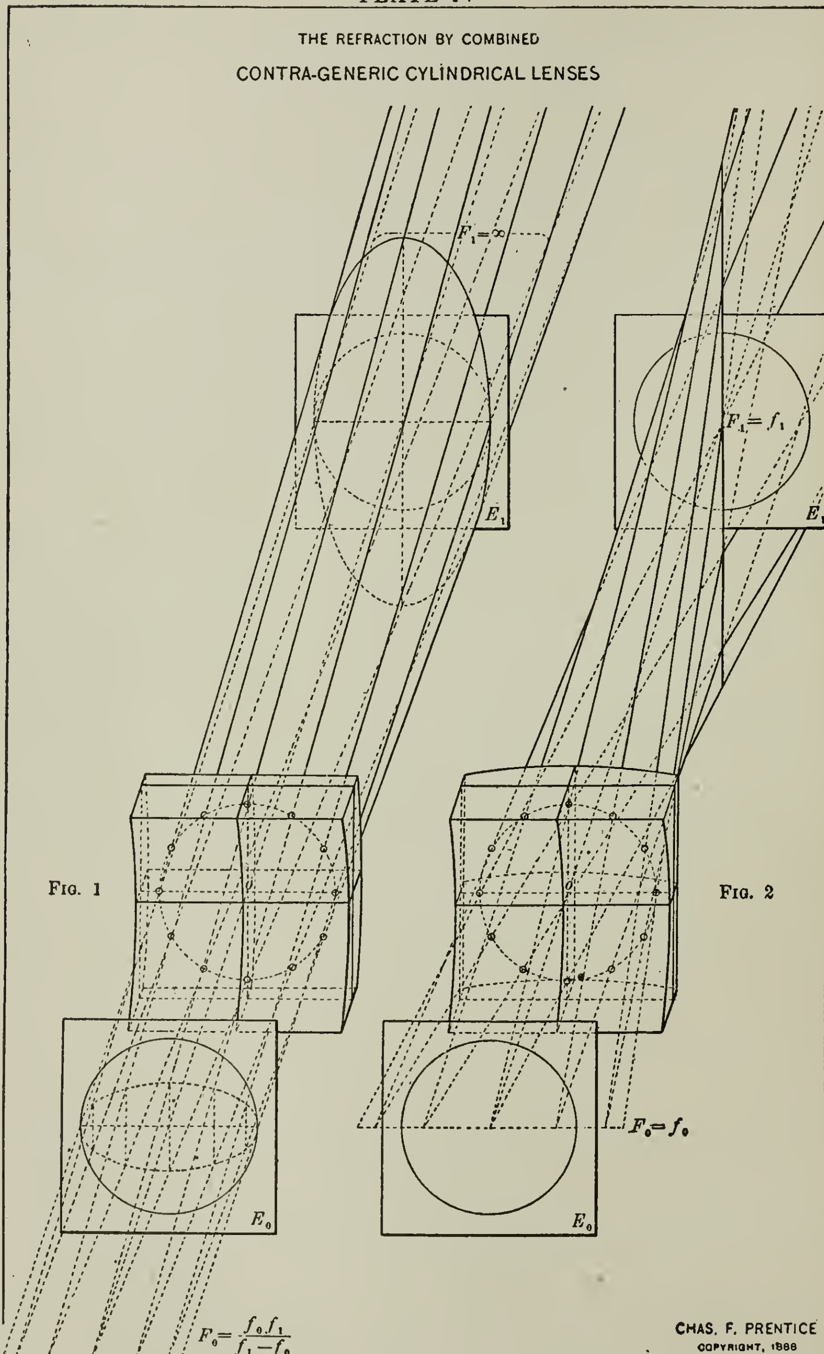
$$\therefore d_1v_1 = \frac{f_1}{f_0}\cos\beta.$$

$$d_1z_1 = \sin \sphericalangle d_1o_1z_1 = \sin\alpha.$$

Substituting these values in the equations for d_1m_1 and (49), we have,

$$-F_0 = -\frac{f_1}{\sqrt{\sin^2\alpha + \left(\frac{f_1}{f_0}\right)^2\cos^2\beta - 2\frac{f_1}{f_0}\sin\alpha\cos\beta\cos\gamma}}$$

PLATE IV


THE REFRACTION BY COMBINED
CONTRA-GENERIC CYLINDRICAL LENSES
$F_1 = \infty$
E_1
$F_1 = f_1$
E_1
FIG. 1
FIG. 2
E_0
$F_0 = f_0$
E_0
$F_0 = \frac{f_0 f_1}{f_1 - f_0}$
CHAS. F. PRENTICE
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and which, by the aid of equation (36) may be written, $-F_0 =$

$$-\frac{f_1 f_0}{\sqrt{\frac{1}{2}\left[f_1(f_1 - f_0\cos 2\gamma) + (f_0 - f_1)(f_0 - \sqrt{f_0^2 - 2f_0 f_1 \cos 2\gamma + f_1^2})\right]}}. \quad \ldots\ldots (50)$$

$\therefore -F_0 =$

$$-\frac{f_1 f_0}{\sqrt{\frac{(f_0 - f_1)^2}{2} + f_0 f_1 \sin^2\gamma + (f_1 - f_0)\sqrt{\frac{(f_0 - f_1)^2}{4} + f_0 f_1 \sin^2\gamma}}}, \quad \ldots\ldots (VIII)$$

which differs from the formula given for F_1 merely by a transposition of the elements in the factor before the second radical, and, consequently when reduced to cylinders of equal fraction, also becomes

$$-F_0 = -\frac{f}{\sin\gamma} \ldots\ldots (X)$$

The formulæ (IX) and (X) correspond to those which were applied to the Stokes lens.

In reducing the preceding formulæ for given values of cylindric foci, f_0 is to be substituted by the focus of the concave cylinder, and f_1 by the focus of the convex cylinder, both being introduced as positive values.

3. *Relations Between the Positive and Negative Focal Planes.*

As in this combination the cylinders likewise affect each other most when their axes coincide, and least when their axes are diametrically opposed, we may here also fix upon the limits of F_1 and $-F_0$ for $\gamma = 0°$ and $\gamma = 90°$, as in the previous theorem.

When $\gamma = 0°$, or $\cos 2\gamma = +1$, from the equations (48) and (50) we find, for $f_0 > f_1$,

$$F_1 = \frac{f_1 f_0}{\sqrt{\frac{1}{2}[-f_1(f_0 - f_1) + (f_0 - f_1)(f_0 + f_0 - f_1)]}} = \frac{f_1 f_0}{f_0 - f_1}$$

$$-F_0 = -\frac{f_1 f_0}{\sqrt{\frac{1}{2}[-f_1(f_0 - f_1) + (f_0 - f_1)(f_0 - f_0 + f_1)]}} = -\frac{f_1 f_0}{0} = -\infty.$$

$$\therefore F_1 : -F_0 = \frac{f_1 f_0}{f_0 - f_1} : -\infty \ldots\ldots\ldots\ldots (51)$$

For $F_1 = \frac{f_1 f_0}{f_0 - f_1}$, we have as the refraction $\frac{1}{F_1} = \frac{1}{f_1} - \frac{1}{f_0}$; consequently,

11. *When the convex cylinder is of greater refraction than the concave cylinder, and their axes are coincident, the positive focal plane will coincide with that focal plane which is defined by the difference of the refractions of the cylinders,* whereas the negative focal plane will be at infinity.*

Placing $\gamma = 0°$, or $\cos 2\gamma = +1$, in the equations (48) and (50), we have, for $f_1 > f_0$,

$$F_1 = \frac{f_1 f_0}{\frac{1}{2}[f_1(f_1 - f_0) - (f_1 - f_0)(f_0 + f_1 - f_0)]} = \frac{f_1 f_0}{0} = \infty.$$

$$-F_0 = -\frac{f_1 f_0}{\sqrt{\frac{1}{2}[f_1(f_1 - f_0) - (f_1 - f_0)(f_0 - f_1 + f_0)]}} = -\frac{f_1 f_0}{f_1 - f_0}.$$

$$\therefore F_1 : -F_0 = \infty : -\frac{f_1 f_0}{f_1 - f_0} \ldots\ldots\ldots\ldots (52)$$

For $-F_0 = -\frac{f_1 f_0}{f_1 - f_0}$, we have as the refraction

$$-\frac{1}{F_0} = -\left(\frac{1}{f_0} - \frac{1}{f_1}\right) \text{ consequently,}$$

12. *When the concave cylinder is of greater refraction than the convex cylinder, and their axes are coincident, the negative focal plane will coincide with that focal plane which is defined by the difference of the refractions of the cylinders,* whereas the positive focal plane will be at infinity.*

This is shown in Plate IV, Fig. 1.

Introducing $\gamma = 90°$, or $\cos 2\gamma = \cos 180° = -1$ in the equations (48) and (50), we have, for $f_0 \gtreqless f_1$,

* Or the sum of their refractions when taken as positive and negative elements.

$$F_1 = \frac{f_1 f_0}{\sqrt{\frac{1}{2}[f_1(f_1+f_0)+(f_0-f_1)(f_0+f_0+f_1)]}} = \frac{f_1 f_0}{f_0} = f_1.$$

$$-F_0 = -\frac{f_1 f_0}{\sqrt{\frac{1}{2}[f_1(f_1+f_0)+(f_0-f_1)(f_0-f_0-f_1)]}} = -\frac{f_1 f_0}{f_1} = -f_0.$$

$$\therefore F_1 : -F_0 = f_1 : -f_0 \ldots\ldots\ldots\ldots\ldots (53)$$

From which we deduce:

13. *The positive and negative focal planes coincide with their correlative elementary focal planes, when the axes of the contra-generic cylinders are at right angles to each other.*

This is demonstrated in Plate IV, Fig. 2.

Between the limits of 0° and 90°, for $f_0 > f_1$, we have consequently found F_1 to vary between the limits of $\frac{f_1 f_0}{f_0 - f_1}$ and f_1 behind the combined lenses, while F_0 varies between the limits of ∞ and f_0 on the incident side of the same.

The convex cylinder being stronger than the concave cylinder, it is evident when their axes coincide that their combined refraction will be equal to that of a periscopic convex cylinder, since $\frac{1}{F_1} = \frac{1}{f_1} - \frac{1}{f_0}$ in the active plane; and $\frac{1}{F_0} = \frac{1}{\infty} = 0$ in the passive plane.

Between the same limits, when $f_1 > f_0$, F_0 will vary between $\frac{f_1 f_0}{f_1 - f_0}$ and f_0 on the incident side of the combined cylinders, while F_1 varies between ∞ and f_1 behind the same. (See Plate IV.)

In this case, when the axes coincide, it is evident that the resultant refraction will be equal to that of a periscopic concave cylinder, since $-\frac{1}{F_0} = -\left(\frac{1}{f_0} - \frac{1}{f_1}\right)$ in the active plane; and $\frac{1}{F_1} = \frac{1}{\infty} = 0$ in the axial plane.

Therefore, with an inequality in the refractive powers of the cylinders, rotation of one of them, from 0° to 90°, will be associated with corresponding changes in the position of the resultant focal planes, between the limits of infinity and the focus of the weaker cylinder on the one side, and between that focal plane which corresponds to the difference of their refractions and the focus of the stronger cylinder on the other. Since in this case the approach of one focal plane is accompanied by a corresponding recession of the other on the opposite side of the lenses, their movements are, as in the previous theorem, in opposite directions.

When the cylinders are of equal refractive power, f_1 being equal to f_0, it follows, from the relation (53), that $F_1 = F_0$, so that between the limits of 0° and 90°, F_1 will vary between infinity and f_1 on the positive side, while F_0 varies between infinity and f_0 on the negative or incident side of the combined cylinders.

Consequently, when the axes coincide, $+ F_1 = + \infty$ and $- F_0 = - \infty$. This is evident, since the refractions of equal convex and concave cylinders, under such circumstances, neutralize each other throughout.

By the previous considerations we therefore here also find:

14. *The positive and negative focal planes are conjugate planes, subject to variations of the angle between the axes of the contrageneric cylinders.*

The diagram, Plate III, has been constructed in accordance with the foregoing provisions.

For practical purposes, it will be found more convenient to use the formulæ in the next section.

Dioptral Formulæ for Combined Cylindric Lenses.

As the task of reducing *dioptries* to their focal distances would render calculation by the preceding formulæ somewhat arduous, we may here give the formulæ, expressed in refraction, which will be found especially convenient when applied to combinations of the dioptral system.

Since original publication, these formulæ have been given their simplest possible form. The new formulæ, II*D*, III*D*, VII*D* and VIII*D* are now introduced as sequences to the preceding original formulæ, and whose transformations have been accomplished through convenient substitutions from the equations 54a, 54 and 55.

For the focal distance F_1 we have as the refraction $\dfrac{1}{F_1} = R_1$, and for

f_1 and f_2, similarly, $\frac{1}{f_1} = r_1$ and $\frac{1}{f_2} = r_2$, which designate the dioptral powers of the cylinders.

By these, and similar substitutions for other foci, we may give the preceding formulæ (I) to (X), the following form:

I. Congeneric Cylinders.

$$\cos a = \sqrt{\frac{1}{2} + \frac{1}{2} \frac{r_2 + r_1 \cos 2\gamma}{\sqrt{r_1^2 + 2r_1r_2 \cos 2\gamma + r_2^2}}} \quad \ldots\ldots (ID)$$

$$R_1 = \sqrt{\tfrac{1}{2}(r_1 + r_2)^2 - r_1r_2 \sin^2\gamma + (r_1 + r_2)\sqrt{\tfrac{1}{4}(r_1 + r_2)^2 - r_1r_2 \sin^2\gamma}}.$$

$$R_1 = \tfrac{1}{2}\left(r_1 + r_2 + \sqrt{(r_1 + r_2)^2 - 4r_1r_2 \sin^2\gamma}\right) \quad \ldots\ldots (IID)$$

$$R_2 = \sqrt{\tfrac{1}{2}(r_1 + r_2)^2 - r_1r_2 \sin^2\gamma - (r_1 + r_2)\sqrt{\tfrac{1}{4}(r_1 + r_2)^2 - r_1r_2 \sin^2\gamma}}$$

$$R_2 = \tfrac{1}{2}\left(r_1 + r_2 - \sqrt{(r_1 + r_2)^2 - 4r_1r_2 \sin^2\gamma}\right) \quad \ldots\ldots (IIID)$$

To retain the significances of R_1 and R_2, in calculating, r_1 should represent the greater cylindrical refraction.

When the cylinders are of equal power, then $r_1 = r_2 = r$, so that

$$R_1 = r(1 + \cos\gamma) \quad \ldots\ldots (IVD)$$

$$R_2 = r(1 - \cos\gamma) \quad \ldots\ldots (VD)$$

II. Contra-Generic Cylinders.

$$\cos a = \sqrt{\frac{1}{2} + \frac{1}{2} \frac{r_1 - r_0 \cos 2\gamma}{\sqrt{r_1^2 - 2r_1r_0 \cos 2\gamma + r_0^2}}} \quad \ldots\ldots (VID)$$

$$R_1 = \sqrt{\tfrac{1}{2}(r_1 - r_0)^2 + r_1r_0 \sin^2\gamma + (r_1 - r_0)\sqrt{\tfrac{1}{4}(r_1 - r_0)^2 + r_1r_0 \sin^2\gamma}}.$$

$$R_1 = \tfrac{1}{2}\left(r_1 - r_0 - \sqrt{(r_1 - r_0)^2 + 4r_1r_0 \sin^2\gamma}\right) \quad \ldots\ldots (VIID)$$

$$-R_0 = -\sqrt{\tfrac{1}{2}(r_1 - r_0)^2 + r_1r_0 \sin^2\gamma + (r_0 - r_1)\sqrt{\tfrac{1}{4}(r_1 - r_0)^2 + r_1r_0 \sin^2\gamma}}.$$

$$-R_0 = \tfrac{1}{2}\left(r_1 - r_0 + \sqrt{(r_1 - r_0)^2 + 4r_1r_0 \sin^2\gamma}\right) \quad \ldots\ldots (VIIID)$$

When the cylinders are of equal power, then $r_1 = r_0 = r$, hence

$$R_1 = r\sin\gamma \ldots\ldots (IXD)$$

$$-R_0 = -r\sin\gamma. \ldots\ldots (XD)$$

If, in (IID) and (IIID), the convex element r_2 be replaced by the concave element $-r_0$, we obtain (VIID) and (VIIID).

By the aid of the preceding formulæ we may also arrive at the following significant facts.

The formulæ (IID) and (IIID) may be written:

$$R_1^2 = \tfrac{1}{2}(r_1+r_2)^2 - r_1r_2 \sin^2\gamma + (r_1+r_2)\sqrt{\tfrac{1}{4}(r_1+r_2)^2 - r_1r_2\sin^2\gamma)},$$

$$R_2^2 = \tfrac{1}{2}(r_1+r_2)^2 - r_1r_2 \sin^2\gamma - (r_1+r_2)\sqrt{\tfrac{1}{4}(r_1+r_2)^2 - r_1r_2\sin^2\gamma)},$$

which, by addition, result in the equation,

$$R_1^2 + R_2^2 = (r_1 + r_2)^2 - 2r_1r_2 \sin^2\gamma.$$

$$\therefore\ (R_1 + R_2)^2 - 2R_1R_2 = (r_1 + r_2)^2 - 2r_1r_2 \sin^2\gamma.$$
$$\therefore\ (R_1 + R_2)^2 = (r_1 + r_2)^2 - 2r_1r_2 \sin^2\gamma + 2R_1R_2.$$

Multiplying (IID) by (IIID), we find,

$$2R_1R_2 = 2r_1r_2 \sin^2\gamma. \quad \ldots\ldots\ldots\ldots\ldots\ldots (54a)$$

$$\therefore\ R_1 + R_2 = r_1 + r_2. \quad \ldots\ldots\ldots\ldots\ldots\ldots (54)$$

From which we conclude:

15. *The sum of the primary and secondary refractions is a constant, being equal to the sum of the elementary refractions for any combination, and all deviations of the axes of two combined congeneric cylinders.*

In the same manner, we obtain from the formulæ (VIID) and (VIIID),

$$R_1 - R_0 = r_1 - r_0, \quad \ldots\ldots\ldots\ldots\ldots\ldots (55)$$

and therefore here also find,

16. *The sum of the principal positive and negative refractions is a constant, being equal to the sum of the positive and negative elementary refractions for any combination, and all deviations of the axes of two combined contra-generic cylinders.*

As the total inherent refraction always remains the same for any combination, the angle γ merely performs the function of allotting the proportions of refraction, R_1 and R_2, or R_1 and R_0, in the resultant principal planes.

By the equations (54) and (55), calculation may be greatly simplified. R_1 being determined for a specific value of γ, we may readily determine R_2 and R_0, by transforming these equations, as follows:

$$R_2 = r_1 + r_2 - R_1$$

$$-R_0 = r_1 - r_0 - R_1.$$

This is demonstrated in the appended tables.

Tables in Verification of the Dioptral Formulæ.

For Combined Congeneric Cylinders.

ELEMENTARY REFRACTIONS.	AXIAL DEV'T'N.	PRIMARY REFRACTION.		SECONDARY REFRACTION.		$R_1+R_2=r_1+r_2$
$r_1 > r_2$	γ	R_1	(*Approx.*)	R_2	(*Approx.*)	
2.5 ⌢ 1.5*D.*	30°	3.75*D.*	3.75*D.*	0.25*D.*	0.25*D.*	4*D.*
2.5 ⌢ 1.5*D.*	45°	3.46	3.5	0.54	0.5	4
2.5 ⌢ 1.5*D.*	60°	3.09	3.	0.91	1.	4

For Combined Contra-Generic Cylinders.

ELEMENTARY REFRACTIONS.	AXIAL DEV'T'N.	POSITIVE REFRACTION.		NEGATIVE REFRACTION.		$R_1-R_0=r_1-r_0$
$r_1 > -r_0$	γ	$+R_1$	(*Approx.*)	$-R_0$	(*Approx.*)	
+ 4 ⌢ — 2.75*D.*	30°	2.397*D.*	+ 2.5*D.*	1.147*D.*	— 1.25*D.*	+ 1.25*D.*
+ 4 ⌢ — 2.75*D.*	45°	3.052	+ 3.	1.802	— 1.75	+ 1.25
+ 4 ⌢ — 2.75*D.*	60°	3.564	+ 3.5	2.314	— 2.25	+ 1.25
$r_1 < -r_0$	γ	$+R_1$	(*Approx.*)	$-R_0$	(*Approx.*)	$R_1-R_0=r_1-r_0$
+ 2 ⌢ — 2.75*D.*	30°	0.856*D.*	+ 0.75*D.*	1.606*D.*	— 1.5*D.*	— 0.75*D.*
+ 2 ⌢ — 2.75*D.*	45°	1.325	+ 1.25	2.075	— 2.	— 0.75
+ 2 ⌢ — 2.75*D.*	60°	1.690	+ 1.75	2.440	— 2.5	— 0.75

Sphero-Cylindric Equivalence of Combined Cylindric Lenses.

Since, for any combination of cylinders, the principal planes of refraction are at right angles to each other for all values of γ, there can be no reasonable doubt, owing to the provisions made at the opening of this demonstration, as to the equivalence of a sphero-cylindric lens to one composed of combined cylinders. However, as the use of such lenses is at present confined to the correction of errors of refraction in the human eye, it is evident, from the movements of the eye behind the fixed lens, that the visual axis cannot at all times coincide with the optic axis of the lens chosen; therefore, in those instances where substitution of one form of lens for the other proves to be unsatisfactory, the cause may be seemingly explained by a possible difference becoming manifest for the more peripheral incident rays, though these be equally distant from the optic center of each lens. In other words, the available field in the one may be greater or less than in the other; yet even this would probably only be appreciable in lenses of extreme curvature, and possibly in combinations where the cylinders differ widely in power.

To substitute a sphero-cylindric lens for combined cylinders is a proposition which merely demands that the focal interval should be the same, at the same distance from the principal plane, at the optic center, for each of the compound lenses. The distances F_1 and F_2 being determined for any angular deviation, γ, of the axes, in a combination of congeneric cylinders, for instance, the substitution is accomplished by making a sphero-cylindric lens in which the focus of the spheric element is equal to F_2, and of the cylindric element is equal to $\frac{F_1F_2}{F_2 - F_1}$, or, if expressed in refraction, $\frac{1}{F_1} - \frac{1}{F_2}$ sph. $= \frac{1}{F}$ cyl. $= \frac{1}{F_c}$.

Should it be desired to place the primary and secondary planes of the sphero-cylindric lens so as to coincide with those resulting from a combination of two definitely placed congeneric cylinders, it will be necessary to refer to the formula (1) and to the laws 2 and 3.

Comparing the sphero-cylindric equivalent with its corresponding rotating cylinders, reference being had to Plate II, Figs. 2 and 3, we find a decrease in the angle, γ, from 90° to 0° to effect a corresponding decrease in the spheric element, F_2, from the focus f_2 to ∞; this being associated with a cylindric element of the focus F_c, which constantly increases from the focus $\frac{f_1f_2}{f_2 - f_1}$ to $\frac{f_1f_2}{f_2 + f_1}$. In other words, a gradually decreasing potency of the spheric refraction $\frac{1}{F_2}$ from $\frac{1}{f_2}$ to $\frac{1}{\infty} = 0$, gives way to a proportionately increasing cylindric refraction $\frac{1}{F_c}$, from $\frac{1}{f_1} - \frac{1}{f_2}$ to $\frac{1}{f_1} + \frac{1}{f_2}$. As an instance, if $f_1 = f_2 = f$, $\frac{1}{F_c}$ will increase from $\frac{1}{f_1} - \frac{1}{f_2} = 0$ to $\frac{2}{f}$, or twice the refraction of either cylinder. In this case, all successive values of cylindric refraction will, therefore, be inherent between 0 and $\frac{2}{f}$.

Should a means be devised to suppress the spheric element for each successive value of γ, the remaining varying cylindric element being thus rendered available for measuring corresponding degrees of astigmatism in the eye, the formulæ here advanced would prove of service in obtaining the graduations upon the rotating scale of such an instrument.

While there are few cases of astigmation which demand correction by combined cylinders, we may nevertheless be permitted to passingly allude to certain methods of procedure in such instances. We shall confine the subject to congeneric cylinders. In a case of astigmatism which has been found to be corrected by two cylinders combined under the angle γ, the lenses should be withdrawn from the trial frame, when they are to be superposed with their plane surfaces in contact; and in such manner as to facilitate their being rigidly held in the required position for γ.

The positions of the principal planes of refraction may then be estimated for this fixed combination, the same as if it were a single lens, though without regard to the exact nature of the elements constituting it. The powers of the principal planes of refraction will be revealed by neutralizing with the lenses from the trial case. The spheric and cylindric elements thus determined are then to be substituted in the trial frame, when rotation of the cylinder will lead to that position of it which produces the best acuteness of vision. The spheric and cylindric elements will probably then also bear of further modification, in case any error may have been made at the outset. In lieu of this practical method, recourse must be had to the formulæ.

It having been shown that successive changes in the angle γ are associated with corresponding changes in F_1 and F_2, the above substitution would indeed seem advisable, since the present appliances for grinding bicylindric lenses are not constructed with sufficient precision to enable opticians to fix the relative positions of the cylinders beyond mere approximation.

As an illustration, let us select two congeneric cylinders of equal foci, say 20 inches, combined under the angle $\gamma = 60°$. Introducing these values in the formulæ (IV) and (V), we find,

$$F_1 = \frac{20}{1 + \cos 60^\circ} = \frac{20}{1 + 0.5} = 13.33,$$

$$F_2 = \frac{20}{1 - \cos 60^\circ} = \frac{20}{1 - 0.5} = 40.$$

We then obtain the cylindric refraction $\frac{1}{F_c}$, for the desired sphero-cylindric equivalent, from the equation,

$$\frac{1}{F_1} - \frac{1}{F_2} = \frac{1}{F_c}. \quad \ldots\ldots\ldots\ldots\ldots\ldots (56)$$

Substituting herein the calculated values for F_1 and F_2 gives,

$$\frac{1}{13.33} - \frac{1}{40} = \frac{1}{F_c} = \frac{1}{19.99} = \frac{1}{20} \text{ (nearly)}.$$

$\frac{1}{F_2} = \frac{1}{40}$ being the spherical element, we therefore have the sphero-cylindric equivalent,

$$\frac{1}{40} \text{ sph.} \supset \frac{1}{20} \text{ cyl.}$$

as an available substitute for the cylindro-cylindric lens,

$$\frac{1}{20} \text{ cyl. axis } 0^\circ \supset \frac{1}{20} \text{ cyl. axis } 60^\circ$$

without regard to a definite position of these lenses before the eye.

By way of comparison, allowing the optician to make an error of apparently so small an amount as 2°, in producing the same cylindro-cylindric lens, we obtain, by introducing $\gamma = 62^\circ$ in the same formulæ,

$$F_1 = \frac{20}{1 + \cos 62^\circ} = \frac{20}{1 + 0.469} = \frac{20}{1.47} = 13.61,$$

$$F_2 = \frac{20}{1 - \cos 62^\circ} = \frac{20}{1 - 0.47} = \frac{20}{0.53} = 37.73.$$

Substituting these values in the equation (56), we have,

$$\frac{1}{13.61} - \frac{1}{37.73} = \frac{1}{F_c} = \frac{1}{21.29},$$

from which we obtain the sphero-cylindric lens,

$$\frac{1}{37.73}\text{ sph.} \supset \frac{1}{21.29}\text{ cyl.}$$

Had the optician been required to make a sphero-cylindric lens $\frac{1}{40}$ sph. $\supset$ $\frac{1}{20}$ cyl., his execution of it presenting such discrepancies as $\frac{1}{37.73}$ sph. $\supset$ $\frac{1}{21.29}$ cyl., would certainly be rejected as being unsatisfactory, on account of the notable difference of 2.27 inches in the focal distance of the spheric element.

On the other hand, instances are likely to occur in which it will be impossible, by the advanced method of neutralization to accurately arrive at the sphero-cylindric equivalent.

Since $\frac{1}{20}$ cyl., axis 0° $\supset$ $\frac{1}{20}$ cyl., axis 62° $=$ $\frac{1}{37.73}$ sph. $\supset$ $\frac{1}{21.43}$ cyl., we should evidently be unable to accurately neutralize such spheric and cylindric elements by any of the lenses from the trial case.

In those instances, therefore, where satisfactory neutralization of the principal planes of refraction in a pair of combined cylinders cannot be attained, the cylindro-cylindric lens will have to be chosen, again under the proviso, however, of a faultless mechanical execution. However, as in most instances a sphero-cylindrical equivalent will be available, *we are to suspect error in our estimate of the refraction of an eye which seems to demand cylinders combined under acute or obtuse angles.*

The following is a case in point:

A cylindro-cylindric lens $-\frac{1}{40}$ cyl. axis 0° ⊃ $-\frac{1}{40}$ cyl. axis 70° had been prescribed for Mr. G. B. O., of New York, by his oculist in Philadelphia, in 1880–'1. With this lens the vision equalled $\frac{6}{6}$ for the left eye.

In this instance the sphero-cylindric equivalent was obtained as follows:

The lenses being congeneric concave cylinders of equal refraction, by the formulæ (IV) and (V), for f = 40 and $\gamma = 70°$, we have,

$$F_1 = \frac{40}{1 + 0.34202} = 29.806 = 30,$$

$$F_2 = \frac{40}{1 - 0.34202} = 60.79 = 60,$$

it being admissible to neglect the fractions for such focal distances.

By law 2, we find the position of the cylindric axis equal $\frac{\gamma}{2} = 35°$, and consequently the sphero-cylindric equivalent,

$$-\frac{1}{60} \text{ sph.} \supset -\frac{1}{60} \text{ cyl., axis } 35°.$$

This lens was substituted with the knowledge and to the entire satisfaction of the patient.

It is, therefore, obvious that the meridian (125°) of greatest refraction in the eye had not been disclosed by the diagnosis.

The weak spheric element in the substituted lens, while being an appreciable factor to the patient, might easily have been overlooked by the practitioner.

In similar cases, the advanced formulæ should prove of value in fixing upon the true state of the refraction.—(C. F. P.)

See, also, **Physiologic optics**; as well as **Astigmatism** and various **Eyeglasses** headings in this *Encyclopedia*.

Lenses, Aspheric, of wide aperture. See **Lenses and prisms, Ophthalmic.**

Lenses, Cylindric. See **Lenses and prisms, Ophthalmic**; as well as p. 3657, Vol. V of this *Encyclopedia.*

Lenses, Bifocal. See **Lens, Bifocal.**

Lenses, Compound. See **Lenses and prisms, Ophthalmic.**

Lenses, Decentration of. See **Lenses and prisms, Ophthalmic**; as well as p. 3790, Vol. V of this *Encyclopedia.*

Lenses, Equivalent. See **Lenses and prisms, Ophthalmic**; also, p. 4505, Vol. VI of this *Encyclopedia.*

Lenses, Numeration of. NOTATION OF LENSES. NUMBERING OF LENSES. DESIGNATION OF LENSES. The *numbering of lenses and prisms* is sometimes confused with the *relative position of the axis in cylinders.* Both these subjects will be considered under the same general heading.

Formerly *lenses were numbered* according to their radii of curvature expressed in the Paris inch (27.07 millimetres). Since there is a difference between this and the English and the German inch, this method of numeration has fallen into disuse. Lenses are now numbered to indicate their focal distance on the basis of the metric system, the unit being a lens having a focal distance of one metre and called a dioptre, the numbers expressing the refractive powers being multiples of this lens.

A lens having a focal distance of one metre would have the sign 1 D. to represent it; a plus or positive sign is prefixed (+ 1 D.) if convex, and a negative or minus sign (— 1 D.) if concave. Should the lens be a spheric one, the sign S. is placed between the characters and the strength sign. If it be a cylinder, the sign C. is substituted for the letter S. and the axis-angle is expressed by the abbreviation, ax. with the degree of angle added (+ C. 1 D.; ax., 90°). The combination of a sphere and a cylinder would be written, if convex, in the following manner: (+ S. 1 D. ⊂⊃ + C. 1 D.; ax., 90°). Under the metric system the recorded strength of a lens is inverse to its focal distance. A lens of two dioptres' power (2 D.) focuses at one-half metre; a 4 D. lens at one-fourth metre. A lens that focuses at two metres is known as 0.50 D. One at four metres' distance = 0.25 D.

To find the focal length of a lens in the dioptric system divide one metre, or one hundred centimetres, by the number of dioptres; thus, the focal length of a lens of 4 D. is $^{100}/_{4} = 25$ centimetres. The inch system was the old way of numbering lenses according to their radii of curvature expressed in inches. The unit 1 was a lens with a focus of about one inch. The successive strengths were expressed by fractional parts of 1; as, a lens of 4-inch focus was expressed as $\frac{1}{4}$, and one of 40-inch as $\frac{1}{40}$.

To convert any strength of dioptre lens into an equivalent one of the old system, divide the dioptric number into 40 (there are 39.37 inches in a metre) and the inches of focal distance will be obtained. Or, having the number of inches of focal distance of a lens and dividing it into 40, we get the number of the lens in the dioptric system.

With the dioptric system the calculation necessary for any combination of lens-power is very easy. As example, a + S. 2 D. added to + S. 4 D. gives a lens of + S. 6 D. Or, with unlike combinations, a + S. 4 D. and a — S. 1 D. added together give a resultant of + S. 3 D.

Similarly formed lenses produce results equal to their added powers, while dissimilarly formed lenses give results equal to their differences. The same rule holds good for cylinders in similar axes, while prisms increase in strength when placed base to base, and decrease in strength when placea edge to base.—(J. M. B.)

The Editor of the *Ophthalmic Year-Book* (p. 72, 1912) regards it as strange that so much ingenuity has been expended in contriving a method of *notation for the axis in astigmatism*, and thus introducing confusion, when a simple and satisfactory method is at hand. The mathematician numbers angles beginning with the initial diameter from zero around the circumference through the four quadrants without risk of confusion. This is the method in use in the United States, and it is to be hoped that the oculists and opticians of this country will not permit themselves to be influenced to change this excellent and simple method for any other. The fact that the zero point is upon the temporal extremity of the horizontal diameter of the right eye, and upon the nasal for the left, is not a real objection. In both cases the angles are counted from the initial diameter around the circumference by the left (counter clock wise), as is the universal custom in mathematics. It is obvious that the semi-circumference only needs be numbered; this fixes the direction of the meridian axis without the possibility of confusion, any more than in mathematical discussions. In France confusion has existed ever since the Commission of 1887 recommended a departure from the usual mathematical methods of designating meridians. Sulzer has proposed (*Ann. of Ophth.*, Vol. XXII, p. 49, 1911), since all the world uses the same kind of clock face, to place zero at the top and to go round the half circle to 180 degrees with the clock hands.

Mayer's (*Ophthalmoscope*, Vol. X, p. 407, 1911) proposal for notation is as follows: "Of the two principal meridians of an astigmatic lens, there is always one which is placed upwards and to the nasal side, or downwards and to the temporal side. It is this meridian the inclination of which is to be indicated by an angle. It is, then, sufficient to indicate the power which the lens is to have in this meridian, and that which it is to have in the meridian at right angles, in order completely to specify the lens from the optical point of view. To distinguish these two meridians, it is only necessary to place the second power underneath the first:

Example, $25° \begin{cases} +2 \text{ D. Sph.} \\ -0.75 \text{ D. Sph.} \end{cases}$

This notification would mean that in the nasal quarter circle, above the horizontal, the meridian at 25 degrees would have a power of +2 D., and that the meridian at right angles would have a power of —.75 D."

See, also, p. 273, Vol. I of this *Encyclopedia.*

Lenses, Thin. See **Lenses and prisms, Ophthalmic.**

Lenses, Tinted. See p. 2388, Vol. IV of this *Encyclopedia;* also the **Eyeglasses** captions.

Lenses, Toric. See **Lenses and prisms, Ophthalmic.**

Lenses, Typical. See **Lenses and prisms, Ophthalmic.**

Lenses, Wide-aperture. See **Lenses and prisms, Ophthalmic.**

Lens expressor. The removal (expression) of the lens in its unruptured capsule is fully discussed on p. 1507, Vol. III of this *Encyclopedia.* The instrument by means of which Pagenstecher expressed the lens is pictured on p. 4876, Vol. VII of this *Encyclopedia.*

Lens, Extraction of the. See various **Cataract** headings.

Lens, Foreign bodies in the. This subject has been discussed on p. 6315, Vol. VIII of this *Encyclopedia;* also under **Cataract, Traumatic,** and to some extent under **Electromagnet** and **Magnet.**

A few histories in point but not referred to in the foregoing captions are the following: Vossius (*Prac. Med. Series, Eye,* p. 175, 1910) has described two cases showing a *chip of iron in the lens* that showed the diagnostic and practical value of siderotic discoloration of the iris, with yellowish dots on the anterior surface of the crystalline. If siderosis of the iris is lacking in a cataract with yellow dots on the anterior surface of the lens, we are justified in inferring the presence of a piece of iron in the lens; whereas siderosis of the iris and cataract with yellow dots on the surface of the lens point to iron in the vitreous or the retina. If the foreign body remains in the eye, the siderosis of the iris may disappear after several years, but the iris may still give the iron reaction, as observed by von Hippel.

An example of non-magnetic foreign bodies in the lens—a piece of coal—is given by W. Zimmermann (*Prac. Med. Series, Eye,* p. 147, 1912). A railroad laborer had noticed impairment of vision of his left eye. There was a compact posterior synechia, and a reflex from the otherwise transparent lens, apparently from a foreign body. After dilation of the pupil fine opacities in the lens near the synechia were visible, and with Zehender's loupe a barely noticeable linear scar in the cornea. The sideroscope and Haab's giant magnet gave no reaction.

After repeatedly being questioned, the patient remembered that in loading coal three months previously, something flew into his eye. As an immediate extraction of the transparent lens seemed too dangerous, on account of the possibility that the foreign body might be lost in the interior of the globe, a preparatory iridectomy and maturation were performed and this was repeated after two weeks. After two weeks further the now cataractous lens was extracted within the capsule. It contained an irregularly-shaped piece of coal, the presence of which could not be guessed from the smooth corneal scar.

Lens grinding. See **Lenses and prisms, Methods of manufacture.**

Lens, Gutter. A very rare anomaly of the crystalline described by Otto Becker in 1883.

Lens, Hess' binocular. This instrument is intended for examination of the cornea or for use in ophthalmic operations. It is to be employed with a 100-volt electric lamp. The binocular does not differ essentially from similar devices described on p. 4610, Vol. VI, of this *Encyclopedia*, and elsewhere. (See p. 3446, Vol. V).

Lens-holder. A support for a lens, or a lens-system, occasionally used for adjusting an object to the focus.

Lens, Isocrystar. See **Isocrystar lens.**

Lens, Luxation of the. See **Lens, Dislocation of the.**

Lens measurer. LENS TESTER. AXIS FINDER. INCLINOMETER. Apparatus for determining the axis of cylinders and the refractive power of spherical and cylindrical lenses—apart from the common and rough-and-ready method of neutralization by lenses from the trial case—are quite numerous.

A very good one is the lens tester invented by Harold Grimsdale (*Ophthalmoscope*, Oct., 1914). This instrument consists of a box about eight inches long and about four inches square. One end of the box is closed except for a circular central opening one inch in diameter; around the opening is a graduated circle, and at the ends of the vertical and horizontal meridia are cut V-sights. Sliding in the box and held in position by a spring is a ground glass screen, on which a cross is ruled. The central crossing of the arm is in the central axis of the box, and therefore corresponds with the centre of the aperture in the closed end. The rear end of the box is open.

The method of use is as follows:—The surgeon takes the lens to be tested and places it over the central opening. If the cross on the screen is seen distorted, so that not all the lines can be brought accurately into the points of the four Vs at one and the same time, there is some astigmatism of the lens and the axis of the cylindrical element can be found by rotating the lens until the angles of the cross form true right angles and the lines fall into the points of the Vs. The angular position of the cylindrical can then be read off directly from the scale.

If there be a question of proper centering or decentering to form a prism, the geometrical center of the lens should be marked by a point of ink, and the lens placed with its center in the horizontal meridian of the anterior opening, and rotated, if necessary, so as to bring the axis of the cylindrical into the horizontal line.

If now the horizontal line of the cross appears unbroken, the lens has no vertical prismatic effect. If, however, part of the line seen through the lens appears above or below the part seen through the empty aperture, there is a vertical prismatic deviation, and this can be measured by placing prisms of known strength over the lens until the two half lines are brought into one. It is often difficult, when the cylindrical is oblique, to calculate the prismatic effect of any decentration, and the correcting prism should be placed with its apical angle in parallel to the horizontal axis of the lens.

In this way very accurate estimation of prisms can be made. The screen is made movable, so as to allow of the examination of lenses of short focal length; normally it is kept about five inches from the aperture.

The Geneva lens measure (see the cut) is a ready, popular and fairly accurate means of determining the curvature and strength of lenses. It is made in watch size, convenient to carry in the vest pocket. There are, also, two styles, the so-called "Regular," for general use, and the "Scale" for measuring bifocal scales and small lenses or pieces of lenses. The latter type is especially desirable where much replacing of lenses is done from broken pieces.

Among other patented forms employed for the same purpose are the Wafer-Segment measure, also depicted in this text.

The so-called Stoco machine (see **Lens and prism centering**) may also be used as a lens measurer.

Rhoads (*Ophthalmic Year-Book,* p. 57, 1912) has devised an instrument for *neutralizing toric lenses.* The instrument consists of a hard-rubber disk one and one-half inches in diameter with a 6 D, convex and concave surface. Both surfaces are marked with a complete circular protractor graduated to 2½ degrees; the disk has two holes in it, one in the center, 7 mm. in diameter, and the other half-way between the circumference and the center, oblong in shape 7 by 10 mm., the latter for the bifocal segment. The lens to be neutralized is placed upon the disk; the axis will be shown upon the protractor, and the strength can be readily found with the lenses from the test case. This little apparatus is of welcome assistance for the somewhat troublesome neutralization of toric lenses. The addition of the protractor will be found of service in determining the axis. A similarly made flat disk would be of use in the rapid neutralization of ordinary non-toric lenses.

1905.

Geneva Lens Measure.

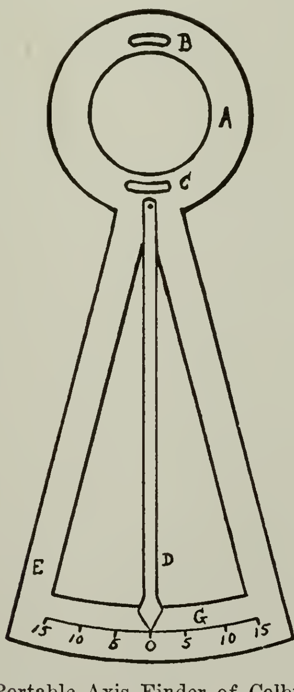
Maddox (*Ophthalmoscope,* Feb., p. 88, 1914) not only describes the Burdon-Cooper (*Ophthalmoscope,* 1910) method of indicating the axis of a cylindrical lens but also suggests an improvement in it. The plan takes advantage of the fact that the reflections from an incandescent lamp can be made to indicate the axis of a cylindrical lens. To give precision to the result and to locate the axis in degrees, he enclosed a lamp in a small cubical box, one side of which contained a rotating disk, with a slit across one diameter, so as to obtain a rotating line of light. This box was mounted at one end of a board, the other end of which either supported the pair of lenses to be tested, or else allowed the patient's own face to be so placed as to let the lenses have their axes determined actually as worn. This was a great advance, and the "optical aximeter" would doubtless have come into general use some years ago, but for the unfortunate limitation that it could not be used for toric lenses, which are becoming more and more general.

Maddox experimented with reflections from glass and metal rods and white knitting pins. He found that the difficulty with torics can be entirely overcome by this means, since the only requisites are to be able

Wafer-Segment Measure. (Exact Size)

Showing Mechanical Construction

This instrument, for the measurement of small cemented segments in bifocal lenses, or of broken fragments of large lenses, is to be slipped over the regular lens measure.



Portable Axis Finder of Colburn.

to choose for each lens an appropriate distance of the object, and that the latter should be thin enough to allow the eye of the observer to be approximately in line with the object and image. The only drawback, therefore, to the "optical aximeter" was its fixed distance. He advises that to examine a single lens, as from the trial case, or a spectacle lens, we need only hold it against a dark background and in comparative shade, while the knitting pin or whitened hat pin is allowed to have the light falling full upon it. The distance at which to hold the rod is very speedily found, since it is that which enables us to see the reflections from the two surfaces of the lens as equally clearly as possible. When they are parallel, the axis is also parallel to them, and to the pin which produces them, or else at 90° therefrom.

Without any apparatus a thin white rod, such as can be conveniently carried in the waistcoat pocket, will be found very handy for ascertaining whether an axis supposed to be vertical or horizontal is really so, since it is easy to hold the rod upright or horizontal and note whether its two images are parallel or not. If they lie at an angle, the tilting of the rod required to restore their parallelism gives a very good idea of the amount of error. For all such tests a black or sombre background is very helpful. A little velvet fixed to a strip of cardboard can be slipped behind the lens. When the trial frame contains both a sphere and a cylinder, the former should be extracted from its cell before testing the cylinder, for though its reflections in no way vitiate the test, they are embarrassing. See, also, **Inclinometer.**

Lens, Periscopic. As Percival (*Ophthalmoscope,* p. 390, July, 1914) and many others have pointed out, patients who are obliged to wear strong convex glasses are obliged to move their heads in order to see distinctly objects that lie to the right or to the left of them. If they keep their heads fixed, and rotate their eyes behind their glasses, their visual lines traverse peripheral parts of the lenses and the resulting image is consequently blurred. Periscopic lenses are designed to obviate this defect; when they are perfectly periscopic, eccentric vision through them is as distinct as centric, so that the wearer can rotate his eyes behind the glasses without being inconvenienced by seeing lateral objects indistinctly. To this Percival adds that the work of von Rohr and Gullstrand stands out pre-eminently among the rest as having given a satisfactory solution to the problem. Unfortunately, as one surface at least of von Rohr's lenses must be aspherical, their cost is too great to be used by any but the wealthy. See **Punktal lenses** and **Isokrystar lenses.**

Percival shows how menisci can be ground with ordinary spherical surfaces for strengths up to + 7 D or + 8 D, which will serve satisfactorily for reading purposes. As said before, von Rohr's aspherical menisci are perfect for higher powers, such as are required by aphakic patients, but even to these some help is given by appropriate spherical menisci, if the cost of the aspherical luxury is prohibitive.

Percival's method of dealing with the problem is as follows:—We will suppose the eye rotates an angle θ (say 25°) from the primary position behind the spectacle lens; it is clear that the incident pencil will traverse an eccentric part of the lens, and on emergence from the lens will form an astigmatic pencil with two focal lines. When the size of the pupil is known, the size and position of the least circle of confusion can be calculated for this emergent pencil for the given lens. It is then a simple matter to find what will be the size of this circle of confusion when it falls upon the macula after refraction through the media of the eye. It is required to construct the lens in such a fashion that the retinal circle of confusion shall not be larger than the sectional area of a macular cone, the radius of which is .001 mm. It is first necessary to find the position of the first and second focal lines (v' and v'') of the emergent pencil from the spectacle lens.

If there is any solution of the problem by the use of a meniscus with spherical surfaces, there are always two possible forms, either a deep meniscus or a shallow meniscus. For instance, a periscopic meniscus lens of + 6 D can be formed in two ways—a shallow meniscus with its anterior surface convex with a curvature corresponding to + 11 D and its posterior curvature of — 5 D, or a deep meniscus with anterior surface + 17 D and its posterior surface — 11 D. When placed in the proper position before the eye, either of these glasses will allow it to rotate 25° on either side of the middle line and still have distinct vision; *i. e.*, the circle of confusion will be smaller than the sectional area of a macular cone, although a meniscus of an intermediate value (say, + 14 and — 8) will be very bad for indirect vision, as the circle of confusion will be far too large. This will account for the many different values that are assigned to the correct form of meniscus. Obviously, the shallow menisci are the most convenient on account of (1) their better appearance, (2) their cheapness, as they are easier to make, and (3) because there is less displacement of their cardinal points.

A thoroughly satisfactory solution of the problem can be obtained with a simple meniscus ground with ordinary spherical surfaces for many powers, say from — 20 D to + 7 D, but it will be found that the meniscus must be of a different form if required for distant vision or if required for reading distance.

For instance if a + 6 D lens were required to be periscopic for distance its form should be + 13 D — 7 D, but as stated above if required for reading distance it should be a less deep meniscus + 11 D — 5 D. The periscopic reading glass will only be periscopic for distance in the lower powers. See, also, **Lenses and prisms.**

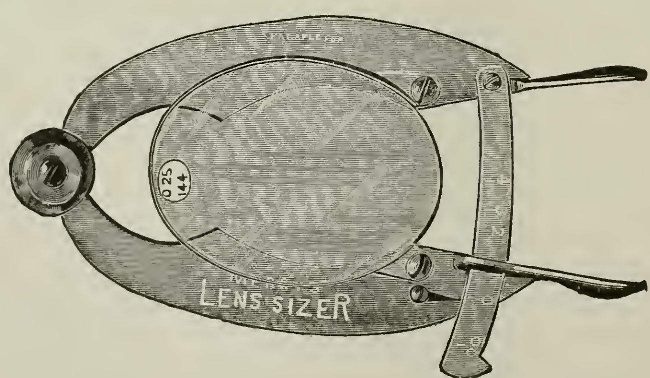
Lens polishing. See **Lenses and prisms, Methods of manufacture.**

Lens, Punktal. See **Punktal lens**; as well as **Lenses and prisms, Ophthalmic; Lens, Periscopic.**

Lens, Radioactive. This term has been applied, especially by Precerutti (*La Clinique Ophtal.*, April, 1913) to a radioactive lens that corrects refraction defects and at the same time, by incorporating radium in the silicates of the glass, gives the curative power of that element. The air space between the glass and eye is ionized and clinical experiments together with the electroscope of Professor Curie are said to have demonstrated the efficiency. The claims for these lenses are: The activity of metabolism is augmented; the nutrition of the eye is increased; the curative action upon the interior of the bulb has a beneficial action upon beginning cataract, choroiditis and retino-choroiditis.

It is also claimed that the visual power of myopes is materially benefited, by easing the convergent force, and asthenopic symptoms are relieved. Hypermetropes and presbyopes who have worn this glass affirm that they feel "refreshed." External diseases which have been relieved by exposure to radium, as conjunctivitis and blepharitis, heal readily, and prolonged treatments with the drug proper can be dispensed with.

Lens-sizer. This is a patented (Merry's) device for measuring the circumference of all round and oval lenses, from Nos. 5 to 00, eye size. See the figure.



Merry's Patent Lens-Sizer.

Lens-spoon, Bowman's. See p. 1666, Vol. III of this *Encyclopedia*.

Lens spots. See **Cataract, Posterior polar.** Since Mittendorf's second article in 1906, Gifford has made a record of the cases he has seen showing the spot on the posterior capsule just to the nasal side of its center. In approximately 1,500 cases he found the spot on one or both eyes of 31 patients, or about 2 per cent. In 4 cases they occurred in both eyes, and in those in which only one eye was affected 12 showed it in the right eye, and 15 in the left. The author agrees with Mittendorf that they are caused by remnants of the hyaloid artery.

Lens star. See page 378, Vol. I of this *Encyclopedia*.

Lens-stereoscope. See p. 1292, Vol. II of this *Encyclopedia*.

Lens, Toric. See **Lens, Periscopic** and **Lenses and prisms, Ophthalmic.**

Lens, Umbilication of the. See p. 2879, Vol. IV of this *Encyclopedia*.

Lens, Wandering. In certain forms of dislocated lens the crystalline may slip back and forth through the pupil—hence this name.

Lente. (It.) Lens.

Lente di contatto. (It.) Contact lens.

Lenticonus. Lentiglobus. A conical projection of the lens surface. When it occurs in front it is known as *anterior lenticonus;* at the posterior pole it is called *lentiglobus* or *posterior lenticonus.*

In addition to a discussion of this subject on p. 2877, Vol. IV, of this *Encyclopedia* it may be added here that a case of *traumatic lentiglobus,* or posterior lenticonus, is described by J. H. Fisher (*Ophth. Rev.,* April, 1913). A concussion injury had caused a minute rupture of the capsule of the lens at its posterior pole. This was so minute that at first it caused no alteration in the curvature of the lens, but it had the effect of abolishing, or at least of reducing, its power of increasing in convexity when the ciliary muscles were thrown into action. Gradually, a small hernia of the lens substance through the rupture produced the posterior lenticonus, so that in eleven months the striking change recorded in the refraction developed and the posterior lenticonus, which he recognized fifteen months after the accident, explained this phenomenon.

The iris and lens were never tremulous. The slowness of the change is what may be expected in a patient of forty years of age with a very small rupture of the lens capsule posteriorly.

Gourfein-Welt (*Archives d'Ophtalmologie,* Vol. XXXI, p: 625 1911) gives a complete bibliography of published cases of this sort and a review of the various explanations which have been offered for the development of posterior lenticonus.

She finds that the diagnosis of posterior lenticonus in the living is difficult but may be made by the coexistence of the double refraction and the irregularity of the image formed by the posterior surface of the lens. In doubtful cases, the congenital origin and a posterior polar cataract speak in favor of lenticonus. The lesion is generally a congenital anomaly, caused by a persistence and thickening of the hyaloid artery following intrauterine inflammation, and the ophthalmoscopic and anatomo-pathologic absence of the artery is no proof against this theory of the origin of the lesion. Other inflammatory conditions, e. g., retinitis proliferans, may take a part in its production.

Lenticula. In *optics,* a small lens; lenticule.

Lenticular. Resembling a lentil in size or form; having the form of a lens.

Lenticular astigmatism. Astigmatism due to causes residing in the crystalline lens.

Lenticular cataract. A cataract in which the opacity is confined to the lens, the capsule remaining transparent.

Lenticular ganglion. CILIARY GANGLION. OPHTHALMIC GANGLION. This important organ is a small quadrate body about the size of a pin's head. It is placed at the back part of the orbit internal to the external rectus muscle. It can be found by tracing the branch of the third nerve to the inferior oblique backward. See **Ciliary ganglion.**

Lenticularly. In the manner of a lens.

Lenticulars. These are lenses so ground that their otherwise unusual weight is diminished. See p. 4947, Vol. VII of this *Encyclopedia.*

Lenticular stereoscope. A stereoscope wherein the superposition of views respectively adapted to the right and left eye is effected by means of lenticular prisms or of prisms and lenses.

Lenticule. Same as *lenticula.*

Lenticulo-optic. Pertaining to the lenticular nucleus.

Lenticulo-striate. Pertaining to the lenticular nucleus and the corpus striatum.

Lenticulothalmic. Relating to the lenticular nucleus and the optic thalamus.

Lentiform. Having the form of a lens; lenticular.

Lentigerous. Provided with a crystalline lens, as an eye; applied to the eyes of some mollusks.

Lentiglobus. A name for posterior lenticonus.

Lentigo maligna. KAPOSI'S DISEASE. See p. 6740, Vol. IX, of this *Encyclopedia.*

Lentigomelanosis. A malignant disease of the skin of the face originating in freckles.

Lenti iperboliche. (It.) Hyperbolic lenses.

Lentil. *Ervum lens.* In ancient Greco-Roman times, spite of the fact that the frequent use of lentils as an article of diet was supposed to be injurious to the sight, a decoction of lentils was also employed as an eye-bath for the purpose of reducing *edema oculi.* A lentil poultice was also employed as a remedy for epiphora.—(T. H. S.)

Lentille crystalline. (F.) Crystalline lens.

Lentitis. (L.) Phakitis; a supposed inflammation of the crystalline lens.

Lentoid. Having the form of a lentil or a double-convex lens; lens-shaped; lenticular.

Leo, Leopold. A Polish physician, who paid considerable attention to diseases of the eye. Born at Königsberg, Prussia, April 19, 1792, he received his medical degree in 1815 at the University in that place. Settling in Warsaw, he practised there for more than 50 years. For a long time he edited at Warsaw (but in German) the *"Magazin für die Heilkunde und Naturwissenschaft in Polen,"* and from 1838-41 he was physician-in-chief at the Warsaw Ophthalmic Institute. He died June 19, 1868.—(T. H. S.)

Leonardo da Vinci. A famous Italian painter, sculptor, architect, musician, mechanician, engineer, optician and physiologist, whose writings on the eye and light are of interest to every ophthalmologist even at the present day. He, in fact, it was who discovered that the essential organ of vision was not, as had been supposed until his time, the crystalline lens, but the retina. He was born in 1452, the illegitimate son of a Florentine lawyer, by one Catarina, who is said by some to have been a peasant, by others, a woman of gentle birth. Leonardo, who was brought up by his father, developed into a youth of great strength and beauty, charm of manner, and intellectual energy. His ability as an artist was discovered by Andrea del Verrochio, who became his first teacher. Unlike most artists of his day (the Renaissance) da Vinci did not content himself with a mere imitation, or interpretation, of classical models, but developed a high degree of originality. The most important of his pictures are: The Annunciation; The Last Supper; The Virgin of the Rocks; and Madonna Lisa. In his later years, he turned to science more and more, and then it was, apparently, that he wrote the most of his works on geography, geology, cosmology, mathematics, astronomy, mechanics, and optics. His work on optics cannot be considered here, because it is given with much detail in this *Encyclopedia,* under **Ophthalmology, History of.**

Leonardo never married, and there is no record of his ever having been in love.

He was a good, as well as a great, man, kind and considerate to all, especially dutiful to his father; a leader of the simple life, courteous, communicative, companionable, charming, charitable and long-suffering.

He would seem not to have been a church communicant till shortly before his decease, which occurred on the 2d of May, 1519.

One of his sayings was: "As a day well spent gives joyful sleep, so does a life well spent give joyful death."—(T. H. S.)

Leontiasis ossea. OCULAR HYPEROSTOSIS. LEONTIASIS FACIEI. A brief reference to one form of this rare disease is given on p. 6109, Vol. VIII of this *Encyclopedia.* A complete account of the matter is, however, quite recently furnished by John Green, Jr. (*Trans. Am. Acad. of*

Leontiasis Ossea. (John Green, Jr.)

Fig. 1.—Photograph taken in 1907. Lips retracted to show spacing of teeth. Note rounded bony bosses on either side of nose.

Fig. 2.—Photograph taken in 1907. Shows outward deviation of left eye on attempt to converge. Complete bony occlusion of nose compels patient to breathe through the mouth.

Ophthal., p. 283, 1915), who has collected all the references to this abnormal thickening of the orbital and cranial bones (involving the visual apparatus) since it was described as *craniosclerosis* by Malphigi in 1667.

Virchow was the first to give an adequate history of the affection. He recognized two principal forms: (a) *leontiasis ossea diffusa,* or general hyperostosis of the cranium and (b) *localized hyperostosis,* in which the bony enlargements appear in the form of rounded bosses of varying size, springing from the bones of the face and cranium.

General hyperostosis is an exceedingly rare condition, and mere mention of its existence will suffice for our present purpose. The localized type varies exceedingly as to the extent and site of the bony involvements. In the milder cases, the enlargements may be small and inconspicuously situated, e. g., concealed by the hair. The more usual type presents bilateral bony tumors of the face and cranium and even of the lower jaw, so that the whole facial appearance is altered and all comeliness destroyed. This alteration of the physiognomy (for the worse) is well illustrated by cases in which the disease has begun in early adult life. Comparing photographs taken prior to the onset of the disease with those taken after its full development one is able to see what gross facial disfigurement may supervene. In the most marked examples the deformity is hideous in the extreme, leading the unfortunate victims to seek surgical intervention solely in the hope of making themselves less repulsive.

The disease begins, as a rule, in childhood or early adult life. Generally speaking, it is progressive, although there may be long periods in which no appreciable change can be discerned. The sexes are about equally represented. The course is "always a very long one and the prognosis is unfavorable" (Church and Petersen).

The *symptoms* are variable. Headache of varying intensity occurs in fully one half of the cases. This may be due to disease of the bone, or, in cases associated with optic neuritis, to increased intracranial pressure. Drowsiness, neuralgia, epileptic attacks, deafness, blindness and gradual mental deterioration are the signs of bony encroachment on the brain and cranial nerves.

The disease should interest ophthalmologists and otolaryngologists, for the reason that the eyes, ears and nose are frequently compromised. A gradually increasing deafness is very common. In many cases the bony masses have completely occluded the nasal passages and surgical intervention has become necessary for the purpose of re-establishing nasal respiration. The globes are not only pushed forward, but are widely separated laterally so that, in extreme cases, the visual axes diverge.

The disease is a rare one. The number of reported cases of unquestioned authenticity certainly does not exceed fifty.

The *diagnosis* in a fully developed case is easy. Early cases have been confused with acromegaly, but the absence of involvement of the hands and feet and of changes in the sella turcica are points to be noted.

Simple osteomata and sarcomata should be readily distinguished. The distinction between leontiasis and Paget's disease (osteitis deformans) is not always clear. Prince and Boit assert the essential identity of the two.

It is impossible, says Green, at the present time to state that any one etiological factor is operative in all cases. That trauma may be a contributary, if not a basic cause, is pretty well proven by the appearance in some cases of the first bony boss shortly after and at the precise site of injury. Erysipelas and other infective processes of the soft tissues have in some instances seemed to bear a causative relation. Dacryocystitis, when present, is probably secondary to the bone disease. Chronic inflammatory changes in the nose and sinuses may have some influence. There seems no good reason to suppose that the pituitary

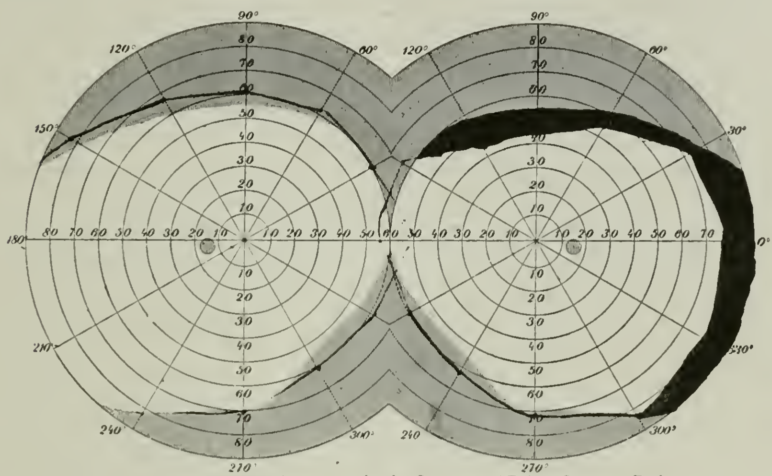
Leontiasis Ossea. (John Green, Jr.)

Fig. 3.—Photograph taken in 1907. Note that apex of cornea is in advance of bridge of nose.

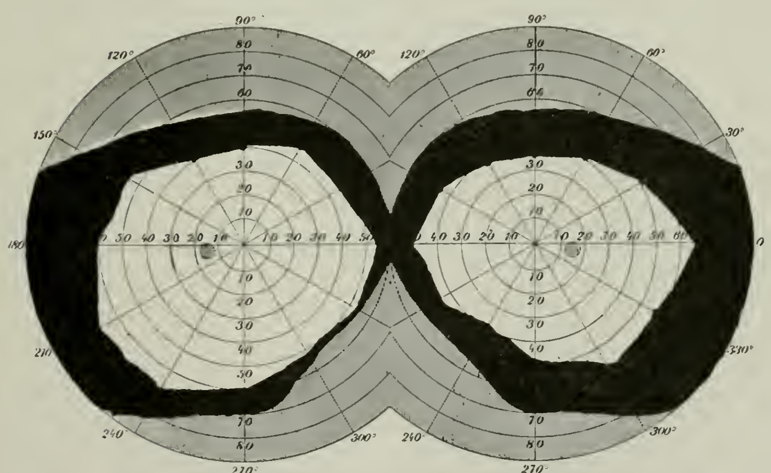
Fig. 4.—Photograph taken in 1915. Note flattening of bony bosses and narrowing of pupillary interspace. Owing to re-establishment of nasal patency, lips can now be held closed.

body bears any relation to this disease. There is wide divergence of opinion as to the rôle of syphilis, if any. Poisson insists that leontiasis is a trophic disease, of neuropathic origin. Virchow attributed it to periostitis.

The microscopic appearances have been described by Boit and his findings have been summarized by Telford as follows: "The spaces seen in the porous bone are bounded by thin walls of bone; these septa are lined by many osteoblasts by the action of which irregular osteoid bone is produced. A similar type of bone appears to arise also by the direct conversion of connective tissue which is very abundant in the diseased areas. Hand in hand with these processes there occurs an absorption of bone which results in the formation of spaces and canals. The thin-walled vessels in the bone bleed easily and hemor-



Visual Fields in Leontiasis Ossea. (John Green, Jr.)



Visual Fields in Leontiasis Ossea. (John Green, Jr.)

rhages are common. On the whole, this new formation of bone appears to preponderate slightly over the destructive changes so that the net result is a steady increase in the size of the diseased bone."

While there is a wide divergence of opinion as to etiology, there is practical unanimity that any form of medical treatment is unavailing. It has been found that removal of the bony masses on the frontal and parietal bones is occasionally effective in relieving headache. The complete blocking of the nasal passages in same cases has led to efforts to re-establish patency by chiseling through the obstructing bony masses. Putnam has suggested that the bone might be starved by shutting off its blood supply.

Of special interest to ophthalmologists are measures which have been suggested and carried out to ameliorate the ocular complications. Horsley, in a patient with unilateral exophthalmos and diplopia, due to a large frontal growth which extended into the orbit, removed the mass together with the anterior two thirds of the orbital roof, resulting in recession of the globe and abolition of diplopia. Optic neuritis and beginning optic atrophy due to pressure on the optic nerve as it passes through the narrowing optic foramen, demand even more radical measures. In such a case, Horsley removed the roof of the orbit as far back as the sphenoidal fissures, the major part of the great wing of the sphenoid, the upper part of the malar bone, and finally, in order to relieve pressure on the nerve, resected the lesser wing of the sphenoid.

Kanavel found that in fifteen cases with well-defined symptoms of cerebral compression, only four presented eye symptoms "suggesting that the optic neuritis may be as much due to local changes in the orbital cavities as to the cerebral pressure." Should, however, signs of increased intracranial pressure arise a decompression should be considered.

Lentocalin. Lentokalin. Roemer (*Prac. Med. Series*, Volume on the Eye, p. 82, 1910) has asserted that by giving patients with subcapsular senile cataract lentocalin prepared from albumin of the lens, the visual acuity not only remained stationary but that there was more or less improvement. An impairment of vision was never seen during the period of observation up to 12 months. Schirmer (*Deutsche med. Wochenschr.*, p. 1180, 1909), with Wissmann and Bornstein, investigated experimentally what becomes of albumin of the lens in the body and in artificial digestion, although lentocalin, which is not generally obtainable, was not at his disposal.

In rabbits, fed with large quantities of lenses of cattle, the albumin of the lens passed into the body and produced, after several weeks, reactive phenomena, specific for albumin of the lens, i. e., specific antisubstances.

In (carnivora) cats, a transit of undigested albumin of the lens into the organism was never ascertained.

Thus the theory of the favorable action of feeding lenses, which might be inferred from Roemer's hypothesis on the origin of senile cataract, is by Schirmer's experiments in carnivorous animals not only not supported, but, on the contrary, speaks directly against such an explanation.

The assertion of Roemer, as to the harmlessness of his method found a contradiction in the observation of the writer who found that quite a number of rabbits died immediately after being fed with lenses, under convulsions due to shock, i. e., showed a state of anaphylaxis.

Königshöfer calls attention to the fact that during the period between Oct., 1897, and April, 1901, he experimented upon incipient senile cataract with animal lenses prepared so that their biochemic properties were unchanged. When so prepared the result was a white tasteless, odorless powder. He employed this remedy in a large number of cases over long periods of time, but abandoned it because the results were not definite enough to be free from the criticism that they might have been spontaneous.

Roemer reports regarding his specific treatment for cataract with tablets "lentokalin" composed of animal's lens, that of 83 cases treated thus for 3 to 12 months, there had been in some improvement of vision. Königshöfer states that he began similar lens feeding in 1897 and continued it over three years. But he abandoned it because he failed to get favorable results; and found the administration of iodids more beneficial. Schirmer's experiments on cats oppose the views of Roemer as to the value of lens feeding.

Because the lens is an epithelial structure, and because of the influence of resorcin on the epidermis, Elze was led to use this drug for incipient cataract. He employed a ½ per cent. in vaselin ointment, applied daily. He reports improvement of vision amounting to 4 Nos. Jaeger type in several cases. Definite opacities remained, but the hazy substance between them seemed to clear up. Verdereau has used subconjunctival injections of potassium iodid, giving 20 minims of a 2 per cent. solution. He reports improvement in 26 per cent. of his cases.

Because certain patients with an excess of ammonia showed an absence of thiocyanates, Le Roy was led to administer sodium thiocyanate either by the mouth or hypodermically; and reports that it was followed by great improvement in cataracts both partial and complete. The dose was from ¼ to 1 grain, well-diluted in water, after each meal; or it was given hypodermically. Improvement in the cataract was preceded by the formation in the eyes of gummy mucus having an offensive odor.

For patients presenting the lens striæ of incipient cataract Connor prescribes: Perfect correction of ametropia; avoidance of eye strain from other causes; soaking the eye three times a day for ten minutes in water as hot as can be borne; vibratory massage of the eyeballs and nape of the neck, lasting two minutes or more three times a week; dionin used once a week, or oftener, and careful attention to general health. Under this treatment some cases recover transparency of the lens entirely, others partially.

A case of lens opacity passing on to Morgagnian cataract, with complete transparency of the fluid, is reported by v. Reuss. The nucleus fell below the pupil sufficiently to allow vision of more than 6/8 with a correcting lens. Claiborne reports a case in which there was great clearing under large doses of potassium iodid, and inunctions of mercury. He then discovered two large vacuoles in the lens, which he thought probably contained Morgagnian fluid. Grandclement calls attention to a form of cataract in which the opacity appears as minute points, which he thinks may consist of cholesterin crystals. This form is slow in its development, permitting useful vision for a long time. Ewing reports a case in which the lens became largely absorbed; and the patient returned with the anterior capsule ruptured and the nucleus protruding through the rent in the anterior chamber.

Leotropic. Letropous. Turning to the left; sinistral.

Lepra. See **Leprosy.**

Lepra tuberosa. The tubercular form of leprosy.

Leprid. A leprous skin lesion.

Leprolin. A preparation of the toxin of the lepra bacillus, said to be curative of leprosy.

Leproma. The tumor-like form of leprosy. See **Leprosy.**

Leprosarium. A hospital or colony for lepers.

Leprosy, Ocular relations of. Leprosy, called also *Lepra; Elephantiasis Graecorum* (see, also, p. 4279, Vol. VI of this *Encyclopedia*); *Satyriasis; Leontiasis,* as well as *Zaraath* in Hebrew, is of world-wide distribution; it is of great antiquity, reaching far back in the history of mankind, and has occupied the minds and interest of the medical world, exciting endless controversy and speculation, for the past 5,000 or 6,000 years.

In view of the positive rarity of the occurrence of leprosy in the experience of American ophthalmologists, it has been deemed proper to give a brief outline of the history of the disease and to indicate its geographical distribution as well as to present a summary of the general symptomatology of the affection, before detailing the manifestations of the malady in the eye and its appendages.

The origin of leprosy is unknown; but as Egypt, and China, have each been called the "cradle of leprosy," it is not improbable that in its earliest history it was limited to Egypt and the Orient. In both India and China the affection was known many centuries before the Christian era. The Hebrew writers make many references to it, yet it is evident, from the description in Leviticus, that many different forms of skin diseases were embraced under the term "leprosy." It was common among the Jews in the third century B. C. Greece had seen the disease before Hippocrates wrote of it; Aristotle was the first among Greek writers to refer to the disease; Aretæus found it (81 A. D.), spreading over Western Europe. The Romans contracted it from the Greeks: The troops of Pompey carried it into Italy in the first century B. C. There are sufficient proofs to show that leprosy existed in Western Europe before the Crusades, yet, it may be accepted as true, that the passage of pilgrims from the Holy Land helped to disseminate the disease into England, and Wales, Ireland, Norway, Sweden and other parts of Europe, as well as to increase the number in those countries and to excite an interest in the disease throughout the Middle Ages. During the 15th century leprosy began to decline and it quite lost its endemic character in Europe by the end of the 16th. It is a singular fact that the decline of leprosy began at about the time syphilis began to increase.

For a long time leprosy appeared to be confined to a few small localities, but in certain places in the last hundred years, there have been signs of recrudescence, and the malady has appeared in parts where it had never before existed. In Europe, it prevails in Iceland, Norway, and Sweden, and parts of Russia, especially in the Baltic provinces, whence it has spread in recent years to East Prussia, and in certain provinces of Spain and Portugal, so also in the Balkan Peninsula, Greece, and the Islands thereabouts. In Great Britain the cases are now all imported, and numbers have developed there after subjects have arrived from infected districts.

The invasion of America by the disease cannot be traced, and evidences of a pre-Columbian existence are doubtful. In the United States the earliest cases were found in Louisiana, among the French, as early as 1785, and of late the number has increased. Lepers settled in South Carolina, and among the Norwegian colonists in Minnesota and in other Northwestern states. It exists also in the colonies recently acquired, the Philippines, the Hawaiian Islands, and in Cuba. In the Philippine Islands there are many cases, and, in the Sandwich Islands, it spread rapidly after 1860, but in recent years all cases are segregated on the island of Molokai. Leprosy is endemic in the West Indies; it occurs in Mexico and throughout the southern states. In most recent years, as might be expected from our nearness to leprous centers, imported cases, especially Chinese, have been met with in California and other Western coast states. Isolated cases in individuals who have contracted the disease elsewhere are encountered from time to time in the great centers of the Atlantic coast. In Canada there are foci of leprosy, in New Brunswick and Nova Scotia; the disease it is believed, was imported into these provinces from France in the 18th century.

In so brief a review as this section is compelled to be, it is quite impossible to give more than a rapid survey of the geographical distribution and other characters of leprosy. Roughly speaking, it may be said that leprosy is practically present everywhere either sporadically or as an endemic disease. The number of cases is lessening, as segregation is gradually stamping it out. Many thousand cases exist in British India. It prevails extensively in China. It has increased rapidly in South America, and it prevails in the South Pacific Continents, chiefly among the Chinese. It is believed that the disease is pretty generally distributed throughout Africa.

Leprosy is a constitutional disease of chronic character, contagious through intercourse with an infected person, endemic in certain localities, and due to the presence of the *Bacillus lepræ* of Hansen; it is therefore a parasitic disease. It is characterized by the presence of tubercular nodules (*tubercular leprosy*) and other nutritional changes in the skin and mucous membranes, and by an eruption, or by changes in the nerves (*anesthetic leprosy*). At first the two forms may be separate, but ultimately both are combined, and, in the characteristic and well developed tubercular form there are usually disturbances of sensation also.

The bacillus of leprosy, discovered by Hansen, of Bergen, Norway, in 1873, is universally recognized as the cause of the disease, and this discovery has proved its infectious nature and refutes forcibly the idea that it is transmitted by heredity. The bacillus appears in large numbers in the leprous tissue, especially in the tubercular form, and when stained it resembles in many points the stained bacillus of tuberculosis.

Under the influence of the bacillus, the leprous tubercles or nodules, which consist of granulomatous tissue made up of a fibrous stroma in which are cells of various shapes, are formed in the skin or subcutaneous tissue. The bacilli are present in great numbers both in and between the cells. The process gradually involves the skin, giving rise to the tuberous outgrowths with intervening areas of ulceration or cicatrization. The mucous membranes, particularly the conjunctiva, the cornea, and the larynx may gradually be involved. More rarely nodules develop in deeper parts of the body, and ulceration may ensue resulting in extensive losses of substance, as of the fingers and toes, the lepra mutilans.

Before the nodules are formed, there may be more or less sharply defined areas of erythema and hyperesthesia of the skin, and as such spots may be somewhat pigmented, the condition is spoken of as macular leprosy, the maculations remaining, in some cases, unchanged for long periods. The eyelashes and eyebrows and the hairs on the face fall out. The mucous membranes become involved, the voice becomes harsh, and may be lost. The conjunctivas are frequently attacked, and the sight is lost by a leprous keratitis. The sufferer's condition may become a most wretched one and death itself may follow through invasion of the larynx and lungs; if not from tuberculosis or some other intercurrent malady.

In anesthetic leprosy the lesions may assume the characteristics of peripheral neuritis, from the invasion of the nerves by bacilli, to which neuritis, the trophic changes in the skin, and the disturbances of sensation are due. Anesthetic leprosy therefore bears no external resemblance to the tubercular variety. It usually begins with pains in the back and limbs and with areas of numbness or of hyperesthesia in the integument and flesh. Maculæ appear but soon disappear, leaving the areas anesthetic. The superficial nerve trunks may be found enlarged and nodular; trophic changes becoming marked, bullous ulcers may cause great destruction, the fingers and toes may be lost while great contractions follow. Notwithstanding these extreme cases the course of anesthetic leprosy is slower in its evolution than that of the nodular form; it is accordingly extremely chronic, and it may persist for many years without leading to any deformity.

Lepra tuberosa and *anesthetica* differ merely in the degree of the development of the new formation, which is of a granulation-like tissue containing the lepra bacilli, with marked implication of the interstitial tissue of the nerves in either a nodular or a superficial form. Some cases exhibit characteristics of all three forms, the macular, the tubercular, and the anesthetic; such mixed cases may become so by gradual modification, and yet, rarely, they may be so from the start.

In the early stages the erythematous maculæ with the areas of anesthesia and hyperesthesia may be sufficiently distinctive and characteristic as to point with certainty to the diagnosis, and in the advanced grades so characteristic are the lesions that neither the tubercular nor the anesthetic form could be mistaken for any other affection.

The disease is to be classed among the contagious diseases, the influence of the contagion being as small as, or even less than, in the case of tuberculosis.

The exact method of inoculation is not known, whether through the mucous membranes of the nose and mouth, or some break in the integumentary covering. According to Eklund, infection often takes place from inoculation into the conjunctival sac by means of towels.

The incubation or latency of leprosy, unlike other infectious diseases, extends over a long period, on the average from three to seven, or even ten to fifteen years, the disease may develop a considerable time after the patient has left a leprous area; yet, not infrequently, the period is shorter, the patches first appearing on the unexposed parts of the body with ulcers in the upper part of the nasal passage, thus rendering the detection of the disease difficult. The primary lesion may therefore be comparatively insignificant and likely to be overlooked or disregarded.

Leprosy of the eye is always a matter of secondary invasion; and it is rare to find a long existent case which has not at some period shown affection of the eye or of the appendages. The eyelids may be and commonly do become involved in leprosy of the face. In Grossman's observations it showed a tendency to limit itself to the anterior part of the eye; perhaps such a limitation depends upon the denseness of the sclera. His studies were made upon Icelanders, in whose country it is most common, and he found that leprosy of the nodular form is always attended with eye lesions unless the patient dies early. Borthen found the eye affected in 75 per cent. of the cases of the maculo-anesthetic, and in 90 per cent. of the cases of lepra tuberosa. On the other hand, the anesthetic form may leave the eye unaffected. The nodular lesions commonly begin in the lids and later attack the eyeball, although this is not always the case. De Silva, among 500 cases, saw 401 suffering from ocular lesions, the most common conditions he found were infiltrations of the eyebrows and lids.

Both the maculo-anesthetic and the nodular forms occur in the lids and brows. The nodules may commence with infiltration of the eyebrows, the lids becoming affected relatively late and then usually at the margins. Here there may be a diffuse infiltration, or anesthetic patches and a row of several small nodules. At times the nodules which are situated in or beneath the skin may grow to the size of a nut, when only one or two have been formed, becoming more or less polypoid. Later they may cease to enlarge and finally disappear through central softening or by ulceration. The hairs fall out, cicatricial ectropion may develop and secondary paralysis of the orbicularis. The skin of the lids may be quite free from bacilli, but the bacilli may be found constantly and in large quantities at the lid margins. The Meibomian glands rarely degenerate though they may be surrounded by the bacilli and become invaded by a few of them. Through extension along the vessels, the infiltration may be conveyed to the ocular structures.

The conjunctiva is rarely attacked independently of the other parts of the eye but it is frequently affected by continuity at the lid margins, and, after this, most frequently at the limbus of the cornea by a papillary hypertrophy, consisting of leprous granulations covered by flattened, often horny, epithelium. These growths of the conjunctiva are rounded, pale-red or yellow, glistening and hard and are not tender on pressure. They are usually situated at the rim of the cornea and beyond, though gradually lessening toward the fornix. They may spread over the cornea and invade the interior of the eye. They do not ulcerate, but may shrivel and soften sometimes, yet only after the lapse of years. These leprous tumors may cause the eversion of the lids and interfere with their closure. The secretion is slight though epiphora may become marked. These granulations cannot be distinguished as leprous from their external appearances alone, but must be taken in conjunction with the clinical condition and by the demonstration of the bacilli within their substance. They seldom extend into the sclera until late in the disease.

Episcleral nodules when they occur have the usual characteristics of nodules elsewhere. The sclera is never attacked primarily and independently, because extension is impeded by the denseness of the tissue, and slow invasion takes place only along the perivascular and interlamellar lymph spaces. The lamellæ, including the elastic fibers, are destroyed and the region about the corneal margin becomes the seat of yellowish, semi-transparent tubercles which may penetrate into the sclera and spread over the surface of the cornea. The breaking down of the tubercles is followed by extensive tissue destruction, with shrivelling of the globe.

The keratitis, which is very frequent in leprosy, is truly leprous in character; yet the cornea because it contains no vessels is attacked only secondarily. Keratitis is found in both the tubercular and the maculo-anesthetic varieties. The types seen may be the superficially punctate, the deep parenchymatous and that marked by the formation of granulomatous tumors.

The superficial, a sub-epithelial keratitis, is characterized by the presence of small grayish nodules around the center. These nodules are collections of bacilli, which may be found free in the lymph spaces, without much alteration of the corneal cells, the inflammatory process consisting chiefly of leucocytes and endothelial cells. Keratitis punctata never leads to blindness. Blindness from external leprosy alone occurs extremely seldom.

The parenchymatous keratitis of leprosy follows infection from the ciliary body and from the deep scleral vessels. The affected portion may be limited to that which has been irritated by the rubbing of the upper lid producing a pannus. The infiltration begins at a corneal quadrant, extending from the limbus inwards towards the center. At first the process may be rapid in development and, as though the active agent had become dormant, remains stationary for a year or so, when apparently a fresh invasion has occurred, it revives and, finally, slowly, inevitably and irresistibly involves the whole cornea. Ulceration may occur. The membrane at the end becomes white and thickened, indicating the marked difference between the leprous and the temporary infiltration of ordinary interstitial keratitis. Usually one eye becomes affected, only to be followed by the other sooner or later, so that the condition may frequently be found symmetrical. It probably is the only one of the leprous lesions of the eye that is painful, for it is usually attended by severe pain; yet cases have been reported in which there was but little irritation.

True exudation may take place with resulting abscess and consequent destruction of the membrane with involvement of the uvea. Studies of such eyes may reveal the disappearance of Bowman's and Descemet's membranes, and the extent of the infiltration, in which are contained the bacilli in abundance, and yet, however, with the epithelium remaining intact.

Leproma of the cornea is rare. It also is never primary, but extends from nodules in the episclera, or from the canal of Schlemm in which case deep infiltrates appear in front of the membrane of Descemet. Granulomata of the cornea may be quite small or they may cover as much as two-thirds of the cornea, besides extending well into the sclera. The masses are more or less translucent, of a pale, grayish-yellow color. They may be very vascular, and besides the covering of corneal tissue, consist of round and spindle-shaped cells as well as of epithelium, and the bacilli exist in them in great numbers. In the anesthetic type, the infiltration may exist without marked reaction for a long time, when it finally softens and ulcerates, to be followed by extensive tissue destruction.

Lids, iris and retina may be found affected in those in whom the cornea is involved. The uvea suffers in all its divisions and, once the uveal tract becomes involved, the proportion of blindness increases disastrously. Facial paralysis may cause lagophthalmos with consequent corneal complications.

Iritis may develop early in the nodular form of leprosy, but in the anesthetic it is usually secondary to disease of the corneas, as of ulceration. In many cases the iritis terminates in complete occlusion of the pupil, and inflammation may extend thence throughout the uveal tract.

Isolated leprous nodules occur only rarely in the iris, but there is usually a general infiltration of leucocytes with bacilli, the infection being secondary to that of the ciliary body. When fully developed it much resembles tubercular iritis, the diagnostic point being, of course, the existence of the lepra bacilli, in masses and within the lymph passages. When nodules do occur they are found accompanying nodules in the cornea. They extend from the periphery, are grayish in color, and are generally situated in the lower half of the iris. Small nodules may disappear spontaneously to be followed by the appearance of others, the disease of the iris thus undergoes several relapses. Others may increase and gradually fill the entire anterior chamber, distending the cornea and producing staphyloma of the adjacent sclera.

The ciliary body is a favorite site for leprosy, indeed, it is believed to arise primarily here in the eye. The bacilli are less numerous along the ciliary blood vessels than is the case in iritis. They are found along the nerves, in the lymph spaces and in the pigment cells. But granulomatous tissue is generally only moderately developed in the ciliary region, yet it may involve and utterly destroy the whole ciliary body.

The choroid is affected secondarily to the disease of the ciliary body. Granulomatous masses such as are found in the iris and ciliary body have not been observed in the choroid. The reaction is usually slight, here and there is found hyperemia with edema and infiltration, and there may be a few wandering cells. The bacilli are found chiefly in the interfibrillar spaces and in great numbers in the suprachoroidal space. They lie in the pigment cells and along the nerves, particularly in the maculo-anesthetic cases, and in the choriocapillaris clumps are found near the vessels.

It is not quite certain that leprosy affects the retina separately. Most of the cases which have shown disturbance have been those seen in connection with nodules in the choroid, or of exudation near the ciliary body. Bull and Hansen believed they found small nodules in the anterior portion; other observers have found inflammatory changes with thickened masses in which bacilli have been found. Several other observers, however, especially de Silva, who in 101 cases, and Otchapevski, in 26, found no specific lesions in the fundus.

Most studies have failed to show that the optic nerve has been invaded, although in a few cases bacilli have been found in the center of the nerve, but without their having excited inflammatory reactions.

Ordinary senile cataract is common in leprous patients, and the lens is cataractous in younger subjects. Yet the bacilli have not been found present in the substance of the lens. The disease may be said to produce no special effects upon the lens, and Bruns has repeatedly extracted cataract in such patients without complications and obtained good visual results.

The lepra bacillus of Hansen, as already mentioned, closely resembles in appearance the tubercle bacillus, although it takes the stains more readily, and it is somewhat shorter. The bacilli are widely distributed in practically all the structures of the body, but the skin and nervous system are the chief tissues to suffer. They are found in large quantities, chiefly in groups or bundles; they are variable in shape, being straight, curved, thickened at the ends or tapering, or they may look like a row of spores. The bacilli may be found in parts which show no specific changes. Besnier found the bacilli in the tears and nasal secretion, but Calderaro did not find the bacilli in the tears nor in the lachrymal passages, neither did he find them in the aqueous, but he found them constantly at the limbus of the cornea after scraping it. Scrapings from the corneal infiltrate may contain the bacillus both in the cells and between them, although it may not always be found. The bacilli are scarcely ever found in the blood, indeed they are soon destroyed by human blood. It is important therefore, in preparing films, not to get blood mixed with the fluid.

The origin of the bacillus is unknown, and it has not yet been successfully cultivated nor inoculated in man, but Calendoli succeeded in inoculating the eyes of a rabbit. In this experiment, after five months, granuloma developed in the cornea, iris and ciliary body and in them he found scattered lepra bacilli.

According to Calderaro, the starting points of the leprous infiltration are the hair follicles, the small sweat glands, the fine capillaries and the nerve twigs, but the globe is invaded by the bacilli effecting an entrance through the conjunctiva and the corneal epithelium.

Without doubt, according to Parsons, the bacilli are carried by both the blood and the lymph, because these vessels are found in the nodules. They are found in the intima and less frequently in the intravascular leucocytes. There is no reaction, however, in the surrounding tissues until the bacilli have escaped. Infiltration consisting of both round and fixed cells then ensues, but the reaction is much less than the reaction in tuberculosis. Bacilli may be found in cells which still seem normal and are undergoing karyokinesis and the lymphoid cells becoming epithelial. The vessels become sclerosed and show proliferation of the intima and adventitia but with little change in the media. The nodules are always vascular, the capillaries and small vessels are dilated and there are many new-formed vessels, while the lepra cells are usually found in the oldest parts of the nodules not far from the vessels. The growth of the nodule is slow but generally continuous.

For a long time the epidermis and the subcutaneous tissues remain intact and free from bacilli, but later the mucosa becomes involved, the deeper cells affected, and the nutrition interfered with. By this time the bacilli have penetrated the cells, though some may remain outside only to excite them to increased mitosis. The hair follicles and glands becoming involved, the hairs and eyelashes fall out. The sweat glands are seldom invaded by the bacilli, but their cells, together with those of the connective tissue and muscle fibers, are excited to a greater deposition of pigment granules.

Tubercular leprosy is more disastrous than other forms, yet despite a less gloomy outlook, the longer anesthetic leprosy exists the more likely and threatening does blindness become.

The ocular symptoms show no predilection as to the time of their onset, neither as to the rapidity of their progress nor to their duration. In de Silva's cases the average duration of the nodular variety was nine years, the vision remaining remarkably good, and in only five was it much affected. Lepra anesthetica had an average duration of fourteen years, the patients were older, however, and the disease had lasted longer, in one case, a man of 87, had been afflicted forty-five years.

The *management of any case of ocular leprosy* must be governed very largely by the general aspect of the case, and it therefore must be subject to considerations as to segregation as well as to the principles of personal hygiene and the maintenance of the general nutrition of the patient. Most certainly all patients are entitled to the utmost care in every respect, and medical science to-day has much to offer for the alleviation of the physical and mental sufferings of the leprous, as well as to present opportunities to prevent the spread of the affection, to enlighten the public upon the truths of the disease and to influence the attitude which should be borne toward the sufferers.

Borthen taught that the systematic treatment of the ocular lesions by methods well recognized as serviceable in affections dependent upon other causes, would yield beneficial results far out-reaching original prognostications. Therefore, few, if any, specific remedies can be offered when leprosy invades the eyes.

Leprous patients should avoid touching their eyes with fingers or handkerchiefs likely to be contaminated with bacilli, and their eyes should be flushed with warm, bland lotions, even by the use of simple salt and water. Because of the knowledge that the bacilli do not penetrate scar-tissue, Calderaro advocated peritomy with deep cauterization of the episcleral tissues as a means of preventing the entrance of the parasites.

As indicated already, the ocular conditions must be managed upon ophthalmological principles. Nodules may be excised from the conjunctiva and the lids, and from the iris as well as from the cornea. The X-ray and other forms of radiant energy have been applied with varying results. It is still the hope of leprologists that a serum may be discovered which shall be available for both prophylaxis and for cure. That leprosy may be cured or at least arrested in its development and die out cannot be denied.

The bibliography of leprosy is of such vast proportions that only a few works can be referred to here. Readers may find it of interest to consult such works as "Leprosy of the Bible in its Medical Aspect," and "Leprosy of the Bible in its Religious Aspect," *Biblical World*, Nov. 3 and 5th, 1911; "Journal of the Leprosy Investigating Committee," Lon. 1890-91; "Leprosy in its Clinical and Pathological Aspects," Hansen and Looft, English translation by Norman Walker, Bristol, 1895; "Leprous Diseases of the Eye," Bull and Hansen, Christiana, 1873, and, *Jahrb. für Aughk.*, 1873, p. 218; "Des Manifestations Oculaires de la Lepre," Jeanselme et Morax, *Ann. d'Oculistique*, CXX, Nov., 1898, p. 321; "Die Lepra des Auges," clinical and pathological studies; Borthen and Lie, Leipzig, 1899; "Origin of Louisiana Leprosy," *Medical Library and History Journal*, January, 1904; and "Historical Sketch of Leprosy in the United States," *Journal Cutaneous Diseases*, May, 1911.—(B. C.) See, also, **Cornea, Lepra of the; Eyelids, Leprosy of the.**

Leptomeningitis. Inflammation of the pia and arachnoid of the brain or spinal cord. Leptomeningitis is variously qualified as acute, basilar, cerebrospinal, chronic, epidemic, external, infantile, intracranial, purulent, non-purulent, serous, tubercular, etc.

Among the *ocular symptoms* of this disease are early external inflammatory symptoms, such as conjunctivitis and swelling of the lids. The cornea may be infiltrated. The pupils at first are usually contracted, and later dilated, or they may be immovable. Hippus has been observed. After a few days the optic disc may become hazy and the vessels are enlarged. The papillitis may be severe, the disc becoming obscured and subsequently atrophied. Blindness may ensue. Retinal hemorrhages and neuroretinitis are not infrequent. The severe infection may cause purulent iridochoroiditis anl panophthalmitis. The third nerve is usually affected, and strabismus, or a loss of conjugate action, results.—(J. M. B.)

Leptomitus oculi. This systematic name was given by Sorokin (*Centralbl. f. pkt. Augenheilk.*, p. 482, 1881) to a parasite which he found associated with catarrh of the conjunctiva and lachrymal sac. It was composed of thin, dichotomous branching filaments and resembled a similar animal discovered by Robin in the lining membrane of the uterus.

Leptoprosope. A person with slender features, round, open orbits, long nose, narrow nostrils, and small mouth.

Leptothrix. A genus of bacteria that occasionally affects the eye, especially the lachrymal apparatus. In the latter instance a number of names have from time to time been given to the principal causative factor in certain obstructions of the canaliculi due to the development of fungoid masses. Leptothrix of the canaliculi is described on p. 1372, Vol. II, of this *Encyclopedia.* See, also, **Concretions, Ocular.**

Leroy de Lorme, Jacques. A French physician, who, at the reception of his degree from the University of Montpellier, presented as thesis "Tentamen Medicum de Ophtalmia" (8 pp., 1779), an affair of little value.—(T. H. S.)

Lésé. (F.) Injured; affected with a lesion, especially of a traumatic nature.

Leseproben. (G.) Test types, letters or print.

Lesescheu. (G.) Dyslexia.

Leslie, Sir John (1766-1833), a celebrated natural philosopher, born at Largo, Fife, Scotland, was variously employed in scientific writing or traveling on the continent of Europe, with pupils, but all the while engaged in experimental research. The fruits of his labors during this period of his career were a translation of Buffon's *Natural History of Birds*, the invention of a differential thermometer, a hygrometer, and a photometer. He also published an important *Experimental Inquiry into the Nature and Propagation of Heat.* In 1805 he obtained the chair of mathematics at Edinburgh. In 1810 he invented the process of artificial refrigeration. In 1819 he was transferred to the chair of natural philosophy, where his peculiar talents found their proper sphere.—(*Standard Encyclopedia.*)

Lesser canthus. Outer canthus.

Lesshaft. An ophthalmologist of Gorlitz, Germany. He was born in 1861, and died April 2, 1909. He was at one time assistant to A. v. Graefe.—(T. H. S.)

Lethin. A proprietary mixture of alcohol, camphor, chloroform, and ethereal oil; used as local anodyne in headache—ocular and other.

Lethologica. Inability to remember the proper word.

Letter-blindness. A form of visual aphasia. See p. 1131, Vol. II of this *Encyclopedia*.

Letter-space. In alphabets and print for the blind this is the blank space between the characters within a word. In New York point this is equal to the horizontal space occupied by one dot. In Braille it varies, but has commonly been somewhat less than the width of one dot. See **Alphabets and literature for the blind.**

Lettuce. *Lactuca sativa.* Two kinds of lettuce were distinguished by Dioscorides—*thridax hemeros and argia.* The latter enjoyed an especial reputation as a cure for corneal ulcers and cicatrices, while the former, if eaten frequently, was supposed to be injurious even to healthy eyes.—(T. H. S.)

Leucæthiops. An albino. See **Æthiops albus.**

Leuchtender Körper. (G.) Luminous body.

Leuchtgasvergiftung. (G.) Poisoning by illuminating gas.

Leuchtkraft. (G.) Intensity.

Leucitis. An obsolete name for inflammation of the sclerotic.

Leuco-. See, also, corresponding title beginning with **Leuko-.**

Leucocythemia, Ocular relations of. See **Leukemia**; as well as **Ophthalmoscopy, Medical.**

Leucoma. See **Cornea, Opacities of the.**

Leucoma adherens. See p. 3416, Vol. V of this *Encyclopedia*.

Leucoma album oculi. A white spot or film upon the cornea, especially when due to a previous inflammation. (Obsolete.)

Leucoma ectaticum. Leucoma with thin walls.

Leucoma gerontoxon. An obsolete name for arcus senilis.

Leucomain. See **Leukomain.**

Leucomatoid. LEUCOMATOUS. Pertaining to or resembling leucoma.

Leucomma. (L.) Another spelling of leucoma.

Leucopathy. Albinism.

Leucophilous. Attracted by sunlight; heliophilous.

Leucophlegmasia palpebrarum. An old term employed by Beer for *edema frigidum palpebrarum,* or chronic, painless (cold) edema of the lids.

Leucophthalmous. Having the eyes white or bordered with white.

Leucopin. Visual white.

Leucops. (L.) Having the eyes white or surrounded by a white border.

Leucoscope. A name given by Koenig to his appliance for the estimation of color-blindness, in which polarization is employed. It resembles the chromatoptometer of Chibret. See p. 2197, Vol. III of this *Encylopedia.*

Leucosis. (L.) A name for albinism. See **Congenital anomalies of the eye,** as well as p. 204, Vol. I of this *Encyclopedia.*

Leucous. Light-colored; albinotic.

Leukanemia. A disease marked by the blood conditions of both lymphatic leukemia and pernicious anemia.

Leukasmus. Albinism; also leukoderma.

Leukemia. LEUCOCYTHEMIA. This fatal disease, marked by a large increase in the number of leucocytes in the blood and by proliferation of the lymphoid tissue in the lymphatic glands, spleen and bone-marrow (myelogenic form) is occasionally associated with eye symptoms, especially with retinal hemorrhages.

A. C. Hudson (*Roy. Lond. Oph. Hosp. Rep.,* Supt., 1911) describes the fundus changes commonly reported as accompanying this disease. He notes that changes are met with in both lymphatic and myelogenous leukemia, and in both chronic and acute cases; they are, however, by no means constant, being found, according to Leber, in only one-third or one-quarter of all cases. Both eyes are almost always affected, but not always in equal degree. The changes are, in some cases, limited to the appearance of scattered hemorrhages, while preretinal hemorrhage may also occur; in other cases, however, more characteristic features are present, consisting in a light-yellowish hue of the whole eyeground; distension and tortuosity of the retinal vessels, affecting more especially the veins, which are of rose tint, while the blood stream in the arteries is abnormally pale; pallor and indistinctness of the optic disc, with a diffuse haze, involving the whole retina, and often more pronounced in the course of the main veins. The veins may be bordered by white bands, while hemorrhages are found scattered through the retina, together with white spots which, according to many authors, are more numerous in the periphery of the fundus, so that they may be invisible to ophthalmoscopic examination. Such spots are also met with in the macula; they are not infrequently surrounded by a red border, and may exhibit a definite prominence. Movement of the blood stream in the veins has been observed ophthalmoscopically. It would seem that in the acute cases fundus changes of hemorrhagic and edematous origin tend to dominate the picture, while the more characteristic fundus changes have been observed in chronic cases. Leukemia may be associated with vitreous hemorrhages, optic atrophy, optic neuritis and also thrombosis of the central vein of the retina. Leukemic infiltration of the orbit was first noted in 1875, and cases have been reported with the lids and the lacrimal glands the seat of tumors. As a result of the infiltration of the orbital tissue there may be limitation of movements of the eye. Leukemic tumors of the bulbar conjunctiva have rarely been noted.

Casolino has reported a case of myelogenous leukemia with iridocyclitis. Koyanagi (*Klin. Monatsbl. f. Augenheilk.*, 53 p. 153, 1914) examined anatomically the eyes of four cases of myelogenous and two of lymphatic leukemia. In the myelogenous form the posterior portion of the choroid was very much thickened by considerable accumulation of leucocytes, which chiefly lay in the enormously enlarged vessels. In the lymphatic cases the posterior portion of the choroid showed also an accumulation of lymphocytes, but free in the stroma. The vessels in the pathological foci were either empty or moderately filled with blood, the leucocytes chiefly occupying the axial part. Thus the lymphatic leukemia has a greater inclination to the formation of lymphoma than the myelogenous.

The *treatment of the ocular complications* is naturally bound up with the general conduct of the case. Croftan (*System of Ophthalmic Therapeutics*, p. 273) regards the treatment of all forms of leukemia as unsatisfactory in so far as effecting a cure is concerned. By judicious treatment life can, however, be prolonged and the patients rendered comparatively comfortable. Here, as in so many other diseases, it must be remembered that spontaneous remissions occur and that the results of any treatment are always ambiguous. The use of drugs in leukemia is always fraught with some danger as the antitoxic function in these patients is as a rule low; hence drug intoxications are very apt to occur; for the same reason violent forms of auto-intoxication following digestive derangements are quite common. He further says that "the remedy that seems to be of the greatest value is arsenic. It should be administered as in pernicious anemia. It is best to give it in the form of cacodylate of soda hypodermically. Injection of arsenic into the lymph glands or into the spleen, a procedure that has been widely advocated, I consider altogether precarious and worse than useless.

"Quinine, best given as the muriate in five to fifteen grain doses three times a day, preferably in combination with arsenic, seems occasionally to exercise a marked effect on the blood picture and the general symptoms. Phosphorus, too, empirically is known to do some good; it can do no harm, when administered in the form of iron phosphate with quinine and strychnine.

"Organic extracts of spleen, lymph glands, bone marrow are advocated. I have never seen any benefits derived from their use. Oxygen in extreme cases affords great relief but exercises no curative effect. Tuberculin and erysipelas toxin have been used on the basis of some good effects seen in leukemics when intercurrent tuberculosis or erysipelas supervened. However true the latter observation may be in isolated cases, the adoption of the toxin treatment is to be condemned as altogether too precarious.

"X-rays have been used extensively in this disease within late years. Symptomatically very startling results are occasionally seen manifesting themselves by a rapid reduction in the size of the spleen and a great drop in the number of leucocytes. These phenomena are not infrequently accompanied by general symptoms that impress one as toxemic and that are in all probability due to the leucolysis produced by the X-ray treatment. All the cases that I have had treated in this way finally had a relapse and ultimately succumbed to the disease within three years, at the latest, after they came under observation. After a relapse has once occurred the splenic tumor does not seem to yield so readily to X-ray reduction and often it does not yield at all. The same applies to the leucocytosis. Nevertheless, the X-rays should be given a trial in each case of leukemia if for no other reason than that, in favorable instances, great symptomatic relief is given by the reduction of the splenic tumor. Together with the X-rays a thorough course of arsenic should also be administered."

Leukine. One of the active agents said to produce immunity in infective ophthalmics. Rudolph Schneider (*Archiv f. Ophthalmol.*, 63, p. 223, 1910) after a number of experiments on both human and lower animal conjunctivæ concludes that the normal secretion of the lacrimal gland and the conjunctiva contains no substance with bactericidal, hemolytic or opsonic properties. After instillation of silver nitrate, protargol, and zinc sulphate leucocytes pass into the conjunctival sac, and under the influence of these reagents give off their bactericidal product, viz., leukine. The curative action of the so-called astringents depends not upon the production of a slough nor upon their disinfecting properties, but upon their power of producing the leukine. The destruction of the infective microbes occurs chiefly extracellularly in the conjunctival secretion owing to the leukine in it, and not to the alexin, which is inactive against most of the pathological microbes of conjunctival inflammations.

Schneider as the result of his investigations distinguishes leukine from alexin. The former is derived from the polynuclear leucocytes, and is more an active secretion than a product of their destruction.

It differs from alexin, which circulates in the blood not alone in its thermostability, but in its action upon micro-organisms which are not affected by blood serum.

Leuko–. See, also, **Leuco–.**

Leukocidin. A substance destructive to leukocytes.

Leukocyte. Leucocyte. Any colorless, ameboid cell-mass, such as a white blood-corpuscle, pus-corpuscle, lymph-corpuscle, or wandering connective-tissue cell. A leukocyte consists of a colorless granular mass of protoplasm, having ameboid movements, and varying in size between 0.005 and 0.015 mm. in diameter. The following varieties of leukocytes are distinguished: (1) *small mononuclear,* of lymphocytes, possessing a relatively large nucleus; (2) *large mononuclear,* containing a large round or oval nucleus surrounded by a zone of protoplasm; (3) *transitional mononuclear,* differing from the large mononuclears only in having a horseshoe-shaped nucleus; (4) the *polymorphonuclear* or *polynuclear neutrophil,* finely granular oxyphil cells with an irregularly-shaped nucleus; (5) *eosinophil,* coarsely granular eosinophil cells with a lobed nucleus; (6) *basophil,* or mast-cells, having their origin in lymphoid tissue and found only rarely in the blood; (7) *myelocytes,* or narrow-cells, occurring in bone-marrow, but found in the blood only in pathologic conditions.—(Dorland.)

Leukocytolysin. A lysin which causes dissolution of leukocytes; called also *leukolysin.*

Leukocytometer. An instrument used in counting leukocytes.

Leukocytopenia. Decrease in the number of leukocytes in the blood.

Leukocytoplania. The wandering of leukocytes or their passage through a membrane.

Leukocytosis. A temporary increase in the number of leukocytes in the blood. It occurs normally during digestion and in pregnancy, and is seen as a pathologic condition in inflammation, traumatic anemia, various fevers, etc.

Leukocytotoxin. A toxin which destroys leukocytes.

Leuko-derivative. Any white derivative from a pigment or coloring-matter.

Leukoderma. Leukodermia. Abnormal whiteness, or albinism, in patches; a congenital lack of normal pigmentation of the skin, especially that which is partial: if acquired, the condition is called vitiiigo.

Leuko-encephalitis. Forage poisoning; a contagious disease of horses, the lesion of which is softening of the white matter of the brain. It is marked by drowsiness, dimmed vision, unsteady gait, and paralysis of the throat.

Leukolysin. A lysin which causes dissolution of leukocytes; called also *leukocytolysin.*

Leukomains. Leucomains. A large group of basic substances, mostly alkaloids, normally present in the tissues, products of metabolism and probably excrementitious. Some of them may become toxic. They may be divided into groups: (a) the *uric-acid group,* including adenin, carnin, gerontin, guanin, heteroxanthin, paraxanthin, pseudoxanthin, spermin, and xanthin; (b) the *creatin group,* including amphicreatin, creatin, creatinin, chrysocreatinin, methyl-hydantoin, and xanthocreatinin; and (c) a miscellaneous group, including aromin and others. Occasionally some of these agents produce a toxic amblyopia of the belladonna type. See **Toxic amblyopia.**

Leukomyoma. A myoma containing fatty tissue.

Leukopenia. Hypoleukocytosis. Deficiency in the number of the leukocytes.

Leukoplakia. The formation of white patches on a surface.

Leukoprophylaxis. The increase by artificial means of the number of leukocytes in the blood in order to secure immunity to surgical infection.

Leukopsin. One of the products of chemical change in the retinal visual purple under the influence of light.

Leukosarcoma. See **Leucosarcoma.**

Leukotoxin. A toxin of the blood destructive to leukocytes.

Leutert's method. See p. 6917, Vol. IX of this *Encyclopedia.*

Leuw, Friedrich Hermann de.[1] A celebrated German ophthalmologist, who wrote very little, but whose operative skill was very great. Born of Dutch ancestry at Dinslaken, near Wesel, Aug. 1, 1792, he received but little early education. When seventeen years of age, however, he began to study in the Düsseldorf Military Hospital, and saw much service later in the battles of Leipsic and Hanau. Becoming sick, he was left in the house of a Dr. von den Steinen, who dwelt in the village of Gräfrath, near Solingen. In this village he afterwards settled and practised for a number of years. In 1823, however, he received his medical degree at Giessen.

Making a specialty of ophthalmology at Gräfrath, he became exceedingly successful, small as the hamlet was, because of his extraordinary operative skill.

"He executed every year hundreds of cataract operations, together with numberless others, often twenty to twenty-five per day. His assistant was his son, Dr. Louis de Leuw, and, after the son's death, Dr. Meurer.

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[1] For the facts of this sketch the writer is indebted exclusively to Hirschberg. As that authority remarks, nothing at all about de Leuw is given in the "*Biographisches Lexikon der Her. Aerzte,*" in Hirsch's "*Lexikon,*" in Baas's "*Geschichte,*" or in Haeser's. On the other hand, the only original source of information—Hoppe's "F. H. de Leuw, der Gräfrather Augenarzt"—has not been accessible to me.—(T. H. S.)

"De Leuw's personality exercised a truly great influence. On the shoulders of the middle-sized man was enthroned a beautiful head with silver locks and a pair of eyes full of elevated thought and benignant mildness. He spoke with fluency Dutch, French, Italian, English. To the needy he sacrificed himself devotedly. In his honor was founded, Aug. 1, 1854, an institution for the blind, known as the 'De Leuw Institute.' . . . On the 12th of January, 1861, were closed the eyes of this benefactor of mankind."

In 1820 he published a report on the contagious character of "the Egyptian ophthalmia" (trachoma) which he addressed to the Royal Prussian Administration in Düsseldorf. This was before his graduation, which, as stated, occurred in 1823. He recurred to the subject in his graduation dissertation, and in 1824, at Essen, and published a tiny work thereon—his only book.

The following paragraphs I now translate almost literally from Hirschberg: "The little town of 1,200 souls attained to unaccustomed opulence, without, however, developing into a noisy city of foreigners. In Flick's hotel he held his consultations. Here the sick were obliged to wait for hours, even days, until their turn had come: the poor beggar, like the rich merchant, high officers, noted scholars, princes, all were in need of his skill.

"At 8 o'clock in the morning the physician was in his consultation room, which, until the evening, he did not leave, except for a very few moments in the middle of the day. At the time of the greatest congestion, he was sought for daily by about 300 patients.—(T. H. S.)

Levator oculi. Rectus (oculi) superior.

Levator palpebræ, Contracture of the. In addition to the general statement on p. 3275, Vol. V of this *Encyclopedia*, it may here be said this condition must be an exceedingly rare one. Gowers was the first to record such a case while the paper of J. Chaillous (*Annales d'Oculist.*, Oct., 1907) gives one the most information regarding it. This writer's case resembled that of Truc (*Bull. et Mém. de la Soc. Frs.*, 1906). An emotional woman, aged 62, had no other nerve lesion except the contracture. The retraction of the upper lids had been present for three or four months. It was so great that the lids were entirely concealed beneath the somewhat swollen tissues of the orbital margin, and the eyes remained widely open even in sleep. They could barely be closed by the greatest voluntary effort. As regards the motility of the globes, there was complete absence of the movement of elevation and of convergence, but the lateral and downward movements were normal. The pupils acted normally.

Truc having had a good result from tenotomy in his case, Chaillous determined to adopt a similar mode of treatment; and the following operation was performed:—An incision was carried across the entire width of the eyelid half a centimetre above the upper edge of the tarsal cartilage. A grooved director was passed between the tendon and the conjunctiva, and the insertion of the tendon in the cartilage was cut through. A suture armed with two needles was passed through the levator where muscle joins tendon, and round this suture a vertical tongue was cut with its base near the lower edge of the tendon. By turning this tongue down and suturing it to the epitarsal tissue and to the lower edge of the skin wound the levator was lengthened. The result was satisfactory two months after operation, as shown unusually well in the photographs reproduced, and Chaillous suggests that such an operation might prove beneficial in some of the extreme cases of Graves' disease.

Levator palpebræ superioris. APERTOR OCULI. PALPEBRARUM APERIENS RECTUS. Under these various names, given at various times from the earliest to the present, is the long, triangular, flat muscle arising from the upper margin of the optic foramen and the sheath of the optic nerve, which passes forward to be inserted by a thin aponeurosis into the upper margin and anterior surface of the tarsal cartilage. Its chief function is to raise the upper lid. See p. 360, Vol. I, of this *Encyclopedia*.

One of the best descriptions is given by Whitnall (*Ophthalmoscope,* p. 259, May, 1914). His observations show that the expanded tendon or aponeurosis of the levator palpebræ superioris muscle has both palpebral and orbital attachments. By the former it is connected to the skin and face of the tarsal plate of the upper eyelid by numerous slender fibres which radiate forwards from its anterior edge. In exposing the tarsal plate from the front these fibres are condensed by dissection into a layer of connective tissue which intervenes between the orbicularis oculi muscle and the plate. By its extremities the aponeurosis is anchored to the margins of the orbit opposite the medial and lateral canthi. The lateral extremity is much the stronger, and in the form of a ligamentous band cuts into and is firmly attached to the lachrymal gland; it is continued on to be fixed to the tubercle on the malar bone just within the orbital margin opposite the lateral canthus. From the position of this band it appears well adapted not only to maintain the lachrymal gland in place, but also to impart some movement to it, an action which may be assisted sometimes by the presence of lateral offshoots from the belly of the muscle itself to the gland. On the medial side the aponeurosis loses abruptly its tendinous nature as it passes across and comes into close contact with the reflected tendon of the superior oblique muscle. From this point it can be traced with difficulty towards the medial palpebral ligament in the form of loose strands of connective tissue. This extremity of the aponeurosis, with the orbital margin on the inner side and the tendon of the superior oblique muscle above, demarks a triangular space in the upper inner region of the orbit; through this space the orbital fat bulges when the overlying orbicularis oculi muscle has lost its tone, and thus there is formed the swelling in the inner corner of the upper eyelid so often seen in the aged.

The levator and the underlying superior rectus muscles are intimately connected by the fusion of their fascial sheaths. Anteriorly where the two muscles separate to reach their several insertions the fascia between them forms a thick mass which is fixed to the superior conjunctival fornix. This indirect fascial attachment, which is shared with the superior rectus, is described as an additional insertion of the levator palpebræ superioris.

Levator pupillæ. Rectus superior (oculi).

Lever, Enucleation (Terson's). See pp. 4398 and 4400, Vol. VI of this *Encyclopedia.*

Levis, Richard J. A well-known American surgeon and ophthalmologist, inventor of the Levis wire-loop for the extraction of cataract. Born in Philadelphia June 28, 1827, he received his medical degree in 1848 from Jefferson Medical College. Settling in Philadelphia, he soon acquired a high reputation both in the general and in the special field. He was surgeon to the Philadelphia Hospital and to the Pennsylvania Hospital, and an attending surgeon at the Wills Eye Hospital. He was one of the founders of the Philadelphia Polyclinic, and for many years taught ophthalmology and otology at the Jefferson Medical College. He died November 12, 1890.—(T. H. S.)

Levoduction. Movement of an eye to the left.

Levophoria. See **Heterophoria**; as well as **Muscles, Ocular.**

Levotorsion. A tilting of the vertical meridian towards the left. See, also, **Muscles, Ocular.**

Levoversion. The act of "verting" the eye to the left. See **Heterophoria.**

Levûre. (F.) Yeast.

Lewis, Francis West. A well-known American general practitioner and ophthalmologist, founder of the Children's Hospital on Twenty-Second St., Philadelphia. Born in 1825, the son of Mordecai D. and Sarah West Lewis, he received his medical degree at the University of Pennsylvania in 1846. Nine years later he became a Fellow of the

College of Physicians. For about two years he studied ophthalmology in Dublin (under Sir William Wilde) and in Paris. Returning to Philadelphia, he soon had an excellent practice, both in the general and in the special field. He died of pneumonia, in February, 1902.—(T. H. S.)

Lewis, Frank Newell. A prominent New York ophthalmologist. Born at Burlington, Vermont, the son of Dr. James Lewis and Abigail B. (Mason) Lewis, October 7, 1857, he received the degree of A. B. in 1879 at the University of Vermont, and the degree of A. M. and M. D. at the same institution in 1882. Serving for a number of years in the Mary Fletcher Hospital, Burlington, the Brooklyn Eye and Ear Hospital, and the New York Eye and Ear Infirmary, he studied ophthalmology and otology in London, Paris, Berlin and Vienna.

Returning to New York City in 1888, he settled there as ophthalmologist and otologist, and soon was widely known as operator and as writer. At the Manhattan Eye and Ear Hospital he served successively as clinical assistant, assistant surgeon, surgeon, and director. He also became Professor of Diseases of the Eye in the New York Post-Graduate Medical School. He was a member of the American Ophthalmological Society from 1898 until his death.

Dr. Lewis married, November 15, 1899, Miss Mary Aymar Fowler. There were no children. He died November 13, 1910.

The personal character of Dr. Lewis was very high. In the words of Dr. Edgar S. Thomson, of New York: "Kind, considerate, courteous and unselfish, with a strict sense of right and justice, and always mindful of the rights of others, he endeared himself to those who were fortunate enough to know him well, and earned the personal respect and confidence of all who came in contact with him."—(T. H. S.)

Lexer's operation. Removal of the Gasserian ganglion.

Liability for damages in eye diseases. See **Visual economics**; as well as **Legal relations of ophthalmology.**

Libanion. LIBANIUM. An ancient collyrium, made with frankincense.

Lice. These parisites belong to the *Pediculidæ,* a family of small, wingless insects. The body is flat, the legs are short and furnished with firmly-grasping claws, the mouth is suctorial, the eyes are simple. They live on or partly in the skin of vertebrates, usually mammals, and suck the blood of their hosts. True lice, harbored by dogs, etc., belong to the genus *Hemantopinus.*

Pediculi attack, among other hairy parts of the human animal the eyebrows, lids and eyelashes. They cause a not uncommon variety of blepharitis marginalis. The treatment is the removal of the mites by forceps and the application of red oxide of mercury ointment twice daily.

E. L. Meierhof (*Jour. A. M. A.*, June 12, 1915) has drawn attention to the efficacy of mopping thoroughly the lashes and brows with a ten per cent. solution of hydrogen peroxid and passing each through the blades of a Noyes forceps—by which means a quick end is made of this troublesome affection. See p. 1031, Vol. II of this *Encyclopedia.*

Lichen. LICHEN RUBER. LICHEN PLANUS. LICHEN SCROFULOSUS. The different forms of lichen occur very rarely on the eyelids. They belong properly to the domain of the dermatologist.

Lichen pilaris. See **Keratosis pilaris.**

Lichen tropicus. MILIARIA. PRICKLY HEAT. This is a common affection of the eyelids, occurring most frequently during the summer and in fat babies. There is usually a mild conjunctivitis accompanying it. *Treatment* by the application of a mild solution of sulphate of copper (gr. x. to ℥ vi of water) is usually efficient and rapid.

Licht. (G.) Light.

Lichtbildkunst. (G.) Photography.

Lichtbrechung. (G.) Refraction of light.

Lichtbrechungsvermögen. (G.) Refrangibility.

Lichtempfindung. (G.) Light perception.

Lichthof. (G.) Halo.

Lichtmesser. (G.) Photometer.

Lichtquelle. (G.) Source of light.

Lichtscheu. (G.) Photophobia.

Lichtsinn. (G.) Light sense.

Lichtstärke. (G.) Intensity of light.

Lichtstoffluft. (G.) Nitrogen.

Lichtstrahl. (G.) Ray.

Lichtvertheilung. (G.) Distribution of light.

Licorice. *Glycyrrhiza glabra.* Sweet-root, ground to an impalpable powder, was dusted into the eyes, in ancient Greco-Roman times, as a remedy for pterygium.—(T. H. S.)

Lid. Compare with other—especially **Blepharo-** and **Eyelid**—captions.

Lid, Anthrax of the. In addition to the matter on p. 4995, Vol. VII of this *Encyclopedia*, it may be stated here that Manulescu (*Bericht der Ophthal. Gesellschaft*, 1912) described a case of bilateral complete optic atrophy which followed a severe attack of anthrax. The malignant pustule was situated on the upper lid, and was surrounded by enormous edema of the tissues, which extended down the neck to the chest. There was great exophthalmos, chemosis, and lid edema. Under the influence of serum, the patient made a good recovery, but as soon as the lids could be opened, she was found to be blind. Ophthalmoscopic examination showed retinal edema and venous hemorrhages. Later on, complete optic atrophy developed. The veins remained of normal size, but the arteries were reduced to threads.

E. Fricker (*Wochenschr. f. Ther. u. Hygiene des Auges*, 16 November, 1911) also reports a case of anthrax of the lower eyelid, in an agricultural worker, following the bite of an insect. After removal of a crust of about the size of a florin, a dirty bleeding ulcer was seen with hard infiltrated base. Edema of the lid and enlargement of the pre-auricular and sub-maxillary glands were present. There was no complaint of pain at any time. The anthrax bacillus was found in scrapings. The ulcer was treated with iodine, and a moist dressing of acetate of aluminum applied. As the ulcer continued to enlarge, and another crust had formed upon its surface by the following day, this was removed, and 3 c.cm. of a 5 per cent. solution of carbolic acid injected into the infiltrated base and neighboring parts. The same dressing was re-applied, and by the tenth day the anthrax bacillus could no longer be discovered in the discharge. Complete recovery followed, and the patient was quite well three months later. Excision of the ulcer was decided against on the ground of the danger of general infection. The virulence of the organism does not appear to have been tested.

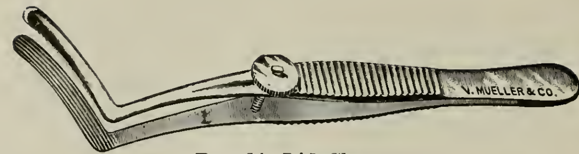
Lidbewegung. (G.) Lid movement.

Lid-Bildungsfehler. (G.) Anomalies of the eyelid.

Lid clamps. Most of the lid clamps in general use have been described and illustrated under **Fixation instruments**, on page 5212, and **Forceps, Ophthalmic,** on page 5245, Vol. VII; also under **Chalazion forceps,** on page 1990, Vol. III of this *Encyclopedia*.

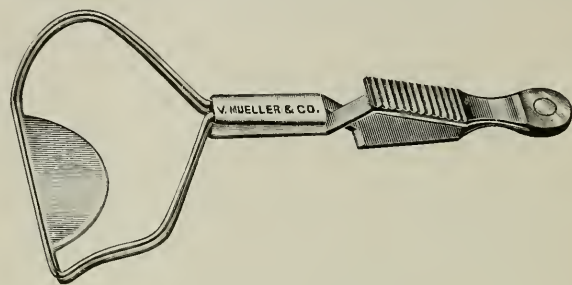
The number and variety of these instruments is large. Mention is made here of a few which have not been described elsewhere in these pages.

Beard's lid clamp is made so that the ends of blades are bent nearly at right angles to the body of the instrument, and are curved to correspond to the natural curve of the lid margin. It is clamped with a screw attachment.



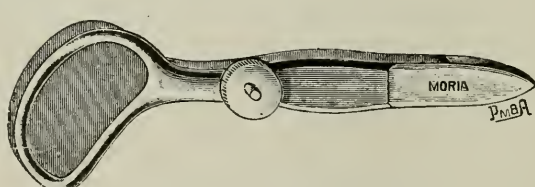
Beard's Lid Clamp.

Ewing's lid clamp has a broad plate, about 10 mm. in width, and of the shape of the upper tarsus, attached to the lower blade.



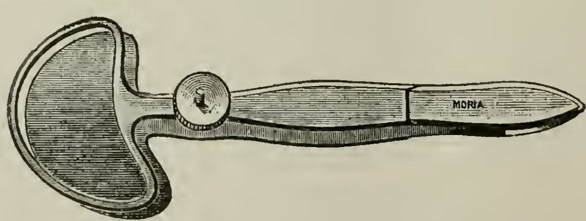
Ewing's Lid Clamp.

Marquex, of Madrid, has invented a lid clamp for operating on distichiasis. It is a modification of the Desmarres type of clamp, the lower blade consisting of a broad plate. The blades are placed at an angle of about 45 degrees with the shaft of the instrument, and are clamped with a screw.



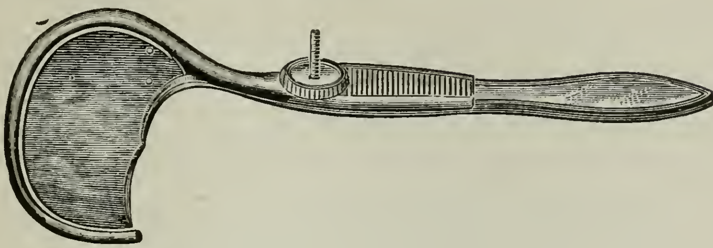
The Lid Clamp of Marquez.

The *lid clamp of Rochon-Duvignaud* also has a broad plate for the lower blade, and because of its curved shape permits of its being introduced well behind the external canthal angle.



Lid Clamp of Rochon-Duvignaud.

Knapp's modification of Desmarres' lid clamp requires only a glance at the figure to be understood.



Knapp's Modification of Desmarre's Lid Clamp.

Ziegler's lid clamp is another modification of the Desmarres type. The clamp is retained in the desired position on the lid, by a sliding adjustment of the upper upon the lower blade, instead of by means of a screw. See, also, **Lid forceps.**

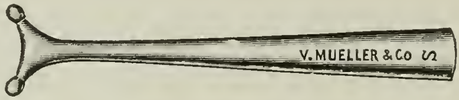
Ziegler's Lid Clamp.

Lid, Cleft. See **Congenital anomalies of the eye,** as well as p. 2344, Vol. IV of this *Encyclopedia.*

Lid-closure pupil reflex. GALASSI'S SIGN. GIFFORD'S SIGN. This phenomenon, known in America as Gifford's sign, was observed by Ballantine (*Ophthalmoscope,* February, 1906) in a poorly-nourished girl of 17 who was suffering from chorea, but the latter condition was found to have no causative influence. The reflexes and eyes in every particular were normal, except for a slight fear of light, when she had a sudden lid spasm, after which it was observed that the pupils were contracted, then slowly dilated. This pupillary contraction could be induced by asking patient to close the lids while they were being forcibly held apart. It was also found that this contraction could be induced in the same way while the lids were being actually held away from the globe, thus controverting the theory that the contraction is due to pressure upon the globe. The same phenomenon was observed in a young woman, highly myopic, who had no reaction to accommodation and convergence. A search of the literature shows that it was first described by Galassi, then by Gifford (Omaha), Westphal, Pilz, Antal, Kirchner, Roth, Franke and Schanz. There seems to be no agreement upon the diagnostic significance of the reflex. The author believes the reflex is an associated action of the sphincter iris and orbicularis muscles. See, also, **Basedow's disease**; also p. 5384, Vol. VII, and p. 4805, Vol. VI of this *Encyclopedia.*

Lid elevator. See **Lid retractor.**

Lid everter. Under this name Sidney Israel (*Journal American Med. Ass'n.,* June 26, 1915) claims to have found an instrument that gives a large exposure of the entire upper lid and cul-de-sac. Its most salient features are simplicity of design, ease of manipulation, and freedom from causing pain in introduction. It has been the means



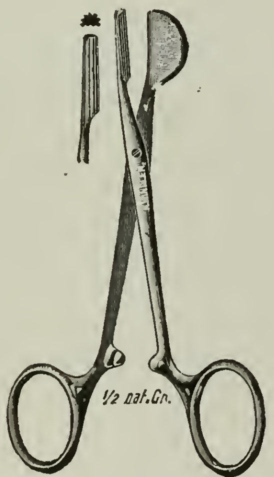
Lid Everter. (Israel.)

Method of Using the Lid Everter.

of revealing several cases of trachoma that had been overlooked by ordinary methods.

In introducing the instrument, it is grasped at its distal end between the tips of the thumb and index finger. With the patient looking down, the lashes of the upper lid are held in the tips of the thumb and index finger of the left hand. The knobbed ends of the instrument are then placed gently on the upper lid about one-half inch from the ciliary margin with the instrument in the vertical position. With the fingers of the left hand holding the lashes, the lid is retracted over the knobbed ends, and with gentle pressure on the distal end, the entire under surface of the upper lid, including the cul-de-sac, is freely brought into view. In this position the knobbed ends can be slid from the outer to the inner canthus, exposing any part desired. In this position also, with the under surface of the lid exposed, the hold on the eyelashes by the fingers of the left hand can be released, and with the tip of the index finger of the right hand on the distal end still maintaining the position of the instrument in the vertical meridian, the thumb of the right hand can be dropped down to hold the lashes in place to maintain a complete eversion of the lid, while with the left hand free, any foreign body that is present on the under surface of the lid is easily removed. See the figures. See, also, **Lid forceps** and **Forceps.**

Another device is that of Grönholm. As shown in the cut, this scissors-like instrument is provided with a blade whose terminal is

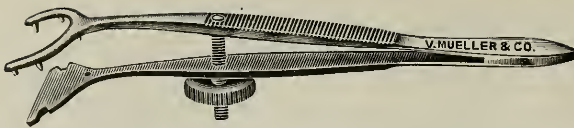


Grönholm's Lid Everter.

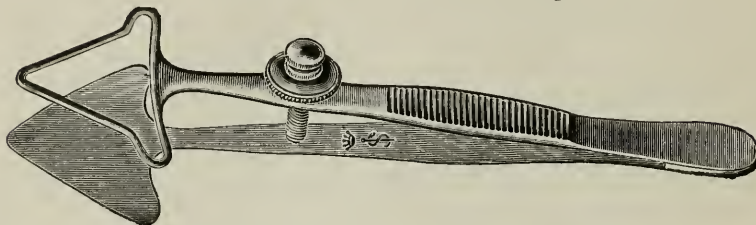
a semicircular plate; the other is rough and rounded. The lid is grasped between them and can be readily rolled out, exposing the sulcus.

Lid forceps. A full description of the various forms of lid forceps will be found under **Fixation instruments,** page 5212; as well as under **Forceps, Ophthalmic,** page 5245, Vol. VII; and **Chalazion forceps,** page 1990, Vol. III of this *Encyclopedia.*

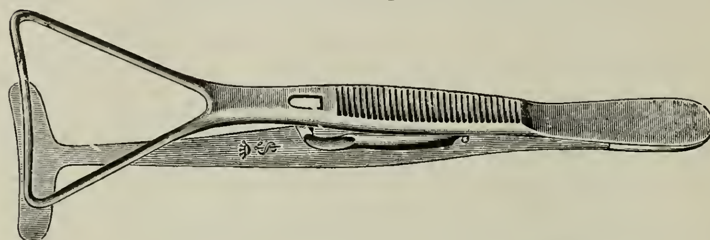
The figures given here are simply to illustrate a few additional types of forceps which have been devised for various operations upon the lids. See, also, **Lid clamps.**



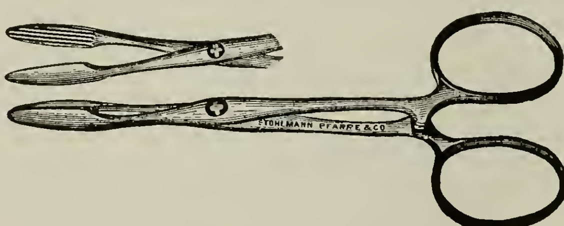
Claiborne's Tarsus (removal) Forceps.



Dohnberg's Lid Forceps for Trichiasis.



Ratti's Lid Forceps for Trichiasis.



Weeks' Lid Forceps.

Lidhalter. (G.) Speculum.

Lidheber. (G.) Lid elevator.

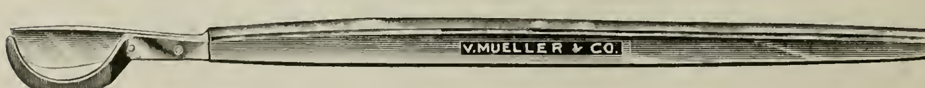
Lidheberkrampf. (G.) Spasm of the levator palpebræ.

Lid-holder, Jaeger's. See p. 4346, Vol. VI of this *Encyclopedia.*

Lid hook. See p. 5999, Vol. VIII of this *Encyclopedia;* also **Cataract in capsule, Extraction of.**

Lid-key. See **Everter, Lid.**

Lid knife, Ewing's. The purpose of this useful instrument for operations on the lid are sufficiently indicated by the figure.

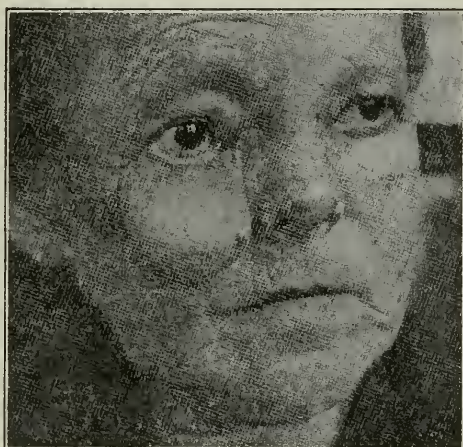


Ewing's Lid Knife with Guard.

Lidknorpel. (G.) Tarsus.

Lidknorpelband. (G.) Tarsal ligament.

Lid, Lymphangiectasis of the. Marked dilation of the lymphatic vessels of the eyelids is an extremely rare condition. Walter H. Jessop (*Proceedings of the Royal Society of Medicine: Section of Ophthalmology,* December, p. 5, 1914) describes a case of tumor-formation in the lower lid of the size of a small orange, in a female, fifty-one years of age. The swelling was of two years' duration. The general characteristics of the swelling, which was in most of its extent semifluid to the touch and which pitted readily upon pressure, are shown in the accompanying figure. The skin covering the mass was smooth



Lymphangiectasis of Lower Lid. (Jessop.)

from distention. The upper eyelid had recently become edematous, and some thickening and edema had made its appearance in the temporal region. Ophthalmoscopic appearances normal, and vision 6/6. Skiagrams showed no changes in bones or sinuses. Nothing abnormal was found in throat or nasal passages. No history of erysipelas.

Considerable pressure was applied to the tumor under the influence of a general anesthetic, when the swelling disappeared, but at the same time there was much swelling in the temporal region, the eye was greatly proptosed, the conjunctiva chemosed, and the upper lid swollen. The tumor regained its original dimensions after six hours. There appeared to be little doubt that the growth was in the nature of a lymphangioma. Eventually, the tumor was removed, and on cutting into it, the skin surface was found to be thickened and a central cavity to contain a blood-stained serous fluid. The cavity, which was lined by endothelium, extended to beneath the conjunctiva of the lower lid, but no communication could be made out with the temporal region. But on pressing over the swelling in the temporal region, blood-stained serum exuded from the wound. The tumor, then, was formed by a cyst-like cavity pushing down and stretching the lower lid.

Specimens were examined by F. W. Andrewes, and reported as lymphangiectasis, pure and simple. In the loose connective tissue of the dermis were dilated lymph spaces, irregular and ragged, and not lined by endothelium. The skin was normal. The fluid contained by the cyst was a mixture in all probability of lymph and serum, its protein content amounting to 2.17 per cent.

Jessop concludes that the tumor was due to lymphangiectasis, the obstruction being probably in the orbit or temporal region. The swelling of the lower lid was caused by enlargement of the tissue spaces, producing a large cystic formation. (Abstract by Sydney Stephenson, *Ophthalmoscope,* Oct., 1915.)

Lid, Necrosis of the. This peculiar and rare lesion is best described by Eppenstein (*Zeitschr. f. Augenheilk.,* p. 16, July, 1914) who reports two cases from streptococci, one due to lues and one from infection by staphylococcus pyogenes aureus. The latter case proved that Wassermann's reaction ought always to be made if there is slight suspicion of lues, even if for many reasons lues is improbable. Each case of necrosis of the lids must be scrutinized in all detail. Generally a relatively simple therapy will be indicated, with satisfactory results.

Lid-plate. See p. 4346, Vol. VI; as well as p. 5247, Vol. VII of this *Encyclopedia.*

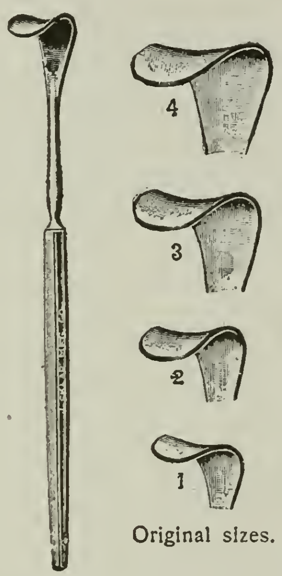
Lid reaction. Lid reflex. See **Gifford's reflex,** p. 5384, Vol. VII of this *Encyclopedia.*

Lid, Retraction of the upper—Von Graefe's sign. See **Exophthalmic goiter.**

Lid retractor. Lid elevator. Instruments for elevating as well as retracting the eyelids for purposes of examination, local treatment, operation, etc., have been described and depicted under various captions, especially under **Cataract, Senile** and **Examination of the eye.** See, also, p. 4284, Vol. VI, and p. 1536 Vol. III of this *Encyclopedia.*

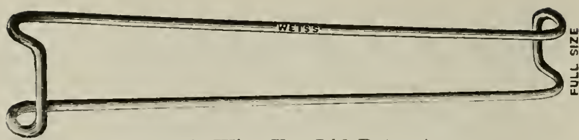
Probably the most widely employed and the best known are the retractors of the Desmarres type, shown in the accompanying figures. The appearance and method of employing others are also indicated by the cuts in this section.

Edgar Browne's Eye-Lid Retractor and Douche Combined.

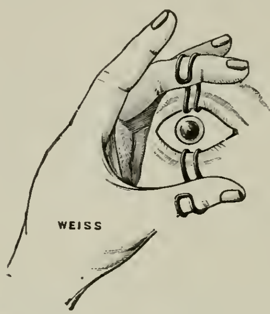


Desmarres' Lid Retractor (four sizes).

Lid Elevator of Krämer.

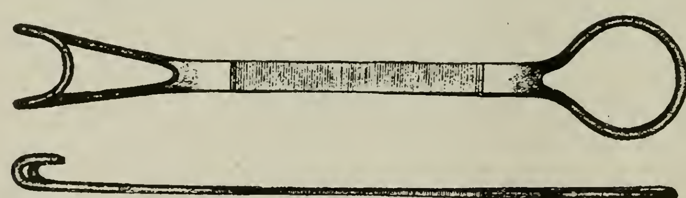


Lang's Wire Eye-Lid Retractor.

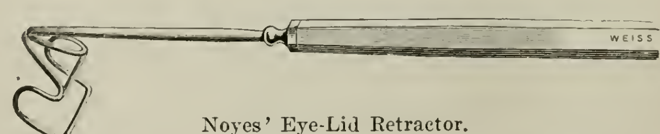


McGillivray's Eye-Lid Retractor.

Moraweck (*Ophthalmic Record,* May, 1908) describes a wire lid elevator which he devised for the prevention of loss of vitreous humor in the operation for extraction of cataract. It is 5⅜ inches long and the ocular end is formed into a wire loop bent on the flat to pass under the lid, the other end terminates in a wire ring through which the finger can be inserted in holding it. An elevator is used for both the upper and the lower lids. These are held by an assistant, who pulls the lids well away from the globe.



Moraweck's Lid Elevator for controlling the lids and preventing loss of vitreous humor in cataract extraction.

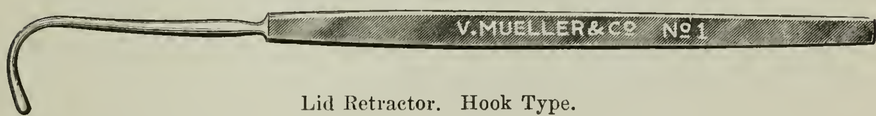


Noyes' Eye-Lid Retractor.

Prince's Lid Retractor.

In addition to the above, Vail (*Ophthal. Rec.,* May, 1915) has devised a lid retractor for the cataract operation which is provided with a heart-shaped guard near the bend of the instrument, designed for the purpose of keeping the lashes from fouling instruments that are used in the operation. One of the principal advantages in the retractor holding the upper eyelid is that the lid hangs on a single bar, so that there is a gable-like exposure above the eye-ball, which gives the operator the greatest possible field.

Stumpf (*Münch. med. Wochenschr.,* No. 23, 1915) has devised lid retractors of heavy glass similar in shape to the Desmarres instrument. They are quite efficient, do not rust, can be used with the electro-magnet and are readily cleaned.



Lid Retractor. Hook Type.

Lid, Sarcoma of the. See p. 5022, Vol. VII of this *Encyclopedia.*

Lidschlag. (G.) Spasm of the orbicularis.

Lids, Granular. See **Trachoma.**

Lidspalte. (G.) Interpalpebral space.

Lid spatula. Lid plate. See **Spatula**; also **Entropion.**

Lid speculum. In addition to what is said on p. 1656, Vol. III of this *Encyclopedia,* reference may be made here to a study of this subject in Wood's *System of Ophthalmic Operations,* Vol. I, p. 503.

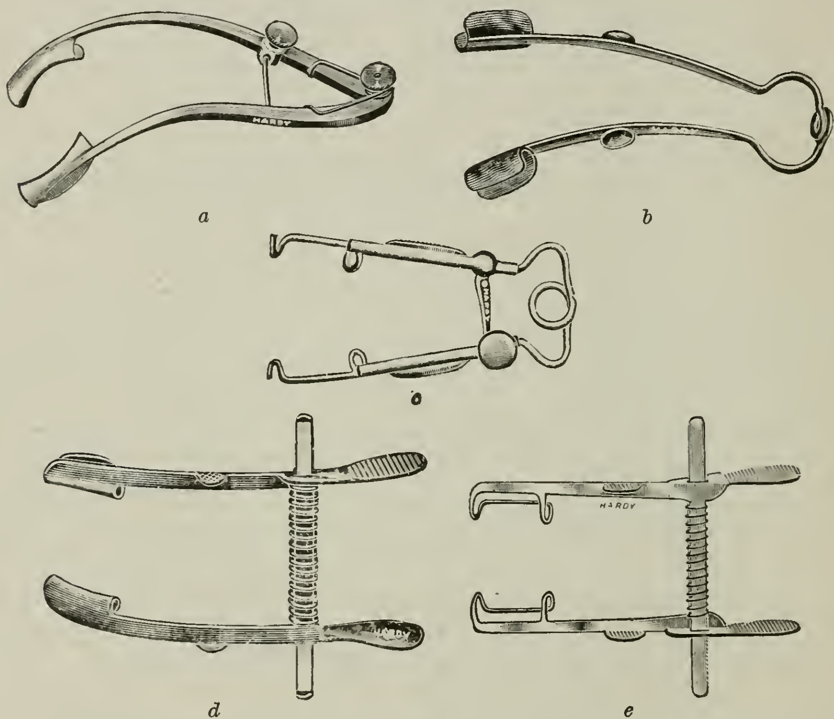
Lid specula are of almost every conceivable size, shape and description, but very few are of any real practical value. Most of them are too large and have too strong a spring. The simpler the instrument, consistent with its purpose, the greater its usefulness. Illustrations show the models of Mellinger and others.

Russell Murdoch's speculum is a modification of his instrument of 1874.

One blade of the speculum has attached at right angles to it a bar, and to the other, in like manner, a closely-fitting canula. At the end of the bar is a button which forms a shoulder that prevents the canula from slipping off. On the side of the canula is a finger-rest which also acts as a handle to slide the canula on the bar. The blades are opened by approximating the button and finger-rest, and closed by reversing the action. The lids lock the instrument. See *Trans. of the Am. Oph. Soc.,* 1883, p. 467.

M. D. Stevenson devised an adjustable lid speculum that is a modification of the Mellinger speculum. The blades are smaller and lighter and are attached to the body of the instrument by a pivot adjustment. (See the *Ophthalmic Record,* April, 1904, p. 153.)

C. H. Beard (*Ophthalmic Record,* Jan., 1905, p. 7) described a modification of the Mellinger-Beard *blepharostat.* The lid holders are shaped to fit the concavity of the lid margins. The inner wall of the gutter conforms to the curve of the globe, and the outer wall to that of the skin surface of the lid. The inner wall of the trough is made decidedly lower than the outer.



Lid Specula. *a.* Lange's; *b.* Stevens'; *c.* Landolt's (nasally operated); *d.* Mellinger-Beard's; *e.* Mellinger's.

The lid speculum suggested by Pedrazzoli (*Arch. d'Opht.,* XXII, 7, p. 456, 1902) for opening the lids in cases of extreme blepharospasm has the size and form of a Péan's speculum. The branches, which are introduced from the temporal side, are flat and have a space corresponding to the cornea. When drawn apart they make a rotary movement, so that the lower margin of the branches eventually lies in the retro-tarsal fold.

K. Emanuel's new lid holder (*Klin. Monatsbl. f. Augenh.,* XIV, 11, p. 563, 1906) is a modification of Schmidt-Rimpler's springless lid speculum made in accordance with Hess' principle.

Paul Greven has invented a very simple speculum which has no screw parts, consisting simply of a curved spring and lid retractors. (See *Wochenschr. für Therapie und Hygiene des Auges,* August, 1906.)

H. D. Noyes' eye speculum is made of moderately-tempered steel, electroplated with either gold or nickel. It is both light and strong. Its blades open by a spring on the temporal side, which is so strong as to overcome the efforts of the orbicularis even when it contracts vigorously. The check to the expansion of the blades is found in a Y-shaped attachment to the upper side of the arms. The extremities of the Y are pivoted to the arms and to the stem, so that it has three joints. The stem is prolonged backward beyond the spring, and runs through a short tube soldered to the spring. A triple thread is cut on the stem, upon which a milled head runs easily and quickly. The head may be set at any point of the screw and effectually stops the expansion of the blades, but does not hinder the closure of them by the fingers of the operator. (See *Trans. Am. Oph. Soc.,* 1869, p. 54.)

A. S. Green and L. D. Green (*Ophthal. Rec.*, February, 1915), in describing their new eye speculum, refer to the fact that no matter how tractable the patient may be an orbicular spasm is apt to be produced through the operator inadvertently pricking the skin of the lids or of the nose with the knife while making the section; or the patient may forcibly squeeze the lids at some time during the iridectomy, delivery of the lens, or even while the toilet is being completed, and thus ruin an otherwise successful operation.

The instrument has the appearance of an ordinary eye speculum to which a handle, directed downward and outward, has been attached at an obtuse angle. This handle enables the assistant to hold it in position with a firm but comfortable grasp and without tiring his hand.

The two cross-bars which hold the lid-plates are bent at their outer extremities to conform to the curvature of the cheek, and are consequently out of the way and do not interfere with the manipulations of the operator. The lid-plates are attached at a slight angle to prevent the lids from slipping off. The instrument is made in pairs—a right and left—one for each eye.

This instrument combines ease of application, proper exposure of the field of operation, and safety from squeezing by the lids. With the tonometer the inventors have repeatedly demonstrated that the intra-ocular tension will not be raised in the least by the most forcible squeezing the patient is able to exert when the instrument is properly held. The lids are at all times entirely under the control of the assistant and the patient is absolutely powerless to cause harm by squeezing. It is introduced at the beginning of the operation and not removed until the toilet is completed and the eye ready to be bandaged.

It is applicable to every form of intra-ocular operation, particularly in the extraction of cataract.

Lieberkuehn, Nathanael. A celebrated German chemist, physiologist, and veterinarian, of a slight ophthalmologic importance because of his *"Ueber die Entwicklungsgeschichte des Wirbelthierauges"* (Cassel, 1872). Born at Barby on the Elbe July 8, 1822, he studied at Berlin, where in 1857 he was made Prosector, and in 1862 Extraordinarius in Anatomy. In 1867 he was called as Professor of Anatomy to Marburg. There he became Privy Medical Councillor, dying April 14, 1887.—(T. H. S.)

Lieberkühn's condenser. Also called a Lieberkühn. A concave mirror attached to a microscope to concentrate the rays upon an opaque object.

Liebermann, Charles H. An early American surgeon and ophthalmologist, the first to perform the strabismus operation in the United States. Born at Riga, Russia, Sep. 15, 1813, the son of a military surgeon, he lost his father in very early childhood. He received the degree of M. A. at Dorpat in 1836, and that of M. D. at Berlin about 1839. He was for a time a pupil both of Dieffenbach and von Graefe. He removed to the United States in 1840, landing in Boston, but settling very shortly afterwards in Washington. Here he repeated the Dieffenbach operation for strabismus in 1840. He was for many years surgeon, afterwards consulting surgeon, to the Providence Hospital, and was one of the founders of the Medical Department of the University of Georgetown. He married in 1841 Miss Bechtold, of Alexandria, by whom he had one son and one daughter. He died Mar. 27, 1886.—(T. H. S.)

Liebig, Justus, Freiherr von (1803-73), German chemist, was born at Darmstadt. Humboldt secured for Liebig the appointment of professor of chemistry at the University of Giessen. This chair he exchanged in 1852 for the corresponding one at Munich. Liebig was one of the most illustrious and fruitful chemists of his age, not less renowned for his investigations and discoveries in pure chemistry than for his researches in applied chemistry. As the inventor of the extract of beef and the prepared infant food, his name is known almost everywhere throughout the civilized world. He was the founder of agricultural chemistry. Among the practical discoveries and applications of Liebig may be mentioned the invention of silver-coated mirrors, an easy method for the preparation of potassic cyanide, now so largely used in electroplating, his plan for making unfermented bread, and his methods for analyzing mineral waters.—(*Standard Encyclopedia.*)

Liebold, Carl Theodor, from 1868 to 1885 one of the leading ophthalmic surgeons of the homeopathic school and profession in the New York Ophthalmic Hospital, was found dead in his office-chair—from cerebral apoplexy—on the 29th of November, 1885. He was born Nov. 24, 1831, at Neu Dietendorf, Thüringen, and came a young man to this country, finally studying medicine four years with Dr. Otto Füllgraf in New York. In 1858 he entered the University of Berlin, receiving in due course its degree and a certificate of attendance upon von Graefe's clinics. Returning to America about 1861 he served as resident army surgeon at Point Lookout Hospital, where he showed marked ability. After returning to New York, at the close of the war, he devoted himself to his specialty and became the chief surgeon of the New York Ophthalmic Hospital in 1868, when its administration was transferred to the homeopathists—a position he held until his death. For years he lectured in the New York Homeopathic Medical College, but this teaching was transferred to the New York Ophthalmic Hospital in 1880, when, in accordance with a charter amendment, the latter was empowered to confer the degree O. et A. Chir., and a graded course, clinical and didactic, was instituted for graduates in medicine.

Dr. Liebold was a member of the American Institute of Homeopathy and the Homeopathic Medical Society of the State of New York, whose *Transactions* were enriched by his contributions. He was a devoted member of the Moravian church, and never married.

Of all men that the writer has ever met, none has ever made such an impression of refinement, dignity and repose. Modest, unassuming, reticent, yet always courteous, he was cordial to those with whom he came in close contact. His bearing, refined handsome features, very high forehead and black hair brushed directly backward—these, with the black eyes and neatly trimmed black mustache, warrant the epithet princely.

In 1880—I cannot say how long previously—Dr. Liebold used after cataract extraction an ordinary black mask with each eyehole covered with a black puff—the predecessor of Ring's mask. In evisceration he wiped out the scleral cavity thoroughly with a clump of lint. His cataract incision was what, with characteristic modesty, he termed "the Liebreich upward;" we were taught to emerge from the cornea one-third its distance from limbus to pupil.

The Liebold eye speculum—I do not know whether he ever published it and have never found it used or known by any but his pupils—consists of heavy stiff wires moulded to the temple, with the usual bends for the lids and two (upwards) for thumb pieces with which to hold and to close it. These wires are pivoted (there is no spring) and straight from the pivot to terminal thumb pieces which serve to retain a freely sliding metallic ring whose position, between them and the pivot, determines how widely the speculum is to be held open. A very satisfactory instrument.—(John L. Moffat.)

Liebreich's ophthalmoscope. See **Ophthalmoscope.**

Life insurance and ophthalmology. In addition to the consideration of this subject under the caption **Legal relations of ophthalmology** a number of monographs on the subject, or portions of the subject, have been published in late years. One of the most useful and valuable of these is the contribution of W. C. Posey (*Jour. Amer. Med. Assn.*, June 14, p. 1867, 1913), and as this article is all important it is given *in extenso:* After commenting upon the fact that many grave, morbid processes in the body are indicated by intraocular changes, it seems extraordinary that life-insurance examiners do not avail themselves oftener of the aid which ophthalmic science offers them.

There is scarcely an organic disease of the nervous system without ocular complications and the earliest signs of circulatory disturbance can frequently be unmasked by the ophthalmoscope. The proper recognition of the initial pupillary changes in tabes and paresis, and of a commencing sclerosis of the retinal vessels in Bright's disease. might often serve to warn the examiner and to recommend the rejection of an applicant for insurance who manifested no other signs of ill-health.

To determine the existence of a disease is one thing; to draw deductions from one's ophthalmic findings regarding the longevity of the individual in whom they occur is another. It is fairly safe to assert, however, that in general, when morbid processes which originate outside the eye produce marked ocular disturbance, the systemic disease causing the lesions must have reached a stage in its development which seriously threatens the health of the individual and renders his tenure of life uncertain. It is not too much for an ophthalmologist to assert, perhaps, that the discovery of hemorrhages in the retina, when not of traumatic origin, in any individual past adolescence.

should always be regarded as indicating a serious state of health in the possessor.

As is well known, albuminuric retinitis occurs most frequently in genuine cases of contracted kidney; that is, in cases in which there is profuse secretion, low specific gravity and little or no albuminuria. In such cases there is usually but little sediment in the urine, with occasional cylindrical casts. As this process often goes on for many years, without apparently affecting the general health, it frequently remains undiscovered. It is in this class of cases that the ophthalmoscopic findings are of paramount importance in revealing a general vascular sclerosis by the discovery of such changes in the retinal vessels.

Retinal changes may also occur in diffuse chronic parenchymatous nephritis, in the so-called large white kidneys, and also in the secondary contracted kidney, which is a sequence of the large white kidney, though not so frequently as in contracted kidney. Finally, several cases are well authenticated in which amyloid degeneration of the kidneys was accompanied by the retinal changes under consideration. Mention need not be made at this time of the not infrequent changes in the retina which accompany the acute nephritis of scarlet fever and pregnancy, or of those which occur in inflammatory conditions of the kidneys secondary to intermittent fever, chronic lead-poisoning, etc.

While it is generally supposed that retinitis appears in and indicates, as a rule, a nephritis of long standing, some authorities believe in the existence of the pre-albuminuric retinitis. These observations, however, as Groenouw has pointed out, can hardly be taken in the sense that the retinal changes precede the nephritis, for this would presuppose both conditions as due to a general derangement, such as a general disease of the vascular system. It is much more likely that the findings indicate that a retinitis may occur with an existing affection of the kidneys before albumin is found in the urine; that is to say, the kidneys may be diseased for some time without the presence of albuminuria, as, for example, has been shown by Litten to be the case in amyloid kidneys. According to Groenouw, a second and more probable explanation of these cases is that albuminuria may sometimes be lacking in contracted kidneys, and if at this stage the patient consults a physician, it is very easy for the latter to mistake the intermittent non-albuminuric condition for a pre-albuminuric stage. Finally, it must be remembered that the ophthalmoscopic picture of retinitis albuminurica is in no way characteristic and a similar form of retinitis may occur from other conditions, notably in cerebellar tumor.

On the whole, the prognostic import of the retinitis albuminurica is unfavorable and by far the greater number of persons so affected die before a retrogression of the retinal changes takes place. The prognosis for life is usually hopeless in cases of chronic nephritis, less so in acute, and comparatively favorable in renal disease complicating pregnancy.

According to Ridley, the average duration of life after the onset of retinitis is about one and one-half years. Snell reports that among 103 patients, 57 died within the first year and 12 within the second year after the appearance of the disease, making 67 per cent. within the first two years.

Trousseau was able to obtain data concerning 45 patients having retinitis albuminurica, and of these 3 lived more than four years; 4 beyond three years, and 10 more than two years; thus 28, 62 per cent., died within two years; among these 8 within the first year and 3 during the first six months. One woman aged 24 years died one month after the onset of the retinal disease. Haehnle found that among 98 cases of retinitis albuminurica 56 per cent. died within the first year, 68.4 per cent. in the first two years and 14.3 per cent. after two to nine years. Seventeen patients, 17.3 per cent., were still living at the time the statistics were tabulated; 11 of them two years, and the others from three to six years after the onset of the disease.

According to Groenouw, the progress is much aggravated by a detachment of the retina, patients with this complication usually dying very soon. It may be stated in general terms, therefore, that only about one-third of the patients with retinitis albuminurica live more than two years after the appearance of the disturbance; and ophthalmic changes must always be considered an indication of an advanced stage in the progress of the renal disease. As de Schweinitz has well said, however, while the prognosis of albuminuric retinitis will always remain exceedingly grave, it is not likely that statistics gathered some years hence will show an improvement, as far as the duration of life is concerned, as compared with the figures cited above. A carefully regulated manner of living, with the best of medical care, may prolong life for many years.

Diabetes. Of almost equal value to the examiner is the recognition of the ocular symptoms of diabetes. These are many and varied, nearly all the tissues of the eye being affected by glycosuria. The most important, however, are the changes which occur in the ciliary muscle, in the lens and in the retina; for it happens, not infrequently, that the ophthalmologist is the first to direct attention to the existence of diabetes, by the discovery of the more or less characteristic disturbances which glycosuria occasions in these structures.

The prognosis *quoad vitam* in diabetic diseases of the eye is not affected in the same manner as in retinitis albuminurica. It may be said in general terms to be unfavorable in degenerative diseases, less so in hemorrhages, of the retina, while the formation of cataracts cannot be considered as evidence of the rapid progress of the disease.

Opinions differ, however, in regard to the vital prognosis, for while Hirschberg and Schirmer consider the appearance of eye diseases among diabetics as unfavorable, Schmidt-Rimpler is less pessimistic, for he found that though 19 out of 44 diabetics had died within two years after the appearance of the eye trouble, one patient with retinitis was still living after three and one-fourth years, one with chorioretinitis after four years and one with neuritis after five years. One woman of 63 and a man of 66 with cataract were still living after seven years, and a girl, who at 10 years of age developed a diabetic opacity of the crystalline lens, was living nineteen years after the appearance of the eye disease.

It had been the experience of the writer that with proper care, diabetics may live for many years after the development of ocular lesions, and that a proper dietary and regimen not only improve the general condition and lengthen life, but also exert a most favorable influence on the ocular disease, even in some instances causing less opacification of the lens, for diabetic cataract is the one form of cataract which yields in any degree to non-operative measures.

Heart-disease. The ophthalmoscope may also give evidence of the existence of heart-disease; thus in aortic insufficiency there is almost constantly a pulsation of the retinal arteries, synchronous with the radial pulse, and alternating with enlargement of the veins. In fatty heart there is not infrequently extensive disease of the vessels, which may give rise to ocular hemorrhages. It may be of interest to mention, in this connection, that ophthalmologists have been unable to recognize the connection between fatty heart and arcus senilis, all forms of heart-disease being absent in those very cases in which arcus senilis develops at a prematurely early age. Cardiac disease may also manifest itself within the eye in the form of an embolism or thrombosis of the retinal vessels. In aneurysm of the aorta or innominata, vasomotor and oculopupillary sympathetic symptoms are often found on the corresponding side. Initial irritative symptoms give place later to paralytic symptoms.

Individuals on the far side of 65 years, who have had repeated small hemorrhages in the conjunctiva and retina usually die within a few years from cerebral apoplexy. Hasket Derby, for example, followed the life history of thirty-one such patients between the ages of 43 and 83 years and found that almost half died within two years of his first observation and most of them rather suddenly from heart-disease or apoplexy. Raehlman found changes in the retinal vessels in nearly half of all patients with general arterial sclerosis.

Lead, tobacco and alcohol often reveal their toxicity in the fundus oculi, and syphilis can affect almost all of the structures of the eye. Tuberculosis also has its ocular manifestations.

Aside from the bearing ocular findings have on the special question of life expectation, it seemed to Posey that examiners should give more consideration to the degree of visual acuity possessed by applicants for insurance, for even partial loss of sight may disqualify a man from earning his livelihood, thereby affecting his insurabilty, by reason of the financial risk of his not being able to pay his premiums. It surely would be advantageous to the insurance officers to be informed that when the company is asked to insure the life of Mr. X., for example, that though in good health otherwise, the examiner found commencing cataracts or evidence of glaucoma or optic atrophy, conditions not necessarily affecting longevity, but all progressive ocular lesions, which in all likelihood would so interfere with vision that within ten years or even less, his earning capacity would be greatly jeopardized. See, also, pp. 7148, 7152, Vol. IX of this *Encyclopedia*.

Lien. (F.) Band; cord.

Ligament, Annular. See p. 496, Vol. I of this *Encyclopedia*.

Ligament, Ciliary. The structure which joins the iris to the corneosclera.

Ligament divider. See p. 4053, Vol. VI of this *Encyclopedia*.

Ligament, Lockwood's. One of the names for the suspensory ligament of the globe of the eye, connecting Tenon's capsule with the orbit on either side.

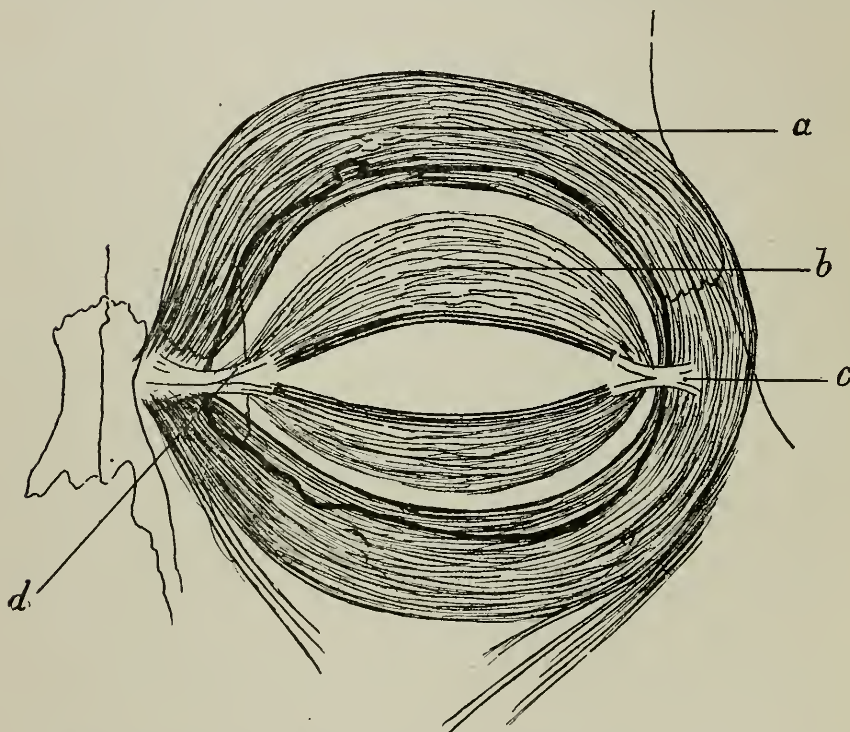
Ligament, Pectinate. LIGAMENTUM PECTINATUM. The lax spongy tissue filling the sinus of the anterior chamber of the eye at the junction of the cornea and sclera (filtration angle), and forming the root of the iris.

Leslie Buchanan (*British Med. Jour.*, Aug. 16, 1913) after examining some carefully prepared specimens of a normal human eye became satisfied that Descemet's membrane really ends comparatively abruptly at some little distance from the true angle of the anterior chamber, and also that it takes no part in the formation of the pectinate ligament. On further investigation it became more and more clear that the radial portion of the ciliary muscle gave rise to a series of fibres which were functionally a tendon, and these fibres formed a large portion of the tissue which was called the pectinate ligament. Other sections showed that fibres did pass from the ciliary body to intermingle with others of corneal origin, and that the spaces of Fontana were the result of the interdigitation so formed. There was one other constituent part of the ligament which required notice, and that was the portion which was derived from the iris. This band was thin, it formed the anterior root, and served to convey the lining epithelium of the anterior chamber from the iris to the cornea. This bundle of tissue passed across behind the canal of Schlemm and lost itself in the cornea in front of Descemet's membrane. He then examined the condition in the monkey (*Macacus radiatus*), and found that a very similar state of things existed there. Similar conditions were found also in the dog, sheep, and ox. See, also, **Comparative ophthalmology.**

Ligaments, Check. Near the insertions of the recti muscles the anterior layer of the capsule of Tenon forms strong, band-like processes called check ligaments. They extend laterally from the external rectus and internal rectus to the malar and lacrimal bones, respectively. Sappey found a small number of muscle-fibres in these bands. Other check ligaments which are usually devoid of muscle-fibres are described. A band which connects the superior rectus muscle with the levator palpebræ spreads laterally and forms an external superior check ligament and an internal superior check ligament. The former passes outward and divides into two parts, one joining the check ligament of the external rectus muscle, while the other part is attached directly to the margin of the orbit. The latter passes inward, joins the sheath of the superior oblique muscle, and is inserted into the trochlea. Inferiorly a fibrous band passes from the rectus inferior to a process from the inferior oblique muscle, the conjoined band being attached to the floor of the orbit. The check ligaments prevent extreme muscular action, and after tenotomy prevent deep retraction of the muscles. By acting on the posterior hemisphere of Tenon's capsule they oppose excessive backward traction on the part of the recti muscles. In addition to the check ligaments, other connective-tissue fibres pass in an irregular manner from one muscle to another (Howe). —(J. M. B.). See, also, **Anatomy of the eye,** as well as **Muscles, Ocular.**

Ligaments, Palpebral. These bundles of connective tissue are in close relation to the orbicularis palpebrarum and Horner's muscle. The latter arises from the posterior limb of the *ligamentum palpebrale mediale* and from the *crista lachrymalis posterior* and a part of the lachrymal bone behind the posterior crest. (See the figure.) Passing forward in two fan-shaped layers the fibers are inserted into the free border of the lid, some of them surrounding the canaliculi.

The *internal palpebral ligament* (*ligamentum palpebrale mediale*) is a bow-shaped tendon which surrounds a triangular space in which rests the lachrymal sac. The anterior limb of this ligament, about 3 to 4 mm. broad, arises from the frontal process of the superior maxilla, passes outward and then backward around the upper end of



Musculus Orbicularis Palpebrarum. *a.* orbital portion; *b.* palpebral portion; *c.* raphe palpebralis lateralis; *d.* ligamentum palpebrale med. *The heavy black line indicates the margins of the orbit.* (After Charpy.)

the lachrymal sac to be attached again to the *crista lachrymalis posterior.* This latter portion is known as the posterior limb of the ligament, and has usually twice the breadth of the anterior.

Fibers of connective tissue pass from the anterior limb to the skin and this portion of the ligament can be easily seen at the inner angle of the eye as a tense band, especially in thin persons or if the lid margins are put upon the stretch by separating and drawing them toward the temple. It forms an important landmark for operations on the lachrymal sac, the upper end of which lies directly behind it.

The *external palpebral ligament* (*raphe palpebralis lateralis*) is not like the medial ligament, a well-defined band, but is a tendinous insertion of firm connective tissue, connecting the lateral ends of the tarsal plates with the temporal margin of the orbit, its fibers often attaching themselves to the wall of the orbit, immediately behind the margin.

Ligament, Suspensory. ZONULA OF ZINN. See p. 5963, Vol. VIII and p. 377, Vol. I of this *Encyclopedia.*

Ligamentum suspensorium glandulæ lachrymalis. See p. 6921, Vol. IX of this *Encyclopedia.*

Ligament, Zinn's. The annular ligament of origin common to the recti muscles of the eye, attached to the edge of the optic foramen, and the inner part of the sphenoid fissure. Called also *annulus tendineus communis, annulus Zinnii,* and *tendon of Zinn.*

Ligatures in ophthalmic surgery. See **Sutures in ophthalmic surgery.**

Light. One of the manifestations of radiant energy, being an intense molecular vibration within an all pervading luminiferous ether, which, through its effect upon the organs of sight, renders it, as well as all objects from which it is reflected, visible. According to the undulatory theory *(wave-theory)*, which is now generally accepted, light is a kind of undulatory motion produced by the luminous body in the particles of an elastic, imponderable medium called the luminiferous ether, which is supposed to fill all space, as also the interstices of all bodies. This motion is propagated in waves in all directions from the luminous body, and with a velocity in vacuum of about 186,000 miles per second. The rays sent out differ in wave-length, although apparently propagated with the same velocity; the eye is sensitive to those rays only whose wave-lengths are included between certain narrow limits, namely, those corresponding to red and violet light (see **Spectrum**). The electro-magnetic theory of light proposed by Maxwell, supposes light (or more generally radiant energy) to be an electro-magnetic disturbance propagated by vibrations at right angles to the direction of the ray, and taking place in the same ether, the strains or vibrations of which serve to propagate electro-magnetic induction. In confirmation of this theory, it is found that the experimentally determined velocities of the propagation of light and of electro-magnetic induction are nearly the same. The principal phenomena of light are defined under the following heads, **Absorption**; **Diffraction**; **Dispersion**; **Fluorescence**; **Interference**; **Phosphorescence**; **Reflection**; and **Refraction.**—(C. F. P.)

While light travels in air at about 186,000 miles or 300,000 kilometres per second, the velocity is lessened in denser media, the decrease being roughly proportional to the density, although this is not invariably the case. Thus, in glass, the rate of progression is about one-third less, and in water one-fourth less, than it is in air. In air the speed is slightly less than in space or a vacuum.

Solar light, which is white, is a combination of seven distinct colors —namely, red, orange, yellow, green, blue, indigo, and violet. Some authorities omit indigo and consider the spectrum to consist of six main colors, and some even omit the yellow, which color, indeed, occupies but a small space in the spectrum. The combination of these colors in correct proportion produces white light.

Sunlight is said to consist of about 50 parts red, 30 parts green, and 20 parts violet in 100, and has about 30 per cent. of luminous rays. Artificial light has a higher proportion of heat or red rays, and the proportion of luminous rays is much smaller, varying from 20 per cent. for electricity (arc), 10 per cent. for oils and coal-gas, to one per cent. for alcohol. With the exception of the electric arc and similar sources, artificial light is very deficient in actinic (violet and ultra-violet) light.

When the temperature of a body is raïsed, the increased molecular activity causes a generation of ether waves of certain length and frequency, which constitutes what is termed *radiant heat.* If the temperature is raised still more, the activity is proportionally increased, so that the waves become shorter and the vibrations more rapid. Thus, when the temperature of a body reaches about 500° centigrade, it not only emits the relatively long waves of *heat,* but also the shorter waves of *light;* the difference between the two forms of radiant energy—heat and light—existing solely in the difference in length of the waves. The undulations must be of a certain shortness and rapidity in order to become "light" as distinct from "heat."

Some bodies transmit light and not heat waves, and others the reverse. Bodies which transmit the invisible heat rays without becoming quickly warmed themselves are termed *diathermanous;* those which do not transmit radiant heat without themselves becoming rapidly heated, are termed *athermanous* or adiathermanous.

The longest light waves, i. e. those of least frequency, give rise to the visual sensation of red when the temperature of a body is raised to about 500° C. On further raising the temperature of the body, shorter waves are also produced which, being of different lengths and frequencies, cause the sensation of various colors, varying from red, the longest, to violet, the shortest visible waves. White is a sensation caused by the combined action of all waves ranging between red and violet, and is produced when the temperature reaches about 1000° C.

The existence of what is known as the *infra-red* waves, or those beyond the visible red of the spectrum which are too long, or too slow, to cause vision, may be shown in various ways. Thus a blackened thermometer bulb placed just beyond where the red in the spectrum ceases will show a rise of temperature, proving the existence of heat rays. Again, by employing a lens made of rocksalt, which readily transmits the long heat waves, the latter can be demonstrated when the visible spectrum is cut off.

Similarly the spectrum extends beyond the visible violet end, this portion, called the *ultra-violet,* consisting of waves whose vibrations are too rapid, or whose length is too short, to cause the sensation of sight. The existence of the ultra-violet waves can be proved by placing beyond the visible violet a screen painted with a solution of a fluorescent liquid such as quinine, which fluoresces brightly under the influence of the ultra-violet light. A quartz prism, which is very transparent to the short vibrations, must be used to produce the spectrum.

In addition to the effect on the eye, and the sensation of heat, it is obvious that light waves possess many other properties, especially the chemical actions which occur in photography, bleaching, the generation of carbonic acid, and the formation of chlorophyll necessary for vegetable life, although, for the latter, the heat rays may be equally active or may be more so than the short waves.

Thus it may be said that, in general, the spectrum within certain limits consists of the long infra-red (heat) waves, the luminous or visible portion, and the short ultra-violet actinic (chemical) waves. In addition there are the long Hertzian (electrical) waves beyond the infra-red, and what are supposed to be the X-rays beyond the ultra-violet.

The incandescence of the sun is, of course, the principal source from which light on the earth is derived. Impact, friction, electricity, chemical combination, combustion, in fact anything which causes increased molecular motion also may give rise to light.

In visual optics 20 feet or 6 metres marks the shortest distance from which light is regarded as parallel, and this distance, or any beyond it, is regarded as infinity, which is written thus: ∞. For some branches of optics a much greater distance is taken as the divergence limit. Thus in photographic optics it may amount to 100 yards or more, while in astronomy the nearest ∞ point may be taken as several miles. If d is the angle of divergence, a the aperture of the lens, and S the distance of the source, the angular divergence of light is, with sufficient exactitude, found from $\tan d\ a/S$. For example, suppose the source of light is at 6 M., and the pupil of the eye to be 3.5 mm. in diameter, then the visual angle of divergence will be 2′, since

$$\tan d = \frac{3.5}{6000} = .0006 = \tan 2'.$$

Since a divergence of 2′ is so small as to be negligible, it explains why 6 M. is considered the same as ∞ in this connection. At 20 cm., with the same pupil, the divergence of the light is one degree.

Similarly, therefore, if light is *converging* to a focus a great distance off, it may be considered parallel—for visual purposes—at any distance greater than 6 M. from the focus. Light is never naturally convergent, but can be rendered so by means of a lens or reflector. A collection of convergent rays is also called a *pencil* of light; the apex of the pencil, towards which they are convergent, is the focus.

Light and shadow. CHIAROSCURO. See page 2038, Vol. III, of this *Encyclopedia.*

Light, Audible. See **Optophone.**

Light, Cold. See p. 2320, Vol. IV, of this *Encyclopedia.*

Light daturine. A term applied by Ladenburg to the hyoscyamine obtained from *Datura stramonium.*

Light effects on the eye. This important subject has been discussed under several captions, especially under **Conservation of vision** and **Illumination.** See, also, **Blindness, Snow**; **Dazzling**; **Lightning**; and **Electric ophthalmia.** Some of the evil influences of excessive light upon the eye are also considered under **Arc lights.**

In a discussion of the subject at the International Medical Congress (*British Med. Journ.*, Aug. 23, p. 280, 1913), Carl von Hess remarked that ordinary daylight had no discoverable evil influence on the eyes either healthy or diseased, and the trouble in cases of photophobia in children was not caused by the cornea or iris, but by disorders which in themselves had nothing to do with photophobia. Prolonged exposure to sunlight, on the other hand, brought about conditions well known to occur during the watching of a solar eclipse, and also in the condition known as snow-blindness. The first were produced by the long wave rays, and the latter by the short wave rays, of the spectrum, and they could both be prevented by suitable protecting glasses. The effects produced by lightning and short-circuiting of an electric current were caused chiefly by the ultra-violet rays, and it had been supposed, but not proved, that the same was the cause of glass-blowers' cataract. The fear that injury to the eyes was caused by modern sources of illumination was to a large extent groundless, and any discomfort could always be prevented by suitable shading of the lamps. Glasses for this were unnecessary except in the case of men who were working for hours together in artificial light rich in ultra-violet rays.

J. Herbert Parsons believes that *photophthalmia* is mostly due to undue exposure to sunlight, and one form had been called snow-blindness, but it could also be produced by the electric arc lamps, and, in fact, any light rich in ultra-violet rays. The milder ocular symptoms of a lightning stroke resembled those of short-circuiting, but the severer forms were generally characterized by the formation of a cataract, though these severer injuries were probably caused by concussion or electrolysis. Heat as well as light was probably concerned in the development of glass-blowers' cataract. Many cases of eclipse blindness following the act of gazing at the sun with the naked eye had been seen, and there were always a number of them after every solar eclipse. These cases showed retinitis, and a scotoma when produced was not always recovered from. He mentioned erythropsia or the red vision so frequently seen after cataract extraction or after the exposure of the eyes to snowfields.

Edridge-Green gave a full explanation of erythropsia on his theory of vision which was capable of accounting for the phenomenon. It was a photochemical condition and due to the visual purple. He thought red a most irritating color, and it was for this reason that some totally color-blind people were able to become aware of it.

Bishop Harman called attention to the great change which had taken place in recent years in the general science of illumination. Unprotected arc lamps, metal filament lamps, and high-pressure gas caused great retinal and cerebral fatigue. New lights of great intensity were put into old fittings and shades were used in 100-candle power lights which were designed for those of 8-candle power. It mattered little how intensely an object which was being examined was illuminated, but it was most detrimental for the intense glare from a highly luminous point to strike the eye in an unprotected manner. He thought it should be an offence to display in a public place a naked lamp above 20-candle power or any arc or equivalent lamp nearer than 30 ft. above the footpath.

Priestley Smith discussed the question of photophobia in children, and George Mackay (Edinburgh) said that the acute pain caused by excessive light was muscular. He called attention to the fact that while one person was quite comfortable with a great glare of light, and found it difficult to read with any less, others could not stand anything like so much. He asked if any one had had experience of moon blindness, which was firmly believed in by seamen; he had never seen a case.

G. A. Berry expressed the belief that blepharospasm was due to light falling on a retina in a state of dark adaptability. For protecting glasses he preferred neutral tint to ''euphos'' glass.

Axenfeld (Freiburg) thought that spring catarrh was really due to exposure to air rather than to light, and he adduced evidence in proof of this idea.

Colonel Elliot said that in India cyanopsia followed cataract extraction in about 60 per cent. of the cases, while black cataract was extremely common. After extraction the pigment of the retina was greatly diminished and he suggested the possibility of its having found its way into the lens. Glare photophobia which was so very common in India, was associated with an irritable condition of the conjunctiva at the fornix, and treatment for that, with silver nitrate or similar drugs, cured it. He thought that previous to a solar eclipse notice should be put into the papers warning people not to look at the sun without protecting glasses; damage was frequently caused in India from ignorance of this fact.

Bernard Cridland thought that ironworkers, that was to say those who had to work with the metal at a white heat, were just as liable to cataract as glass-blowers. It should, he suggested, be included among the trade diseases.

Other important articles on this subject will be found in an editorial in the *Jour. Am. Med. Assocn.*, Jan. 25, p. 284, 1913; in an article by Fritz Schanz (*Biochem. Zeitschr.*, p. 406, 1915); J. H. Parsons (*Jour. Am. Med. Assocn.*, p. 2027, 1910) and the various sections under *Lumière* in the *Encyclopédie Française d'Ophtalmologie.*

Light-elasticity. That elasticity of the luminiferous ether upon which the propagation of light-undulations depends.

Light-filter. A device transparent to rays of certain wave-lengths, but opaque to others. A color screen.

Light flux. The flow of light that in one second crosses a given surface.

Light, Homocentric. A term applied by Listing to rays of light that, sufficiently prolonged, meet at one side in the same point; they have a common center.

Light, Incandescent. See **Illumination**; as well as **Light.**

Lighting. See **Lamp**; also, **Illumination** and **Light.**

Light, Lime-. See **Lime-light.**

Light magnesia. See **Magnesia, Calcined.**

Light magnesium oxid. See **Magnesia, Calcined.**

Light, Magnitudes of. The comparative intensity of various lights. See **Arc lights**; as well as **Illumination.**

Light-moderator. A compound color-screen used in microscopy.

Light, Monochromatic. Light of only one wave-length or color. See **Monochromatic.**

Light, Neon. See **Neon light.**

Lightning injuries of the eye. See **Electric ophthalmia**, p. 4226, Vol. VI, of this *Encyclopedia.* In addition to the material there abstracted the reader is referred to the experience of Mahrenholtz (*Zeitschr. für Augenheilk.,* Nov., 1912) who relates the case of a woman, aged 56, who was sitting with her right side next the window, and was suddenly struck by lightning and fell down unconscious. The hair and the eyebrow on the right side were singed, but there were no other injuries on the body. The next day a painful inflammation of the right eye set in and gradually grew worse, but she did not seek medical aid until six weeks later, when von Mahrenholtz found V. R. 0.1, V. L. 1. Right eye exhibited photophobia and pericorneal injection. Pupil narrow; its medial margin, adherent by posterior synechiæ, dilated slightly with atropin. At the medial half of the lens capsule were several yellowish dots. The optic disc was opaque and indistinct. A gray focus, with white margins, one-half of the size of the disc, was seen at the macula; two disc-diameters from the disc toward the temporal side an atrophic portion of the retina, in the form of a slight arc, ran from above downward. It was covered with pigment. The visual field was concentrically contracted, chiefly for red, and two absolute scotomas corresponded to the foci. After three weeks' treatment with atropin and dionin, the iritis subsided, and the synechiæ were torn, but the pupil never dilated beyond medium width. Vision and the changes of the lens and fundus were the same.

The deep alterations of the eye, especially the long chorio-retinic focus, could be due not to thermic, mechanical or glaring actions, but to direct electric influence, electrolytic or catalytic. As the opacities of the lens corresponded almost exactly with the places of the torn synechiæ, the author attributes them to disturbances of circulation, not to cataract by contusion. If they should become total, an extraction does not seem advisable on account of the chorio-retinitic alterations and the preceding iridocyclitis.

Santos Fernandez has reported ocular injuries from lightning. Cataract developed in the right eye of a boy who had been struck unconscious by a lightning flash. A telegraphist approached his apparatus during a thunder-storm; and the right eye was exposed to an intense flash of light during an electrical discharge. Although he did not lose consciousness and did not feel the effect of the current in his body; five days later the lids and conjunctiva of this eye were edematous, the pupil fixed and contracted, the aqueous turbid and the lens cataractous. Light perception was permanently lost. In a third case the history indicated a lightning stroke as the primary cause of a total adherent leukoma.

In Sautter's (*Ophth. Rec.*, XX, p. 238, 1911) case opacities of both lenses supervened several months after exposure to a brilliant light from short-circuiting; the flash had burned the eyelashes and eyebrows. The opacities were made up of a series of fine dots and lines; numerous fine myelin crystals were scattered throughout the lenses.

Grimsdale and James observed opacities in the cortex of both lenses, consisting of fine stippling, six weeks after contact of the head with a live overhead wire. There were extensive burns of the face and a large and deep burn of the sole of the right foot. The opacity in the lenses gradually increased; a year later the right one practically mature was extracted with resulting V.=6/5. Toczyski observed, following a severe stroke of lightning, purulent infiltration of the entire cornea, which terminated by perforation in a shrunken eyeball. The stroke perforated the upper lid, seared the cornea, tarsus and margins of both lids and reached the earth through the left side of the body. The patient was unconscious for twenty-four hours after the shock.

Machek (*Archiv. f. Augenheilk.*, p. 417, 1912) gives an interesting account of a woman, aged 30, who was struck by lightning and was unconscious for 24 hours. Aside from symptoms in the sensory sphere of the left side of the body and a slight burn of the left arm and leg, the left side of the face was burned, and the eyebrows and cilia were singed. A vertical wound had severed the lid borders, the conjunctiva and tarsus from inside, and corresponding to this there was a vertical wound of the cornea. When she came to the clinic the whole cornea showed purulent infiltration, which took a rapid course, ending with perforation. After 26 days the wounds had cicatrized and the eyeball shrunken.

The appearance was that of a gunshot injury. The bolt, after perforating the upper lid, reached the conjunctival sac, severed the cornea, the tarsus and the margins of both lids, injured the left side of the face and traveled through the left side of the body to the earth.

Light perception. In the examination of the eye, when there exists inability to recognize fingers, it will be necessary to find whether light perception, PL, exists. This can be done by taking the patient into a dark-room and throwing a faint light upon the eye by means of an ophthalmoscope or retinoscope. The mirror can be turned so as to illuminate different parts of the retina, and the intensity of the light can be varied. The result of these observations is to be recorded for future comparison. Light perception may be *qualitative or quantitative.* If qualitative, the patient will distinguish between two sheets of paper, one of which is entirely white, the other with printing on it. If quantitative, he will recognize the difference between a dark and a lighted room.—(J. M. B.)

Light, Polarized. See **Polarized light.**

Light pressure. RADIATION PRESSURE. Pressure exerted by light where it falls, and also on the source of light by reaction.

Light ratio. A number, 2,512, used to multiply the light of a star of a given magnitude, so that it may equal the light of a star in brightness one magnitude brighter.

Light reaction. See **Light reflex.**

Light reflex. LIGHT STREAK. In addition to a brief consideration of this ophthalmoscopic appearance on p. 5317, Vol. VII of this *Encyclopedia,* the most exhaustive work on the subject is that of F. Dimmer (*Klin. Monatsbl. f. Augenheilk.*, April, 1907). An excellent abstract of this article with comments thereon appeared in the *Ophthalmic Review* for March, 1908. Dimmer believes that the light streak on the retinal veins is a reflection from the anterior surface of the blood column; while that on the arteries is due to the "axial stream."

Against Loring's theory, which is that the reflex on the retinal arteries is due to refraction of the light from the subjacent fundus by the cylindrical blood column, Dimmer argues that entopic examination shows it to be false, for the vessels are merely dark shadows as so observed. Also Dimmer finds that no such phenomenon is seen when either frogs' or men's blood is observed in capillary tubes immersed in cedar oil. The center of the blood column is, on the contrary, darker than the edges, just as one would *a priori* expect it to be.

Again the microscope shows that the axial stream is a central portion of the current where the corpuscles are closely packed in an almost optically homogeneous mass, while around this axial stream there is a hollow cylinder of less densely packed corpuscles, where they can be seen rolling over each other. With both transmitted and reflected light the central stream can be seen through the thin outer cylinder, and with reflected light the outer region of the vessel shows the well-known dark lines owing to the larger amount of the outer cylinder there present to absorb light. A similar explanation holds for the appearance of the axial stream in transmitted light.

The absence of a definite smooth surface to this axial stream prevents its reflecting light itself as a thin streak, such as is seen in the retinal veins.

Dimmer has occasionally observed that the arterial light streak is displaced from the center towards the side of the vessel when pulsation is produced by pressure. This phenomenon, he affirms, can only be accounted for if the streak is due to the axial stream. No reflex from the vessel wall or from the blood column could behave in such a manner.

The most striking of all these observations is that often a doubling of the arterial light streak may be seen during pulsation. This doubling occurs in the trunk of the artery immediately before bifurcation, and is obviously due to the regurgitant axial streams from the two branches not promptly fusing when the blood flows back into the collapsed trunk of the artery.

Some additional light is thrown on the subject by observations on pathological eyes, viz., leucemic eyes. Grunert has described a visible blood stream in a leucemic eye which suffered from "choked disc." The movement of the blood stream was visible in the larger veins, and the explanation given by Grunert is that the slow current and the enormous amount of large and slowly moving leucocytes made the observation possible.

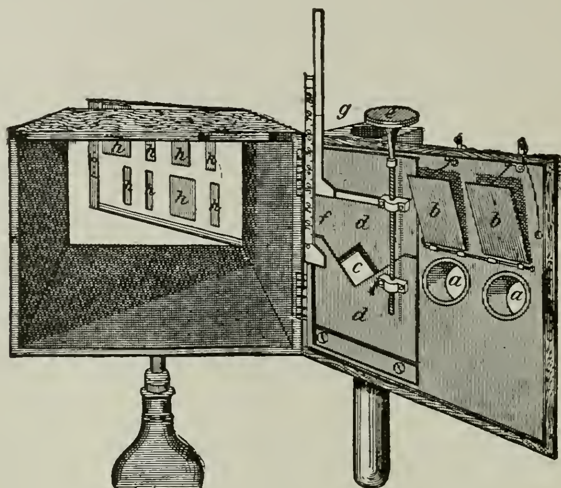
Dimmer has seen in leucemia light streaks on veins as large as those on the arteries, viz., about one-third the diameter of the blood column. On pressure the venous blood column contracted, and a white streak appeared at each side. These white streaks coalesced on further pressure, leaving then one broad white streak, which was narrower than the blood column before application of pressure. In the more peripheral portions of the vein the light streak was broken up into white specks which moved centripetally towards the disc, just what is seen in the frog's eye in retardation of the circulation. Dimmer believes that these cases prove that in leucemia we may, owing to the pallor of the blood, occasionally observe the axial stream in veins as well as in arteries. In another leucemic eye Dimmer was able to observe a distinct doubling of the light streak in the trunk of a vein during application of pressure.

Whether Dimmer's conclusions are to be accepted unreservedly or not the following were, in the reviewer's opinion, beyond question:— The arterial light streak is larger than the venous. It is red in color, while that on the veins is white. The arterial streak is continuous, the venous interrupted. Normal human blood cannot be described as otherwise than opaque, even in the arteries. Its opacity is manifest in the purely dark shadows seen in entopic examination. Therefore the blood-vessels containing normal blood cannot act as cylindrical lenses as stated by Loring. If they did the image formed would be red. In the veins the light streak is white, therefore it is not due to refraction. Of course, refraction might cause the red arterial streak, but if so it should be absent on arteries passing over pigment masses, and be brighter on arteries passing over white backgrounds, and this most observers deny.

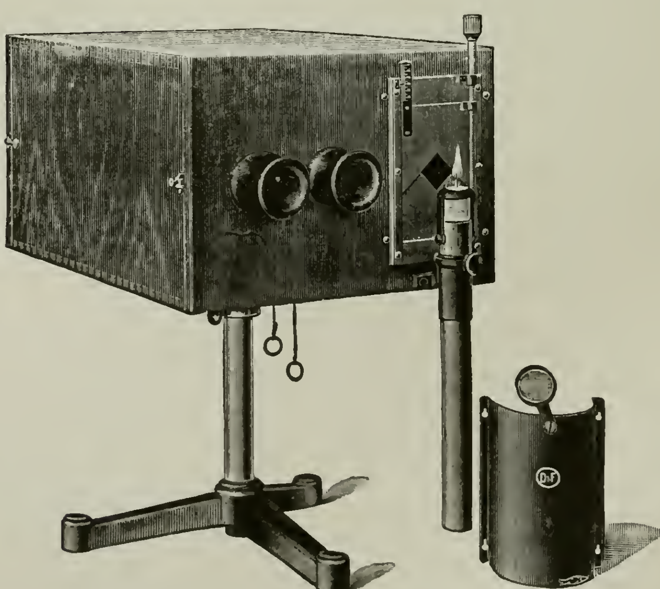
It must be admitted that some reflex may come from the vascular walls both of veins and arteries, for the larger vessels at any rate have walls which can be seen with the ophthalmoscope, and some reflex should be obtained in eyes with "perivasculitis." But having admitted so much we must attribute to the blood column the chief part of the venous light streak. As regards the arteries, it will be necessary to adopt Dimmer's axial stream theory if further observations establish the accuracy of the statement that under certain conditions a distinct duplication of the light streak can be obtained.

Light sense. This term relates to the capacity of the visual apparatus to appreciate variations in the intensity of light. The testing of the light-sense was at one time regarded as a scientific curiosity, but of late years it has come to occupy a practical place in ophthalmic examination. By the light-sense is meant the ability of the eye to distinguish different intensities of light. Two persons may have equal acuteness of vision,—i. e., equal space-sense,—and yet under feeble illumination one will not discern Snellen's letters, while the other will read them. In this case the persons have a different appreciation of brightness: i. e., the light-sense is different in the two. Instruments for the purpose of comparing the intensity of one light to another, which is taken as a standard, are called photometers. In the practical application of photometry it is the sense of stimulation, not the sense of contrast, which is measured: i. e., the power to distinguish the effect produced by the smallest possible quantity of light where the surroundings are dark. Since daylight is an uncertain quantity, photometers are constructed in such a way that the illumination is produced by a normal candle (one of one-candle power). The instruments of most widely accepted use are those of Förster and Henry. In the use of either it is necessary first for the patient to sit in a dark-room with bandaged eyes for ten minutes before-hand, in order that the retinæ may become adapted to darkness.

Förster's photometer (see the plates) is a box measuring 1/3 metre by 1/4 metre by 1/6 metre. It is blackened inside, and provided with two apertures for the eyes to be tested. A window for the admission of light from a candle placed in a separate compartment, and black test-marks on a white ground, complete the apparatus. The test consists in finding the smallest apertures admitting the candle's rays which will permit the recognition of the test-letters. The size of



Förster's Photometer. (Fick.)
The instrument is here shown with the doors open. When in use they are closed.



Light Sense Measurer or Photometer of Förster.

the aperture is recorded on a scale marked in millimetres. Should one eye see the test with an aperture of 1 square millimetre, and a second eye see it only when the aperture is enlarged to 4 square millimetres, the second eye possesses functional power four times greater and a light-sense four times smaller than that of the first eye.

The Henry photometer consists of a box provided with an aperture, a candle, and nine discs of opal. After the preliminary bandaging of the eyes, the eye not under examination being covered, and the head enveloped in the hood, "the opal discs are, one by one, removed, and the patient is told to say when he detects any light; should he detect it through seven opals his light-perceptive power is registered at 7; if through six, five, or four, etc., 6, 5, or 4 is entered; a note is also made of the sex and age of the patient, and the condition of the fundus."

The light-sense is diminished in many cases of general disease in which the blood is in a vitiated condition. It is often diminished in choroidal, retinal, and optic-nerve diseases.—(J. M. B.)

A practical *light-sense apparatus* has more recently been invented by R. H. Elliot and manufactured by Spiller, 32 Wigmore St., Cavendish Square, London W. See, also, **Discs, Photometric,** p. 4032, Vol. VI, of this *Encyclopedia.*

Light-source. Any object from which light proceeds.

Light-streak. See **Light-reflex.**

Light-struck. Fogged (photographically).

Light, Theories of. See **Light.**

Light, Transmitted. See **Light.**

Light treatment. Light therapy. See **Phototherapy**; **Blue Light**; and **Heliotherapy.**

Light-vector. A line indicating the direction and intensity of a ray of light.

Light, Velocity of. See **Light.**

Light-wave. Etherial undulations to whose action on the eye the sense of sight is due. See **Light.**

Light-year. The space traversed in one year by a ray of light, which in air travels at the rate of about 186,600 miles per second. It is employed as a unit in stating the distances of the stars; for example, the pole star is distant 45 *light-years* from the earth, Capella 71 *light-years,* and Vega 23 *light-years.*

Ligne droite. (F.) Straight line.

Lignières test. A skin reaction for tuberculin.

Lignum Guajaci. See p. 5654, Vol. VII, of this *Encyclopedia.*

Lily. *Hemerocallis flava.* The leaves of the lily, in ancient Greco-

Roman times, were employed as a local application for ocular phlegmon.—(T. H. S.)

Limb. The edge of a graduated circle.

Limbal puncture. See p. 5515, Vol. VII, of this *Encyclopedia.*

Limbus corneæ. LIMBUS CONJUNCTIVÆ. CILIARY ZONE OR REGION. CORNEOSCLERAL MARGIN. SCLEROCORNEAL JUNCTION. The apparent union of those histologically similar eye-coats, the sclerotic and cornea, constitutes a fairly well-defined seat of growths and other pathological changes of much interest to the ophthalmologist. See **Anatomy of the eye**; as well as p. 3523, Vol. V of this *Encyclopedia.*

Limbus luteus. Macula lutea.

Limbus palpebralis anterior. The anterior or outer edge of the margin of the eyelid.

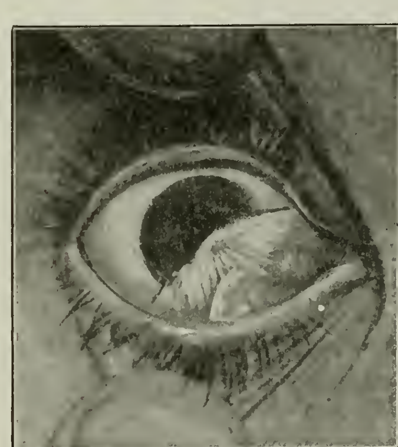
Limbus palpebralis posterior. The posterior or inner portion of the margin of the eyelid, which is so placed as to form in connection with the limbus palpebralis posterior of the other eyelid and the anterior surface of the eyeball, when the lids are closed, a triangular canal for the passage of tears.

Lime burns of the eye. An account of these serious accidents will be found on p. 6216, Vol. VIII of this *Encyclopedia.* A practical discussion of the same subject has been introduced by W. W. Watson (*Annals of Ophthalm.*, p. 649, July, 1912) who describes a lime burn of the left eye, involving both cul-de-sacs. The severity of the burn was marked in the first forty-eight hours, but by rigid applications of hot compresses, atropin, boric acid wash and iodoform ointment, and daily separation of the lids from the globe, deep ulceration was avoided, and in three weeks the patient was discharged from the hospital with entire absence of symblepharon and only a slight haziness of the cornea. The writer points out that the severity of the conjunctival involvement depends on the amount of lime imbedded, its early removal and neutralization. Adhesions of the lids and globe are prevented by frequent manipulations of the former, by irrigation of the sac with permanganate solution, by introducing a mixture of carbolic acid and olive oil or iodoform ointment, and by the separation of the surfaces with eggskin, as suggested by Coover and Black.

Deep ulcers of the cornea may give rise to staphyloma, corneal fistula, iris adherens, or panophthalmitis. The opacities of the cornea were thought by Watson to be due to an irregular infiltration of the substantia propria with the lime salts, and not to scar tissue. Though showing little tendency to clear up, these opacities may be somewhat relieved by the application of a 10 per cent. solution of neutral ammonium bitartrate, especially if this be applied early.

Zentmayer holds, regarding the prognosis, that with the separation of the slough the ulcer does not always go on to cicatrization. Frequently there was a deep burn of the sclera adjacent to the corneal lesion which so delays reparation of the corneal tissue that perforation takes place. He had years ago been led into giving a favorable prognosis because of the cleansing of the burned surface, in which perforation subsequently occurred; and once in consultation had been obliged to revise the prognosis given by the surgeon in charge, because of oversight of this danger.

Posey does not believe it possible to prevent symblepharon by the interposition of a protective material between the lid and the globe. The prognosis in this class of cases should always be most guarded,



Traumatic Pterygium Following Lime Burn. (Würdemann.)

and particularly caution against giving an opinion by the appearance of the eye during the first forty-eight hours following the burn, as in most cases violent reaction did not set in until later.

Burton Chance separates the lids from the globe as widely as possible, and instructs the patient to rotate the globe. At each dressing he gently but firmly massages the cul-de-sac with ointments on a cotton carrier. In is his belief that numerous cases have been benefited by this procedure and that impending adhesion has been prevented. In certain instances he has used thin lead plates conforming to the conjunctival sac, but he is prejudiced against them, as he believes they act as irritating foreign masses and excite rather than arrest exudation, whereby the resultant contraction is greater than one can afford.

Lime incrustations of the cornea. These are usually the result of mortar or slacking lime entering the eye, which produce a permanent corneal opacity, due to a deposit of calcium carbonate particles. Calcareous opacities show no tendencies to clear up. The experiments of H. Guillery determined that corneal opacities, due to deposits of calcium albuminate are soluble in ammonia chloride, to a 10 per cent. solution of which is added 0.02 to 0.1 per cent. tartaric acid. Cocaine is first instilled into the eye to obviate the burning sensation and it also renders the ammonium tartrate more effective by its loosening effect upon the corneal epithelium. The solution is used in an eye bath (which acts in about three-quarters of an hour), beginning with a 2 per cent. solution which is increased to 10 or even to 20 per cent. strength. This method is followed by considerable absorption and improvement in vision.

Lime-light. Oxyhydrogen light. Calcium light. This brilliant light is produced by a blowpipe-flame directed against a block of pure, compressed quicklime. The lime, which ought to be warmed beforehand, becomes brilliantly incandescent. The blowpipe-flame may be produced in various ways: (1) blowing oxygen through a spirit flame—light obtained, about 150 candles; (2) oxygen under pressure, and coal-gas from the mains, brought in concentric tubes to a nozzle, where the mixture is burned in a fine jet—light, about 200 candles; (3) oxygen and coal-gas, both under pressure—light, about 400 candles; (4) the same, the coal-gas or the oxygen saturated with benzoline or ether, or both benzoline and ether—light, up to 800 candles when both are employed; (5) warm oxygen, saturated with benzoline, gives light up to 1,350 candles; (6) oxygen and hydrogen, up to about 800 candles.—(*Standard Encyclopedia.*)

Lime liniment. See **Carron oil.**

Lime permanganate. Calcii permanganas. Calcium permanganate. A violet-colored, crystalline substance, soluble in water. It is said to be 100 times more powerful than the potassium salt and more valuable than mercuric chloride as a germicide. Kalt, who has had much experience with the use of large volumes of irrigating fluids in infections of the eye, considers this salt to be a very valuable disinfectant and advises its use—1 gramme to 3 litres of water at 25° C. One eye to be irrigated with this solution from two to four times daily, alternating, if need be, with irrigations of warm, sterile water.

Lime water. Aqua calcis. Liquor calcis, U. S. Aqua calcaria P. G. A saturated, aqueous solution (0.14 per cent.) of calcium hydroxide.

About the only use to which this solution is put in ophthalmic therapy is in the manufacture of cold cream, in making "black wash" and for other subsidiary purposes.

Limitans. The limiting membrane of the retina.

Limitation, Eccentric. A circumscribed condition of the visual field, more pronounced at some parts of the periphery than at others.

Limitrophes. The sympathetic ganglia and their connections.

Linadin. A patented dry extract of the spleen of animals, combined with iodin and iron: used for malarial cachexia, splenomegaly, and leukemia.

Lincke, Karl Gustav. A celebrated German otologist, of some importance ophthalmologically. Born at Kosmin, in the province of Posen, in 1804, he received his medical degree at Leipsic in 1828, presenting as dissertation "De Fungo Medullari Oculi," Part I. In 1834, he published at Leipsic a remarkably excellent amplification of his graduation thesis under the title "Tractatus de Fungo Med. Oculi," which Hirschberg calls "das erste in Deutschland erschienen Werk, welches die krankhaften Geschwülste des Sehorgans einigermassen befriedigend dargestellt hat."

Lincke died at Liepsic, Sept. 13, 1849.—(T. H. S.)

Linear extraction. See p. 1613, Vol. III, of this *Encyclopedia.*

Linear magnification. See **Magnification.**

Line, Base-apex. A line perpendicular to the edge of a prism and bisecting the refracting angle of the prism.

Line, Ehrlich's. A name given by Türk to the coloration of the anterior chamber after hypodermic injection of fluorescein for the determination of the course of the aqueous in the anterior chamber; also in connection with the fluorescein test of death. See p. 5229, Vol. VII of this *Encyclopedia.*

Line, Helmholtz's. A line perpendicular to the plane of the axis of rotation of the eyes.

Line, Focal, Posterior. A line whose direction is perpendicular to that of the meridian of least curvature of a refracting surface.

Line, Nasolabial. The furrow extending from the ali nasi to the angle of the mouth.

Linen-prover. A small microscope for determining the coarseness of texture in linen.

Line of accommodation. Czermak's term for that portion of the visual line in which lie objects which are seen without any perceptible indistinctness, and with a given state or degree of accommodation. See p. 51, Vol. I of this *Encyclopedia.*

Line of collimation. See **Collimation.**

Line of direction. See **Muscles, Ocular,** in the first part of the section.

Line of fixation. An imaginary line, drawn from the object, viewed through the center of rotation of the eye.

Line of regard. Line of fixation.

Line of sight. An imaginary line drawn from an object viewed through the center of the pupil.

Lines, Atrope. See **Atrope lines**; p. 666, Vol. I, of this *Encyclopedia.*

Lines, Chiene's. A set of lines established to aid in localizing the cerebral centers.

Lines, Focal. See p. 5234, Vol. VII, of this *Encyclopedia.*

Lines, Fraunhofer's. Dark lines of the solar spectrum. See **Light**; as well as **Spectrum.**

Lines, Neutral. The optic axes of a crystal.

Lines of Helmholtz. Lines normal to the plane of the axes of rotation of the eye.

Line spectrum. A spectrum consisting of a number of sharply defined lines which may possess a certain obvious regularity of arrangement, or may be scattered, seemingly without any order over the range of the spectrum.

Line, Three-level. In alphabets and print for the blind (q. v.), this is the plan in which dots appear on three lines, upper, lower and middle.

Line, Two-level. In alphabets and print for the blind (q. v.), this is the plan in which all the dots are on an upper and a lower line, as in New York point.

Line-type. The ordinary Roman letters enlarged and made palpable to the touch of the blind. See **Alphabets for the blind.**

Line, Visual. A line from the object seen, through the nodal point of the eye, to the macula lutea.

Linhart, Wenzel von. A well-known German surgeon, of some importance in ophthalmology. Born June 6, 1821, at Seelowitz, in Moravia, the son of a surgeon of much local reputation, he received his medical degree in 1844 at Vienna, and then proceeded to study operative surgery with von Wattmann. For a time he taught surgical anatomy and operative surgery in Vienna, and in 1852 qualified as privatdocent in the University. In 1856 he removed to Würzburg, in order to accept the chair of clinical surgery in the University at that place. While here it was that he lectured on the eye, and also gave a number of practical courses in ophthalmic surgery. None of his writings, however, fall within our special field of work. His masterpiece was "*Compendium der Chirurg. Operations-Lehre*" (1856, 4th ed., 1874). He died of lingual cancer, Oct. 22, 1877.—(T. H. S.)

Liniment of conicine. A preparation prescribed by Mauthner. It contains 1 drop of conicine, and 4 grammes of sweet-almond oil. It is applied with a brush to the eyelids in cases of spasmodic contraction in phlyctenular diseases.

Linimentum calcis, U. S. See **Carron oil.**

Links. (G.) On or toward the left.

Linkshirnig. (G.) Left-brained.

Linse. (G.) Lens.

Linseed. Flaxseed. The seeds of flax. *Linum usitatissimum.* They are demulcent and emollient. The seed affords a fixed drying-oil (*oleum lini*), and the residue left after the removal of the oil is used in preparing poultices.

A flax-seed is commonly used by the laity for the removal of foreign bodies from the conjunctival sac. Introduced into the eye it soon becomes softened, moves about and may occasionally dislodge a cinder or other *corpus alienum.*

Lint. An absorbent dressing-material made by scraping or picking apart old woven linen; also a specially finished woven fabric for surgical dressing.

Lintin. A loose fabric of prepared absorbent cotton: used in dressing wounds.

Lion, The. The gall of the lion, diluted with water and well rubbed into the eyes, was an ancient Greco-Roman remedy for "dimness of sight."—(T. H. S.)

Lipæmia. See **Lipemia.**

Liparis monacha. One of the numerous caterpillars whose hairs produce ophthalmia nodosa (q. v.).

Liparolé de belladone. (F.) Unguentum belladonnæ.

Lipemia. See **Lipemia retinalis.**

Lipemia retinalis. A condition whose ophthalmoscopic view, first described by Heyl in 1880, is characterized by a light salmon color of the blood contained in the retinal vessels, by the increased diameter of these vessels, and sometimes by the very light color of the fundus oculi, these appearances being due to the presence of fat in an abnormal amount in the serum of the blood.

Ernest Thomson gives an abstract of a paper by R. Foster Moore (*The Lancet*, p. 366, Feb. 20, 1915) in which the ocular manifestations of this rare and curious disease (in two cases) are fully described. The abnormal features of the first case were entirely limited to the appearance of the retinal vessels. These were of a salmon color on the disc and for a short distance beyond, but when traced towards the periphery, the color became much less saturated, and gradually merged into a cream color with almost no pink tinge. The color of the arteries and veins did not differ at all. In the center of the disc a faint central light streak was seen on the arteries, and by this means, but by no other, could the arteries be distinguished from the veins; towards the periphery both sets of vessels were identical in appearance. Both arteries and veins were well filled, perhaps a little abnormally so, but there was no turgidity or obvious distension. The general tint of the fundus was rather pale. The optic disc was normal in appearance, its edges were perfectly sharp and clear-cut, and there were neither hemorrhages nor exudates anywhere to be seen.

In the second case the appearances were similar, except that the vessels, both arteries and veins, were markedly distended and tortuous.

Lipemia is described as occurring, the author says, in chronic alcoholism, phthisis, asphyxia, nephritis, phosphorus poisoning, pneumonia, peritonitis, gout, starvation, and diabetes. He has been unable to discover any reported case of lipemia retinalis except associated with diabetes. Both the present cases were diabetics, and the retinal condition appeared shortly before death. The author discusses the cause of the peculiar appearance of the retinal vessels. He holds that this is not due to any chemico-physical change in the hemoglobin, but to the opacity of the plasma. The fact is the retinal vessels come to resemble the *normal* choroidal vessels as seen with the ophthalmoscope. They become ribbon-like, lose the light streaks, and appear pink. The reason the choroidal vessels have this appearance is that the light has to be transmitted from them through the retina. When the central axial stream of the retinal vessels is surrounded by a plasma which, on separating, has the appearance of cream, the effect of a ground-glass instead of a transparent envelope is produced. The great diffusion of light through this envelope results in the retinal vessels having an appearance similar to those of the choroid as seen through the retina.

Although it has been suggested by Heyl that there is a certain similarity between leukemic retinitis and lipemia retinalis, Moore does not think they can be confused. The color is different. In leukemic retinitis there is distension of the veins more than of the arteries, and there are hemorrhages.

Some other conclusions come to by Moore are as follows: Lipemia retinalis occurs in young diabetics who are usually bordering on coma, and it consequently implies an immediately grave prognosis, but recovery from the condition may occur. It implies a high degree of lipemia and it is probable that in no condition other than diabetes does lipemia attain a sufficiently high degree to give rise to the appearances of lipemia retinalis. Vision may remain unaffected in spite of a very high degree of lipemia retinalis. The ophthalmoscopic picture of the condition is so striking and characteristic that it cannot be overlooked nor mistaken for any other condition.

C. G. Darling (*Archives of Ophthalm.*, p. 355, July, 1912) has also described a case of lipemia of the retina occurring in a male aged 48 years who had a severe diabetes. The fundus was of normal color, normal retina (no hemorrhages), optic disks clearly outlined, vessels not tortuous, moderately dilated, and looking like waxy, light pink lines on a red back ground of normal color.

Lipochrin. A pigment from the retinal fat-globules.

Lipoidemia. The presence of lipoids in the blood.

Lipoiodin. A new (proprietary) iodine compound recommended by A. Dutoit (*La Clin. Ophtalmol.*, April 10, 1914) in the treatment of optic neuritis. He claims the temporary fixation of the iodine in fatty and nervous tissues, and the consequent advantages of the preparation. Lipoiodine is an ethylic ether of a bi-iodised non-saturated higher fatty acid known (in French) as *acide biiodobrassidique.* Its formula is $C_{19}\ H_{39}\ CI{=}CI{-}COOC_2\ H_5$.

Lime, Chlorinated. BLEACHING POWDER. CHLORIDE OF LIME. CALCIUM HYPOCHLORITE. A variable compound of calcium chloride and calcium hypochlorite with water that should yield not less than 35 per cent. of chlorine. It is a deliquescent, white powder with an unpleasant odor and taste. It is partly soluble in water and is sometimes employed, like chlorine water, in eye diseases as a disinfectant collyrium in 4 per cent. solution. As a compress (15 to 30 parts in 1000) it is occasionally prescribed.

For the formula of the important *Dakin's solution*, so widely and successfully used to irrigate and disinfect wounds of the eye and other organs and parts, see **Military surgery of the eye.**

Lines, Zöllner's. In optics, if three parallel horizontal lines be drawn one centimeter apart, and through the upper and lower ones short, oblique, parallel lines in the direction from above and the left are also drawn to below and the right; and through the middle line similar oblique lines are drawn but in the opposite direction; then the three original horizontal lines no longer appear parallel, but some appear to converge and others to diverge.

Lipodermoid, Ocular. DERMO-LIPOMA. This rather unusual form of tumor is generally found in the same situation as the dermoid, at the outer margin of the cornea, or farther out, between the insertions of the external and superior recti. It is a congenital growth, and was first described as an ordinary lipoma, the earliest being recorded by Kranke, in 1854. It owes its origin, according to Van Duyse, to a circumscribed adhesion between the amnion and the surface of the eyeball, which before the fourth month is not covered by the lids. The tumors are yellowish, about the size of a pea or bean; microscopically they consist of fatty tissue with irregular strands of fibrous tissue, and, as more recent investigations show, elements of skin, as in ordinary dermoids. The tumors are often unnoticed owing to their position under the lids until towards the time of puberty, when they may increase in size. At this time it is usually desirable to remove them because of the disfigurement they produce, or because of irritation from the long hairs growing from them. The complete removal renders a relapse impossible. Stoll (*Amer. Jour. of Ophthal.*, Jan. 1913), describes a case of double multiple lipodermoids of the conjunctiva and cornea, accompanied by intrabulbar and other anomalies. The operative technique is illustrated by sketches and many references to the literature of this condition are given. Tyson (*Arch. of Ophth.*, Vol. 42, p. 178, 1913) reported the case of a double-lobed lipodermoid on the eyeball, overlying the external rectus. It was removed for cosmetic reasons. By far the larger number of reported cases have occurred in females. See, also **Tumors of the eye**; as well as p. 3844, Vol. V of this *Encyclopedia*.

Lipoids, Ocular. Lipoid is a name given to a fat-like substance which, while like true fat in some respects, differs from it in certain physical and chemical properties. Among these is the fact that when examined with the polarization microscope it is found to be doubly refractive, while with osmium it assumes a gray color and only becomes black when treated with alcohol; it loses this black color in xylol or chloroform, and being easily soluble in ether and alcohol it is impossible to find it in sections obtained after imbedding in celloidin or paraffin. This necessitates the employment of fresh material or of eyes previously prepared exclusively in formalin.

Within the last few years certain fat-like substances have been found in the kidney only in cases of nephritis, and Lauber and Adamük (v. Graefe's *Arch. f. Ophthal.*, 71, 3), have made investigations to determine whether a similar deposit occurs in the retina, simultaneously with ordinary fat, in albuminuric retinitis.

In a series of 13 cases of albuminuric retinitis which the authors collected and submitted to a most thorough and careful examination they were able in four to look for the presence of lipoid in fresh frozen sections. It is unnecessary to describe these cases or the methods of examination in detail here, but a short summary of the general results obtained may be given.

Detachment of the retina is a very common complication. The small detachments were not seen clinically, because they were flat and with the thickening and opacity of the retina they looked more like edematous areas. They were all the result of an exudation which, sometimes serous, sometimes fibrinous in character, was in most cases derived from the choroid, although, where the internal limiting membrane was detached, or the outer limbs of the rods and cones were found separated from the rest of the retinal elements, the exudation must have arisen in the retina itself.

As to the rôle which the vascular changes found in this disease are supposed to play in its causation, they vary so much in degree that the authors consider it extremely doubtful that they are really the cause of the conditions in the retina. It is possible that while they may at times be of great significance in the development of albuminuric retinitis they are often merely a symptom of an intoxication due to the alteration in the composition of the blood and a result of the renal disease.

According to Leber the pigment epithelium cells play a very important part in the production of the histological picture of albuminuric retinitis by taking up fat, losing more or less of their pigment and appearing as fatty cells which wander into the retina. Lauber and Adamük, however, were unable to confirm this in their cases. As regards the absorption of fat-droplets by the pigment epithelium cells this was observed in only one case to a very limited extent; the changes they found more or less pronounced in all their cases consisted either of a proliferation or a destruction or even disappearance of these cells; they found no trace of fuscin pigment in the fat-containing cells in the retina. It is of interest to note the changes in the retina corresponding to the white spots of the clinical picture. These spots may be accounted for by the ganglion-like degeneration of the nerve fiber layer, the presence of fibrin, the deposit of fat or fat-like material, either separately or together. The fatty substances may be found in any of the layers of the retina. The fat may lie free, or it may be contained in the supporting fibers or in "fatty granular" cells. While these fat-containing cells, however, may not be in sufficient numbers to explain the white spots seen clinically it should not be forgotten that many substances that appear white ophthalmoscopically may be removed in the preparation of celloidin sections (*e. g.*, lipoid). In the cases which the authors were able to examine for lipoid by their special method they found it in sufficiently great quantity to account for the ophthalmoscopic appearances. In every case it showed the same position and properties above referred to, and as it corresponded in amount to the parts of the retina clinically most affected its presence must possess considerable significance in albuminuric retinitis. It remains to find out the origin of this substance and to prove whether, as the authors are inclined to think, it is a specific product of this form of retinitis as it seems to be in the kidney in nephritis, occurring simultaneously with lipoid there.

In opposition to the foregoing theory, however, Ginsberg (v. Graefe's *Arch. f. Ophth.*, Vol. 82, part 1; reviewed by Story, see *Ophthalmic Review*, p. 273, Sept., 1912), has demonstrated the presence of this substance in a wide range of pathological conditions not only in the retina but in other parts of the eye. He has found it too in various situations in the normal eye, and refers to its occurrence in other tissues throughout the body both in health and disease. The deposition of lipoid is therefore not peculiar to this special form of retinitis. The significance of its formation is not clear, but it at least points to a disturbance in the metabolism of the cell, a change, however, that does not necessarily lead to its destruction.

In reviewing the various histological appearances found in a series of 15 cases of albuminuric retinitis, all presenting an advanced stage of the disease, Ginsberg draws attention to the entire absence, or quite insignificant amount, of pathological change in the retinal vessels, as well as to the lack of signs of any disturbance in the circulation (thrombosis, etc.), such as Leber observed. The pathological conditions which the retina invariably presents consist of edema, sero-fibrinous exudates, and the deposition of lipoid: hemorrhages and clumps of varicose nerve fibres were often met with, but rarely retinal pigment.

While regarding the exudates and the clumps of varicose nerve fibers as mainly responsible for the white spots of the ophthalmoscopic picture the author is unable to determine from his own cases how far the lipoid both in and outside the cells plays a part in their formation, although in places the lipoid cells were so numerous as to lead him to believe that they did sometimes form the anatomical basis of these spots.

The pathological substance found in the retina is for the most part anisotropic lipoid, usually combined with only a very small amount of neutral fat. It is present particularly in the protoplasm of all the various cells in the retina, also in Müller's fibers, and not infrequently between the retinal elements and among the fibers in the foci of varicose nerve fibers. As to the exact mode of production of the extracellular part the writer is unable to decide. There is, however, certain proof that the cells in which the lipoid droplets appear are constituent parts of the retina itself: in his cases pigment was found there only in traces and in exceptional cases. On this point he agrees with Lauber and Adamiik but differs from Leber who was of opinion that the fat-cells came from pigment epithelium cells that had wandered into the retina and taken up "fat" from the blood. Ginsberg will not admit that the large granular cells within the retina are identical with retinal pigment cells found in the subretinal exudate, because such cells may be derived from various sources, e. g., from glia cells: but from appearances presented by one of his cases and shown in an illustration he suggests the possibility that the cells in the subretinal exudate may be neuroepithelium that through the increase in thickness of the retina has been pressed into the subretinal space and there taken up lipoid, and hence may resemble retinal epithelium that has lost its pigment.

Changes in the blood vessels of the choroid have been emphasized by various authors but differently described. Ginsberg recognizes that the conditions may vary very greatly, but while admitting that in a small proportion of his cases the changes in the choroidal arteries may seem secondary to those in the veins and capillaries he is convinced from the others that the arteries may become primarily diseased, i. e., independently of any preceding disturbance in the capillaries and veins. The most pronounced change in the arteries was found in the intima—in the form of hyaline thickening, not a fibrinous infiltration as described by Leber: or the intima was replaced by a meshwork of new-formed tissue which may be converted into a hyaline mass, lipoid being often found either in this mass or as fine drops in the endothelium. The changes in the choroidal vessels cannot be regarded as part of a general ocular angiosclerosis. The character of the changes in the intima of the arteries accords well with the old theory of a toxic substance arising probably in the kidneys and producing the changes found in the eye, a theory of the pathogenesis of albuminuric retinitis which, in the author's opinion, it is not yet possible to discard.

Lipoma of the ocular apparatus. This variety of benign tumor is not of frequent occurrence about the eye. In the orbit the large amount of normal fat makes it difficult at times to be absolutely certain as to the exact condition. On the other hand, the skin of the lids is peculiar in having no adipose tissue; hence lipomata of the lid are probably always secondary extensions from the orbit. See **Tumors of the eye.**

Subconjunctival lipoma. This congenital benign tumor may be single or multiple. It has a yellowish appearance, is covered by conjunctiva and is movable upon the eyeball. The size of the tumor is usually between one and two centimeters in breadth. These tumors do not return after removal. See, also, **Tumors of the eye.**

Lipoma of the iris. This neoplasm is of rare occurrence in this situation. Mooren reported a case in a ten-year-old girl, the size of a large pea, which had developed in the outer segment of the iris.

Lipoma of the eyelids. See p. 5014, Vol. VII of this *Encyclopedia.*

Lipoma of the eye muscles, especially of the tendinous sheath, has been reported by a number of observers, including the Editor.

Lipoma of the orbit. Although the orbit contains a large amount of fat, lipomata arising actually within the orbit are exceedingly rare. These tumors are encapsulated, frequently lobulated, sometimes congenital. They are benign and grow slowly. In some instances they are symmetrical, sometimes multiple. Certain varieties, *lipomata telangiectodes,* are very vascular, and some, *lipomata cavernosa,* contain blood channels. See, also, **Tumors of the eye.**

Lipomata cavernosa. See *Lipoma of the orbit.*

Lipomata telangiectodes. See *Lipoma of the orbit.*

Liposarcoma. Sarcoma containing fatty elements.

Lipp, Eduard. A well-known Austrian dermatologist, and, to a certain extent, ophthalmologist. Born Feb. 20, 1831, at Wundschuh, near Leibnitz, Steiermark, the son of a surgeon, he received the degree of M. D. at the University of Vienna. After a brief period of service as assistant physician in the Wiedener hospital at Vienna, he became, in 1861, chief physician to the General Hospital in Gratz. Four years later he was privatdocent for dermatology and syphilis at Gratz. Though ill at the time, he was president of the German Dermatologic Society, at its third assembly, in Leipsic, 1891. He died of carcinoma of the esophagus, Dec. 30, 1891.

His chief ophthalmologic article was entitled "Ueber Pemphigus Vegetans und Pemphigus Conjunctivæ" (1891).—(T. H. S.)

Lippincott's test. A device for exposing the ocular malingerer by means of cylindrical glasses. See p. 1184, Vol. II of this *Encyclopedia.*

Lippitudo. Blear eye. The appearance caused by exposure to the air, dust, etc., of the marginal conjunctiva together with the loss of the cilia.

Lippitudo angularis. (Obs.) A chronic marginal blepharitis at the external canthus.

Lippitudo neonatorum. (Obs.) Ophthalmia neonatorum.

Lippitudo pruriginosa. Psorophthalmia. An old name for a violent form of blepharitis simplex, in which pustules form on the edge of the lid, and at the mouths of the hair follicles. The crusts are continuous and, when removed, leave a raw and bleeding surface with ulcerated spots.

Lippitudo senilis. A form of blear-eye supposed to be peculiar to old age.

Lippus. (L.) Blear-eyed; a blear-eyed person.

Liqueur de Van Swieten. (F.) An alcoholic solution of perchloride of mercury.

Liquid prism. WATER PRISM. In this form the interior is filled with distilled water in a glass container having a prismatic form.

Liquor antisepticus alkalinus. See **Dobell's solution.**

Liquor argentamini. See **Argentamine.**

Liquor calcis U. S. See **Lime water.**

Liquor formaldehydi. See **Formalin.**

Liquor hydrargyri perchlor. See **Aqua sublimatis.**

Liquor Morgagni. See **Cataract, Morgagnian,** p. 1561, Vol. III of this *Encyclopedia.*

Liquor ophthalmicus Mindereri. A preparation proposed in certain eye diseases by Mindereri. It corresponds to the liquor ammonii acetatis, but is made with impure ammonium carbonate containing animal oil, which is saponified in the formation of the solution.

Liqueur ophtalmique détersive. HYDROLÉ DE SULFATE DE ZINC COMPOSÉ. (F.) A preparation made by macerating for two days 6 parts of zinc sulphate with 540 each of rose-water and water of plantain and 11 of powdered iris, and straining. It is used in the chronic forms of conjunctivitis, trachoma, etc.

Liquor plumbi subacetatis dilutus U. S. See **Lead water.**

Liquor potassæ. This is a clear colorless liquid with a strong alkaline reaction and a very caustic taste. It is, in fact, a 5 per cent. aqueous solution of potassium hydroxide. When it, through any accident, reaches the conjunctival sac it burns the tissues almost instantly and produces serious lesions of the whole eyeball. For the effects of this agent upon the ocular apparatus, see **Injuries of the eye.** See, also, p. 1346, Vol. II, of this *Encyclopedia*

Liquor potasii arsenitis. See **Fowler's solution.**

Liseur optotypique. (F.) Reading test type.

Lister, Lord Joseph (1827-1912) was born at Upton, Essex, England; studied at London and Edinburgh. He was professor of surgery successively at Glasgow, Edinburgh, and (from 1877) at King's College Hospital, London. In addition to observations on the coagulation of the blood and on inflammation, his great work was the introduction of the antiseptic system of surgery, which revolutionized modern surgery. He was president of the British Royal Society from 1895 to 1900, and of the British Association in 1896. He became a baronet in 1883, and a peer in 1897. He was one of the original members of the Order of Merit instituted in 1902. He contributed many valuable papers to scientific journals, and published *On the Effects* *of the Antiseptic Treatment upon the Salubrity of a Surgical Hospital* (1870), and *A Contribution to the Germ Theory of Putrefaction and other Fermentative Changes* (1875).—(*Standard Encyclopedia.*)

Lister's antiseptic. See **Mercuro-zinc cyanide.**

Listerism. The principles and practice of antiseptic and aseptic surgery. See **Lister, Joseph.**

Listing, Axes of. See **Listing, Law of.**

Listing, Johann Benedict. A German ophthalmologist, of Hungarian descent, inventor of the expression, "entoptic phenomena" (entoptische Erscheinungen), well known for his researches in physiological optics. Born at Frankfort a. M., July 25, 1808, he was doubly orphaned at an early age. From 1829-'34 he studied at Göttingen, making a specialty of mathematics and graduating in the last named year. After a number of wanderjahre, he began teaching mathematics and mechanics at the higher tradeschools in Hanover. In 1839 he was made extraordinary professor, in 1842 full professor, of mathematical physics and optics at Göttingen.

Most of Listing's writings relate to mathematics. He wrote, however, an article on "The Path of The Light Rays in the Eye" for Vol. IV of Wagner's "*Handwörterbuch der Physiologie*" and a very useful "Beitrag zur Physiologischen Optik" (in Göttinger Studien, 1845).* He also contributed several articles to the "*Göttingen Nachrichten*" and to Poggendorff's "*Annalen der Physik u. Chemie.*"

He died suddenly, as the result of an accident, Dec. 24, 1882.—(T. H. S.)

Listing, Law of. According to this law, the eye may be brought from the primary position to any secondary position by a rotation around an axis perpendicular to the two successive directions of the visual line. The axes of Listing are all contained in a plane perpendicular to the primary direction and pass through the center of rotation of the eye. Therefore this plane, like the primary position, stands in a fixed relation to the head.

A practical account of the workings of Listing's law is also given under **Physiologic optics,** as well as in the biography of **Le Conte, Joseph,** who plainly stated its value and its applications to ophthalmology.

Listing, Reduced, diagrammatic or schematic eye of. That one may simplify the problem connected with the formation of retinal images, physiologists have constructed schematic and reduced eyes. The

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* Reprinted in Ostwald's *Klassiker der Exakten Wissenschaften* (Nr. 147) (Leipsic, Wm. Engelmann, 1905).

measurements given below are for the reduced eye of Listing:—Radius of curvature of the single refracting surface, 5.1 mm; index of refraction of the single refracting surface, 1.35 mm.; antero-posterior diameter of the reduced eye, 20.0 mm.; distance of the single refracting surface behind the anterior surface of the cornea, 1.8 mm.; distance of the nodal point from the anterior surface, 5.0 mm.; distance of the nodal point from the principal focus (retina), 15.0 mm.

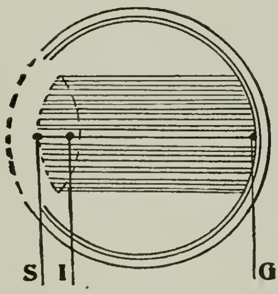


Diagram of the Reduced Eye.

S, The single spheric refracting surface 1.8 mm. behind the anterior surface of the cornea. I, The nodal point, 5 mm. behind S. G, The principal focus (on the retina), 20 mm. behind S. The cornea and lens are represented by dotted lines in the positions they should occupy. (Ball.)

Liston, Robert. A famous English surgeon, of little importance ophthalmologically except for the fact that he assisted in introducing into England the strabismus operation of Stromeyer and Dieffenbach (*Brit. and For. Med. Review*, May 6, 1840, Report by W. R. Ancram; and Liston, *Lancet*, I, 433, 1844). Liston was born Oct. 28, 1794, in Linlithgow, West Lothian, Scotland, studied at Edinburgh and London, and settled first at Edinburgh, where he was widely known both as author and as operator. In 1833 he was called to London as Professor of Clinical Surgery at the University College. Here he labored with very distinguished success until his death from an aneurism of the arch of the aorta, Dec. 7, 1847.—(T. H. S.)

Literature for the blind. See **Alphabets and literature for the blind.**

Lithemia, Eye symptoms of. See under **Gout,** p. 5617, Vol. VII of this *Encyclopedia.*

Lithiasis conjunctivæ. The formation of calcareous deposits in the retained glandular secretions of the Meibomian glands. See **Conjunctiva, Lithiasis of the.**

Lithiasis palpebralis. Chalazion terreum. See p. 1993, Vol. III, of this *Encyclopedia.*

Lithium benzoate. This compound is a white, crystalline powder soluble in three parts of water and generally used as a diuretic. Its application in ophthalmic surgery is extremely limited, although Mazet has used it with benefit (in from 2 to 10 per cent. solution) for the removal of calcareous opacities of the cornea.

Lithium bromide. See **Bromide of lithium.**

Lithophosphor. A stone which becomes phosphorescent when heated.

Litmus. The coloring matter obtained from the species of *Rocella, Variolaria, Leconora,* and similar lichens. It occurs in commerce in light, friable, finely granular cakes, not over an inch long, having an indigo, or deep-violet color, an odor somewhat like that of indigo and that of violets, and a somewhat saline taste. It is used chiefly as a test for acids and alkalies, being colored red by the former and restored to its original color by the latter.

Littell, Squier. An early American ophthalmologist, author of the once well known *"Manual of Diseases of the Eye."* Born at Burlington, N. J., Dec. 3, 1803, a son of Stephen and Susan Gardiner Littell, he lost both parents while still a small child. He was, however, adopted by his uncle, Dr. Squier Littell, of Butler Co., Ohio, and, in this county, received his early education at the public schools. Turning his attention to medicine, he studied at first with his uncle, then with Dr. Joseph Parrish, of Philadelphia, and finally, at the University of Pennsylvania, at which institution he received his degree in 1824. For a time he attempted to practise in Buenos Ayres, S. A., but soon returned to Philadelphia. Here he married Mary Emlen, by whom he had one son and one daughter, and here, too, he practised for very many years both as general physician and as ophthalmologist. In addition to the above-mentioned volume he wrote a considerable number of journal articles, and edited *"The Monthly Journal of Foreign Medicine."* Late in life he suffered from choroiditis, and soon was nearly blind. On the morning of July 4, 1886, he was found dead in bed at Bay Head, N. J., whither he had gone for his health.—(T. H. S.)

Little, David. A well-known British ophthalmologist. Born in Lockerbie, Dumfriesshire, Scotland, in 1840, he studied at Edinburgh, and, in 1863, became house physician at the Ophthalmic Institute, Manchester. In 1878 he was made instructor in ophthalmology at Owen's College, a position which he held for 21 years. In 1901 he was president of the Ophthalmological Society of the United Kingdom. He wrote little, but was widely known as an operator. His death occurred Oct. 27, 1902, at Congleton.

Little's ophthalmic writings are as follows: 1. On the Operation for Lamellar Cataract. 2. On the Extraction of Senile Cataract, with the Results of 1248 Extractions. (*Br. Med. J.*, 1889.) 3. Sarcoma of the Iris. (*Trans. Oph. Soc.* III, 215.) 4. Intoxication Amblyopia. (*Trans. Oph. Soc. U. K.*, VII, 73.) 5. Clinical Experience with Chronic Primary Glaucoma, and the Value of Iridectomy. (*Trans. Oph. Soc. U. K.*, XXII, 1, 1902.)—(T. H. S.)

Liver. It has long been the belief of the laity that the ingestion of the liver of the sheep will cure night-blindness. This opinion has been confirmed by scientific observers. The patient should ingest from 6 to 8 ounces of the liver of the goat, sheep, or ox, three times a day. The liver is to be fried in oil and is seasoned with spices. Buchanan, who treated twenty cases in this manner, states that five or six days are sufficient to effect a cure. Under ordinary tonic treatment such cases are not improved for several months. The liver treatment should be followed by a course of codliver-oil and ferruginous tonics. The night-blindness of retinitis pigmentosa is not improved by this treatment.—(J. M B.)

Liver, Cirrhosis of the. It is very rarely that eye symptoms are associated with or are dependent upon sclerotic liver. Landolt (*Archiv f. Ophth.*, 18, 1, 1872) has described two cases of retinitis pigmentosa, which he believed due to this disease. Purtscher attributed night-blindness, xerosis, iritis, and whitish exudates into the retina to the liver disease, to bacterial action and to the solvent effect of biliary salts upon the visual purple. See, also, **Jaundice.**

Lizard. Various parts and products of the lizard were employed in ancient Greco-Roman times as medicaments in ophthalmology. Thus, for example, the egg of a lizard, applied to the borders of a lid, was supposed to hinder the return of the cilia, after epilation. The gall of a lizard was also now and then employed for the same purpose. It was placed in a copper vessel and evaporated in the sun till about as thick as honey, then mixed with white wine. Lizard dung was used for corneal cicatrices, and lizard brain for cataract ("suffusio"). The head of a lizard, burnt to ashes and mingled with antimony, was deemed of value in epiphora. Finally, a carbonized green lizard was used for both epiphora and cataract.—(T. H. S.)

Lobe, Broca's. See **Broca's lobe.**

Lobes, Optic. Lobi orbitales. Lobi optici. A small portion of the encephalon, derived from the mesencephalon of the embryo, measuring about 12 mm. in antero-posterior diameter and 15 mm. in width; lying upon the posterior aspect of the caudex cerebri (q. v.), behind the third ventricle, beneath the splenium of the corpus callosum, anterior to the vermis superior, and above the upper extremity of the aquaductus Sylvii. A shallow crucial sulcus divides the mass into four rounded eminences, the larger two of which are situated side by side anterior to and above the lower and smaller pair. From each of the anterior eminences extends a tractus of white substance (*brachium anterius corporis quadrigemini*) to the corpora geniculatum externum of the corresponding side. From each of the posterior eminences extends a somewhat similar tractus (*brachium posterius corporis quadrigemini*) to the corpora geniculatum internum. The structure of the eminentiæ arteriores is as follows: 1st, an outer layer of white substance (*stratum zonale*); 2nd, beneath this a layer of gray matter (*stratum cinereum*); 3rd, a layer of gray matter mixed with fibers from the optic nerve (*stratum opticum*); 4th, a deep-lying layer of which the fibers participate in the formation of the lemniscus. Beneath this layer is the central gray substance surrounding the aquaductus Sylvii. (Foster.) See, also, **Intracranial organs of vision.**

Lobstein, Johann Friedrich. The father of Johann Friedrich Daniel Lobstein, and an ophthalmologist of some repute. Born at Lampertsheim, Alsace, May 30, 1736, the son of a German surgeon, he received his medical degree at the University of Strassburg in 1760, travelled in many lands, and began to practise general medicine at Strassburg in 1762. Gradually he turned his attention more and more to ophthalmology, but never to the total abandonment of other practice. He became especially famous for cataract extraction, and was often called in consultation to distant lands. In 1764 he became prosector at the University of Strassburg, and in 1778 professor of anatomy and surgery. He died Oct. 11, 1784.

His chief ophthalmologic writing was "*Suffusiones Secundariæ,*" etc. (1779).—(T. H. S.)

Lobstein, Johann Friedrich Daniel. A Strassburg ophthalmologist of the early 19th century. Born at Strassburg, the son of Johann Friedrich Lobstein (q. v.), in 1777, he was deprived of his father by death when only seven years of age. He studied at Strassburg and Paris, was for many years a military surgeon, and at length, in 1815, settled in Strassburg. He seems to have given much attention to ophthalmology, but never to the total exclusion of other forms of practice. According to Gurlt, he led, at least in Strassburg, a dissolute life, became bankrupt, fled to New York, where he lived in wretched circumstances till his death in 1840.

His only ophthalmologic writing was "*Tableau de la Séméiotique de l'Oeil à l'Usage des Médecins*" (1818).—(T. H. S.)

Local anesthesia. See **Anesthesia, Local.**

Local bleeding. See **Leeching**; also, **Blood-letting.**

Localization of ocular foreign bodies. The localization of foreign bodies—magnetizable and other—within the eyeball and orbit has been discussed under **Electromagnet,** p. 4268, Vol. VII, of this *Encyclopedia,* as well as under **Asmus, Sideroscope of** and to some extent under **Injuries of the eye,** and **Fluoroscope.** See, also, **Magnetometer.** Here it may be added that the use of the X-rays for localization purposes was for a time discouraged by several writers who considered that the media of the eye were impermeable to the rays. Dariex and Rochas presented the results of their experiments before the Académie des Sciences, March 3, 1896, and concluded that the rays could not penetrate the transparent media of the eye.

Van Duyse did some experimental work with rabbits, and succeeded in demonstrating the fact that a foreign body in the eye would cast a shadow. He, however, believed that the bones of the skull would interfere greatly with the rays and suggested that salt injections in Tenon's capsule be used so as to force the eye forward into a proper position. His skiagraphs were taken obliquely, so as to include the anterior part of the globe and avoid the bones.

Lewkowitch made experiments by placing the plate alongside of the nose and the Crooke's tube at the temple. He introduced a gilt spangle into the conjunctival cul-de-sac, and took two negatives—one of the eye adducted, the other with the eye abducted. With the aid of a bent wire as indicator, he then worked out the situation of the spangle by proportionate triangles. Both Van Duyse and Lewkowitch believed that it would be impossible to make a radiograph of the eye through the cranial bones.

Finally, the attempt was made by F. H. Williams, of Boston. He succeeded in obtaining a skiagram after a ten-minute exposure, which showed a foreign body one-fourth of an inch long by one-eighth wide, a fragment from a copper cartridge. It was removed by Charles H. Williams, by scleral incision, but the eye was afterwards lost. This was the first attempt to show a foreign body in the globe, and was entirely successful, although exact localization was not attempted. The rays were passed across the nose through the thin tissue. A little later than this, Clark made a skiagram of a piece of steel in the anterior chamber, and then went in at the corneal margin where, after some efforts, he succeeded in removing with a magnet a foreign body 1 mm. square. Exner attempted to devise a scheme of localization by employing two leaden discs perpendicular to each other as fixed points, so as to have known measurements for triangulation. Ring demonstrated a foreign body but did not localize it. Dahlfeld and Pohrt experimented with shot and pieces of wire introduced into the orbits of cases of phthisis bulbi, and from these located a piece of steel 3x1 mm. in the globe. They advised several exposures at different angles, so as to clear the orbital margin. De Schweinitz obtained an approximate localization by reference to the bony landmarks, and removed a foreign body measuring 4 x 2 mm. and weighing 7-16 grains. Fridenberg took two negatives at right angles to each other and made the exposure through the entire thickness of the skull. The plates were bandaged—one to the front of the orbit, in the first exposure, the other to the temple, in the second exposure. The exposure lasted for 35 minutes. At the meeting of the American Ophthalmological Society in May, 1897, several papers on the subject were presented. William Thomson reported a case in which the localization had been done by Sweet; Oliver reported three cases in which the localization had been done by a method devised by Leonard after Exner's method of triangulation; and Sweet gave his method with two metal indicators, which was the first accurate method of localization. After this Kibbe attempted to localize the foreign body through its relations to bony points, and also used a shot bandaged to the eye as an indicator. Hansel reported cases where localization by Sweet's method was successful.

The practicability of accurate localization of foreign bodies in the eye being now established, the various methods followed rapidly, and have continued almost to the present time. They are very numerous and are of all grades of accuracy. The best ones are based on geometric calculations and give remarkably accurate results. These will be described later. Fluoroscopy also has been attempted in this connection, but in a situation like the orbit, where there is so much confusion from bony shadows and, as a rule, such small shadows to be viewed, it is worthless and cannot be depended upon.

The localization of particles of metal or other foreign material in the interior of the globe or orbit may be said to be the most important use of the X-rays in ophthalmology today. Not only are we able to diagnose the presence of a foreign body, but we are able to determine its size, and, with a great degree of accuracy, its position. The information obtained by the X-ray is of the greatest value in enabling the surgeon to choose the proper method of operation and to avoid the operative complications which are not infrequently the cause of disaster. The X-ray very rarely fails to give us a satisfactory diagnosis, while the other instruments for the diagnosis of foreign bodies in the globe have all marked disadvantages. The ophthalmoscope is frequently limited in its value on account of the haziness of the media from hemorrhage, swollen lens substance, etc. The so-called "Giant" magnets which have been used for this purpose should never be so employed. Not knowing the size of the foreign body, or being able only to infer its size from the appearances of the wound, and knowing nothing of its situation, to apply a powerful magnet to the eye is at the present time the worst possible practice. If the particle be large it may be suddenly and violently dragged forward and do serious damage to the tissues of the eye; and while foreign particles in the vitreous usually sink to the lower part, they do not always do so, and it is important to know the exact situation so as to be able to lead the foreign body in the proper direction. Besides these disadvantages the magnet at times utterly fails to give any reaction, either because the particle is too small or too far away from the point, or because the particle is enclosed in an envelope of connective tissue, or finally, because the particle is of some non-magnetizable material. The sideroscope is only of use in the case of magnetizable foreign bodies, and while localization may be obtained it is only approximate. Moreover, the instrument is extremely delicate, is difficult to manage, and is readily disturbed by extraneous influences, as has been before stated. If the sideroscope is not affected, it is probable that the eye does not contain a magnetizable foreign body, while the negative diagnosis in the case of the magnet is of uncertain value.

The X-ray, however, rarely leads to a wrong diagnosis, if a photographic negative is used. Except in the case of a few substances—not commonly found in penetrating wounds of the eye—a clear, distinct shadow is cast. If no shadow is cast, there is almost certainly no foreign body present. It is possible that a very thin scale of metal may be overlooked, especially if it be situated in dense bony shadow, but even this is rare. Sweet reports two cases of failure from this cause in his series of 702 cases, of which 395 contained a foreign body. Given a good negative, the X-ray today is the method of all others for the diagnosis and localization of foreign bodies in the globe, and the results of localization are accurate to a surprising degree. The table, given below, shows the relative transparency of various substances to the rays.

TRANSPARENCY OF VARIOUS SUBSTANCES FOR ROENTGEN RAYS:
(Batelli and Garbasso) Water = 1.

Material.	Sp. gr.	Trans-parency.	Material.	Sp. gr.	Trans-parency.
Pine wood	0.56	2.21	Tin	7.28	0.118
Walnut	0.66	1.50	Zinc	7.20	0.116
Paraffin	0.874	1.12	Iron	7.87	0.101
Rubber	0.93	1.10	Nickel	8.67	0.095
Wax	0.97	1.10	Brass	8.70	0.093
Stearine	0.97	0.94	Cadmium	8.69	0.90
Cardboard		0.80	Copper	8.96	0.084
Ebonite	1.14	0.80	Bismuth	9.82	0.075
Wool cloth		0.76	Silver	10.50	0.070
Celluloid		0.76	Lead	11.38	0.055
Whalebone		0.74	Palladium	11.30	0.053
Silk		0.74	Mercury	13.56	0.044
Cotton		0.70	Gold	19.36	0.030
Charcoal		0.63	Platinum	22.07	0.020
Starch		0.60	Ether	0.713	1.37
Sugar	1.61	0.60	Petroleum	0.836	1.28
Bone	1.90	0.56	Alcohol	0.793	1.22
Magnesium	1.74	0.50	Amyl-alcohol		1.20
Coke		0.48	Olive Oil	0.915	1.12
Glue		0.48	Benzol	0.868	1.00
Sulphur	1.98	0.47	Water	1.00	1.00
Lead ointment		0.40	Hydrochloric acid	1.26	0.86
Aluminum	2.67	0.38	Glycerin	1.24	0.76
Talcum	2.60	0.35	Bisulphide carbon	1.293	0.74
Glass	2.60	0.34	Nitric acid	1.42	0.70
Chalk	2.70	0.34	Chloroform	1.525	0.60
Antimony	6.70	0.126	Sulphuric acid	1.841	0.50

Methods of localization by means of the X-ray.

In general the methods which have been followed aim at geometric calculations from fixed points of measurement, calculations from bony landmarks—or from some indicator placed on the lid, in the cul-de-sac, or even sutured to the ocular conjunctiva—or from stereoscopic skiagrams. Pouzol classifies them as follows:

1. Geometric.
   (a) Rectangular radiography (Radiguet and Guichard, Fouveau de Courmelles, Friedenberg, Friedmann, Galtier, Gorsch, Valencon, and Blondeau).
   (b) Double projections (Remy and Contremoulins, Sweet, Guilloz and Kibbe).
   (c) Mobility of the Eye (Grossman).
2. Anatomic Relations (Kibbe).
3. Stereoscopic (Ribaut and Marie).

Before describing in detail the most important methods, it will perhaps be as well to dispose of some of the less important ones. It need not be said that localization, to be of any proper value, in the succeeding operation, should be accurate, and only the methods which are accurate are worthy of serious consideration from a practical standpoint.

Use of the stereoscope. The effort has been made to adapt the principle of the stereoscope to this use. Two radiographs are taken, at the proper angles, and are mounted in a single frame for insertion in the stereoscope, either as prints or as transparencies. This gives a very attractive and useful effect in connection with other uses of the X-ray, but it is obvious to depend on one's own judgment of distances for an estimation of the situation of the foreign body—even if it is shown with sufficient clearness—is a very inaccurate procedure in eye work and is of little more value than a single plate would be.

Anatomic relations. Here the main difficulty is that the bony points or landmarks do not show as clearly in the negative as a metal indicator, and the opportunity for error in measuring the distance from the bony point to the cornea is at least as great as in measuring from an indicator.

Geometric methods of localization.

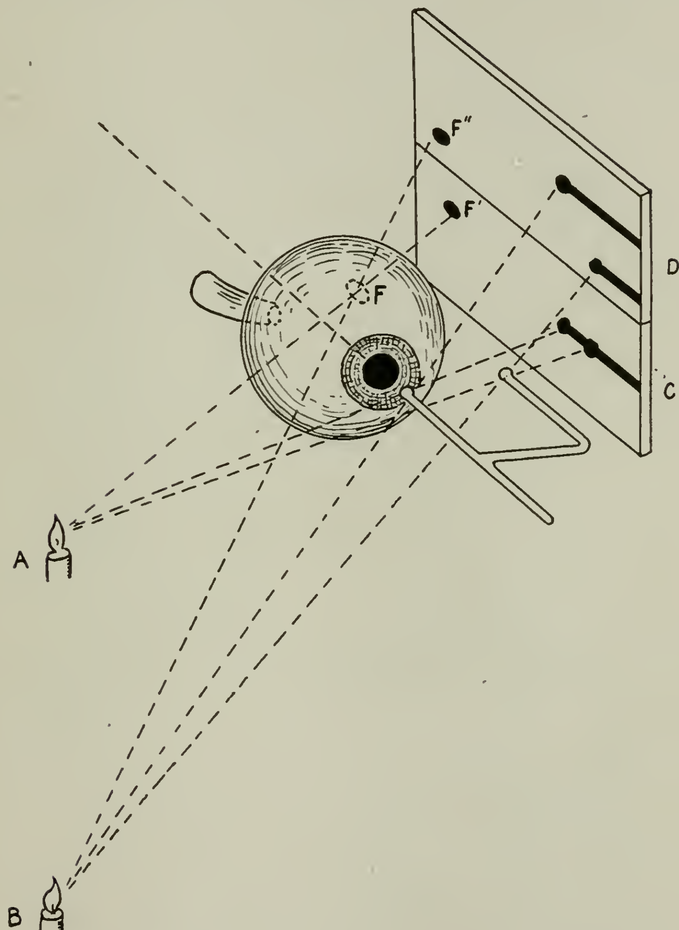
Rectangular or graphic methods The foundation of all that has been done here is the effort to dispense with the localizing apparatus and the succeeding calculations. Spectacles with cross-line centering opposite the corneal center have been used for this purpose. Two negatives are made, one from behind the head with the cross lines opposite the corneal center; the other, a lateral view, with the cross lines of a single eye-glass, which is fastened to the temple, centering on the external canthus opposite the corneal center or at an arbitrary point on the temple. The resulting negatives give an approximate localization by showing the relation of the foreign body to the cross lines on the spectacle lens and to the frame. A similar method of localization is used by Fox. He employs an oval form with cross wires, which is made of gold or some non-irritating metal, so shaped that it can be inserted into the conjunctival cul-de-sac after the eye has been cocainized. He takes two negatives—one from behind forward, the other laterally. These methods give only approximate results, and the opportunity for error in questions as to whether the particle lies at the posterior pole or in the orbit, in the lens or in the vitreous, on the ciliary body or below it, and other questions of like importance in the operation for removal of the foreign body, is very great. Their only advantage lies in the simplicity of the means employed. The advantage claimed that they save time, has been rather overdrawn. The part of the process that takes the most time is the exposing and the developing of the plates. When this is done, the method of triangulation by Hulen's plan, or measurement by Sweet's, is a matter of a very few minutes. For those who cannot command the Sweet or Dixon apparatus, these methods are better than nothing, but they do not seriously compete with the more accurate methods.

Mobility of the eye. Grossman devised an ingenious plan before the general introduction of the more accurate methods. An exposure was made while the eye was looking up, then one while the eye was looking down. In the same way, exposures were made with the eye in the position of extreme abduction and extreme adduction. The situation of the foreign body was inferred from the amount of displacement of its shadow with reference to the center of rotation of the eye.

Holth of Christiania publishes a method, really a "rectangular" method, which attempts greater accuracy by the method of attaching the indicators. Two indicators are used—small buttons of lead—and are sutured to the bulbar conjunctiva—one just above the cornea, the other just below. Bi-temporal and occipito-frontal negatives are made and the situation of the foreign body is measured by its relations to the indicators. While there is no question but that it is highly desirable to secure an exact point from which to measure, this method involves a surgical procedure, which is certainly objectionable.

Double projections. The methods yielding the most accurate results are all based on geometric calculation, and have as their basis the comparison of the images of two exposures, or what may be roughly designated as "triangulation."

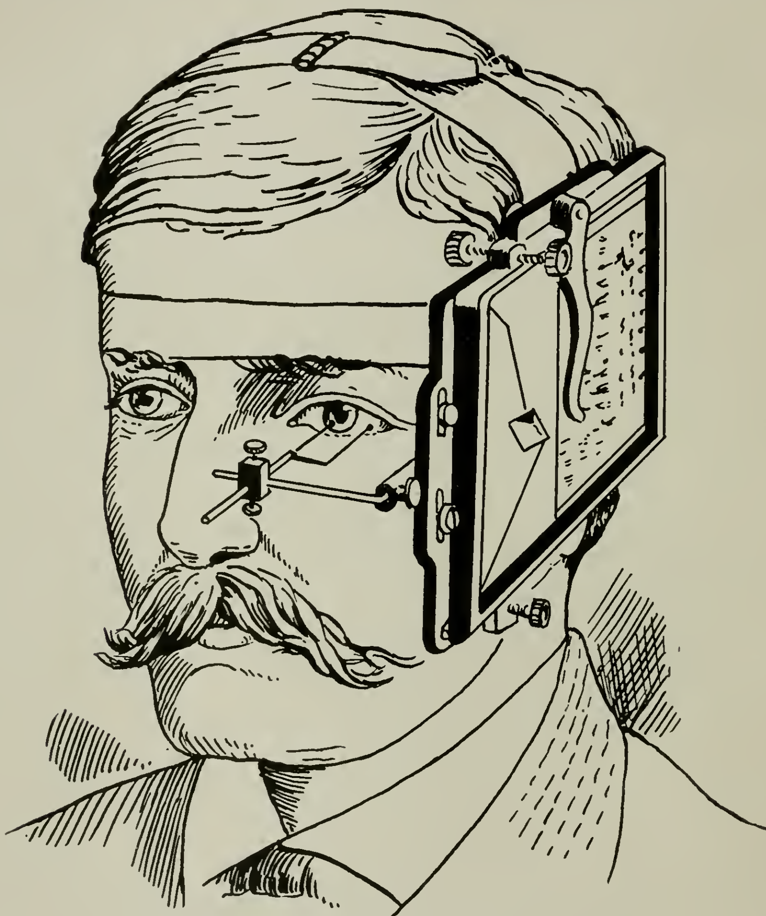
The first of these, and one of the best, was devised by Sweet. He used two metal indicators which were connected, one pointing at the corneal center, the other at the temporal side at a known distance from the first. Two exposures were made, one with the tube horizontal to the plane of the indicators, but at a slight angle, so as to throw the shadow of one indicator farther forward than the other,—in this way leading to the identification of the indicators on the negative,—the other at any distance below this plane. The figure shows very well the principle of the method. In one of the accompanying figures, C represents the negative of the first exposure, while D represents the second exposure. The apparatus is extremely simple, in fact nothing is required but a properly made indicator with its attachment to the plate holder, which is bound to the head, as shown in the cut. The important point is to have the indicators and the axis of the eyeball both parallel to the plane of the plate. The central indicator is placed exactly opposite to the center of the cornea, and the distance between the indicator and the cornea is measured by a rule. It is, of course, necessary to identify the indicators, and this is done easily, because the tube being anterior to the head of the patient, the shadow of the indicator opposite the center of the cornea will be the farthest back.



The Principle of Sweet's Method of Location, showing the two metal indicators, one pointing at the corneal center, and the other at a known distance from the first, on the temporal side.

In making the measurements on the negatives, it is necessary to continue the line of the indicator back until it is directly over the shadow of the foreign body, then letting fall a perpendicular to the foreign body. In this way the distance of the foreign body below the indicator is accurately determined.

In determining the situation of the foreign body, the position of the indicators is first entered on the chart, as shown in the accompanying figure. A and B, that is, in both the horizontal and the vertical section of the globe. On the diagram marked "Front view" is entered the measurements of the distance of the shadow of the foreign body



The Indicating Apparatus in Position. (Sweet.)

below each indicator taken from the first negative, the one near the plane of the indicators, in this case represented by the letters C and D. A line drawn through these points represents the direction of the rays when the first negative was taken. In like manner, the measurements are taken from the second negative and entered on the chart, represented by the points F and E. A line drawn through E and F represents the direction of the rays when the second exposure was made. The situation of the foreign body is at the intersection of these two lines. To determine the distance of the foreign body back of the corneal center, the negative with the tube horizontal is taken. The distance between the two ball-shaped ends of the indicators is measured, and this is transferred to the chart in the figure marked "Horizontal section." It is entered on the line above the marker and is represented by the distance BK. A line drawn through K and the indicator A, represents the direction of the rays, since in the negative

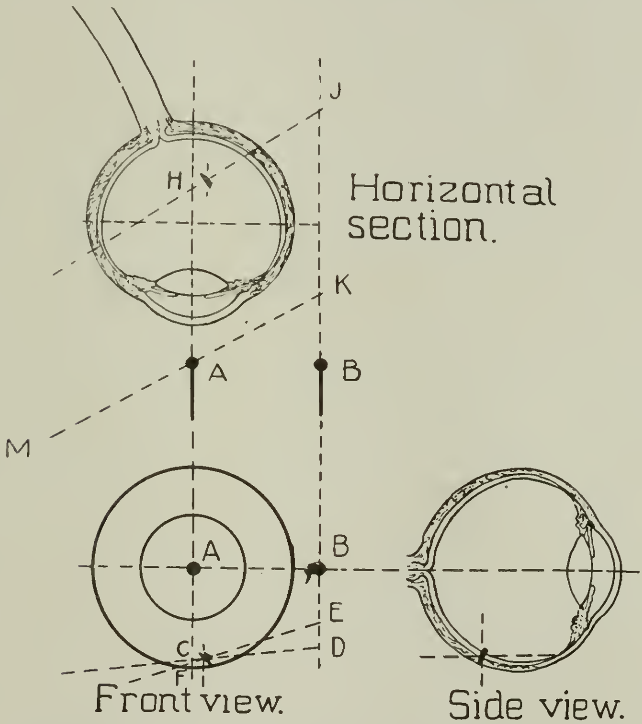


Diagram of Position of Foreign Body in Eyeball. (Sweet.)

the shadow of A is cast farther back than B, equal to the distance BK. On the same negative the distance of the foreign body back of each of the indicators is measured, and these measurements are transferred to the chart, in this case represented by the distances BJ and AH. A line drawn through J and H represents the plane of the shadow cast by the foreign body, and so it follows that a perpendicular drawn from the position of the foreign body in the diagram marked "Front view" will represent the position of the body at the point where it intersects the line JH. If the body is far back in the orbit or far away from the indicators, a source of error arises in the divergence of the rays, and it is better in this case to measure the distance of the tube from the cornea (this is indicated by the line KM). Now a line drawn from J to the tube will represent the divergence of the rays and the plotting will be more accurate. If the foreign body is in the orbit, a slight error arises in causing the patient to look at a fixed object so as to make the optic axis parallel to the plane of the plate on account of the rotation of the globe from the primary position. The plate-holder and the indicators are attached to the head on the side of the injured eye, as shown in the cut, and the tube is placed 12 inches to the opposite side and slightly forward. The patient is usually recumbent, to insure steadiness of the head.

The foregoing method has been used by its inventor in more than 700 cases, with accurate results, and there is no doubt that it is one of the best. The measurements must be carefully laid out with mathematical accuracy, and it is best to have a chart similar to the figure, so as to maintain a certain uniformity. The size of the globe is made 24 mm., which is an average length.

Sweet's Later Method.

At the meeting of the American Ophthalmological Society in 1909, Sweet presented a new method based upon the old, but in which the apparatus is such that the measurements do not have to be taken: the negative is simply placed upon a plate of "Focal Coördinates" and the readings taken directly. This method is best described in the author's own words.

In the new apparatus the planes of shadow of the foreign body are accurately determined by the instrument without the necessity on the part of the operator of taking measurements from the plates or drawing lines upon the chart. The tube-holder, indicating ball, and plate-holder are upon a movable stage and therefore preserve a known relation to each other which does not vary. The angle of the rays with the eyeball and the distance of the tube from the plate are always the same, so that one indicator is sufficient, and this consists of a small steel ball supported in a ring of translucent celluloid. The setting of this ball opposite the cornea is made by means of adjusting screws conveniently placed on the frame of the instrument. Accuracy in the measurement of the distance of the indicating ball from the center of the cornea is secured by means of a telescope and reflecting mirror. The mirror gives an image of a cross-wire and a lateral image of the cornea. Through the telescope the observer adjusts the instrument until the image of the cross-wire is in direct contact with the image of the summit of the cornea. When the adjustment is made, the indicating ball is exactly 10 mm. from the center of the cornea. A miniature incandescent lamp, mounted in an adjustable shade, illuminates the side of the nose of the patient, insuring a well-lighted image of the cornea and cross-wire.

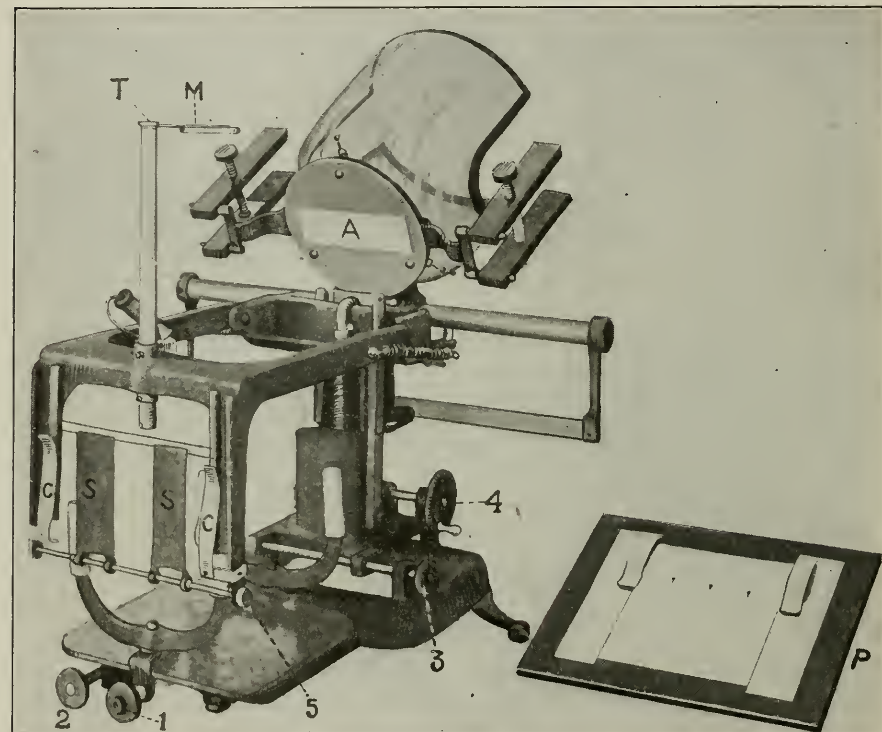
Instead of a ball of cotton or other object for fixation, as in the older method, a circular mirror is placed at a distance of 12 inches above the injured eye. The patient gazes in the mirror and sees a reflected image of the injured eye and the circular celluloid disc with the steel indicating ball in its center. After the ball has been adjusted to a point opposite the center of the cornea of the injured eye, the patient, by fixing the ball with the seeing eye, prevents any movement of the eye during the exposure and holds the visual line of the injured eye parallel with the plate.

In order to shorten the time of making the radiographs and lessen the possibility of any movement of the patient or apparatus in changing plates, the two exposures in the new apparatus are made upon one plate, metallic shutters protecting those portions of the plate which are not to be exposed to the X-rays.

The tube-holder contains the usual cylindrical lead-glass shield for protecting the operator from the action of the rays, with the customary lead diaphragm. The central orifice of the diaphragm is covered with aluminum, which offers little obstruction to the rays but lessens the risk of any unfavorable action of the rays upon the patient and guards against possible damage to the eyes in the event of breakage of the tube. The tube-holder slides upon a graduated rod, and the first exposure is made with the indicator at zero, in which position the rays pass in a direction corresponding with the horizontal plane of the eyeball. The second exposure is made with the tube at its farthest point to the right or left of the first position, depending upon which eye is to be examined. The illustration gives a view of the complete apparatus.

Since the relative position of the tube in reference to the indicating ball and the photographic plate remains to be fixed and known, it is readily seen that the direction of the X-rays in passing through the eyeball must follow a definite course, which is always the same for the two separate exposures. It is, therefore, possible to indicate on the localization chart the direction of the rays at the two exposures, and this has been done in the chart, a copy of which is here reproduced, reduced in size one-half. Only those lines representing rays 2 mm. apart are reproduced, but each line is drawn with the required amount of divergence to indicate the rays as coming from a point the distance of the tube from the photographic plate.

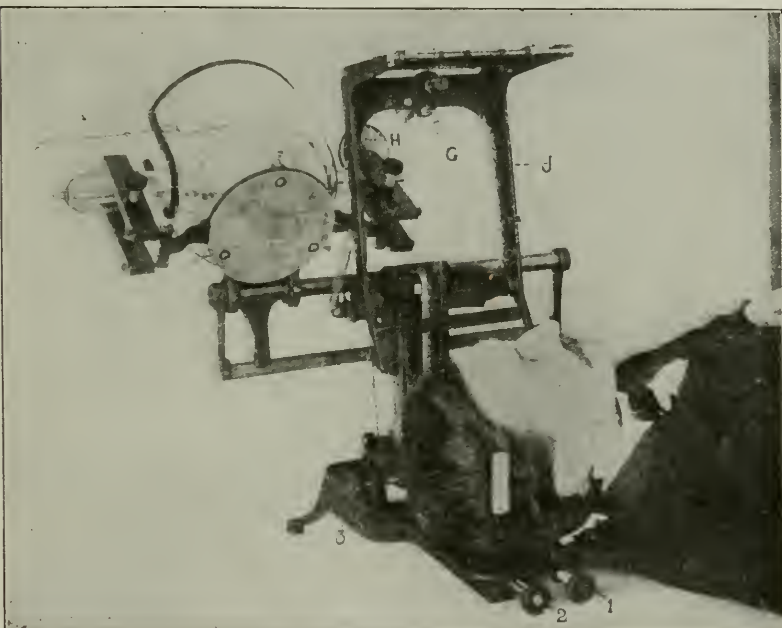
Method of employing the new localizer. The apparatus is arranged as shown in the figure. The patient lies with the head on a platform of hard fiber, with a pillow beneath the shoulders and a small sand-bag under the head and neck. The upright supports for holding the head are now adjusted by means of the wheel, 1, and the jointed part of the apparatus, J, containing the indicator is brought down in position. The indicating ball, G, is now roughly adjusted until it is



Sweet's Improved Localizer.

opposite the center of the cornea and about 12 or 15 mm. distant. The patient looks with the uninjured eye into the mirror, M, and fixes upon the iris or cornea of the injured eye, or, better, upon the indicating ball in the center of the celluloid disc. The indicating ball is now carefully adjusted directly over the corneal center by means of the wheels 2 and 3, and the correctness of the position verified by observation through an opening in the mirror, M. The operator then adjusts the light of the small electric lamp so that the side of the nose next the injured eye is illuminated, but the light is not thrown into the eye. With this area lighted, it is possible to see clearly through the telescope, T, when the cross-wire is exactly tangent with the summit of the cornea. The movement necessary to secure this position of the wire is made by means of the adjusting wheel, 4. When the image of the cross-wire touches the image of the corneal summit, the indicating ball is exactly 10 mm. from the eyeball.

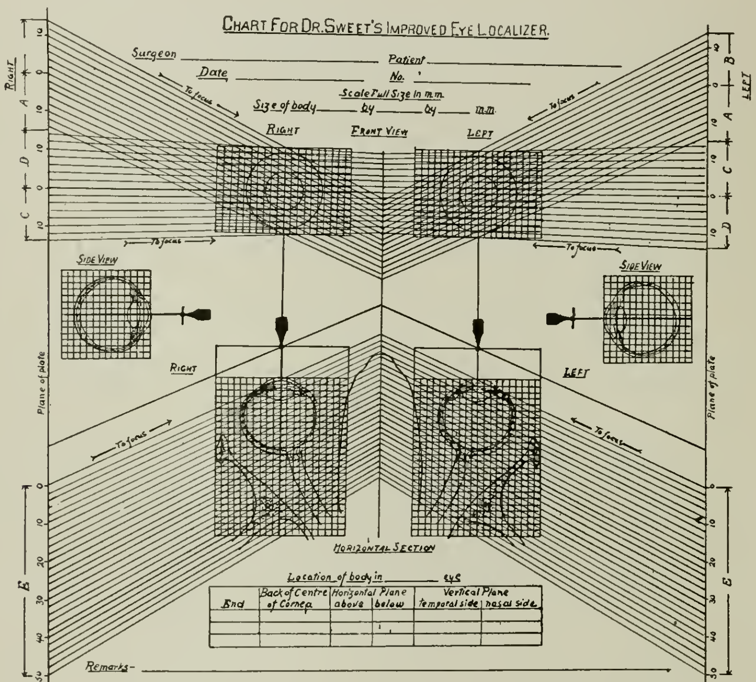
The photographic plate is inserted beneath the spring clips, C C, the shutters, S S, moved so that the center area is open, and the tube-



Sweet's Improved Localizer. The Patient in Position.

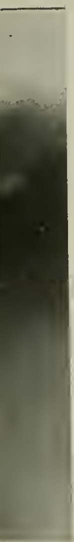
holder adjusted to the zero point on the sliding scale. The current is turned on, and one exposure made. The tube-carriage is then moved to the limit of the sliding rod, always in the direction of the chin of the recumbent patient (to the end marked R if the radiographs are made of the right eye, and to L if of the left eye). The upper shutter is moved to cover the exposed central portion of the plate and uncover the unexposed portion. The current is again turned on and the second exposure made. The time of exposure for the second picture should be about one and a half times that of the first, to allow for the increased distance of the tube from the eye.

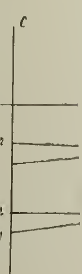
After the plate is developed it is placed in the frame, P, containing the key plate of focal coördinates (here reproduced) with the film side of the radiograph next to the key plate. The radiograph is moved until the shadow of the indicating ball of the first exposure is in apposition with the middle ball on the key plate and the heavy horizontal line of the radiograph parallel with the horizontal line on the plate. Holding the frame body with respect to the vertical lines of "C" and "D," a reading is made to the light, there is noted the

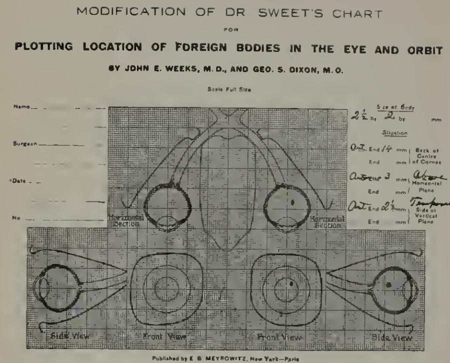


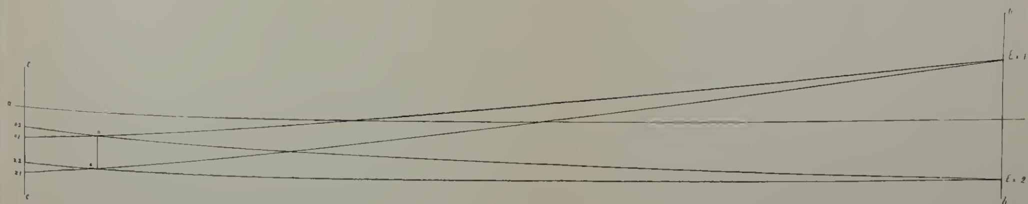
Localization Chart, with Lines Representing the Course of the X-Rays (one-half actual size). (Sweet.)

position occupied by the shadow of the foreign body of the line or lines which pass through the body, and this is transferred to the corre sponding lines of the "C" or "D" scale of the chart, to the right or left side, depending on which eye is under examination. Without moving the plate the "E" reading is similarly made and transferred to the chart. To take the "A" or "B" reading the plate is shifted slightly until the image of the indicating ball on the second exposure coincides with the "Right" or "Left" ball of the vertical coördinates "A" or "B." The line or lines of the "A" or "B" coördinates which cross the shadow of the body are noted and indicated on the




c
c


MODIFICATION OF DR. SWEET'S CHART
FOR
PLOTTING LOCATION OF FOREIGN BODIES IN THE EYE AND ORBIT
BY JOHN E. WEEKS, M. D., AND GEO. S. DIXON, M. D.
Scale Full Size
Name
Surgeon
Date
No.
Size of Body
mm
Situation
End
mm
Back of Centre of Cornea
Horizontal Plane
Side of Vertical Plane
Horizontal Section
Horizontal Section
Side View
Front View
Front View
Side View
Published by E. B. MEYROWITZ, New York—Paris



"A" or "B" lines of the chart. The horizontal coördinate "E" should be the same in both readings. If the focus point on the anode of the tube was accurately set by the cross-lines on the lead-glass

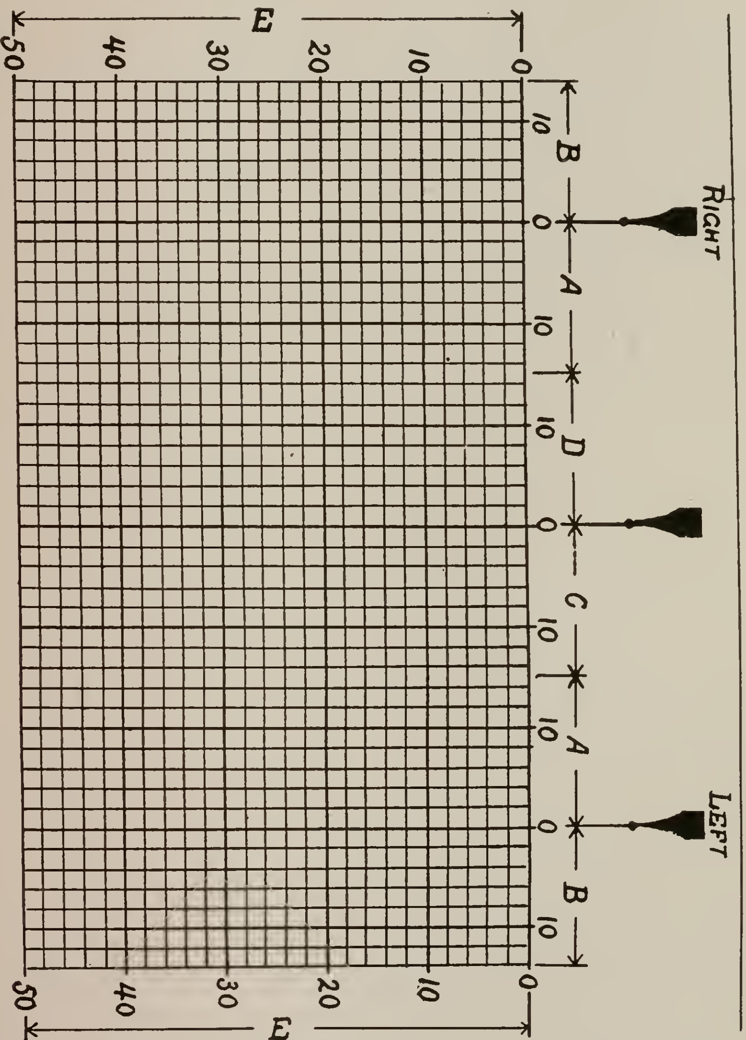
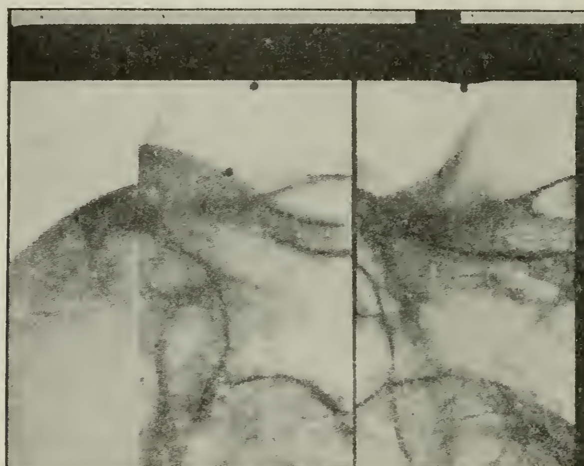


Plate Showing Focal Coördinates (three-fourths actual size). (Sweet.)

shield of the tube-holder, the images of the indicating ball on the plate will coincide simultaneously with those on the transparent key plate, and it will then not be necessary to reset the plate to read the position of the "A" and "B" coördinates.

After the three readings have been transferred to the chart, the point of crossing of the "A" or "B" and the "C" or "D" lines is found, which gives the location of the foreign body in reference to the front view of the eyeball, indicating its situation above or below the center of the cornea, and to the nasal or temporal side of the vertical plane. Where a vertical line from this point crosses the "E" reading on the horizontal section of the globe, it gives the depth of the body in the eyeball or orbit. In bodies of large size both ends should be localized to give the position in which the body rests in the globe. The situation of the body on the side view is determined by transferring its measured depth from the horizontal section and its dis-



Radiograph of Foreign Body in the Eye (three-fourths actual size). (Sweet.)

tance above or below the horizontal plane from the front view localization.

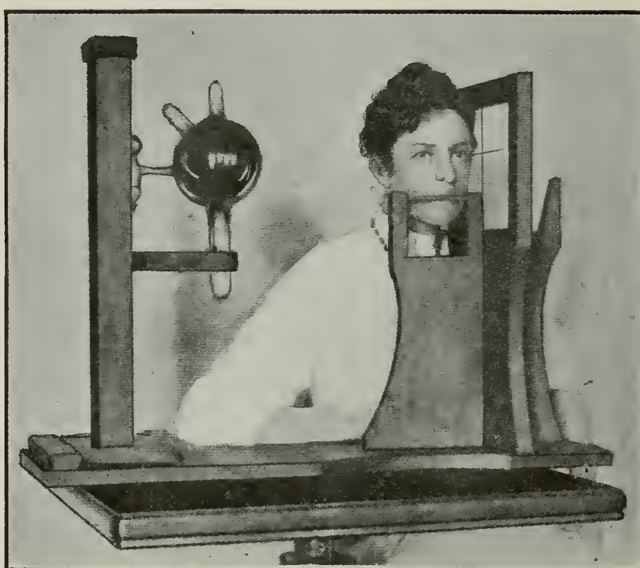
The new apparatus is based on the same general principles as was the old, but its mechanical features eliminate some of the errors that may occur in the use of the present instrument through carelessness of the operator in making the measurements and transferring them to the chart. The inexperienced worker in eye localization is also relieved of the necessity of studying out the position of the tube and the direction of the lines of shadow at the two exposures. The construction of the new apparatus insures that these factors are positively determined and recorded. The accuracy of the localization depends only upon the care with which the operator adjusts the indicating ball opposite the center of the cornea and at the definite and fixed distance from it. After the exposures are made and the plate developed, the determination of the situation of the foreign body is simply a question of reading from a keyplate and transcribing these readings to a chart.

This method has the advantage, in common with the old one, of taking the negative with the rays somewhat oblique so that no greater thickness of bone is penetrated than can be avoided. It necessitates the use of special apparatus and, while undoubtedly easier to work, is more difficult to understand than the old one. It furnishes accurate results.

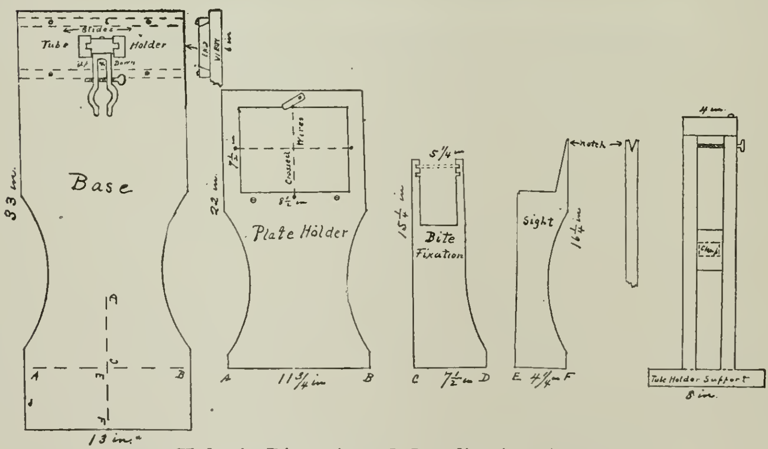
Mackenzie-Davidson's Method.

This method which, in its modified form, seems to the writer the best, was first published by Mackenzie-Davidson, January 1, 1898. It was first devised, not especially for foreign bodies anywhere in the eye but for foreign bodies anywhere in the body, and was accurate from the beginning though somewhat cumbersome. The essential principle of the method was the diagrammatic reproduction of the course of the rays in a duplicate of the apparatus used for the exposure, and which he called the "localizer."

His apparatus consisted of a table, to which was attached two upright bars connected by a cross-bar for the support of the Crookes' tube, and a plate of vulcanite with two cross-wires on it dividing the plate into four equal parts. The wires on the plate were brushed with India ink so that a mark would be left on the patient's skin. The plate was placed on the table and the vulcanite on top of the plate, the two being centered below the middle of the cross-bar by means of a plummet, in such a manner that the cross-bar was parallel with one cross line and at right angles to the other. The cross-bar being graduated, the center of the lines was placed exactly below the zero mark. A coin, or some opaque object, was placed on the corner of the photographic plate so that the plate after development could be properly placed. The affected part was then placed on the vulcanite plate and the exposure made. There were two exposures made with the tube a given number of centimeters on each side of the zero point. The resulting negative gave two images of the foreign body, and the marks left by the ink on the patient's skin gave the position from which to apply the measurements after these had been worked out. The localizer was an exact duplicate of the exposing apparatus, and consisted of two uprights and a graduated cross-bar, all of exactly the same measurements as the original. There was a mirror under the bar with cross lines scratched on it. The negative was centered under the zero mark of the cross-bar, so that the cross lines were in the same position as they had been when the exposure was made, and silk threads were used to represent the course of the rays. These threads were attached to the cross-bar at the positions of the ex-

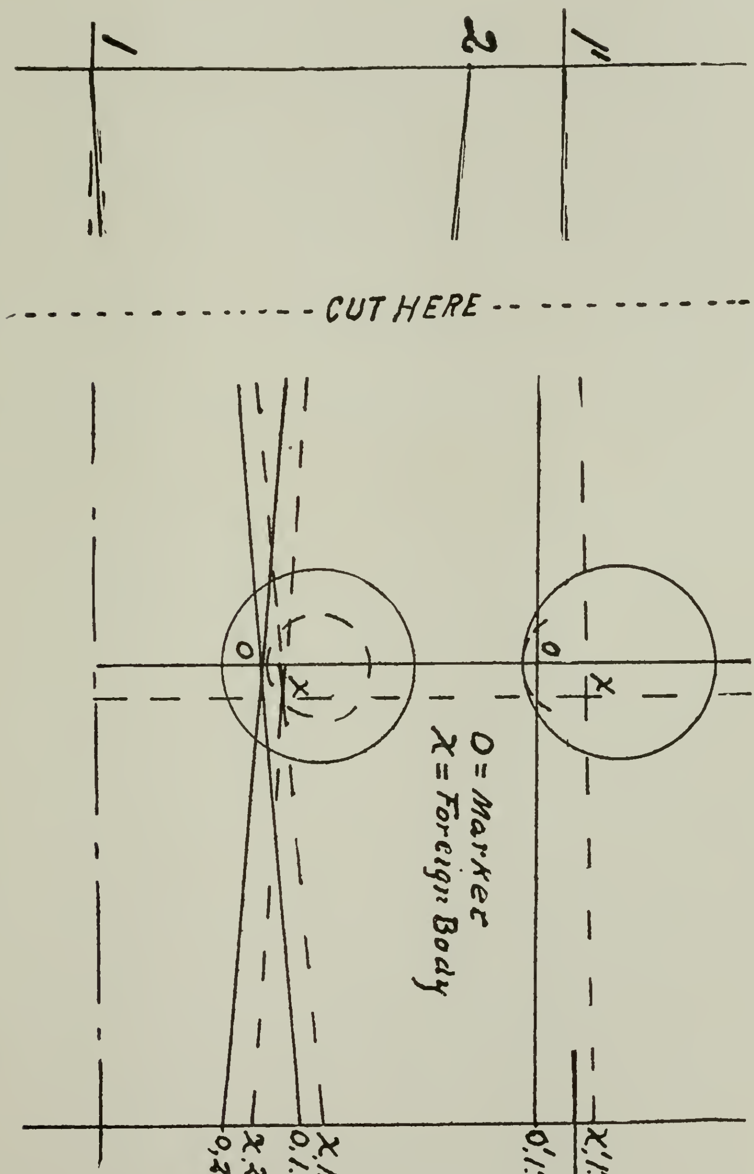


Hulen's Method of Localization.



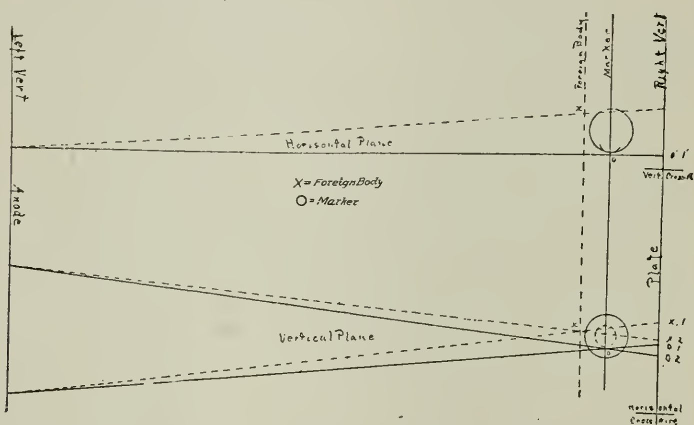
Vard Hulen's Disseminated Localization Apparatus.

posures and held in place on the negative by weights connected with the threads, being run directly to the shadows of the foreign body, visible by means of the light reflected in the mirror. The point of intersection of the rays, as represented by the crossing of the threads, gave the position of the foreign body, and it was only necessary to measure the distance from this point to the cross lines, to have an absolute guide, based on the marks on the patient's skin.



Vard Hulen's Method of Locating Foreign Bodies.

This method was first adapted to the eye in a case of Treacher Collins. Two exposures were made, as before, but a small piece of lead wire was attached to the lower lid at a point which bore some definite relation to some point of the eyeball, as a scar. When the negative was placed upon the localizer, the position of the wire indicator was first determined, and a needle was left to indicate this. Either one of two head rests was used, one with the patient lying down, the other with the patient sitting up. While this method gave accurate results, the use of the localizer was somewhat troublesome. It was very easy to disturb the positions of the threads and great delicacy was necessary in taking the measurements.



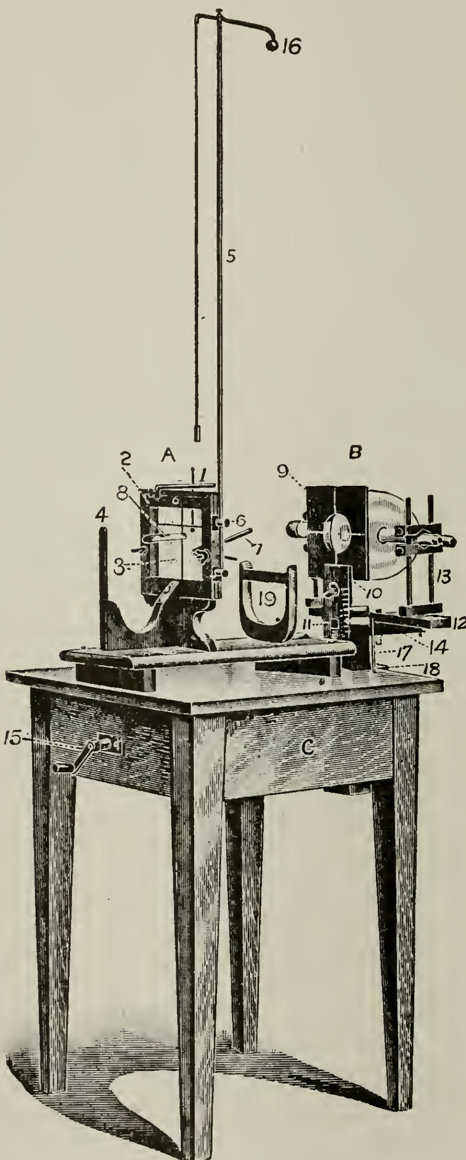
Vard Hulen's Chart for Locating Foreign Bodies in the Eye and Orbit.

Hulen modified the method by having the patient sit up and grasp a wooden rod in the teeth, as shown in the accompanying figure. This rod was attached to a frame and was at right angles to the plate-holder, which had cross-wires on it as in the old apparatus. An upright holder was constructed for the Crookes' tube, which was measured so that the tube was at a known distance from the plate, and the anode was in the horizontal plane and opposite the intersection of the cross-wires. This holder allowed the tube to be raised or lowered. The marker of fuse wire was attached in the same manner as in the old method and the distance of the marker from the cornea, below and forward, was recorded. The first exposure was made with the tube in the horizontal plane, and then the tube was raised a definite distance, usually three inches, and a second exposure made on a second plate. The patient was instructed to look at some object straight ahead, so as to bring the eye in a correct position, and was kept as still as possible while the two exposures were made. The lines of direction of the rays were then represented by laying them out on a drawing board according to the known meaurements, as will hereafter be described.

Dixon's Method.

A description of this method was first published in its entirety in 1906. He originally used Mackenzie-Davidson's method, but soon modified the procedure by using a single ball pointed indicator, after Sweet's model, which he placed opposite the center of the cornea. He placed the patient in the recumbent position and devised a head rest which, while simple, meets all the requirements. He used Hulen's method of plotting with T-square and rule. So that his method in its final form is based on Mackenzie-Davidson's principle, with Sweet's indicator and Hulen's method of plotting. It is in use at the New York Eye and Ear Infirmary and the Manhattan Eye, Ear, and Throat Hospital, and seems to the writer the most satisfactory of all.

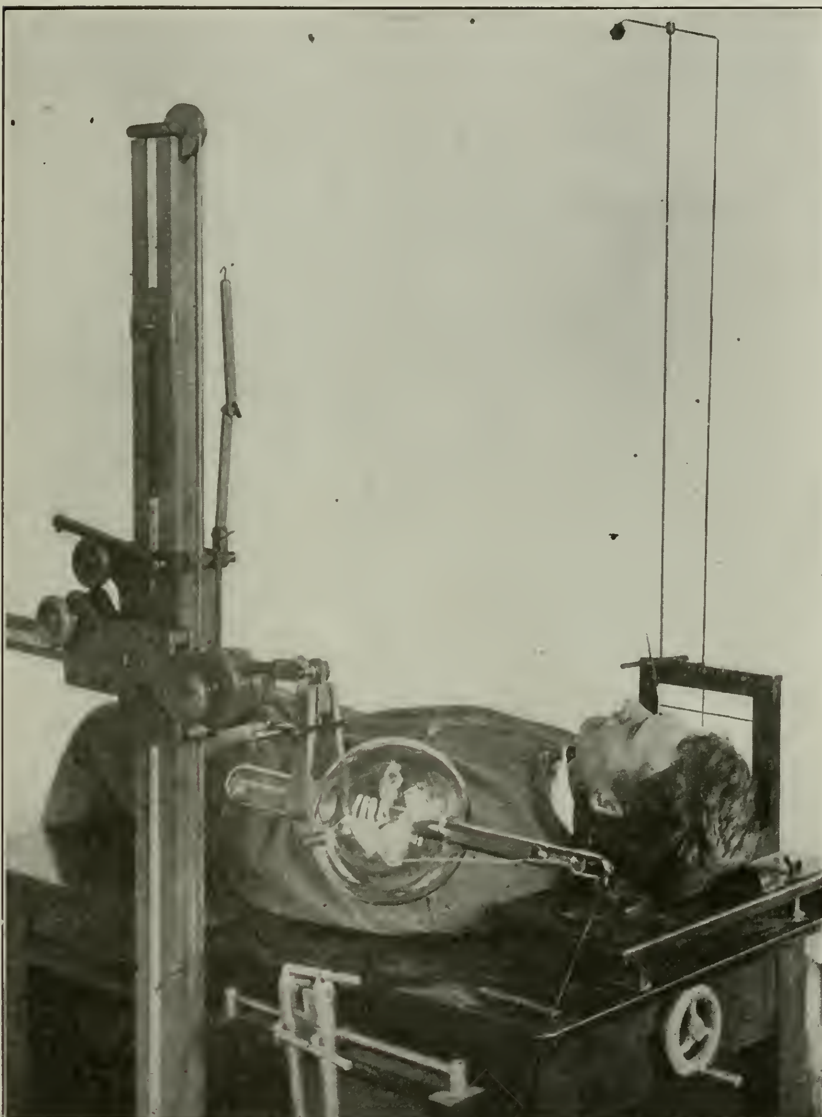
The apparatus is mounted on a 22 inch table, which is placed at the head of the bench upon which the patient lies, and can be reversed,—depending on which eye is affected. It has a vertical plate-holder, represented in the figure by A.—large enough to hold a 4 x 5 plate in its envelope,—which is erected on a platform elevated by cleats to compensate for the shoulders of the ordinary sized patient. Small blocks of wood of different sizes can be used beneath the back of the neck to act as a pillow and to keep the proper elevation. The plate-holder is supplied with the usual cross-wires (3) and a spring (8) to retain the plate in position during the exposure. A mouth gag (7) of aluminum is attached to the face of the frame with a jamb-nut, to hold the patient's head steady. A clamp (19), with a rubber band which can be pressed tight to the side of the head and screwed fast, gives additional stability. A steel rod (5) is attached to the frame and extends well up over the patient's head. It has a sliding cross-piece of brass tubing at the top through which a thread is run to a little woolen ball (16), balanced by a piece of lead at the other end of the thread. The rod can be rotated and fixed by a screw (6) so that the ball can be adjusted in whatever position it is desired to have the patient look. An upright sight (4) is fastened to the other end of the platform for the purpose of adjusting the tube in the horizontal plane, the lower part of the notch of which is at the exact height of the cross-wise center. On the frame is placed the instrument for squaring the head (1), which consists of a sleeve with a wire with a ball at each end, so that it may be pointed down at the glabella and then rotated to the horizontal position. The tube-holder consists of



Dixon's Apparatus for Localization.

(B), a box (18), 2 x 3 inches inside, open at each end, within which moves a pillar (11) controlled by a worm gear operated by a crank

(15) from the opposite side of the table. Attached to the upper end of the pillar is a diaphragm (9) adjustable for height. It is supplied



The Patient in Position. Dixon's Method. (The indicator is not shown.)

with cross-threads for alignment with the cross-wires in the plate frame. A projecting arm (14), one end of which is morticed into the head of the pillar, carries a cross-piece (12) to which is attached the arrangement (13) for clamping the tube. Both the arm and the cross-pieces are slotted so that the parts supporting the tube can be moved in all necessary directions and clamped. The arm (14) is graduated so that it is possible to read the distance of the center of the target from the plate. The face of the upper end of the pillar (11) and the lower end of the diaphragm (10) are graduated in centi-

The Indicator in Position. Dixon 's Method.

meters,—six above and six below the zero mark. Attached to the box (18) is an adjustable indicator (17) to measure the distance the tube has been moved.

The writer uses the wooden "pillow" without the mouth-gag, and prefers a Brickner stand, as shown in the illustration, which allows the tube to be raised and lowered at will and is attached to the side of the table at exactly 50 cm. from the plate holder, so that no measurement is necessary (Dixon's original plan). The indicator consists of a ball pointed rod attached to a head band, which is strapped to the patient's head, thus avoiding any danger of injury to the eye by a sudden move (see figure).

In using the method, the tube is first adjusted to the horizontal plane by sighting across the wires at the anode, the tube being exactly 50 cm. from the intersection of the wires. The indicator is then strapped to the patient's head, he is placed on the table, on his back, with his head raised by a wooden pillow to the proper height, so that the affected eye, which is placed next the plate-holder, is in the part of the negative nearest the top of the head and below the horizontal wire. The vertical wire should run at the level of the floor of the orbit, so that there will be little chance of a very small body being concealed by the wire. The head is now squared by means of the squaring instrument, which is then removed from the frame. The woolen ball is now lowered directly over the patient's eye, and when the proper direction has been secured it is drawn up as far as it will go and the patient is instructed to look steadily at the ball during the time of both exposures. In the case of squint, the direction must be modified until the affected eye takes the proper position. The indicator, (see figure), is then more accurately adjusted and placed exactly opposite to the corneal center and as close to the cornea as possible,—usually about 3 mm. The distance is then measured with a millimeter gauge, and recorded. The plate is then put in position, the tube raised 3 cm. above the horizontal plane, and the first exposure is made. The plate is changed, the tube lowered to 3 cm. below the horizontal plane, and the second exposure is made. The time of exposure varies, but under fair conditions an exposure of more than 10 seconds is never necessary. The plates are developed, and the plotting can be done immediately, without waiting for the plates to dry.

Plotting. The first step is the identification of the exposures, and if these have not been kept separate it is a simple matter to tell which is which by the relation of the indicator to the cross-wire which represents the horizontal plane (see Plate). In the negative from the first exposure the indicator extends farther down, below the wire "a," where the tube was displaced upward, than in the second where the tube was displaced downward. A drawing board with T-square, triangle, and compass, with a scale rule are necessary, with the special chart figured in the cut. This chart represents three sections of the globe, right and left, of an average diameter of 24 mm. The chart was devised by Weeks and Dixon after Sweet's chart, and is graduated in millimeters. It is best in plotting to use the full scale, as it is really easier and there is less opportunity for inaccuracies. The measurements must be made with mathematical accuracy, and it is best to use a fine-pointed pair of compasses and a hard fine-pointed lead pencil. The horizontal plane as is first drawn, and then a perpendicular at the right end, bb, which represents the plane of the displacement of the tube. At the left, exactly 50 cc. from bb, is drawn another perpendicular, which represents the position of the plates, cc. On the line bb is indicated the positions of the tube at the time of the exposures, the first 3 cm. above the line aa (Ex. 1), the second 3 cm. below the line (Ex. 2). The distance of the ball end of the indicator below the horizontal plane, which is the same as the wire aa, is now measured in each negative and measured on the line cc at the points "o^1" and "o^2," and lines representing the course of the rays are drawn from these points to the positions of the tube during exposure, respectively. The point at which these lines intersect represents the position of the indicator, o. In the same way, the distances of the foreign body below the line aa are measured and transferred to the line cc at the points x^1 and x^2. Their intersection represents the situation of the body, x, in the case shown,—a piece of stone. A perpendicular is now let fall from "o" and a line is drawn, at right angles, to "x." These distances are measured, and we find that the foreign body is back of the indicator at 17 mm. As the indicator was three mm. from the cornea, it follows that the foreign body is 14 mm. back. As x is nearer the plate, it follows that the foreign body is so much to the temporal side of the indicator (corneal center),—in this case, 1½ mm. Now, taking either radiograph, we measure the distance of the indicator above the line bb, and the distance of the foreign body above the line bb, and the difference,—in this case, 3mm.,—represents the distance of the body from the corneal center in the vertical plane. Either negative may be used for this last measurement, since no displacement of the tube has taken place in this direction. The three measurements are then entered on the chart, as shown in the cut.

This is substantially the same as Hulen's plan for plotting, and gives remarkably accurate results. Besides the location of the foreign body, it gives two dimensions of the size. If the particle is long and thin, it may be necessary to make two sets of measurement—one from each end—but as a rule this is not necessary. It is enough, in the majority of cases, to make the measurements from the anterior end or center, and, the size being directly measured on the plate, the entire particle can be sketched in accurately.

Advantages of the method. The most patent advantage of this method is its simplicity. It is readily understood and the rationale is readily followed. It is quickly done. If one is familiar with the procedure, and if everything is ready at hand, it is possible to complete the whole process in half an hour—exposures, developing, plotting, and all. The plotting takes but a few minutes—five or ten at the outside. The advocates of the so-called simpler methods have done nothing except dispense with the measuring and plotting. The adjustment of any sort of indicating apparatus takes as much time as the Dixon head rest, and the development is, of course, the same. It has been urged against X-ray localization, especially by the advocates of the sideroscope and the giant magnet, that these latter are much quicker. But it is a very doubtful point whether the time consumed in the X-ray examination adds materially to the gravity of the prognosis, especially when the foreign body has been in the globe for a matter of hours, and the accurate information gained is surely worth the disadvantage.

The indicator. It is undoubtedly of greater importance to be accurate in localization in the anterior part of the globe than in the posterior, so the most desirable position for the indicator is in the center of the cornea. In this position the liability of error, when the foreign body is situated in the lens or on the ciliary body, is very small, and the measurements should be within 1 mm. of the exact location. In the posterior segment of the globe, farther away from the indicator, a slight error in accurate plotting will give a wider error in the angle the farther the foreign body is from the indicator. The size of the globe being an unknown factor, which can only be inferred from the refraction of the fellow eye, it is not always possible to say with certainty that the foreign body is in the retina or in the orbit outside of the globe. However, this latter difficulty applies to all methods, and is rather due to our lack of knowledge of the anatomical measurements in the particular case than a defect in the method. Certainly, the methods which rely on an indicator placed on the lids, external canthus, etc., have a much larger element of uncertainty, as the distance must be measured to the corneal center, in any event—three measurements are often necessary—and it is difficult to be sure that the distance has not varied between the time of measurement and the time of exposure. Finally, the nearer the indicator is to the cornea, the less chance there will be for error in this measurement.

The author prefers the method of Dixon to that of Sweet in that it is more readily understood, the apparatus is fully as easily managed, and the results are as accurate.

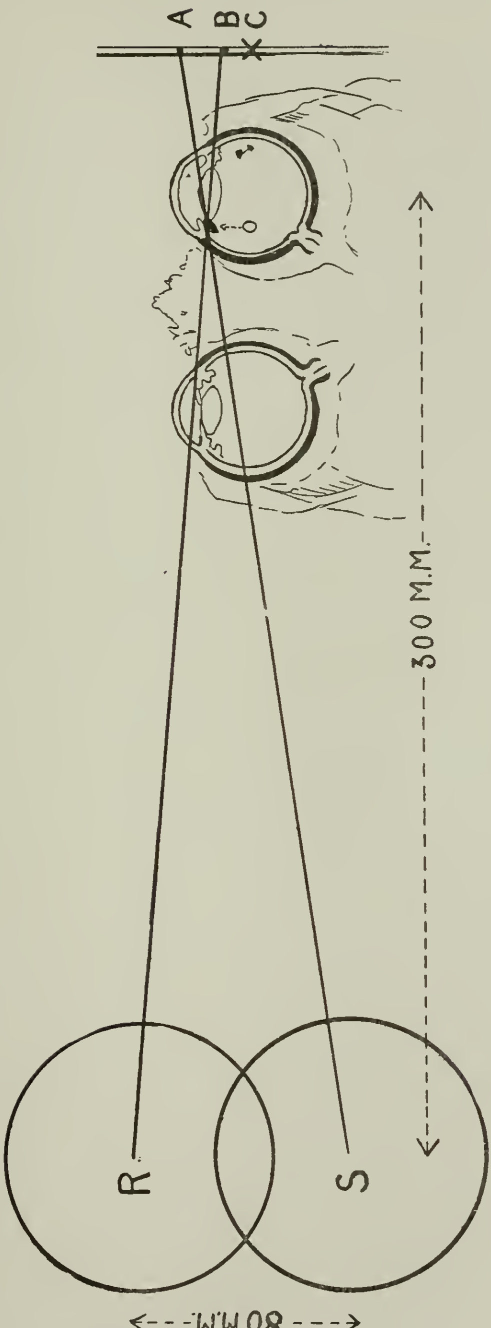
Ramsay's Modification of Mackenzie-Davidson's Method.

Ramsay uses a modification which is somewhat simpler as regards the apparatus used. He has the patient sitting in a chair with a plate-holder and chin-rest attachment, so that the plate is closely applied to the side of the injured eye. A small wire cross is fixed to the external orbital margin on a level with the outer canthus, to act as an indicator. The Crookes tube is then placed on a level with the eye and 300 mm. from the center of the cornea, "the center of the anode being exactly opposite the center of the small wire cross." (This is evidently somewhat approximate.) Two exposures are made, the one with the tube 40 mm. in front of the plane of the indicator, the other 40 mm. behind. On the developed plates the distance of the foreign body from the indicator is measured, as is shown by the positions A and B in the accompanying diagram, C being the shadow of the indicator.

Assuming that AB = 9 mm., then, according to the laws of similar triangles, we have:

RS : SO :: AB : BO, or 80 : 300 :: 9 : BO ∴ BO = 270/8 = 33.75 mm.; so that the foreign body is situated 33.75 mm. to the nasal side of the indicator, or the outer canthus. It will be noted, that the distance of the tube being measured from the corneal center, there is a slight error in the figure "300," which should represent the distance of the tube from the foreign body. However, this is small in proportion, and is disregarded in the method. The antero-posterior distance is computed by taking the middle point between A and B, or by the formula CA + CB ÷ 2, which in the illustrative case equals 14 + 5 ÷ 2 = 9.5 mm. The vertical distance is measured directly from either negative, as both are on the same vertical plane.

While these measurements may be sufficiently accurate for all practical purpose, as is claimed by the author of the method, it is evident that the resultant figures give the distances from the indicator only, and are therefore open to a greater error than where the indicator points directly to the corneal center, as in the methods of Sweet and Dixon. In plotting the location of the foreign body with reference to the envelopes of the globe, a further measurement must be taken into account, i. e., the distance of the indicator from the corneal center; and while this may be estimated with a fair degree of accuracy, it must be done at the time of exposure, as any change in the axis of the globe would necessarily introduce an error into the calculation. The method, while simple and convenient, takes as much time as the more accurate methods, and cannot be reliable.



Ramsay's Method of Localization.

Method of Guilloz.

This method, which is mentioned as the best in the *Encyclopédie Française d'Ophtalmologie* is also quoted by Beard. Two tubes are used and exposed at the same time. They are aligned exactly 50 cm. above the plate, which has a wire wrapped around it and placed so that the wire is exactly parallel to the line joining the anticathodes.

The patient has three indicators attached to a point just external to the supra-orbital notch, to the margin immediately below the first, and to the external orbital rim, respectively. The patient lies with the affected eye next the plate, and fixes so that the orbital axis is parallel to the plane of the plate. The resulting negative gives double images, or "biconic projections" of the indicators and the foreign body. The indicators are easily identified by their positions and lines connecting the shadows of the same indicator should be parallel to the shadow of the guide-wire. The distances between the indicators are measured on the patient, and the distance of the tubes from each other and the distance from the plate (50 cm.) being known, it is easy to work out the distance of the foreign body from the indicators by triangulation (as in Mackenzie-Davidson's method), which is done by a special instrument. The distances are measured on bits of wire, which are then attached to small pieces of lead, one for the foreign body, to which the three wires are attached, and the other end of each wire to a piece of lead which represents the position of each indicator. A special form of compass is now used, with three adjustable outer points, which are adjusted to the indicators on the patient's orbit, as a matter of verification, and one central point to represent the position of the foreign body. The points are first fixed in position, and then stuck into the three lead pieces representing the indicators, and the external one is stuck into the lead representing the foreign body. It will be remembered that these three outer leads are connected to the central one by wires which have been measured, and it follows that if the central point is pressed down until the wires are taut its point will represent the position of the foreign body. The central point can be slid up and down without altering its direction, and is graduated. The distance back of the plane of the three indicators is read on the scale and then the central point is withdrawn to a sufficient distance so that it will show by its direction where the foreign body lies,—always providing that the patient's eye is in the same position as it was during the will not touch the cornea, the leads are removed, and the compass is placed on the indicators on the patient's orbit, when the central point exposure.

To the writer, this procedure seems unnecessarily complicated. The three indicators make the proceeding cumbersome and offer no advantages over one indicator placed over the corneal center. The calculation is as easy with one indicator as with three, and the method of anatomical localization is troublesome and gives only a more or less graphic representation of the location of the foreign body when it is done. To be sure, in the Sweet and Dixon method the surgeon about to operate must judge—when he is shown that the foreign body is 10 mm. back of the corneal center—just how far that is, but this is not more exact in the method of Guilloz, while the chart which is dispensed with by Guilloz is often of the greatest value, particularly when the foreign body is in the anterior segment and the surgeon wishes to know whether the particle is in the lens, on the ciliary body, or in the vitreous.—(E. S. T.)

Loch. (G.) Foramen; hole.

Lochbrille. Stenopeic glasses.

Locke, John (1792-1856), born at Fryeburg, Me., graduated in medicine from Yale in 1819, and became geologist on the United States survey of the North-West territories and Ohio. From 1836 onwards he was professor of chemistry in the medical college of Ohio, and was a pioneer in scientific research. He invented and improved many instruments for use in optics, physics, electricity, and magnetism, notably the gravity escapement for regulator-clocks (1844), and his electro-chronograph, purchased for the United States naval observatory for $10,000. He contributed largely to the proceedings of various scientific societies and to the *American Journal of Science,* besides publishing text-books on botany and English grammar.—(*Standard Encyclopedia*).

Locke's solution. A solution used for the purpose of attempting to maintain the activity of the isolated mammalian heart. The solution consists of sodium chloride, potassium chloride, calcium chloride and sodium bicarbonate in the proportion in which they exist in blood serum, with the addition of a small quantity of dextrose. It has also been used—by Magitot, for instance—as a preservative fluid in transplantation of the human cornea. See **Cornea, Transplantation of the.**

Lockwood's ligament. Suspensory ligament of the globe, connecting Tenon's capsule and the orbit.

Loco weed is the common name for the several plants which produce the "loco-disease" of western animals. The best known are *Astragalus mollissimus,* the purple-flowered, woolly loco-weed; *A. hornii, Aragallus spicatus,* the most dangerous variety, and *Oscytropis lamberti.* These silvery-white perennials, growing about 1 ft. high with

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Locomotor ataxia. See **Tabes dorsalis.**

Locus unionis nervorum opticorum. (L.) Chiasm.

Loebenstein-Loebel, Eduard Leopold. A physician of Jena, Saxe-Weimar, who seems to have devoted considerable attention to diseases of the eye. Born at Lübben, lower Lausitz, in 1779, he received his degree in medicine at Jena in 1802, and settled at once as general practitioner in that city. In 1811 he became extraordinarius, and, in 1814, medical councillor. He died April 16, 1819.

His only ophthalmologic writing was "*Grundriss der Semiologie des Auges für Aerzte.* (Jena, 1817; Fr. Trans. by Lobstein. Strassburg, 1818.)—(T. H. S.)

Loeb's capsule bacillus. This micro-organism resembles the capsulated bacillus of Pfeiffer, although it is somewhat larger and thicker than the latter. It was originally obtained from a case of keratomalacia in a child. It is an aërobic, non-motile and non-liquefying bacillus, and is capable of growth in the usual culture media at ordinary temperatures.

Loemology. The science of contagious diseases.

Loemophthalmia. (L.) An obsolete name for contagious ophthalmia.

Loeser, Leo. A German ophthalmologist, born at Meiningen, Germany. He studied with Schweigger and Silex, and settled in Berlin. For a long time he was correspondent of the *Centralblatt f. Praktische Augenheilkunde.*—(T. H. S.)

Löffel. (G.) A spoon; a scoop.

Löffelweise. (G.) By spoonfuls.

Löffler bacillus. A pathogenic form from diphtheric membranes. It is the specific bacillus of diphtheria. It forms non-motile rods, straight or somewhat bent, 1 to 5μ long. Called also *Klebs-Löffler bacillus.* See **Bacteriology of the eye.**

Löffler's serum. Blood-serum of the bullock, 3 parts; glucose bouillon, 1 part: used as a medium in preparing slant-cultures.

Löffleria. A disease in which the diphtheria (Klebs-Löffler) bacillus is present without the ordinary symptoms of diphtheria.

Logadectomy. A term, invented by S. M. Griffith, meaning excision of a portion of the conjunctiva.

Logades. (L.) The "whites" of the eyes.

Logaditis. (L.) (Obs.) Scleritis.

Logadoblennorrhea. An old term for conjunctival blennorrhea.

Logger, Johannes. A Dutch surgeon who devoted considerable attention to the eye. Born in Dordrecht, he studied at Leyden, where he practised until his death—Oct. 12, 1841. He wrote "*Over de Zwarte Staar*" (Amsterdam, 1812).—(T. H. S.)

Log-glass. Hand-glass. A small magnifying glass for increasing the power of sight.

Loimophthalmia. An obsolete name for contagious ophthalmia.

Lolium perenne. Ray grass. Cattle eating this plant have been blinded.

Lolium temulentum. Bearded Darnel. Lover's steps. This poisonous grass, a native of the temperate regions of Europe and Asia, has been naturalized in the United States. Numerous cases of poisoning have been reported through its presence in flour. Its toxic properties are due to the presence of temulin which acts as a powerful nervine. The production of vertigo, headache, loss of sensation, tinnitus, deafness and quite frequently mydriasis and loss of vision have been noted from the earliest times. Ovid says of this plant that its ingestion is productive of blindness. It has long been believed that the so-called "moon blindness" in cattle has been brought about by their feeding upon the different forms of lolium. Cordier (*Nouv. Journ. de Médec.* p. 379, Vol. 6, 1819) noticed a clouding of vision half an hour after eating bread known to have been contaminated with the parts of this plant.

Lombard. A French ophthalmologist of the early nineteenth century, who seems to have been a charlatan. Neither the places nor the dates of his life or of his death are now known. He practised first at Antibes, then at Montepellier, finally (perhaps) at Paris. He published a little book which was filled with ignorance, superstition and quackery, and which bore the title, "*Considerations et Observations sur la Guérison des Cataractes et des Affections de la Cornée par une Méthode Resolutive et de Fistules sans Opérations*" (Paris, 1839).—(T. H. S.)

Longeur de foyer. (F.) Focal length.

Longevity and eye diseases. See **Life insurance and ocular findings.**

Longinus. The name may be derived from the greek *logxe*, a lance. According to a sixth century tradition, the name of the soldier who, at the crucifixion, pierced Christ's side with a spear. The legend also identifies this soldier and the centurion who conducted the crucifixion. According to the same tradition, the blood and water which flowed from the wound, fell into one of the eyes of the soldier, or centurion, and healed it, according to some, of an ophthalmia, according to others of a squint.

According to Thomas Malory (*History of Prince Arthur*, I, 40 *Anno* 1740) the spear of Longinus was brought to Glastonbury by Joseph of Arimathea, and from it sprang the famous Glastonbury thorn.—(T. H. S.)

Longius. The same as **Longinus,** q. v.

Longitudinal aberration. A term applied to the distance of a ray from the geometrical focus, measured along the axis. See, also, **Aberration.**

Longmore, Sir Thomas. A celebrated English military surgeon, who devoted considerable attention to the eye. Born at London, Oct. 10, 1816, he studied at Guy's Hospital, became Assistant Surgeon in the Army in 1843 and Surgeon in 1854, finally rising to the office of Inspector General in 1872. In 1876 he retired from military practice. He was one of the founders of the Geneva Convention (in 1864) and was a Fellow of all the Red Cross congresses. In 1886 he was knighted. He died Sept. 30, 1895, at Swanage, Dorset.

His only ophthalmologic writing was "*The Army Medical Officer's Ophthalmic Manual*" (London, 1863; 2d ed., 1875).—(T. H. S.)

Long-sighted. Hypermetropic (or presbyopic).

Long-sightedness. Hypermetropia.

Lonicera xylosteum. Honeysuckle; a species with emetico-cathartic properties. Lewin and Guillery (*Die Wirkungen von Giften auf das Auge*, Vol. I, p. 225), report several cases of dilated pupil, photophobia and bloodshot conjunctivæ in children who ate the red berries of the common plant. Probably the active principle, to which the intoxication is due, is the xylostein.

Looming. A form of mirage.

Loops, Capillary corneal. See **Capillary loops of the cornea.**

Lopacki, Stanislaus Anton. A Polish physician, botanist and pharmacologist, who devoted considerable attention to the eye. He studied at Cracow and Padua, settled in Cracow, and there, in 1691, became Professor of Botany and Pharmacology. He died in 1738. His only writing, ophthalmologic or general, is entitled "*Questio de Ophthalmia*" (Cracow, 1691).—(T. H. S.)

Lorch, Leo Hugo. A well-known German ophthalmologist. Born at Mayence, May 25, 1808, he received his medical degree in 1830 at Mayence. After a year of further study in France, he settled as ophthalmologist at Mayence. Here, in 1834, he founded an ophthalmic institute, which, however, in the following year, burned down. Before he could re-erect the structure, he died—Nov. 12, 1835, only 28 years of age.

Lorch's only writing was "*Makrobiotic der Augen,*" which was published posthumously in Mayence, 1837.—(T. H. S.)

Lordat, Jacques. A well-known Monspellensian anatomist and physiologist, who devoted considerable attention to the eye, especially the theory of vision. Born at Tournay (Hautes-Pyrénées) Feb. 11, 1773, he received the medical degree at Montpellier in 1796, and, for the next three years, was physician in the military hospitals at that place. In 1799 he began to give instruction in anatomy and physiology, and in 1802 was elected prosector at the medical school. Two years later he was chief of the anatomical department. In 1811 he obtained by competition the chair of operative medicine, and, two years later, that of physiology, which he held for nearly fifty years. He resigned in 1860, but did not die until April 25, 1870, when he was 98 years old.

His writings are mostly in the general field. One article he wrote, however, within the limits of our specialty: "Réflexions sur quelques Points de la Théorie de la Vision" (*Ephémérides Méd. de Montp.,* 1828, Vol. VI, pp. 340-376.)—(T. H. S.)

Lorenz chromometer. See **Chromatic eye test.**

Loretin. This is a complex organic acid occurring as a yellow, crystalline powder insoluble or only slightly soluble in water and alcohol. It has been put forward as a substitute for iodoform. Nicati has advised its employment as a dusting powder for diphtheria of the conjunctiva in the following mixture:—Loretin; calomel, āā 1.00 (gr. xv); pulv. acid. boric., 50.0 (℥ii); to be dusted on the infected areas, as well as upon the lids and the whole covered with a sterile cotton dressing.

Lorgnette. An opera-glass; a name also (improperly) given to a *lorgnon.*

Lorgnon. (F.) An eye-glass, or a pair of eye-glasses, capable of being shut into a frame, which serves as a handle.

Loring, Edward Greely. A famous American ophthalmologist, inventor of the Loring ophthalmoscope and author of the well-known "*Text Book on Ophthalmoscopy.*" Born in Boston in 1837, the second son of Judge E. G. and Harriet Booth Loring, he began to study medicine at Florence, Italy, in 1859. Later he studied at Pisa, and, returning to Boston in 1862, he entered the Harvard Medical School in that city, and received the degree of M. D. in 1864. Deciding to become an ophthalmologist, he secured an appointment as externe to the Ophthalmic Clinic of the Boston City Hospital, and, later, at the Massachusetts Charitable Eye and Ear Infirmary. In 1865 he settled in Baltimore, Md., but, next year, removed to New York, where he formed a partnership with Dr. Cornelius Rea Agnew. He was surgeon to the Brooklyn Eye and Ear Hospital, the Manhattan Eye and Ear Hospital, and to the New York Eye and Ear Infirmary. He was a member of numerous medical societies.

He married twice; first, a daughter of the art connoiseur, James Jackson Jarvis, and afterwards a Mrs. Swift of New York City. There were no children by either marriage.

His death was extremely sudden, for even he himself had had no suspicion of the presence of disease in his own person. But, walking across a street, he staggered, caught at a lamppost, fell, and was lifted up dead by a policeman who had happened to be passing. This occurred April 23, 1888. There was found, at the autopsy, atheroma of the coronary arteries.—(T. H. S.)

Losophan. Trimetacresol iodid; a crystalline substance, insoluble in water, and used in eczema and syphilis in 10 per cent. solution and in ointment.

Loss of blood, Blindness from. See p. 292, Vol. I, also p. 5797, Vol. VIII, of this *Encyclopedia.*

Lota vulgaris. The *burpot, eel-pout* or cony-fish is a fresh-water species locally distributed in central and northern Europe and in North America. The bladder is used in Russia in the preparation of an inferior quality of ichthyocolla; the liver oil was formerly official under the name of *liquor hepaticus mustela fluviatilis,* and was used for spots on the cornea, for hemorrhoids, and in preparing an eye salve.

Lotio nigra. Lotio hydrargyri nigra. P. Br. Black mercurial lotion. Aqua nigra. Aqua mercurialis nigra. Aqua ophthalmica nigra. See **Black wash.**

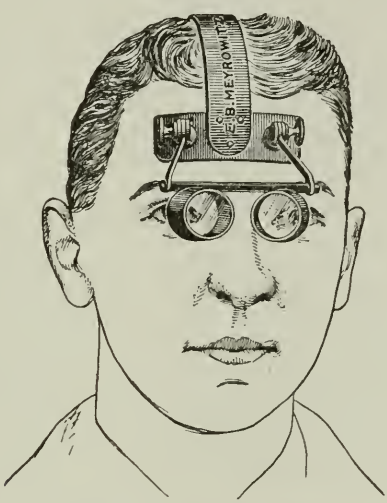
Lotion, Eye. See **Collyrium.**

Lotus biflorus. A plant found in Southern Europe, where the seeds are employed as an emollient poultice in colic and inflammation, and especially in eye diseases.

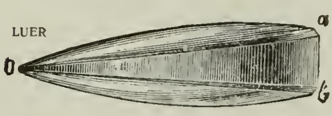
Louche. (F.) Squint-eyed; squinting.

Louchettes. (F.) Squinting spectacles. The eyehole opposite the squinting eye is filled with a kind of opaque glass in which there is a small perforation, which makes it impossible for the wearer to look in any other way than through the opening. In medieval times this device was employed for the *cure* of strabismus and not, as in modern times, for the training and visual improvement of the unused and defective eye.

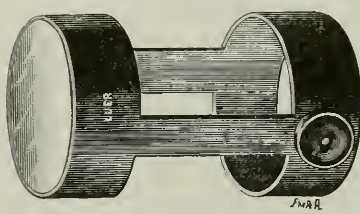
Loupe. (F.) A magnifying glass and condensing lens, especially used by watchmakers, engravers, surgeons, etc. These ophthalmically useful instruments (both monocular and binocular) are described and their purposes indicated under various headings, e. g., on p. 4609, Vol. VI, as well as on pp. 2771 and 2772, Vol. IV, of this *Encyclopedia.* See, also **Berger's binocular loupe,** as pictured on



Jackson's Binocular Loupe.



Galezowski's Loupe, for Obtaining a Lateral View of the Ocular Interior.

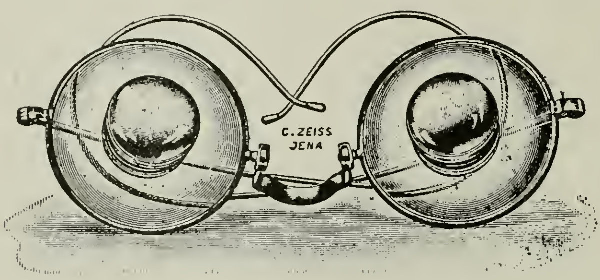


Polak's Loupe, for Examining both the Exterior and the Interior of the Eye.

p. 936, Vol. II; and under **Convergiscope**; and **Corneal loupe.** The most useful binocular loupe for the ophthalmic surgeon is probably that of Edward Jackson, which with a few others are herewith depicted in the text.

A specially constructed *spectacle loupe* for both emmetropic and ametropic observers has also been made by Von Rohr and Stock (*Oph-*

thalmic Year-Book, p. 54, 1913). This useful instrument gives a magnification of two diameters at 25 cm. distance. It is achromatic and also corrected for oblique pencils. The combination consists of a convex loupe of 12.5 cm focal distance as the objective, with a concave ocular. Each of these components consists of two lenses, those of the objective not in immediate contact but separated by a layer of air, thus giving two additional surfaces for optical corrections. The negative component consists of two lenses, one of crown and the other of flint glass, cemented together. Two such magnifying systems are attached to a spectacle frame and adjusted to each eye of the wearer. The entire instrument weighs but 15 grams, and permits an emmetropic eye to look below or to the side of the magnifiers. In the case of an ametrope the loupe can be inserted in the center of his correcting



Achromatic Spectacle Loupe of Von Rohr and Stock Attached to Correcting Glasses.

lenses so that he may have a view but slightly impeded around them. The weight of one such combination is 27 grams. No compensation is made for convergence, but this is not necessary. Threefold magnification can also be attained by varying the strength of the components. See the figure.

Loupe à bague. (F.) A magnifying lens attached to the finger by a ring.

Loupe à tirage. (F.) A magnifying reading or drawing lens.

Loupe bocal. (F.) A "vessel" loupe, i. e., a magnifying device consisting of a hollow glass sphere, filled with greenish-hued water. Its object is to concentrate the light of a lamp or candle on the field of a workman's activity—e. g., that of a shoemaker. The focal length of a loupe bocal is several inches greater than that of a solid glass sphere, and the greenish light is thought to be soothing to the eyes.

Loupe, Corneal. This is fully treated under **Corneal loupe,** p. 3386, Vol. IV of this *Encyclopedia.*

Loupe redressante. (F.) Erecting eyepiece.

Louse. A general name for various degraded parasitic insects; the true lice, which infest mammals, belong to the suborder *Anoplúra*. Those which are parasitic upon man are *Pediculus capitis,* or head-louse; *Pediculus corporis,* the body- or clothes-louse; and *Pediculus pubis,* or crab-louse, which lives in the hair upon the pubes and in the eyelashes and eyebrows. See **Lice.**

Love-peas. JEQUIRITY. See **Abrus precatorius.**

Löwe's ring. A bright violet ring seen on looking through a solution of chromic chlorid.

Low-power objective. Objectives of low magnifying power and long focal length.

Loxophthalmus. (L.) An old term for strabismus; also, having oblique or squinting eyes.

L-suprarenin. A synthetic adrenal compound. Stoll (*Lancet-Clinic,* 109, p. 679, 1913) has given an account of its use in ophthalmic surgery. See **Suprarenin.**

Luca, Domenico di. An Italian ophthalmologist. Born in 1820, he became assistant to Castorani, and afterwards extraordinary professor of ophthalmology at Naples. He wrote a few articles and a small handbook on diseases of the eye, and died in 1887.—(T. H. S.)

Lucas, Francesco. A Spaniard who is believed to have been the first (in the sixteenth century) to devise tangible letters for the blind. See **Alphabets for the blind.**

Lucas, Richard. A famous blind clergyman of the Church of England. He was born at Presteign, Radnorshire, Wales, in 1648. At the age of 16 he entered Jesus College, Oxford, and, in 1672, was ordained. Shortly afterward he was appointed Master of the Free School at Abergavenny. Later, he was given the vicarage of St. Stephen's, Coleman St., London. About this time he became blind. He continued, however, in active service, and, in fact, in 1691, was installed as Prebendary of Westminster.

Lucas was an excellent writer, not always clear, but ever persuasive and now and then sublime. Among his works are: "*Practical Christianity;*" "*An Enquiry after Happiness;*" "*The Morality of the Gospel;*" "*Christian Thoughts for Every Day in the Week;*" "*A Guide to Heaven;*" "*The Duty of Servants;*" five volumes of sermons and a Latin translation of "*The Whole Duty of Man.*"

He died in 1715, and was buried in Westminster Abbey. His grave, however, remains unmarked.—(T. H. S.)

Luce. (It.) Light.

Lucent. Bright; reflecting light vividly; resplendent.

Lucernal. Relating to a lamp or other artificial light.

Lucernal microscope. A microscope in connection with which a lamp is employed as the source of illumination.

Lucida. A star visible to the unaided eye.

Luciferase. An enzyme produced by *Pholas dactylus,* a luminiferous marine mollusk. When its aqueous solution is mixed with the alcoholic solution of luciferin, light is produced.

Luciferin. A crystalline body, soluble in water, found in the photogenic organs of animals.

Lucific. Producing light.

Luciform. Resembling light; of the nature of light.

Lucifuga. An obsolete name for "night sight," or nyctalopia (q. v.).

Lucifugal. Lucifugous. Avoiding bright light.

Lucigen. This is a name given to one of the most powerful artificial lamps, which is specially well adapted for lighting large spaces, whether open or covered. The light, which is produced by burning creosote-oil, is brilliant and diffused, and does not cast black shadows. The construction of the lamp is exceedingly simple. The tank or oil-reservoir is a plain circular drum, to the top of which the burner is fixed. A burner-tube extends to the bottom of the drum, passing through an outer tube, which is pierced with holes through which the oil is strained, and passes down into the small well in the bottom of the tank. The compressed air enters the drum, and forces the oil up the tube to the oil-cone. The heated air from a heating-coil enters the annular space between the oil-cone and burner, where the air and oil become amalgamated and escape in the form of a spray or vapor which is immediately inflammable.—(*Standard Encyclopedia.*)

Lucilia hominivorax. A fly whose larva is occasionally found in the ocular tissues. W. Reis (*Ophthalmology,* Vol. 10, p. 153, 1913) reports the case of an old woman, poorly nourished, in whom he found, at the bottom of an orbital ulcer, 240 larvæ of this species.

Lucimeter. A photometer; a sunshine recorder in the form of an evaporometer.

Lucotherapy. Phototherapy. The treatment of disease by rays of light. See, also, **Blue light.**

Lücke, Optische. (G.) Optic foramen.

Luculent. Luminous; transparent.

Ludicke's chromatoscope. An instrument for determining the refractive index of the colored rays of light.

Ludwig, Christian Gottlieb. A celebrated Leipsic surgeon of some importance ophthalmologically. Born April 30, 1709, at Brieg, Silesia, he received his medical degree at Leipsic in 1737. In 1740 he became extraordinary professor of medicine at his *alma mater,* then, successively at the same institution, professor of anatomy and surgery in 1747, professor of pathology in 1755, and of therapeutics in 1758. In the last named year he was also made dean of the faculty. He died May 7, 1773.

Among his most important writings may be mentioned six successive volumes of "*Institutiones,*" which appeared from 1752 to 1765, and all of which became well known authorities. These were the Institutiones "*Physiologicæ,*" "*Medicinæ Clinicæ,*" "*Chirurgicæ,*" "*Pathologiæ,*" "*Therapiæ Generalis*" and "*Medicinæ Forensis.*" The "*Institutiones Chirurgicæ*" (Leipsic, 1764) contains some sixty or seventy pages on diseases of the eye, the matter contained in which was, for many years, of high authority among specialists as well as among general practitioners.—(T. H. S.)

Lues. (L.) A plague, pestilence; syphilis.

Lues celtica. An old name for syphilis.

Lues amboinica. (L.) An obsolete synonym of syphilis.

Luesan. A trade name for "the organic union of mercury with wheat proteid, which brings about a marked reduction of the toxic characteristic of the drug and permits of long-continued administration, without the disadvantages that attend the use of the mercuric salts." Luesan is issued in glass tubes of twenty-five tablets, each of 1/6 grain mercury; the average dose is one tablet two or three times a day, after meals.

Luetic keratitis. See **Keratitis parenchymatosa.**

Luetin. This cutaneous reaction for testing the presence of syphilis was devised by Noguchi. It is performed by injecting intradermatically a sterile emulsion containing killed spirochetæ pallidæ obtained from pure culture. Martin Cohen (*Arch. of Ophthal.* Jan., 1912) believes that thus far the test had been absolutely harmless in 170 cases inoculated during the previous five months, there having been no reactions in 94 per cent. of cases considered non-syphilitic, and only mild and atypical reactions in the remaining 6 per cent., the test appears to be of considerable negative value. In 76 per cent. of the ophthalmologic cases in which the test was performed, it conformed either with the clinical evidence and the Wassermann reaction together, or with one of these factors of comparison separately. It may, therefore, be concluded, even in the present experimental stage of the study of the luetin test, that a positive reaction is strongly presumptive evidence of the existence of syphilis. It is anticipated that with more active luetin and improvement in its method of preparation the above mentioned percentage conformity will be much higher. The luetin test was positive in ten cases regarded clinically as syphilitic in which, presumably because of previous antisyphilitic treatment, the Wassermann was negative.

Löwenstein (*Med. Klinik,* No. 11, 1913) tried the luetin reaction in twenty cases of hereditary metasyphilitic and gummatous affections of the eye. The luetin reaction is a spirochetal reaction; therefore, it is not surprising to find cases or hereditary lues (evidently metalues) with negative Wassermann reacting positively to luetin. If in many cases of hereditary or metaluetic affections, despite negative Wassermann, a positive luetin reaction is obtained, it would indicate the presence of spirochetes or their reaction products.

S. H. Browning (*Ophthalmic Review,* January, 1914) has used the luetin test in conjunction with the Wassermann reaction in a series of eye cases, and has found that in several instances the latter was negative while the former was positive, and in most of these cases there was from the clinical point of view little doubt that the patients were syphilitic. In a few cases Browning obtained a positive Wassermann and a negative luetin test.

As a means of deciding whether a patient is cured of syphilis, the author is inclined to believe that the luetin is superior to the Wassermann reaction. The skin test should possess great value where the question of syphilis is complicated by a history of some other protozoal disease, such as malaria. In chronic cases of syphilis, where the Wassermann reaction is positive in 60 to 70 per cent. of the cases, the luetin reaction has special importance. Briefly, in 78 of the 100 cases he examined both the Wassermann and the luetin tests were made, and of that number the two yielded the same result in 62, or 79.2 per cent. The luetin test was positive and the Wassermann reaction negative in 9 cases (interstitial keratitis, 4; choroiditis, 2; tabes dorsalis, 2; and severe anemia, 1). Of the 22 cases where the Wassermann reaction was not done, 15 were indefinite cases of syphilis which had been treated; these were all positive. Five were definite cases of syphilis with negative luetin test.

In reply to a question the *Jour. A. M. A.,* Mar. 6, 1915, says that the luetin reaction is comparatively seldom positive in the secondary stage of syphilis. In such cases it may become positive when the treatment is instituted. The reaction in these cases, in which the Wassermann is likely to be negative, is of diagnostic value because it shows that the case under treatment is reacting to the treatment with the production of allergy. When such a positive reaction becomes negative again, it may be assumed that a temporary immunity has been established. See, also, **Syphilis**.

Luft. (G.) Air.

Lugol's solution. See **Iodine.**

Lumbar puncture, Ocular relations of. See, also, **Meningitis.** Until within recent years the therapeutic rôle of lumbar puncture in ocular pathology had attracted little attention. From their observations on eight cases in which this operation was performed, Babinski and Chaillous (*Ann. d'Oculistique*, July, 1907) conclude that lumbar puncture ought to be considered as a curative method of treatment of optic neuritis due to intra-cranial effusion either of post-traumatic or of inflammatory origin. In cases due to intra-cranial tumor the puncture is only palliative. In all cases lumbar puncture ought to be practised with prudence, and the quantity of fluid evacuated ought to be less elevated where the symptoms of compression are less marked. The puncture ought to be repeated whenever it is deemed necessary to avoid the disorders due to the compression, and in particular the optic atrophy which may follow optic neuritis of intra-cranial origin.

Frenkel (*Ann. d'Oculistique*, Jan., 1908) states that this procedure while considered palliative in tuberculous meningitis, has a number of cures to its credit in the non-tubercular forms. It appears to be particularly effective in the clinical type described by Quincke under the name of serous meningitis. In many cases of meningeal hemorrhage, particularly the traumatic, the method may be indicated when there is no urgent necessity to evacuate the blood. Palliative results are obtained in hydrocephalus. In optic neuritis from cerebral tumor prudence should be used in treatment by lumbar puncture, as in some cases sudden death has followed it, and in others there has been an aggravation of the nervous symptoms, particularly of headache and vomiting. In the uremia of Bright's disease there may be real relief, though only of symptoms. In labyrinthine diseases of the ear lumbar puncture diminishes the vertigo and tinnitus and even the deafness.

In all three the effect is obtained by diminution of the tension produced by the excess of cerebrospinal fluid. There is a very reliable clinical sign of this hypertension in the optic neuritis of stasis, and the diagnostic and therapeutic value of lumbar puncture in optic neuritis has recently attracted the attention of neurologists and ophthalmologists.

Igersheimer (*Klin. Monats. f. Augenh.*, V 53, p. 63) emphasizes the importance of lumbar puncture in determining the etiology of retrobulbar neuritis with scotoma. The significance of the test, he asserts, is so far too little known to or valued by ophthalmologists. His illustrative cases include one or two in which lumbar puncture cleared up doubts as to the presence of syphilitic involvement of the central nervous system, and one in which a negative result of the test of the spinal fluid, in an unquestionable case of general lues, rendered it probable that the disease of the optic nerve had arisen, not by extension from a meningitis, but through the blood stream in the same way as syphilitic iritis may be assumed to occur. Where central scotoma develops, secondary to syphilitic meningitis, he assumes an extension of the infection along the nerve sheath, with consequent disturbance of the peripherally placed papillo-macular bundle. He hopes that fuller investigation will show to what extent examination of the spinal fluid may be depended on to indicate whether an optic neuritis is the result of cerebral lues, or rests, like iritis and other involvements of the coats of the eye, on a metastatic basis.

The experience of American operators seems to incline them to trephining (decompression) rather than to lumbar puncture in cases of cerebral hypertension. The danger is at least no greater than in lumbar puncture and the results are regarded as more satisfactory, and more permanent. See, also, **Brain tumor, Operations for,** on page 1276, Vol. II, and **Choked disc,** p. 2074, Vol. III, of this *Encyclopedia.*

Lumbar anesthesia, Ocular symptoms from. This method is occasionally followed by eye symptoms, much less frequently than formerly however, because of experience and improved technique. One of the early cases was reported by Gontermann (*Berlin Klin. Wochenschr.* p. 1522, 1908) who on the eighth day after lumbar injection of 0.0625 tropacocain (without adrenalin) between the 1st and 2nd lumbar vertebræ, noticed the left abducens become paretic; also the right one slightly. Recovery occurred after six weeks. The late occurrence of the paralysis spoke for a toxic affection of the nuclei, not through direct local action, but by way of absorption, similar to nephritis after lumbar anesthesia and other palsies.

Lumen. An old term for the pupil of the eye.

Lumière. (F.) Light.

Lumière blanche. (F.) White light.

Lumière intra-oculaire. (F.) The light which constantly penetrates the eye when the eyelids are closed, giving a sensation of dull, yellow-white light.

Luminant. Emitting light; radiant of light.

Lumine. The luminiferous ether.

Luminescence. The state of a body wherein it emits light without having been rendered incandescent.

Luminiferous ether. A hypothetical medium filling all space through which the vibrations of light, radiant heat, and electric action are propagated.

Luminosity. The intensity of light in a color, photometrically measured.

Luminosity of the animal eye. Conditions favorable to the luminous appearance of the eyes of animals are the tapetum, the hypermetropia of the animal eye and the direction of the rays of light impinging on the eye, as described by Cumming and Brücke. W. Lohman describes the following experiment:

In a dark room, one meter above a dog or cat, a candle or electric pocket lamp is held, which illuminates the face of the observer, while the animal is in the shadow. If the animal looks at the face of the observer he sees the eyes of the animal shining. If the observer turns his head so that the nose shades one of his eyes he sees only with his other, illuminated, eye the luminosity of the eye of the animal. The luminosity ceases at once if the illuminated eye of the observer is shaded by the finger or a stenopeic hole or by the upper orbital margin, after turning his head around the horizontal axis. It suffices to shade the cornea of the observer to stop the luminosity; so it may be assumed that the reflex image of the cornea of the observer is used as an ophthalmoscope.

Schauenburg makes in his booklet "*On the Ophthalmoscope,*" in 1859, the observation of the well-known entomologist Verloren that "The reflex image of his cornea sufficed for illuminating the eyes of some insects." See **Comparative ophthalmology**; also **Ophthalmoscope.**

Luminous paint. This is a phosphorescent powder, such as sulphide or oxysulphide of calcium, ground up with a colorless varnish or other medium, and used as a paint. Even in a dim light the phosphorescence goes on, and the object painted remains visible in the dark.

Lunar amblyopia. See **Moon-blindness.**

Lunar caustic. See **Silver nitrate.**

Lunar white. See **Eyes of soldiers, sailors, etc., Examination of the.**

Lund, Andreas. A Copenhagen physician, who devoted considerable attention to ophthalmology. Born at Copenhagen June 14, 1772, he there received his medical degree in 1797. In 1812 he was made Professor at the University, and in 1813 Fellow of the Sanitary College. In 1832 he became chief court physician. He died Feb. 15, 1832.

His only ophthalmologic writing was "*Exophthalmus utriusque oculi.*"—(T. H. S.)

Lundy, Charles J. A well-known ophthalmologist of Detroit, Mich. The date and place of his birth are not procurable. He received, however, the degree of M. D. at the University of Michigan in 1872, and the same degree *ad eundem* at Bellevue Medical College in 1875. For the next three years he studied ophthalmology. Returning to Detroit in 1878, he was soon recognized as an expert operator. He became professor of ophthalmology at the Detroit College of Medicine, President of the Michigan State Medical Society, and a collaborator on the *American Journal of Ophthalmology.* He died of appendicitis May 24, 1892.—(T. H. S.)

Lune. (F.) Moon; silver (alchemy).

Lunella. (L.) An old term for hypopyon.

Lunette. (F.) An eyeglass, a telescope; in the plural, *lunettes,* spectacles.

Lunette capillaire. (F.) Stenopeic glasses.

Lunette d'essai. (F.) Trial lens.

Lunette pantoptique. Stenopeic glasses.

Lunghezza centrica. (It.) Focal distance.

Lunula lacrimalis. (L.) A small ridge of bone which separates the antrum of Highmore from the lachrymal groove.

Lupe. (G.) Magnifying glass.

Lupenspiegel. (G.) The simplest form of ophthalmoscope.

Lupinus albus. Lupin or white lupin; an annual species, probably of Egyptian or east Mediterranean origin. It contains lupinin and lupanin, poisonous uncrystallizable alkaloids, producing paralysis of the nervous trunks and centers with symptoms somewhat analogous to those produced by atropine, but without the delirium of the latter or the spots on the skin indicative of vaso-motor paralysis, and with less pronounced mydriasis. Occasionally an amblyopia is produced, but as this is generally the result of the paresis of accommodation it passes off in a few hours or days.

Lupus. See **Lupus vulgaris.**

Lupus erythematosus. See **Lupus vulgaris.**

Lupus vulgaris. This manifestation of tuberculosis involving the dermal tissues at times invades the ocular structure also. The affection is so rare in America that both dermatologists and ophthalmologists of wide experience have seen few cases in this country, but in Europe the disease has been seen frequently. Because of the likelihood that an increasing number of cases might be seen here in immigrants in coming years, a somewhat extensive account of its manifestations will be given in this work.

The disease is marked by a chronic specific cellular infiltration of the skin, characterized by the formation of small, dark-red nodules beneath the surface. The nodules increase in size and in time coalesce to form appreciably elevated patches. The nodules themselves are soft; so that they become absorbed, or they break down and ulcerate, to be followed by more or less cicatrization. The disease owes its origin to an invasion of the integument by the tubercle bacillus.

The disease, though common on the continent of Europe is, as has already been stated, comparatively rare in America; certain dermatologists have declared that they have not seen it in natives of this country. Its manifestations are milder when seen here, than when seen among Europeans. It is a disease of early life, generally manifesting itself between the third and sixth years, invariably, however, before puberty, at which period of life it has been found more commonly in girls than in boys. It occurs more frequently in the debilitated and in those in whose family history are evidences of general tuberculosis; yet, though it affects more frequently the illy-nourished, the anemic and the victims of bad-housing, it is not confined to them. Measles, or the effects of traumatisms, it is believed, may act as exciting causes, because it has been seen to develop soon after such affections, but the direct cause of the disease is the tubercle bacillus.

The view that the dermal lesions were tuberculous was held by clinicians long before the discovery of the tubercle bacillus, because of the frequent association of lupus with other tuberculous processes. The truth of this view has been demonstrated amply by the evidence found in examples of contagion by accidental inoculation; by the success of experimental innoculation and by the exciting of reactionary symptoms by tuberculin injections.

The disease process consists of a combination of proliferation and ulceration, granulation and cicatrization, affecting chiefly the corium, in which layer the nodules are formed. The nodules, consisting of cells, which are clustered around the capillaries and lymph channels, show at their periphery layers of small round cells, beneath which is a zone of larger epithelial cells, and in the cells are large and well developed giant cells containing homogeneous centers and many peripherally arranged nuclei. These giant cells are more numerous and the epithelial cells are of greater size than those found in tubercular areas affecting other regions of the body.

Because the multiplication of the cells in the center of the nodule interferes with the vascular supply, the centers of the nodules degenerate and the nodules themselves undergo coagulation necrosis, followed by fatty degeneration and disintegration, the epidermis becoming so distended and attenuated that it is likely to rupture, in which event it is followed by ulceration.

In the epidermis, also, the rete proliferates and degenerates, and connective tissue forms between the papillæ, so that in a single specimen there may be equally well presented both the advance of the disease and its cicatrization. Similar changes occur in the epithelia of the glands and hair follicles. The presence of the tubercle bacillus is absolutely pathognomonic; it is constantly present, though not numerously, indeed in some cases it may be found only after prolonged search through many sections.

The reaction to tuberculin tests is distinctly positive, and notwithstanding the fact that tissue transplanted in animals produces tuberculous nodules, the scarceness of the bacilli in the lupus area is remarkable, although it cannot easily be explained. Nevertheless, it is not improbable that the bacilli are rapidly destroyed, and that morbid reactions result from the products of toxins generated by their destruction. The mode of entrance into the skin, too, is uncertain, although it may be by direct inoculation, or, by the extension from deeper tuberculous foci, while other cases may have arisen by transmission through the lymphatics and the circulatory systems, in which instance the idea of maternal inheritance should not be overlooked.

The onset of the disease is marked by an eruption of pinhead-sized spots which gradually enlarge and form nodules. After a time this initial eruption is followed by others and the nodules soon run together and constitute appreciably elevated patches. The area beneath the surface after a time becomes soft and yellowish, and as the disease spreads along the surface it acquires new territory as it spreads, hence the term 'lupus'—a wolf. The old areas usually then undergo atrophy, or, more seriously, it may be, ulceration occurs, which is inevitably followed by cicatrization. The ulcerations follow the course of the lymph channels, and, in the spreading of the disease, tissues of all kinds are destroyed, including muscles, cartilage and even bone. The subjects often reach an advanced age, so that one of the most conspicuous clinical features of lupus is its protractedly chronic course, the process exhibiting scarcely the slightest change for weeks or months at a time. In some cases, the areas may undergo fatty degeneration and become absorbed without ulceration, and leave only a white, wrinkled and shiny scar. But more frequently the areas break down into indolent ulcers, their flabby borders and unhealthy granular floors bathed in purulent secretion are soon covered by dirty-yellow crusts, and after a time heal into thin, white glistening cicatrices, only to be followed by the development of firm and fibrous scar-tissue. In some cases, the healing may be complicated by pus-infection, and there is always the likelihood of erysipelas infection arising also, while in others, epithelioma has been known to have developed in the patch. It must not be overlooked too, that lupine tubercular infarctions may be transmitted to the bones and joints and to the lungs and the viscera.

Usually the patients are anemic, and commonly present the scrofulous cachexia, but aside from the presence of the ulcers which may be tender but not at all painful, they complain of but few subjective symptoms.

The lymphatic glands adjacent to the patches may become enlarged and inflamed, especially in cases where the ulceration is marked, and exhibit a tendency to suppuration, because of the addition of pyogenic elements, yet adenitis may arise as a part of a general tubercular infection as well as through the direct transmission of bacilli from the lupus area.

The malady is most commonly situated on the face, showing a predeliction for the tip of the nose, while the next common seats are the extremities, especially the forearms and the legs. It is usually confined to a single patch, which spreads slowly, requiring often several years before attaining to any size. When foci develop on the general surface, they do so conjointly with or subsequent, usually, to the facial manifestation, and, conversely, the face may share in the disease when the eruption is noted primarily in other parts.

The mucous membrane too, of the nose and mouth may become affected and present indolent granulating ulcers which bleed readily.

When lupus of the face has lasted for a long time it may invade the eyelids and the globes with disastrous effects, even to the extent of complete blindness, but more commonly when the spreading disease encroaches upon the eye, the cicatricial formations which ensue may only distort the eyelid and produce moderate ectropion, yet in severe cases the ectropion may be so marked as to lead to irreparable damage to the globe.

As has already been surmised, extensive involvement of the face is likely to be accompanied by lupus of the lids, which ensues usually by the migration of the diseased cells from neighboring regions, particularly from the nose, the cheek or from the lachrymal duct. It is not improbable that because of the frequence with which the nasal and lachrymal regions are affected, many cases of primary infection arise within the nose, for, as has been pointed out, the most commonly involved site is near the outlet of the nares, but careful study of each case must be made before it can be decided whether or not the infection has passed from the conjunctiva to the nose or from the nose to the conjunctiva.

The process may involve the tarsal and Meibomian glands without at first causing ulceration, yet as they commonly become involved in the general process, ulceration invariably ensues, and causes great destruction of the skin and underlying tissues, with the consequent given, although usually just sufficient to produce reddening of the tissues, but only that quantity which shall cause a slight general reaction which should not exceed 1° F. Small, non-irritating doses may then be continued at intervals of two days while larger doses can be given after long intervals, the adjustment of the time can be so arranged as to allow for the subsidence of the reactions occasioned by such dosage.

In situations where it would be inexpedient to attempt such radical measures as the excision of the surface, local applications may consist of the use of pastes of pyrogallol, although its use is quite painful; Arsenic ointment, of strengths graduated to the extent of the surface to be treated, followed by the use of boric acid salve.

Whenever possible the lupus area should be removed without delay, either by excising well out into sound tissue, or scraping it with a sharp curette and then dusting with iodoform. Or, by destroying the ulcerated surface by searing it with the actual or the galvano-cautery, as well as by the high frequency current flames. All of these measures are among the most efficient of treatment; but, when the surface has been more or less dry, Finsen light, in the inventor's hands, has yielded good results. X-ray emenations applied from 10 to 20 minutes, according to the power and softness of the tube, may effect a cure.

When the disease invades the mucous membrane of the eye, the treatment consists in the radical excision or curettement of the ulceration, and the cauterization of the raw surface, great care being taken not to damage the cornea. When the area is so extensive that complete removal would likely be followed by symblepharon or other deformity, we may have to rely solely upon the use of tuberculin. The after-treatment should consist in the long continued use of powdered iodoform, which has long been regarded as of special value in tuberculous processes.—(B. C.)

Lusardi, C. M. L. A celebrated Parisian oculist. of Italian extraction. Probably born in Italy, he received his medical degree both at Duisburg and at Montpellier, and settled in Paris about 1820. A man of much ability, he was what today would be designated as "semi-ethical."

In addition to numerous journal articles, Lusardi wrote: 1. *Traité de l'Altération du Christallin et de ses Annexes. . . . Suivi de l'Extrait d'Un Mém. Inédit sur la Pupille Artificielle.* (Paris, 1819; 2d ed., 1821.) 2. *Mém sur la Cataracte Congéniale.* (Montpellier, 1823, 4.) 3. *Essai Physiologique sur l'Iris, la Rétine et les Nerfs de l'Oeil.* (Paris, 1831.) 4. *De l'Ophtalmie Contagieuse.* (1831.) 5. *Hygiène Oculaire. Fluide Philoptique contre la Faiblesse de la Vue,* etc. (Paris, 1832.) 6. *Préjugé sur l'Opération de la Cataracte,* etc. (1839.) 7.

Mém sur le Fingus Hématode et Médullaire de l'Oeil, etc. (Montpellier, 1846; with plates. 8. *Traitement de la Cataracte et de Quelques Autres Maladies des Yeux, sans Opérations Chirurgicales.* (1844, with figures.)—(T. H. S.)

Lusciosité. (F.) Myopia.

Luscitas. Fixed misdirection of the eye.

Luscosity. Shortsightedness.

Luster is the characteristic appearance of a bright, metallic surface, or of air within glass or under water as seen under certain angles of total reflection. It is supposed to be due to the conflict between the images in the two eyes, which do not coincide in respect of brightness all over the field.

Luster, Stereoscopic. See **Color mixture, Binocular.**

Lustgarten's bacillus. A bacillus discovered in syphilis, and by some thought to be the cause of that disease.

Lususparasit. (G.) The hookworm. See **Ankylostomum duodenale.**

Lutein. This word has long been applied in physiologic chemistry to designate a group of fat-coloring matters which occur in nature and which have more recently often received the general designation of lipochromes. These yellow pigments are found in the adipose tissue, in the serum of the blood, in serous fluids, in fatty structures of the retina, in the egg-yolk, and in the corpora lutea. The use of the term "lutein" has been restricted as a rule to the yellow coloring-matter which develops in these ovarian structures, although one can find the word applied to derivatives of other physiologic tissues as synonymous with lipochrome. Thus in a recent discussion respecting the appearance of a yellow pigment in cerebrospinal fluid in cases of tumor of the spinal cord the word "lutein" is employed to designate the color. Hitherto the chemistry of this group of compounds has been very indefinite and they have been classified and identified by their solubilities and other physical properties. Now that the subject is receiving more serious study, however, and the precise nature and relationships of the lipochromes or luteins is being cleared up, it may soon be possible to speak accurately of carotin or xanthophyll or some other specific substance instead of applying the more indefinite group expressions referred to above. It therefore seems particularly unfortunate at this time to find the word "lutein" entering anew into the nomenclature of medicine in an entirely different sense. Lately various preparations of desiccated corpora lutea from animals are being sold under the designation of lutein. This new therapeutic product obviously represents something more than merely the yellow pigment of a part of the ovarian structure, for there is no evidence that the lipochrome itself is responsible for any physiologic effects. Evidently the word "lutein" has commended itself, without consideration of the historical import of the word, as a euphonious designation which would at once suggest the natural origin of the product. This is not an isolated instance of confusion of terms. The word "bromalin" has been devised by manufacturers for a synthetic bromin derivative despite the existence of the word "bromelin," the name of the proteolytic enzyme of the pineapple. (*Jour. A. M. A.*, Sept. 26, 1914.)

Luteous. Of a saffron or reddish-yellow color; like mud or clay.

Lutidin. One of the products of the (burning) smoking of tobacco, thought to take part in the production of toxic amblyopia (q. v.).

Lutron. (L.) A bath. Of the old writers, an ophthalmic medicine.

Luxatio bulbi. Avulsion of the eyeball. The extreme degree of exophthalmia, in which the eyeball is entirely outside the cavity of the orbit. It is in all cases the result of traumatic violence. In addition to what has already been written on this subject under **Automutilation, Ocular,** Vol. I, page 711, and **Dislocation of the Eye,** Vol. VI, page 4037 of this *Encyclopedia,* it may be added here that the prognosis in both luxation and avulsion, as regards life, is good if there be no infection leading to orbital phlegmon and meningitis, which depends usually upon concomitant fractures of the bones of the orbit and cranium. In case of luxation, if the eye be immediately replaced the sight may return, but there will be some interference with its movement on account of tearing of the muscles. If the optic nerve or its sheaths be torn blindness results. Reposition or the completely avulsed globe has not resulted in its retention.—(H. V. W.)

Luxation of the lens. Dislocation of the lens. See p. 6321, Vol. VIII of this *Encyclopedia.*

Luxfer prisms. A patented device for refracting light into the dark rooms of buildings, especially in crowded cities. They are often inserted into sidewalks and used as "batteries" before otherwise badly illuminated windows. See **Illumination,** p. 632, Vol. I, of this *Encyclopedia.*

Luys' body. Corpus subthalamicum. See **Corpus Luys.**

Lycetol. Dimethylpiperazin tartrate, a white powder, soluble in water, $NH\ (CH_2CHCH_3)_2\ NH+H_2O$: a patented remedy for gout and rheumatism. Dose, 4-10 gr. (0.26-0.66 gm.) daily.

Lychnidiate. Phosphorescent, as is a glowworm.

Lycopin. A resinoid preparation from *Lycopus virginicus:* used as a tonic and stimulant in diseases of mucous membranes. Dose, 1-4 gr. (0.066-0.26 gm.).

Lye. This powerful caustic contains chiefly potash salts, especially the carbonate and hydrate. Koerber (*Zeit. f. Aug.*, 27, March, p. 247, 1912) has reported the case of a boy, aged 19, whose right eye was injured in the laboratory with hydrate of potash and pieces of glass from the breaking of a bottle. Two days later there was moderate traumatic conjunctivitis, a subconjunctival hemorrhage and a small wound of the superficial strata of the cornea. In two more days the cornea was slightly opaque, the wound yellowish and its edges swollen. Corresponding to its seat a membrane extended from the posterior surface of the cornea to the iris, covering the pupil. The writer diagnosed plastic iritis from the chemotatic action of lye diffused in the eye. He extracted the membrane through a section with the lance-shaped knife in the lower limbus. The operation had the desired effect, and after 45 days V. was 0.50. Koerber considers the case as a confirmation of Pichler's recommendation in severe injuries by lye to puncture the anterior chamber in order to evacuate the alkaline aqueous and thus to remove as far as possible the damaging agent from the eye. See, also, **Injuries of the eye.**

Lygosin. A greenish, crystalline substance, sodium lygosinate: used like silver salts in gonorrhea.

Lymph. A transparent, slightly yellow liquid of alkaline reaction which fills the lymphatic vessels. It is occasionally of a light-rose color from the presence of red blood-corpuscles, and is often opalescent from particles of fat. Under the microscope lymph is seen to consist of a liquid portion (*liquor lymphæ*) and of corpusles. These lymph-corpuscles are about $\frac{1}{2500}$ of an inch in diameter, are granular, and are not to be distinguished from white blood-cells. Lymph coagulates when drawn from the body. Lymph liquor differs chemically from the blood liquor, rather in quantity than in constituents, both fluids consisting of water, albumin, fibrin, and salts. The lymph contains as much fibrin as the blood, but less albumin; more water, but an equal quantity of salts.—(Dorland.)

Lymphaden. A lymphatic gland.

Lymphadenoma. A tumor made up of lymphoid tissue. It may attack almost any part of the external eye containing lymph tissue, especially such organs as the lacrimal gland.

Lymphagogue. An agent which promotes the production and excretion of lymph. By far the most important ophthalmic remedy of the kind we possess is dionin. See p. 3975, Vol. V. of this *Encyclopedia.*

Lymphangiectasis. A varicose dilatation of the lymphatic vessels, one of the forms of lymphangioma.

Lymphangiectasis, Ocular. Dilation of the lymphatic vessels of the eye.

Rossler (*Klin. Monatsbl. f. Augenheilkunde*), Sept., 1912) describes the case of a man, 18 years of age, who appeared with a tense, elastic swelling of the *left upper eyelid* and its neighborhood, rendering even passive opening of the eye extremely difficult. His history was that three years earlier, he had a small pustule on the left cheek, which disappeared after he had scratched the top off it. A few weeks later he received a blow on the left parotid region, which was followed, at an interval of some weeks, by a painful swelling in front of the left ear. Pus was removed from this by incision. Then a swelling of the same kind appeared at the angle of the jaw. When this had been evacuated, still another swelling appeared lower down, below the jaw. During the healing of the wounds, swelling of the upper lid rapidly appeared, and it had been present ever since, if anything increasing in degree. There had never been any inflammation of the lid or of the eye; there had been no pain; and he suffered from no constitutional disease.

When seen he had a number of indrawn, irregular cicatrices in front of the left ear, over the angle of the jaw, and in the submaxillary region.

In discussing the pathology of this condition, the author points out that there is reason to believe that the mere destruction of the glands would not occasion such a lymphstasis. Perhaps the septic inflammation of the glands led to an occlusion of the peri-glandular lymph paths.

The case was treated by removal of part of the swollen lid and overlying skin. In the excised portion the connective tissue fibers were found to be thickened and twisted, forming homogeneous, strongly refractile strands, which gave no amyloid reaction. In some places they presented a fine longitudinal striation. The interfibrillary spaces were reduced in size and filled with red blood corpuscles. The lymph- and blood-vessels were much dilated and well filled, and were surrounded in places by heaps of small round cells and mast cells. This is the microscopic picture characteristic of *pachydermia lymphangiectatica.* The localization of the swelling is explained by the involvement of the glands which drain this area. (*Ophthalmoscope,* Oct., 1915.)

Lymphangioma. A growth, congenital or acquired, consisting of new-formed, dilated lymph spaces and lymphatic vessels, the resulting structure resembling cavernous tissue. This neoplasm has been found in the orbit, conjunctiva, eyelids, caruncle and other ocular structures. In the conjunctiva they occur in three forms, which cannot be dogmatically separated, viz. lymphangiectasis, lymphangioma, and lymphatic cysts.

Parsons regards lymphoma and lymphangioma as distinct pathological entities, although they are often confounded. There are, he says, only five cases of lymphangioma of the orbit on record. The tumors are small and increase in size very slowly. They are probably congenital, though the ages of the patients were 46, 43, 21, 53, and 12 respectively. The structure is that of cavernous hemangiomata, except that the spaces contain lymph instead of blood. Some of the spaces contained blood in Wintersteiner's case, and diagnosis rested on continuity with the perivascular lymphatics of the long posterior ciliary arteries. The tumors observed have grown inside the cone of extrinsic muscles.

Cob (*Zeitscher. für Augenheilk.* Feb., 1913) also describes a case of *lymphangioma of the ocular conjunctiva;* Fehr (*Centralbl. f. pkt. Augenheilk.*, May, 1908) one of *lymphangioma cavernosum of the orbit* and E. M. Maxwell (*Br. Journal of Children's Diseases,* Nov., 1915) two cases of simple *lymphangioma of the orbit.* The last-named reports his first case, that of a girl aged three years. The mother stated that the child "had a cold in the right eye since birth." For the past year the lower half of the right eye seemed more raised than the other. The conjunctiva was raised in a grayish, semitranslucent mass which pitted on pressure with a probe. A piece was removed for microscopical examination and showed numerous empty spaces lined with endothelium. A few small round cells were seen scattered in the connective tissue. Electrolysis was employed in the treatment. A needle was attached to the negative pole which was inserted into the growth for half a minute. The current employed was of a strength of four to six volts. Treatment was repeated at intervals of ten days and the tumor showed no increase in size. The second case, also of a girl, aged three and a half years, showed in addition a proptosis of the left eye downward and outward to the extent of three mm. The motion of the eye inward was limited. Kroenlein's operation was performed, but nothing abnormal was found on the outer side. On the inner side the growth appeared to go back indefinitely into the orbit. Microscopical examination was the same as in the first case. Treatment along the same lines resulted in a diminution in the proptosis of one mm. The improvement is explained by the fact that electrolysis sets up inflammation, which is followed by the formation of contracting connective tissue.

Lymphangiosarcoma. Lymphangioma blended with sarcoma.

Lymphatic cataract. See **Morgagnian cataract.**

Lymphatic conjunctivitis. A doubtful form of conjunctivitis considered by some authors identical with phlyctenular conjunctivitis; by Herz, as a herpes ciliaris very often caused by reflex irritation of pediculi capitis through the branches of the fifth nerve supplying the conjunctiva.

Lymphatic system, Ocular. See p. 2256, Vol. III; also under **Current, Intraocular,** p. 3591, Vol. V, of this *Encyclopedia.* See, also **Anatomy of the eye.**

Lymph channels of the eye. See **Lymphatic system, Ocular.**

Lymph currents, Ocular. See **Lymphatic system, Ocular.**

Lymphectasia. Distention with lymph. See **Lymphoma**; and **Lymphangioma.**

Lymphemia. The presence of an undue number of lymphocytes or their forerunners in the blood; lymphatic leukemia.

Lymphendothelioma. Endothelioma arising from lymph-vessels or lymph-spaces—the ordinary variety of endothelioma.

Lymph infiltration, Ocular. See **Lymphomatosis, Ocular.**

Lymphoblastoma. A tumor composed of cells of the lymphocyte series. The term includes lymphocytoma, lymphoma, lympho-sarcoma, and pseudo-leukemia.

Lymphocyte. 1. A variety of leucocyte which is produced in the lymphoid tissues of the body, especially in the lymph-nodes. The nucleus is single and is surrounded by protoplasm which is generally described as non-granular. Two varieties are described: (a) the small lymphocytes *(small mononuclear leucocytes* or *microlymphocytes),* which are about the size of a red corpuscle and constitute from 22 to 25 per cent. of the white corpuscles; (b) the large lymphocytes *(macrolymphocytes* or *lymphoblasts),* which are probably lymphocytes in their developing stage, are two or three times larger than the small lymphocytes and contain a larger proportion of protoplasm. They form about 1 per cent. of the white corpuscles. 2. A lymph-corpuscle. —(Dorland.)

Lymphocytoma. A tumor of the lymphatic system in which lymphocytes are the predominating elements.

Lymphocytosis. An abnormal increase of lymph corpuscles (lymphocytes) in the blood.

The reviewer (*Ophthalmic Review*, p. 216, July, 1913) of the work of Franke (*Bericht der Ophthalm. Gesell.* p. 86, 1912) says that the question of the increase of lymphocytes in sympathetic ophthalmia has acquired considerable importance not only on account of prognosis, but also with regard to the treatment of that as yet but little understood and disastrous affection. Thanks to the pioneer work of Gradle, Browning and Jones in this connection we have been tempted to regard the affection as belonging to the protozoal type, a view which has been further supported by the undoubted success of salvarsan in its treatment. Now comes Franke with the following conclusions as a result of the examination of numerous blood-counts in a variety of cases both sympathetic and non-sympathetic. 1. Lymphocytosis can occur in recent eye injuries and indeed in those that heal without any inflammation, as well as in those which are followed by severe irido-cyclitis. 2. The same condition of the blood may occur in old perforating injuries as well as in mere contusions, which from the nature of the injury do not lead to sympathetic ophthalmia. 3. In a large number of severe injuries of the sclerotic, in which for a number of years the complete freedom from any inflammatory symptoms renders the onset of sympathetic ophthalmia very improbable, the picture of lymphocytosis remains conspicuous. 4. The absence of lymphocytosis with freedom from inflammation of the injured eye is no security against the onset of a later inflammation of a nature to lead to an attack of sympathetic ophthalmia. 5. The presence or absence of lymphocytosis in severe perforating injuries of the eye is of no diagnostic or prognostic value in relation to sympathetic ophthalmia. Some of these conclusions are rather startling, especially number three. What possible explanation can there be of a lymphocytosis lasting for years after the infliction of a healed and uninflamed injury? May not the observer have overlooked some other cause for the lymphocytosis? The difficulty of strict accuracy in all these investigations is well known and indeed it is impossible to make accurate comparisons between the work of different observers, so much does the personal equivalent vary. In the subsequent discussion Sattler stated that investigations of the blood-count in severe cases of sympathetic ophthalmia had shown only slight amounts of leucocytosis. He asked Franke if he had observed any increase in eosinophiles as indicating an anaphylactic reaction. Fleischer stated that in recent eye injuries he had observed an increased lymphocyte content in the cerebro-spinal fluid. Franke replied that there was no noticeable increase in the eosinophiles. As a further source of error we may point out that it is well known in malaria and such like definite protozoal complaints that periods of some duration occur in which no lymphocytosis occurs. In an undoubted case of sympathetic ophthalmia under the reviewer's care last year, during the first three weeks of the disease repeated blood-counts showed no leucocytosis and then an enormous increase took place. The whole subject is one in which further investigation should yield valuable results.

Lymphocytozoon. A genus of ameboid bodies, species of which are found in leucocytes.

Lymphoma conjunctivæ. See **Parinaud's conjunctivitis**, as well as p. 3134, Vol. IV of this *Encyclopedia.*

Lymphoma of the eye. A tumor having a micrôscopic structure like that of the lymphatic glands, and a finely reticulated meshwork, connected with which are some fixed cells at tolerably regular intervals, not unlike the fixed cells of connective tissue, but generally larger. There is no strict line of demarcation between true lymphomata of the eye and lymphomatosis (q. v.) or lymphoid infiltrates. However, most of the ocular organs and tissues have been reported—although very rarely—as having been the seat of true lymph-glandular neoplasms, either alone or associated with sarcoma, carcinoma, adenoma, etc. Lymphoma is often confounded with or used synonymously with *lymphangioma* (q. v.). It is often associated with a general lymphomatosis—as in splenic leukemia.

Lymphoma of the eyelids. This is not the rarest of the lymphoid tumors of the eye. For example Duboys de Lavigerie (*Annales d'oculistique,* April, 1914) records the case of a woman, aged 58 years, who suffered from numerous cutaneous and subcutaneous tumors of a lymphatic type, but had no early glandular enlargement or leukemia. Three and a half years after the onset of the disease, she died from cachexia.

The interest of the case from an ophthalmological point of view consists in the fact that at one period one of the tumors, which was situated in the right lower eyelid, assumed such importance as to lead the patient to consult an ophthalmic surgeon.

Lymphomata of the *conjunctiva and tarsus* in a boy, 10 years old, is reported by Baslini (*Clinica Oculistica,* May, 1907). The local examination showed the left upper lid in a condition of ptosis and a swelling of the tarsus. The lid could be only slightly turned up; there could be seen large, red granulations on the conjunctival tarsus. Treatment was removal of the affected conjunctiva and tarsus. The patient made a good recovery.

The Russians are especially partial to it. The upper lid usually reacquires its function through the skin fibers of the levator palpebræ which are not divided in the operation. A microscopic examination of the excised tarsus in the writer's case showed that the epithelium of the conjunctiva was in great part lost. The subepithelial connective tissue layer and the superficial part of the tarsus were infiltrated with lymphocytes and young connective tissue cells. Some of the vessels contained no blood. The connective tissue proliferation was less marked in the superficial part of the tarsus but presented numerous young cells in different stages of evolution and the vessels were infiltrated in the adventitia. No mitoses were found. In some sections the connective tissue trabeculæ appeared better developed and extended by means of outshoots into the tarsal conjunctiva, circumscribing large spaces filled with numerous lymphocytes and a few young connective tissue cells. In some parts of the trabeculæ could be seen hyaline degeneration. The lobules of the Meibomian glands appeared reduced in volume.

Lymphoma of the iris has been found in cases of splenic leukemia. The growths may be situated deeply or superficially in the iris-tissue. When superficial, they are present as multiple gray, transparent nodules surrounded by a vascular network. When deeply placed they cannot be seen, but their presence should be suspected because of chronic iritis with pupillary exudate and vitreous opacities. Unlike tubercles, lymphomata of the iris do not suppurate. They may be confounded with gummata. The disease is found chiefly in young persons, and, according to Horner and von Michel, it precedes the general manifestations of leukemia. Microscopic examination shows a mass of leucocytes in the stroma of the iris, which is more dense than normal and presents vessels gorged with white corpuscles. In benign forms the neoplasm may entirely disappear, leaving the iris partially discolored and atrophic, while grave cases end in total atrophy of the globe. Aside from the use of atropin, local treatment is not indicated in these cases.—(J. M. B.)

Lymphoma of lachrymal gland and of the orbit is best studied under **Lymphangioma.**

Lymphomatosis, Ocular. A condition of lymphatic engorgement, associated or not with deposits of lymphatic and lymphoid material in some portion of the eye structures, in the cornea, for instance.

George Coats (*Archiv. Ophthal.*, May, 1915) describes one of these cases affecting the orbit. There was proptosis of the right eye forward and slightly upward and outward, of ten months' duration, in a man aged 37. Movements practically full. Firm resistance to backward pressure. Some enlargement of the retinal veins and blurring of the outline of the disc. Vision with correction, right eye, equaled 6/6 pt.; left eye, equaled 6/5. Exenteration of orbit. Seven years later commencing similar affection on the left side. Patient's health perfect throughout. Physical examination revealed no abnormality. Blood examination negative.

Pathologically: orbital tissues strewn throughout with numerous isolated nodules of lymphoid tissues, situated chiefly in the fibrous trabeculæ and along the larger vessels. These nodules are composed not only of lymphocytes, but also of fully developed lymph follicles. No special concentration of the changes in the vicinity of the fornix or lachrymal gland. No microörganisms demonstrable.

The only cases presenting a real resemblance to this one are two reported by Birch-Hirschfeld. Coats believes that these three cases belong in a special classification.

Coats gives a very clear exposition of present views on the lymphomatoses, their classification and their relationship one to another. Most symmetrical tumors of the eyelids and orbits belong in this group. Tumors are commonly multiple, and usually appear in the lymph glands simultaneously. They rarely invade the orbit deeply.

The writer believes that lymphoid tumors in the orbit arise from pre-existing cells in the tissues, the condition being a local expression of a general over-activity of the lymphopoietic apparatus. The condition in his case probably was more closely related to the inflammation than to the tumor. It seems probable that the follicles may have been deposited in response to the inflammatory stimulus. Many features of the case are, however, obscure.

Lymphorrhagia, Retinal. Bearing the caption *Angiopathia retinæ traumatica* (see p. 469, Vol. I, of this *Encyclopedia*), Purtscher records (Graefe's *Archiv* II, 82, 1912) two cases under his own observations, and three others supplied by Koerber and Liebrecht, illustrative of a condition which he believes to be lymph extravasation (*lymphorrhagia*) in the retina, the result of excessive intracranial pressure due to severe and sudden injury.

The author's summary of these cases and his conclusions are that recent investigations show that numerous white lustrous spots are frequently observed in the fundus oculi in cases of disease, in which we are justified in assuming an increased intracranial pressure, either transitory or persistent. In the opinion of many it is very probable that these spots are caused by stasis. The ophthalmoscopic picture of such cases is characterized by white spots which are mostly situated in the inner layers of the retina and appear to follow closely the course of the retinal veins. They are generally limited to the neighborhood of the disc and yellow spot. In most cases there are also more or less numerous streaks and spots of hemorrhage. Papilledema may or may not be present. In a certain number of these cases there is a history of severe trauma, and as sudden increase of intracranial pressure may be induced thereby, injury must be recognized as a possible etiological factor. This applies especially to severe head injuries, but also to compression injuries of the trunk, which, as shown by experiment, cause transient but great increase of intracranial pressure. In many cases it is doubtful if the presence of white spots in the retina can be explained as the effect of chemical or toxic agents, and in some cases a mechanical factor in the production of the retinal changes may be found in embolic processes. The occurrence of hemorrhage and white spots in the retina, the latter being most probably derived from lymph channels, after injuries to the body, seems to justify the employment in the widest sense of the term angiopathia retinæ traumatica.

Lymphotoxemia. Toxemia due to excess of lymphoid matters or lymphoid tissue, as in rickets, exophthalmic goiter, enlarged thymus, etc.

Lymphotoxin. The toxin or lysin contained in lymph-glands.

Lymphstaar. (G.) (Obs.) Lymphatic cataract.

Lymph stasis, Ocular. See **Lymphomatosis, Ocular.**

Lynceus. One of the Argonauts, and a very sharp-sighted person. He is said to have been able to discern small objects at a distance of 130 miles. According to some writers, he could even see through the earth, and, according to still others, he could see as far as Hades. He was one of the sons of Aphareus, and also one of the hunters of the Caledonian boar. He, with his brother Idas, slew Castor. He was himself slain by Pollux.—(T. H. S.)

Lysargin. A form of colloidal silver appearing as shiny lamellæ of a steel-blue color. These are readily soluble in water, forming a yellowish-brown solution, which may be used for the same purpose as collargol.

Lysemia. Disintegration of the blood.

Lysin. 1. An antibody which has the power of causing dissolution of cells. The term includes hemolysin, bacteriolysin, cytolysin, etc. 2. A hydrolytic cleavage product of protein after boiling with hydrochloric acid. It is also obtained from gelatin, from the pancreatic digestion of protein, and from the decomposition of protamins.

Lysoform. This is a liquid formaldehyde potash soap, highly antiseptic, only slightly poisonous, odorless, deodorizing and cheap. It does not coagulate albumen and mixes readily with alcohol in all proportions. Owing to its highly bactericidal qualities it is extremely useful for washing the hands in ophthalmic operations. A two or three per cent. solution is sufficiently strong for general purposes.

In addition to its use as a hand and skin disinfectant it is occasionally applied as a 2 per cent. ointment in the eczematous and squamous forms of blepharitis.

Lysol. A mixture of the higher phenols with resinous and fatty soaps, made by boiling heavy tar oils, fats and resins with alkalies. It is a brown, oily fluid with a peculiar, creosote odor; contains about 50 per cent. of cresols; soluble in water and alcohol.

Although it has been proposed to use this agent as a disinfectant (in proportion of 1 :5000 to 1000) and as a germicide collyrium in ocular diseases, there have been no extensive trials of it in that capacity. On the other hand, it acts admirably in 2 to 4 per cent. aqueous solutions as a disinfectant hand lotion and for the sterilization of instruments.

E. Hempel (*Klin. Monatsbl. f. Augenheilk.*, Dec., 1911) reports the case of a man who was syringing a horse's wound with a solution of lysol (supposed to be 2½ per cent.) and got some in his own eye. Although washed out with water, the eye became severely inflamed, and vision was clouded. When examined, there was redness and swelling of the palpebral conjunctiva, ciliary injection, and total opacity of the cornea. Vision was 3/35. Two months later there was still slight ciliary injection, the periphery of the cornea was clear and superficially vascularized, and vision was 4/60. The corneal opacity was permanent. In experiments on rabbits, guinea pigs, and monkeys, 2½ per cent. lysol produced irritation and corneal erosions, but healing took place in three days and left no permanent opacity. The author suggests that the patient may have got the material in stronger concentration than was thought.

Lysopast. A lysol-soap preparation containing 70 per cent. of lysol, used for disinfection of the hands and the skin field of operation.

Lysosolveol. An antiseptic and disinfectant mixture of tricresol (44.5 per cent.), potassium linoleate (38 per cent.), and water.

Lyssa. (G.) Hydrophobia.

Lythol. A proprietary antiseptic and germicide recommended for "catarrhal conditions of mucous membranes."

M.

M. An abbreviation for *mille,* thousand; *misce,* mix; *mistura,* mixture; *macerare,* macerate; *meter, minim, muscle, myopia,* and *manipulus.* handful.

M. A. Abbreviation for meter angle.

ma. Abbreviation for milliampere.

M + Am. Compound myopic astigmatism.

Macchia cieca. (It.) Blind spot.

Mackenzie's eye-wash. The formula for this eye-wash (*Indian Medical Gazette,* Nov., 1907) is as follows: Corrosive sublimate 1, ammonium chloride 6, belladonna extract 10, coccus cacti 1½, proof spirit 55; rub together and add water to 330. Mix with equal parts of boiling water to bathe the eyes. The *Extra Pharmacopeia* cautions us that the foregoing collyrium is about five times as strong as is usually employed in ophthalmic therapy, and, it may be added, that American eyes would be the better for a collyrium of 1-10 strength.

Mackenzie, William. One of the greatest of British ophthalmologists, founder of the Glasgow Eye Infirmary and author of the celebrated text-book, "*A Practical Treatise on the Diseases of the Eye.*" Born at Glasgow in April, 1791, he studied in the Glasgow Grammar School and also in the School of Arts at Glasgow University. For a time, intending to become a minister, he studied at Divinity Hall, but, in 1810, deciding to be a doctor, he entered the Royal Glasgow Hospital. From 1815 to 1818 he studied ophthalmology in London, Paris, and Vienna, as well as a number of places in Italy.

Returning to England, he settled as ophthalmologist in London, but, it seems, without success. Even his work, entitled "*Essay in the Excreting Parts of the Lachrymal Organs,*" attracted no attention. His waiting-room was always empty, and London permitted, without a remonstrance, the greatest British ophthalmologist of his time to remove to Glasgow.

In Glasgow he was almost immediately successful, and there he practised till the day before he died. He never entirely abandoned general medicine or surgery, but he gave to ophthalmology the greater portion of his time. In the Andersonian University he lectured on anatomy, materia medica and medical jurisprudence. In 1824, together with Dr. George Monteith, he established the Glasgow Eye Infirmary. In 1827 or '28 he was appointed instructor on diseases of the eye in Glasgow University, receiving as emolument the funds of the Waltonian lectureship. This position he held for more than forty years—i. e., until his death. For two years he edited the *Glasgow Medical Journal,* to which he contributed freely, especially on ophthalmic subjects. In his later years he was appointed surgeon-oculist to the Queen in Scotland. He had an enormous practice, many of his patients arriving from Continental Europe and America.

Dr. Mackenzie was hard at work the day before his death. However, he complained of feeling slightly unwell, and, in the night he was seized with a violent illness. He died on July 30, 1868, of stenocardia.

Mackenzie was a small, brisk man, compact of energy and activity. His eyes were large, blue, and piercing. He was bald from about the age of thirty. One of his eyes being myopic, he seldom troubled himself with glasses even in his later years. He was humorous, witty, wise, a constant story-teller, and had an unconquerable aversion to what is called "society." He was modest, unassuming, magnanimous and free from jealousy of every sort. Somewhat conservative toward innovations (as, for example, the strabismus operation, the ophthalmoscope, and iridectomy for glaucoma) he would finally yield, when the proof adduced was very strong, and acknowledge himself to have been in error. He was kind to the poor, loyal to friends, forgiving to enemies.

In addition to numerous journal articles, Mackenzie wrote the following:

1. *Introduction to a Course of Lectures on the Diseases and Operative Surgery of the Eye.* (1824.)

2. *Practical Treatise on the Disease of the Eye.* (1830. Later Eds., 1835, 1839 and 1854; two or three American editions; numerous German and French translations; Mackenzie's greatest service to ophthalmology. According to Prof. Hirschberg, "This textbook was decidedly superior not only to such English works as had appeared during the first third of the 19th century—Saunders, 1811; Vetch, 1820; Travers, 1820; Watson, Edinburgh, 1830—but the best in general since that of Joseph Beer [1813-1817]; it is the first English textbook on ophthalmology which belongs to the literature of the world." The work in question possesses for the present writer an especial asso-

William Mackenzie.

ciative value, because it was the first treatise which he ever read on the subject of ophthalmology—the American edition of 1855; but the opinion of Prof. Hirschberg is probably unbiased, and, moreover, would seem to be supported by that of all historians of medicine in every portion of the globe.)

3. *Physiology of Vision.* (1841.)—(T. H. S.)

Mackenzie, Sir Stephen. A brother of the famous rhino-laryngologist, Sir Morrell Mackenzie, and a general physician, dermatologist and ophthalmologist of considerable importance. Born, the son of a physician, in 1844, he studied at the London Hospital and at the University of Aberdeen, where he received the degree of M. B. in 1873. In 1874 he was a Member of the College of Physicians of London, and in 1879 became a Fellow of the same body. He was for a time assistant physician at the London Hospital, in charge of the skin department, and, later, was lecturer on medicine and pathology at the London Hospital Medical College. He was also for some years physician to the Moorfields Hospital. He was a charter member and the first honorary Secretary of the Ophthalmological Society of the United Kingdom. He was knighted in 1903, and died at Dorking, Surrey, after a long illness, Sept. 3, 1909.

Among his ophthalmologic writings are: "Glycosuric Retinitis" (*Roy. Lond. Ophth. Hosp. Rep.*, IX) and "On the Immediate Causation of Optic Neuritis" (*Brain*, II).—(T. H. S.)

Mackmurdo, Gilbert. An English ophthalmologist, the date of whose birth is not known. He was, for a short time, surgeon to St. Thomas's Hospital, London, and also instructor in anatomy and physiology at this institution. From 1830 to 1856 he was surgeon to Moorfields. In 1843 he became a Fellow of the R. C. S. of England, and, a little later, a Fellow of the R. S. He died, very old, in 1869.—(T. H. S.)

MacNab, Angus. The *Ophthalmoscope* of December, 1914, announced the death under tragic circumstances of Angus MacNab, the widely-known and accomplished London ophthalmic surgeon. Capt. MacNab, while serving as senior surgeon with the London Scottish regiment of Territorials, took part in the now famous charge of that gallant body of men at Messines and was left with two wounded soldiers under his care in a somewhat isolated position. When found by his comrades MacNab and his charges had been bayoneted—in other words, foully and barbarously murdered—by the Germans. According to one account he was engaged in tending to the wounded in a farmhouse behind the British trenches. The British were forced to retire, but MacNab, unarmed, remained behind with the wounded. A counter attack drove back the Germans, but MacNab and his defenceless comrades were found bayoneted.

It was a bright, moonlight night, and MacNab had a white badge with a red cross on his arm, and a blue tunic, so that the uniform and badge were unmistakable. He had seen military service as a dresser in the South African war, to which he went before he was qualified.

He was of Scottish descent, and was born in New Zealand, where his brother was once Minister of Agriculture. He studied in the Universities of Otago, Edinburgh, Freiburg and Vienna. He graduated B. A. (N. Z.) in 1895, and in the following year took the degree of B. Sc. In 1901 he proceeded to the degrees of M. B. and Ch. B. in the University of Edinburgh, and a few years later took the F. R. C. S., England.

After acting as house surgeon to the Ophthalmic Department of the Edinburgh Royal Infirmary MacNab continued his special studies at Freiburg i. Br. and Vienna. His interest in ophthalmic bacteriology was attested by several original communications upon that subject, as well as by his masterly translation of Axenfeld's *"Bacteriology of the Eye."* He also wrote a very useful book dealing with the *Ulceration of the Cornea* (1907) which included much of the work he had done at Freiburg. At the time of his death he was ophthalmic surgeon to King Edward VII Hospital at Windsor, and was also connected, in the capacity of chief clinical assistant, with the Royal London Ophthalmic Hospital. In 1913 he translated W. Lohmann's *"Disturbances of the Visual Functions,"* a most favorable review of which was published in the *Ophthalmoscope.* At the time of his death, at the early age of thirty-eight, he was a resident of London. A widow and two children survive him.

MacNab's ointment. This disinfectant mixture, employed as one would White's ointment, has the following formula: Hydrarg. bichlor. gr. ss; Iodoform gr. xj; Atropine (alk.) gr. ij to vij; Vaseline ℨ j.

Macroblast. An abnormally large red blood-cell; a megaloblast.

Macrocornea. Unusually large cornea.

Macrocyte. A giant red blood-corpuscle, especially characteristic of the blood in pernicious anemia; also, a large lymphocyte.

Macroesthesia. A sensation as if objects were larger than they really are.

Macromania. Delusive belief that external objects or one's own members are larger than they really are.

Macromelia. Enlargement of one or more members, due to occlusion of the lymph-channels.

Macrometer. A surveying instrument for measuring inaccessible heights of objects.

Macrophthalmus. (L.) Having very large eyes.

Macropia. (L.) MACROPSIA. MEGALOPSIA. A disorder of vision, in which all objects seem larger than they really are. It occurs often with spasm of the ciliary muscle and miosis.

Macroplasia. Excessive growth of a part or tissue.

Macropsia. (L.) See **Macropia.**

Macroscopy. Examination with the naked eye.

Macroscopic anatomy of the eye. See **Anatomy of the eye,** as well as p. 6886, Vol. IX of this *Encyclopedia.*

Macroscopic preparations of the eye. See the major heading, **Laboratory technique.**

Macroseme. Having the orbital index greater than 89°.

Macrotome. An instrument for cutting thick sections.

Macula. A spot. See **Macula lutea**; also, **Macula corneæ.**

Macula arcuata. (L.) Arcus senilis.

Maculæ ante oculos volitantes. (L.) MUSCÆ VOLITANTES. Small faint shadows of various shapes which float before the eye, but do not interfere with vision.

Macula, Coloboma of the. See p. 2896, Vol. IV, of this *Encyclopedia.*

Macula corneæ. A permanent opacity on or in the cornea from a preceding keratitis or ulcer. See **Cornea, Opacities of the.**

Macula corneæ arcuata. (L.) Arcus senilis.

Macula, Diseases of the. LESIONS OF THE MACULAR REGION. This subject has already been largely discussed under numerous captions, especially on p. 5971, Vol. VIII; as well as under **Cherry spot,** p. 2033, Vol. III, of this *Encyclopedia;* **Choroiditis in general,** p. 2144, Vol. III; **Familial diseases,** p. 5150, Vol. VII; **Injuries of the eye**; and **Congenital anomalies.** Lesions of the macular region are, in addition, so closely associated with acquired alterations in and congenital anomalies of the optic nerve and retina that the various items included under these headings ought to be studied in a survey of the subject.

Rare alterations (apart from the foregoing lesions) in and about the yellow spot are also described in literature. An example of this is found in the report by Nuel (*Archiv. d'Ophtalm.*, p. 465, August, 1912) of a *mottled degeneration of the macula lutea,* formerly described by him under the name of vesicular edema of the macula lutea. This mottled condition of the macula is sometimes of traumatic origin, sometimes idiopathic. It is seen in old people, with arteriosclerosis and more or less cardiac changes, both eyes (generally) showing a marked amblyopia (fingers at several meters), generally without contraction of the visual fields. Once established, the amblyopia shows small tendency towards diminishing, but, on the other hand, seldom leads to total blindness. The bilaterality and the chronicity of the affection, and the kind of amblyopia (central scotoma), suggest toxic origin, but the ophthalmoscope establishes the true diagnosis. The macular region, and this only, is dotted with small bright circles, the edges of which fade into the surrounding retina. Their location may be restricted to one side of the macula, and the color is shrimp-pink to yellow. The optic disc, which is normal in appearance at first, later on shows a temporal pallor similar to that seen in toxic amblyopia. There is central scotoma, generally double, and a diminution of vision which is more intense when the macula proper is the seat of the lesions. As a rule the patients complain of metamorphopsia at the point of fixation; this becomes less with time. A prominent symptom is nyctamblyopia, and achromatopsia is often complained of in the region of the central scotoma.

Throughout the macular region the pigmented epithelium of the retina is shown to be raised in spots by a solid transparent exudate; this exudate is finely granulated, shows no evidence of a lamellar structure, and takes none of the stains used by the author. The covering pigment epithelium is normal in appearance, except that it is somewhat thinned where it is uplifted. The internal lamella of the choroid is also normal. The fovea proper is not the seat of an exudate, but shows great disturbance of the nerve elements, the cones being elongated and warped.

Macula, False. See **False macula**; p. 5142, Vol. VII, of this *Encyclopedia.*

Macula flava. The yellow spot, or fovea.

Macula, Hole at the. See **Hole at the macula,** p. 5971, Vol. VIII, of this *Encyclopedia.*

Macular keratitis. See p. 6779, Vol. IX, of this *Encyclopedia.*

Macula lutea. Yellow spot of Soemmering. The yellow spot in the center of the retina, where vision is most perfect.

In addition to the description of this most important visual area given under **Anatomy of the eye, Fundus oculi,** and **Histology of the eye** it may here be added that there are various theories to account for the yellow appearance of the macula.

Lindsay Johnson (*Photography in Colors*) advances the view that its action is comparable to the action of the photographers' yellow color-screen, in conjunction with a color-sensitive plate, in cutting out some of the highly active blue-violet rays. If there were no pigment in the macula, when looking at a bright white surface, we should see, not white, but blue-violet.

Meisling (*Klin. Monats. f. Augenh.,* Nov., 1912) finds the yellow color of the macula can be brought out by looking through a gelatin film colored with a solution of auramin and potassium bichlorate. It is also seen by white daylight. Vogt (Graefe's *Arch. f. Ophthal.,* Vol. 84, p. 293) has brought out the yellow color by using light from which the red rays were filtered.

Van Der Hoeve (Graefe's *Archiv fuer Ophthal.,* Vol. 80, Part 1) declares that Gullstrand's assertion that the yellow color of the macula is due to postmortem changes, as otherwise it would be apparent in highly pigmented fundi and in acute ischemia of the retina, is not upheld by the facts in a case of ischemia observed by the writer.

In this instance after a severe traumatism there occurred clouding of the retina with contraction of the retinal arteries. Complete rupture of the nerve seemed a reasonable conjecture. The color of the macula was yellow, the size of the yellow portion being about ½ disc diameter. The center was dark in color and the margin greenish. Examination with electric light and daylight gave the same results.

He attributes the yellow appearance of the macula in this case to associated choroidal anemia. When the choroid remains unaffected (no lesion of the ciliary vessels), its red color shines through and obscures the normal yellow color of the macula.

In a most important series of contributions to a study of the *cortical area for macular vision* Bramwell (*Edinburgh Med. Jour.,* July, 1915) gives a report on the anatomic findings in the case of a man of 45, who, in February, 1886, complained of loss of sight. His fundus was normal. The loss of sight, which consisted of complete loss of peripheral vision, with very marked reduction of macular vision, had come on suddenly, with an attack of what appeared to be uremic convulsions, in June, 1884.

The writer diagnosed the condition as probably due to a bilateral lesion of the occipital lobes in the region of the half-vision center. The case did not appear to be one of the rare cases of double homonymous hemianopsia, in which a lesion of one occipital lobe (say the right) produces a homonymous hemianopsia on the opposite (say the left) side, and a second and subsequent lesion in the other (say the left) occipital lobe produces a homonymous hemianopsia on the opposite (say the right) side, but a simultaneous bilateral lesion in the right and left occipital lobes—an infinitely rare, if not a unique, condition.

During the whole period (twenty-four and one-half years) that the patient was under the writer's observation the condition remained, practically speaking, unchanged, and there were no further cerebral developments—central (macular) vision improved slightly, peripheral vision remained completely obliterated. Throughout the whole course of the case there was no motor paralysis, no loss of sensation, and no aphasia, either sensory or motor.

The man died in 1910, and a post-mortem examination showed that the brain lesion consisted in extensive destruction of the white matter and part of the cortex of the left occipital lobe and very extensive destruction of the white and gray matter of the right occipital lobe. The lesions apparently were the result of old softenings, probably, from the very sudden onset, embolic in origin, with great secondary (compensatory) dilation of the lateral ventricles.

The fact that the visuo-sensory area generally was normal in distribution made it certain that the gross contraction of the visual fields, which was found clinically, was due to an associative block, and that this block was not quite so complete on the left side of the visual apparatus as on the right (and in the right fields of vision as in the left), in association with a smaller or less important lesion on the left side of the cortex. This was indicated histologically by the disuse atrophy of the visuo-sensory cortex, which was everywhere marked, with the exception of the more central (calcarine) portion.

It would therefore appear that the calcarine core of the visuo-sensory area serves in some degree as an anatomical basis for macular as distinct from non-macular or panoramic vision.

This conclusion is supported by the fact that the lesion in the right hemisphere reached up to the posterior portion of this calcarine core. This fact at the same time incidentally explains why in this case the right field of (central) vision was a little more extensive than the left.

It appears, therefore, to be probable that human macular vision is an evolution dependent on (1) the development of binocular vision, i. e., on the employment of corresponding parts of the retinæ simultaneously, and on (2) the simultaneous development of the capability to pay prolonged and individual attention to particular points of the general visual panorama.

Macular vision is thus superposed on the neuronic apparatus for panoramic, and the two types shade into one another, the central parts of the retinæ and the corresponding central (calcarine) cores of the pear-shaped visuo-sensory areas being the parts concurrently employed in macular vision.

The associative block caused by the lesions in this case, therefore, being greater on the right side than on the left, must thus be regarded as having been enough to stop the passage of the feebler panoramic stimuli without interfering seriously with the macular and stronger visual stimuli.

The continued passage of the latter has prevented the onset, in the calcarine core of the visuo-sensory area, of the disuse atrophy which elsewhere in these areas is general.

Lastly, the slight maiming of the right calcarine core posteriorly is responsible for the fact that the clinical visual field of the case was rather less extended on the left side.

The histological investigation of this case may thus claim to have added to our knowledge of the part played by the visuo-sensory area in macular and in non-macular or panoramic vision. It may, in fact, be stated that the anatomical basis of the former is the cortex of the calcarine core of the pear-shaped visuo-sensory area, and that the anatomical basis of the latter lies in the surrounding and remaining visuo-sensory cortex.

Macula margaritacea. (L.) Macula corneæ.

Macula, Myopic. Fuchs' disease of the macula. This affection, first observed by Foerster, was more accurately described by Fuchs from long-continued observations of 40 cases and an anatomic examination. It consists in a characteristic small, round, black spot, sharply defined, of a grayish-red or whitish hue in the center. Its typical course is enlargement to the size of the disc and beyond, growing lighter, and the formation of an atrophic peripheral zone. It differs from the ordinary choroiditic foci according to L. Pick (*Zeitschr. f. Augenheilk*, January, 1911) by never showing the stroma and vessels of the choroid nor the white sclera, whence Fuchs concluded that the choroid is not destroyed, but is either converted into, or covered by, a callosity. It commences with sudden visual disturbances in the form of metamorphoses or positive scotomas, which in the course of years become more marked. Anatomically there is an intense proliferation of the pigment epithelium covered by a gelatinous acellular exudation (coagulum of fibrin), adherent to the retina. The etiology is obscure; certain only is its connection with myopia, or with its process of ectasia.

The prognosis is not unfavorable. The process scarcely lasts less than a year, and is almost always followed by a central or paracentral scotoma. A connection with lues is very doubtful. The prognosis depends on the degree of myopia and is favorable in low degrees, much more unfavorable in medium and higher degrees. It is the better the younger the individual. Protection from light and avoidance of near work for several months is very important. Mercurial inunctions seem best of all medications. Ulrich saw in several cases acute impairment after diaphoresis.

The etiology remains obscure. It is peculiar that after the occurrence of the black spot other severe myopic changes (opacities of the vitreous, diseases of the choroid) seem to be arrested. A coincidence of the black spot with detachment of the retina is never observed.

Macula, New-formed. See **False macula.**

Macula, Progressive disease of the. Batten's disease. Batten (*Trans. Oph. Soc. U. K.*, XVII, p. 48, 1897) first described it, and it is further discussed on p. 5150, Vol. VII, of this *Encyclopedia.*

Marcus Feingold (*Trans. Oph. Sec., A. M. A.*, p. 312, 1916) reports three cases and gives a complete bibliography to date.

Macular region. See **Macula lutea.**

Macularity, Universal. See **Central Vision, Universal,** p. 1964, Vol. III, of this *Encyclopedia.*

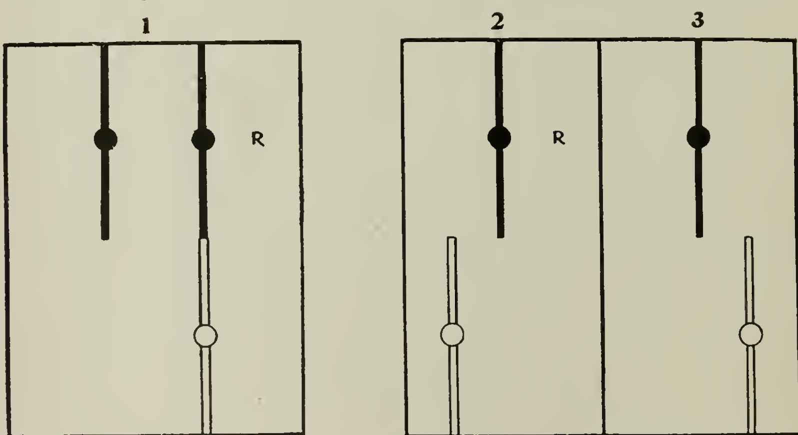
Macular vision, Cortical area of. See **Macula lutea.**

Madarosis. Madarotes. The condition in which the eye lashes are permanently destroyed.

Madarosis ciliaris. (L.) Alopecia affecting the cilia.

Maddox'sches Stäbchen. (G.) Maddox rod.

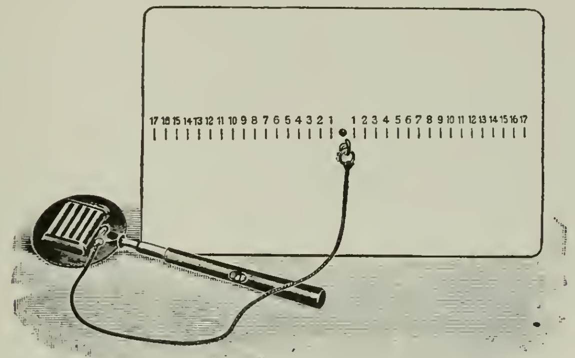
Maddox tangent scale. The measurement of horizontal and vertical deviations is facilitated by the use of a tangent scale which is fastened



The von Graefe Test, used at the reading distance. (After Ball.)
1, Orthophoria. 2, Exophoria. 3, Esophoria. The prism is placed base up before the right eye. The lower image belongs to the right eye.

to the wall. The tangent scale of Maddox is used at a distance of 5 meters. It is in the form of a cross; at the center is a small light on which the patient fixes. A Maddox rod is placed before one eye, which sees a streak of light. The uncovered eye sees the scale, and thus the patient can read off the amount of the deviation of the uncovered eye. Maddox has devised a similar scale for use at 25 centimeters in connection with the square prism test.—(J. M. B.)

Maddox test. Maddox rod. Maddox prism. In addition to the matter to be found on p. 4682, Vol. VI, of this *Encyclopedia,* the revolving form of the multiple rod is depicted here.



Maddox Rod for Testing Muscle Balance for the Near Point.

Stephenson's Arrangement of the Maddox Rod for Testing the Muscle Balance.

Madisterion. Madisterium. (L.) (Obs.) A forceps used for epilation.

Magaritomas. See **Cyst of the iris.**

Magawly, Count John. A well-known Russian ophthalmologist, of Irish extraction. Born July 7 (19), 1831, at Cummingshof, near Riga, he received his medical degree at Dorpat in 1856. He then for a time continued his studies at Vienna, Berlin and Paris, deciding at last to devote himself to ophthalmology because of the influence of von Graefe. In 1859 he settled in St. Petersburg, where he was appointed physician to the Eye Infirmary. In 1873 he became body-oculist to the Imperial Court, and in 1885 a Fellow of the Medical Council. In 1901 he resigned his offices on account of ill health, and from that time onward lived in great retirement at Leutsch, near Leipsic. He died of pneumonia Aug. 29, 1904, at Bad Salzungen.—(T. H. S.)

Magazines, Ophthalmic. See **Ophthalmology, Literature of.**

Magic lantern. A device for throwing pictures in a darkened room on to a screen.

Magne, Pierre Alexander Charles. A distinguished Parisian ophthalmologist. Born at Etampes, France, in 1818, he received his medical degree at Paris, presenting as dissertation "Quelques Mots sur l'Ophtalmologie." He was a pupil, and, later, the assistant of Sanson. He was a skilful operator and a prolific writer. He died in 1887. His ophthalmologic writings, in addition to numerous journal articles, are as follows: 1. *Hygiène de la Vue.* (Paris, 1847.) 2. *Des Lunettes, Conserves, Lorgnons. . . . Conseils aux Personnes qui Ont Recours à l'Art de l'Opticien.* (Paris, 1851.) 3. *Etudes sur les Maladies des Yeux.* (Paris, 1854.)—(T. H. S.)

Magnet, Giant. See p. 5374, Vol. VII of this *Encyclopedia.*

Magnesia. See **Magnesia, Calcined.**

Magnesia, Calcined. Light magnesia. Light magnesium oxid. Magnesia. Magnesia usta. MgO. A very light, white powder with a slightly alkaline taste.

Occasionally used as a powder to abrasions of the lid.

The following collyrium has been highly recommended in the treatment of "pink-eye" by J. G. Thompson, in which, doubtless, some magnesium borate is formed. Acid. boric., ʒiss.; magnesiæ calc., ℈ss.; aquæ dest., fl. ℥iii. Mix and filter. A few drops to be used in the eye every four hours.

Magnesiumblitzlicht. (G.) Magnesium flashlight.

Magnesium lamp. A contrivance used for burning magnesium ribbon.

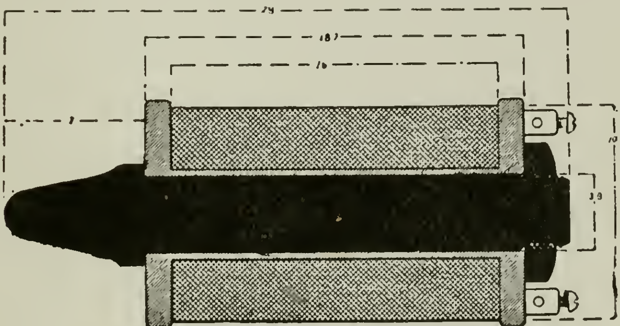
Magnesium sulphate. Epsom salts. Bitter salt. Small, colorless, odorless, bitter, saline needles, very soluble in water, insoluble in alcohol.

This salt is rarely used as a local application in eye disease, but E. E. Holt advises that in any sthenic inflammation about the eye with swelling of the lid or conjunctivæ, the application of a saturated solution in several thicknesses of gauze, bound comfortably tight about the orbit during night time, will materially help to check the inflammation.

Magnet in eye diseases. In addition to the observations made under **Giant magnet**, p. 5374, Vol. VII, and in particular under **Electromagnet**, p. 4252, Vol. VI, of this *Encyclopedia*, attention is drawn to the fact that a history of the *magnet operation* is given under **Meyer, Nikolaus.**

Two forces must be considered in the case of the electro-magnet-lifting power and attractive force. The latter alone is applied in ophthalmology. The strength of the attractive forces varies with the form of the pole. Flat poles develop, at a distance of more than 3 cm., greater attractive force than conical ones at 3 cm. distance, while at a shorter distance, the conical pole is superior to the flat. Hence, inasmuch as extraction of intraocular foreign bodies is performed at less than 3 cm. the conical form is to be preferred here. As regards the technique, Arbez (*Klin. Monatsbl. f. Augenh.*, Aug., 1913) recommends iridectomy whenever the Roentgen plate shows a long foreign body or when traumatic cataract is present. The author urges extraction of the foreign body in every case, even if it appears to be aseptic, for danger of sympathetic ophthalmia is always present. Favorable results were obtained with Rollet's electromagnet. Of eighteen extractions the vision was satisfactory in one-third.

Sherman (*Cleveland Med. Jour.*, Vol. V, 1912) reports that as long ago as 1894 he had constructed a powerful electro-magnet, consisting of a bar of soft Norway iron, 18 inches long and 3 inches in diameter, wrapped with hundreds of feet of fine copper wire, properly insulated. The magnet was energized by the current from the street supplying



Cross-section of magnet.

The Sherman Magnet.

arc lamps and, by means of a transformer and a rheostat, consisting of thirty coils of iron wire, the voltage was efficiently reduced to make it safe for use on the eye. This magnet showed the presence of a foreign body in the eye and led to its migration through the sclera, enabling it to be removed through an incision in the conjunctiva. Sherman reports five interesting cases of foreign body in the eye, in four of which satisfactory vision was obtained notwithstanding the severity of the traumatism. His lengthy experience has convinced him that many eyeballs can be saved in spite of very grave traumatism and severe reaction. Sherman, as well as Stieren (*Ophth. Rec.*, Vol. XXII, 1911) is opposed to removing foreign bodies from the vitreous via the anterior chamber, but inserts the magnet in a scleral wound as nearly opposite the foreign body as possible. The latter's experience with foreign bodies in the orbit has been that metals with the exception of brass and copper are well borne and need not be disturbed. Wood, however, tends to create fistulous tracts, and glass to wander.

Jacqueau (*Arch. d'Opht.*, Vol. XXXIII, p. 665, 1911) extracted a small bit of steel, four days after injury, through an incision in the sclera with the hand magnet from the vitreous of an eye already inflamed, and giving the impression of an impending infectious hyalitis, with vision reduced to fingers. The radiograph had previously localized the foreign body. The inflammatory and infectious phenomena receded rapidly. Twenty days after the operation the vision had risen to nearly one-half. Dor observed that this case substantiated his opinion that small magnets are preferable to large; the former can be introduced into the vitreous and attract the magnetic bodies without injuring the ciliary body. The sight is retained in a larger proportion of cases than where large magnets have been employed.

Elschnig (*Cent. f. p. Augenh.*, Vol. XXXVII, p. 230, 1912) reports 68 cases, exclusive of those seated superficially upon the cornea, of wounds by bits of iron of one eye only, from his clinic during the past six years. From the anterior chamber and iris, the foreign body was extracted in four cases with the giant magnet, in five with Hirschberg's, in two others with the same, after unsuccessful attempts with the giant magnet. Besides, four eyes infected, in two on account of insidious iridocyclitis, enucleation or exenteration had to be performed. In 14 cases the foreign body was situated in the lens; two were infected on admission and an additional one proved to be so subsequently. The foreign body was extracted in six instances with the giant magnet, in five with Hirschberg's hand magnet, and in eight with both. One eye was enucleated at once. In seven others, enucleation or exenteration was required on account of insidious iridocyclitis.

In twenty-one cases the foreign body was situated in the vitreous or retina; two were infected upon admission and one proved so subsequently. The foreign body was removed in four instances with the giant magnet; in four with Hirschberg's primarily, in ten by the latter after failure of the giant magnet, and in one case with the giant magnet and attached magnetized forceps. In two cases the foreign body could not be removed, in both of which, as also in five cases after removal, the eye had to be enucleated or exenterated. In three cases the foreign body was seated in the sclera, one not infected, the other two infected, both of which had to be sacrificed, in one after extraction with the forceps, the other with the giant magnet. Three cases of double perforation were observed, in two of which the foreign body was removed by Hirschberg's magnet introduced into Tenon's capsule.

Of these sixty-eight cases, fifty-four of which were not infected, the foreign body was removed in all but eight, while the eyeball had to be sacrificed in twenty-two. Those in which the ball could be retained preserved a degree of visual acuity corresponding to the extent of the original injury. Elschnig remarks that the importance of penetration of a foreign body into the interior of the eye is frequently underestimated. He has observed in a series of cases in which the extracted body was shown to be sterile, severe iridocyclitis to supervene. While he fully agrees with Hirschberg's dictum that every sliver of iron should be removed as soon as possible, an exception should be made in those cases in which detachment of the retina occurs shortly after penetration of the foreign body; reattachment will probably take place, and when this has occurred the chances of a favorable result are greater. He would also infer from his experience that the question whether the giant magnet or Hirschberg's hand magnet is to be preferred, is beside the mark, but that either or both are to be employed according to the circumstances of the individual case.

Hüttemann (*Klin. Monatsb. f. Augenh.,* Sept., 1915) reports 54 cases of intraocular iron splinters and one within the orbit, occurring during the past three years in the Strassburg University Eye Clinic. He tabulates and analyzes this material with regard to the size, form and seat of the foreign body, age and sex of the patients, clinical history and condition at the time of admission, diagnostic methods employed, form of infection, course of the magnet extraction, subsequent intraocular interventions and finally in regard to the termination of the case.

Lambert (*Arch. of Ophth.,* Vol. XLII, p. 510, 1912) removed from the vitreous by means of the small magnet a foreign body which had been in the eye ten years. It was embedded in the remains of the lens and some exudate, which had to be removed by linear extraction previous to application of the magnet.

A hand-magnet designed by Parker, (*The Ophthalmoscope,* Aug., 1906) measures 8 inches in length, with 1½ inches of the core projecting. The diameter is 3 inches, while that of the core is 1¼ inches. The weight is 1¼ pounds. There is a button switch on the magnet which is arranged on the knife switch principle to avoid arcing and blackening of the contact points. A soft iron spring indicator at the front end of the magnet shows contact when the current is on. To facilitate the easy handling of the magnet the tips are set at an oblique angle and fasten on with a lock instead of a screw. The tips intended for scleral penetration are drawn out to long, round, slender points. The ends of these tips are not rounded, but are countersunken so as to make them concave, thus affording a receptacle for the lodgment and better retention of the foreign body as it is pulled through the lips of the scleral wound.

A local electrician made a Basle coil for Gifford (*Ophthal. Record,* Feb., 1907) which he suspends with a transverse rope bale and counterweight so that it can be used with the patient in a reclining position. He also constructed extra cores for intraocular use. He does not find this inner-pole magnet as powerful as the Haab magnet, but considers it very handy for the removal of steel from the eye after the steel has been drawn forward by the Haab magnet. He thinks his coil is not as powerful as that described by Hagenbach-Bischoff of Basle and that more experimentation with its construction may further perfect it.

Lampe (*Klin. Monats. f. Augenh.*, Aug., 1913) reports that of twenty cases the inner-pole magnet had been successfully employed in nineteen. The globe had to be enucleated in five. In seven cases a visual acuity of 1/7 to less than 4/7 was attained. The weight of the foreign body varied between 0.00032 g. and 0.0435 g. These results with Mellinger's inner pole magnet are thoroughly satisfactory and its employment is to be recommended. Examination with the sideroscope is highly important; the foreign body was localized in fifteen instances by its means. In general, he remarks, the sideroscope is to be preferred to the X-rays, as the application is cheaper and simpler.

Petit (*Soc. d'Opht. de Paris,* Dec., 1912) removed a voluminous foreign body from the lid by means of the electromagnet. The body weighed 50 cg. It measured 12 x 8 x 2 mm. The case is interesting from the weight of the foreign body, the slight degree of annoyance which it caused, its ready entrance into the tissue and massing at the point of entry, and finally as illustrating the utility in doubtful cases of the electromagnet.

Egypt being almost entirely an agricultural country, injuries from iron splinters are rare and the magnet uncommon even in Cairo. Meyerhof (*Cent. f. p. Augenh.*, Vol. XXXVII, p. 335, 1912) succeeded in removing a bit of iron from a gaping corneo-scleral wound from which iris, ciliary body, and vitreous were protruding, by means of a Hirschberg magnet, attached to an alternating current. In spite of the lack of all antisepsis in the first treatment of the patient following the injury, and the irrational conduct of the patient himself in purposely displacing he bandage, the final result gave 5/10 vision.

O. Haab (*Arch. f. Augenheilk.*, p. 271, Vol. LXXVII) again reports his experiences (of about 300 operations) and the principles that guide him in the use of his large magnet. A study of the shape and size of pieces of iron make his method of extraction through the anterior chamber most commendable. Haab considers this operation *as the rule,* the more damaging method through the sclera, as *the exception.* In order to avoid entanglement of the foreign body in the iris, after it has passed around the lens through the zonula, the operator interrupts the current, with his foot. For good illumination Haab found a Nernst lamp, with a large convex glass for concentration, very useful. Iridectomy must be avoided as much as possible. If the foreign body does not readily come through the pupil, an incision is made through the cornea and the hand-magnet is introduced behind the iris; or a suitable point connected with the cable of Lang, is attached to the giant magnet.

If the piece has become lodged in the ciliary insertion of the iris and cannot be moved, a dialysis of the iris is made by introducing an iris forceps through an incision at the corneal margin, pulling with it the iris toward the pupil. The tip of the magnet is next introduced into the gap made in the iris and the foreign body extracted. If the magnet cannot be introduced through the original wound, a vertical incision, between the corneal margin and the center, which must be at least twice as large as the foreign body, is made with a Graefe knife. He considers an opening at the limbus wrong, as a prolapse or healing in of the iris at this place is apt to follow, and the extraction at this seat of the wound is more difficult. The giant magnet generally attracts the foreign body; it is only when it fails that the sideroscope and Roentgen rays are necessary for determining the seat of the foreign body.

If one operates according to Haab it is irrelevant whether the foreign body lies in the vitreous up or down, to the left or right, more in front or farther back. Haab's magnet is a very powerful one, and he believes the failure of other giant magnets to be due to their insufficient power.

The patient ought not to lie on a table, but sit in a chair, so that his head is free and can be drawn back should he experience pain. Pain is induced by contact of the moving foreign body with the iris; imbedding of the splinter in this membrane may be prevented by withdrawing the patient's head.

Magnetization of light. The rotation of the plane of polarization of light in a magnetic field.

Magnetism, Animal. See **Hypnotism.**

Magnetometer. This is a name given specifically to an instrument of Gallemarts (*Ophthalmology,* p. 486, July, 1913). It is really a form of the sideroscope, described on p. 639, Vol. I, of this *Encyclopedia.* The inventor claims that it is superior in the localization of magnetizable objects to other forms of the instrument.

Magnet operation. See **Electromagnet**; also **Magnet,** and **Giant magnet.**

Magnification. In *optics,* the act or state of being enlarged, as by a lens. *Angular magnification,* the ratio of conjugate slope-angles, in which the tangent of the slope-angle of the image-ray divided by the slope-angle of the object-ray, proceeding from the conjugate axial object-point, is a constant. Also called the *"convergence ratio,"* which is an important magnitude in the theory of optical instruments. *Axial magnification,* the ratio of infinitely small line-sements of the principal axes in an optical system. It is inversely proportional to the abscissa on the axes. *Depth-magnification,* same as *axial. Lateral magnification,* the ratio of the corresponding linear dimensions of the object and the image, or the ratio of their semi-dimensions (height above or below the axis) measured perpendicularly from the axis (of a lens or mirror) to the peripheral edges of the object and image. It may have any value depending on the position of the axial object-point, and is the measure of the actual magnification. When the semi-dimensions o and i, of the object and image, respectively, are projected to opposite sides of the *axis,* the image is *real* and *inverted;* if the semi-dimensions are on the same side of the *axis,* the image is *virtual* and *erect. Lateral magnification of a thin lens,* is expressed through the equations:

$$M = \frac{i}{o} = \frac{v}{u} = \frac{f}{u + f} = -\frac{(v - f)}{f},$$

wherein M is the magnification, u, the distance of the object and v, the distance of the image from the center of the lens, and f, its focal length. *Lateral magnification of a mirror* is similarly expressed:

$$M = \frac{i}{o} = -\frac{v}{u} = -\frac{f}{u - f} = -\frac{(v - f)}{f}.$$

When using these formulæ for numeric values of u, v and f, regard must be had for the *continental convention,* which see. Whether the image is real (inverted) or virtual (erect) will depend on the position of the object with respect to the mirror as well as on whether the mirror is convex or concave. If the sign of M is positive (+), the image will be erect; whereas, if M is negative (—), the image will be inverted. The absolute value of M depends on the relative heights of the object and its image; it will be greater than, equal to, or less than, unity, according as the height of the image is greater than, equal to, or less than, that of the object. *Linear magnification,* same as *lateral.* —(C. F. P.)

Magnifier. This term is often applied in optics and ophthalmology to single, compound or binocular lenses for enlargement of the image for various purposes. See, for example, p. 4610, Vol. VI of this *Encyclopedia* where the subject is fully discussed and illustrated.

Magnifier, Telescopic. Under this trade name Zeiss advertises a combination of simple magnifiers with a prism telescope. Such a combination furnishes magnifying powers ranging from 2 to 30 diameters, whilst the instrument can be held a very considerable distance away from the object. This is a quality which enhances its utility in the hands of medical men and others. In many cases the instruments may assist the vision of weak-sighted persons. They are supplied for use with one or both eyes. In the latter case it is, however, necessary to use a binocu-

Monocular Telescopic Magnifier.
Handle, together with a +3-diopter amplifying lens attachment and a —15-diopter glass for attachment to the eyepiece.

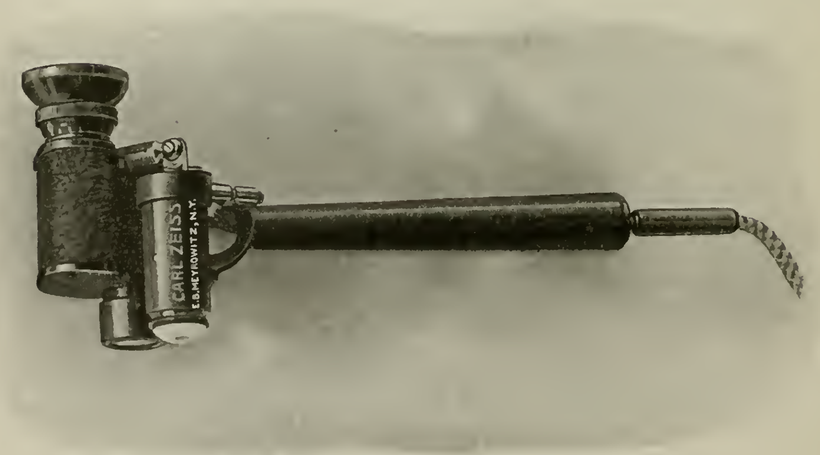
lar telescope component having the objectives nearer together than the eyepieces. This can be readily accomplished by a suitably arranged connection of the two prismatic telescope bodies.

The magnification may be increased by the use of a prism telescope of higher power, as well as by attaching to the objective a stronger amplifying lens; the latter has, however, the effect of shortening the free working distance.

The telescope magnifier forms at infinity a magnified image of an object situated in its principal focal plane.

Those persons whose sight is not normal require the use of ordinary spectacle glasses to see the image clearly. In such cases the observer should either retain his spectacles or use a correcting glass in the form of an eyepiece attachment mounted so as to slip on the eyepiece. When intended for use with ordinary spectacles the prism glasses should have flat eyepiece cups, otherwise the full benefit of the size of the field will not be obtained.

Binocular Telescopic Magnifier.
The fragmentary magnifying lens together with the bayonet mount by which it attaches to the objectives is shown detached from the binocular.



Monocular Telescopic Magnifier with Illuminating Attachment.

When prescribing telescopic magnifiers for weak-sighted persons it is advisable to note in the prescription the existing degree of amblyopia and to indicate the required correction. To view distant objects with a monocular instrument, it is only necessary to remove the lens attachment from the objective; the magnification of the retinal image will then be simply that resulting from the amplifying power of the telescope.

Monocular Telescopic Magnifier with Illuminating Attachment, showing manner of using the apparatus.

Magni, Francesco. A well-known Bolognese ophthalmologist. Born in July, 1828, he received the degree of Doctor in Medicine at Pisa, afterwards, studying ophthalmology at Vienna, Paris and Berlin. At first he settled in Florence, where he founded a Polyclinic for eye patients. Removing to Bologna he became renowned internationally as an operator. Called to Peru to operate, he remained in South America for a year, operating in all the larger cities of that continent. Some years later he also performed a number of operations in Egypt. He died in 1887.—(T. H. S.)

Magnifying glass. A convex lens; so called because objects seen through it have their apparent dimensions increased. Also called *magnifying lens*. See, also, **Lens**.

Magnifying lens. A convex lens through which the dimensions of an object are seen enlarged. See **Magnifying power.**

Magnifying power. In *optics,* the ratio involving a comparison, either between the angle subtended by the object at the center of the entrance-pupil of an optical system and the linear dimension of the image, or between the angle subtended by the image at the center of the exit-pupil and the linear dimension of the object. *Intrinsic magnifying power,* the ration ($\tan\Theta'/y$) of the visual angle (Θ') subtended at the nodal point of the eye by the image viewed through the instrument to the corresponding linear dimension (y) of the object. According to Abbe, this is the proper measure of the characteristic magnifying power of an optical system on the order of a microscope. *Objective magnifying power,* in an optical projection-system, the ratio, $y'/\tan\Theta$ of the linear size (y') of the image to the *apparent size of the object,* the latter being the trigonometric tangent of the angle (Θ) subtended by the object at the center of the entrance-pupil (which see). It is so called in distinction to the *subjective magnifying power,* which is applied to instruments designed to be used subjectively in conjunction with the eye for the purpose of amplifying vision, as for instance, in the case of the ordinary magnifying glass, or the microscope. *Subjective magnifying power,* the ratio of the visual angles (or their trigonometric tangents $\tan\Theta'/\tan\eta$) subtended at the nodal point of the eye; where one of the angles (Θ') corresponds to the image viewed in the instrument, and the other (η) to the object,as seen by the naked eye at the distance of distinct vision. This ratio involves the so called "distance of distinct vision," *a,* which, being variable among different individuals makes it necessary to conventionally adopt 25 millimeters or 10 inches as the standard distance of distinct vision for the normal eye. However, even where allowance is made for the different distances of distinct vision among far-sighted and near-sighted observers, Abbe has pointed out that, both observers looking through the instrument will, as a matter of fact, view the image of the same object under the same visual angle; so that whatever difference there may be in the magnification is to be found not in the instrument itself, but in the different organs of sight that are employed in conjunction with the apparatus. Therefore, as the angle subtended at the ocular nodal point by the object seen by the naked eye has nothing to do with the instrument, it is convenient to substitute its value ($\tan\eta$) by its equivalent, namely the linear dimension (y) of the object divided by the distance (a) of distinct vision or y/a, when the ratio for the subjective magnifying power becomes $\frac{\tan O'}{y}$.a, the product of two factors, one of which is a, the distance of distinct vision. However, Abbe ignores the variable factor (a), having shown that from a strictly scientific point of view his equation for the intrinsic magnifying power is far superior, since it is strictly a constant of the instrument itself. (Southall, *Principles of Geometric Optics.*)

Magniscope. A variety of chromo-photograph.

Magnitude, Estimation of. See under **Distance, Estimation of,** p. 4045, Vol. VI of this *Encyclopedia.*

Magnitude of lateral aberration. See **Aberration.**

Magnitudes of light. The comparative intensity of various lights has been measured by a number of observers, including Merkel, Weber, and Fechner. These experiments are interesting to ophthalmologists, in view of the effect of various sources of illumination upon the eye. See **Arc lights.**

Magnus, Hugo. One of the greatest of German ophthalmologists. Born at Neumarkt, Schleswig, Germany, he received his medical degree at Breslau in 1867. While a student, the men who chiefly influenced him were Lebert and Middledorpf. In 1873 he qualified as privatdocent in ophthalmology at his alma mater, and in 1883 became extraordinary professor. He was a prolific and highly valued writer, as well as a clear and forceful teacher. He died April 13, 1907. His most important writings relate to the color faculty, to ophthalmic economics, and to the history of ophthalmology. A fairly complete bibliography is as follows: 1. *Die Albuminurie in ihren Ophthalmoskopischen Erscheinungen.* (Leipsic, 1873.) 2. *Opthalmoskopischer Atlas.* (Leipsic, 1872.) 3. *Sehnervenblutungen.* (Leipsic, 1874.) 4. *Die Bedeutung des Farbigen Lichtes,* etc. (1875.) 5. *Geschichte des Grauen Staars.* (Leipsic, 1876.) 6. *Die Geschichtliche Entwicklung des Farbensinnes.* (Leipsic, 1877; French trans., 1878; Spanish trans., Madrid, 1884.) 7. *Die Farbenblindheit.* (Breslau, 1878.) 8. *Die Blindheit, ihre Entstehung und ihre Verhütung.* (Breslau, 1883.) 9. *Augenärztliche Unterrichts-Tafeln für den Akademischen und Selbstunterricht.* (Founded 1892.) 10. *Leitfaden für Begutachtung u. Berechnung von Unfallsbeschädigungen des Augus.* (Breslau, 1894; 2d ed., Breslau, 1897; translated into English, re-written, and adapted to American conditions by H. V. Würdemann, in 1902, under the title *Visual Economics.*) 11. *Die Einäugigkeit in ihren Beziehungen zur Erwerbsfähigkeit.* (Breslau, 1895.) 12. *Die Untersuchung der Optischen Dienstfähigkeit des Eisenbahn-Personals.* (Breslau, 1898.)—(T. H. S.)

Maidismus. (G.) Pellagra.

Maier's sinus. An occasional diverticulum of the lacrimal sac into which the lacrimal canaliculi open.

Maiotic. Marked by miosis; old form of *miotic.*

Maissiat, Jacques Henri. A Parisian physician, and comparative anatomist, of a slight ophthalmologic importance, because of his *"Lois Générales de l'Optique"* (1843). Born at Nantua, he studied at Lyons, Montpellier and Paris, receiving his degree in 1838. He was the chief founder of the Museum for Comparative Anatomy at the École de Médecine. He died at Nantua, Mar. 26, 1878.—(T. H. S.)

Maître Jan, Antoine. A famous French surgeon and ophthalmologist, especially noted for his re-discovery of the true nature and situation of cataract. He is often called the "Father of French Ophthalmology." Born at Méry-sur-Seine in 1650, he studied at Paris, returning to his native town for the practise of his profession. His success as a surgeon was almost immediate. He became a corresponding member of the Paris Academy and Body Physician to the King.

He wrote *"Observations on the Chicken, or the Different Changes which occur in the Egg,"* etc. (Troyes, 1707); "History of a very Singular Monster" (*Hist. of the Acad. of Sciences,* 1705); "Report of a very Voluminous Nasal Polypus" (*Ibid.* 1706). His only ophthalmologic work was *"Treatise on the Diseases of the Eye and the Remedies Proper for Its Cure"* (Troyes, 1707; Paris, 1722 and 1741).

The ophthalmologic work has always, and quite properly, received the very highest praise. It marked, in fact, a great improvement over all preceding ophthalmologic treatises. It is a large quarto of 570 pages, one hundred of which are devoted to Ocular Anatomy and Physiology. In this portion is included an excellent (of course, for its day) treatment of the Nature of Vision, together with a number of "experiments" relating to the camera obscura and to the reflection and refraction of light.

In the pathologic portion of his work, Maître Jan takes the position, then very new, that a cataract is not an inspissated humor in a (wholly imaginary) space between the pupil and the lens, but the lens itself in a hardened and clouded condition. Maître Jan was not really the discoverer of this, the true, doctrine concerning cataract, but its re-discoverer. Quarré seems to have been the first in history to announce the doctrine in question, while to a German, Rolfinck, belongs the credit of having been the first to demonstrate the truth of the doctrine by actual anatomical investigation. To the young Brisseau, however, and to Maître Jan, must certainly be conceded the re-discovery of the great truth which, in the thirty or forty years since its first announce-ment and anatomical demonstration had been absolutely forgotten. To these re-discoverers, furthermore, must be allowed the honor of having fought for the truth of their great re-discovery until the attention of the scientific world was properly and for all time focused upon it.

The new teaching concerning the nature and situation of cataract, however, was not accepted till after a long and bitter controversy which involved a majority of the prominent ophthalmologists of the day, especially those of France. The leader of the opposition was Woolhouse, an English oculist resident in Paris. Lesser opponents were Hovius, Freytag and Hecquet.—(T. H. S.)

Major, Johann Daniel. A German physician who paid considerable attention to ophthalmology. Born at Breslau in 1634, he studied at Wittenberg, Leipsic, and Padua, at the last named institution receiving his medical degree in 1660. He practised, successively, at Wittenberg, Hamburg, Kiel and Stockholm. He died at Stockholm in 1693.

His only ophthalmologic writing was *"De Amaurosi"* (Kiel, 1674.) —(T. H. S.)

Majoram. Modern, and more correct spelling, *Marjoram*, (q. v.). *Origanum majorana.* In ancient Greco-Roman times, majoram, rubbed up with salt, was employed as a local application in ocular diseases generally.—(T. H. S.)

Major axis. In *conic sections*, the diameter which passes through the foci. In the ellipse it is the longest diameter; in the hyperbola it is the shortest; and in the parabola it is, like all other diameters, infinite in length. Also called *transverse axis.*

Makro-. For words thus beginning, see **Macro.**

Mal. (F.) Disease; ache.

Malacatmon. A large tree found in the Philippines, which yields a limpid sap used in dysentery, peritonitis and in ophthalmia.

Malachite green. This aniline derivative has been known to produce ocular disturbances in workmen employed in its manufacture. In one case some of the dye-stuff flew into the conjunctiva and this accident was followed by swelling of the lid and acute conjunctivitis. Shortly afterwards a yellow-white membrane attached itself to the conjunctiva and gradually invaded the cornea. Complete recovery occurred in six days.

Malacocataracta. (L.) Obsolete term for soft cataract.

Malacoma. Morbid softening; also a morbidly soft part or spot.

Maladie de Périnthe. (F.) An epidemic disease described by Hippocrates that appeared at Perinthus, in Thrace, first presenting a cough that intermitted and on its recurrence was accompanied by nyctalopia, angina, or paresis of the extremities.

Maladie des cartiers. (F.) Lead poisoning in persons engaged in making playing-cards, contracted from a gelatinous gum containing lead carbonate with which the cards are glazed.

Maladie de terre. (F.) Tunnel anemia. Dirteater's anemia. Hookworm disease. See **Ankylostomiasis**, p. 487, Vol. I, of this *Encyclopedia.*

Maladif. (F.) Sickly; affected with chronic disease.

Mal ansérine. (F.) Pellagra.

Malaria, Eye disease of. The most important complications of this infection are conjunctivitis and the dendritic form of keratitis, described on p. 3347, Vol. V, of this *Encyclopedia.* According to Poncet (*Annales d'Ocul.*, p. 79, 1878) ocular complications of the general disease are found in 10 per cent. of all cases of true malaria.

In addition to these symptoms iritis, iridocyclitis, metastatic ophthalmia, retinitis pigmentosa, choroiditis, vitreous opacities, retrobulbar neuritis, cataract, glaucoma, etc., are described. Retinal hemorrhage is relatively common and severe vitreous hemorrhage may occur. Uhthoff found 17 cases of optic neuritis in 253 due to infectious diseases. It is doubtful if primary optic atrophy occurs. Of course the treatment of these complications is bound up with that of the underlying infection. See, also, **Mosquito.**

Malattia. (It.) Disease.

Malaxation of the eye. Malaxation of the eyeball after the operation of sclerotomy. The term is used by Dianoux for the making of a series of pressure-movements on the eyeball with the ends of the index fingers, in order to separate the lips of the wound, and thus evacuate a portion of the aqueous humor. This maneuver is to be repeated twice a day for five or six days, and is said to be superior to the ordinary method of massage.

Mal de Sainte-Euphémie. (F.) Syphilis; probably called by this and other saints' names because of the popular belief that through prayers to saints the disease might be cured.

Mal de tête. (F.) Cephalalgia.

Mal d'Hercule. (F.) Epilepsy.

Mal égyptiaque. (F.) Diphtheria.

Malerbrillen. (G.) Pantoscopic spectacles.

Male fern. See **Felix mas**, p. 5198, Vol. VII, of this *Encyclopedia.*

Malformations of the eye. See **Congenital anomalies of the eye**, p. 2776, Vol. IV of this *Encyclopedia.*

Malgaigne, Joseph François. A famous Parisian surgeon, of some importance in ophthalmology. Born Feb. 14, 1806, at Charmes-sur-Moselle (Vosges) the son of a country doctor, he at first studied medicine at Nancy, and, in 1825, was an *officier de santé*. Proceeding shortly afterward to Paris, he studied at the military hospital of Val-de-Grâce, and received his medical degree in 1831. He then for a number of years served in the national army in his medical capacity. Returning to Paris, he became in 1835 associate professor and surgeon at the Central Bureau. So brilliant were his lectures at the École Pratique that he almost immediately became famous. He founded in 1843 the *Journal de Chirurgie,* and served as its editor-in-chief for twelve years. In the course of these years, he was appointed surgeon to all the most important Parisian hospitals, and in 1850 made full professor on the faculty. He was world-renowned as an operator, teacher and author when, owing to cerebral apoplexy, he passed away, Oct. 17, 1865.

Malgaigne's most important ophthalmologic writings, which, for the greater part, appeared in the earlier years of his practice, are as follows: 1. Nouvelle Theorie de la Vision. (1830.) 2. Traitement de la Fist. Lac. (1835.) 3. Lettre sur la Nature et le Siège de la Cataracte. (*An. d'Oc.,* VI, pp. 62, 66; VIII, p. 148.) 4. Lecture sur la Nature et le Siège de la Cataracte. (*Ibid.,* IX, p. 50.) 5. Sur les Diverses Éspeces des Cataractes. (*Ibid.,* XX, p. 234.) 6. Sur le Siège et les Éspeces des Cat. (*Revue Méd. Chir. de Paris,* Jan. and Feb., 1855; Canstatt's *Jahresbericht für 1855.*) 7. La Cure des Taches de la Cornée. (*An. d'Oc.,* IX, p. 95, 181.) 8. Sur les Consequences de l'Abrasion. (*Ibid.,* XIII, p. 211.)—(T. H. S.)

Malignant glaucoma. See p. 5403, Vol. VII, of this *Encyclopedia.*

Malignant pustule. CHARBON ANTHRAX. See **Bacteriology of the eye**; as well as **Anthrax**, p. 512, Vol. I, of this *Encyclopedia.*

Malingering. This may be defined as a voluntary simulation of illness. It may take the form of a mere pretense, an exaggeration of an already existing ailment, or a morbid state or wound entirely produced by artificial means. There is no end to the varieties of malingering. Almost every disease may be simulated, and remarkably closely, and the same patient may exhibit symptoms of many diseases. An acute observation and application of small mistakes in the presentment of a disease often enable the practitioner to detect its true nature.

As regards *ocular malingering* or *simulation* and its detection the reader is referred to p. 1188, Vol. II, as well as to **Legal relations of ophthalmology**, p. 7093, Vol. IX, of this *Encyclopedia.*

Among the more recent tests for exaggeration or simulation of amblyopia is the device of Roche, *Ophthalmoscope* review of *Rec. d'Ophthalm.,* Sept., 1911.)

He tests the vision by means of a hundred cardboard squares, in each of which one of the test letters of Monoyer or Snellen types is pasted.

Adopting the decimal test type, he thus has ten squares for each line of test type. The squares are all mixed up together anyhow and similarly exposed to the patient at 5 meters distance; he is asked to name those letters he can recognize and the corresponding squares are put on one side and compared with those which were said not to be recognizable. Having no means of comparing one letter with another, the simulator finds it extremely difficult to deceive the examiner and be consistent in his answers. The test may be further modified by varying the distance from the patient at which the letters are held, by putting glasses, plain or otherwise, before the eye, or by asking the patient to read the letters reflected in a mirror. By these means it generally happens that the patient's real vision can be ascertained, and the inconsistency of his answers can be very clearly demonstrated to the patient by showing him the two packets of letters as selected by himself.

Mal intellectuel. (F.) Epilepsy.

Malpractice. The law in various lands, with especial reference to ophthalmologists, is fully stated under **Legal relations of ophthalmology,** in the last third of the section.

Mal rouge. (F.) Erysipelas.

Mammals, Eyes of. See **Comparative ophthalmology.**

Mandible capsule forceps. A name given by Ewing (*Am. Journ. of Ophthalm.*, May, 1913) to a form of capsule forceps.

Mandragora. *Mandragora officinalis.* MANDRAKE. DEVIL'S APPLE. In ancient Greco-Roman times an important constituent of the *armamentarium oculisticum,* at least according to Celsus and Dioscorides. Both these authors mention two varieties of mandragora—the male, white (*Mandragora vernalis*) and the female, black (*Mandragora autumnalis*). The white mandragora was known by a great variety of names; as, *arsen, hippophlomus, norium.* The juice, expressed or boiled from the bark of the root, was the product chiefly used. This was drunk, as a rule, mixed with wine or vinegar. Besides the juice of the bark of the root, the roots themselves, powdered, were employed, and the leaves were used as a poultice to inflamed eyes. Mandragora was regarded as a remedy of the very highest value in antiquity in diseases of the lachrymal apparatus.

The most important use, however, of mandragora, according to ancient authors, was as a surgical anesthetic. Three minæ of the root was added to one amphora of sweet wine, and, of this mixture, the subject of the operation drank three cyathi. He was then supposed to undergo the operation without pain. According to Pliny, mandragora was also now and then administered for anesthetic purposes by inhalation. The root and the juice of mandragora were combined with the leaves of the poppy in a porridge of chestnut meal, and the steam of the mixture was inhaled.

As pointed out by Hirschberg, it is doubtful in the extreme whether the surgeons of antiquity really ever employed mandragora as a surgical anesthetic. Neither Celsus nor Paulus makes the slightest mention of the subject, while Pliny and Dioscorides, to whom we are chiefly indebted for the matters above set down, were, neither of them, surgeons. In fact, Dioscorides was merely a writer on materia medica, while Pliny, though an author of great repute, was a superstitious layman.—(T. H. S.)

Mandragorin. A crystalline alkaloid, $C_{17}H_{23}NO_3$, obtained from the roots of *Mandragora autumnalis* and *Mandragora officinalis*. It has a bitter, nauseous taste, with properties like atropine. The sulphate forms lustrous deliquescent scales, the solution of which is mydriatic.

Mandrake. See **Mandragora.**

Mandrin. A stilet or guide for a catheter or hollow sound.

Mangel des Auges. (G.) Anophthalmia.

Mangold. *Beta vulgarus.* According to Archigenes (48-117 A. D.) the ordinary beet was, in his time, regarded as a remedy for "nyctalopia."—(T. H. S.)

Mania, Postoperative ocular. See **Cataract, Senile.**

Manifest hypermetropia. See p. 6098, Vol. VIII, of this *Encyclopedia.*

Manolesco, N. A well-known Bulgarian oculist. Born in 1850, he received his medical degree at the University of Bucharest. He then studied ophthalmology at Paris, chiefly under de Wecker, and became assistant to that master ophthalmologist. Later, he studied at Vienna under Arlt. In 1881 he was appointed professor of ophthalmology and surgeon-in-chief to the Ophthalmic Hospital at Bucharest. He wrote almost nothing, but invented a number of instruments, as well as two or three methods for the removal of cataract. He is said to have invented abrasion of the conjunctiva for the treatment of trachoma—a procedure, however, which was very well known to the ancients. He died very suddenly of heart disease, Sept. 4, 1910.—(T. H. S.)

Manometer. An instrument used to determine the force of blood-pressure, consisting of a long graduated tube filled with mercury, on the surface of which is a float carrying an indicator. The lower end of the tube is inserted into a large artery, so that by the force of the blood-current the mercury is carried upward, and the pressure is recorded on the tube. See p. 1227, Vol. II, of this *Encyclopedia;* as well as **Circulation of the intraocular fluids.**

Manoscope. Manometer; baroscope.

Manus hominis mortui. (L.) The hand of a dead man. Formerly the touch of a dead man's hand, or rubbing with it, was considered efficacious in the treatment of various kinds of tumors, including tumors of the eyelids.

Manz's glands. Glandular depressions on the borders of the eyelids.

Manz, Wilhelm. A well-known German ophthalmologist. Born at Freiburg i. Br., May 29, 1833, he studied medicine at Freiburg, Vienna, Prague, and Berlin, at the last named center receiving his degree in 1858. The following year he qualified as privatdocent in his native city, and four years later was made extraordinary professor in the same institution. In 1868 he received the full professorship, and was also appointed director of the Freiburg Ophthalmic Hospital.

He wrote a large number of articles, chiefly on choked disc, ocular tuberculosis and the embryology and teratology of the eye. His most important composition was the division on ocular embryology and teratology in the Graefe-Saemisch *Handbuch*. He invented the lymph-stasis theory of the production of choked disc.

Manz was a small, wizened man, with piercing blue eyes, stern of countenance and rough of manner. The students almost always stood in awe of him. He was, however, gentle to his patients and almost rigidly just to his students.

As a teacher he was sound, but not brilliant. He lacked the power of ready expression in language, but, if he was slow, still, on the other hand, he was very methodical and careful that his students should acquire the right ideas. He almost never exhibited more than three or four cases in a single hour, but these were almost always typical, and he went into them thoroughly. Manz retired in 1901 and died in 1911, aged almost 78 years.—(T. H. S.)

Map-like choroiditis. A synonym of diffuse choroiditis.

Mapouria guianensis. A plant species the leaves of which are employed in the West Indies in lotions for ophthalmia.

Maragliano's serum. Maragliano has immunized animals (horse, cow) against tuberculosis, and finds that the resulting immune serum possesses bactericidal, antitoxic, and agglutinating properties for the tubercle bacillus. His statistics as to the clinical value of the serum, while not conclusive, seem to show somewhat more favorable results in cases in which the serum was used than in those in which the treatment was hygienic only. In some of his cases, Maragliano combined passive and active immunization, using for the latter gradually increasing doses of an extract of tubercle bacilli.

Marasmus. A kind of atrophy; a wasting of flesh without fever or apparent disease; the continuous low condition of nutrition due to defective nourishment or to senile changes. It may affect the eyes secondarily.

Marasmus senilis corneæ. (L.) Arcus senilis.

Maraugia. (L.) An old and now obsolete term for metamorphopsia.

Marcellus Empiricus (i. e., "the empyric"). A well-known Burdigalian pharmacist and courtier of the later fourth and earlier fifth centuries. Born at Burdigala (now Bordeaux) in Gaul, he rose to be chief apothecary and master of the household *(magister officiorum)* to Theodosius I. About A. D. 410 he compiled a dispensatory for the poor, entitled *"De Medicamentis."* The substance of this work was taken chiefly from Scribonius Largus, but its author added much new matter of a magical and superstitious kind. It consists of 28 chapters, or divisions, of which the eighth, devoted to ophthalmology, is entitled "Ad Omnes et Multiplices Oculorum Dolores Collyria et Remedia Diversa, etiam Physica de Probabilibus Experimentis." The whole book closes with a poetical epilogue in 78 lines.

Marcellus, the Empiric, is not to be confounded with Marcellus Sideta (i. e., of Sida, in Pamphylia). The latter, a general physician, was the author of *"Iatrika,"* and lived in the second century A. D., in the reigns of Hadrian and Antoninus Pius.—(T. H. S.)

Marchetti, Luigi. A celebrated Milanese ophthalmologist, founder of the first outdoor clinic for eye patients at Milan. Born in 1807, he was for a time assistant to Flarer. For thirty-five years he practised at Milan as ophthalmologist, enjoying a wide reputation, especially as an operator for cataract. According to Hirschberg, the only method he employed was depression. He wrote a booklet on ophthalmoscopy and a number of case reports.—(T. H. S.)

Marchi's reaction. MARCHI'S STAIN. Failure of the myelin sheath of a nerve to become discolored when treated with osmic acid.

Mare, The. Mare's milk was highly esteemed, in Greco-Roman antiquity, as a remedy for ulcers of the eyes.—(T. H. S.)

Mareschal's test. See p. 1184, Vol. II, of this *Encyclopedia.*

Marginal definition. The sharpness of the image towards the edges.

Marginal diseases. See **Corneoscleral margin,** p. 3523, Vol. V, of this *Encyclopedia.*

Marginal keratectasia. See p. 6746, Vol. IX, of this *Encyclopedia.*

Marginal keratitis. See p. 6779-81, Vol. IX, of this *Encyclopedia.*

Marginal rays. The limiting rays of a pencil of light.

Marginal ring ulcer. See p. 3440, Vol. V, of this *Encyclopedia.*

Marginol. Under this trade name is marketed, in small, collapsible tubes, the following ointment: Hydrarg ox. flav. gr. ?/1, petrolati ʒii.

Marginoplasty. A term applied by Spencer Watson to an operation for the relief of entropion. See p. 4354, Vol. VI, of this *Encyclopedia.*

Margo ciliaris iridis. (L.) The outer margin of the iris.

Margo lacrimalis. The anterior lip of the lacrimal sulcus. See **Lachrymal apparatus.**

Margo lacrimalis ossis maxillæ. (L.) The posterior margin of the nasal process of the superior maxilla which articulates with the lachrymal bone.

Margo palpebralis. (L.) The free border of the eyelids.

Margo pupillaris. (L.) The margin of the pupil.

Marie's disease, Eye symptoms of. See p. 79, Vol. I, of this *Encyclopedia.*

Marin, D. Francisco. An 18th century ophthalmologist of Spain, who, in 1770, translated into Spanish the *"Traité des Maladies des Yeux et des Moyens et Opérations Propers à leur Guérison"* of Dehais Gendron —an important service to Spanish ophthalmology.—(T. H. S.)

Marini's test. See p. 1184, Vol. II, of this *Encyclopedia.*

Marine glass. A *night-glass.*

Mariotte's blind spot. See **Blind spot, Mariotte's.**

Mariotte, Edme. A celebrated French physicist, immortal for his discovery of the "blind spot" of the eye—often known as "the blind spot of Mariotte." He was born in Burgundy in 1620, became a priest, in this capacity officiated at St. Martin sous Beaune, near Dijon, and there became Prior. He was one of the early members of the Academy of Sciences—which, by the way, was founded in 1666, the year in which the blind spot was discovered. Strange as the fact may sound, the physicist-priest was the very first person in history to investigate the visual function of the optic papilla. To the investigator's great surprise, he found that the ocular end of the optic nerve was absolutely devoid of every sort and kind of light perception. Two years after this discovery, Mariotte was called to London for the purpose of demonstrating the blind spot (which, now, was very well known by his name) before the King. The experiment was, of course, successfully repeated by all persons present.

In 1681 Mariotte published a work entitled *"Essai sur la Nature des Couleurs"* (Paris, 1681) in which he attacked (unfortunately) the color theory of Newton, but in which, with greater increase to his reputation, he included his "Investigations of the Colored Rings round the Sun and the Moon." In this portion of the book he correctly assigned as the cause of the major halos and of the mock-sun and mock-moon the presence in the higher atmosphere of floating needles and prisms of ice; to account for the minor halos, however, he wrongly resorted to the theory of double refraction through drops of water which lay suspended in the upper regions of the air. Mariotte died at Paris, May 12, 1684.—(T. H. S.)

Marjoram, Eye symptoms from. There are numerous spellings—ancient and modern—of the English plant name. See, e. g., **Majoran.** Any of several perennial herbs of the genus *Origanum,* of the mint family, with nearly entire leaves, dense oblong spikes of flowers and colored bracts. The principal ones are the sweet or knotted marjoram, the pot marjoram, and the wild or goat's marjoram.

The reviewer in the *Oph. Rev.* notes that Hilbert (*Woch. f. Ther. v. Hyg. des Auges,* Feb., 1909) came across an interesting case of skin and conjunctival irritation in a youth of 16 years, a gardener employed in making up bundles of *Origanum marjor* l. (the common knotted marjoram of England) for the market. During the course of the work his face and hands began to smart, and the eyes pricked and discharged. Hilbert saw the lad the same evening, and found a marked erythema of the parts, and a profuse mucoid secretion from the eyes, with a good deal of blepharospasm. The boy acknowledged that he frequently buried his face in the herb to enjoy the fragrant smell.

For *treatment* heroic measures were avoided; he merely smeared lanoline over the affected skin, and applied cold compresses to the eyes, with the result that the irritation speedily subsided. To make sure that the suggestion of cause and effect was a true one, when the lad was quite recovered he rubbed one finger with some of the freshly gathered herb: almost immediately the skin became red, and, later, swelling appeared.

He remarks that country people sometimes use an ointment of the herb which not infrequently produces marked irritation of the skin. Planz published some cases of this nature in Rostock in 1905. In Lloyds' *Encyclopædic Dictionary* (1895) it is said that the herb is used by farriers as a blistering agent.

Proceeding to discuss the manner in which the herb acts, Hilbert says that plants irritate in three ways: (1) some possess sharp oxalic crystals, like the *Scylla maritima L.;* (2) others spines with formic acid, like the nettle; (3) others, like the majoram, are delicately soft plants but contain essential oils which are irritating to susceptible persons.

Markhaltige Fasern. Medullated nerve-fibers.

Markhügel. (G.) Optic disc.

Marksmanship, Ocular relations of. Gunfire and the eyesight. Relation of the eyes to soldiers' rifle shooting. Apart from the ocular traumatisms incident to modern warfare, fully treated under **Military**

surgery of the eye, and the visual relations of combatants discussed elsewhere in this *Encyclopedia,* the most favorable conditions for accurate shooting form a section that ought to be considered by the educated ophthalmologist. Probably the best account of this subject is given in the writings of Donovan, and Roderic O'Connor. (*Ophthalmology,* July, 1915.) See also a paper by Berry (*Edinburgh Med. Jour.,* June, 1913).

After an examination of the subject in all its bearings O'Connor gives the following summary of the requirements of a good marksman: 1. The necessity of focusing the three points—target, front and rear sights and, (2) the ability to rapidly make the necessary change of focus from one to another of these three points. 3. Alignment once being secured: (a) The sights furnish the diffusion images, being seen by indirect vision; (b) the bull's-eye, more especially its lower edge, is seen clearly and by direct vision.

He regards as the *essentials necessary for best results:* 1. Normal distant vision in order to (a) allow of locating accurately the mark, (b) assist in distance estimating. 2. Sufficient accommodative power to allow of a clear focusing of rear sight. 3. Normal color perception as an aid in (a) locating the object, (b) perceiving details, (c) estimating distance. 4. Binocular vision in order to estimate distances more accurately.

O'Connor gives the following list of the chief *optical aids to marksmanship:* A. Black sights to prevent blurring by irradiation of light from them. B. Lenses. 1. Those correcting refractive errors must be absolutely accurate and best prescribed after refraction under atropine mydriasis as a more accurate correction of any astigmatism is thus obtained. The best method is to correct all the astigmatism and then give the spherical correction, while case is sighting at a mark, with the rifle, up to the clearest view of the mark. This allows for the fact that in aiming one cannot look through the optical center of the lens as ordinarily placed and also for the fact that refraction is different through the periphery of the lens. 2. Amber lenses are of value: (a) By diminishing glare, thus preventing tiring from excessive contraction of the pupil; (b) by cutting out to a great extent the irritating actinic rays of light; (c) by lessening the irradiation of white portion of target over the bull's-eye, thus allowing the latter to stand out clear, sharp and apparently larger; (d) by not cutting down to any noticeable extent the actual illumination; (e) by assisting in bringing out slight contrasts in shades of green, which are those chiefly encountered in nature, and consequently on dull days everything is actually brightened. C. Rear sights: 1. Disadvantages of present rear sight: (a) The necessity of aligning three points; (b) the necessity of accommodating to see it, which is a strain even to the normal, and impossible for the presbyopic eye; (c) the comparatively short distance between the two sights, thus lessening accuracy of aim; (d) the difficulty in rapidly finding point of aim and front sight through the peep, due to the fact that it affords, through it, a field of vision of but one foot for each 100 yards of range. 2. Advantages of peep sight close to the eye: (a) Only necessary to align two points, target and front sight, the mere act of looking through the peep aligning it; (b) no strain put on the accommodation, as it becomes unnecessary to focus even the front sight, hence presbyopes have no difficulty; (c) the corrective effect of the small aperture on spheric aberration and circles of diffusion, thus aiding those who have reduced vision; (d) allows of more rapid aiming because of advantages (a) and (b) and because a much greater field of vision is permitted. A one-millimeter aperture one inch from the eye affords a field of about eleven feet per 100 yards of range. In addition no time is lost finding the rear sight. With the sight one-half inch from the eye the above field would be doubled; (e) increased accuracy of aim because of greater distance between sights; (f) reduction in amount of glare; (g) prevention of side views and lights; (h) the possibility of incorporating amber glass or correcting lens with sight, thus insuring accurate and permanent centering. The problem of locating the peep sight as recommended is one for ordnance experts, but optically there is no doubt whatever but that the place for it is as close to the eye as possible. It would be simplified by omitting the knurled cocking head and by lengthening the stock which at present is too short for the average man. This shortness produces too much bend at the wrist for the free play of the tendons of the forearm muscles, for it must be remembered that the trigger-pulling muscles are in the forearm. With the distance between sights so greatly increased the barrel could be shortened and still maintain the present accuracy. This would be of advantage to the cavalry arm. The alteration necessary to place the sight where recommended may be considerable, but every consideration, of drill, etc., should give way to an increase in the usefulness of the rifle.

O'Connor gives the following *recommendations as to visual requirements:* 1. For the line of the army, the signal and engineer corps: (a) 20/20 in each eye; (b) binocular vision; (c) normal color perception; (d) sufficient accommodation to allow a clear focus at 8 inches from the eye—this does away with the necessity of setting a limit to the degree of hyperopia for different ages; (e) eyes must be free from disease and from asthenopia. 2. For officers, cadets, hospital corps, ordnance, subsistence and quartermaster's departments any degree of defect in either eye provided there is no ocular diseases and that normal distant and near vision may be secured by use of proper correcting lenses. These various classes do not take part in firing in battle, consequently there is not the same need for normal eyes, and besides they are in a better position to take care of lenses. It requires but a low degree of myopia to greatly reduce distant vision, while a high degree of hyperopia, which is more apt to cause headaches, etc., may be overcome, in the young, by the accommodation, and yet at the end when accommodation fails the vision is reduced to the same extent as in myopia. A young officer wearing glasses for myopia is just as useful as an old one wearing them for hyperopia. Finally, officers are required to carry field-glasses and so are not helpless in case they lose or break their glasses. See also **Eyes of soldiers and sailors.**

Donovan (*Jour. A. M. A.*, Sept. 21, 1912) claims that the expert marksman of today must be a scientist, must understand the laws of internal and external ballistics, the effects of wind, temperature, light, mirage, barometer, hydrometer on the elevation and deflection of each shot fired.

A number of theories are mentioned by the writer that attempt to explain the function of accommodation during the act of firing. One theory, as taught by Surgeon-General Longmore, C. B., is that an alteration of accommodation takes place in rapid succession in shooting. Bouchart gives credit to Sulzer for solving the problem by the theory of the continuation of retinal impressions (6/100 of a second) gained by seeing each sight and the target separately. To add to this, he shows that the time necessary to send impressions of objects to the brain is augmented with the distance. This theory has much in its favor and seems to have gained many adherents among us. The length of a retinal impression depends on the illumination and size of the object. On the other hand, Greener, a British expert, says: "The sights, both being out of focus, will be to some extent blurred and must therefore be of shape and color best adapted to impress the eye directed on the target." Hudson, one of the world's best experts, says:

"If the eye is focused on the bull's-eye, the rear sight will be blurred very much, and perhaps the front sight may blur a trifle, but not sufficient to make it indistinct. Therefore, all that is necessary is to be certain that we see top of front sight through center of aperture, and after that we may disregard rear sight."

The United States War Department, in the books of instructions, recognizes the same facts. Their advice is to look at what one is shooting and not think of the sights. The writer has tested this theory by suspending his accommodation with homatropin, being then able to make the same scores. With accommodation fully paralyzed, distant vision was reduced to 20/70, yet through the rear aperature sight on a Springfield he could read 20/15. Wearing correction for the hyperopia, the rear sight was a complete blur, the front sight indistinct, yet in five scores at 200 yards his results were up to his usual average. Lieut. T. Whelen, U. S. A., says:

"Some men have difficulty in seeing the bull's-eye distinctly when aiming. It may appear gray and blurred. In this case center the bull's-eye in the peepsight, instead of the front sight, bringing the front sight to its correct position relative to the bull's-eye."

Experience has shown that those who shoot with both eyes open have much less strain on the eyes and can maintain a clear bull's-eye which otherwise would become blurred.

The best argument in favor of the theory of the necessity of accommodation in focusing the sights instead of the target is made in an excellent article by Maj. Henry A. Shaw, surgeon United States Army, and Lieut.-Col. J. M. Banister, Department of Surgeon-General, United States Army. They quote several noted authorities, and with ten sharpshooters made many careful tests, firing five shots each with naked eye, five each with vision blurred by + lenses to make it 20/40, and five each vision blurred to 20/70. The results showed equally good. From this, they prove that an accurate focus of the sights only is necessary. They do not take into account that once the expert finds the bull's-eye and is holding good, he can make each successive shot come near the other as long as he retains his fixed position. Nor do they consider that the bull's-eye is a spot; thus its distinctness depends on its illumination, and the law applicable to Snellen's test-type would not bear the exact relation. It has been shown that the bull's-eye has sufficient size to be easily discernible by a man with at least one-third normal vision. In fact, all that such a test really did accomplish was equivalent to shooting at a poorly colored target or in a bad light, which, as a matter of choice, no man would make. If accommodation is necessary, why do we find it so much less tiresome and the bull's-eye often more distinct when both eyes are kept open? If we are using accommodation, then we must suspend our convergence. Why does a sportsman choose the aperture and gold bead for use in the woods, if the main part of his vision is to be centered on his sights? On seeing his game, he glances through the rear sight simply to bring it into position. then at the front sight to know the general position of his rifle, and than, watching the game until he notices that the sights come perfectly into his line of vision, he fires. The first two movements, made to bring the gun into line, becomes unnecessary with long practice. The only requirement is to have sights distinct enough to produce a definite retinal impression once they come into perfect alignment with the object. The snap shooter becomes unconscious of his sights.

The eyes should be protected from the glare and a uniform light be maintained by the use of that form of tinted glass which experience shows is of the most practical value for this purpose. Full correcting lenses should be not only allowed, but constantly worn. They must be made high enough, in far enough and large enough so that when the head is down and the eye looking upward to almost its limit, vision will be distinct through the glass. The cylinder, if strong, must be rotated in the trial frame, with the head in the firing position, to determine that vertical lines appear as such with the glasses on; otherwise, the rifle will be canted and will shoot to one side. A toric lens is necessary, and for shooting in bright lights or artificial lights, a light amber or some other color is essential. For presbyopia, bifocals are preferable or a pocket lens should be carried to adjust the sights and do other near work. The front sight should be large enough and of color contrasting to the target, to be clearly discernible to the emmetropic eye without accommodation. The rear sight should be close to the eye and of such a size and shape that the light, being best through its center, the eye will naturally see the tip of the front sight through the center of the rear without accommodating, while vision is being centered on the target. Finally, to the ametrope, large tinted lenses, properly correcting the ametropia and snugly fitting, will more than compensate the soldier in relief from fatigue, and in the protection of his eyes from accidents, for all the disadvantages at present urged against them. The frame should be of stiff material, solid temples with soft ear pieces.

A valuable paper on *naval marksmanship* is contributed by Surgeon E. J. Grow of the United States Navy (*Ophthalmology,* October, 1912). He tells us that during the winter of 1911 a number of gun pointers and trainers were sent from various battleships then at anchor in Guantanamo Bay, Cuba, to the hospital ship "Solace" for ocular examination. This was done with the view of determining the relation that visual acuity has to accurate shooting; also as to whether the pointers and trainers should be selected with more consideration as to vision than is now required, to the end that the maximum efficiency in gunnery may be attained in so far as the eye is concerned.

It will be remembered that for the past three years a visual acuity of 20/15 in the sighting eye and 20/20 in the other eye has been required by navy general order, before a man can qualify for the rating of either gun pointer or trainer. This means that with the eye to be used in sighting, the applicant must read the test letters at a distance of twenty feet, which the so-called normal eye must approach to within fifteen feet in order to read. This might seem paradoxic were it not for the fact that a vision of 20/20, which is generally accepted as normal, is in reality a very low standard. Many individuals have vision far in excess of this; in fact, a vision of 20/15 would more justly represent normal vision.

Among the gun pointers and trainers who were examined a reduction of visual acuity was almost invariably commensurate with, and due to the astigmatism present. Astigmatism of more than .75 of a diopeter blurs and often doubles one of the cross lines in the telescopic sight and thereby interferes with accurate aiming. Astigmatism of less amount may be considered as having a negligible effect for purposes here considered. High degrees of astigmatism introduce an ocular parallax which cannot be eliminated even though the telescopic parallax is completely removed.

A visual acuity of 20/15 will, in a simple and practical way, eliminate all cases of astigmatism and myopia which by any chance would reduce or interfere with the most accurate aim which is possible to be obtained through telescopic sights. Plenty of men can be obtained who have this vision. Nothing is to be gained by a higher visual requirement.

The elimination of dangerous amounts of hyperopia cannot be accomplished by our simple visual tests. When this condition is suspected a special ocular examination should be required to determine the amount. Hyperopia of over 3.00 diopters should be cause for rejection.

Exceptional vision is no guarantee of good shooting and ordinary or slightly reduced vision (18/20) if associated with less than .75 of a diopeter of astigmatism is no hindrance when United States Navy telescopic sights are used.

Twenty-nine per cent. of the gun pointers and trainers examined failed to meet the visual requirements which have been in force since July 1, 1908. Many of these men have had several years' experience in gun practice and made most excellent scores. A slight diminution of vision often followed long-continued practice with telescopic sights. Such men should be allowed a moderate reduction in visual acuity, so that they will not be disqualified for an ocular defect when it is of such amount as to be of no determinable importance. The services of highly trained gun pointers, who by virtue of their experience are of incalculable value, will in this way be saved to the Navy.

Care should be taken that the individual who adjusts and fixes the telescopes in focus is free from any error of refraction which would preclude the possibility of others, who may be called upon in succession to use the same sight, from obtaining an accurate aim.

It is impracticable for gun pointers to wear glasses correcting their visual error and equally so for each individual to change the telescopic sight to suit himself. Consequently, it is imperative that the eyes of all who are to use these sights should be sufficiently near normal so that the gun pointers can instantly use any telescope as they find it, with a maximum of aiming efficiency.

In reference to small arm (rifle) shooting, an entirely different problem is presented. Any attempt to draw satisfactory conclusions as to the relation of eyesight to marksmanship is valueless when an ordinary service target, such as is generally used, is the object. Men of experience in rifle shooting, with markedly reduced vision, will generally make excellent scores, even though the bull's-eye is invisible, provided their vision is still sufficient to allow them to just discern the target, which is large, white and made as distinct as possible.

There is an intensely practical side to this important subject of the relation of vision to markmanship which must be carefully considered. In view of all the evidence obtainable it is believed that the best interests of the service will be furthered, as far as eyesight can possibly be concerned in relation to shooting with telescopic sights, by adopting the following requirements:

1. That all candidates for the original rating of gun pointer or trainer should have a minimum visual acuity of 20/15 in the sighting eye and 20/20 in the other eye.

2. Hyperopia of over 3.00 diopters is cause for rejection.

3. The medical officer of each ship should carefully reëxamine the eyes of all men holding these ratings, at the beginning of each calendar year, entering the vision in the Health Record for future information. If the vision has fallen materially since the last examination, or evidence of asthenopia or disease exists, an ocular examination should be made by some one trained in ophthalmology who will enter his findings and recommendations in the Health Record. Should the individual's condition be such as to warrant the revoking of his rating, full information of the case, including recommendations, should be forwarded by the medical officer, through official channels, to the department for consideration and final disposition. Very few will fall into this class if the original visual requirements are rigidly enforced.

4. Gun pointers and trainers who have served as such during one enlistment may on subsequent enlistments be accepted with a minimum

visual acuity of 18/20 in the sighting eye and 15/20 in the other eye, provided such reduced vision is not due to progressive organic disease, myopia or astigmatism of over .75 of a diopter. Entry is to be made in the Health Record to such effect.

5. In all cases vision should be tested by the so-called Navy "Unlearnable Vision Test Card," as there is considerable temptation to learn the letters found on ordinary charts by those especially anxious to secure or retain the rating of gun pointer or trainer.

Marmarygæ. PHOTOPSIA. An old term for the appearance of sparks or coruscations before the eyes.

Marmorek's serum. See **Streptococcus serum.**

Marmorokoniasis, Ocular. Irritation of the eyes from marble dust Trantas observed *marmorokoniasis* in workers in hard marble. Grayish red streaks appear in the left cornea in right handed workers who hold the chisel in the left hand and in the right corneas of left-handed workmen. The workers in soft marble show no corneal deposits.

Marple, Wilbur Boileau. A well-known New York ophthalmologist,

Wilbur Boileau Marple.

inventor of the Marple ophthalmoscope. Born in northern Ohio in 1856, he received the degree of A. B. at Amherst College in 1877 and that of M. D. at the Starling Medical College, Columbus, O., in 1881. For a time he practised general medicine with a Dr. Foster at Washington Court House, O. Later, he studied ophthalmology at the New York Ophthalmic and Aural Institute, and from then until his death practised in New York City. He was a Fellow of the American Ophthalmological Society and of the American College of Surgeons, also ophthalmic surgeon to the New York Eye and Ear Infirmary, visiting ophthalmic surgeon to the Almshouse and Workhouse hospitals, Blackwell's Island, and consulting ophthalmic surgeon to the Babies' Hospital, New York. He died suddenly, of cerebral hemorrhage, on the golf links at Kennebunkport, Me., Aug. 30, 1916.—(T. H. S.)

Marsh's disease. Exophthalmic goiter.

Marshall's cerate. A mixture containing 2 parts each of calomel and palm-oil (or, according to the Paris *Pharmacopeia,* 2 of calomel and 10 of palm-oil), 1 part of lead acetate, and 4 parts of citrine ointment; formerly used as an ointment in ophthalmic practice.

Marston, Philip Bourke (1850-87), the blind poet, was born in London, England. His memory survives through his friendships, rather than through his poems. Some of these are exquisite, but too sad for a world with good eyesight. See *A Last Harvest,* with memoir by Mrs. Moulton.

Marsupials, Eyes of. See **Comparative ophthalmology.**

Marsupion. Marsupium. The pecten of birds—a vascular, erectile organ in the posterior chamber of the eye. See **Comparative ophthalmology.**

Marten, The. The marten, reduced to ashes, was employed, according to Pliny (XXVIII, 25), for *suffusio oculorum*—a term which covered "cataract" and a number of other diseases, in early Roman days, hopelessly confounded with that affection.—(T. H. S.)

Martinasch, N. J. A well-known French-American ophthalmologist, discoverer of the method of treating corneal ulcers by means of the actual cautery. Born at Hornaing, near Douai, Departement du Nord, France, Nov. 24, 1834, he received the medical degree at Paris May 25, 1861. He then studied ophthalmology under the famous de Wecker. In 1869 he removed to San Francisco, Calif., where he became professor of ophthalmology and otology in the Medical Department of the University of California. His discovery of the method of treating corneal ulcers by means of the actual cautery was made in 1873. He died suddenly, of apoplexy, at San Francisco, Dec. 23, 1892.—(T. H. S.)

Martin's test. See **Blindness, simulated, Martin's test for.** See p. 1184, Vol. II, of this *Encyclopedia.*

Martini, Alphons. A distinguished Swabian surgeon and ophthalmologist. Born at Salgau, Upper Swabia, Aug. 1, 1829, the son of Dr. Ferdinand Martini, he studied at Munich, Vienna, Tübingen, Paris and London, and, returning to Munich, there received his medical degree about 1853. Settling in Ochsenhausen, Würtemberg, he was there an official physician for fifteen years. In 1869 he removed to Biberach, and became chiefly an ophthalmologist. He died April 14, 1880.

Though a skillful operator on the eye, his only ophthalmologic writing was his graduation dissertation, entitled "Ueber die Hornhautwunden und ihre Folgen."—(T. H. S.)

Mas. (L.) The centre-pin of a trephine.

Masawaih Abu Juhanna. This renowned operator on the eye (but not ophthalmographer) flourished at Bagdad in the 8th century A. D. He is said to have cured the Caliph Haroun Alraschid of an obstinate ophthalmia, and to have received therefor a pension of 2400 drachma yearly.—(T. H. S.)

Maschaliatry. Medication by inunction into the armpit.

Masern. (G.) Measles.

Masked diplopia. A form of indistinct vision occasionally met with in paralytic squint, in which the patient has the impression of seeing one object through another, since each eye sees a different portion of the field of vision. The disturbance occurs only in binocular vision. See, also, p. 4006, Vol. VI of this *Encyclopedia.*

Maskelyne, Nevil (1732-1811), astronomer and physicist, inventor of the prismatic micrometer, was born in London. In 1758 he was elected a Fellow of the Royal Society, and resolved to devote himself to astronomy. In 1763 he went to Barbados for the Board of Longitude to test the newly-invented Harrison chronometers, and after his return was (1765) appointed astronomer-royal. The first of his very numerous publications was the *British Mariner's Guide* (1763). In 1767 he commenced the *Nautical Almanac.* In 1776 he produced the first volume of the *Astronomical Observations made at the Royal Observatory, Greenwich, from 1665*—an invaluable work still continued.—(*Standard Encyclopedia.*)

Mask for general anesthesia, Camus's. This is an inhaler for giving chloride of ethyl, which permits its inhalation in fractional doses.

Mask, Eye. These protective devices are generally employed after cataract extraction and similar procedures. They are fully described on p. 1652, Vol. III of this *Encyclopedia.*

Massage. This term is used generally to denote a system of treatment in which the manipulation and exercise of parts (passive movement) are employed for the relief of morbid conditions. The general result of massage is to hasten tissue metabolism, and to equalize the distribution of the blood by facilitating its flow. In surgical cases massage is of service in helping to break down adhesions, to reduce chronic thickenings, and to help repair and avoid waste of tissues.

Ocular massage. The employment of this remedy in its several forms for the relief of ocular diseases, has been referred to under a number of captions, **Brown ointment**, for example. It may be added here that *finger massage of the lids and eyeball* is valuable in most chronic diseases of the lid borders and substance, in many subacute and chronic diseases of the conjunctivæ, and in the repair stages of a large proportion of ulcers and deposits; in the cornea. It is also employed for the temporary reduction of the increased tension of glaucoma. It is contraindicated in all conditions in which its use is followed by much injection of the eyeball, photophobia or lachrymation.

Massage may be applied alone but is best used in conjunction with some oily remedy, or ointment, which should be made perfectly smooth and of such a consistency that it is readily distributed over the conjunctival and bulbar surfaces. It is best applied with the pulp of the finger placed on the skin of the lid. The patient is told to look down in massaging the upper lid and upper portion of the eyeball. and up in treating the lower lid and lower portion of the eyeball. In each instance the other lid should be drawn away from the one undergoing massage.

If the cornea is to be treated the patient should be directed to look straight forward. The finger movements should be fairly rapid, and made at first in a circular fashion about the cornea as a center; then they ought to radiate from the pupil to the bulbar equator in all directions. In no instance should they exert undue pressure upon the eyeball. The duration of the seances must not be more than three or four minutes each, and their frequency will vary from once daily to three or four times a week. The application should never produce severe pain or other marked discomfort, although this remedy usually causes a temporary congestion of the conjunctival vessels and a slight ''foreign body'' sensation'' both of which should pass off within half an hour after the application.

The value of this remedial measure consists in emptying the palpebral ducts (Meibomian and sudoriparous) as well as the blood and lymphatic vessels situated around the sclero-corneal margin and the lymph spaces in the cornea, thereby promoting absorption of any exudates that may be present. At the same time the blood vessels are still further stimulated to contraction by irritation of the vasomotor system.

Calvin R. Elwood has found it of great service in chronic conjunctivitis. He feels that there is no question about the stimulation of the ocular lymphatic circulation, with consequent elimination of waste products.

Elschnig has found massage very useful in chronic trachoma with thickened tarsus, marked pannus or progressive ulcerations of the cornea that resists other methods of treatment. It is also of value in the recurrent keratitis of trachoma. He employs a probe armed with cotton which is dipped into a solution of oxycyanide of mercury (1:4000) and introduced beneath the eyelid, the latter being mediately pressed against the forefinger of the other hand held against the outer surface of the lid. The probe is rubbed firmly back and forth against the palpebral conjunctiva. A 2 per cent solution of cocain is used for the first two or three sittings, after which no anesthesia is needed. An ice-bag must be used immediately after the massage. At first this is carried out every day, then every two or three days, the duration of each sitting for each eye being five minutes. In conjunction with other methods of treatment massage is useful in most external diseases of the eye (except acute trachoma), particularly in all forms of chronic conjunctivitis, when these are associated with hypersecretion or with retention of secretion in the Meibomian glands, in phlyctenular conjunctivitis, spring catarrh, small chalazion, and in certain chronic diseases of the iris and even of the choroid.

Maklakof uses the Edison spring modified for purposes of massage, the treatment lasting from five to ten minutes, the ball of the apparatus touching the eye directly. Various observers furnish contradictory reports of the good and bad results obtained from its use; most of these are favorable, especially where the treatment is employed in suitable cases; for example, Corcashvili reports four cases of episcleritis in which the results were very good.

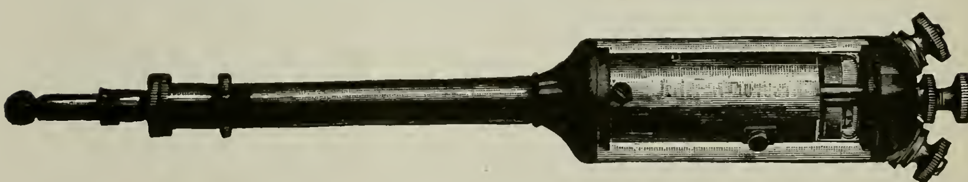
Darier (*Thérapeutique Oculaire*, p. 21) advises for finger massage mercurial lanoline. This is a preparation put up by Paris druggists in gelatine capsules, each containing four grammes. He believes that the preparation undergoes slighter alterations and is more easily absorbed than similar preparations of mercury.

In this connection Darier believes that digital massage should always be carried out under the immediate supervision of or, better, by the surgeon himself. Otherwise it is likely to be useless or harmful.

Vacher uses for the same purpose what he calls compound gray oil.

This, Darier says, has about the same formula as his mercurial lanoline.

The Editor (Wood's *System of Ophthalmic Therapeutics,* p. 96) prefers simple massage with the tip of the finger to any form of the instrumental variety, such as direct rubbing with pieces of cotton wool, tetanization, the use of sounds and other devices. The sitting should rarely exceed three or four minutes and the best application for the purpose of pure massage is a drop or two of cod liver oil, or pure castor oil. He prefers for disinfectant or stimulating medication mercurials of various strengths combined with oleaginous excipients, such as the citrine ointment diluted with brown cod liver oil. At the end of, or during the massage, combinations of the remedy with the ocular secretions, especially mucus, should be coaxed out of the sac by means of small pieces of damp cotton and the stroking movement resumed until nothing further comes away. He finds the most satisfactory employment of massage in chronic diseases of the lid-borders and substance, in almost all the sub-acute and chronic forms of conjunctivitis, in most forms of ulcer of and deposits in the cornea, for the temporary relief of glaucoma and in some forms of retinal embolism. He believes it is useless or harmful in the early stages of acute conjunctivitis and keratitis, in most forms of true trachoma, spring catarrh, disease of the iris, ciliary body, lens, choroid, vitreous, or optic nerve.



Piesbergen's Instrument for Ocular Massage.

Vibratory *massage of the optic nerve* in certain forms of atrophy has also been recommended. Ocular vibratory massage by the aid of instruments in such diseases as interstitial keratitis, episcleritis, corneal opacities, phlyctenular and purulent conjunctivitis, not to mention hypopion keratitis, iridocyclitis, traumatic cataract and absolute glaucoma has, it is claimed, been successful when the agent employed is Piesbergen's machine. See the figure which represents an electric driven ball at the end of a long rod.

Stephenson advises the use of a one per cent. ointment of the subacetate of lead in follicular conjunctivitis (q. v.). A small piece is applied to the everted conjunctiva once a day. After two weeks' time the strength of the ointment is doubled, the application being followed by massage. Under this treatment the hyperemia disappears, the discharge is less, the follicles become reduced in size and eventually disappear.

Vibratory massage. Leartus Connor favored this method and obtained definite effects from its use. It reduces the tension of the eyeball, improves intraocular circulation and increases the activity of all the living cells in the uveal tract. It frequently improves defective vision when other remedies have failed.

Domec uses an elliptical eye-cup with concave margins to fit snugly about the globe. He exhausts the air with each inspiration of the patient, exercising 50-200 tractions at a sitting. In nervous asthenopia. in glaucoma and infectious cases associated with severe pain this method relieved the pain. It can be employed as a preliminary measure to pressure massage or as a substitute for the latter. The analgesic action he attributes to traction on the ciliary nerves.

For the maturation of unripe cataract by direct massage of the anterior capsule see p. 637, Vol. I, of this *Encyclopedia*.

Pneumomassage of the eyeball may be carried out by suction, using, for example, the cups in the Victor machine. These cups are made of clear crystal glass, through which the operator can clearly perceive the action that is taking place during treatment. They are moulded to follow the conformation of the eyeball as closely as possible. They can be used in connection with any ear pumps or with any apparatus capable of compression, suction and vibration of the air. See p. 4892, Vol. VII of this *Encyclopedia*.

Another device for *massaging the cornea* is also pictured in the text. The knurled collar is removable and is used to hold some suitable elastic material, such as rubber dam stretched tensely across the opening. The instrument is attached to the ear pump, which pneumatically vibrates the rubber diaphragm.

Another form of (direct) corneal massage is by means of Morton's instrument. See cut on p. 3400, and pp. 3419 and 3391, Vol. V of this *Encyclopedia*.

Massage à friction. (F.) In massage, those movements forming a combination of friction or stroking and pressure or kneading.

Masselon's spectacles. Spectacles with an attachment for keeping the upper lid raised in case of paralytic ptosis.

Masseurs, Blind. See **Institutions for the blind.**

Massotherapy. The treatment of disease by massage.

Massons Scheibe. (G.) Masson's disc—for testing the light sense. See p. 4033, Vol. VI of this *Encyclopedia*.

Masters, John Lewis. One of the best known ophthalmologists in Indiana. Born near Fairfield, Franklin Co., Ind., Sept. 23, 1859, son of Jacob Harris, and Maria Louisa, Masters, he received his medical degree from the Louisville, Ky., Medical College in 1885, being honor man of his class. He served as interne at the Louisville City Hospital for one year, and then engaged in general practice at Shandon, Ohio, till 1892, when he went to New York City for the

John Lewis Masters.

study of ophthalmology and oto-laryngology. For about one year he was house physician at the New York Eye and Ear Hospital.

In 1893 he settled as ophthalmologist and oto-laryngologist at Indianapolis, Ind., where he lived and practised until his death. In March, 1894, he was elected lecturer on Histology and on the Eye and Ear at the Central College of Physicians and Surgeons, now a part of the Indiana University School of Medicine. Two months later he received the full professorship in these branches. In 1896 he was made treasurer of the College. All these positions he held till 1903, when he went to Berlin for further study.

Returning to Indianapolis in 1904, he was elected in 1906 clinical professor of otology in the Indiana Medical College, later the Indiana University School of Medicine. This chair he held till 1909 or 1910. He was oculist and aurist to the Indiana City Hospital and City Dispensary from 1894 until 1905.

He married Elizabeth Flora Urmaton Aug. 17, 1887. Of the union were born three sons, Paul L., Robert J., and Melvin.

Dr. Masters for many years was afflicted with chronic nephritis and a high blood pressure. In 1911, suffering from nervous breakdown, he took a trip to Europe for recreation only. He returned improved, but soon began to fail in health again. Early in the morning of May 25, 1916, he was stricken with paralysis, and, an hour or two thereafter, was dead.

Dr. Masters was a gentle and friendly being, the perfection of courtesy, a tireless worker and a firm, unflinching champion of all that was just and right. He was of rather impressive appearance, six feet tall, of medium build, fair complexion and very bright blue eyes. His manner was modest and retiring, excepting when his interest was well aroused, and then he became extremely vivacious and enthusiastic. He read extensively in fiction, poetry and science, and had a large collection of ancient and modern coins. He was an independent republican and an active member and trustee of the Methodist Episcopal Church, to which institution he gave of his time, money and energy without stint. He was also very charitable, both within and without the circle of his professional activities. His devotion as a Christian was, in fact, particularly shown in the honesty and thoroughness of all his professional work. As has been said by one of his life-long friends, "Dr. Masters belonged to that conscientious and loyal band which deems it not only a privilege but a duty and an impelling mission to alleviate suffering and to heal the sick. It was in the persistent and energetic performance of active duty in his profession that the Doctor gave overfreely of his strength and vitality. Almost literally he gave his life to his profession and to those who needed his services. No man can do more than this."—(T. H. S.)

Master Zacharias. See **Zacharias, Master.**

Mastic. *Pistacia lentiscus.* In ancient Greco-Roman times the resin of the mastic tree was employed both in entropium and in ectropium, while the leaves were used as a poultice in a number of inflammatory affections of the eye.—(T. H. S.)

Masturbation. This act has been held responsible for photopsiæ, photophobia, conjunctivitis, amblyopia, and, in the predisposed, for retinal hemorrhage.

Materia ophthalmiatrica. (L.) An ophthalmic remedy.

Maturation of unripe cataract. See **Artificial ripening of cataract**; also **Senile cataract**; also p. 637, Vol. I of this *Encyclopedia*.

Mature cataract. A cataract involving the entire lens, so far advanced and so homogeneous as to be ready for extraction.

Matys, Wenzel. An Hungarian ophthalmologist, who was born in 1868 and died Nov. 18, 1908, at the early age of 40 years. A few days after his death his appointment as extraordinary professor of ophthalmology in the Czech University of Prague was officially promulgated.—(T. H. S.)

Mauchart, Burkard (or Burchard) David. A celebrated Württemberger ophthalmologist. Born at Marbach, Württemburg, April 19, 1696, he received an excellent all round education, then began to study medicine at Tübingen. Migrating in 1717 to Altdorf, he studied, still later, at Strassburg and Paris. In 1722 he settled in Tübingen, and soon was court physician to the Duke of Württemberg. Four years later he began to teach at the University: according to Gurlt, anatomy and surgery; according to Hirschberg, "all the divisions of the healing art and still more."

He seems to have been an excellent operator, and was certainly a clear and forceful writer. He never wrote a book, but his numerous ophthalmologic dissertations were very valuable. These were, in part, as follows: 1. De Ophthalmoxusi Nov-Antiqua seu Woolhusiano-Hippocratica, quam præside Burc. David Mauchart P. P. Defendet Jo. Georg. Gmelin. 2. Diss. Med. de Ectropio, quam præside Joan. Zellero M. D. and P. P. P. pro Doctorato Defendet Author Egidius Crato Keck, Heidenh., Tubingæ die 17 Oct. anno 1733. (According to Hirschberg, the term, "Ectropion," was invented either by Mauchart or by Woolhouse. The ancient expression was, in fact, "phalangosis." "Entropion" was, of course, among the ancients, in very common use.) 3. De Hypopyo Diss. Med. Chir., quam Præside B. D. Mauchart P. P. Defendebat Phil. Frid. Gmelin Tubing., Tubingæ M. Martio a 1742. 4. De Empyesi Oculi seu Pure in Secunda Oculi Camera Diss. m. ch., quam præs. B. D. Mauchart Tuebatur G. Fr. Seiz, Schorndorfensis, Tub. 10. Nov. 10, 1742. 5. Tobiæ Leucomata, Diss. Med. Dilucidata, quam præs. B. D. Mauchart Defendet C. Dav. Brecht, Theilfingens., Tubing. 24 Maji Anno 1743. 6. Diss. M. Ch. de Setaceo Nuchæ, Airicularum Ipsiusque Oculi, quam præs. B. D. Mauchart Tuebatur Chr. D. Zeller, Tubingens., Tubing. 10 Dec. anno

1742. 7. Dissert. Corneæ, Oculi Tunicæ, Examen Anatomico-Physiologicum Sistens, Ferd. Godefr. Georgii, Tubingen, 24 Jun. 1743. 8. Diss. M. Ch. de Pupillæ Phthisi ac Synizesi s. Angustia p. N. et Concretione, quam fr. B. D. Mauchart, P. P. Defendet Christ. Frid. Fras. Kircho-Teccens., Tubing. 29 Dec. Anno 1745.—(T. H. S.)

Maurolycus, Franciscus. A celebrated churchman and mathematician who was born of a Greek father at Messina in 1494 and who died in 1577. He is remembered chiefly for his optical work, entitled "*Photismi de Lumine et umbra*" (Venice, 1597). In this book he overthrew the old Galenic doctrine that the essential organ of vision is the crystalline lens, and taught, instead, that the office of that body is merely the production of a distinct image in the deeper portions of the eye. With considerable elegance he declared that the crystalline humor of the eye is the convex lens of nature, while the lope made of glass is the crystalline body of art. He also correctly explained for the first time shortsight and farsight, by postulating that, in the former abnormality, the ocular lens was too strongly curved, in the latter, however, too weakly.—(T. H. S.)

Mauthner, Ludwig. A celebrated German ophthalmologist, equally remarkable as writer, teacher and operator. Born April 13, 1840, at Vienna, Austria, he received his medical degree at the University of Vienna in 1861. In 1864 he qualified as privatdocent for ophthalmology in his alma mater, and served in that capacity till 1869, when he was called to the extraordinary professorship at Innsbruck. In 1877 he returned to Vienna, where, in 1894, he succeeded Stellwag von Carion in the full professorship of ophthalmology at the University. Very shortly afterward (Oct. 20 of the same year) Mauthner died. A monument to his memory was unveiled in the Arcade of the Vienna University Mar. 19, 1899.

Concerning the personality of this man we reproduce the words of Hirschberg (*Amer. Jour. of Ophth.*, Dec., 1894): "In personal contact Mauthner was one of the most intellectual and humorous of men with whom it has been my fortune to become acquainted. No one who came in close relationship with him will ever forget him. . . . Unknown to him I heard his public lectures in 1881. Three students listened to him; two of whom were American physicians, who did not understand the language, and one a Russian who did not understand the subject. Yet Mauthner discussed in a truly artistic, completely scientific manner, in the short space of one hour, the whole theory of the ophthalmometer and the measuring of the optical constants out of the living eye, as nobody else on the whole earth could have done it. This I know from my many travelling experiences. . . .

"Reality is more tragic than all tragedies. For seventeen years he had with unwavering efforts striven for the one place, which, strange to say, he considered the highest good—the position of Professor Ordinarius in the Medical Faculty of Vienna. On October 19, his nomination for this place is made public; in the following night he dies, 54 years of age—like the leader of an army after the victorious battle."

The more important writings of Mauthner are as follows: 1. *Lehrbuch der Ophthalmoskopie.* (Vienna, 1868.) 2. *Die Optischen Fehler des Auges.* (Vienna, 1872 till 76.) 3. *Die Sympathischen Augenleiden.* (Wiesbaden, 1879.) 4. *Die Functionsprüfung des Auges.* (Wiesbaden, 1880.) 5. *Gehirn und Auge.* (1881.)—(T. H. S.)

Mauthner's sheath. The double granular protoplasmic sac or layer, marked with lengthwise striæ, beneath Schwann's sheath. It incloses the myelin.

Mauthner's test for color vision. A number of small phials (33) containing different pigments, used in much the same manner as Holmgren's worsteds.

Maxwell's color-box. See p. 2431, Vol. IV of this *Encyclopedia.*

Maxwell, James Clerk (1831-1879), Scottish natural philosopher, born at Edinburgh. His first published scientific paper (on "*Ovals*") was written before he was fifteen. He went to Cambridge (1850), was second wrangler, and equal with the senior wrangler as Smith's prize man, and (1854) became a professor in Marischal College, Aberdeen (1856) in King's College, London (1860). He finally became (1871) professor of experimental physics in the University of Cambridge.

The great work of his life is his treatise on *Electricity and Magnetism* (1873). His main object was to construct a theory of electricity in which "action at a distance" should have no place; and his success was truly wonderful. Besides a great number of papers on various subjects, mathematical, optical, dynamical, he published a text-book of the *Theory of Heat* and a little treatise on *Matter and Motion.* He took a prominent part in the construction of the British Association Unit of Electrical Resistance, and in the writing of its admirable reports on the subject; and he discovered that viscous fluids, while yielding to stress, possess double refraction. His *Scientific Papers* were edited by W. D. Niven (8 vols., 1890); and his *Life* has been written by Campbell and Garnett (1882).—(*Standard Encyclopedia*).

Maxwell's ring. A faintly defined halo around the fovea when the eye rests on a homogeneous blue surface.

Mayne, Robert Crawford. A distinguished Dublin physician, who paid considerable attention to ophthalmology. Born March 11, 1811, at Allenstown, County Meath, he became in 1836 a Licentiate, in 1844 a Fellow, of the Royal College of Surgeons of Ireland. In the last named year he began to teach anatomy in the Richmond Medical School. From 1863 to 1864 he was professor of internal medicine in the same institution. He wrote the article entitled "The Optic Nerve," in Todd's *Cyclopedia,* and died of typhus April 7, 1864.—(T. H. S.)

Mayrhofer, Karl. A celebrated Austrian gynecologist, who devoted considerable attention to diseases of the eye. Born June 2, 1837, at Steyr, he received the degree of doctor in medicine at Vienna in 1860. He was for a time private assistant to Arlt. He became, however, privatdocent in gynecology (having studied the subject with Carl von Braun), and in 1875 extraordinarius. Then he removed to Russia. In Tiflis he was very successful; removing, however, to St. Petersburg, he met with many reversals of fortune. In 1881 he again removed, to Franzensbad, where he died, June 3, 1882.

Mayrhofer was a prolific writer on gynecological subjects. His only ophthalmological writing, however, was "Ueber die Wirkung des Gesteigerten Intraoculären Druckes" (*Zeitschr. der k. k. Gesellsch. d. Aerzte,* 1860).—(T. H. S.)

Mazda lamp. See **Eyes of soldiers, sailors, etc., Examination of the.**

McClellan, George. A well-known American surgeon and ophthalmologist, founder (at the age of twenty-five) of the Institution for Diseases of the Eye and Ear in Philadelphia and one of the founders of the Jefferson Medical College. Born at Woodstock, Conn., in 1796, he received his degree in arts at Yale in 1815, and four years later his medical degree at the University of Pennsylvania. He was sued, in 1828, for malpractice in connection with a cataract operation, and was forced to pay a judgment of five hundred dollars. Dr. S. D. Gross, however, declared that "the suit had been instigated by professional enemies." Dr. McClellan died in Philadelphia in 1847.—(T. H. S.)

McHardy, Malcolm Macdonald. A celebrated British ophthalmologist, inventor of MacHardy's perimeter. Born at Springfield, Mar. 15, 1852, son of Admiral J. B. B. MacHardy, he studied at St. George's Hospital, London, and became an M. R. C. S. in 1873. Four years later he was made an F. R. C. S., Edinburgh. Having held for years a number of subordinate positions in various hospitals, he finally became ophthalmic surgeon and professor of ophthalmology at the King's College Hospital. In 1909 he retired from teaching and practice alike, and died at Dumfries, Scotland, in 1913.

MacHardy edited the fourth edition of Wells on *Diseases of the Eye,* adding to the book an ophthalmoscopic atlas of his own. He also wrote (in addition to works of a general character): Case of Double Black Cataract (*Trans. Oph. Soc.*), Electro-Magnet for Removal of Iron and Steel from Within the Eye (*Clin. Soc. Trans., Brit. Med. Jour.,* 1881) and A New Self-Registering Perimeter.—(T. H. S.)

McHardy's perimeter. See **Examination of the eye,** and **Perimetry.**

McKee's bacillus. This is an organism of the influenza group, which is described as a cause of infantile conjunctivitis with definite clinical characteristics. It is a Gram-negative, tiny bacillus, very like a coccus in appearance. See **Bacteriology of the eye.**—(S. H. M.)

McKeown, David. A well-known English ophthalmologist and otologist, brother of the much more celebrated W. W. McKeown. He practised in Manchester, was surgeon to the Manchester Eye and Ear Hospital, and died in 1907, aged fifty-six.—(T. H. S.)

McKeown's irrigation method. See **Cataract, Unripe.**

McKeown, William Alexander. A famous Irish ophthalmologist, who was first to remove a foreign body from the ocular interior by means of a magnet. Born in 1844, at Ballyclare, County Antrim, Ireland, he studied ophthalmology in Paris for a year, then settled in Belfast. There he became surgeon to the Ulster Eye, Ear, and Throat Hospital, and lecturer on ophthalmology in Queen's College. He practised in Belfast until his death, July 9, 1904.

His chief writing was entitled *"A Treatise on Unripe Cataract"* (1898).—(T. H. S.)

McReynold's method. See **Pterygium.**

Mead, Richard. A celebrated English physician, of moderate importance ophthalmologically. Born at Stepney, near London, Aug. 11, 1673, he studied at first in Leyden, then in Padua, at the latter university receiving his degree in 1696. The following year he returned to London, where he began to practise general medicine. He became physician to the Prince of Wales, and also to St. Thomas's Hospital. He grew very wealthy, and became a patron of the fine arts. He wrote *"A Mechanical Account of Poisons"* (London, 1702, and numerous later eds., with many translations), which became a classic in the world of legal medicine. He also published many other works, of which we need to mention only *"Monita et Precepta Medica"* (London, 1751; numerous later eds. and many translations). This work, which, for many years, enjoyed an amazing vogue in many lands, devoted its eleventh chapter to diseases of the eye. The chapter was much read and was universally regarded as a high authority on ophthalmology, but it contained no original matter or any exceptionally clarifying remarks or observations.

Dr. Mead died Feb. 16, 1754.—(T. H. S.)

Mean dispersion. In *optics,* the difference between the indices of refraction for the light corresponding to two definite lines of the spectrum. These lines being C and F, the difference n_F-n_C is about proportional to the length of the visible spectrum included between C and F. See also **Chromatic dispersion.**—(C. F. P.)

Mean index of refraction. In *optics,* the index of refraction determined for that line of the spectrum which lies midway between the chosen spectral lines of reference. For instance, between the fixed lines B and F, it is the index of refraction for the line D in the yellow space, whereas, between B and H, it is the refractive index for the fixed line E in the green space of the spectrum.—(C. F. P.)

Mean ray. In *optics,* the refracted ray which corresponds to that fixed line of the spectrum located midway between two chosen spectral lines of reference.

Measles, Ocular complications of. Like all infective general diseases, measles may cause complications which are often benign, but occasionally assume a grave character. When the eyelids are involved, the same characteristic splotches are present as occur in other parts of the skin. A mild conjunctivitis, in the scant secretion from which the staphylococcus and the streptococcus are sometimes found, occurs in almost every case of measles, usually just preceding the rash. The lowered power of resistance of the system permits the invasion of other parts by these microorganisms, and various infective processes may develop. An unusual case of keloid of the eyelids in which the onset was associated with measles, was reported by Wilson (*Lancet,* Nov. 30, 1912). It is probable that the condition was caused by the inflammation of the eyes that accompanied the attack of measles, acting on structures already irritated and abraded.

In 1901 Trantas published his observations upon the condition of the cornea in cases of measles seen at Constantinople. He found superficial punctate keratitis to be a very frequent symptom of the disease; it was present in 76 per cent. Morax in 1903, stated that he had carefully examined 27 cases of the disease in Paris, and in these he had found no sign of such corneal disturbance. On the contrary, he constantly found "a hypersecretion of the glands of the ciliary margin" which produced small gray masses: these were deposited upon the corneal epithelium, and suggested the lesions described by Trantas.

Trantas (*Receuil d'Ophtalmologie,* Aug., 1907) then says he cannot suppose that the discrepancies between his own observations and those of Morax arise from any difference in the type of measles as seen in Paris and Constantinople, and his observations have extended over several epidemics in which there were variations enough to exclude accident; further, he has found various corneal lesions in exanthemata other than measles and also in acute skin affections from other diseases, such as pemphigus, syphilis and eczema.

His second series of measles comprises 125, noticed in epidemics occurring in 1901, 1902, 1903 and 1904. In these the lesion was present in 86 per cent. Repeated examination of cases where the initial result was negative sometimes showed the appearance of the symptom at a later date, and, including these, the incidence of the symptom reaches 90 per cent. Most frequently both eyes were affected.

The corneal symptom occurred at varying periods of the fever: in three cases on the first day, 12 times on the second, 14 on the third, 14 on the fourth, 14 on the fifth, 10 on the sixth, 13 on the seventh, 8 on the ninth. Once it did not appear until the seventeenth day.

He describes the lesion as minute disseminated points (about 0.5 mm.), usually few in number, sometimes in the center of the cornea, at other times in the periphery, but sometimes seen faintly over the whole area. The epithelium is rarely cloudy, except where there is photophobia or other sign of irritation. Sometimes fine lines may be detected in the cornea giving the appearance of quilting. The sensibility of the cornea is not affected; the visual acuity is not diminished save in the rare cases where there is a central confluent lesion.

He believes that this lesion is the corneal expression of those changes in the skin which are constantly associated with the febrile attack, and that they explain the frequency with which grave corneal lesions follow the action of this exanthem. Either the sequelæ are a direct continuation of the earlier lesion, or else that lesion prepares the way for the graver affection.

He concludes that the punctate keratitis of measles is distinctive of this disease, and that it may be possible to find changes in the cornea peculiar to each of the exanthemata.

Comby (*Traité des Maladies de l'Enfance*) has recorded the observation of similar lesions in several cases of measles; and in conversation with a physician who had an unusually large experience with measles, Bishop Harmon found that, though unaware of the work of Morax or Trantas, he was well acquainted with the form of keratitis described by the latter.

Five cases of corneal ulcers, developing mostly between the first and the fourth day after measles, are reported by Cosmettatos (*Arch. d'Ophtal.*, May, 1908). Phlyctenules were first observed, later they involved the deeper layers, and one developed hypopion. They were all unilateral. The author considers the condition to be of endogenous origin.

A case of acute diffuse choroiditis following measles is reported by Mikami. The fundus showed diffuse depigmentation and haziness, and small white spots at the periphery. Literature does not contain a similar observation. He attributes the condition to bacterio-toxic influences.

Among the more serious ocular complications of measles, manifestations in the central or peripheral nervous system are important. Optic neuritis is the most frequent as well as the most serious of these. Von Graefe first reported a case of optic neuritis after measles in 1866.

Griscom (*Ann. of Ophthal.,* Jan., 1912) has been able to find reports of only twenty-three cases of blindness due to optic nerve lesions following measles. After a careful review of the literature he says that the cases may be divided into three classes; first, those showing evidences of primary cerebral involvement with secondary optic nerve change; second, those showing meningitis as the most prominent symptom, with consequent optic neuritis; and third, those showing optic neuritis without any other local or general symptoms. In these cases there may be a circumscribed meningitis in the region of the optic nerve or the neuritis may be due to the selective action of the toxins of measles.

In a case of his own, that of a girl of eleven years, the right eye became blind a week after a light attack of measles, and in a few days the left eye was likewise involved. After persistent treatment vision began to improve and in eight months reached 20/20 in each eye with full visual fields. The edematous swelling he attributes to the irritating toxins circulating in the blood, and not a true inflammatory condition.

Vancresson (*Annales d'Oculistique,* March, 1906) refers to a number of cases in literature and reports the following one: A soldier, 24 years of age, had an attack of measles, with severe bronchitis, high temperature and intense headache. Ten days later when he was convalescent, vision was suddenly and almost completely lost in the right eye. With the ophthalmoscope the papilla appeared punctated as if it had a number of minute hemorrhages on its surface. There was no edema and the disc margins were sharply defined, but the vessels were slightly dilated. In a few days the congestion became more intense, the papilla lost its definite outline and the vessels were more enlarged. No albumin in urine. Left eye normal.

In three weeks vision was entirely abolished in the right eye and the ophthalmoscope showed a glistening white disc.

In most cases, as in this one, the neuritis commences several days after the disappearance of the eruption. The infection in this case must have been particularly violent, as the evolution of the disease is not usually nearly so rapid, and in many cases complete recovery has resulted. Generally both eyes are affected.

In view of the violent headaches the author is inclined to believe that the neuritis had its origin in meningitis.

Santos Fernandes (*Anales de Oftalmologia,* April, 1913) reports the case of a girl of seven years who lost her vision after the disappearance of the eruption of measles. The pupil was fairly well dilated, although no eye drops had been used. The optic disc was bluish-white, and there was peripapillary edema. On account of the fairly frequent association of measles with diphtheria, the case was treated with Roux's antidiphtheric serum. In all, five injections of 20 cm. each were given at intervals of four days. Some improvement of vision was noticed by the patient the day after the first injection. The vision steadily improved, reaching normal by four weeks after the first dose of serum. She was last seen five months after the occurrence of the amaurosis, when the vision was perfect. Notwithstanding the clinical improvement, however, the appearance of the optic disc remained as at first.

Mechanical Eye, Brown's. See **Phonopticon.**

Mechanics of fitting glasses. See **Eyeglasses and spectacles, Mechanical adjustment of.**

Mechanism of accommodation. A term used to signify not only the manner in which accommodation takes place, but also the structures by which it is accomplished (the ciliary muscle, the zonule of Zinn, and the crystalline lens). See **Accommodation.**

Meckel's ganglion. A ganglion of the sympathetic, facial, and other nerves situated in the sphenomaxillary fossa. Called also *sphenopalatine ganglion.*

Meconarcein. A preparation of the active alkaloids of opium other than morphin: sedative and narcotic. Dose 1/6—1/2 gr. (0.011—0.033 gm.).

Meconium. See **Opium.**

Media. 1. The tunica media, or middle coat of an artery. 2. Plural of *medium.*

Media, Dioptric, of the eye. The cornea, aqueous humor, lens and vitreous.

Mediad. Situated or directed toward the middle, especially toward the median plane.

Mediæval anonymous. See **Anonymous, Mediæval.**

Median center of Luys. The second of a series of four centers described by Luys as situated in the optic thalamus; a small nucleus near the central part of the thalamus into which fibers from the optic nerve may be traced; considered by Luys as a visual center. Its existence has been denied.

Median line. In *physiologic optics*, a line perpendicular to and bisecting the distance between the centers of rotation of the eyes.

Mediaometer. An instrument for detecting and measuring refractive errors of the dioptric media.

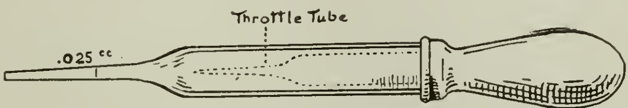
Mediastinus. An obsolete designation for an assistant physician or surgeon.

Medicated waters. See **Hydrotherapy.**

Medical jurisprudence, Ophthalmic relations of. See **Legal relations of ophthalmology.**

Medical ophthalmoscopy. See the major heading, **Ophthalmoscopy, Medical**; also **Fundus oculi.**

Medicine dropper. This well-known device is fully described on p. 4708, Vol. VI of this *Encyclopedia*, an improved example being here depicted in the text.



Eye-dropper with Throttle for Measured Drop.

Medicolegal relations of ophthalmology. See **Legal relations of ophthalmology.**

Medifrontal. Median and also frontal; pertaining to the middle of the forehead.

Medium. Any substance through which action, light waves for example, is transmitted to a distance.

Medulla oblongata, Ocular symptoms from disease of the. Apart from the occasional appearance of papillœdema accompanying tumor of this center eye symptoms are rare. In hemorrhage from the vertebral arteries affecting the medulla oculomuscular pareses have been noted; also in myelitis and other processes affecting the cord in the neighborhood of the medulla the eye symptoms proper to the diseases are recorded. See p. 1976, Vol. III, as well as **Neurology of the eye,** in this *Encyclopedia.*

Medullated fibers of the optic nerve. See **Fundus oculi,** p. 5316, Vol. VII, as well as **Anatomy of the eye,** in this *Encyclopedia.*

Medusa head. See **Corkscrew vessels.**

Meek'ren, Job Janszoon van. Called by Tulp "chirurgus industrius" and by Haller "celebris et candidus chirurgus." Born at Amsterdam, he studied with Tulp, and practised mostly in his native city.

He held a large number of official positions, and was widely known as a dexterous operator, especially on the eye. He invented a conical needle for the removal of hypopion. He died in 1666. His only writing appeared posthumously under the title *"Heel-en Geneeskonstige Aanmerkingen"* (Amsterdam, 1668; The Hague, 1673; Ger. trans., Nürnberg, 1675; Lat. trans., Amsterdam, 1682).—(T. H. S.)

Megalakria. Acromegaly.

Megalocephalia. MEGALOCEPHALY. 1. Unusually large size of the head. 2. Progressive enlargement of the bones of the head, face, and neck; leontiasis ossea.

Megalocornea. Abnormal increase in the corneal diameters is uniformly seen in keratoglobus (p. 6828, Vol. IX, of this *Encyclopedia*), buphthalmia and juvenile glaucoma. See p. 2829, Vol. IV, of this *Encyclopedia.*

Recently Axenfeld and Elschnig questioned the existence of megalocornea and maintained that on closer examination of many cases of so-called megalocornea changes will be found to be merely part of an infantile glaucoma. J. Staehli contests this view and reports four typical cases of clinically pure megalocornea, which did not show the least signs of infantile glaucoma. With Horner and Haab, Staehli considers these cases of megalocornea as partially hyperplasia and partially gigantism. Horner observed it in members of the same family, never alternating with hydrophthalmus, and Kayser found it in seventeen members of the same family. Another important point is that there are numerous transitions from the normal-sized cornea to megalocornea, which have nothing characteristic of glaucoma. Analyzing the terms glaucoma and gigantism, the writer can not see why eyes should be considered as glaucomatous which have nothing in common with the hydrophthalmic eye but the large cornea, and are in everything else normal, vision, visual field, tension (even subnormal), media, no disturbances at puberty. This does not mean that megalocornea is not pathologic. The spontaneous dislocations of the lens, occasionally fatal to the eye, the early opacities of the cornea in the form of an arcus senilis, the dissemination of pigment from the iris and the deposits of pigment on the posterior corneal surface, observed in cases of megalocornea, bespeak its pathologic character.

Megalograph. A form of camera lucida used with the microscope or kaleidoscope.

Megalophthalmus. MEGALOPHTHALMOS. A congenital deformity in which the eye is excessively large and protuberant; usually the result of intraocular disease. See **Buphthalmia,** and p. 2829, Vol. IV, of this *Encyclopedia.*

Megalopia. (L.) Megalopsia. See **Macropia.**

Megalopsia. (L.) An affection of the eye in which objects appear unnaturally large. See **Macropsia.**

Megaloscope. A large magnifying lens; a magnifying speculum or mirror.

Megascope. An optical instrument for projecting enlarged images of solid objects; a solar microscope for examining comparatively large objects.

Megaseme. An orbit whose index is above 89.

Megophthalmus. Buphthalmos.

Megrim. See **Migraine.**

Meibom, Heinrich. (*Lat.*, Meibomius.) This distinguished professor of medicine, history, and the poetic art in Helmstädt, Germany, was born at Lubeck in 1638 and died in 1700. He did not, as has been alleged, discover the glands which bear his name; these were, in fact, observed for the very first time by Galen. However, the first exact description of the structures in question was made by Meibom, so that, in this instance, history has not been so very unjust.—(T. H. S.)

Meibomian cyst. CHALAZION. MEIBOMIAN STYE. HAILSTONE. TARSAL TUMOR. BLIND STYE. GRANULOMA GIGANTO-CELLULARE (de Vincentiis). A very common, small tumor in the substance of the tarsus, formerly regarded as a retention cyst, or as a non-suppurating hordeolum, the result of obstruction in the excretory duct of one or more Meibomian glands. It is now regarded as a granuloma. See **Chalazion.**

Meibomian glands. TARSAL GLANDS. A series of glands imbedded in the tarsus of the eyelid. They are about thirty in number in the upper lid, and somewhat fewer in the lower. They correspond in length with the breadth of each tarsus. Their ducts open on the free margin of the lids by minute foramina. These glands are a variety of the cutaneous sebaceous glands, each consisting of a single straight tube or follicle, having a blind termination into which a number of small secondary follicles open. They are lined by a mucous membrane covered by squamous epithelium. They secrete a sebaceous material which prevents adhesion of the lids. See, also, p. 348, Vol. I, of this *Encyclopedia.*

Meibomian glands, Diseases of the. In addition to the ordinary form of retention cyst, commonly known as chalazion (see p. 1983, Vol. III, of this *Encyclopedia*), these glands are the seat of various other morbid alterations.

Meibomian infarcts are small, chalky concretions that appear as yellowish spots beneath the conjunctiva. Usually they set up no irritation, but if they project beyond the surface of the conjunctiva they should be removed through a tiny incision and scraped out with a small curette or, better, by the point of a cataract knife.

Abscess of a Meibomian gland is not uncommon, and is generally regarded as a "stye." Reitsch has even observed a chronic purulent inflammation of the Meibomian glands set up by a species of capsule bacillus. As the same bacillus was found in the nasal mucous membrane, inoculation of the lid margin by the fingers is the probable cause. These bacilli are believed to be but slightly pathogenic for the external structures of the eye.

Meibomian stye, hordeolum internum, or acute chalazion, is described on p. 6003, Vol. VIII, of this *Encyclopedia.*

Carcinoma of a Meibomian gland has been occasionally reported. Simeon Snell (*Oph. Review,* p. 945, 1908) has described such a case in a woman, aged 63, in whom a small tumor of the upper lid appeared 10 years before. It was removed in 1904, removed again with a portion of the lid in 1905, but in 1906 it was found necessary to excise the globe and exenterate the orbit; in October, 1907, however, the orbit was filled with a large growth, and there was involvement of pre-auricular and cervical glands. It was a spheroidal-celled carcinoma.

Scheerer reports another instance in a woman, aged 63, which had the aspect of a large chalazion. It was extirpated with the lid, and this was replaced by a plastic operation from the auricular cartilage. The chief seat of the tumor is uniformly the tarsus; the lid is sagittally thickened, the skin intact and certainly not the starting point of the tumor. In one case Axenfeld made the diagnosis of probable tumor from the peculiar atrophy of the skin of the ciliary margin and the cilia, because the atrophic skin was adherent to the thickened tarsus, because the whole ciliary edge was peculiarly broadened, and because the thickening seemed to affect the convex margin of the tarsus so that eversion of the whole lid was difficult. The consistency of these malignant neoplasms is in general tough, even hard as cartilage, although soft tumors have been described. In Scheerer's case the capsule of the tumor was more or less lacking. The prognosis must, of course, be guarded.

Meighan, Thomas Spence. A well-known Scotch ophthalmologist. Born in 1849, he received the degrees of M. B. and C. M. at the University of Glasgow in 1870, and the degree of M. D. at the same institution in 1874. In 1897 he became a Fellow of the Glasgow Faculty. He was a member of the Ophthalmologic Society of the United Kingdom and of many other scientific associations. At the time of his death he was a widower. The circumstances of his decease were these:

Having performed a number of important and exacting operations at the Glasgow Eye Infirmary, he was stricken with apoplexy when he had gone but a very few steps from the door of the institution. Carried to a neighboring house, he soon ceased to breathe. This was on October 15, 1909.—(T. H. S.)

Meiners, Heinrich. One of the assistants of the great English charlatan, John Taylor. He followed Taylor to Constantinople, but did not remain long in that city—owing, as Hirschberg tells us, to the anger of deluded patients. Meiners published the following: 1. Lista delle Operazioni e Sciolta delle piu Singulari Curazioni Fatte in Turino sulle Malattie degli Occhi. (Turin, 1742.) 2. Lista delle Operazioni Fatte per la Cataratta, Gotta Serena, Glaucomi, Prunelle Artificiali. (Milan, 1742.) 3. Lista delle Operazioni Fatte a Cento Dodeci Persone per Cataratta.—(T. H. S.)

Meiosis. (L.) (Obsolete.) A shrinking, contracting—especially of the pupil. That period in a disease when the intensity of the symptoms begins to diminish.

Meiotic. An obsolete form of *miotic.*

Meissner's experiment. A method that verifies the law of Listing (q. v.). A full description of it will be found on p. 294 of Tscherning's *Optics,* translated by Carl Weiland.

Méjan, Bénoit. A well-known Monspellensian surgeon, father of Thomas Méjan, and himself an ophthalmologist of some importance in his day. He was made professor at the College of Surgery and surgeon-in-chief at the Hôtel Dieu Saint-Eloi in Montpellier in 1747. After adopting the extraction method for cataract, he soon returned to depression, after the fashion of many of his contemporaries. He invented a "special treatment of the laryngeal fistula," which possessed a considerable vogue for a time, but which unfortunately has not descended to our day.—(T. H. S.)

Méjan, Thomas. Son of Bénoit Méjan, and a surgeon of some repute, who flourished at Montpellier, France, in the latter portion of the 18th century. He wrote "Sur une Nouvelle Méthode de Traiter la Fistule Lacrimale" (*Mém. de l'Acad. R. de Chir.* II, 193, 1753) and "De Cataracta, Dissert. Medico-Chirurg." (1776).—(T. H. S.)

Melanin. The black pigment found in melanotic sarcoma. A good account of the subject is given by Parsons (*Pathology of the Eye,* pp. 514, 515), part of which is here quoted. He believes that the pigment has never been obtained pure for analysis. Addition of caustic potash to a melanotic growth turns the pigment bright-red; concentrated sulphuric acid causes a play of colors—green, then blue, then red (Virchow). Heintz first attempted the analysis of melanin, and found that it contained carbon, 53.4 per cent.; hydrogen, 4.02 per cent.; nitrogen, 7.10 per cent.; and no iron. Dressler found traces of iron. Berdez and Nencki found carbon, hydrogen, oxygen, nitrogen, and as much as 10.67 per cent. of sulphur, but no iron, phosphorus, or chlorine. They called the pigment phymatorusin. The subject was exhaustively investigated by Mörner; both the urine, which often contains the pigment (melanuria), and the tumors were examined. The pigment gave no absorption bands, but was found to contain iron, which was estimated spectrophotometrically. Failure to find iron is due to the use of hydrochloric acid, which dissolves out nine-tenths of the metal. The high percentage of sulphur (up to 8.65 per cent.) was confirmed. The pigments in the tumor and in the urine are identical. There is a precursor, melanogen; it is this which is usually passed in the urine. It is colorless, but becomes black on exposure to air, or on the addition of nitric acid (Eiselt's reaction) or other oxidizing reagents. Hoppe-Seyler attributed this to admixture with indican, which is frequently present in the urine. The urine gives a black precipitate with very dilute ferric chloride, and with dilute sodium nitroprusside and caustic potash a pink coloration, which turns blue on the addition of acids. The latter reaction is not due to melanin, but to some substance excreted simultaneously. Brandl and Pfeiffer confirmed Mörner's results, and agree, in opposition to Nencki, that melanin is derived from hemoglobin. Sheridan Lea's criticism is to the point, and should be borne in mind in considering iron reactions in sections. "Some of the melanins may contain iron, some none, but whether they do or do not is not a decisive test of their derivation. If they do, it makes the connection more probable; if they do not, they may still take their origin from blood-pigments, as in the highly-colored but iron-free hematoporphorin."

Melanocataracta. (L.) Black cataract.

Melanoma, Ocular. The term melanoma is applied to growths which are probably of congenital origin, which do not alter in appearance or size, and are composed of aggregations of deeply pigmented chromatophores. They are regarded as a malignant development of nevus-cell growth. In a certain number of cases, melanomata which were benign in the beginning, may in the course of years acquire malignant characters, and give rise to metastases. Leber, from a study of the malignant forms, believes that the cells are epithelial. It is suggestive that they never occur isolated in the deeper tissues, but always in connection with the epithelial surface. It is common to find cysts in these tumors, and the cystic development may be very pronounced. The cysts are most frequently empty in sections; evidence of their containing simply serous fluid; or, according to Wintersteiner, they may contain coagula with degenerated cells, or even hyaline concretions.

Beauvieux and Muratet (*Arch. d'Opht.*, Vol. 33, p. 620) record a case of *melanoma of the conjunctiva* of the ball of the right eye in a woman 39 years of age. The growth had first been noticed ten years before and increased very slowly until it was cauterized. The pigmentation extended from the limbus to the commissure. The sclerotic was not involved. Microscopically the pigmentation was found in the deeper portions of the episcleral layer. In the subepithelial tissue there were small cavities lined with pigmented epithelium, and in the center a mass of pigment. The condition was considered to be congenital and of the nature of a nevus. Steiner (*Klin. Monats. f. Augenh.*, Oct.-Nov., 1913), whose practice for twenty years had been among Malays and Chinese, in whom pigment flecks and nevi are the rule in the conjunctiva, has seen but one instance in which a malignant pigment tumor developed. The growth was a small, pedunculated pigment adenoma of the fornix. It was composed of round acini lined with pigmented epithelium, and showed no evidence of malignancy. There is, however, no race immunity from malignant ocular growths. In these races, then, such pigment areas need give no concern. This is contrary to the dictum of surgeons practising among Caucasian races, who look on pigment spots with suspicion and advise their extirpation.

Melanomata of the iris are seen as small circumscribed tumors, situated in the anterior limiting layer. Knapp found such a growth to consist of a circumscribed development of branching and anastomosing stroma cells, some of which were unpigmented, but most were pigmented. Fuchs divides the melanomata into two classes: (1) those which are due to proliferation of the pigmented stroma-cells of the iris; (2) those which occur at the pupillary margin of the iris, and are developed from the retinal epithelial cells. The first class often reach a certain size—usually quite small—and remain for many years unchanged. They are liable at any time to take on malignant growth, and the resultant tumors are, according to Parsons, rightly designated sarcomata. The second class resemble the normal outgrowths found at the pupillary margin in horses and many lower mammals. Anargyros states that melanomata of the iris are by no means limited to the pupillary margin, although this is undoubtedly the favorite place, and this is explained by the meeting of the two layers of the secondary optic vesicle at this spot. The next commonest site is the neighborhood of the peripheral edge of the sphincter, where ingrowths of the retinal pigment are not infrequent in normal eyes. The growths may lie at the extreme periphery of the iris, in such a position as to be invisible.

John Griffith published a case (most rare) of probable *retinal melanoma,* springing from the pigment epithelium, and comparable with the melanomata found in the iris. The tumor may, however, have been a sarcoma of the choroid, with somewhat exaggerated proliferation of the retinal pigment epithelium.

Moore (*Roy. Lond. Ophthal. Hosp. Reports,* Vol. 19, part 3) gives a histopathologic account of four cases of *melanoma of the choroid.* He says that the clinical appearances in all four cases were in every essential precisely similar, the differences being only as regards size, shape, position, and density of color of the growths.

In size they varied from about one-half the area of the optic disc to about four times its area.

They were roughly circular or oval in outline. The edges were everywhere quite definite without being quite hard and sharp; there was no shading off into the surrounding fundus, nor was there any light fringe or evidence of pigmentary disturbance at the edge.

They were of quite homogeneous appearance, and the choroidal pattern, though plainly seen around (in two cases), was not seen over the area of the growths.

In color they were exactly that of "blue ointment," differing only in their density.

All were single and close to the optic papilla, the one farthest away being distant about two discs' breadth.

The retinal vessels in their course as they crossed the growths were markedly darker in color than elsewhere; this no doubt was owing to the fact that they were seen against a darker background; the contrast was well seen at the points where they reached the area; in all other respects the vessels were normal in appearance, the overlying retina itself looked quite natural.

In the case of the three smallest growths, although the retinal vessels had an appearance as if riding over a slightly raised area, he was unable to be sure of any difference in refraction between them and the vessels of the surrounding retina; in the case of the largest growth, however, a difference of 2 D. was estimated.

The visual acuity was not affected, and there was no scotoma corresponding with the area of the growth in the two cases in which this was examined for.

During the time the patients were under observation (six weeks, five and one-half months, five and one-half months, ten days) there was no change in the appearances.

There was no abnormal pigmentation of the eyes discoverable on external examination.

Moore thinks that in the case of a minimal pigmented growth of the choroid, the presence of some or all of the following characters may prove to be evidence of malignancy: A simple non-feathered edge; the presence of stippling or vesicle-like bodies in the overlying retina; irregular pigmentation; any subjective symptoms such as micropsia or possibly a partial scotoma; and evidence of pigmentary disturbance around the edge; that in their presence an accurate outline drawing be made, using the retinal vessels as lines of latitude and longitude, and that increase in size, demonstrated by such means, should lead to enucleation. See **Tumors of the eye**; also, **Iris, Melanoma of the.**

Melanophthalmous. Having black eyes. In botany, having spots surrounded by black circles, like eyes. Affected with melanoma of the eye.

Melanosarcoma. Sarcoma with pigmentary elements. See **Tumors of the eye**; as well as **Melanin.**

Melanosarcoma of the choroid. See p. 2171, Vol. III of this *Encyclopedia.*

Melanoscope. A form of compound color screen.

Melanosis, Ocular. Pigmentation of the conjunctiva, cornea, sclera, iris, etc., has been observed and described by various authors. In dark-colored races, spots and patches of pigment occur normally at the limbus. In the white races, however, pigmented spots in the conjunctiva are always suggestive of malignant disease. Diffuse pigmentation occurs very rarely and is apt to spread. It may terminate in death from melanotic sarcoma in other organs.

A case of this rare condition of *melanosis of the conjunctiva* is placed on record by Randolph (*Trans. Amer. Ophth. Society,* Vol. XIII, Part III, 1914, p. 703). The patient, a woman, whose age is not mentioned, presented three patches of pigment in the lower conjunctival sac of her right eye. Two of the curious patches were situated almost at the junction with the ocular conjunctiva. The third lay well in the palpebral conjunctiva about midway between the outer and the inner canthus. The caruncle was of a much deeper shade of pigmentation than the other areas. As to the other (left) eye, there was one small patch of pigmentation in the lower conjunctival sac, and the inferior half of the caruncle was black. The pigmented areas showed no elevation. They had apparently always been present. No opportunity for anatomical examination.

De Schweinitz had under his notice a patient, now nearly seventy years of age, with marked pigmentation in both conjunctival sacs, with patches of pigment in the semilunar folds and dark pigmentation of the caruncles. Besides all this, he had, as a family peculiarity, large patches of pigment on the lobe, the back, and the outer part of each ear.

Melanosis of the cornea may be a congenital anomaly of development, when it is characterized by pigmentation of the deepest layers of the middle portion of the cornea. See **Cornea, Melanosis of the.** Quackenboss (*Ophthalmoscope,* March, 1915) observed marked pigmentation, extending completely around the cornea, in a woman sixty-eight years of age. The caruncle and the conjunctiva of the upper and lower lid were also affected. The condition was congenital.

Patches of *pigment in the sclerotic* are common in lower animals, and are seen occasionally in man. Slight pigmentation around the anterior perforating ciliary vessels is not very uncommon. Acquired pigmentation occurs in some cases of Addison's disease. Pigmentation of the sclera is usually accompanied by similar conditions in the iris and choroid. The peculiar condition of the iris was first observed by Coats (*Trans. Ophth. Soc.*, 32, p. 165. 1912).

Fleischer (*Klin. Monats. f. Augenh.*, Vol. LI, ii, p. 170, 1913) refers to thirty reported cases of *melanosis of the sclera,* and describes a case in which only one eye was affected. The anterior deeper layers of the sclera were pigmented. The iris showed abnormal coloration and the surface was thickened and wart-like. Various pigment anomalies were seen in the choroid. The other eye was normal. The patient was a young girl who gave no evidence of disease or other abnormality, although a consanguinity existed between the parents.

Congenital *pigmentation of the retina* has been reported by a number of observers. In reporting the microscopic examination of one such case Parsons found that the pigmented spots consisted of aggregations of very densely pigmented retinal epithelial cells.

Pigmentation of the optic disc was observed in two albinotic eyes by v. Forster (*Klin. Monats. f. Augenh.* XIX, 1881). Hilbert (*Klin. Monats. f. Augenh.,* XX, 1882) found a disc surrounded by a wide ring of dense black pigment. There is at times a radial striation, as in a case described by Pick (*Arch f. Augenh.*, 41, 1900) in which the disc had a black center with a gray ring, outside of which were masses of medullated nerve fibers. Thomson and Ballantyne (*Trans. Ophth. Soc. Unit. King.*, 23, 1913) have described a pigmented coloboma of the disc.

Melia azedarach. China tree. Indian lilac. Bead tree. The juice of the leaves and rind of the root are used in the East as an anthelmintic for ascarides, and in toxic doses has produced stupor, difficulty of breathing and mydriasis.

Meliceris. Chalazion.

Melituria. Diabetes mellitus.

Melli, Sebastiano. An Italian surgeon of the early 18th century, who paid considerable attention to diseases of the eye. Born at Venice, son of the surgeon, Bernardo Melli, he studied with his father, and, settling in his native city, there became professor of surgery. His only ophthalmologic writing was "Delle Fistole Lacrimale il Pro e Control vel Nuovo Metodo di Guarirla," etc. (Venice, 1713; 2d ed., 1740).—(T. H. S.)

Meloë. Oil-beetles. A genus of the Coleoptera, of which several species yield cantharidin. A Mexican variety exudes a very irritating juice from its joints. When any of the products of this genus, for example of *M. detonans* or *proscarabeus*, reaches the eyes it causes symptoms resembling those from cantharides. See p. 1383, Vol II, of this *Encyclopedia.*

Melsken's test. See **Blindness, simulated, Melsken's test for.**

Membrana capsularis. The vascular network formed by the distribution of the hyaloid artery about the posterior pole of the lens and over the posterior lenticular capsule during early fetal (human) life, and in some cases of persistent hyaloid artery. See p. 616, Vol. I, of this *Encyclopedia.*

Membrana chorio-capillaris. See **Membrana Ruyschiana.**

Membrana circumcaulalis. (L.) An old name for the conjunctiva.

Membrana conjunctivæ. (L.) An old name for the conjunctiva.

Membrana coronæ ciliaris. (L.) The zonule of Zinn.

Membrana coronoides. (L.) An ancient name for the iris.

Membrana extrachoroidea. (L.) Lamina suprachoroidea. See **Histology of the eye.**

Membrana fusca. (L.) Lamina suprachoroidea.

Membrana granulosa interna. (L.) The two granular layers of the retina.

Membrana hyaloidea. (L.) Hyaloid membrane. See **Anatomy of the eye**—under Vitreous.

Membrana iridis anterior. (L.) Anterior layer of the iridic tissues.

Membrana iridis posterior. (L.) Posterior layer of the iris.

Membrana Jacobi. (L.) Bacillar layer of the retina.

Membrana limitans. (L.) The limiting membrane of the retina. See **Retina.**

Membrana limitans externa retinæ. (L.) A delicate retinal layer, formed by the terminal extremities of the fibers of Müller, situated between the outer granular layer and the layer of rods and cones. See **Histology of the eye.**

Membrana limitans hyaloidea. (L.) Hyaloid membrane.

Membrana limitans interna retinæ. (L.) An extremely thin, delicate and structureless membrane, lining the inner surface of the retina, and more or less intimately connected with the hyaloid membrane.

Membrana limitans Pacini. (L.) Bacillar layer of the retina.

Membrana nictans. Membrana nictitans. The nictating membrane, third eyelid, or haw; a structure highly developed in certain of the lower animals, especially in birds and some reptiles. It consists of a fold or reduplication of the conjunctiva, covering a sheet or lamina of fibro-cartilage which can be made to advance and more or less completely cover, protect and cleanse the eyeball. See **Comparative ophthalmology.**

Membrana orbitalis musculosa. A system of smooth muscles deep in the orbit.

Membrana orbicularis musculosa. This unstriated muscular tissue—innervated by the sympathetic—is in close relation with the tarso-orbital fascia (see p. 406, Vol. I, of this *Encyclopedia*). Krauss (*Ophthalmic Year-Book*, p. 344, 1912) having studied the orbit on eight cadavers of the newly born describes both it and the *membrana orbito-palpebraris musculosa.* The fibers are transverse, sagittal and oblique. This powerful muscle closes, as a plate, the inferior orbital fissure and pterygopalatine fossa. Small veins pierce the membrane while larger veins are enveloped by it or receive some fibers. The writer thinks the increase or decrease in the volume of the orbit, through the contraction or relaxation of the unstriped fibers is responsible for exophthalmos or enophthalmos.

Membrana orbito-palpebraris musculosa. See **Membrana orbicularis musculosa.**

Membrana pupillaris. The delicate, transparent, vascular membrane which closes the pupil in the fetus during the process of development of the eye. It is attached all round to the sphincter margin, and is more or less closely connected with the anterior capsule. It contains numerous minute vessels continued from the margin of the iris to those on the front part of the capsule of the lens. Between the seventh and eighth months this membrane begins to disappear by gradual absorption. Sometimes it remains permanently after birth. See **Development of the eye.**

Membrana pupillaris perseverans. The membrana pupillaris when it or a portion of it remains after birth.

Membrana Ruyschiana. Membrana Ruychii. Membrana choriocapillaris. (L.) The middle layer of the choroid, between the vitreous lamina and the layer of larger blood-vessels. It is composed of a very fine capillary plexus formed by the short ciliary vessels and contain pigment-cells. See **Ruysch, Membrane of.**

Membrana semilunaris conjunctivæ. (L.) Nictitating membrane or third eyelid.

Membrana semipellucida corneæ. (L.) An old term for macula corneæ.

Membrana verricularis. (L.) An old term for the retina.

Membrana versicolor. (L.) A name given by Fielding to a peculiar membrane supposed to be situated immediately behind the retina. It has no real existence.

Membrana wachendorfiana. (L.) An old term for the membrana pupillaris.

Membrana Zinnii. (L.) Zonule of Zinn.

Membrane, Amphiblestroid. An obsolete term for the retina.

Membrane, Araneous. (Obs.) Hyaloid membrane.

Membrane bacillaire. (F.) Bacillar layer of the retina.

Membrane, Basement, of the choroid. Bruch's membrane.

Membrane, Bowman's. The uppermost layer of the corneal stroma. See **Anatomy of the eye,** under *Cornea.*

Membrane, Bruch's. The inner layer of the choroid coat of the eye. See **Bruch, Membrane of.**

Membrane, Capsulopupillary. The membrane inclosing the capsule of the lens of the eye of the early embryo.

Membrane, Chorio-capillary. Membrana ruyschiana (q. v.).

Membrane, Cyclitic. In addition to the matter on p. 3611, Vol. V of this *Encyclopedia*, J. Beets (*Inaugural Thesis,* 1914) has gone thoroughly into the subject. He believes that the cyclitic membrane is formed as a consequence of the organization of exudates. A fibrocellular exudate forms in the vitreous body, mostly in the anterior part behind the lens; from the ciliary body and into this exudate elements grow, organize, and replace it by connective tissue. In the beginning long spindle-cells are seen, which here and there become pencil-shaped and at other places form capillaries (that are chiefly derived from the pars plana) and advance into the vitreous. Alt and others considered these cells to be grown-out ciliary epithelia. Such spindle-cells are first seen in the connective tissue between the uvea and the lamina vitrea, then between lamina vitrea and the epithelium; later they perforate this epithelium to find their way into the exudate. The most numerous outgrowths of vascularized connective tissue originate in the ora serrata, then the pars plana produces additional vessels and connective tissue, while the ciliary processes produce the fewest. The cyclitic membrane fills the entire space behind the lens, extends within the entire ring of the pars plana, or occupies the lenticular fossa in case the lens has disappeared. In the beginning the membrane is made up of loose spindle-cells and vessels; becomes more firm and then looks as a fresh scar with numerous interwoven spindle-cell bundles, wherein are vessels that originate chiefly from the ora serrata and pars plana. This tissue becomes adult connective tissue, and consists of bundles of fibers and endothelia, between which vessels still are seen. This tissue in the middle of the eye contracts and pulls at the neighboring tissues, wherewith it is connected. This connection is formed by the vessels, although since the older connective tissue does not need such a blood-supply many vessels become atrophied. These vessels become mere tissue strands and form supports for the cyclitic membrane, through which they can produce tissue displacements while contracting. These strands elongate the ciliary processes, and the cyclitic membrane may become loosened. This explains why many vascular strands in the cyclitic membrane are not connected with other vessels; they were pulled loose while still pervious to the blood-stream while other vessels became closed while still attached. It is possible that with the rupture of these nearly normal vessels blood became extravasated and became the matrix for the pigment of the vessel strands, although the great quantity of pigment makes it more probable that the older vascular strands, because of their origin from the uvea, again began to produce pigment.

Membrane, Demours'. The posterior lining membrane of the cornea.

Membrane, Descemet's. The posterior layer of the cornea.

Membrane du corps vitré. (F.) Hyaloid membrane.

Membrane, Henle's. The inner layer of the choroid coat.

Membrane, Hovius'. The entochoroidea.

Membrane, Hyaloid. A delicate membrane investing the vitreous humor.

Membrane, Jacob's. The layer of rods and cones of the retina.

Membrane, Limiting. See **Membrana limitans.**

Membrane of Ruysch. Chorio-capillaris. The network of capillaries spread over the non-pigmented, inner portion of the choroid. See Vol. II, p. 1388, of this *Encyclopedia.*

Membrane, Pupillary. A delicate membrane closing in the fetal pupil and disappearing about the seventh or eighth month of fetal life.

Membrane, Reichert's. The uppermost layer of the corneal stroma.

Membrane, Tenon's. The fibrous sheath that envelops either eyeball and forms its socket.

Membrane, Vitreous. The inner layer of the choroid coat.

Membrane, Wachendorf's. 1. The pupillary membrane (q. v.); also the membrane which invests a cell.

Membrane, Zinn's. The ectiris, or anterior layer of the iris; sometimes a name given to the zonula of Zinn.

Membranous cataract. See **Cataract, Membranous.**

Membranous conjunctivitis. See **Conjunctivitis, Membranous.**

Membranula coronæ ciliaris. (L.) An old name for the zonule of Zinn.

Membranula semilunaris conjunctivæ. (L.) A semilunar fold of mucous membrane at the inner canthus of the eye; the plica semilunaris.

Memory, Visual. The mnemonics of vision belong to the psychology of that subject. Here reference may be made to the article of Aaron Brav (*American Medicine*, June, 1912) who in particular considers the relation of the motor apparatus to it. He says that in physical or objective vision the stimulus comes from without, in the process of visual memory reflexly from within, stimulating the optic nerve and tract as in ordinary vision. He believes that likewise in order to produce a clear image from visual memory the muscles of accommodation and convergence are also stimulated. He cites as proof of this the experiment of closing the eyes and forming a mental picture of a large object in the distance, then changing to a mental picture of a small object close at hand, noting a similar sensation of muscular contraction to that which can be felt when actually looking at similar objects with the eyes open. He also refers to diminution in the power to recognize objects or recall them mentally when the cortical visual memory center or the path leading up to this center is disturbed.

Mendel, Gregor Johann (1822-1844). See **Heredity in ophthalmology,** as well as **Mendel's law.**

Mendelian theory. See **Mendel's law;** and **Heredity in ophthalmology.**

Mendel's law. Mendelian theory. Mendelism. These headings relate to a theory of heredity, so called after Gregor Johann Mendel (1822-1884), abbot of Brün in Moravia. During eight years Mendel scientifically studied the pea plants in his monastery garden till the closure of the monastery by the Austrian government put an end to his experiments. The results of his observations and his deductions therefrom were published in 1865 under the title of *Versuche über Pflanzenhybriden*. His experiments were made in the following manner. He divided the varieties of the *Pisum sativum* into seven groups. Each group was made up of two varieties absolutely identical in appearance, and differing only in one easily recognized character such as shape of seed, or color of seed, or length of stem, etc. The results in all the groups were strictly comparable and in every respect analogous, and may be summarized from the facts observed in one group, where the only difference was length of stem; 6 to 7 ft. in one case and ½ to 1½ ft. in the other. On crossing the tall one (T) with the dwarf (D) he found that the hybrid (H) was a tall plant, to all appearance identical with the original T. On further investigation, however, he found that while T always bred true, self-fertilization of H gave origin to dwarfs as well as tall plants. Of this first generation from H, the dwarfs bred true like their ancestral D, while the self-fertilized talls produced again dwarfs and talls just as H had done.

The same phenomenon was reproduced in all subsequent generations. Moreover, there was always a certain numerical proportion between the talls and the dwarfs, 3 to 1. It was obvious that the talls were not a pure strain, and Mendel found out that only one-third of them were pure. Thus in each generation from H there were 25 per cent. pure dwarfs, 25 per cent. pure talls, and 50 per cent. impure talls (or hybrids). It will be remarked that the progeny were either tall or dwarf; there was no tendency to a compromise in length of stem. To such peculiarities Mendel applied the term unit-characters, that is to say, characters that do not blend, which either exist or do not exist in the adult plant. On the other hand it is clear that of the unit-characters dwarfness and tallness, both do not exhibit the same power, and so the latter is termed the "Dominant," and the former the "Recessive."

Such were the facts observed. Mendel framed the following theory to explain them. He assumed that every "gamete" (or sex-cell) was made up of two parts; these parts might be similar to each other, or they might be different (allelomorphic). Two gametes join together to form the fertilized ovum, and ultimately the developed plant or animal (zygote). If the parts of the gamete are similar, and two similar gametes join, the resulting zygote is *homozygous,* but if the two gametes are different, the zygote is then called *heterozygous.* When the zygote is homozygous it breeds true indefinitely. The heterozygous is, however, very different. The zygote H, which we have instanced above, is made up from the dissimilar gametes, T and D. In the gametes formed in H there is a rearrangement of these elements so that the gametes are formed of two T's or two D's, but not of a T and D conjoined. On self-fertilization, a T gamete may meet another T gamete and so produce a pure T zygote, or a D gamete meet its like, and so produce a pure D zygote. There is also the chance of a T gamete fertilizing a D gamete, and thus lead to an heterozygous zygote like the original H. With an equal number of T and D gametes the chance of the occurrence of the forms T, D, and TD may be represented by the formula — $(T + D) \times (T + D) — T^2 + 2TD + D^2$ and as T and D are, *ex hypothesi,* equal, then the numerical relationship between T and TD and D are as 1 : 2 : 1, which is the exact proportion found in the observations recorded above.

It is a singular circumstance that this remarkable paper attracted no attention at the time of publication. Indeed its very existence was entirely forgotten for thirty-five years, and it was only in 1900 that De Vries re-discovered it. During the short period that has elapsed since then, Mendel's views have exerted a profound influence on modern scientific thought, and it is generally recognized that his experiments are the most far-reaching that have ever been made in this particular direction. His theory of gamete-segregation has been placed by many on the same level as Darwin's natural selection, though it has been recently challenged by Karl Pearson, Weldon, and others. His facts, however, have never been disputed, and they lay open to scientific workers a hitherto undiscovered region, rich in promise and boundless in extent. Their practical importance is beginning to be realized, and Biffen, working along Mendelian lines, has developed a strain of wheat which is immune to the attacks of "rust."—*(Standard Encyclopedia.)*

Ménière's disease. An inflammatory process associated with congestion of the semicircular canals, manifested by pallor, vertigo, and various aural and ocular disturbances. The symptom-complex is called also *aural vertigo* and *auditory vertigo.* See also, p. 4114, Vol. VI, of this *Encyclopedia.*

Meningism. A condition due to pain in the meningo-cortical region of the brain, marked by excitation, followed by depression of the cortex, with vomiting, constipation, and thermic disorders. Also a hysteric simulation of meningitis.

Meningitis, Ocular relations of. Any one of the various forms—tubercular, luetic, traumatic, serous, purulent, metastatic—of inflammation of the cerebral and spinal meninges may give rise to ocular symptoms, and, as a matter of record, most aspects of this whole subject are discussed elsewhere in this *Encyclopedia,* especially under **Brain abscess**; **Encephalitis**; **Neurology of the eye**; **Military surgery of the eye**; **Choked disc**; **Eye and ear, Relations of the**; **Enucleation of the eye**; **Gradenigo's syndrome**; and on p. 1974, Vol. III.

In this place attention is further drawn to a case of *serous meningitis* reported by Frenkel (*Ophthalmic Year-Book,* p. 67, 1909) in which a woman of 21, with double optic neuritis, headache, vomiting, convulsions, and finally coma, was subjected to lumbar puncture which produced marked improvement. The puncture was repeated and recovery ensued, with full vision and normal fundus, one month later.

As is well-known to every ophthalmic surgeon extirpation of the eyeball in the presence of a panophthalmitis is occasionally followed by a serous form of meningitis, a sequel discussed on p. 4386, Vol. V, of this *Encyclopedia.* For instance, Jacqueau (*Lyon Médical,* p. 1129, May 26, 1912) reported a case of meningitis developing thirty-six hours after enucleation of the eyeball for panophthalmitis, general anesthesia being employed. On the evening of the first day after a perforating injury the panophthalmitis developed; on the morning of the second day, the enucleation was performed; on the afternoon of the third day, meningitis first made its appearance; and death ensued on the fifth day. The meningitis was of the serous type. Kontorowitsch reviewed the literature (to the year 1912) of fifty-eight cases of meningitis developing after enucleation during panophthalmitis, beginning with the first two cases ever described (von Graefe). One hundred and eighteen cases of operation from Haab's clinic were reviewed and the author concluded that, on the whole, enucleation is a fairly safe procedure. However, in certain cases of very virulent panophthalmitis, evisceration is to be preferred. Darrieux also reported forty-two cases of panophthalmitis (thirty traumatic and twelve metastatic), from which number three deaths followed enucleation. The first death was due to a heart lesion, and autopsy showed no meningitis. In the second and third cases, death followed enucleation for metastatic intra-ocular inflammation, but in neither case did the autopsy reveal any infectious lesions along the optic nerves or in the chiasms, although patches of meningitis were present. Hence Darrieux concludes that the meningitis was merely associated with the ocular inflammation and secondary to the localized source of infection, not to the panophthalmitis. He concludes that in traumatic panophthalmitis, enucleation is the operation of choice, while in other forms of panophthalmitis, that operation offers no greater danger than any other operative procedure.

A case of penetrating injury of the eye by a fishhook, is reported by C. E. Veasey (*Arch. f. Ophthal.,* January, 1915), the fishhook remaining in the eye seven hours before removal. On removal of the hook, enucleation was advised and declined. Fifty-seven hours after the accident the eyeball was enucleated, and twenty-four hours later a purulent meningitis developed, followed by death three days later.

To the matter on p. 1974, Vol. III, of this *Encyclopedia* may be added here the unusual experience of Vinsonneau (*Archives d'Ophtal-*

mologie, June, 1914) who observed twenty cases of cerebro-spinal meningitis. Two cases, or 10 per cent., presented ocular lesions. The first of these latter was in a previously healthy soldier, who eighteen days after the onset of the disease, and when he was convalescent, suddenly discovered that his right eye had failed him. Vinsonneau examined him and found that he had a detached retina with extensive irido-choroiditis.

Previous observers have differed in their opinion as to the frequency of this complication but all agree in stating that it is more often observed in the acuter forms of the disease. The present case was a subacute one, the temperature falling immediately after the first injection of antimeningococcic serum.

The second case was a child of twenty months. Examination of the eyes seventeen days after admission showed marked double optic neuritis.

Vinsonneau contends for an ocular examination in every meningitis. If such epidemics as that of 1904 and 1909 are only characterized by slight ocular lesions, such as conjunctivitis, keratitis, temporary disturbances of intra- and extra-ocular muscles, and slight papillitis, other epidemics such as 1905 (Silesia), 1914 (Angers), presented severe complications, irido-choroiditis with atrophy of the globe and neuro-retinitis with complete blindness. The discovery of any ocular complication renders a repetition of the lumbar puncture and serum injection necessary.

Meningocele. This condition (which may be congenital) is generally associated with encephalocele of the orbit. See p. 4306, Vol. VI, of this *Encyclopedia.* It takes the form of a prolapse, or hernia, of the meninges with cerebro-spinal fluid contents, projecting through a breach in the retaining skull-wall. Encephalocele is the same with the addition of brain-substance prolapsing within the meningeal sac. The bony defect is in the line of a suture. It generally involves the junction of the ethmoid and the frontal bone, the tumor then presenting at the upper inner orbital angle. Very rarely a posterior orbital meningocele or encephalocele presents near the apex of the orbit. Its diagnosis without exploratory operation is impossible. The following points must be observed: Meningocele and encephalocele are often reducible, and after reduction the bony margin of the aperture through which they came can be felt. Pulsation and hemic sounds can be elicited. The size and tension of these protrusions are variable, depending upon varying blood-pressure within the cranium. A dermoid cyst will present none of these phenomena. A meningocele may become constricted and its neck obliterated, leaving a complete cyst with cerebral fluid contents within the orbit.

Non-interference must be observed in the treatment of meningocele and encephalocele.—(J. M. B.)

Meningococcus. MENINGOCOCCUS INTRACELLULARIS. The exact ocular relations of this microorganism are somewhat doubtful but that the organism is on occasions responsible for conjunctival infections has been proved by a number of investigators. Weeks (*Text Book,* p. 237) observes that the *diplococcus intracellularis meningitidis* (Weichselbaum) has been reported as having been found in the secretion from a mild form of conjunctivitis accompanying cerebrospinal meningitis without culture tests. Axenfeld reports one case which was combined with keratomalacia from the pneumococcus, in which there was no meningitis. The meningococcus was recovered by cultivation. It is as yet doubtful whether the meningococcus is capable of causing conjunctivitis. If it does, the conjunctivitis is of mild form. That the meningococcus is at times present in the conjunctival sac cannot be doubted. As it closely resembles the gonococcus and is Gram negative, culture tests should be made before a positive diagnosis is made.

See, also, **Bacteriology of the eye**; as well as **Cerebrospinal meningitis.**

Meningoencephalitis. Inflammation of both the brain and meninges.

Meningoencephalocele. Hernial protrusion of the brain and meninges.

Meniscal. Pertaining to, or having the form of, a meniscus.

Meniscoid. MENISCOIDAL. Like a meniscus.

Meniscus. 1. A crescent or crescent-shaped body. Specifically—2. A lens, convex on one side and concave on the other, and thickest in the center, so that its section presents the appearance of the moon in its first quarter. As the convexity exceeds the concavity, the *meniscus* is a convex or *converging lens* deriving its name from the cusps (points) of the crescent moon; the lens of reversed form, in which the concavity is greater than the convexity, is the *contrameniscus* (q. v.), sometimes improperly called a concave or diverging meniscus. See also **Lenses and prisms, Ophthalmic.**—(C. F. P.)

Meniscus of the papilla. A name given by Kuhnt to a delicate membrane occasionally seen in the depths of the physiological excavation.

Menopause. CHANGE OF LIFE. A period in the human female when the activities of the ovaries finally cease and the child-bearing period of life closes. It occurs, as a rule, from forty-five to fifty years of age, and it is frequently characterized by distressing symptoms, such as flushings, headaches, giddiness, and other such manifestations of nervous irritability. The severity of these symptoms varies largely, however, with the constitution of the patient and circumstances of her life. See, also, p. 2291, Vol. III, of this *Encyclopedia.*

Menstrual blood. Menstrual blood was now and then employed in antiquity, internally and externally, as a remedy in diseases of the eye. Pliny recommends that a patient suffering from epiphora should be massaged by a person who is menstruating.—(T. H. S.)

Menstruation, Eye affections due to. According to Parsons (*Pathology of the eye,* p. 1303) even the normal function may aggravate ocular disease already present, and there are grounds for thinking that it may give rise to ocular complications in debilitated women. Amongst the disorders directly ascribed to menstruation are coloration of the lids, edema of the lids, hordeolum, hemorrhage into the lids, conjunctivitis, conjunctival hemorrhage, herpes corneæ, hemorrhage into the anterior chamber, vitreous hemorrhage, contraction of the field of vision, retinal hemorrhage and papillitis, amaurosis, muscular asthenopia, etc. An attack of glaucoma may be indirectly induced by normal menstruation. Hysteria and other nervous disorders may affect the vision at this period. Normal menstruation may aggravate diseases already present, e. g., elephantiasis of the lids, chronic conjunctivitis, herpes corneæ, interstitial keratitis, phlyctenular keratitis, episcleritis, iritis, iridochoroiditis, optic neuritis, quinine amblyopia, exophthalmos. The effect of menstruaton is ascribed to circulatory changes, and to toxemia.

Mentagra. A disease marked by inflammation of the hair-follicles, forming papules or pustules that are perforated by the hairs and are surrounded by infiltrated skin. The disease results from general debility and constitutional disturbances. This term (in such sense now obsolete) is also applied to a form of ulcerative blepharitis.

Mental blindness. Mind or psychic blindness. See p. 1131, Vol. II of this *Encyclopedia.*

Mental treatment. See **Psychotherapy**; as well as **Hypnotism,** p. 6112, Vol. VIII of this *Encyclopedia.*

Menthol. A camphor obtained from oil of peppermint by cooling. It has been used by the Japanese for 200 years and is known by them as Hakka-no-Hari. The chief source is the *Mentha arvensis purpurescens,* the oil of which yields more menthol than that of peppermint. In neuralgia, headache—including that of ocular origin—menthol in the form of cones often gives relief. When the cone is rubbed on the skin a twofold action results. The menthol rapidly evaporates, giving a sensation of cold; but if evaporation be prevented it acts as a rubefacient, producing a feeling of warmth. Instillation of a solution or the solid substance into the eye may set up a transient "chemical" conjunctivitis.

Mentor system. One of the modern writing systems in vogue on the continent of Europe. It is also known as Pählmann's. The effect of this system on the increase of myopia in schools is claimed by some to be marked; but this claim is contested by other observers.

Menzer's serum. A serum for treating the acute manifestations of rheumatism. It is obtained by inoculating horses with living cultures derived from human cases.

Meramaurosis. (Obs.) Partial loss of sight; amblyopia.

Mercolint. A cloth impregnated with metallic mercury and worn over the chest in the treatment of syphilis.

Mercuran. A 50 per cent. mercurial ointment prepared with goose-fat stearin, and used chiefly for the inunction treatment of lues.

Mercurette. A proprietary preparation of mercury in cocoa-butter.

Mercurial balsam. See **Balsamum ophthalmicum yveanum,** p. 871, Vol. II of this *Encyclopedia.*

Mercuriali, Hieronymus (It. Geronimo). Born at Forli, Italy, Sept. 30, 1530, he studied at Bologna, graduated at Padua, and settled for the practise of medicine in his native town. He then became professor of medicine successively at Padua, Bologna, and Pisa. He wrote a large number of medical works on a wide range of subjects. Of these the only volume of ophthalmologic importance is "*Hier. Mercurialis Forliviensis Medici Celeberrimi de Oculorum et Aurium Affectibus Praelectiones.* . . . Francofurdi, 1591." To the eye are devoted, in this book, 137 octavo pages. The work, although an authority in its day, possesses but little of original value, being for the most part a mere re-hash of the ancients and the Arabs.—(T. H. S.)

Mercurial ointment. Unguentum hydrargyri. Gray ointment. This is a triturated mixture of oleate of mercury, metallic mercury, benzoated lard and prepared suet, containing 50 per cent. of metallic mercury.

This, the favorite mixture for inunction in the treatment of ocular lues, is occasionally applied (in 10 per cent. salves) like the mercury oxides, to the lids and palpebral margins for dermal affections. The disagreeable odor, the staining of the skin and the fact that the remedy is inferior for this purpose to other remedies limits its employment in this neighborhood.

Mercurial preparations. See **Mercury.**

Mercuric ammonium chloride. See **Mercury, White precipitate of.**

Mercuric benzoate. White crystals, soluble in solutions of sodium chloride and ammonium benzoate. The mercurous salt is insoluble.

Mercury benzoate is used by some ophthalmologists as a substitute for sublimate and other mercurials in the hypodermic treatment of luetic affections of the eye. This method is less painful than with most other salts of mercury. Armaignac believes that the results are at least equal to those obtained by the use of the other salts. Of its use in non-specific cases he is noncommittal. The salt is employed in the following solution: Benzoate of mercury, 1 gram; benzoate of ammonia, 3 grams, with 100 grams of distilled, sterilized water.

The internal dose is gr. 1-30—1-10 (0.002—0.006 grm.), while hypodermically 15 minims (icc.) of the following solution may be used as indicated: Hydrarg. benzoat.; sodii chloridi, āā 0.25; aquæ dest., 30.00.

Mercuric cyanide. Cyanuret of mercury. Cyanide of mercury. Occurs in white, odorless, prismatic crystals with a bitter, metallic taste; soluble in both water and alcohol. Very poisonous. It is permanent in air if the light be excluded. It is used subconjunctivally; otherwise in 1:20,000-5,000 solutions as a substitute for corrosive sublimate, than which it is less irritative.

H. W. Woodruff strongly advises subconjunctival injections of solution of cyanide of mercury in purulent infections of the eye-ball, such as ulcers of the cornea, hypopyon keratitis and infections following cataract extraction. He has become convinced that this method of treatment, if used in the first twenty-four hours, will check such a process. In the post-operative infection known as ring abscess, he has proven certainly to himself and to others that this method, if used early, even when the ring of exudate is distinctly seen, will check the purulent process.

D. C. Bryant uses the following formula in nearly all forms of conjunctivitis: Acid, boric., ℈i; hydrarg. cyanid., gr. ss.; aquæ dest., fl. ℥vi.

He prefers the cyanide of mercury to the bichloride, as long experience with it has convinced him that it is a better germicide and less irritating.

Burton Haseltine has used subconjunctival injections of oxycyanate of mercury in several cases of sympathetic or transferred ophthalmitis with better results than could have been reasonably expected from other forms of treatment. From three to five drops of a 1-2000 solution were injected into the sympathizing eye every two, three or four days, according to the severity of the symptoms.

H. J. Hornbogen prefers the following formula in phlyctenular and other forms of corneal ulcers. Dionin., gr. v; cocain. mur., gr. iii; sol. hydrarg. cyanid. (1-4000), fl. ℥i.

In 1901 the Editor (Hare's *System of Therapeutics*, III, p. 663) drew attention to its employment in conjunctival catarrh. After cleansing the mucous membrane it is to be touched lightly with a cotton swab soaked in the following solution: Hydrarg. cyanid., 1.00 (gr. xv); aquæ dest., 100.00 (fl. ℥iijss). This should immediately be washed off with distilled water.

Mercuric iodide. See **Mercury, Red iodide of.**

Mercuric oxycyanide. See **Mercury, Oxycyanide of.**

Mercuric salts. See **Mercury.**

Mercurivanillin. A proprietary remedy for syphilis, said to contain 40 per cent. of mercury.

Mercurol. Mercury nucleide. Mercury nucleinate. A compound of mercury and nucleinic acid containing about ten per cent. of the former; a light brown-white powder, soluble in water, insoluble in alcohol. It is an effective antiseptic, astringent and bactericide recommended in infectious conjunctivitis—especially in ophthalmia neonatorum in 2 to 5 per cent. collyria. Solutions should always be freshly prepared.

Mercurous chloride. See **Calomel.**

Mercurous salts. See, also, under **Mercury** headings.

Mercuro-zinc cyanide. Lister's antiseptic. A white powder obtained by precipitation from a saturated solution of the cyanide of mercury and potassium and a saturated solution of zinc sulphate. In this powder the two cyanides are combined in somewhat varying proportions; it should contain at least 20 per cent. mercury cyanide, $Hg(CN)_2$.

As is well known this is one of the most powerful antiseptic solutions that the ophthalmic surgeon can make use of as a lotion for the eye. In infectious conjunctivitis and similar conditions it is used in 1-5,000 to 20,000. The Moorfield's *Pharmacopeia* gives a salve containing one or two per cent. of the double salt in soft paraffin for use in burns of the lids and for granular lids. This ointment is known in the Royal London Ophthalmic Hospital as Silcox's ointment.

Mercury. Mercurial remedies in eye diseases. See, as well, **Mercurial preparations**; also other captions of mercurial compounds, including such rubrics as **Calomel.**

Methods of administering mercurials. The administration of mercurials is, of course, an extremely important subject with which the ophthalmic surgeon should be familiar. The employment of these remedies *intraspinally* as well as by *injection into the cerebral ventricles* is now on trial and it may be that in a year or two these methods may find a definite place in ophthalmic therapeutics.

Weeks (*Text-Book,* p. 902) gives an excellent resumé of the usual modes of administering mercury.

Mercurial inunctions. The introduction of mercury into the system by inunction is painless, efficient, and safe, provided ptyalism is avoided. Two preparations are employed—mercurial ointment, U. S. P. (blue ointment), containing 50 per cent. of mercury, and the oleate of mercury, U. S. P., containing 20 per cent. of mercury.

Mercurial ointment. The ointment is sometimes rather hard and not sufficiently easily manipulated. This may be avoided by incorporating with it 33 per cent. of vaseline. If the ointment is applied to the skin in one location for a number of days in succession, a mild dermatitis may develop. On this account it is better to change about, using the same location only twice in two or three days. The areas best adapted for the inunction are the inner surfaces of the thighs, the inner surfaces of the arms, sides of the chest beneath the axillæ, and the groins. It is desirable to cleanse the surface with soap and water and dry it before applying the ointment. The dose of ointment is ordinarily 4.00 gm. (1 dram). If applied by a person other than the patient, finger-cots may be employed to prevent the absorption of the remedy into the individual's system; ordinarily the amount absorbed through the skin of the fingers of the one applying it is so insignificant that this precaution may be disregarded. The ointment is applied to the skin and gently rubbed in until all has been absorbed. This will require two to twenty minutes. If it is desired to influence the system rapidly, two inunctions daily may be employed. If after the treatment has been established a mild continuous effect is desired, one inunction daily or every second day will suffice.

The oleate of mercury may be employed in the same manner as the ointment. Absorption of the oleate is thought to be more rapid than absorption of the ointment.

If the ointment is to be used for infants or small children it may be smeared on the lower part of the abdomen and an abdominal bandage applied, a layer of thin linen cloth being placed next to the skin. In adults a closely-fitting undershirt to take up surplus ointment and to maintain a more or less continuous contact with the skin, permitting of continuous absorption, may be worn during the treatment.

Intramuscular injections of mercury. By this method the dose may be accurately measured. The rapidity of absorption depends (a) on the solubility of the preparation of mercury employed and (b) on the character of the menstruum. Oily preparations are absorbed less rapidly than watery preparations. The site usually preferred is the nates about 7 cm. back of the great trochanter, but the muscles of the back may be used. The needle employed should be sufficiently long to enter the tissues 2 to 4 cm. It should be introduced perpendicularly to the surface and should enter muscle tissue. It is sufficient to rub the surface of the skin vigorously with alcohol, 90 to 95 per cent., before piercing the skin with the needle. The puncture should be sealed subsequently with collodion. Massage after the injection is not advised. The preparations employed are: (a) Watery solutions. —(1) Mercuric chloride, 1 to 2 per cent., in solution of sodium chloride, 1 per cent.; inject 1 c.c. every third or seventh day, as required. (Painful.) (2) Succinimide of mercury, 1 per cent. solution; inject 1 to 2 c.c.; said by Selenew to be superior to the salicylate or the gray oil. (3) Sozoiodolate of mercury, 1 per cent., in solution of iodide of sodium, 2 per cent.; inject 1.5 c.c. once a week. (b) Oily solutions.—Hydrarg. salicylate, 1.0; Vaseline liquid, 10.0-m.; inject 1 c.c. every fifth or seventh day. Shake well. Hydrarg, oxidi flav., 0.5; vaseline liquid, 10.0-m.; inject 1 c.c. every fifth or seventh day. Gray oil, 1.0; olive oil, 1.0-m.; inject 0.1 to 1.5 c.c. every second or third day. Injections of the watery solutions are painful, the mercuric chloride being more painful than the others. The pain may be lessened to some degree by the addition of a small quantity of cocaine (1 per cent.). Injections of the oily preparations are slightly painful.

Intravenous injections.—After cleansing the skin of the forearm, the forearm is constricted just below the elbow. When the superficial veins become prominent, the needle of the sterile hypodermic syringe is caused to enter a vein in the axis of its lumen. When this is accomplished a slight withdrawal of the piston of the syringe will cause the venous blood to enter the syringe. When it is ascertained that the point of the needle is in the lumen of the vein, the piston is pressed home and the withdrawn blood and the medication are slowly forced into the vein, the constricting band having first been removed. Cyanide of mercury, 0.05; distilled sterile water, 5.00; inject 1 c.c. intravenously every second day.

This method is said to be painless. It has been found (Rochon-Duvigneaud) that young subjects tolerate the mercury by intra-venous injection better than the aged. It is well to begin with 0.25 to 0.5 c.c. in old people. Syphilographers advise a course of thirty injections, followed by an intermission of varying length.

When mercury is being given by whatever channel, the teeth and mouth should be kept free of decomposing food to prevent ptyalism. It is a good plan to brush the teeth with sal solution, 1 to 2 per cent. after each meal and to wash the mouth at least once a day with a

1 per cent. solution of potassium chlorate. On the development of tenderness of the teeth or puffiness of the gums the mercury should be discontinued until these symptoms have subsided.

The extreme *value of mercurial remedies in luetic diseases of the eye* is generally accepted, and the subject is discussed, for example, under **Syphilis.** Bourgeois (*Receuil d'Ophtal.,* July, 1907) also points out that ophthalmic surgeons use mercurials largely not only in syphilitic affections, but in those where there is no suggestion of the taint; and that it is remarkable how numerous and how varied are the affections that are amenable to its action. He does not pretend to have solved the riddle of this action, neither can he give any precise indications where such treatment will be of service; but he considers that we should continue the habit of resorting to mercury when all else has failed, and that the practice is justified by its success. Moreover, where one mode of exhibiting mercury has failed another should be tried; the changes should be rung on inunctions, injections and administration by the mouth. Particularly in cases of iridochoroiditis, even when the history is negative and there have been no previous manifestations that would suggest the particular utility of a mercurial, mercury with salicylate of soda gives good results. One insists on this because many practitioners refuse to use it unless a syphilitic origin of the disease be manifest. Grasset insists on the same point with regard to disease of the central nervous system; and Schmidt-Rimpler in 1906 similarly justified this medication in non-syphilitic eye diseases, particularly in the graver forms of iritis, irido-cyclitis with hyalitis, choroiditis, optic neuritis, and tobacco or alcoholic amblyopia. (Abstract in the *Ophthal. Review,* p. 120, April, 1908.)

Mercury, Ammoniated. See **Mercury, White precipitate of.**

Mercury bichloride. Corrosive mercuric chloride. Corrosive sublimate. Sublimate. This important compound, with the formula $HgCl_2$, occurs as heavy, white, odorless, transparent, crystalline masses with an acrid, metallic taste. It is quite soluble in water, alcohol and camphor solutions; the aqueous solution has an acid reaction, and is a powerful poison.

Mercuric chloride is one of the most useful of germicides, and when employed with due care forms an almost indispensable agent in the treatment of eye diseases. Hirschberg believes mercuric chloride, in solutions of 1 to 5000 to 1000, to be the most important remedy the ophthalmic surgeon possesses. He uses it with compresses, for irrigating the conjunctival sac before operations, for the cleansing of wounds old and new, for moist dressings in the after-treatment of operations, as an antiseptic collyrium and as a disinfectant solvent for alkaloids and other therapeutic agents. It may be applied as an ointment (see **White's ointment**) or in solution. In the latter case it is prescribed alone or in conjunction with other remedies with which it is not chemically incompatible, but it is too powerful an escharotic to be applied pure to any of the ocular tissues.

As a mild astringent and antiseptic collyrium it may be used in 1:20,000 to 5,000 solution; as a detergent wash, irrigating fluid or spray, a warm 1:10,000 solution will be found sufficient, while decided germicide qualities will be found to reside in solutions of 1:3,000-1,000. A most useful detergent and mild antiseptic collyrium is the following: Acid boric, ʒ ss (grm. 2.0); sol. hydrarg. bichlor. (1:10,000), fld. ℥i (cc. 30.00). In that form of conjunctivitis often seen with "grippe" R. L. Randolph has found this combination useful: Hydrarg. bichlor., gr. 1/12; cocain. mur., gr. i; adrenalin. chlor. (1.1000), ℥i; aq. dest. ad., ℥iii. This simple mixture (and a small amount of borax may with propriety be added in most cases) is more soothing and less likely to irritate than the plain bichloride solution.

The Editor has also found corrosive sublimate a useful application to corneal ulcers in a one per cent. alcohol solution. Stronger mixtures form efficient escharotics. Hirschberg long ago advised the use of 1:5,000 bichloride solution in water as an efficient preventive of germ growth in collyria.

In ordering mercuric chloride for eye lotions the chemist should be directed not to use tablets or alcohol in the preparation of the collyrium—as he may do, without thinking how irritating the excipient of the tablet (ammonium chloride, etc.) or the spirit may be to an irritable or inflamed eye.

Under various headings will be found described several substitutes for mercuric chloride (formaline, sublamine, oxycyanate of mercury, zinc chloride, phenol, etc.) where their advantages and drawbacks are discussed at length. Here it will, perhaps, suffice to say that few antiseptics have proved as effective and have held their place as long in popular favor as corrosive sublimate.

For the *oculotoxic effects* of this drug see **Toxic amblyopia.** The locally irritant effects of sublimate also must not be forgotten, and in this connection Schwenk (*Trans. Wills Hosp. Soc.,* Jan., 1911) has reported a case of erysipelatous eruption following the use of mercuric bichloride ointment after cataract extraction.

Mercury, Biniodide of. See **Mercury, Red iodide of.**

Mercury nucleide. See **Mercurol.**

Mercury nucleinate. See **Mercurol.**

Mercury, Ointment of. See **Ointment of mercury.**

Mercury oleate. This compound is really a solution of yellow mercuric oxide in oleic acid. Yellowish semi-solid mass, soluble in ether and oils. The U. S. P. has a 25 per cent. mixture. Ball (*Text-book,* p. 118) advises the use of the following salve as an application in seborrhea of the lid skin: Sulphur precip.; hydrarg. oleat. (5 per cent.), āā part. equal; ungt. aquæ rosæ, q. s. Make into an ointment.

Mercury oxycyanate. See **Mercury, Oxycyanide of.**

Mercury, Oxycyanide of. MERCURIC OXYCYANIDE. HYDRARGYRUM OXYCYANATUM P. G. This valuable ophthalmic remedy is a white crystalline powder, with a yellowish tinge, soluble in 17 parts of water.

This salt is used as an antiseptic substitute for mercuric bichloride in 1 : 2,000 to 1 : 500 solutions, being generally regarded as about one-fourth the strength of the latter. It is used in exactly the same way as sublimate without exhibiting its irritating properties. Ohlemann, Oliver's translation, quotes Schlösser as saying that it may be used as an eye-water for conjunctivitis in one or two per cent. solution. It is much less injurious to instruments and may, accordingly, be used as an antiseptic in preparing them for operation.

Merck (*Annual Reports,* 1907) announces that he prepares two different salts; one a pure oxycyanide styled Hydrarg. oxycyanid., Holdermann, and another prepared by the old process and designated Hydrarg. oxycyanid. cryst. As most of the reported observations have evidently been made with the latter variety, it is doubtful whether the observed effects are due to the oxycyanide or the cyanide. Mercuric oxycyanide does not attack metals, and has therefore been found useful for disinfecting surgical instruments; for this purpose a half to one per cent. solution, with the addition of 5 per cent. sodium carbonate or bicarbonate, is used. As an antiseptic it is equal in effect to sublimate, while it does not corrode instruments, injure the hands, or precipitate albuminous solutions.

Hirsch (*Wochenschr. f. Therapie des Auges,* June 28, 1906) uses subcutaneously a preparation of 1 per cent. aqueous solution of oxycyanide of mercury with 0.5 per cent. acoin, made by a special method in the Heyden chemical works. He has treated 20 cases of congenital and acquired syphilis. Pain was practically absent in all the cases, and the site of injections remained free from reaction. Hirsch injected at intervals of 2 to 4 days 1 to 1½ ccm. in adults and correspondingly smaller doses in children. The injections were made subcutaneously on both sides of the spinal column. According to Hirsch the injections work more rapidly and permanently than inunctions. In *iritis* synechiæ are prevented, and the extension of inflammation in parenchymatous keratitis is checked. This soluble salt of mercury is very rapidly excreted. Eight days after the last injection, the urine shows no trace of the mercury.

In blennorrhea neonatorum some surgeons prefer it to silver nitrate or corrosive sublimate, using it as an irrigating fluid twice or three times daily in 0.20 per cent. solution.

The oxycyanide is preferred by an increasing number of surgeons to the bichloride in treating eye diseases. Haitz has found it, in the same dosage, of at least equal value to the sublimate as a subconjunctival injection in central choroiditis, vitreous opacities and other intraocular diseases. See, e. g., p. 1733, Vol. III, of this *Encyclopedia.*

Kenneth Scott, who has enjoyed unusual opportunities of studying the disease in Egypt, treats chronic trachoma by painting the lids with a four per cent. solution followed by the home use of a 1:500 to 1:1,000 solution as an eye water. As a germicidal douche in corneal ulcer due to infective conjunctivitis it is extolled by several writers, while in the conduct of chronic dacryocystitis with pus formation it acts better than any other mercurial.

Solutions of the oxycyanide do not precipitate cocain, as mercuric chloride does, and for the purpose of preventing decomposition in these anesthetic solutions ought for that reason to be preferred to the latter. See, also, an account of its use with cocain or acoin by subconjunctival injection on p. 77, Vol. I, and p. 3458, Vol. V, of this *Encyclopedia.*

Mercury perchloride. See **Mercury bichloride.**

Mercury, Red iodide of. MERCURIC IODIDE. BINIODIDE OF MERCURY. HYDRARGYRUM BIJODATUM, P. G. HYDRARGYRI IODIDUM RUBRUM. This compound appears as a heavy, scarlet-red, amorphorus or crystalline powder. It is almost tasteless and quite inodorous. It turns yellow at 150° C., slowly returning to red. It is a powerful irritant poison, like the bichloride.

It is well to remember that neither calomel nor any other salt of mercury should be applied to the conjunctival sac if iodides are being taken internally lest an irritating mercuric iodide be formed.

This remedy is rarely employed as an eye water. One of the elder von Graefe's formulæ, to be used as a stimulating collyrium in corneal infiltrations, especially in parenchymatous keratitis, is: Hydrarg. biniodidi, 0.3 gm. (gr. iv); potass. iodidi, 3.0 gm. (gr. xlvi); aquæ dest., 30.0 c.c. (f℥vii). Sig.—Five drops to be instilled 3 times daily.

For aborting styes the following mixture has been recommended: Hydrarg. iodidi rubri, 0.40 (gr. vii); ol. olivæ, 100.00 (fl. ℥iii¼). This should be applied several times daily to the incipient stye.

In the recurrent forms of the disease also smearing the lid edges daily for three months with the following has been advised: Aristol., 0.50 (gr. vii ss); petrolati; lanolin, āā 5.00 (ʒiiss). Lanvole recommends for this purpose, also, bathing the lids regularly with: Acid salicylic, 5.00 (ʒ iss); boracis, 3.00 (gr. xlv); aquæ dest., 30.00 (fl. ℥j). In the ulcerative form of blepharitis when the lesions do not readily heal they may be curetted and have applied to them on a cotton swab a small quantity of this solution: Hydrarg. iodidi rubi; ol. olivæ, 250.00 (fl. ℥viii). The red iodide is sometimes employed as an ointment (1:1,000) in ulcerative forms of blepharitis but for that purpose milder salts of mercury are generally preferred.

Mercury, Red oxide of. RED PRECIPITATE. HgO. This agent appears as a heavy, bright, orange-red powder, insoluble in water or alcohol, but very poisonous.

It was formerly employed in the place of, and for the same purposes as, the yellow oxide (q. v.) but owing to its milder, less irritant and equally effective action the latter salt is now invariably preferred. Schmidt-Rimpler has advised its employment as an ointment, in the proportion of 1:16, for syphilitic lesions of the lid. Owing to its insolubility in water or fluids commonly used as menstrua in ocular therapy it is not employed as a collyrium.

Mercury, Subchloride of. See **Calomel.**

Mercury, White precipitate of. MERCURY, AMMONIATED. MERCURIC AMMONIUM CHLORIDE. White precipitate is a white, inodorous, amorphous powder with an earthy, metallic taste and poisonous properties. It is insoluble in water and decomposes when exposed to it.

This remedy is used instead of the yellow oxide, where that drug is indicated, in ointment form, and is regarded by some surgeons as superior to Pagenstecher's salve because it is less irritating. It combines readily with all the ordinary excipients and in suitable cases makes an excellent application in lesions of the lid edges and to the conjunctival sac. It is commonly ordered in from 1:100 to 1:10 strengths.

Mercury, Yellow oxide of. HYDRARGYRUM OXYDATUM, P. G. YELLOW MERCURIC OXIDE. PRECIPITATED, OR YELLOW PRECIPITATED, OXIDE OF MERCURY. HYDRARGYRI OXIDUM FLAVUM, U. S. HgO. This ancient, important and much-used ophthalmic remedy is commonly seen as a heavy, smooth, odorless, tasteless, amorphous, yellow-red powder, darkened by exposure to light, which partially decomposes it with the formation of mercurous oxide. It is insoluble in water and ordinary fluids. Yellow oxide is more finely divided than the red oxide, hence is more easily acted on chemically and has a more marked therapeutic action.

Practically the only use made of this agent is in the preparation of the so-called Pagenstecher's ointment or "yellow salve" so extensively employed in ophthalmic surgery.

In one of its strengths it constitutes the *unguent. hydrarg. flav.* U. S. and ought to be ordered under that caption, diluted, when necessary, with petrolatum, lanolin or other excipients.

Peter Callan (p. c.) suggests that the salt used in making yellow oxide salve be first mixed in olive oil; then add the petrolatum. He has found this mixture very efficient in phlyctenular keratitis and phlyctenular conjunctivitis, and it may be used in this combination in the strength of three grains to the dram as often as three times daily without producing irritation.

Mergal. A mixture of tannate of albumen and mercuric cholate. Rosenbauch (*Practical Med. Series*, Eye, p. 223, 1910) gives the history of a man 24 years of age, who had had a primary syphilitic lesion 3 years previously, and showed in the right eye an extensive, gummatous exudate in the retina, with sharply circumscribed margins. V = fingers at 4 mm. Rosenbauch administered mergal in increasing doses internally and unguentum cinereum inunctions in the temporal region, with the result that the retinal lesion disappeared and vision and the fields were retained as at the first visit.

An account of the use of mergal in ophthalmic practice is also given by J. Hand (*Therapeut. Med.*, p. 437, 1911).

Mergandol. Mercury sodium glycerate: used in syphilis by injection. Dose, 30 min. (2 c.c.) every other day.

Meridian. A circle drawn from pole to pole on the surface of a spherical body, for example, of the eyeball, and passing through a given point of which it is said to be the meridian.

Meridian of greatest refraction. In an optical system or lens having different meridians of curvature, the one in which the refraction is a maximum.

Meridian of least refraction. In an optical system or lens having different meridians of curvature, the one in which the refraction is a minimum.

Meridian, Principal of the eye. The meridian of the cornea that has the greatest and least curvature.

Meridians of the eye. See **Physiological optics**; as well as **Muscles, Ocular.**

Merkel's line. A line (imaginary) indicating the course of the lachrymal sac and nasal duct, running from the center of the internal palpebral ligament to the space between the last bicuspid and first molar teeth.

Meromicrosomia. Unusual smallness of some part of the body.

Meropia. Literally, "part vision"; characterized by defects in the visual field. The term, introduced by Rosas, has not been generally accepted. It should, however, have a place in ophthalmic nomenclature as it is the only correlative to "scotoma," that is to "partial *non*-vision."

Méry, Jean. A celebrated anatomist, surgeon and ophthalmologist, one of the predecessors of Helmholtz in the field of ophthalmoscopy. Born the son of a surgeon at Vatan (Berry), in 1645, he studied surgery for a number of years at Paris, in the Hôtel Dieu. In 1681 he was appointed surgeon to the Queen, and, two years later, surgeon to the Institute for Military Pensioners. In 1684 he was sent by Louis XIV to Lisbon to treat the Queen of Portugal. Remaining for some time in Lisbon and Spain, he was sent, in 1692, by the King on a private embassy to England. A number of other royal, or semi-royal, appointments followed, and, in 1700, he accepted the position of surgeon-in-chief to the Hôtel Dieu. From that time forward he rejected with great resolution all temptations to wander from a strictly scientific career, devoting himself with great assiduity to surgery, anatomy, otology, and ophthalmology.

Among his most important writings are: *Exact Description of the Human Ear, with a Mechanical and Physical Explanation of the Functions of the Sensitive Soul* (Paris, 1677, 1687); *Observations on the Manner of Cutting in the Two Sexes for the Extraction of Stone, Practised by Brother John* (Paris, 1700; Amsterdam, 1687); *New System of the Circulation of the Blood, by the Foramen Ovale, in the Human Foetus, with Replies to the Objections*, etc. (Paris, 1700); *Six Problems of Physics Upon the Generation of the Human Foetus* (Paris, 1700); *On the Movements of the Iris, and, Incidentally, on the Essential Portion of the Organ of Vision* (in *History of the Royal Academy of Sciences*, 1704, 10 pp.—containing, however, his account of the famous cat-submersion experiment, by which he obtained a view of the *fundus oculi*).

Ophthalmologically, Méry is of great importance for reasons other than merely the cat experiment. Thus, though at the beginning of "the battle concerning the new theory about the nature and location of cataract," he fought on the side of the opposition, yet, seeing very early his error he promptly faced about, and then was one of those who contended most earnestly and persistently for the acceptance of the new and true doctrine.

A word or two concerning the history of cataract pathology will render clearer the nature of the services which this great man rendered. Throughout antiquity, all the middle ages, and the earlier centuries of the modern period, the supposition was that cataract consisted of an exudate of corrupt and inspissated humor which had flowed down (hence, the Greek, *hypochyma,* the Latin *suffusio,* and the *cataracta* of Constantinus Africanus) into a (purely imaginary) space between the pupil and the lens (the lens being supposedly situated exactly in the center of the eye). The operation performed for cataract throughout antiquity and until the time of Ammar (an Arabian of the middle ages) was, exclusively, ''depression'' or ''couching.'' This consisted, as is well known, of thrusting a needle through the sclera, and then pushing down (hence ''depression'' ''couching'') really the lens, but supposedly the thickened, inspissated ''membrane'' which had been formed out of the down-flowing and corrupted humors. Ammar introduced the procedure known as ''the suction operation,'' whereby what is known as a soft cataract (i. e., a cataract in the young) is extracted from the eye by means of suction through a hollow tube, or needle. Still, however, a cataract was supposed to be an exudate between the pupil and the lens. Fabricius ab Acquapendente (by means, it is highly probable, of first freezing an eye and afterwards dissecting it) was the first to demonstrate that the lens lies virtually in contact with the pupillary border of the iris. Then Qarré, in the seventeenth century, taught, but did not actually demonstrate, that a cataract is really a hardening and opacification of the crystalline lens. Next, the German Rolfinck (in 1656) showed the truth of Qarré's teaching by actual anatomical demonstration. The new theory of cataract, however, spite of its great importance and its absolute truth, was permitted to be well-nigh forgotten for exactly fifty years. Then Brisseau and Maître-Jan revived the new-old doctrine and fought for it vigorously, and, in spite of bitter opposition (led by Thomas Woolhouse) finally secured its unconditional acceptance for all time. In this bitter and long-continued controversy, one of the ablest supporters of Brisseau and Maître-Jan was the subject of this sketch—Jean Méry.

As early as 1707, Méry declared that extraction of cataract was among the possibilities. Daviel, be it remembered, did not perform his ''first extraction in history'' until about 1749 or 1750. However, Méry did not himself carry out the procedure he recommended, hence to Daviel belongs the paternity of cataract extraction.

Méry will, however, always be remembered chiefly for his cat-experiment. That experiment was this: He immersed a cat in water, and, as its pupil dilated (as a result of suspended respiration) he beheld in all its glory the fundus of the animal's eye—the entrance of the optic nerve, and all the colors and vessels of the choroid.

Méry understood quite well enough that something more than mere pupillary dilatation was necessary to account for the possibility of observing the fundus of the eye when the eye was under water. His explanation, however, of the "something more" was wholly erroneous. He believed that the view of the fundus was rendered possible by the water, because that fluid filled up a multitude of tiny "unevennesses" of the anterior surface of the cornea. Five years later, de la Hire stepped forward with the correct explanation. According to him, the water obviated the refraction of light by the cornea, so that all rays leaving a given point upon the fundus emerged from the eye not as parallel, but as divergent, rays. He also observed, incidentally, the disturbing light-reflexes proceeding from the cornea *in aere* are done away with by the water.

Neither of these discoveries (Méry's or de la Hire's) was at the time regarded as of any great importance. Yet, bit by bit, the mosaic of modern ophthalmology was being put together. Lacking either of these items, the pattern is incomplete.—(T. H. S.)

Mesal. Pertaining to the median line or plane.

Mesarteritis. Inflammation of the middle coat of an artery.

Mesaticephalic. Having a skull with a breadth index of from 75° to 80°.

Mesauchenous. Having the angle formed by the intersection of a line joining the inion and basion with the radius fixus from 26° to 38°.

Mescal poisoning. See **Anhalonium Lecoinii.**

Mesial. Situated in the middle, median.

Mesion. The plane that divides the body into right and left symmetric halves.

Mesiris. The middle layer, or *substantia propria,* of the iris.

Mesmer, Friedrich Anton or **Franz** (1733-1815), the founder of the doctrine of animal magnetism, born near Constance, Germany, took up the study of medicine at Vienna, and took his doctor's degree in 1766. About 1772 he began with a Jesuit, Hell, to investigate the curative powers of the magnet, and was led to adopt the opinion that there exists a power, similar to magnetism, which exercises an extraordinary influence on the human body. This he called animal magnetism, and published an account of his discovery, and of its medicinal value, in 1775. In 1778 he went to Paris, where he created a great sensation. His system obtained the support of members of the medical profession, as well as of others; but the government was induced in 1785 to appoint a commission, composed of physicians and scientists, whose report was unfavorable to him. He fell into disrepute, and retired to Meersburg, in Switzerland, where he spent the rest of his life in obscurity.—(*Standard Encyclopedia.*) See, also, **Hypnotism** as well as **Psychotherapy.**

Meso-. A prefix signifying "middle," either situated in the middle or moderate; in chemistry, a prefix signifying inactive or without effect on polarized light.

Mesoconch. Having an orbital index of between 80° and 85°.

Mesocytoma. A connective-tissue tumor; a sarcoma.

Mesolepidoma. A tumor made up of tissue derived from the persistent embryonic mesothelium.

Mesology. The science of the relations of living beings to their environments.

Mesoprosopic. Having a face of moderate width.

Mesoretina. The middle or mosaic layer of the retina.

Mesoropter. The proper position of the eyes with relation to each other, under normal circumstances, when they are not fixed, i. e., when the muscles are in a relative state of rest.

Mesoropter, Muscular. The angle formed by the visual lines of the two eyes when the muscles of both eyes are completely at rest.

Mesoseme. An orbit whose index (q. v.) is between 89 and 84.

Mesothelioma. A tumor developed from mesothelial tissue.

Mesothelium. That part of the mesoblast whence the serous cavities and the muscles are developed. It is formed by the development of sacs from the archenteron, which become separated by constriction to form closed cavities (*somites*) between the epiblast and hypoblast.

Mesothorium in ophthalmology. This agent is generally regarded as the first disintegration product of thorium and whose place is somewhere between thorium and radiothorium. It has decided radioactive qualities.

Thorium has, according to Chalapecky (*Wien. klin. Rundschau*, Jan. 5, 1913), properties similar to those of uranium. Mesothorium when applied to the eye of a rabbit had the same effect as an application of radium, than which it is much cheaper. Doubtless the x-ray is the most powerful ray. The effect of radium and mesothorium upon the eye is considerably weaker. The reason of this can readily be explained by the fact that the x-ray can be applied directly to the eyeball, while radium and mesothorium must be applied to the lids, and the rays must penetrate these before they can exert their effects on the eyeball.

Cuperus (*Oph. Year-Book*, p. 31, 1914) illustrates the effect of mesothorium radiation on ocular disease. The first case was one of unilateral scrofulous iritis in a youth of 16 years. After the usual methods of treatment had been tried over a considerable period without results, four half-hour radiations were followed by recovery from the keratitis, and the visual acuity improved from 1/50 to 5/6. In a case of blennorrhea of the lacrimal sac, with corneal ulcer and hypopion from lagophthalmus, the treatment of which by other methods had shown very little improvement, the ulcer healed, and the visual acuity rose from 2/50 to 5/20, after four irradiations of a half-hour each. Seven treatments of the same duration in a case of nodular tuberculous iritis resulted in partial clearing of the vitreous. The radiation was done with 4 mg. contained in an ebony capsule. Exact tests showed this amount to possess radiant efficiency corresponding to that of 10 mg. of radium bromid.

Cuperus has recently made the applications by direct contact of the capsule with the cornea for from five to fifteen minutes, after instillation of cocain. The same duration was employed latterly for the iris, while the interior of the eye was treated through the sclera for from fifteen to forty-five minutes. The lids were held apart with the fingers. The interval between treatments depended on the duration of the reaction from the preceding treatments. Caution is required in more or less acute cases of painful keratitis and iritis. Analgesic effect on the part of the radiation was not confirmed. In quiet eyes radiation was occasionally followed by troublesome irritation which sometimes persisted for months, but caused no permanent injury.

A. Köllner (*Archiv für Augenheilk*, p. 173, 1914) reported in a woman, aged 53, a proliferation developed at the left temporal limbus, similar to a pterygium, and was removed. After six weeks a relapse occurred which was again removed and cauterized. Still later the whole periphery of the cornea was covered, in a width of from 2 to 4 mm., with flat, gray proliferations associated with scars of the conjunctiva downward and toward the temporal side, extending to the lower lid in the form of a symblepharon. As repeated excisions had no permanent effect the tumor was, on eighteen successive days for from one to three minutes, exposed by the writer to radiations from mesothorium, 0.01 in a capsule. When the patient returned the tumor had completely subsided. Extremely fine, gray scar tissue marked its former seat at the periphery of the cornea. The histologic structure of the epithelial tumor differed from papilloma in the complete absence of blood-vessels.

Metabasis. A change or variation (e. g. in a disease or its symptoms, in method of treatment, etc.

Metabolism, Diseases and ocular relations of. To some extent this subject has already been discussed under **General diseases**; **Diabetes**; **Dyspepsia**, etc.

Schwann (1839) gave this name metabolism to a series of chemical changes occurring in nutritive material taken into an organism by which it is converted into an integral part of the living substance (constructive metabolism, anabolism), also the changes taking place in living substance by which energy is set free (destructive metabolism, catabolism). In the setting free of energy the complex material in the living substance is reduced to a simpler form, oxidation occurs, and carbon dioxide and other waste products appear.

Croftan (Wood's *Sys. Ophth. Ther.*) says in part: "Among the diseases of metabolism are included diabetes, obesity, gout and the uric acid diathesis, osteomalacia, rachitis, and in a special sense, chronic rheumatism. In many other diseases perversions of metabolism occur, but there the metabolic derangement is merely one more or less unimportant and, at all events, a secondary symptom of a definite and known underlying cause. In the diseases of metabolism proper the metabolic derangement is the primary event and the determining factor in the production of the disease. All the diseases of this group, especially diabetes, obesity and the uric diathesis are intimately related to one another pathogenetically, chemically and clinically, so that much that can be said in regard to the treatment of one member of the group often applies with equal force to the treatment of the others. Causal treatment, however, in view of our ignorance, for the present, of the etiology of the diseases of metabolism, and also in view of the intangible hereditary element that is so important a factor in all functional weakness of perversion of protoplasmic function, is not satisfactory; the main therapeutic indication is, therefore, by dietetic means to compensate the defective intracellular nutrition and at the same time to maintain adequate general nutrition. This can only be done by applying accurate, almost mathematical, measures."

As one of the many relations, direct and remote, between metabolic changes and eye affections E. Sulzer (*Ann. d'Oculistique*, Oct., 1913) made with a colleague an exhaustive examination of the urine in a number of cases of primary glaucoma, secondary glaucoma, and optic atrophy simulating glaucoma, with a view to discovering whether any disorders of metabolism are associated with these conditions. They concluded that primary glaucoma is always associated with hepatic insufficiency, relative renal impermeability, and diminution in the destruction of albumin, and is frequently accompanied by intestinal troubles and general instability. These abnormalities are absent from secondary glaucoma and from optic atrophy. The relief of these abnormalities by appropriate dieting, etc., may render complete and permanent the reduction of tension obtained by miotics or operative measures. These abnormalities constitute a variety of arthritism to which an ocular predisposition must be added in order to produce glaucoma. The tension of the eyes of a number of patients with urinary abnormalities similar to those found in glaucoma, but no subjective or objective visual defects, was examined with the Schiötz tonometer, and cases were found in which it differed in the two eyes of the same patient, or varied considerably from time to time, but became and remained constantly normal when the disorder of metabolism was remedied. The investigators concluded that it is of prime importance to seek for and to remedy disorders of metabolism in patients suffering from glaucoma, but that this treatment must be combined with operative measures, which it cannot replace.

An important article on the *Chemistry of metabolism in its relations to ocular disease* has been written by S. L. Ziegler (*Annals of Ophthalm.,* Vol. XX, p. 249, 1911).

Metachromasia. METACHROMATISM. Staining in which the same stain colors different tissues in different tints; the change of color produced by staining.

Metachrosis. Power of changing color at will.

Metadioxy-benzene. See **Resorcin.**

Metallic dots. A name for (probably) crick dots. See p. 3560, Vol. V, of this *Encyclopedia.*

Metallic foreign bodies in the eyeball. See **Injuries of the eye** and **Giant magnet.**

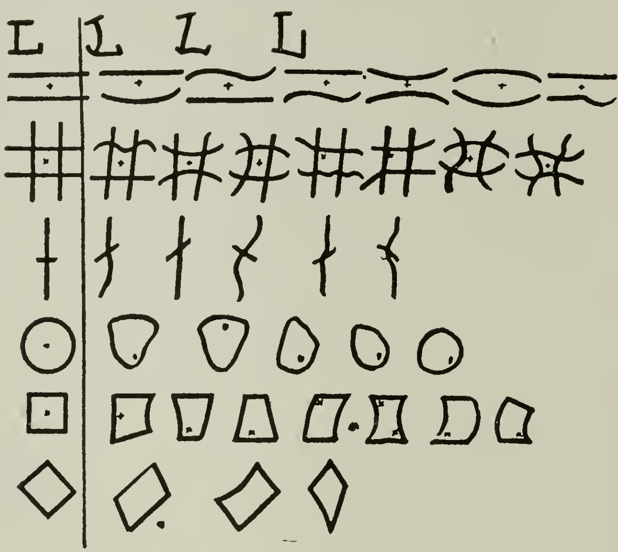
Metallic refraction. The refraction produced by certain metals whose indices of refraction have been determined through the employment of very small acute-angled metallic prisms. Kundt found that silver, gold and copper, whose refractive indices are 0.27, 0.58 and 0.65, respectively, produce deviation of light *toward* the refracting edge of the prism.—(C. F. P.)

Metallophon. This is a device invented by Weiss (*Centralbl. f. pkt. Augenheilk.,* Aug., 1906) for the detection of metallic foreign bodies within the eye. The apparatus is practically a Wheatstone bridge which measures the electric resistance of the tissues of the eye between two electrodes applied on the sclera while the latter is searched all over. A relatively small piece of metal, not necessarily iron or steel, placed between the electrodes increases the resistance and is indicated by the ringing of a telephone connected with the wire measure. Only very weak currents are to be employed.

Metalloscopy. Of Dujardin-Beaumetz, the phenomena observed in hysterical cases, produced by the application of metals to the skin.

Metamorphopsia. An abnormal condition of the eye in which objects appear elongated, irregular, or confused. This distortion of images is generally due to disease of the macular region, generally a central chorioretinitis.

Metamorphopsia varians. Dudley has reported the cases of three middle-aged men, each of whom complained of (right) monocular metamorphopsia varians: i. e., the distortion of the object viewed was constantly changing (see the figure). Since abnormal refraction and retinal changes did not exist, he concluded that the cause must be mental. Savage believes that the condition depends on retinal



Metamorphopsia Varians. (Dudley.)
The test-objects are placed at the left of the vertical line; the figures at the right show the varying distortions.

changes which are too minute to be visible ophthalmoscopically.—(J. M. B.)

Metamorphoscope. An optical toy for producing pictorial transformations.

Metaplasis. The stage in which the organism has attained completed growth.

Metastasis, Ocular. Metastatic ophthalmia. Metastatic infection of the eye. Endogenous affections of the eye. By the term metastatic ophthalmia is generally meant an inflammation of the eye-ball, resulting from endogenous infection. This takes place through embolism, as first pointed out by Virchow; septic substances from a focus of suppuration getting into the circulation and becoming arrested in the choroidal vessels. It may also occur by transfer of inflammation from behind forward, in phlegmons in the orbit, and in thrombophlebitis of the orbital veins. In meningitis and especially in cerebrospinal meningitis in children, suppurative choroiditis is often observed.

These cases are generally comparatively mild, a small degree of sight being actually retained in rare cases. In severe cases, however, the disease resembles panophthalmitis from traumatic or ectogenous infection. Metastatic ophthalmia may be either unilateral or bilateral. Unilateral cases generally afford a better prognosis as far as the pyemia is concerned, and particularly so when no metastases are observable, except the one in the eye. The prognosis in bilateral cases, on the other hand, is extremely bad, even for life itself. In children, suppuration of the umbilical cord, and sometimes vaccination, may give rise to pyemia with metastatic ophthalmia. In rare instances, as mentioned by Fuchs, this condition may occur in other acute infectious diseases such as typhoid fever, variola, scarlet fever, anthrax, influenza, ulcerative endocarditis, diphtheria, erysipelas, pneumonia, and Weil's disease. Of 166 cases of metastatic ophthalmia studied by Axenfeld, in 1894 (*Arch. f. Ophthal.*, Bd. 40, pp. 3 and 4), 96 occurred in puerperal pyemia, 60 in surgical pyemia, and 30 in cryptogenetic septic pyemia. Surgical and puerperal cases are much less frequently seen since the use of antiseptic methods of treatment in these cases.

The microorganisms which have been found in eyes affected with metastatic ophthalmia, include the streptococcus, pneumococcus, typhoid bacillus, bacillus coli, influenza bacillus, and meningococcus intracellularis; and when occurring in connection with the various acute infectious diseases, there is generally a mixed infection.

The first symptom of the disease to be noticed by the patient is a blurring of the vision of one or possibly both eyes. If it is possible to make an ophthalmoscopic examination of the fundus, the retinal veins will appear engorged and tortuous, the outlines of the disc blurred and indistinct, and the vitreous cloudy. There may be slight hemorrhages from the arteries or veins. Conjunctival and ciliary congestion, with some conjunctival chemosis soon appear; the iris is sluggish to light, and vision becomes very much diminished. As the disease progresses, the eyelids become swollen and edematous, and a deep-seated pain, increasing in severity, comes on excepting in mild forms of the disease, which often are attended by very little pain. The tension of the eyeball is increased, and the eye may be exquisitely tender to pressure. The iris becomes discolored and posterior synechiæ develop. Hypopion appears, the cornea becomes cloudy and opaque, and finally the pus in the interior of the eye escapes through the softened sclera or cornea, the condition known as *phthisis bulbi* resulting. Milder cases occur, in which the eyeball does not rupture, the exudate organizes and after months or years the eyeball gradually shrinks, leaving the condition known as *atrophia bulbi.* Treatment is the same as in panophthalmitis, and is of little avail except to alleviate the suffering of the patient. See, also, p. 2146, Vol. III, of this *Encyclopedia.*

Metastasis resulting from *pyemic infection* usually occurs in about the following order: First, the absorption (often from some trifling lesion, a scratch, an ulcer, a furuncle, etc.) of inflammatory agents; next, the formation of a thrombus at the point of absorption and the colonization in the former of pyogenic bacteria. From this thrombus minute portions, laden with cocci, break away, enter the blood-stream, and are carried to important organs. Here secondary thrombi and emboli form, and the eye at length becomes infected with colonies of bacteria. Casey Wood (*Medical News,* Apr. 27, 1895) reported a typical case of pyemic panophthalmitis from septic embolism. The patient, an express-driver, twenty-eight years of age, had a "weather-crack" on one of his fingers, which, owing to exposure to the weather and the sort of work he had to do, would not heal. There developed a chill and fever, and some swelling of the glands in his left axilla, and stiffness of the corresponding shoulder-joint. Stiffness and rheumatic pains in the left shoulder and elbow, as well as numbness and pains in the right fingers followed. He also had swelling of the inguinal glands in both sides, as well as pains in the knees and hips. He died about four weeks after the initial chill, with all the signs of pyemia. Twelve days after the first chill he found that he had only perception of light in the right eye, and two days later the eye presented the well-known picture of a panophthalmitis.

Bacterial origin of metastatic diseases of the eye. While it is generally accepted that in purulent inflammations of the eye conveyed through the circulation there is always a deposit of the bacteria in that organ, i. e., a true metastasis, the nature of the mild non-suppurative inflammations (apart from lues and tuberculosis) has not been so fully studied, as they have been much less frequently the subject of bacteriological examination. However, numerous instances are recorded where *streptococci* have likewise produced the most severe metastatic infections from surprisingly trivial lesions. The affections of the eye in which streptococci are present include impetigo, mucopurulent conjunctivitis, small gray ulcers of the cornea which may end in sloughing of the entire cornea, uveitis which always leads to panophthalmitis, lacrimal abscess, and purulent orbital cellulitis. In puerperal septicemia the streptococcus is highly dangerous to the eye, leading as it does to phthisis bulbi or to panophthalmitis.

Schüssele (*Klin. Monatsb. f. Augenh.,* July, 1909) has observed a case of chronic streptococcic septicemia with a mild metastatic inflammation in both eyes.

The patient was an army officer, 40 years of age, with a good family and personal history; he contracted articular rheumatism, which was followed by symptoms of cardiac weakness. Severe endocarditis with prolonged rise of temperature supervened upon repeated attacks of "rheumatism." A bacteriological examination of the blood revealed the presence in it of streptococci in large numbers. The patient ultimately succumbed to the disease.

During the course of these attacks there developed in another eye symptoms which were diagnosed as a mild "rheumatic" scleritis and iritis; they very soon yielded to treatment. When the patient subsequently came under the author's observation he suffered from repeated attacks of iritis or irido-cyclitis, varying from a very mild form to a severe inflammation with posterior synechiæ and occlusion of the pupil. Those attacks were further complicated by changes in the fundus similar to retinitis septica; these changes continued up to the death of the patient.

The clinical history of the case and the finding of streptococci in the blood prove conclusively that it was one of general septicemia characterized by relapses through the repeated invasion of the micro-organisms; and the condition in the eyes is a distinct metastasis.

A relatively large number of metastatic eye affections is due to staphylococcus infection. Morax (*Ann. d'Oculistique*, July, 1910) would recognize a special clinical picture for the staphylococcus infection, in that such is characterized essentially by relatively circumscribed lesions (intraocular or periocular abscesses) which either burst externally or become absorbed *in situ;* the evolution of the disease is peculiar, too, for it is not a rapid extension to the different intraocular structures of a suppurative process such as one gets with streptococcus or pneumococcus, but on the contrary its onset may be almost unnoticed, while its extension is slow and limited, some weeks generally elapsing between the first symptoms indicative of an ocular or periocular affection and the appearance on the surface of pus requiring removal.

The primary affection in this condition is often almost trifling, *e. g.*, wounds of the fingers, and whitlows, although pyelo-nephritis and uterine infection after retained placenta have been recorded as causes. In some of these cases the metastasis is visible ophthalmoscopically, but the diagnosis of staphylococcus is made on morphological grounds only. Holmes Spicer (*Medical Press*, Oct. 24, 1906) reported a number of such instances.

The first case was that of a young man who had a sudden attack of pain in one eye, with obliteration of the central part of the field of vision. He was in good general health, except for a large crop of boils on the buttocks. On examination of the eye three days after the attack of pain, a brilliant green mass was seen springing from the center of the disc; it was round, sharply-defined, and had no appearance of structure, such as hooklets. Its appearance suggested a parasitic cyst. It continued to grow, and was making the patient very ill. It was lacerated with a needle under ophthalmoscopic guidance, but it only contained some cloudy, opaque material like pus. The eye was enucleated. The swelling was found to be an abscess in the substance of the retina, having in its center a large mass of staphylococci. The patient made a rapid recovery in health.

The second case was also that of a young man, who had had a large boil on the neck, and was suddenly seized with pain in one eye, with loss of sight. He had well-marked phlebitis of the retinal arteries in one eye and slightly in the other. After prolonged treatment one eye got well, and the other became quiet with loss of sight. Two years later it became acutely inflamed and was then enucleated. Although very seriously ill at the time, he recovered promptly after removal of the eye, showing it to be the only part affected.

The third case was also that of a young man, who had retinal phlebitis, followed by local keratitis profunda after a serious attack of diarrhea and ptomaine poisoning.

The fourth case was one of diffuse exudation on the surface of the choroid, invading slowly nearly the whole of it and producing in places detachment of the retina. This also occurred in a young man suffering from a large crop of boils on the neck. Treatment by anti-staphylococcal injections was commenced, but he refused to continue it.

A case of metastatic choroido-retinitis resulting from an abscess of an upper bicuspid tooth, was reported by Greeves (*Trans. Ophth. Soc. Unit. King.*, Vol. 32, p. 135, 1912). The tooth was removed and the patient given an injection of stock staphylococcus vaccine (150 million). This injection was repeated weekly for three weeks, when an auto-vaccine was prepared from organisms obtained from a suppurating chalazion in the right upper lid *(Staphylococcus aureus)*. Injections of this auto-vaccine were first given weekly for three weeks, and then fortnightly for several weeks longer. The condition gradually improved until vision of 6/6 was obtained.

Blake (*Yale Med. Jour.*, June, 1911) reports the case of a young Italian woman of 23 years of age, whose previous confinements had been normal. The third delivery was on April 4, 1911, attended only by a midwife. On the ninth day phlegmasia alba dolens appeared and the right eye became greatly inflamed. Atropine and hot applications were ordered for the eye, and four days later the case was seen by the writer and a diagnosis of panophthalmitis made. The eye ruptured in about three weeks and a small amount of pus was evacuated. Smear preparations showed staphylococci and a few short chains of streptococci. The same organisms were found in culture. The infection was evidently not very virulent, as no more pus came from the eye, which gradually became quiet and moderately atrophic. The patient made a good recovery in all other respects.

Vogt (*Centralbl. f. Pkt. Augenheilk.*, May, 1911) reported the occurrence of an abscess in the lower portion of the sclera of a man, who for four months had been suffering from a furuncle of the right forearm and carbunculosis of the lumbar region. It commenced as a painful nodule of the size of a pea, 2 mm. below the cornea; the conjunctiva over it was reddened, the lower portion of the cornea and aqueous were slightly hazy and the pupil was adherent. Ulceration set in after five days, and a yellowish, puriform piece of tissue was excised, which under the microscope contained fibers of connective tissue, leukocytes and staphylococcus pyogenes. Episcleral affections and tenonitis are not of frequent occurrence. Tenonitis is characterized by painful progressive exophthalmos with chemosis and immobility of the globe, with the appearance after some weeks of pus beneath the bulbar conjunctiva near the muscle insertions. In staphylococcus infections grave general signs are usually absent, and the temperature may rise slowly to 38.5° C. or may resemble that of intermittent urinary fever, in one case the metastases taking place after four days of apyrexia. Usually there is less temperature than in streptococcus or in pneumococcus infections. The ocular or periocular involvement may be the first sign of a general infection, and this may occur as early as the seventh or as late as the twenty-fifth day after the original infection.

Among the cases of ocular metastasis occurring in association with a *bacillus coli* toxemia, Lawson (*Trans. Ophth. Soc. Unit. King.* XXXI, p. 27, 1911) reports one in which the local condition was that of an optic neuritis with exudate and hemorrhages. This condition disappeared simultaneously with the bacilluria under the use of helmitol. He presented a second case of a rheumatoid arthritis with secondary recurrent vesicular keratitis, which disappeared under the use of B. coli vaccine. Bentley (*Ophth. Record*, XX, p. 352, 1911) presented a case of an adult with a disseminated sclerosis and a colon bacillus pyelitis and cystitis. For the first few days, the eye condition seemed to be a simple severe case of iritis, but soon the picture changed and a low-grade panophthalmitis developed. On the ninth day, a hypopyon appeared and the anterior chamber was punctured, obtaining a small amount of yellowish pus. Scleral puncture was negative except that it was followed by a luxation of the lens which appeared underneath the conjunctiva. A culture of pure colon bacillus was grown from the pus. Gradually the eye became quiet and developed a phthisical condition. As there had never been an injury of any sort, Bentley calls the condition endogenous, or mestastatic.

Sidler-Huguenin (*Arch. f. Aug.*, 69, p. 346) reported 14 cases of metastatic gonorrheal ophthalmia: 5 cases of violent, 4 of slight monocular gonorrheic metastatic iridocyclitis, 3 of bilateral gonorrheic metastatic conjunctivitis, 2 of bilateral metastatic iridocyclitis, chorioretinitis and hyalitis of non-gonorrheic origin. Twelve patients with gonorrhea had before the ocular affection one or several gonorrheas. In 10 of these typical gonococci were found in the urethral secretions. Two were not examined for gonococci. The gonorrhea was in most cases complicated with cystitis, prostatitis, endometritis, salpingitis, effusions into the joints, etc., due to a general sepsis by gonococci. Particular importance must be attributed to the uro-genital apparatus, because of the fact that many patients who die after gonorrhea from metastatic endocarditis, pericarditis, myocarditis, pneumonia, pleurisy, meningitis, etc., show at the autopsy suppuration somewhere in the uroseptic organs. In 5 out of the 12 gonorrheic patients gonococci were found in the blood, whereas pure cultures of gonococci from the aqueous of 6 patients with violent iridocyclitis only once. This was probably due to technical difficulties. For growing gonococci from the blood or aqueous the gonococci must be obtained at the periods of highest temperature, as no gonococci seem to circulate in the blood during the afebrile period. In 5 mild acute cases of gonorrhea (4 with iridocyclitis, one with conjunctivitis) no gonococci could be found in the blood.

In the 12 cases gonorrhea was undoubtedly the cause. It is surmised that gonococci are transported through the circulation directly into the ciliary body and iris and with the effused blood and the aqueous into the anterior chamber. On the other hand, the gonococci themselves may not always enter the aqueous, but by their presence in the bloodvessels irritate the surrounding tissue. In other cases the gonococci seem to penetrate through the vascular wall into the tissue, where they increase and propagate. This was proven in the case of conjunctivitis, in which gonococci or at least Gram negative diplococci were found in a section of conjunctiva excised from the lower tarsal fold.

Sigler-Huguenin found within the last ten years 12 cases (9 with iridocyclitis and 3 with conjunctivitis) of endogenous gonorrheic ophthalmia out of about 65,000 patients, but considers the percentage higher, if more carefully searched for. From his proof of the existence of real gonorrheic metastatic iridocyclitis and conjunctivitis, he assumes a priori that other inflammations—keratitis, chorioretinitis, neuritis, scleritis, etc.—may occasionally be due to metastases by gonococci.

Metastatic conjunctivitis. Taking these endogenous diseases of the eye in their order, we find the commonest causes of this disease are the gonorrheal. See **Conjunctivitis, Metastatic.**

Davids (Graefe's *Archiv f. Ophth.*, Band LXXXVII, Heft. i., 1913), believes that many of the milder cases of the nature of metastatic conjunctivitis, more especially those infections that run a mild catarrhal course, are those that exhibit no or very few gonococci. Recently he met a case which demonstrated that the severe form of conjunctivitis with numerous cocci may occur as a metastatic affection.

In a cited case the metastatic gonorrhea at first produced a mild conjunctivitis in both eyes, then in one eye the organism reached the surface and caused a typical gonorrheal conjunctivitis, and later the same thing happened in the other eye in a milder form.

Two cases of *metastatic gonorrheal conjunctivitis* were described by Carroll (*Jour. Amer. Med. Assoc.*, July 13, 1907). Arthritis was conspicuous in the first case, the diagnosis in the second instance being based on the presence of gonorrheal urethritis, the type of bilateral conjunctivitis, the absence of gonococci in the conjunctival secretion, the iritis which appeared on the fifth day, and the slight but appreciable systemic disturbance.

This affection usually starts out with an ordinary purulent gonorrheal urethritis. Conjunctivitis appears rather early, but at times during a second or third attack involves mainly the fornix and ocular conjunctiva of both eyes, is associated with mucopurulent secretion containing no gonococci, generally with arthritis, and shows a marked tendency to relapse. An increase in the urethral discharge is often a forerunner of the fresh attack of blennorrhea and joint affection. Metastatic arthritis or iritis, bilateral involvement, mild blennorrhea without much swelling of the lids and with profuse discharge or tendency to corneal complications, and the absence of gonococci in the conjunctival secretions are the characteristic features.

All reported cases have occurred in men. Metastatic gonorrhea may affect the serous and mucous membranes throughout the body, notably those of the heart, pleura, lungs, pericardium, brain, veins, kidneys, and muscles, besides causing subcutaneous abscess, general septicemia, diseases of the peripheral and central nervous system, and lesions of the skin. In the eye we may have metastatic iritis, dacryoadenitis, tenonitis, keratitis, iridochoroiditis, retinitis, neuritis and panophthalmitis due to gonorrhea. The ocular affection may be due to bacilli or toxins transported in the blood current to a mixed or secondary infection in which the gonococcus merely prepares the soil. Early bacteriologic examination of conjunctival secretion, blood and fluid from any involved joints in cases of metastatic conjunctivitis might shed light on this subject.

Metastatic abscess of the episclera is an extremely rare condition, said to follow carbuncle, pyemia, cerebrospinal meningitis and general furunculosis.

A case of *metastatic gonorrheal keratitis* was reported by Posey (*Ophthalmic Record,* May, 1909). The patient, a man of 28 years, first suffered from some unknown corneal disturbance twelve years previously. The disease had been preceded by an attack of urethritis. During the succeeding twelve years he had a chronic urethral discharge, but no rheumatism. He had also had occasional ocular disturbances, but they were apparently not associated with increase of the urethral discharge.

The present attack was more in the nature of a vascular keratitis, the entire membrane being superficially hazy, the central portion more or less opaque and the seat of some six or eight small vesicles. A culture was made from the cornea and gonococci were found in it and also in the urethra. He was suffering at this time with a fresh outbreak of gonorrhea. Mulford's antigonococcic serum was administered in ½ to 1 cc. doses. The patient was in the hospital for about two months and was finally discharged with the eye and urethra healed.

Metastatic choroiditis. See, in particular, p. 2146, Vol. III of this *Encyclopedia;* also **Metastatic panophthalmitis,** here following.

Metastatic panophthalmitis. The course of this disease, so far as concerns the eye, depends upon the character of the infection, the origin of the metastatic emboli, and the degree of resistance of the tissues. For example, Dalmer (*Beiträge zur Augenh.,* Heft 87, 1914) describes the case of a woman who was admitted for cataract extraction, with the general history that for the past three years she had occasionally had febrile attacks attended with jaundice and vomiting, which as a rule lasted only a short time; there being no ocular contraindication, the left cataract was extracted without any mishap, and the after-course was normal, till at the end of a fortnight one of these gallstone attacks occurred. Ten days later she complained of pain in the right eye, and panophthalmitis rapidly supervened. The eye that had been operated on was perfectly normal. On the following day a paracentesis of the anterior chamber was performed on the right eye, and some bile-stained pus withdrawn which was found to contain abundant pneumococci. A week later the patient died. Post-mortem examination showed an impacted stone in the common bile duct, with marked cholangitis, and secondary abscess formation in the liver, from which abscesses the pneumococcus was grown.

Bilateral panophthalmitis developing during the course of a fatal pneumosepticopyemia was reported by Beauvieux and Lacoste (*Arch. d' Opht.*, XXXI, p. 727). The left eye became involved on the third day of the disease, the right eye on the fourth day, and death ensued on the eighth day.

Hansel (*Ann. of Ophthal.*, Jan., 1912) reports the case of a man, aged 46, who for two days had been suffering with inflammation of knees and ankles of both legs. In twenty-four hours the right eye became injected and he complained of failing vision.

He had had the usual diseases of childhood and had recovered from them without sequelæ. At the age of 36 he had specific urethritis, but denied syphilitic infection. He had used alcoholic liquors to excess during the past twenty years, and during the last two years has had several attacks of mania potu. During this time he had frequently suffered with rheumatic pains in the larger joints of the extremities.

The inflammation of the eye appeared to commence in the iris. The membrane rapidly thickened and exuded a filmy opaque material into the anterior chamber and pupil. The membrane of Descemet was covered with grayish deposit, and the cornea propria was infiltrated and opaque. The injection of the conjunctiva and cornea rapidly increased, tension became high and the eyeball sensitive to the touch. The eye became entirely blind and almost immobile. All the signs of a violent purulent panophthalmitis were present. The left eye remained unaffected. Pus obtained by puncture of the prepatellar bursa revealed myriads of streptococci. Blood culture also showed streptococci. The patient's condition became progressively worse and he succumbed at the end of the third day.

Postmortem examination showed chronic interstitial nephritis, small and hard liver, chronic mitral valvulitis and aortitis, engorged vessels of the dura mater and pia mater, and streptococci in the culture media made from clots removed from the anterior cerebral vessels.

Macroscopic examination of the eye: anterior and vitreous chambers filled with purulent material, distended and tortuous vessels in the sheath of the optic nerve, especially in a focus about one-half inch from the globe. Microscopic examination: diminution of the number of axis cylinders in the optic nerve, disintegration of the white substance of Schwan; choroidal vessels engorged, and some of them blocked and small, round cell infiltration between the blood vessels. No streptococci could be found.

A metastatic panophthalmitis following a *pelvic abscess* is described by Veasey (*Ann. of Ophth.*, XX, p. 84) in a patient who had suffered from a gonorrheal abscess of the pelvis about six weeks previous to the time of affection of the left eye, in the form of blindness, pain, and edema. At the time of examination only a slight conjunctival infection could be seen, but one centimeter to the temporal side of the limbus there was a hole in the sclera through which a probe could be passed into the eye proper. A purulent discharge poured out from this upon pressure. The eye was enucleated.

Another case is reported by C. C. Boyle (*Jour. Oph. Otol. and Laryn.*, June, 1915). Two weeks after confinement a pelvic abscess developed with septic temperature. The right eye became inflamed, with symptoms of irido-choroiditis. Examination of the blood showed a streptococcus infection. A stock vaccine was given, also a subconjunctival injection of 10 minims of 1-500 sol. cyanide of mercury. The pupillary exudate promptly cleared and the eyeball gradually whitened, but the vitreous remained hazy, the vision was reduced to hand movements and the eyeball was beginning to shrink.

Metastasis from the eye to the system in general. Finally, it must be remembered that there is, though rarely, a reverse current of metastatic infection, that poisonous material may be carried from a diseased focus in the eye to distant organs, and that tuberculosis, syphilis, etc., may be so transferred; also that malignant tumors of the eye may spread to the liver, kidneys, etc., through the lymph and blood channels. —(C. P. S.)

Metastasize. To form new foci of disease in a distant part by metastasis.

Metathalamus. The internal and external geniculate bodies.

Metcalf, John. A celebrated, blind, road-builder. He was born at Knaresborough, Yorkshire, Aug. 15, 1717. At the age of six he started to school, but, two years later, was totally blinded by smallpox. Nevertheless, when a few years older, he hunted, fished, boxed, played cards, and ran horse races. After a number of other occupations, tried and soon abandoned, he turned to road-making and bridge-building. In this capacity he is said to have distanced all competitors, building scores of bridges and hundreds of miles of roads. He married and had four children. He died in 1802, aged 85 years.—(T. H. S.)

Meter-angle. METERWINKEL (G.) (Nagel). In *physiologic optics,* the angle through which each eye turns when it abandons parallelism of the binocular lines of fixation in order to fix an object situated upon the median line one meter from the eye. It is the arc embraced between the median line and the line of fixation, whose length is one meter. For an invariable inter-pupillary distance Nagel demonstrated that the meter-angle is equal to the arc sin of half the inter-pupillary distance or base-line, b, divided by one meter, or arc sin b/C, when multiples of the meter-angle become dependent only upon the decreased lengths of the visual line, C, for all points of fixation or convergence nearer than one meter. Thus, if b is a constant made equal to 1, when C equals one meter, the corresponding convergence $c = 1/1 = 1$ ma.; or when $C = 1/x$ meter, the convergence $c = 1\frac{1}{x} = x$ ma. Values of the meter-angle in degrees, for inter-pupillary distance varying between 50 and 75 millimeters, were computed by Nagel, who selected the average of 64 millimeters in order to show that a substitution of the angle for its sine caused an error of only 1° for a distance of 6.66 centimeters from the eye, a limit rarely met with in practice. To express the meter-angle in prism-dioptries: "Read the subject's inter-pupillary distance in centimeters, when half of it will indicate the prism-dioptries required to substitute one meter-angle for each eye." (Prentice, *Archives of Ophthalmology,* Vol. XIX, No. 1, New York, 1890.) See, also, **Angle, Meter.**—(C. F. P.)

Meterwinkel. (G.) Meter angle.

Methaform. A proprietary preparation identical with chloretone.

Methanal. Formic aldehyd, a powerfully disinfectant gas, CHO, used as a disinfectant for rooms, clothing, etc. The (forty per cent.) aqueous solution, *formalin,* is a colorless, volatile fluid. See **Formaldehyde.**

Method, Crède's. The placing of a drop of 2 per cent. solution of silver nitrate in each eye of a newborn child, for the purpose of preventing ophthalmia neonatorum.

Method, Direct. In ophthalmoscopy, that in which the ophthalmoscope is held close to the eye examined and an erect virtual image is obtained of the fundus. See **Ophthalmoscope**; and **Examination of the eye.**

Method, Reclus'. The induction of local anesthesia by cocain.

Methods, Laboratory, in ophthalmology. See p. 6886, Vol. IX of this *Encyclopedia.*

Methods of ophthalmic examination. See **Examination of the eye.**

Methyl alcohol. WOOD ALCOHOL. See **Alcohol, Methyl;** as well as **Toxic amblyopia.** See, also, p. 2510, Vol. IV, and p. 3253, Vol. V, of this *Encyclopedia.*

Methyl aldehyde. See **Formaldehyde.**

Methylaminoalcohol. See **Suprarenin, Synthetic.**

Methylatropine bromide. ATROPINE METHYLBROMIDE. This mydriatic and cycloplegic agent occurs as white crystals soluble in water. It is recommended as an atropine substitute in 3 per cent. solution or 1 per cent. ointment. It has also been successfully used by Aronheim in conjunctival catarrh and corneal infiltrations. He thinks it is best combined in the following prescription. Methylatropin. brom., grm. 0.003; aquæ dest.; hydrarg ox. flav., āā grm. 0.2; lanolin, 10. Methylatropine bromide was introduced by Merck in 1902. It has advantages over atropine in that it is much less poisonous, while the mydriases and cycloplegia from a 2 to 3 per cent. solution set in as quickly and are as complete as that of a 1 per cent. atropia solution, but disappear much sooner. Darier uses it chiefly for ophthalmoscopic purposes and finds that a single drop of a half per cent. solution is quite sufficient to produce effective and transient dilation of the pupil with little or no paresis of accommodation. Winselmann uses a still weaker solution (0.25 per cent.) because he finds stronger doses occasionally cause ciliary paresis and mydriasis lasting 24 hours. The Editor much prefers to any of these agents a mixture of cocaine and euphthalmine.

D. Bruno (*Riforma Medica,* Vol. 22, 1906, No. 4) advises as a most powerful prescription in cases of iritis complicated with secondary glaucoma, the following: Atropin, methylbromid, 0.10 (gr. 1½); tropacocain., 0.05 (gr. ⅝); paranephrin (solut. 1: 1000), m. x; aquæ destil. steril., 10.0 (f. ℥ ⅓). One drop every morning, noon and evening.

Methylatropine nitrate. See **Eumydrin.**

Methyl-benzoyl-ecgonine. See **Cocaine.**

Methyl blue. See **Pykotanin.**

Methylene blue. METHYLTHIONINÆ HYDROCHLORIUM, U. S. P. METHYLTHIONINE HYDROCHLORIDE. This purified dye-stuff occurs as a dark-green, crystalline powder with a bronze luster. It is readily soluble in water, the solutions having a deep-blue color. It is a decided antiseptic and is occasionally used as a germicide in ophthalmic therapy. It should not be confused with methyl violet.

Dunbar Roy uses it as a saturated solution in water, in corneal ulcers and in mucopurulent conjunctivitis and has had more success with it in these diseases than with any other remedy.

Melville Black uses a two per cent. solution as a test for abrasions of the cornea and conjunctiva and for unhealed corneal ulcers. He considers it more effective and easier to use than fluorescein and unlike the latter agent, it undoubtedly has some therapeutic value.

Wiener (*Jour. Okla. State Med. Assn.*, v. 6, p. 248, 1912) has found the use of methylene blue powder almost invaluable in the treatment of all forms of infected, sloughing corneal ulcers. After cocainizing, he dusts some pure methylene blue powder in the eye, washing out with boric solution the superabundant stain. Only the denuded surface is deeply stained. A bandage is applied and the performance repeated daily until the hypopyon disappears and the ulcer is left clean and free from secretion. Atropin should be used in conjunction.

Methylene disalicylic acid iodide. See **Formidine.**

Methylenophil. Methylenophilous. Stainable with methylene-blue.

Methyl-ester. See **Sanoform.**

Methyl gallate. See **Gallicin.**

Methylguanidin. As with guanidin (see p. 5655, Vol. VII, of this *Encyclopedia*) this compound acts as a mydriatic and has exhibited this action on the pupils of animals.

Methylil. A proprietary local anesthetic: ethyl chlorid with small proportions of chloroform and methyl chlorid.

Methylthionine Hydrochloride. See **Methylene blue.**

Methylthioninæ hydrochlorium, U. S. See **Methylene blue.**

Methyl violet. See **Pykotanin.**

Methyl-violet reaction. See p. 6917, Vol. IX of this *Encyclopedia.*

Metre. See **Meter.**

Metrochrome. An instrument for the measurement of colors.

Metroscope. An instrument devised by Snellen to take the place of the ophthalmometer for making ophthalmostatometrical examinations and based on the same principle.

Metz, Abraham. A distinguished American ophthalmologist, born in Stark County, Ohio, in 1828. He lost his parents at a very early age, but, by teaching at a district school, he saved sufficient money for his medical education. His medical degree was received at the Cleveland Medical College in 1848. Thereupon he settled as family physician at Massilon, Ohio, but, turning his attention to ophthalmology, his practice was soon confined to that specialty alone. From 1864 until his death he was professor of ophthalmology in the Charity Hospital Medical College at Cleveland. He wrote a considerable number of journal articles, but his *magnum opus* was the once well known *Anatomy and Histology of the Human Eye* (Phila., 1868). Metz died Feb. 1, 1876.—(T. H. S.)

Meurtrissure. (F.) Contusion.

Meyer, Eduard. A distinguished Parisian ophthalmologist, author of the well known *Traité Pratique des Maladies des Yeux,* and for many years an editor of the *Révue Générale d'Ophtalmologie.* Born at Dessau, Nov. 13, 1838, he studied at Halle, Berlin and Paris, receiving his medical degree at Berlin in 1860. For the next three years he studied ophthalmology under A. von Graefe in Berlin, and in 1863 he settled in Paris, where he lived until his death, in 1902.

His most important ophthalmologic writings are: 1. *Du Strabisme et de son Traitemente* (Paris, 1863). 2. *Leçons sur la Réfraction et l'Accommodation* (Paris, 1869). 3. *Traité des Opérations qui se Pratiquent sur l'Oeil* (Paris, 1870). 4. Ueber die Affectionen des Uvealtractus in ihren Beziehungen zum Sexuellen Leben der Frau (*Gaz. des Hôpitaux,* 1877). 5. Contribution à l'Étude des Maladies du Nerf Optique de Cause Intra-Crânienne (*Révue Clin. d'Oculistique,* 1881). 6. La Valeur Thérapeut. de la Nevrotomie Optico-Ciliaire (*Jour. de Thérap.*, VII, 1882). 7. Das Sehen und der Blick (Virchow und v. Holtzendorffs *Populär-Wissenschaftliche Vorträge,* 1883, Nr. 402).—(T. H. S.)

Meyer, Nikolaus. Born at Bremen Dec. 29, 1775, he studied at Halle, Kiel, and Jena, receiving at the last-named institution his professional degree in 1800. He practised first at Bremen, later at Minden. He wrote but little, yet is very important ophthalmologically because he was the first to remove by means of the magnet a foreign body from the interior of the eye.

The history of the magnet operation on the eye before this celebrated performance by Meyer is, very briefly, as follows: The ancient Greeks knew of the lodestone, but employed it merely as an ingredient in eyesalves. The physicians of ancient India (as mentioned in the *Ayur Veda* of Susruta) made use of the attractive power of the magnet in general surgery, but not, it would seem, in ophthalmology. Susruta lived, probably, about the beginning of the Christian era.

Neither the mediæval Greeks nor the Saracens employed the magnet for its power of attracting certain kinds of foreign bodies, but only as an ingredient in salves.

The first employment in ophthalmology, or at least the first recorded description of such an operation, dates back only to 1462. This description occurs in a work by Hieronymous Brunschwyck, or Braunschweig (often called by English-speaking physicians, Brunswick), entitled *Dis ist das Buch der Cirugia, Hantwirkung der Wundartznei.* This work was composed in 1462, but not published till 1497. The passage in question runs as follows: "Ob es aber wer von eysen figelot (Feilicht) so sper das aug etwas auff unnd heb dar für ain magneten stain der Zëuhet das ansich." Fabricius Hildanus, in 1624, repeated the operation.

Until the time, however, of Nikolaus Meyer—the subject of this sketch—no one had attempted anything more than the mere removal of foreign bodies from the superficial layers of the cornea. Meyer removed a foreign body from the ocular interior. The passage in which this notable event is recorded occurs in the *Medicinische Zeitung, herausgegeben von dem Verein für Heilkunde in Preussen,* Vol. XI, 1842, No. 11, p. 50, and runs as follows: "I was called to the smith, G., into whose eye a glowing piece of steel had flown. The small, long piece had forced itself through the sclerotica and under the iris, and could not be seized. With the help of a magnet weighing over 30 pounds, we succeeded in drawing forth the foreign body. The very painful inflammation gave way to leeches and applications of cold water, after which aqua laurocerasi was added with great improvement." As will have been observed, we do not know whether the patient's vision was preserved or his eye saved.

For sake of completeness; we add that MacKeown, in 1874, first made an incision into the eye for the purpose of withdrawing from the ocular interior an attractable body by means of a magnet, and that Julius Hirschberg in 1875 invented the ocular electro-magnet. Meyer died in 1855.—(T. H. S.)

Meyer's rings. The indistinct circles observed around a candle flame against a dark background, caused by a diffraction of light by the cell elements of the cornea.

Meyer's theory of sympathetic ophthalmitis is that ciliary nerve irritation causes sympathetic ophthalmitis only if the second eye already contains microbes. If, however, the eye be normal it sets up only sympathetic irritation.

Meynert's commissure. A small commissure of white fibers imbedded in the gray matter behind the optic chiasm, separated from the latter and from the optic tracts by a layer of gray substance, and passing backward to penetrate the ventral surface of the cerebral peduncles.

Mezereon. *Daphne mezereum.* Spurge-olive or spurge-laurel was in ancient Greco-Roman times esteemed as a remedy for trichiasis, distichiasis, and corneal cicatrices. When employed for the corneal scars it was gathered just before sunrise, while the gatherer stated clearly the purpose he had in view. When used to prevent the return of eyelashes after epilation, it was mixed with frog's blood. Mezereon seems also to have had some reputation in veterinary ophthalmology. —(T. H. S.)

Mho. The sign of the unit of electric conductivity.

Mica spectacles. Spectacles made of mica, used as eye protectors.

Michael, Francis Morley. An American ophthalmologist of much promise, who died before that promise could be fulfilled, was surgeon to the Manhattan Eye and Ear Hospital, oculist to the Binghamton State Hospital and to the Binghamton City Hospital. He died in 1908, aged 38 years.—(T. H S.)

Michel, Charles Eugene. A famous ophthalmologist of St. Louis, Mo. Born May 9, 1832, at Charleston, S. C., son of John and Anna Faive

Charles Eugene Michel.

Michel, he received the degree of M. D. at the Medical College of the State of South Carolina, at Charleston, in 1857. A surgeon in the Confederate army throughout the Civil War, he was, at its close, a division medical inspector.

From the end of the war until his death, Michel practised, as ophthalmologist exclusively, at St. Louis, Mo. Here he was for many years professor of ophthalmology in the Missouri Medical College, and surgeon at the St. Louis Eye, Ear, Nose and Throat Infirmary. He was also for a time ophthalmic surgeon to the Martha Parsons Hospital for Children. He was the first to employ electrolysis in ophthalmology, and invented a number of instruments and operations. He was a skilful operator, and enjoyed an international reputation. He was also a clear and forceful writer and teacher.

He married in 1873, at St. Louis, Celeste Nidelet. C. E. Michel, Jr., of St. Louis, is their son.

Dr. Michel was a man of medium height, neither lean nor stout, who wore a mustache and French goatee, had a clear olive complexion and blue eyes, and, when the present writer knew him, hair that was absolutely white. His manner, as a rule, was very deliberate and quiet, but at times he was rapid in the extreme.

The present writer recalls no pleasanter scientific recreations than those he enjoyed on a number of occasions in the office of Dr. Michel—the whimsical, kindly, genial, yet withal stately and dignified gentleman, as well as thoroughly accomplished scientist. The comments of the doctor on his cases were, in fact, a novel and a work on science rolled together. Bacteriology, human nature, historical reminiscences, the keenest and carefullest diagnoses, outlines of plans of treatment, humorous instructions, ridiculous (but very valuable) rebukes, flowed on in one unceasing stream. A child there was, one day, who was so terribly frightened because of the mere presence of the doctor, that he seemed almost upon the point of real convulsions. Dr. Michel, however, with intuitive knowledge of childhood, screwed up a "funny eye," declared the child could not repeat that very difficult performance, then took hold of the child's lids in order to demonstrate precisely how easy it is to do certain things, if one only, exactly, precisely, knows how—to—do. And behold! another thing had been done too. And the patient was laughing!

The present writer is greatly indebted to Dr. Michel's son for the following account of his father's life: "From my earliest recollection, I associated my father with books, books of all description; in his reading room he always had a pile of medical works filled with book markers, and as I studied by his side, he would read and refer to these by the hour. When tired he usually did some light reading in French literature; this, he has many times told me, was a great rest. He was a surgeon with rank of major in the Confederate Army, and would never by any chance read a novel, regardless of its merits, that in any way referred to the civil war, stating that the recollection of those times was painful to him, and that he preferred to dwell only on pleasant subjects.

"He was an indefatigable worker with the microscope. Up to about his seventieth year his chief enjoyment was the preparation of specimen slides for his classes, and I have been informed by many doctors, among others Dr. Terry, that his collection of slides was very remarkable. There were hundreds of them, that I know from personal knowledge, took him several hours a day over a period of many years to prepare.

"His physical recreation during the summer months consisted of early morning rambles in the large rose garden, which he had on his summer place at Normandy, Mo. Here he had a collection of roses and fruit trees gathered from all over the world, and before leaving for the city and his office, each morning, he would spend from one to two hours collecting the choicest of the blooms and fruit.

"During the winter months one night each week he played billiards with his club mates. Each week saw the same faces around the table at the same hour: Doctors Gervais Robinson, Hardaway, Steer, Spencer, Steele and Glasgow. I cherish the memory of the few evenings I was permitted to spend in the company of these altogether delightful and intellectual gentlemen.

"My father was a keen sportsman; here was by long odds his chief recreation in life; normally a thorough man when it came to his hunting equipment, it reflected the careful, mature thought of a master and was complete to the minutest detail and of the best the world afforded. Among his guns were arms made to his specifications by such world renowned makers as Purdy, Westley-Richards and Bradell. In his kennel, it was nothing unusual to see from twenty-five to thirty-five of the bluest-blooded English pointer pups being developed under his knowing eye, so that one or at most two could be shipped to such men as Nesbit or Stafford for training.

"A part of each fall he spent in the north woods shooting and fishing to a certain extent, but most of his hours were put in reading in some quiet spot; he loved and understood nature as but few. His personal friends in the profession twitted him in a mild manner from time to time on his extravagances and excessive accuracy in all things pertaining to his out-door sport; at such time, his nimble mind quickly framed grave, good natured answers that amused but never hurt."

Dr. Michel died at St. Louis, Mo., Sept. 29, 1913, and the writer will always remember the pang with which he learned of the demise of this gentle, dignified and skilful father in ophthalmology. A thousand skilful oculists may come and go, but none will ever exactly fill the place which he left vacant. May the unique personality and great services of Charles Eugene Michel be permanently remembered.—(T. H. S.)

Michelia champaca. Champak. A magnoliaceous tree of India and

Indo-China. Its highly fragrant flowers are used for headache and in various ocular diseases.

Michelia, Rheedii. A species identified by Hooker with *michelia champaca*. The flowers of the variety found in India (where it is considered entirely distinct from *michelia champaca*), when boiled in oil, are used in headache and in affections of the eyes.

Michel, Julius von. A celebrated German ophthalmologist. Born July 5, 1843, at Frankenthal in the Palatinate, he studied at Zürich and Würzburg, at the latter institution receiving his degree in 1866. He accompanied the military expeditions of 1866 and 1870 in his medical capacity. From 1868 till 1870 he was assistant to Horner at the Zürich University Eye Clinic. In 1871 he studied histology under Schwalbe in the Ludwig Physiological Institute. The following year he became privatdocent for ophthalmology at Leipsic, and in 1873 removed to Erlangen to accept the extraordinary professorship of ophthalmology at that university. The following year he reached the full professorship—a position which he held till 1879. In that year he became professor of ophthalmology at Würzburg, and, in 1900, removed to Berlin, where he filled the corresponding chair in that city. Together with H. Kuhnt, he founded the *Zeitschrift für Augenheilkunde*. He wrote the division on diseases of the lids in the Graefe-Saemisch *Handbuch*, as well as (among other independent works) *Klinische Leitfaden der Augenheilkunde* (2d ed., Wiesbaden, 1897) and *Lehrbuch der Augenheilkunde* (*Ibid.*, 1890). After a long illness, he died, Sept. 28, 1911, aged 68.—(T. H. S.)

Michel's test for ocular malingering. This is one of the numerous modifications of Arlt's test. See **Blindness, Simulated, Michel's test for.**

Michelson's interferometer. See **Interferometer,** p. 6532, Vol. IX of this *Encyclopedia*.

Micranatomy. Microscopic anatomy.

Micro-. A prefix signifying small, short or less than the average.

Microactinic. Pertaining to the operation of actinism; short in duration or feeble in intensity.

Microbe. Any individual microörganism; a microphyte or microzoön: chiefly used as a synonym of vegetable microörganism.

Microbicide. An agent that destroys microbes; destructive to microbes.

Microbicidin. Sodium betanaphtholate: an external antiseptic; internally an antiseptic and antipyretic; administered in a 3 per cent. solution.

Microbiohemia. A diseased condition resulting from the presence of microbes in the blood.

Microblepharia. Partial ablepharia in which the lids are rudimentary and only partially surround the orbital opening.

Microblepharon. Partial absence of the lids (usually congenital). See **Ablepharia**; as well as **Congenital anomalies.**

Microblephary. (Obs.) Unusual smallness or shortening of the eyelids.

Microcidin. Sodium betanaphtholate: an external antiseptic: internally an antiseptic and antipyretic; administered in a 3 per cent. solution.

Micrococcus. A minute bacterial coccus. See **Bacteriology of the eye.**

Micrococcus botryogenus (Rabe). See **Botryomycosis of the eyelids.**

Microcoria. An old term for meiosis.

Microcornea. The small cornea found in all cases of microphthalmia. See p. 2815, Vol. IV, of this *Encyclopedia.*

Microgram. One-millionth part of a gram; a photograph of a microscopic object.

Micrograph. An instrument for recording extremely minute movements. It acts by making a greatly magnified record on a photographic film of the minute motions of a diaphragm.

Microkinematography. This is an application of the kinematograph to the representation of objects as seen through high powers of the microscope. In the usual microscopic preparations the greater the magnification the less the illumination becomes, and it is only by artificially increasing the contrast by means of stains and other devices that clear differentiation is obtained. The problem which has been so ingeniously solved is to take in one minute some thousands of successive photographs of a living and moving unstained object, magnified 600 or 1000 times.

Although the resulting pictures show but little of the internal structure of the object under examination, there is no doubt as to their great value, especially in teaching biological and medical subjects. Thus, the nucleus of a cell can be made to appear quite distinctly, and the ameboid movements of a leucocyte may be shown, the heart may be seen beating, and a spirillum wriggling its way between the corpuscles. Again, many movements in nature occur too rapidly for the eye and brain to follow them properly, or analyze them. By reproducing at a slower pace the changes which do occur, the kinematograph can assist the scientist in his efforts to discover the real nature of the movements. Conversely, when the processes or changes are slow, as in the growth of a plant, a succession of photographs taken at intervals and passed rapidly in review shows in a few minutes what actually took hours or days. The sequence of the phenomena then becomes more apparent, and a clearer perception as to their character is attained.—*(Standard Encyclopedia.)*

Micromegalopsia. The condition in which objects appear too small or too large, or too small and too large by turns.

Micrometer. This is an instrument used in astronomy for the measurement of very small arcs in the field of a telescope, and in making very small linear measurements in other departments of physics. It is also a name sometimes given to a device for determining the size of intraocular organs and objects.

Micrometer ocular. An ocular which is connected with a micrometer for the purpose of measuring the real image.

Micromicron. In microscopy, the thousandth part of a micron, represented by the symbol $\mu\mu$.

Micromillimeter. In microscopy, the one-millionth part of a meter or one-thousandth part of a millimeter; a micron (q. v.). It is usually represented by the Greek letter μ.

Micromyces. A genus of schizomycetes in the form of slim, elongated filaments inclosed in a sheath.

Micron. In microscopy, the one-millionth part of a meter or one-thousandth part of a millimeter; a micromillimeter. It is usually represented by the Greek letter μ.

Micro-ophthalmoscope. This term originated with Wolff (*Zeitschr. f. Augenheilk.*, Oct., 1912; abstract in the *Ophthalmoscope,* Sept., 1914), who utilizes the catoptric principle instead of the more usual dioptric method. The light is reflected into the eye by a small mirror which utilizes half the pupil, and reflects light from an obliquely-placed optical system. The other half of the pupil is used to observe the interior and exterior of the eye by means of a system of lenses which act as a microscope. In this way the various reflexes are not received by the microscope, which gives a highly magnified image of the object. With a similar instrument Wolff has obtained photographs of the fundus of his own eye. The whole field is sharply defined and the smallest details of the retina can be made out, details which are only partially seen with the ordinary direct vision ophthalmoscope. The normal pulse of the retinal arteries is perfectly visible. A stereoscopic ocular may be employed and it affords a stereoscopic picture of the retina which is of great value. The instrument is equally available for the examination of the vitreous, the lens, and the cornea —in fact, it may be used as a corneal microscope. If it is adjusted so that it transmits light through the retina, it shows up small tumors which are invisible by any other method.

Microörganisms of the eye. See **Bacteriology of the eye.**

Microphakia. Abnormally small crystalline lens. See p. 2879, Vol. IV of this *Encyclopedia.*

Microphotograph. A microscopic photograph of a macroscopic object.

Microphthalmia. MICROPHTHALMOS. Small-eyedness. This abnormal condition is generally congenital, the subject being fully treated on p. 2815, Vol. IV, of this *Encyclopedia.*

Micropia. MICROPSIA. A condition in which objects seem to be smaller than they really are.

Micropolariscope. A microscope with polariscope attachment.

Micropsia. MICROPIA. A pathological condition of the eyes in which objects appear abnormally small.

Micropy. Old name for *micropia,* a state of vision in which objects appear smaller than natural.

Microscope. This instrument enables one to examine objects which are so small as to be almost or quite undiscernible by the unaided eye. Its early history is obscure; but it is generally believed that the first compound microscope was made by Zacharias Jansen, a Dutchman, in the year 1590, and was exhibited to James I, in London, by his astronomer, Cornelius Drebbel, in 1619. It was then a very imperfect instrument, and it was not until the invention of the achromatic lens, a century later, that it reached the advanced position it now occupies among scientific instruments.

The magnification is independent of the eye, and is the relation between the size of the image and that of the object.

So large a pencil of light passing through a single lens would be much distorted by its spherical figure, and by the chromatic dispersion of the glass. This is partly rectified by applying a stop to the lens, so as to allow only the central portion of the pencil to pass. But, while such a limited pencil would represent correctly the form and color of the object, so small a pencil of light is generally unable to illuminate the whole of the magnified picture with any adequate degree of brilliancy. Wollaston overcame this difficulty by constructing a doublet, which consists of two plano-convex lenses, having their focal lengths in the proportion of 1 to 3, and placed at a distance best ascertained by experiment. Their plane sides are placed towards the object, and the lens of shortest focal length next the object. By this arrangement the distortion caused by the first lens is corrected by the second, and a well-defined and illuminated image is seen. Further improvement has been effected by substituting two lenses for the first in the doublet, and so making a triplet.

Simple microscope. By this term we mean an instrument by means of which we view the object through the lens directly. These instruments may be divided into two classes—those simply used in the hand

(and often called magnifying glasses), and those provided with a stand or frame, capable of being adjusted by means of a screw to the exact focal distance. The single lens used may be either a bi-convex or a plano-convex. When a higher power is wanted a doublet, such as we have already described, may be employed.

Compound microscope. In the compound microscope, in its simplest form, an inverted real image or picture of the object is formed by one lens or set of lenses, and that image is looked at through another lens. The compound microscope consists of two lenses, an object lens or objective, placed next the object, and an eye-lens, or ocular, placed next the eye. The objective is generally made of two or three achromatic lenses, while the eye-piece generally consists of two plano-convex lenses, with their flat faces next the eye, and a diphragm, or stop, between them. Lenses of high power are so small as to admit only a very small beam of light, and consequently produce deficient illumination. Various devices have been employed to overcome this difficulty. The light may be concentrated by achromatic condensers placed beneath the stage, or a lens with large angle of aperture may be employed. Recently lenses, termed "immersion lenses," have been constructed, of such a curvature that when immersed in a drop of liquid placed over the object light is admitted on all sides.

A mirror is placed under the stage for reflecting the light through the object under observation, when the object is transparent. When opaque, light is reflected on the object by a bull's-eye lens, called a condenser. The best instruments are supplied with six or seven object-glasses, varying in magnifying power from 20 to 2500 diameters. The eye-pieces supplied are three in number. As the magnifying power of a compound microscope depends on the product of the magnifying powers of the object-glass and the eye-piece, it follows that its power may be increased or diminished by a change in either or both of these glasses. In the mechanical arrangements it is of importance to have the instrument so constructed that, while every facility is afforded for observation and easy adjustment, there should also be great steadiness. In the binocular microscope one object-glass and a double eye-piece permit both eyes to be used at once in observation, the rays being divided by a prism.—(*Standard Encyclopedia.*) See, also, **Laboratory technique**; as well as **Microscopy.**

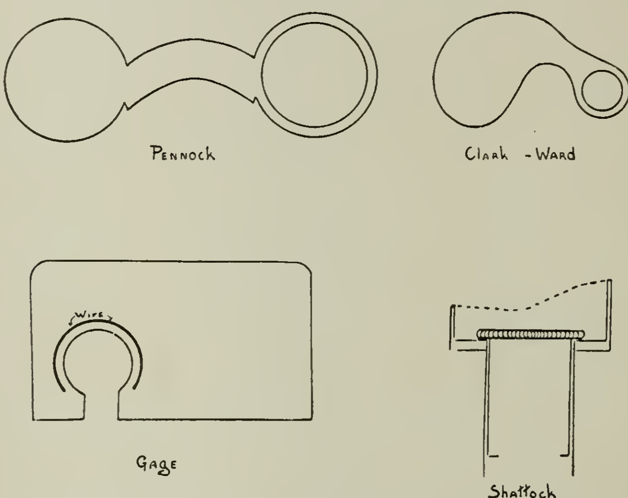
Microscope à préparer. (F.) Dissecting microscope.

Microscope, Corneal. See p. 3386, Vol. V, as well as p. 2771, Vol. IV and under **Examination of the eye,** on p. 4610, Vol. VI of this *Encyclopedia.*

Microscopical anatomy of the eyeball. See **Histology of the eye.**

Microscopic examination of the eye. See **Laboratory technique,** p. 6886, Vol. IX, of this *Encyclopedia.*

Microscopy. MICROSCOPICAL EXAMINATION OF THE OCULAR TISSUES. The use of magnifying lenses and the various microscopes in examining the histologic details of ocular tissues in health and disease is governed by much the same rules as obtain in general histomicroscopy; and it is not necessary to argue that the educated ophthalmologist should have an average knowledge of *all* medical laboratory processes. A practical acquaintance with these methods can be acquired only in a properly equipped laboratory under the direction of a trained

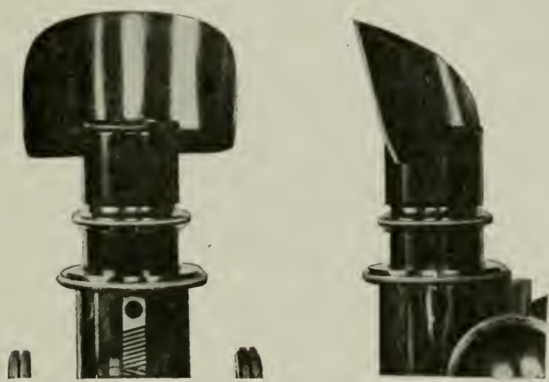


Forms of Eye-shade for Microscope by Various Designers.

teacher; it certainly cannot be had from books alone. Moreover, there are (see **Laboratory technique**) many methods of examining and preserving the ocular tissues that form a study apart from the usual laboratory courses. While these are especially considered under various captions in this *Encyclopedia,* the reader is strongly advised to adopt as a text-book for his investigations such complete laboratory manuals as Greeff's *Guide to the Microscopic Examination of the Eye,* especially as translated and amended by Hugh Walker. A few observations are here appended on the particular ophthalmic relations of the microscope.

Ellis Keller (*Jour. Am. Med. Assoc'n,* April 1, 1916), speaking of the *Care of the Eyes in Microscopic Work,* says that in earlier times, when lenses and illumination were less perfect than at present, eye-shades of varying construction were in common use. These usually were intended to afford a blank surface to shield the unused eye, and consisted of a flat piece of board, fiber, or metal with a perforation at one side to admit the drawtube which supported the shade. Such shades have been designed by Gage, Ward, Pennock, Clark and others.

Laboratories are now constructed with large windows which permit an abundance of light to flood the microscopic table. When one is working before such a window the diffused light tends to render less distinct the image seen in the microscope, and very fine details may be entirely obliterated. Any device which will exclude the light entering the eye above the ocular is of distinct advantage. The image will become more sharp and, what is just as important, eyestrain is dimin-



E. Kellert's Eye-Shade for Microscopic Work.

ished. A simple test will readily demonstrate the truth of this statement.

The shade herein described consists of a short piece of tubing of diameter large enough to fit over the upper end of the draw tube. This tubing measures 2 cm. in height and is lined with felt or other soft material to prevent scratching of the lacquer. To the front of the tubing and slanting forward at a slight angle is a thin plate 8 cm. in width and 4 cm. in height. This is bent laterally so as to cup about the eye, and can be made to fit more snugly by cutting down a trifle the nasal side of the shade. It is made of aluminum with a dull black finish. The illustration affords a better idea of the construction of the shade than will a description.

The state of the accommodation while using the microscope has been studied by Brocher and Doret (*Ann. d'Ocul.*, CXLVI, p. 463, 1911). They reflected the image of a distant object, and that obtained by the microscope into the two eyes with mirrors; and ascertained if both could be seen clearly at the same time. They find some persons use the microscope without accommodation. These experience no fatigue. They are mostly persons accustomed to its use. Others accommodate up to as much as 3 D. Microscopy tires their eyes. These are generally beginners, or occasional users of the instrument. Those who must use the microscope much should learn the former method. When one who accommodates has to draw what is seen in the microscope, the adjustment of the paper to the proper distance from his eye will help.

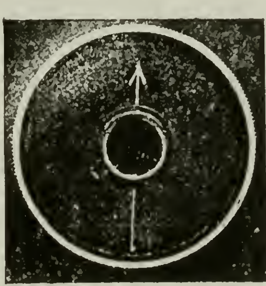
Pignatari (*Rivista Ital. di Ottalmol.*, Aug., 1911) says that Gallenga had from the first noticed a decided difference in the appearance of microscopic objects according as to whether he observed them with the right eye or the left, not only in respect to the clearness of outline, but also in the luminosity and distinctness of the color, although the acuity of vision and the refraction were the same for the two eyes.

Pignatari has made many experiments on this point, and has found it constant that he sees color better with the left eye than the right, while form is better seen with the right eye. He then examined the vision of others, and obtained for the most part similar results. To interpret this diverse sensation between the eyes, an experiment made by Gallenga must be taken into consideration: he interposed, at the moment when the right eye was exchanged at the microscope for the left, a glass colored with cobalt between the reflector and the object. He noticed that the left eye then saw details more clearly, but color less clearly, than before.

The explanation given by Pignatari is that the two eyes have a different sense of luminosity; with excessive illumination, the left eye becomes exhausted sooner than the right, and therefore colors appear to it less saturated, brighter, and mixed with a greater quantity of white light.

The correction of errors of refraction for microscope work. Leishman (*British Med. Journ.*, p. 123, Jan. 20, 1913) believes that the eyestrain which not infrequently results from prolonged use of the microscope, especially when working with high powers and artificial light, is often so great as to cause considerable discomfort and headache, and may even lead to the abandonment of microscope work, except for brief examinations. In many cases this trouble is caused by errors of refraction, more particularly by some degree of astigmatism. If this astigmatism is considerable, the microscopist is practically certain, in these days, to be aware of it, and to possess glasses which correct his particular error, but if it is small it may never be detected until advancing years lead him to consult an oculist as to his first pair of presbyopic glasses. In either case, when he attempts to work at his microscope with spectacles or pince-nez in situ, he is certain to find them so uncomfortable and inconvenient that, sooner or later, he discards them, and trusts once more to his unaided vision and his powers of accommodation, with the frequent result that continuous work becomes increasingly difficult and the effects of eyestrain more conspicuous.

The small device here illustrated has been designed with a view to correcting the error of refraction without employing spectacles. It is so obvious and simple that it is very probable that something similar may have been described and used long ere this, but, since the writer has been unable to discover that this is the case, it appears worth while, for the sake of others similarly situated, to describe the ocular cap which he has had made for his own use. The increased definition which has resulted from the use of this cap is unmistakable,



Attachment for the Microscope to Correct Refractive Errors. (Leishman.)

and there has also been a marked lessening of the feeling of strain which used to result from long hours of high-power work.

No lengthy description is needed, the principle being merely that the lens necessary to correct the error of refraction of the eye commonly used is fitted accurately into the center of an aluminum carrier, so constructed as to form a cap which may be placed over the microscope ocular. In the case of a lens with cylindrical correction for astigmatic error the vertical meridian is permanently marked on the carrier by means of an arrow, as shown in the illustration. As most workers employ oculars of the same make, the external diameter of which is approximately the same, the cap may be made to fit them all by arranging to have the internal diameter adjusted to fit the largest ocular used. The photograph has been taken from the cap made to the author's design by Messrs. Cary and Co., 7, Pall Mall, London, England.

Microseme. An orbit whose index is less than 84.

Microslide. The slide on which objects for microscopic examination are mounted.

Microspectroscope. A combined microscope and spectroscope.

Microsporon trachomatosum. The name given by Muttermilch to the supposed (fungoid) organism that produces trachoma.

Microstat. The stage and finder of a microscope.

Microtome. An instrument for cutting microsections.

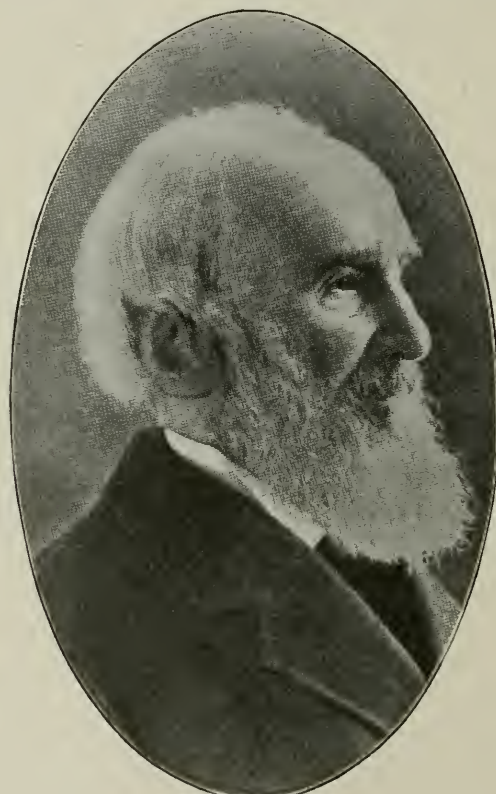
Microvolt. One-millionth part of a volt.

Microzoön. Any microscopic animal organism.

Microzyme. One of numerous particles existing in the protoplasm and regarded by some as living microbes capable of causing fermentation.

Mid-angle lens. A lens whose focus is intermediate between that of a wide-angle lens and a long focus one.

Middlemore, Richard. A celebrated ophthalmologist of Birmingham, England, renowned especially for his lectures on the eye and for his



Richard Middlemore.

numerous benefactions to ophthalmic institutions, etc. Born Oct. 12, 1804, he studied at St. Bartholomew's Hospital, London, chiefly with Laurence, Vincent and Abernethy, and finally removed to Birmingham. Here he was a student of Hodgson's for about three years, and then, for ten, his assistant. He settled in Birmingham, where he practised until 1879, and continued to reside until his death. He never, even in his private practice, entirely relinquished general medicine and surgery, though ophthalmology engrossed the greater part of his attention. In 1877 he founded a prize in ophthalmology, awarded triennially by the British Medical Association; in 1888 he gave £1,000 "to endow a course of lectures in ophthalmology at the Birmingham and Midland Eye Hospital, and another of £2,000 to the Birmingham Asylum for the Blind." He died March 1, 1896.

A person who was well acquainted with Richard Middlemore has written of him as follows: "Throughout the whole of his life his earnest love for and devotion to his profession, and his generous unostentatious sympathy, endeared him to those associated with him. Conscientious in his relations with his professional brethren, modest, never seeking notoriety, simple, kind, generous, sensitive to a fault, always maintaining a high standard of professional life, he has furnished his survivors an example which we shall do well to follow. Of him and his teaching it may well be said, '*Memoria bene redditæ vitæ sempiterna.*' " Middlemore's most important writings are as follows: 1. *A Treatise on the Diseases of the Eye and its Appendages.* (2 vols., London, 1835. 2d ed., London, 1839. The most important English work on ophthalmology till that of Wharton Jones.) 2. *On the Treatment of Certain Injuries of the Eye, occurring in Infants and Young Persons.* (London, 1840.)—(T. H. S.)

Midollo spinale. (It.) Spinal cord.

Midperiphery. A name for the middle zone of the retina.

Midwife in ophthalmology. Although there is a fallacy in the array of statistics sometimes quoted to prove that the ignorance of midwives is not responsible for as many cases of eye disease, especially of *ophthalmia neonatorum,* as are general practitioners, yet there is no question but that, in this country at least, there is not a universal compliance with the well-known prophylactic rules set forth on p. 1148, Vol. II, and elsewhere in this *Encylclopedia.*

In this connection E. M. Alger (*Medical Times,* Nov., 1914) has shown that many more cases of ophthalmia neonatorum appear in cases that were attended by physicians than in those attended by midwives. One reason may be that the midwife is more likely to employ prophylaxis as a part of the routine, while the physician who has been permitted to use his own intelligence and who believes ophthalmia neonatorum is only of gonorrheal origin does not use a prophylactic where he feels certain no such infection exists. The writer gives statistics, some placing the gonococcus as present in 64 per cent. of cases of ophthalmia neonatorum, others as low as 20 per cent. or 30 per cent. He also calls attention to the fact that ophthalmia neonatorum is ordinarily a comparatively mild affection, the mother having acquired a systemic immunity to the gonococcus or other pyogenic organism which she has harbored and which the child during its intra-uterine life has acquired. The author warns against too severe measures being used in treatment, believing that more eyes are lost through the violence of the disease itself, since the great danger is ulceration of the cornea from traumatism. He believes the watchwords should be cleanliness, drainage and gentleness, and he believes that many cases can be treated as well at home as in the hospital, and that since the nutrition of the child is all important, it should not be separated from its mother.

Migrainator. An instrument for the relief of migraine by compressing the head.

Migraine, Ocular relations of. HEMICRANIA. SICK HEADACHE. MEGRIM. SCINTILLATING SCOTOMA. AMAUROSIS PARTIALIS FUGAX. This section should be read in conjunction with **Headache, Ocular,** p. 5709, Vol. VIII of this *Encyclopedia.*

Migraine is a distinctive type of headache or head pain, the origin of which remains very obscure. It occurs most frequently in persons of a neuropathic constitution and is acquired by direct inheritance. Migrainous attacks, although variable, are, as a rule, sudden in onset, paroxysmal, self-limited, irregularly recurrent and in the majority of cases are further characterized by unilateral headache, nausea, vomiting and visual phenomena. The ocular symptoms assume such special prominence in this neurosis that to one group revealing purely sensory visual anomalies the term *ophthalmic migraine* has been applied, and for the other, presenting oculomotor paralyses (a purely motor type), the appellation *ophthalmoplegic migraine* has been suggested. In the one form (ophthalmic) a sensory nerve, the optic, is mainly involved, and in the other, the oculomotor, and more rarely the trochlear and abducens is affected, but it is not at all uncommon for these varieties to merge. Still another clinical distinction prevails, called *psychical migraine,* in which mental symptoms predominate.

The visual signs in ophthalmic migraine include, according to Lloyd, "1. Amblyopia. 2. Scintillations. 3. Scotoma. 4. Hallucinations." The ocular signs in the ophthalmoplegic type are in the great majority of cases confined to the third nerve, the paralysis of which is usually complete, but variable in duration from a few days to several months. It is held to be due to some basal lesion, in many cases probably to a rheumatic periostitis of the orbital fissure.

An attack of migraine is characterized by the development of a blind area usually to one side of the center of the field of vision. As described by Weeks, the area is irregular in shape, its outline being often defective or broken on one side. The borders of the line or the defect may be broad and composed of changing prismatic colors (*scintillating* or *spectrum* scotoma). The limiting border is often zigzag. It may assume the shape of the angles of a redoubt (*fortification* scotoma). This limiting border of the scotoma is convex outward. It may remain quite small, but usually gradually extends upward and toward the side on which it started, sometimes assuming the hemianopic type. The dimness of vision extends throughout the area surrounded by the limiting border lines, but is most intense just within the border, fading out at the defective side of the area. The play of colors may assume various shapes and invade the field differently. The spectrum may be progressive rather than expansive, may travel throughout part of the periphery of the field, usually only on one side. The blind area may be outside of the spectrum. The spectrum may be stellate in form and gradually work across the field much like a comet. It may be zigzag and progress radially. It may form an arch. While the blind area is more often to the side of the fixation point it may involve the center of the field and expand to include almost the entire field. In some cases a scintillating spectrum border at the periphery of the field only remains. The scotoma passes off gradually in from five to thirty minutes, fading first from the part of the field first affected, with perfect restoration of vision. In some individuals the attacks are periodical; in others, very irregular. There is often a marked difference in degree of severity in the different attacks in the same individual. The attacks of migraine become less frequent or less violent after 45, until they generally disappear with advancing years. The phenomenon is generally due, in all probability, to disturbance in the cerebral cortical circulation, affecting the side opposite that to which the scotoma is referred. If the scotoma affects both sides, both cortical visual areas are involved. The attacks of this disease have certain clinical affiliations with epilepsy, but are not to be regarded as indicative of disease of the eye, although ocular disturbances form an important part of the symptom-complex. Hubbell believes that these affections are two distinct forms of neurosis, and doubts that a genuine transformation of one into the other ever takes place, although Gowers, Charcot and others claim that they are related. and Spiller has recently reported 2 cases in which he finds a connecting link in transitory paresis, paresthesia and disturbances of speech. These supposed "connecting link symptoms" are not essential to true epilepsy, and not necessarily forerunners or concomitants of it. The great disproportion in frequency between the 2 neuroses also speaks against this theory. Migraine is common, epilepsy rare; and while transitory paresis and paresthesia are frequently noted in the former, there are thousands in whom these symptoms never develop into epilepsy and in whom there is no family history of the disease. The two affections may, of course, occur in the same individual, but the attacks are entirely separate and independent. The clinical picture may be modified, both as to migraine and to epilepsy, by the association, but this proves neither kinship nor transformation. Of late years Gowers seems to have come to a similar conclusion.

Attacks of this disease are not infrequent among physicians and other brain-workers. Dufour (*Ophthalmoscope*, July, 1913) reports on his own attacks, and says he could determine when the scintillating scotomata were unilateral and when bilateral. He found little relief from remedies. Pichler (*Wien. Kl. Woch.*, Jan. 12, 1911), who is himself subject to such attacks, reports a study of 53 cases of scintillating scotoma. In most of the patients he found hereditary predisposition. In 39 there was pronounced neurasthenia; and in almost the same proportion the attack was noticed to follow close use of the eyes. The partial blindness cannot be influenced by treatment. But by lying down and taking a sedative as soon as the visual disturbance is noticed, the headache may be lessened or the attack cut short. Zentmayer (*Ann. of Ophth.*, XXI, p. 279, 1911) reports a case of migraine with ring scotoma, in which two of the early attacks were preceded by the appearance in each temporal field of a slowly revolving wheel with flashing spokes. The blindness was never absolute. Tested in the interval between the attacks the field presented at one time a ring scotoma, complete in the right eye, hemianopic in the left, and lying between the periphery of the field for red and the limit for form. Five days later the ring scotoma was similarly situated but confined to the temporal half of each field. In some attacks the defect had been a homonymous hemianopsia.

Ormond (*Lancet*, May 10, 1912) reports two cases of permanent homonymous hemianopsia following severe attacks of migraine in young adults. The first patient, a woman 33 years of age, had for more than ten years been subject to attacks of migraine. After an unusually severe spell lasting three or four days, she noticed that she could not see anything on her right side. There was a right homonymous hemianopsia. The second patient, a woman of 32 years, had been subject to bilious attacks for many years. After a headache followed by sickness, she found herself unable to see on her left side. In each case central vision was normal, but the hemianopsia was otherwise complete in both eyes. In each case the general condition of the patient was normal. The writer concludes that the most probable explanation of these disturbances is that a spasm of the corresponding branch of the posterior cerebral artery produced permanent changes in the visual center. Filehne (*Deutsch. Arch. f. Klin. Med.*, V. 112, p. 190, 1912) offers a more or less mathematical explanation of the possible anatomic origin of flicker scotoma.

Pöllot (*Klin. Monatsbl. f. Augenh.*, Dec., 1913) mentions the case of a woman 52 years of age, who complained of scintillating scotoma, which at first was quite definitely confined to the left eye, but appeared later in both. She had repeated attacks of about half an hour's duration day after day, and sometimes several times in one day. These attacks were followed by some giddiness, but there was no headache. She gave, at the same time, a history of "dead fingers" occurring on exposure to the slightest cold, a tendency that had been present since childhood. She suffered from pulmonary tuberculosis, and the blood-pressure was abnormally high. An inquiry into the family history showed that in two preceding generations and one succeeding generation there was frequent occurrence of "dead fingers," scintillating scotoma, pathological blushing, cyanosis of the face and hands, "heart disease," and arterio-sclerosis. This, in the author's opinion, points to a family instability of the vasomotor nervous system. This is manifested in the case under discussion by the vasomotor spasms in the fingers and the scintillating scotoma. The condition is a vasomotor neurosis related to, but not identical with, Raynaud's disease. The non-hemiopic character of the scintillating scotoma points to the neighborhood of the chiasma as the seat of the visual disturbance.

In the *ophthalmoplegic form* of this disease, Veasey (*Ophth. Record*, Aug., 1909) remarks that the symptoms are divided into two periods; first, the period of pain; second, the period of paralysis. The onset of pain is usually quite sudden and is ordinarily confined to one side. It is sometimes in the neighborhood of the eye, and although it may be preceded by a visual aura, the latter is more frequently absent. The pain gradually increases in severity and although it is, as a rule, more localized than in ordinary migraine, it may spread over a large area. According to most observers, however, in almost all cases it is confined to one side. The duration of the pain is variable. In most cases the period is short; in others it lasts several days. It is ordinarily terminated by an attack of vomiting, which may be regarded as a sort of crisis, as it usually brings sudden and prompt relief.

Upon the disappearance of the pain and vomiting the paralysis appears. This, in a great majority of cases, is confined to the oculomotor nerve, and is usually total and complete, producing both an external and an internal ophthalmoplegia. The paralysis, however, is not always limited to the third nerve and, as previously stated, the fourth or sixth nerve may be involved. The duration of this symptom may extend from a few days to several months and, according to some authors, is always confined to one eye. After repeated attacks it may become permanent. The migraine is very apt to begin at an early age and, in some instances, ordinary, or ophthalmic migraine changes to the ophthalmoplegic type.

Veasey reports the following illustrative case:—A girl, at 4 years of age, began to have attacks of violent supra-orbital and temporal pain on the left side, lasting for an hour or two and followed by nausea and vomiting. Marked photophobia was usually present. She was seen by the writer when she was six years old, when the attacks were growing more frequent and severe. Six months before he saw her a squint in the left eye followed an attack. The squint and the attending diplopia disappeared after a week or two. A few days later she had an unusually violent attack, followed the next day by diplopia. The writer found an almost complete paralysis of the external rectus muscle. This disappeared in about 10 days. Lenses were prescribed for the correction of a compound hyperopic astigmatism, and for a time the attacks became somewhat less frequent; but this period of improvement was succeeded by a succession of three violent attacks, the last of which was followed by paresis of the left external rectus. The paresis lasted three weeks. The patient then passed from under observation and the subsequent history is unknown.

The position taken by Posey and Spiller (*"The Eye and Nervous System"*), wherein they fail to charge the eye with being an important etiologic factor in the production of migraine, is challenged by Baker (*Ophthalmic Record,* January, 1907), who, in order to settle this question, wrote to 100 patients who were suffering from migraine, and asked them first: "How frequently did you have attacks of sick headache before you were fitted with glasses?" Second, "How frequently have you had such attacks since you were fitted with glasses?" Third, "Do you have a return of sick headache if you leave off the glasses?" The replies received show that fifty-five patients were cured. Thirty-one patients were greatly benefited and seldom had attacks. Fourteen patients were not benefited by correcting the error of refraction, but five of these were cured by muscular tenotomy, and one by the use of a pessary, leaving eight who continue to suffer from migraine. The author believes that excessive use of normal eyes is productive of eyestrain which may cause migraine. He is convinced that eyestrain is the most common cause of migraine.

While the exciting causes of migraine are usually fatigue, long use of the eyes, and hunger, the following reported case (*Le Monde Médical,* Feb., 1915) adds another possible etiological factor. Mrs. J., age 23, who had been suffering for some time from a decayed lower molar tooth, had it extracted without an anesthetic. The operation was tedious and very painful. Two hours later the patient noticed the complete disappearance of the dental pain and she felt remarkably well—"as after a dose of morphia." She went to bed and, wishing to read, found that she could not see anything. She closed her eyelids for a few minutes and then became conscious of a luminous point on fixation with absolute scotoma crossed by numerous zigzag flashes of plain and colored light, affecting the outermost part of the visual field on the left and the supero-external region under the right eye. The sparkling scotomata disappeared and were replaced by greyish, veiled scotomata studded with small black points. At this time headache set in, very severe from the onset, extending over the upper part of the face. Fixation became clearer, but with pronounced photophobia.

An hour after the onset of the symptoms an ophthalmoscopic examination was made which revealed slight hypermetropic astigmatism. Papillæ normal but slightly congested. Reflexes normal. The patient's state of fatigue and the migraine prevented investigation of the field of vision.

The attack lasted from 9:30 a. m. to 12:30 p. m., when she fell asleep, and half an hour later normal vision had returned. She still complained of pronounced photophobia but the headache had given place to dental neuralgia. Throughout the attack the patient retained complete consciousness and displayed no tendency to syncope or vomiting.

The first question that suggests itself is whether this was in reality an attack of ophthalmic migraine. The sparkling scotomata and the characteristic headache might be held to point to that conclusion and this case suggests a neuralgic, peripheral origin.

On scrutinizing the symptoms closely it will be seen that the hemianopsia was in this instance replaced by absolute negative scotoma; that the attack was preceded and followed by neuralgia of the lower dental nerve and that it lasted three hours, i. e., much longer than is usually the case in ophthalmic migraine. Is not the mere fact of irritation of a branch of the trifacial sufficient to clear up the pathogenesis of the attack?

We are all familiar with the lachrymation that follows irritation of the nasal mucosa and the amblyopia that follows sinusitis and dental neuralgia. The fact that irritation of the inferior dental nerve, communicated to the ophthalmic branch of the trifacial, should determine ophthalmic migraine is interesting and deserves to be placed on record.

although this one case is hardly sufficient to warrant our classifying it as one of ophthalmic migraine.

For years there has been a general understanding that there is a so-called prodromal period in glaucoma antedating the final attack. The indefiniteness of the literature in regard to the prodromal period of glaucoma, together with the very great difference of opinion as to its etiology, has led Lamb (*Ann. of Ophth.*, Oct., 1915) to make a special study of this condition. In discussing symptoms with glaucomatous patients he found a number who gave a history of migraine headaches, including scintillating scotomata, and because of the similarity of some of the symptoms which occur in these two conditions, he believes that migraine may be a forerunner of glaucoma.

He began by taking the tension by palpation. Occasionally the tension was plus one and sometimes only slightly plus. In order that there might be more accuracy about the matter, he determined thereafter to take the tension of both eyes in all cases presenting the history of recurring attacks of unilateral headache, with or without scintillating scotoma. In all cases he found the tension up a few points, sometimes markedly so. Occasionally the tension was up in one eye only, the eye on the same side as the unilateral headache. More often the tension was up in both eyes, and in some cases where the tension was up in both eyes the headache had a tendency to become general, although it began on one side; and occasionally cases occurred in which the tension of the eye on the side opposite the one having usually the unilateral headache was higher than the tension of the eye on the side with the headache.

Invariably in these cases the tendency later on was for the headache to shift, alternately, or at least occasionally, from one side to the other. He can only account for this in that the astigmatism was against the rule in these cases in the eye on the side of the headache, whereas the good eye was more apt to have the astigmatism with the rule. The usual tension in these cases varies from 22 or 23 millimeters to 35 or 40 millimeters in some few cases. The average, therefore, was in the neighborhood of 28 millimeters. In other words, there was an increase which was so slight as to be considered normal for some persons. On the other hand, when we consider those patients whose vision becomes normal after trephining, with a tension of 13 or 15 millimeters, we realize that the normal tension has to be considered somewhat as we do blood pressure—i. e., according to body weight and the habit of the individual.

In cases in which error of refraction, chiefly astigmatic, more often though not necessarily of a hyperopic character, is an exciting factor, acting upon a general run-down system, fatigue, overwork, and a highly nervous organization, under bad hygienic conditions, such as faulty illumination, there is chorioretinitis more or less severe, and a sufficient disturbance of circulation to produce an imbalance between the inflowing blood and lymph and the drainage from the eye.

It is a well known fact that migraine headaches almost invariably follow intense effort in which the eyes as well as the brain play a part. It is not so well understood that shocks of all sorts bring on exacerbations of migraine headache in the same way as that in which acute inflammatory glaucoma is brought on. Sudden shock, or some accident followed by anxiety and worry, may precipitate an attack.

Let us look for a moment at several points of similarity between migraine and glaucoma. First, the fact that both are inclined to occur in families, as in the case of parent and child, and among those whose physical characteristics are similar, such as the color and general appearance of the eyes.

Another point of similarity is the fact that gouty subjects are more inclined to migraine and to glaucoma than are other persons. One of our French confrères has stated that migraine and gout are sisters. For years this has been a matter of belief, and great attention has been directed toward the correction of gastrointestinal conditions in migraine and in glaucoma.

In regard to the field of vision, there is nothing accurate to offer as to the similarity of changes in the field, and this perhaps is the greatest objection to the proposition that migraine is a forerunner of glaucoma. However, there is at least in each case a disturbance of the retinal elements, transient in migraine, a little more permanent in prodromal glaucoma, which seems to show the probability of the first being in the irritative stage; the second, in the stage of beginning degeneration.

Some of the French writers who have studied the subject of migraine go so far as to record the presence of changes in the iris. This has been denied by other observers. Piorry many years ago precipitated a discussion which lasted over a number of years, by insisting that overstrain of the iris and overstrain of the retina were responsible for migraine. His theory has, however, never been accepted.

On close observation of cases of migraine it has been possible to ascertain on which side the pain was in the habit of occurring by observing that the pupil of that side was more dilated and the anterior chamber was shallow as compared with that of the other eye. There was also a slight difference in the color of the iris—i. e., in the clearness of the color; and in addition, what is more significant, a definite though slight ciliary congestion, the difference brought out under the Zeiss loupe.

On ophthalmoscopic examination chorioretinitis is more marked in the migrainous eye, usually more marked in the central region, which would account for the sudden blindness or obscuration of vision occurring in these attacks, also for the photophobia. All this complex is relieved by one or two drops of eserin salicylate or sulphate, one-half grain to the ounce solution. It is well known that migraine has been relieved by pilocarpin, either as a diaphoretic or by local use alone, just as cases of prodromal glaucoma for many years have been controlled by myotic treatment. Four cases of migraine are described by the author, in all of which the symptoms seemed to be much relieved by the use of pilocarpin. Many points of similarity are also brought out between the migrainous eye and the prodromal stage of glaucoma.

Treatment of the ocular symptoms of migraine should be included in the general conduct of the symptom-complex. It is questionable whether glasses, relief of heterophoria, etc., exercise much influence over the course of the affection in more than 10 per cent. of the cases. —(C. P. S.)

Migraine, Charcot's ophthalmic. This symptom-complex, known also as recurrent oculo-motor paralysis, consists of a paralytic ptosis which may exist alone or in conjunction with paralysis of the other ocular nerves, especially the fourth and sixth.

Migrainin. A patented headache remedy: said to contain antipyrin (85 per cent.), caffein (9 per cent.), and citric acid (5 per cent.). Dose, 15 gr. (1 gm.).

Migratory ophthalmia. See **Sympathetic ophthalmia.**

Migrol. A proprietary headache remedy composed of caffein, guaiacetin, and sodium bicarbonate.

Migrosine. A proprietary remedy for migraine, consisting of menthol dissolved in acetic ether.

Mihalkovics, Victor Geza. A well-known Austrian anatomist and embryologist, of some ophthalmologic importance. Born at Budapest Jan. 29, 1844, he there received his medical degree, there in 1868 became assistant in anatomy, thence proceeded to Vienna, where he studied histology with Schwalbe and Ludwig, removed to Strasburg and became assistant to Waldeyer, then, in 1874, back to Budapest where he became privatdocent for descriptive anatomy, and, in 1881, Extraordinary Professor of Complete Descriptive Anatomy. In 1884 he was made Ordinary Fellow of the Hungarian Academy. He died July 11, 1899.

Mihalkovics's ophthalmologic writings were: 1. Ueber den Kamm des Vogelauges. (*Archiv f. Mikr. Anat.*, IX, 1873.) 2. Ein Beitrag zur Ersten Anlage d. Augenlinse. (*Ibid.*, XI, 1875.)—(T. H. S.)

Mikroskoptisch. (G.) Microscope stage.

Mikulicz' disease, Ocular symptoms of. This disease is a chronic, non-inflammatory affection in which there is bilateral lymphomata of the lachrymal, parotid, and submaxillary glands, and great enlargement of the eyelids. The disease is not associated with any demonstrable systemic condition. The prognosis is favorable. It should be treated by arsenic, the iodids, and pilocarpin.

Krailscheimer (*Die Ophthal. Klinik,* Aug. 5, 1908) reports a case in the person of a merchant's apprentice of healthy parents. He had 9 brothers and sisters living and healthy. The 3 eldest died in early childhood of children's diseases. Three years before the patient suffered from pneumonia, but otherwise he had been well. The present trouble had been insidious. It began with dryness of the mouth and eyes and inflammation of the throat. Ten weeks later there was bilateral iridocyclitis, accompanied (in the right eye) by descemetitis. Beside the enlargement of the lachrymal the parotid and both submaxillary and sublingual glands the left Blandin-Nuhn gland (upon the under surface of the tip of the tongue) was palpable. The palatine glands were not enlarged. The glands in the neck, axilla and groin and at the elbow were enlarged. The spleen could not be palpated. Pulse 140. Heart boundaries normal. There was involvement of the lungs. Urine and blood normal. The left eye quieted under treatment, but the right later developed nodules in the iris, one at the pupillary border, the other at the angle of the anterior chamber.

Microscopic study of the axillary glands showed interstitial inflammation with numerous tubercles and giant cells in the stroma and in the lobes of the glands. Injections of tuberculin (old) were positive.

Here we have Mikulicz's disease associated with tuberculous iritis and tuberculous glands, but whether the former was caused by the latter or the lymphadenoid disease predisposed to tuberculous infection cannot with certainty be declared.

Elliot and Ingram (*Ophthalmoscope,* IX, p. 90, 1912) describe a case in a female Hindu aged 49. Both lacrimal glands were much enlarged, bulging almost like blunt horns, and they were nearly as hard as cartilage. The accessory portions of the glands were also enlarged as were the parotid, submaxillary and sublingual glands. In other respects the patient was quite healthy. There were no signs of tubercle in the lungs. The tumors were removed, with favorable results to the salivary glands. Pathologic examination showed multiple cellular growth presenting some resemblance to lymphoid tissue, but also some definite points of difference so that the term "lymphomatous" is regarded by the reporter as the most suitable in the present state of knowledge.

In a well-marked case Aubineau (*Ann. d'Ocul.*, Vol. CXLVII, p. 422, 1911) saw complete recovery in about eight months of radiotherapy.

Finally, H. Frenkel (*Arch. d'Ophtalmologie,* p. 721, Dec., 1912), who has given much attention to the subject, contends that with the physiologic syndrome of Mikulicz (symmetric hypertrophy of the salivary and *lacrimal glands*) we must admit the existence of an analogous physiologic syndrome concerning only the salivary glands of both sides. In the physiologic syndrome of Mikulicz the parotid, sublingual and submaxillary glands are concerned, showing an increase in size, hardening, but no pain or derangement of function. The glandular hypertrophy is symmetric, with small variations between the sides as well as between the increase in size of the parotids and the other salivary glands. The submaxillary glands are often displaced, both as to their surface relations and as to their depth and nearness to the larynx. The histologic examination of a submaxillary gland excised from a living subject has shown the perfect integrity of the acini as well as of the cellular components. The frequency of this physiologic syndrome may be estimated at 1 per cent. of the population (of Toulouse), affecting men more than women, and seeming to be dependent somewhat on heredity. The parotid swellings, resembling mumps, are the first to attract attention, and lead to the detection of the other glandular swellings. The other glands throughout the body, and the lymphatic system, are normal, and the blood shows no abnormalities. If to the physiologic syndrome an inflammation of the lacrimal glands is added, the picture of Mikulicz's disease is complete. Frenkel denies a tuberculous etiology to this syndrome.

Milammeter. An instrument for measuring the strength of an electric current in milliamperes.

Milben. (G.) Mites or acari.

Milburn, William Henry (1823-1903), the "blind preacher," born in Philadelphia, Pa., as a boy lost the sight of his eyes through an accident. Educated at Illinois College, he entered the Methodist Episcopal Church in 1843, laboring in the southern circuits. Accusations of heresy drove him to the Protestant Episcopal Church in 1865, but in 1871 he resumed his former connection. He was twice chaplain of Congress, in 1845 and 1853, held a similar post in the House of Representatives (1885-93), and was chaplain to the Senate thereafter till his death.—(*Standard Encyclopedia.*)

Milchsäure. (G.) Lactic acid.

Milchstar. (G.) Milky cataract.

Mile, Experiment of. If in the experiment of Scheiner (q. v.) one looks at the more distant of two needles through a single small opening in a screen a slight movement of the screen causes the nearer needle to move in the opposite direction.

Mile, Johannes. A distinguished Polish physician and obstetrician, who devoted considerable attention to diseases of the eye. Born at Warsaw July 7, 1789, he was at first apprentice to a clockmaker. In 1810, however, he began to study medicine at Warsaw, and in 1814 received his medical degree. For the next three years he studied physics, physiology, and obstetrics in Germany, France, Holland and England. Returning to Warsaw in 1817, he became in 1819 full professor of physiology and obstetrics—a title which he held till 1831. He died at Warsaw in 1839.

Mile's ophthalmologic writings are as follows: 1. De la Cause qui Dispose l'Oeil pour Voir Distinctenent les Objets Placés à Différentes Distances. (*Magendie's Jour.*, 1826.) 2. Ueber die Richtungslinie des Sehens. (*Poggendorff's Annalen*, 1837.) 3. Ueber die Empfindung, welche Entsteht, wenn Verschiedenfarbige Lichtstrahlen auf dieselben Stellen der Retina eines einzigen Auges Fallen. (*Müller's Arch.*, 1839.)—(T. H. S.) See **Mile, Experiment of.**

Miliaria. See **Eyelids, Lichen tropicus of the.**

Miliary aneurism (of the retina). This rare condition is referred to on p. 462, Vol. I, of this *Encyclopedia*, but quite recently Leber (Graefe's *Archiv f. Ophthalm.*, Vol. 81, pt. 1, 1911; excellent abstract by R. R. James, *Oph. Review*, p. 150, May, 1912, from which we largely quote) has furnished a full account of the disease. He divides miliary aneurisms of the retina into two groups.

Cases in group one depend principally on senile changes in the vascular system, such cases show small aneurisms, without any inflammatory accompaniment, which do not give rise to any tissue change in the retina, save minute hemorrhages, while in sharp contradistinction to such cases are those which fall into group two in which the miliary aneurisms are combined with gross changes in the retinal tissue.

Cases in group two have an undoubted similarity to retinitis circinata.

The fact that miliary aneurisms occur both in the part of the retina affected with opacity, and in the zone immediately surrounding it, shows that the two are not dependent on chance, but that there must be an intimate connection between them.

Leber limits himself to the discussion of cases which show multiple miliary aneurisms in conjunction with a form of opaque degeneration of the retina; in his opinion disease of the vascular system is probably the primary feature, while the retinal degeneration is secondary.

He adds two cases to the eleven already in the literature, and thinks it barely possible that there may be some connection between these cases and a tuberculous infection, but this is doubtful. Ophthalmoscopically the disc and large vessels are usually found to be normal, even in those cases where the changes in the retina have advanced to the edge of the former. For the most part the aneurisms form roundish lumps at the ends of the small arteries, like berries on a stalk, sometimes they occur on the veins; they are often surrounded by thin hemorrhages, which extend into the surrounding tissue in a streaky manner, but rarely do such hemorrhages reach a large size.

Aneurisms occur only in the neighborhood of the diseased retina, the rest of the fundus where the retina is in a normal condition shows no aneurisms. In Leber's first case, that of a man aged twenty-five, there was a detachment of the retina, numerous miliary aneurisms, multiple white spots, and extensive infiltration of the retina. Glaucoma and absolute blindness supervened. Examination showed a suspicious apical catarrh in one of the lungs, and an injection of tuberculin gave rise to a raised temperature, but very mild local reaction.

The second case was only examined cursorily; a man aged twenty years, had a detachment of the retina and numerous small red spheres which appeared to be connected with the vessels.

Leber points out that vision in these cases is usually much diminished, but complete blindness only sets in with the onset of secondary glaucoma; if the changes are limited to a small and unimportant part of the retina, of course fairly good sight may be kept for a while.

The course of the disease is usually chronic, and the case of Pergens, occurring in a youth of 13 years, where blindness developed rapidly is exceptional.

The pathological appearances in miliary aneurism of the retina have been elucidated by Coats (*Roy. Lond. Oph. Hosp. Reports,* vol. xvii, part 3, p. 440, 1908).

Miliary tubercle of the choroid. See p. 2159, Vol. III of this *Encyclopedia;* also **Tuberculosis of the eye.**

Milieu. (F.) Medium.

Military conjunctivitis. MILITARY OPHTHALMIA. Synonyms of trachoma.

Military surgery of the eye. Ramifications of this important subject are dealt with under various headings in this *Encyclopedia* but especially in Volume VIII, page 6,200, **Injuries of the eye,** which should be read in conjunction with this section.

The lessons learned from the unprecedented use of heavy armament, of high explosive charges of terrific detonating power, of enormous numbers of machine guns and of predominant trench warfare during the European conflict of 1914-1917 are certain to influence if not to dominate the methods of warfare and military surgery for some time to come.

As a direct consequence of the introduction of these modern factors, the nature and relative frequency of military wounds has been materially altered. The problems of trench fighting have become those of siege rather than of mobile warfare and the necessity for blasting men out of reinforced earthen entrenchments by high explosive shells has led to the natural result that wounds from artillery projectiles have become more than twice as frequent as bullet wounds; whereas in the various types of mobile warfare, artillery wounds seldom exceed from 10 to 25 per cent. of all wounds. Trench warfare has also been responsible for a sharp increase in the proportion of killed to wounded, this rising from about 1 to 5, as reported by the British in the Boer war, to about 1 to 3 for all classes of military activity and about 1 to 2 in essential trench fighting. The greater frequency of projectile injuries of the head, are due to its relatively greater exposure, the excessive mortality of the wounds being largely instrumental in this increase. The lists of wounded in the field and base hospitals do not register this increase in the frequency of cranial injury with any accuracy, however, for well over 50 per cent. of the artillery and short-range bullet wounds of the unprotected head are immediately fatal, between 25 and 35 per cent. of the survivors die within 36 hours and fully 20 per cent. of the remainder succumb from infection and other early complications.

In the last wars of magnitude before the introduction of modern armament, the relation of wounds of the eyes to other wounds (*Sanitätsbericht über die Deutschen Heere im Krieg gegen Frankreich,* 1870/71, 111 Bd., 2. Kap., S. 157) was as follows:

War	Number of Eye Wounds	Per cent. of All Wounds	Per cent. of Head Injuries
Crimea—English	49	0.65	3.28
Crimea—French	595	1.75	11.30
American Civil war	1,190	0.50	5.50
Franco-Prussian, 1870—German	860	0.86	8.50
Franco-Prussian, 1870—French	672	0.81	8.70

In the Franco-Prussian war ophthalmoscopic diagnosis was first, although not generally, employed.

The use of arms having greater range and of projectiles having greater penetration led to an increase in the gravity and frequency of head and ocular injuries. In the Chino-Japanese war of 1894 the eye injuries formed 1.2 per cent. of all wounds, an increase which was maintained in the Spanish-American, the Boer and the Russo-Japanese wars. Oguchi (Graefe's *Arch.*, 1912, Bd. 89, S. 3530 and Deutschmann's *Beiträge zur Augenh.*, Heft lxxxiii, 1913) gives the number of wounds of the eyes occurring among the Japanese during this last war as 3,093, 1,605 being rifle and 771 artillery wounds. These made 2.22 per cent. of all wounds and 21.01 per cent. of head injuries. v. Merz (*Kl. Mbl.*, 1907, Bd. 45, Beilag., S. 238) states that 54.2 per cent. of the killed in a single division of the second Japanese army exhibited head-neck wounds and that the total eye wounds of both sides exceeded 2 per cent.

It will be many years before exact data of the present European war will be available, but it seems certain that these percentages will be somewhat, if not largely, increased. Rollet and Mangini (*Lyon Chir.*, Oct. 1, 1915) found that facial wounds formed 5 per cent. of their wounded during the mobile operations of August, 1914, the percentage rising to 13 in January, 1915, under the subsequent conditions of trench fighting. Genet (*Lyon Chir.*, Nov., 1915) gives figures showing that in his experience wounds of the eyes are about thirty times more common in trench warfare than in open combat. v. Grósz (*Wien. klin. Wochnsch.*, Nov. 11, 1915) concluded from an experience with over 5,000 military eye cases, that wounds of the optic apparatus in the present war would total 20 per cent. of all wounds, while in Schreiber's work in a base hospital (*Muench. med. Woch.*, Nov. 23, 1915) they made but 5 per cent. of the total. Indirect injuries of the eyes, which had seldom been recognized before the Russo-Japanese war, have been found to occur with surprising frequency, and persistent and fine observations of wounds of the cervico-dorsal spine, the face, the skull and the brain have demonstrated the involvement of the optic apparatus with resulting ocular symptoms in fully two-thirds of the injuries of the skull and brain, in a large proportion of wounds of the face and to some extent in the spinal injuries. Various observers have estimated that head wounds form from 13 to 25 per cent. of all wounds and the direct or indirect implication of the eyes in these injuries has been upon an unprecedented scale. Probably Uhthoff's estimate (*Klin. Monatsbl. f. Augenh.* 55, S. 104) that ocular injuries and visual disturbances form about 8 per cent. of all war injuries will prove to be very nearly correct.

It is remarkable that the eyes, whose combined surface is only about 1/375 of the surface of the body, should be involved in approximately 8 per cent. of all injuries, but the explanation lies in the constant exposure of the head, and especially of the eyes, in trench warfare; in the fact that the eyes are so frequently injured by fine particles which would have no deleterious effect elsewhere in the body; and in the great frequency of symptomatic involvement as a consequence of remote lesions.

The degree of prevention of cranio-ocular injuries which may be effected by the use of metal casques of the type adopted by the French, later modified by the Belgians, English, and Germans, still remains to be determined. They seem to be highly effectual against shrapnel, spent projectiles and the multitude of fine secondary missiles which so frequently and disastrously involve the eyes, and the overhanging brim protects the eyes and the occipital visual centers equally. The frequency of minor wounds and contusions still is increased but helmets apparently largely reduce the proportion of severe or fatal cases. Many articles have appeared in enthusiastic advocacy, the papers of Le Dentu et Devraigne (*Bull. de l'Acad. de Méd.*, June 1, 1916), of Matignon (*Jour. de Méd. de Bordeaux,* Feb. 1, 1916) and of B. Roussy (*Bull. de l'Acad. de Méd.*, March 7, 1916) offering convincing proofs of the extreme value of this form of prevention of injury.

The present war, among other advances, has led to a better knowledge of cerebral localization and particularly of cortical visual representation; to the recognition of concussion syndromes of the brain and of the optic apparatus due to high explosives; to a clarification of the causes and treatment of traumatic ocular neuroses or psychoses and, possibly above all, in the bacteriology and treatment of infections, the lessening of which has become the greatest problem in military surgery.

In the earlier wars the occasional ocular wounds met with prompt enucleation or exenteration or, most often, with neglect and consequent great loss of vision, atrophy, or total blindness from sympathetic inflammation. Even as late as the war of 1870, 56.5 per cent. of the cases of projectile injury of the eyeball developed sympathetic ophthalmitis. (Steindorff—*Berl. klin. Woch.*, Nov. 9, 1914, S. 1787.)

The frequency and gravity of lesions of the intra-cranial optic apparatus and of the orbits and their contents, in the present colossal war speedily made aware the necessity for early, specialized care in such cases, despite the active opposition of many general military surgeons, who feared loss of efficiency in the magnification of personnel. Specialist centers were established for each military zone and cases of ocular injury were sent to them with the least possible delay. The services of these skilled ophthalmologists in the early treatment of the relatively enormous number of grave perforating injuries of the eyes, of corneal and conjunctival abrasions and infections, their active prevention of sympathetic ophthalmitis and their aid in determining the location, gravity and treatment of cerebral injuries, have proven of such incalculable value in terms of vision and of life, that a similar organization, or, at least, the inclusion of a consulting ophthalmologist upon the medical staff of each large military unit is to be urged most earnestly.

It is well known that the outcome of industrial injuries of the eyes often depends upon how and when the first attention is given, for failure to close or to cover the perforating wound of the eye may be as responsible for the ensuing infection as the injuring foreign body. Alsen (*Klin. Erfahrungen über Augenverwundungen,* 1913) showed that 39.3 per cent. of eye injuries treated on the day of injury retained a visual acuity of 1/3 or more and only 17.4 per cent. required enucleation, while only 11.9 per cent. of cases which were first treated from five to fourteen days after injury retained this amount of vision and 30.9 per cent. required enucleation. This contrast becomes exaggerated in the case of military injuries, and particularly in those of trench warfare, where infections are so frequent and severe, and every ophthalmologist in active military service has saved numerous eyes which otherwise would have been lost, by promptly covering the bulbar wound by an adequate conjunctival flap, and has seen many instances in which more or less vision could have been retained by early and fitting treatment, but in which the time for such treatment has long passed and irreparable lesions and blindness have ensued.

In this connection it frequently happens that the missile which has damaged the eye produces other lesions of gravity in its direct or deflected course, tears off the lower face, opens the anterior cranial fossa, traverses the larynx, fractures the cervical spine or enters the thorax, and it is the rule in these cases that the grosser clinical damage dominates the scene and that the ocular injury receives little or no attention from the general surgeon, but is seen by the ophthalmologist weeks or months after the injury, when its condition has become irremediable, or an active source of danger to the other eye. Elschnig (*Med. Klin.*, May, 1915) goes so far as to suggest that the authorities of the hospitals through which these neglected cases have passed may be held responsible for damages for blindness, where the requisite minor treatment has been omitted. Naturally, the less imperative measures, such as the routine radiographic examination, the more complicated cases of intraocular foreign bodies and extensive plastic operations on the orbit and lids are preferably done in the reserve or civil hospitals, but provision for the adequate first aid treatment for these and for all eye wounds soon after injury and while en route to the rear is a matter of such consequence in preserving vision and in preventing infection, that a knowledge of its essentials should be spread among civilian surgeons suddenly called to active military duty, and among professional military surgeons as well, by means of special instructions. A comprehensive summary of such instructions follows:

First Aid in Battle Wounds of the Eyes.

1. Before cleansing or manipulating a recently injured, sensitive eye, lightly anesthetize it with from 2 to 3 drops of 4 per cent. solution of cocaine, instilled at 3-minute intervals.

2. Cleanse the skin of the lids and the adjacent field by gently washing with soap and water, followed by benzene (benzol).

3. Cleanse the conjunctival sac of loose foreign material by free irrigation with warm 3 per cent. solution of boric acid, warm normal saline or warm 1-10,000 bichloride or oxycyanate of mercury, whichever may be available, not forgetting that strong antiseptics may seriously damage the cornea.

4. Where foreign bodies are deeply imbedded in the cornea and where the whole cornea and conjunctiva is tattooed with indriven mud, fragments of stone or metal, the dangers of corneal perforation and infection are so great that such cases should be hurried to the nearest specialist center.

5. A wound of the eyeball, the gray-white change of a traumatic cataract and effused blood in the anterior chamber, usually mean perforation of the eye by a foreign body. These cases demand the earliest possible specialized care and should be given precedence of way to the rear.

The chances of infection of the globe through the open wound are so greatly lessened by promptly covering the wound with a flap of conjunctiva that more eyes can be saved and more practical vision retained in such eyes by this than by any other single procedure. With corneal wounds a sufficient amount of adjacent conjunctiva is undermined and drawn down and held in place over the opening by simple conjunctival sutures of fine silk at each angle. If the laceration is considerable, but there are possibilities that some vision may be retained, the entire cornea may be thus covered and protected by undermining the conjunctiva throughout the whole circumference of the cornea and uniting it over the front of the globe.

6. Both eyes should be put at rest by full dilation of the pupils with 1 per cent. atropine, a matter of much importance during rough transportation, and, unless contraindicated, both eyes should be lightly bandaged, using gauze, cotton and bandage material from within outwards. In a few cases the tension of the eye, determined by palpating the globe between the index fingers, is high, and in this condition instillations of a 1 per cent. solution of eserine are indicated, instead of atropine, until the pupil is very small.

7. Eyes which are suppurating from any cause should not be bandaged but are to be washed out freely and frequently. Extension of the infection to the sound eye and to the eyes of others is to be guarded against.

8. Unless an eye is completely shattered, too early enucleation is not to be counseled. Sympathetic inflammation of the sound eye is almost unknown inside of two weeks after injury, and many eyes are blinded for the time being by intraocular hemorrhage which may clear in a few weeks or months and leave more or less useful vision. The decision in this matter of such importance is best made at the specialist center.

9. Inflamed and tender eyes with failing vision or without vision are best enucleated at once, because of the danger of sympathetic inflammation of the sound eye. The conjunctiva and the ocular muscles are spared as much as possible in order to form the best possible socket for an artificial eye.

10. Eyes that have been shattered are to be enucleated at once, with particular care to remove all fragments of bone, which are so commonly driven deeper into the orbital fat. By early operation, excessive cicatricial contraction is avoided and a far better bed formed for an artificial eye.

11. Fragments of missiles lodged in the orbital tissues are harmless especially if they produce no evidence of irritation.

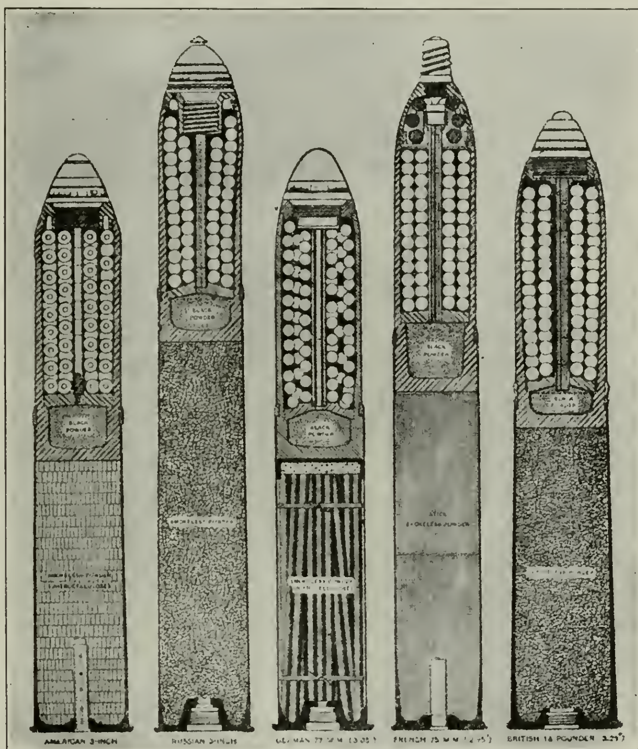
12. Defects in the lids should be repaired at once, lest cicatricial contraction make a good operative result difficult or impossible to obtain.

13. Wounds of the eyes and orbit are no exceptions to the routine employment of antitetanic serum in military wounds.

14. The routine use of narcotics in injuries of the eyes is to be

deplored, in view of the possibility of habituation. Small doses of paregoric or tincture of opium are usually sufficient.

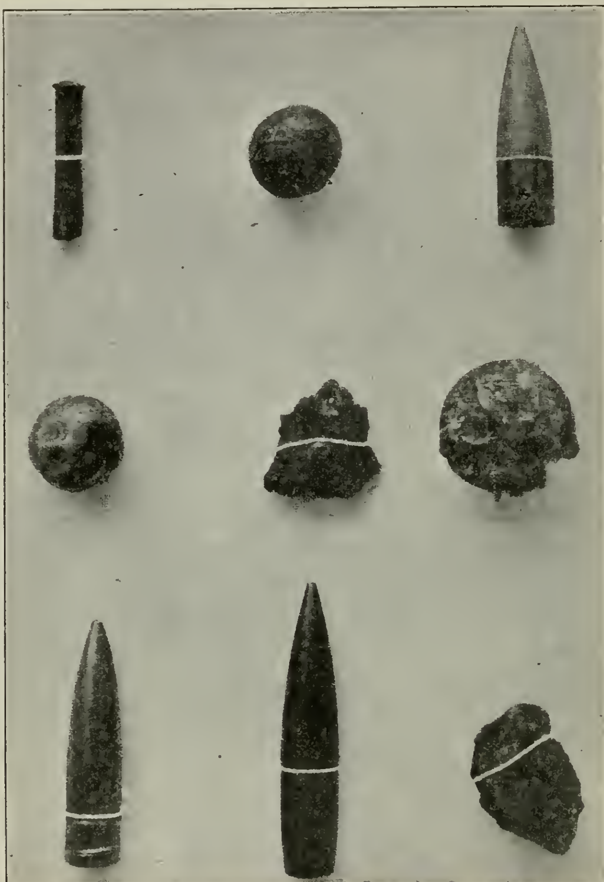
15. The inclusion in the medical equipment of a focusing lens, a self-retaining lid retractor, an instrument for removing foreign bodies from the cornea, and of atropine, eserine and cocaine in the form of



Types of Shrapnel in Modern Use.

salts or solutions is essential for the adequate care of battle injuries of the eyes.

Because of the deep position and bony investment of the eyes, projectile wounds thereof are frequently complicated by grave damage to adjacent tissues, often of such a nature that even serious ocular injury becomes of secondary importance. The orbital buttresses, of such protection to the eyes in civil accidents, become a positive menace in military life because of their tendency to extensive comminution and secondary missile effect. The lids, the walls of the orbits, the nose, of any and all of the accessory sinuses and of the anterior and middle cranial fossas may be crushed, splintered or wholly torn away, putting the orbits into wide communication with meninges, nose and mouth and producing horrible mutilations. Complicated injuries of



Actual size of shrapnel bullets, pieces of shell and a German bullet (upper right hand corner) removed from wounds, and (lower left-hand corner) an English and French bullet for comparison.

this sort not infrequently fall to the care of eye surgeons, especially during and after the colossal battles of the present day, where no medical organization can be elastic enough to handle the crowded transports of wounded and where with all departments of the service strained to their utmost, the lines of cleavage between the specialties are lost.

The general care of battle wounds of the eyes and the optic apparatus presupposes some knowledge of the conditions of employment of shrapnel, shells and bullets, of the mechanism of their action, of their characteristic effects upon living tissues of the head, and of the general principles of treatment of military wounds.

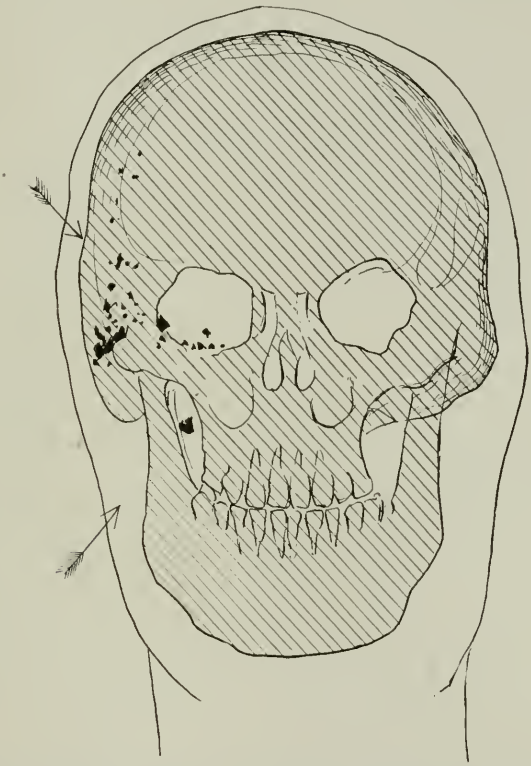
1. *Shrapnel,* which are responsible for about three-fourths of all artillery wounds in mobile warfare, consist of cylindro-conoidal casings of cupro-steel weighing from 15 to 20 pounds, containing from 300 to 500 round lead bullets, usually hardened with antimony, from 1 to 1½ cm. in diameter and weighing from 10 to 16 grams each. These are imbedded in a smoke-producing matrix, usually some variety of sulphur, which indicates the point of explosion to the artillery observer. The base of the cylinder contains a bursting charge of some high explosive, usually of terrific detonating power, which is timed, by a fuse in the detachable head, to explode at any given point in the projectile's flight, or upon impact. The characteristic feature of shrapnel which determines its main use and makes it most effective against bodies of troops in the open, is the forward-reaching and rather flat trajectory of the charge after bursting, the bullets being propelled forwards and downwards in a cone-shaped stream whose velocity depends upon the velocity of the shell rather than upon the power of the bursting charge. The effective area of dispersal of shrapnel fragments is, accordingly, much greater than that of the fragments of a high explosive shell of the same calibre, but with its characteristic downward trajectory after bursting. At 3,500 yards, the usual shrapnel range, the bullets of an 18-pound shrapnel cover an area of about 7,500 square yards, while the splinters of the 18-pound field gun high explosive shell are effective over an area of about 500 square yards, but within that smaller space the latter shell destroys everything, and its power for destruction increases in proportion to the cube of the diameter of the shell, a 12-inch, for example, being eight times more deadly than a 6-inch. More than 70 per cent. of the ammunition used by field guns in modern battles is in the form of shrapnel, and anti-aircraft guns are exclusively of this type.

Each shrapnel bursts into from 2,000 to 3,000 fragments, varying in size from large, irregular pieces of casing possessing all the terrible lacerating effect of solid shot, to jagged lumps of metal, fine, sharp slivers and tiny, dust-like particles whose presence in tissues like the eye is often demonstrable only after repeated radiograms, or is told only by the intraocular damage they have produced. This large number of fragments and the infinitely larger number of secondary missiles, such as earth, mud, stones, wood and metal, set in motion by the explosion of shrapnel, in common with all manner of shells, explains the frequency of shrapnel injuries of the eyes, of multiple perforations and of the lodgment of numerous metal splinters and secondary missiles in the orbital fat, the lids and the adjacent face. Shrapnel wounds of the eyes occur about a third more often than bullet wounds, but owing to the grosser and more intense trauma of the latter missiles, the eyeball is saved far more frequently after shrapnel injury.

The effect of shrapnel bullets is comparable to that of the old-fashioned rifle bullet in that the power of penetration is comparatively slight. They cause local depressed fracture of the skull without lacera-

The Multiple Wounds of Shrapnel Fire.

tion of the dura much more often than they perforate the dura and lodge in the brain, and the passage of a shrapnel bullet through both orbits, an occurrence of no rarity with modern rifle bullets, is almost unknown. The characteristic tendency of a shrapnel ball is to break one bone and to lodge immediately. Octave Laurent, in "*La Guerre en Bulgarie et en Turquie,*" reports primary infection in 40 per cent. of general shrapnel wounds occurring in comparatively mobile warfare. Lloyd Mills (*Jour. Am. Med. Assn.,* April 10, 1915) states that 85 per cent. of the total shrapnel wounds of mixed trench and mobile warfare seen during his service in Austria were infected, while others, like Sir Almroth Wright (*Brit. Med. Jour.,* April 10 and Nov. 13, 1915), report infection of practically all shrapnel and shell wounds in trench warfare. Disregarding its exact percentage, it is certain that infection is the most serious element of these wounds and that orbital cellulitis of all degrees, panophthalmitis, meningitis and erysipeloid inflamma-



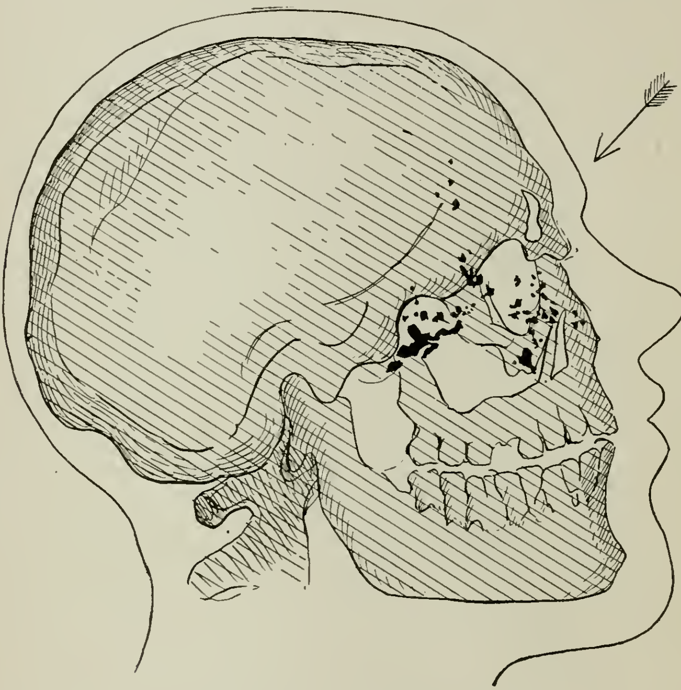
Radiographic Tracings of Shrapnel Fragments in Side of Face.

tions of the lids, face and scalp are common, distressing and not infrequently fatal sequels of perforation and laceration of the eyes and adjacent regions by shrapnel and the smaller shell fragments. The literal covering of entrenched soldiers with mud, largely manurial in origin, is mainly responsible for this excessive infection in trench warfare.

2. *Shells,* among which are included bombs, grenades of all kinds and, from their similarity in effect, mines, range from sizes scarcely larger than shrapnel to great cylindro-cones of steel as tall as a man

and weighing over a ton. The cavities of these iron or steel casings enclose a violent explosive charge which, in the case of bombs and grenades, is often partly replaced by irregular metal fragments of all kinds, as well as by corrosive fluids and irritant and poisonous gases.

From the size and solidity of their fragments and their enormous concussive violence and detonation, shells are used mainly to demolish cover, to break down wire entanglements, and especially to search



Side View of Preceding Illustration.

out the depths of trenches, their downward trajectory after bursting making them especially effective here. The explosive force of picric acid and of trinitrotoluol, which are most often used as bursting charges, is 135,820 and 119,000 pounds per square inch, respectively, which explains the terrific action of concussion often seen upon the central nervous system and in the eyes of those who survive its effects or only partly sustain them. Shells charged with picric acid produce volumes of black smoke on detonation, the asphyxiant carbon monoxide and the corrosive nitrous oxide gas being evolved from the picric acid compounds in the process and both being accessory instruments of death or injury in the stagnant air of the trench depths.

It is evident that facial wounds are far more often the product of the fatal frontal shrapnel trajectory than of the more overhead shell explosion, and that shell fragments produce grosser lacerations which more nearly resemble the great traumas of railroad accidents. Soft tissues are bruised to a pulp, bones are crushed and splintered as if pounded, and wide areas of muscular tissue die and may be cut away without pain or bleeding. A characteristic of these wounds is the formation of numerous "pockets" owing to the separation of muscle layers along the fascial planes, a matter of great importance if infection is allowed to gain a foothold. Surgical experience has shown that the larger and the more irregular the missile, the greater the probability of infection from the larger amount of tissue torn and exposed, and as shell fragments are always very rough and jagged, these wounds are nearly always found infected, streptococci and staphylococci being invariably present, with the fecal organisms of tetanus and gas gangrene frequently superadded.

The larger naval and armor-piercing guns have been introduced in land operations during this present war, but their effect upon human tissue is one of such extreme laceration that their only relation to lesions of the optic apparatus comes through those factors common to all types of artillery projectiles, i. e., through the mechanical and psychic effects of detonation or of explosive violence and through the production of clouds of secondary missiles.

3. *Bullets* cause the majority of the more serious wounds of the eyes and the optic apparatus, as is shown by the fact that not more than 25-30 per cent. of eyes wounded by bullets can be saved, whereas about 60 per cent. of those injured in explosions of artillery missiles are conserved, although the vision in all of these retained eyes is usually much impaired. A comparison between the results of 118 cases of eyes wounded by artillery explosions and under the care of Cords (*München. med. Wchnschr.,* Aug. 31, 1915) with those of 406 bullet wounds of the eyes treated by v. Grósz (*Wien. klin. Wchnschr.,* Nov. 11, 1915) shows that enucleation was necessary in about 27 per cent. of the former and 39 per cent. of the latter; intraocular foreign bodies were found in over 33 per cent. of the artillery and in 7 per cent. of the bullet wounds; of the conserved eyes, unilateral blindness existed in 58 per cent. of artillery and 11 per cent. of bullet injuries, while both eyes were blind in about 6 per cent. of the former and about 11 per cent. of the latter wounds.

Because of the position of the head in trench fighting, wounds of the head and face are probably the most frequent of all injuries in modern battle, and the terrific energy developed by the modern bullet at short ranges has been no small factor in the unprecedented mortality from these wounds. Some idea of the force of impact of the modern pointed bullet may be gained when it is understood that the 10-gram German bullet of ferro-nickel has a muzzle velocity of over 2,900 second-feet and revolves on its long axis, its boring motion, about 2,500 times per second. In terms of energy, this means that at 100 yards the bullet has a working force capable of raising a weight of over three-quarters of a ton to a height of one foot; at 300 yards a half ton would be raised an equal distance, while at 600 yards the force drops to about 600 foot-pounds. As a blow of only 60 foot-pounds is sufficient to kill a human being, it becomes obvious why so few, relatively, of the short-range bullet wounds of the cranium figure in the lists of the wounded who arrive at the base and reserve hospitals.

The modern bullet tends to lose its shape and break in fragments upon meeting slight obstructions, because of the difference in the density of its core and its thin outer coat or jacket. Further, because of its deliberately imperfect balance, it has a wobbly, gyrating motion during the first 800 yards of its flight, as well as when nearly spent. This imbalance often causes the bullet to somersault or turn on its axis when it meets the least resistance, and if this resistance be that of the tissues, the oblique, transverse or reversed projectile assumes the lacerating proclivities of a dum-dum bullet, producing the deep, irregular wounds, often with large cavities in the softer tissues, known to the French as "anfractuous" wounds. The rotary spin of the bullet, produced by the rifling, continues to the end of the penetration, regardless of the reversal of the butt, and I am convinced that the cavities, filled with blood and bruised tissue, so often found about lodged bullets in all parts of the body, including the orbit, are due wholly to the persistence of this rotation after the bullet's advance has been checked. In a certain number of cases of rupture of one or more of the ocular coats by indirect violence, the possibility that transmission of this rotary force may be responsible for the damage has been suggested. As the modern bullet rotates around its long axis once in approximately every 3 feet of space traversed, the ratio of rotation to distance traveled, about ⅓ to ½ of a turn in passing through the body, seems much too small to give this rotary motion much, if any, standing as a force effective for trauma.

According to Delorme (*Précis de Chirurgie de Guerre,* Paris, 1915) about one-third of all bullets ricochet, and this is especially the case in trench fighting, where the bullets strike sandbags and the innumerable forms of parapets at all angles, the impact on rock or metal often breaking the mantle, with extrusion and spattering of the core, and either from this cause or from the oblique direction at which the undeformed bullet hits, producing the so-called "explosive" effect so characteristic of modern bullets. The real explosive bullet, which explodes on impact, naturally does not ricochet. On the other hand, projectiles of very high velocity which have not ricocheted, not infrequently cause explosive effects by breaking up during their course through the tissues, as the result of the thinness of their outer jackets and the different density of their cores.

The more or less complete shattering of the eyeball when directly hit by a bullet is due to the transmission of the velocity of the missile to the incompressible fluid contents of the eye, and the general law may be laid down that, velocities being equal, the smaller the eye, the greater the destruction, the addition of the volume of the bullet to that of the fluid producing a greater increase of pressure in the smaller eye.

The bullets of modern rifles, machine guns and high-powered revolvers produce nearly identical effects upon the orbital region and the cranium at short range. Condensed bone, like that of the superciliary ridges, the external angular processes and the whole lower jaw, are subject to extreme comminution, the degree of which is in direct relation to the calibre and velocity of the bullet and the compactness of the bone. In general, the higher the velocity, the more limited in length the fracture and the greater the comminution, and the extremes of this effect are nowhere more marked than in shot wounds of the skull at close ranges. Reconstruction of these skulls shows that the modern, undeformed bullet often passes completely through the skull and emerges before the collapse of the cranium occurs, and further demonstrates that this shattering of the cranial vault is the result of the interlacing of radial and circular fissures which arise from both the wounds of entry and of exit, thereby converting the dome into a myriad of fragments which collapse or fly apart under the continued energic action of the projectile, as transmitted to the semi-fluid brain.

When the bullet is moving evenly, at about 1,000 yards or over, if it hits without having ricocheted, it is likely to make clean perforations of the orbital buttresses and the skull, although such wounds are relatively uncommon, owing to the conditions of modern warfare.

It is worthy of note that portions of some bullets, like the casing of some forms of shrapnel and shells, are magnetic. The jacket of the German rifle bullet, made of steel, with over 30 per cent. of nickel, is strongly magnetic, although the body, containing 97 per cent. of lead and 3 per cent. of antimony, is, of course, non-magnetic. The jacket of the English bullet, being made largely of copper and nickel, is also non-magnetic.

Remote injuries of the optic apparatus, such as wounds of the cilio-spinal sympathetic circuit, of the cortical visual centers and deep wounds of the optic tracts and radiations, are caused mainly by bullets.

A brief consideration of the *infections of modern warfare* and of the *principles of military surgery,* in so far as they apply to wounds of the optic apparatus, may precede the regional study of these wounds.

Careful clinical and bacteriological study of battle wounds has solidly established the following facts:

1. The prevention and cure of infection constitute the greatest single problem of military surgery.

2. Little or no bacterial growth occurs in projectile wounds during the first four to six hours following injury. Such as does occur comes mainly from implantation of organisms with the projectile or secondary missiles, and where these wounds can be effectually opened and cleansed of foreign material before bacterial growth extends to and into the surrounding tissue, infection does not occur, or is almost negligible.

3. Wherever, from the nature of the wound, it is possible to excise the bruised and contaminated tissue about the path of the missile, the usual result is primary union.

4. If, owing to faulty transport, excessive casualties, or extreme shell shock or exhaustion, prompt surgical care is impossible and infection spreads to all parts of the wound, free incision, adequate drainage, the use of light dressings, frequently changed, and continuous irrigation offer the surest means of recovery.

The use of antiseptic solutions in battle wounds has undergone much revision as the result of the brilliant and painstaking researches of Almroth Wright, Carrell, Dakin and many others, who have shown the uselessness of merely washing pus out of infected wounds without directing treatment to the walls of the wounds where the delicate biological changes of tissue resistance to bacteriological invasion are taking place. Two solutions stand out among the many advocated for continuous irrigation and wet dressing: Wright's solution of 5 per cent. sodium chloride with 1 per cent. sodium citrate has for its object the "lymph lavage" of the infected tissue by introducing this fluid of high osmotic properties freely into every part of the wound, while Dakin's solution of sodium hypochlorite, similarly employed, is an effective antiseptic without the albuminotropic properties, which make solutions of bichloride of mercury or of iodine or phenol objectionable. Dakin's solution is made by adding 200 grams of chlorinated lime to 5 liters of tap water, allowing it to macerate over night. To this is added a solution of 100 grams of anhydrous sodium carbonate and 80 grams of sodium bicarbonate in 5 liters of cold tap water; the mixture is stirred vigorously for a minute and then the calcium carbonate is allowed to precipitate. After a half hour, the supernatant fluid is filtered through paper and is ready for use without heating. The value of these solutions in uncomplicated wounds of the globe is untried, or at least unreported, but in the gross, infected lacerations which so commonly involve the orbital and adjacent tissues, their worth, and particularly that of the Cl compounds, is inestimable when continuously applied. In his admirable study on the drainage of wounds, Wright (*Lancet,* Oct. 16, 1915) suggests the use of a light, water-tight trough of formalin-gelatine to protect the skin from maceration and irritation and to avoid soaking the clothing and bed. This is built upon the skin by soaking short strips of bandage in a solution of 40 grams of gelatine in 200 c.c. of water, to which is added 20 c.c. of ordinary 40 per cent. formalin. These short lengths of bandage, overlapping each other, are pasted over a half-moon of cotton, bent beneath the wound, and when dry, form an effectual confining channel firmly fixed to the patient's skin.

For a complete study of the biologic evolution of battle wounds the reader is referred to the researches of Wright (*Brit. Med. Jour.,* Oct. 30 and Nov. 6, 1915), of Carrell (*Bull. de l'Acad. de Méd.,* lxxiv, No. 40), of Dakin (*Brit. Med. Jour.,* Aug. 28, 1915, p. 319, and *ibid.,* Dec. 4, 1915, p. 809) and of Policard and others (*Lyon Chirurgical,* January-February, 1916). Extensive clinical study of the successful use of Wright's solution is reported by Gray (*Brit. Med. Jour.,* Jan. 1, 1916), while the success of Carrell's method of application of Dakin's solution is strongly corroborated by Tuffier (*Lancet,* Oct. 23, 1915, p. 933), Dehelly (*Bull. de l'Acad. de Méd.,* May 2, 1916), Perret (*Bull. de l'Acad. de Méd.,* April 11, 1916), and Dehelly and Dumas (*Presse Médicale,* May 8, 1916). Moynihan (*Brit. Med. Jour.,* March 4, 1916, p. 335) reports favorably on the use of 4 per cent. solutions of tolamine, a combined chlorine which acts as a chlorinating agent when in contact with proteins, and which was introduced by Dakin, Cohen and Kenyon (*Brit. Med. Jour.,* Jan. 29, 1916) as a less irritating and more powerful germicide than sodium hypochlorite.

[Lewis A. Stimson (*Jour. Am. Med. Assocn.,* p. 1687, Dec. 2, 1916) gives the following formula of Dakin's solution, which he obtained recently from Dr. Carrell at Compiège in May, 1916:

1. Chlorinated lime (bleaching powder)............ 200 gm.
   Sodium carbonate, dry.......................... 100 gm.
   Sodium bicarbonate .... 80 gm.

2. Put the chlorinated lime in a 12-liter flask with 5 liters of ordinary water, and let it stand over night.

3. Dissolve the sodium carbonate and bicarbonate in 5 liters of cold water.

4. Pour (3) into the flask containing (2), shake it vigorously for a minute, and let it stand to permit the calcium carbonate to settle.

5. After half an hour siphon off the clear liquid and filter through paper to obtain a perfectly limpid product. This must be kept protected from the light.

The antiseptic solution is then ready for surgical use; it contains about 0.5 gm. per cent. of sodium hypochlorite with small amounts of neutral soda salts; it is practically isotonic with blood serum. It should meet the following tests:

Test.—Put about 20 c.c. of the solution in a glass and pour on its surface a few centigrams of phenolphthalein in *powder;* shake it with a circular movement, as in rinsing; the liquid should remain colorless. A more or less marked red discoloration indicates the presence of a notable quantity of free alkali, or incomplete carbonation imputable to an error in technic.

Errors to Be Avoided.—Never heat the solution. If in an emergency it is necessary to triturate the chlorinated lime in a mortar, do so only with water, never with the solution of the soda salts.

Titration.—To 10 c.c. of the solution add 10 c.c. of distilled water, 2 gm. of potassium iodid and 2 c.c. of acetic acid. Pour into this mixture of decinormal (2.48 per cent.) solution of sodium thiosulphate (hyposulphite) until it is decolorized. The number of cubic centimeters of thiosulphite employed multiplied by 0.03725 equals the percentage of sodium hypochlorite in the solution.—Ed.]

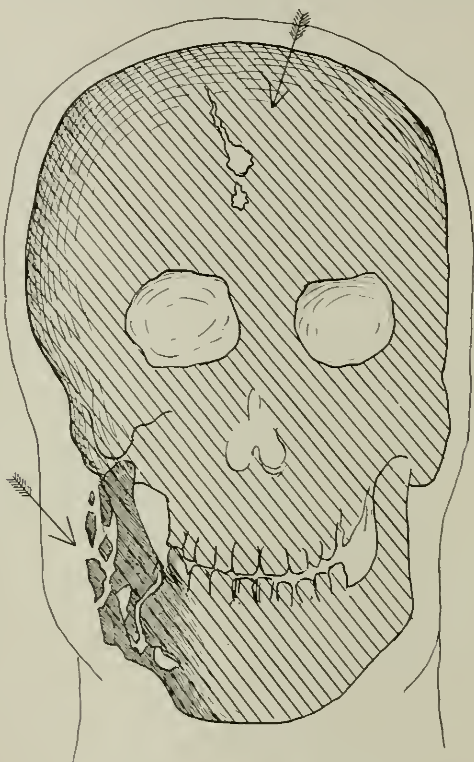
The efficacy of nearly all of the numerous other solutions which have been urged in the treatment of battle wounds depends mainly upon their high osmotic properties. Most prominent among them are various strengths of sea water or of solutions of sea salt; 50 per cent. glucose; 5 per cent. sodium benzoate; magnesium hypochlorite; magnesium sulphate, advocated by Morison and Tulloch (*Brit. Jour. Surg.,* Oct., 1915) in a solution of 40 ounces of the salt to 30 ounces of boiling water and 10 of glycerine; magnesium chloride in 1.2 per cent. solutions of the anhydrous and 1.7 per cent. of the crystalline salt (Delbet and Karajanopoulo—*Bull. de l'Acad. de Méd.,* Sept. 17, 1915, p. 266, confirmed clinically by Pinard, *ibid.,* Nov. 23, 1915, page 577); and finally, Locke's Ringer's and Schiassi's artificial serums, urged with much enthusiasm by Soubeyran (*Paris Médical,* Nov. 6, 1915) as nutrient serums during the reparative stage of wounds. All of these solutions have the common advantages of comparative painlessness and cheapness.

Surgical opinion has not yet crystallized on the use of *vaccines* in the treatment of battle wounds. There is much favorable clinical testimony, often of a striking nature, and in doubtful cases, or in those in which a smear shows streptococci, a prophylactic injection of vaccine containing streptococci, staphylococci and the bacillus of Welch seems indicated.

5. Wounds of the optic apparatus are no exceptions to the routine injection of prophylactic doses of antitetanic serum, usually 1,500 units given subcutaneously.

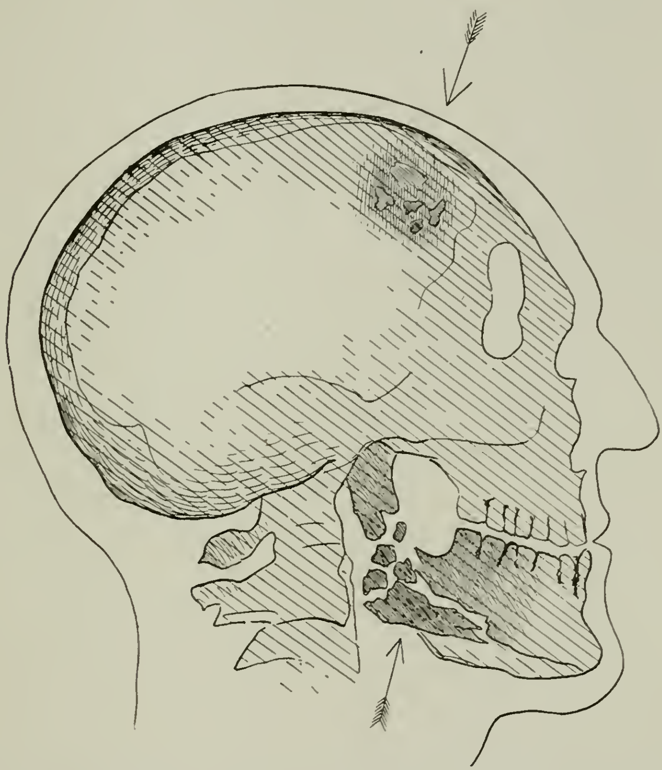
Before the principles of early cleansing of wounds, free drainage and continuous irrigation were clearly established in the present war, the incidence and mortality of tetanus and gas-bacillus infections was appalling. Bruce (*Lancet,* Oct. 23, 1915) reported a mortality of 57.7 per cent. out of 231 cases. Those with a short incubation were more often fatal, and most cases began on the tenth day after injury. Carbolic acid or magnesium sulphate injections were valueless. Bruce believes that the marked reduction in the incidence of tetanus seen in the British army after October, 1914, was due to the more rapid and effectual surgical treatment, to the routine use of prophylactic doses of serum "and generally that experience had taught medical officers how better to cope with the conditions obtaining in time of war, to unlearn the lessons of modern aseptic surgery and to revert to the older methods of free incisions, thorough drainage and constant removal of septic products by bath or irrigation." Wounds with much black, necrotic tissue, wounds which are uncommonly dry and those which discharge large amounts of very foul pus are likely incubating grounds and should be treated as such by cutting away the necrosed tissue as soon as possible, making smears from every wound as soon as expert bacteriological advice is available, and by using antitetanic serum immediately, persistently and, if symptoms have begun, extravagantly. At least 3,000 units of serum may be given intrathecally and up to 20,000 units subcutaneously or intravenously, combined with the unstinted use of chloral and of bromides, by mouth and by rectum.

Although the eye is one of the most, if not the most, susceptible and least resistant organs to infection, no case of tetanus has been reported after a simple perforation of the eyeball. Its relation to wounds of the eyes is mainly in connection with the wide crushing and lacerated artillery wounds of the orbital regions, and its treatment differs in nowise from that in general. In tetanus complicating head wounds, spasms localized on the same side of the head and neck, may occur together with trismus, as a genuine form of partial tetanus, although usually trismus, opisthotonos and other general symptoms follow tetanic infection of head wounds in close sequence. When such



Oblique Perforation of Skull, Face and Lower Jaw. Eye Lost by Indirect Violence. Comminution of Jaw Simulating Tetanic Trismus.

a condition remains localized on one side, the possibility of deep injury to the lower jaw, to one of its articulations or its muscles, must be considered. A case to the point is reported by Mills (*Jour. Am. Med. Ass'n.*, Oct. 23, 1915) in which a bullet traversed the right neck and face, ruptured the right eye by indirect violence, and emerged through the right external angular process. Under the Roentgen ray, a condition which had so simulated the crampy pains and trismus of tetanus that vigorous antitetanic treatment had been instituted, resolved itself into an extensive comminution of the right coronoid process, with spasm of the corresponding masseter and temporal muscles. The figures show the tracings of the roentgenograms of a similar case, in which the bullet perforated the midline of the frontal bone, ruptured the right eye posteriorly, and emerged through the neck after comminuting the entire right angle of the lower jaw. This patient recov-



Side View of Preceding Illustration. Abscess of Front Brain. Recovery.

ered after enucleation and the evacuation of an abscess of the right frontal lobe.

Bazy (abstr., *Jour. Am. Med. Ass'n.,* March 11, 1916, p. 829) calls attention to the gravity of *delayed tetanus,* which may occur from thirty to fifty days after the original injury, either as the result of secondary operations, or of operations remote from the site of trauma, or even without manifest cause. Drennen (*Jour. Am. Med Ass'n.,* July 24, 1915), Moynihan (*Brit. Med. Jour.,* March 4, 1916) and others have remarked that both tetanus and gas-gangrene infections may follow relatively trivial operative procedures upon old wounds of sinuses in which the circulation is feeble and bacteria have persisted in spore forms. Such cases, in particular, should receive a prophylactic injection of antitetanic serum the day before the secondary operation, and Bond (*Brit. Med. Jour.,* Sept. 2, 1915) suggests that the *recrudescence of severe local sepsis* which may follow reoperation upon completely healed but previously infected tissues, indicates the need for temporary routine drainage in such cases. Uhthoff (*Berl. klin. Wchnschr.,* Jan. 24, 1916) reports the case of a soldier who had been blinded by an oblique perforation of both orbits and globes and who suddenly developed symptoms of an orbital phlegmon over a year after the original injury. This led to death within a few days, apparently from cerebral sinus or venous thrombosis.

Gas bacillus infection of the orbital regions fortunately is rare, for the rapid and often dramatic spread of the *bacillus perfringens* beneath the scalp makes it exceedingly difficult or impossible of control in this location. Wide, multiple incisions, continuous irrigations and light, moist and frequently changed gauze dressings, or none at all, give the greatest possible aid, although most of these cases succumb at an early stage from meningeal complications, the orbit itself not infrequently being the atrium of infection to the meninges.

6. The condition and consequent treatment of the wounded often is more dependent upon the degree of their psychic and physical exhaustion than upon the nature and extent of their wounds. Bowlby (*Brit. Med. Jour.,* Dec. 25, 1915) illustrates this vividly: "When the intense excitement of fighting for life and killing other men in the midst of the crash of shells and the clatter of rifles and machine guns has passed, then there comes the reaction and the exhaustion of a tired-out man and an overwrought nervous system. Those who only see the men in the base hospitals have little idea of the silence of a crowded room in a clearing station when heavy fighting has been in progress for a day or two. There are hundreds of men whose best chance of life is to be kept warm and left absolutely quiet and persuaded to take hot soup or cocoa before again going to sleep. It is at first surprising to find how many quite pulseless men will slowly pull round if given time and kept thoroughly warm. Often they are so nearly dead that it may be several hours before an attempt can be made to dress their wounds, and even with every care there are not a few who die."

Numerous lives have been saved by the free subcutaneous and intravenous injection of normal saline, by the use of enemas of hot water and brandy and hypodermics of pituitary extract. In multiple wounds such as result from fragments of bombs and showers of gravel and mud, although the wounds may be quite superficial, the patient may be collapsed, as after extensive superficial burns with shock, and Bowlby completes the parallel by suggesting the use of picric acid solution in such cases.

A regional classification of battle wounds of the optic apparatus is necessarily inexact, for uncomplicated injuries of the eyeball, as well as of other parts of the optic apparatus, are the exceptions, but only by such a classification can the essentials of military ophthalmology be systematically approached.

1. *Wounds of the lids and adnexa* very often complicate lesions of the globe and of the face, and the problems of plastic surgery which arise out of their injury frequently tax the ingenuity of the surgeon to the utmost.

The majority of these wounds are caused by the explosion of bombs, grenades and shells, and the lids and the surrounding regions are often so incrusted with incompletely burned powder grains and with gravel, powdered earth, mud and metal particles that the picture is one of literal tattooing and gives the features a characteristic brown-black mask, in which the conjunctivæ and corneæ usually share. The lids are generally contused and more or less lacerated, tears of the palpebral borders are common, and areas of contusion-gangrene frequently result. The lids rapidly become edematous and swollen, the swelling often closing the eyes within a few moments; the conjunctiva becomes chemotic and the lids are soon glued together by a sticky, brownish discharge. Foci of necrosis form soon about each imbedded particle, a bright-red areola being the initial stage of a frank suppuration which appears within a few days and usually loosens such small foreign bodies as have not been removed. This form of focal suppuration singularly resembles the pustule, and, in its result, the cicatrix of variola. Recurrent attacks of fugitive erysipeloid inflammation, as well as true erysipelas, often follow multiple perforations of the lids and adjacent tissues by projectile splinters and secondary missiles and are seldom grave, although in connection with adjacent open meningeal and cerebral wounds, rapidly fatal infection is not uncommon, as the meninges and brain seem to be especially susceptible to the action of the streptococcus. If attacked by injections of antistreptococcic vaccine early enough, these erysipelatous conditions can practically always be checked and cured. A 1 to 80 solution of phenol in a half-saturated solution of glucose, as suggested by Whitehouse, may be used in the form of a light but continuous wet dressing with much relief.

In bullet wounds of the lid and the grosser lacerations made by fragments of artillery missiles, extensive and at times irreparable loss of tissue occurs, often associated with rupture of the eyeball and more or less extensive conjunctival laceration. In the smaller colobomata and in gutter shots of the lids where the gain in sightliness of first intention scars is of first consideration, infection can be aborted in suitable cases by immediately excising the contused surfaces and suturing the fresh wounds together. It is of the utmost importance for the later wearing of a prothesis that tears of the lids and conjunctiva be united, even if but loosely, as soon as possible and this is particularly true of tears of the canthi. If primary union does not take place because of the extreme chemosis, at least the severity of the secondary plastic will have been much modified. Often the ciliary borders are turned in or out, as part of the original effect of the projectile or of the cicatricial contraction or symblepharon, and it is at times exceedingly difficult to reconstruct their line or to so recreate the lids that an artificial eye may be supported or retained. Where lids have been partially or completely torn away, or the late contraction has become excessive, sliding pedicled flaps or heteroplasties may be used as soon as conditions permit. The complete temporary closure of the lids by suture is often necessary to secure coaptation of the flaps and to prevent their retraction, the later separation of the opposed lids leaving no trace. Complete loss of the upper lid practically always means loss of the eye, even if this has been uninjured, although the use of a pedicled flap, backed with a conjunctival transplant from the eye of a recently killed donor and sutured temporarily to the lower lid offers some slight chance of saving the eye; or, in many cases, it will at least support a prothesis. Where the lower conjunctival cul de sac has been totally obliterated, the cicatricial adhesion between the lid and orbital tissue is completely freed and the newly formed cul de sac is lined by an ellipse of skin—the prepuce is highly adapted to this use—and held in place by suture and a gauze tamponade, after the manner depicted by Terrien (*Paris Médicale*, Sept. 25, 1915, p. 343); or, if this procedure fails, the method of Hotz or others may be tried. See p. 1080, Vol. II of this *Encyclopedia*.

Among plastic operations for these extensive defects Uhthoff (*Berl. klin. Wchnschr.*, Jan. 3, 1916) uses that of Fricke most often and finds that it is always possible to create some sort of a sac for artificial eyes.

Powder burns of the lids, conjunctiva and cornea are the result of the premature explosion or careless handling of artillery fuses, trench bombs or grenades. They produce leucomatous markings upon the cornea but seldom tattoo it. After the explosion of mines the ocular injuries resemble similar injuries in civil mining practice, the lids, conjunctiva and cornea being encrusted with innumerable tiny foreign bodies, the cilia burned off and the globes injured in every conceivable manner.

Genet (*Lyon Chirurgical,* Nov. 1915) calls attention to erosions and lacerations of the lids and conjunctiva from the barbed wire of wire entanglements and refers to subconjunctival ecchymosis following shell concussion.

Bayonet wounds make up practically all of the incised wounds of the lids and eyes. A direct lunge into the orbit is practically always fatal at once from cerebral laceration and uncontrollable hemorrhage, but for the most part the rather infrequent bayonet wounds of the orbital region which survive to reach surgical aid are received during sharp parries and most of them are merely superficial slits of the lid margins, with or without perforation of the eye. As bayonets are frequently used as accessory trench and camp tools, their wounds are nearly always infected. One of my patients was standing in his trench with his rifle at rest and its fixed bayonet tip about on a level with his eye. A bullet struck the blade, driving the tip smartly backward and cutting through the lower lid and sclera of the left eye from canthus to canthus and requiring enucleation.

As a complication of stab or projectile wounds of the lids, nose and face, sometimes the lachrymal duct is more or less completely severed. Usually, by the time the patient reaches specialist hands a suppurative dacryocystitis has developed and extirpation alone makes the cure certain, but where treatment is possible shortly after injury, suture of the mucous membrane and skin in front of a hard rubber sound passed through the canaliculus and the severed ends of the duct usually gives a patent duct. For similar injuries of the canaliculi Elschnig (*Klin. Mon. f. Aug.*, 55, p. 144) passes a fine, hard-rubber sound through the punctum and down through the nasal end of the severed canaliculus, after silk sutures have been placed both on the conjunctival and skin surfaces of the injured lid. The sound, cut off so that about an inch protrudes from the punctum, remains in place for seven days, vaselined gauze being placed between lid and probe for protection.

Wounds of the orbit and orbital tissues, while more often the result of fragments of artillery projectiles and their secondary missiles, are usually of a more serious nature when caused by bullets, especially at the closer ranges, and associated lesions of the eyeballs, the optic and other ocular nerves, the nose and accessory sinuses and of the anterior and sometimes the middle cranial fossa are seldom lacking and occur in every possible form and combination. Practically the only uncomplicated injuries of this region result from the very occasional oblique, classical, long-range perforations of the orbital buttresses by rifle bullets and from the much more common lodgment of small metal and other fragments of primary and secondary missiles in the orbital tissues, without injury to the globe. The orbit and its contents are further often involved, through the media of fractures and fissures, in contusions, penetrations and perforations of the bones of the mid-face of the frontal and temporal regions and of the base of the skull.

The results of orbital injury vary according to the type and velocity of the projectile, to the obliquity of its path and its depth in the orbit. Spent rifle and shrapnel bullets may merely contuse the orbital margins, and lacking sufficient force to perforate, may merely fall back or may flatten out and spatter or lodge without further injury. Mills reports a case of the last sort (*Jour. Amer. Med. Ass'n.,* Oct. 23, 1915, p. 1427) in which a supposed gutter shot of the lid inexplicably reduced the vision to 6/18. No particular limitation of motion was observed. The wound became reinflamed about three weeks after the injury and at operation an undeformed bullet was found lying snugly in the soft tissue beneath the bulb, slightly in front of the equator, its axis in the coronal plane. Vision returned to 6/6 shortly after the removal of the foreign body. The effect of short-range bullets upon the condensed bone of the orbital margins is one of intense comminution. It is not uncommon to see the entire orbital rim fractured into numerons fine fragments which may be driven in upon and into the globe throughout the whole circumference. Often only portions of the rim are indriven, in which case they cause localized injury to the globe or, by lacerating and becoming inextricably mingled with the extraocular muscles and nerves, limit motion of the globe mechanically, or by causing peripheral paralysis of the motor nerves. In the great majority of such injuries, however, the globe is more or less irretrievably ruptured. Uhthoff (*Berl. klin. Wchnschr.,* Jan. 3, 1916) reports that 83 per cent. of his cases of orbital injury, mainly by bullets, required enucleation. In the great majority of these cases where the globe is ruptured, this has not been caused directly by the projectile, but by the fragments of the orbital margin, which thus becomes a peculiar menace to the eyeball in military injuries, instead of the stout protection which it affords against industrial traumas.

The difference between the condition of the tissues surrounding the eye and that of the eye itself is often amazing. A simple contusion of the orbit of such a nature that the wound can scarcely be found not infrequently causes serious intraocular damage, while with a gaping wound of the frontal bone or an open fracture of the superior maxilla, the lids may be so swollen and filled with blood that they can hardly be opened with retractors, and yet the globe may be found intact.

Injuries of the bony orbit by the larger fragments of artillery projectiles are chiefly crushing injuries, usually with considerable loss of tissue and consequent mutilation. Most of these cases die at once, or within a short time from cerebral injury and shock. In the

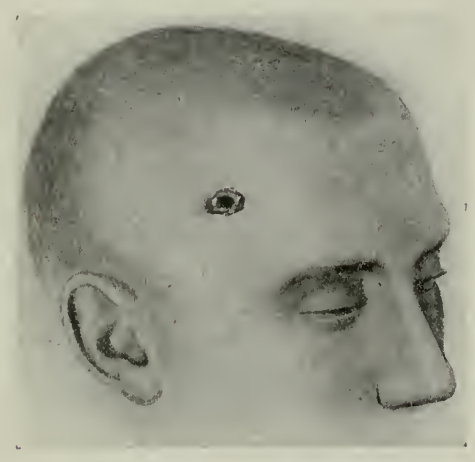
Shell Wound Simulating an Operation Flap.
The superior orbital margin was powdered, fragments being driven into the protruding right frontal lobe, as well as causing rupture of the globe posteriorly.

surviving cases the involved eye is always lost, in fact is frequently so destroyed or blown out that no trace of it can be found, and infection occurs in practically every instance from the amount of dirt and foreign matter which is always ground into the large, irregular wound and because these, together with short-range bullet wounds of the region, are particularly the cases in which the nose, the antrum and the other accessory sinuses, together with the anterior cranial fossa, are breached into a single, gaping, infected cavity. Death from streptococcus and rarely from B. perfringens or tetanus infection not infrequently follows unless the dead, contused tissue is unsparingly cut away, foreign bodies removed, the freest drainage provided by means of gauze wicks, wet in sodium hypochlorite solution, and lightly but effectually placed into every recess of the wound and frequently changed. Above all things such dressings should not be "waterproofed" with rubber tissue or other impermeable coverings. Where such treatment is instituted promptly, little or no pus forms, foul wounds clean themselves quickly, vigorous granulations spring up and the treatment resolves itself merely into that of a large granulating wound. Of course all such cases receive antitetanic serum, and a mixed vaccine, in which the streptococcus predominates, often seems to be of marked assistance. In view of the initial destruction of tissue, the final deformity is often surprisingly slight.

To devise plastic operations to lessen the disfigurement and to enable artificial eyes to be worn is the final work of the ophthalmic surgeon in these cases and it must be kept in mind constantly that the time for bone-grafting, for cartilage implantation and for the replacement of soft parts by fat transplantation, which are the foundations of this work of restoration, is before vicious fibrous or bony union has taken place, and further, that cicatricial over-effect following operation must be watched for and treated by long, patient and often painful effort, frequently lasting over months. In neglected cases tissue upbuilding is possible only through patiently repeated operations. The detail of some methods of repair is discussed by W. Levy (*Centralb. f. Chir.*, July 3, 1915) under the title "Osteopathic Restoration of the Orbital Margins after Battle Wounds." Morestin (*Bull. et Mém. Soc. de Chir. de Paris*, Nov. 2, 1915, and Feb. 15, 1916) also details the successful treatment of a number of cases of traumatic defect of the upper orbital arches, as well as of frontal and other skull depressions or defects, by implanting or grafting the costal cartilages of the sixth, seventh and eighth ribs, trimmed to the required shape, the graft "taking" without difficulty even when not autogenous.

The effect of shrapnel bullets upon the orbit is often indistinguishable from that of fragments of shells or from close-range rifle bullets. They not infrequently smash the temporal side of one orbit, crush the eye and lodge in the orbit or in the bones of the nasal fossas, true to their characteristic lack of penetrating power. The same characteristic marks their effect upon the fronto-temporal regions; nearly always grave, depressed fractures, or penetration of the skull and lodgement in the brain being the rule.

Probably the most typical bullet wound of the orbit and certainly the most striking one is that in which the external angular process of the frontal bone and the anterior portion of the temporal wall of the orbit are more or less completely carried away, giving an exposure of the orbital contents so identical to that afforded by the Krönlein osteoplastic resection as to suggest the name "Krönlein shot" for this particular form of injury. The eye is always torn out, or more or less completely shattered, scleral and uveal remains being driven deep into the soft orbital tissue. The immediate deformity is considerable and unsightly, especially as a traumatic coloboma of one or both lids usually occurs, but the final deformity is often amazingly small when the extent of the injury is considered. This is greatly aided by the earliest possible closure of the remains of the lids by any form of



Shrapnel Bullet Wound. Bullet Lodged in Opposite Temporal Lobe. Death from Meningitis on Eighth Day.

blepharorrhaphy most applicable to the individual case. Probably because of the free drainage, serious infection seldom follows this particular injury. Where the damage has been limited to a temporal gutter, with little or no fragmentation of the orbital margin, the wound may be excised at once and sutured, saving time, possibly septic complications and giving a sightly scar.

Antero-posterior bullet shots of the orbit are rare, probably because of the frequency of enfilading fire and of the usual lateral and decidedly prone position of the head in sighting. For the same reason the great majority of cranial wounds are oblique, and in many of the facial wounds the orbital injury represents merely the wound of entrance of a missile whose oblique course through the face, neck and chest is often spectacular in its results and not infrequently immediately fatal. In one common injury the bullet enters the front or side of the orbit and, after seriously contusing or rupturing the eye by direct or indirect violence, passes through the antrum, the mouth or the lower jaw and emerges through the neck or thorax, or lodges somewhere in the lower part of this course. The full extent of these injuries is seldom disclosed without the aid of the X-ray. The immunity of the great cervical vessels and nerves seems to be remarkable, and we have seen many cases in which bullets crossed the entire neck obliquely from above downward, or passed transversely, without the slightest injury to vessels or nerves. These, however, were the fortunate cases. Vertebral injury is not rare in these oblique shots, and the relation of damage to the sympathetic ganglia and the eyes is not to be lost sight of in such injuries.

In many of these oblique shots the antrum, frontal sinuses, ethmoid and rarely the sphenoid cells are opened, and unless treatment of the direct path of the missile is combined with careful endonasal therapy, such as the removal of bone and metal fragments, the free drainage of the inevitably infected sinuses, and particularly the prevention of the almost constant turbinal synechiæ, the soldier may be discharged as relieved of his ocular condition, only to be invalided back from the front after a brief period, with all the distressing sequels which follow the intranasal sequestration of fragments of bone, empyema of the sinuses or the formation of dense, broad and often complete turbinal synechiæ. In this connection it should be remembered that transillumination and radiographic findings are of uncertain value in such cases, owing to the amount of swelling and granulation tissue in the mucous membranes and to the later bony thickenings which obscure the definition and often are mistaken for accumulations of pus. Wounds of the antrum may give rise to more or less marked enophthalmos through defects in the orbital floor.

Fractures of the orbital plate are not uncommon in wounds of the upper face and of the anterior portion of the skull. These fractures run mainly in zigzag, sagittal direction, may be single or multiple, and in nearly all cases fragments are driven more or less deeply into the orbit, lacerating vessels and nerves and often, though not always, injuring the eye. The main evidences of this injury appear as diffuse hemorrhage into the orbital fat, the lids, especially the upper, and the conjunctiva and more or less protrusion of the globe and limitation of movement, both being most marked in localized retrobulbar hematoma. Mills (*Jour. Amer. Med. Ass'n,* Oct. 23, 1915) reports an extreme case of orbital fracture accompanying a bullet fracture of the frontal bone, in which "the lacerated frontal brain, with much serum and cerebral fluid had poured through the widely-spread breaches in the orbital plate, had driven the eye forward and had transmitted the cerebral impulse to the protruded ball,'' producing a form of pulsating exophthalmos hitherto unreported. The fracture most often seen at operation or autopsy, lies just external to and roughly parallel with the olfactory bulb and may involve the lesser wing of the sphenoid and the optic foramen posteriorly, or fissure into the frontal sinus anteriorly. A partial or complete loss of function of the optic nerve is not uncommon, owing to the laceration or actual crushing of the optic nerve in the optic canal, to compression by hemorrhage into its sheath, or by a large orbital hematoma. Although the first objective evidence of damage to the optic nerve in these cases is the failure of reaction of the pupil to light, while the consensual reaction is preserved, more or less gross defects in the visual field quickly become apparent and in the course of two or three weeks distinct whitening of the disk indicates the progress of an optic atrophy. The full visual defect is not usually apparent for some additional weeks or months.

That the danger of purulent affections of the frontal and ethmoidal sinuses involving the brain through the defective dura in these fractures is real, is shown by two cases of Genet's (*Lyon Chir.*, Nov., 1915), in one of which a fracture of the orbital plate connected with a horizontal fracture of both frontal sinuses and with a fine comminution of the cribriform plate. In the second the orbital floor was opened into the nasal cavity, which was thus put into communication with the brain through the fractured orbital plate. Both men died with symptoms of meningo-encephalitis on the 31st and 13th days respectively after injury.

Lateral or side-to-side perforations of one or both orbits by bullets have occurred with much greater frequency in modern wars because of the increased penetrating power of the modern bullet and the greater frequency of close-range conflict. In the war of 1870 the Germans collected 28 cases of transverse wounds of the orbit, in 9 of which both eyes were immediately destroyed, while in the present war an average of all available statistics shows that both eyes are lost in about one-tenth of all bullet wounds of the orbital regions. Where both bulbs are perforated, the area affected at the exit of the bullet nearly always presents a great, gaping laceration through which bullet, orbital contents and bone have emerged, the secondary missile action of the orbital walls nearly always causing grosser damage than the bullet.

Many of the anterior, and most of the retrobulbar transverse perforations of the orbits are immediately fatal owing to direct injury to the brain, to pulpification of the adjacent brain by intense molecular vibration, the counterpart of the condition seen not infrequently in bullet wounds of the spine, or to hemorrhage from the large retrobulbar and basilar vessels. In these last cases marked degrees of simple or of pulsating exophthalmos are not uncommonly observed on the battlefield before death. Among the surviving cases of retrobulbar perforation of the orbit, the eye may be ruptured about the posterior pole, or may be blown out of the orbit, the optic nerve may be severed more or less completely close to the globe or near the apex of the orbit, or may be crushed or torn in its canal by fissures or fracture of the canal, orbital hematoma may form from laceration of the vessels, motor and sensory nerves may be divided or destroyed and finally, in the deeper perforations, pulsating exophthalmos may result. Grave and even fatal infection may follow.

In rupture of the posterior segment of the eye by the near passage of a bullet, the rupture may be complete, with only scattered scleral and uveal tissue remaining in the orbital tissue. Behind an intact anterior segment of the eye, however, choroidal and retinal ruptures of types almost never seen in civil traumas not infrequently exist. The typical concentric rupture seen in contusion of the globe is rare, but many-shaped tears, stellate, Y-shaped, branching, vertical, horizontal, single and multiple, occur throughout the whole posterior segment in common with retinal detachment, choroidal tears and grave intraocular hemorrhage, often sufficiently severe of itself to destroy the eye. Such wounds offer an unusual nidus for infection and loss of the eye by suppuration, or by atrophy, if no infection occurs, is almost certain.

One of the most spectacular occurrences of the war is reported by B. Fleischer (*Muench. Med. Wchnschr.*, Jan. 19, 1915, p. 98), who records the case of a soldier who felt a sudden blow on his head which caused his helmet to fall off forward. The man naturally was astounded to find his own right eyeball lying in the hollow of the helmet, unruptured. A bullet had entered just in front of the left ear and had emerged in front of the right external canthus, leaving the bulbar conjunctiva as smoothly divided as though an ideal enucleation had been performed.

The immediate intraocular effect of the more or less uncomplicated *division of the optic nerve* depends upon the nearness of the point of severance to the bulb. When the lesion is close to the bulb and the central retinal vessels are divided with the nerve, the retinal vessels are bloodless and the retina has become gray, cloudy and dead by the time of the first examination. The pupils are dilated and the light reflex is abolished. Often large retinal hemorrhages are found about the papilla, which may be much distorted owing to the traction placed upon it at the time of injury. In the more remote and uncomplicated lesions the intraocular changes are slight and the picture is one of simple, rapidly progressive atrophy, and when these cases are seen some time after the injury the cutaneous scars alone mark the path of the missile and indicate the type of lesion. Very often the path of the bullet has not been exactly transverse and the same bullet may divide the optic nerve near one apex and rupture the globe of the opposite orbit. Often the olfactory nerve is destroyed in transverse wounds.

Both rifle and shrapnel bullets lodge in the orbit and may cause *pressure atrophy of the optic nerve* either directly, by causing hemorrhage into the sheath of the nerve by the crush of depressed bone in fracture or fissure of the canal, or as a result of a large retrobulbar hemorrhage which is almost inevitable if the bullet passes through the orbit near its apex. The pressure and final fibrosis of the larger extravasations of blood and possibly the drag of the long-continued protrusion may be factors in the atrophy which follows large retrobulbar hematoma. In view of the fact that practical vision may be restored after apparently complete paralysis of the optic nerve following perforation of the orbit, which may be ascribed to the resorption of blood clot, to the subsidence of inflammatory reaction in the adjacent tissue or, possibly to recovery from molecular changes produced by concussion or contusion of the nerve, it seems possible that some further advance may be made in those cases of blindness in which, after plotting the course of the ball, there is a possibility that the nerve has not suffered direct injury. Under such conditions a deep incision into the orbit, carried along the floor nearly to the apex, as in deep orbital phlegmon, may be of aid, with consequent drainage, or a Krönlein resection of the external wall may be justified.

Only in rare cases are the motor and sensory nerves and the optic nerves injured by orbital fracture and fissure within the optic canal. Terrien (*Paris Médicale*, Sept. 25, 1915, p. 346) has observed 3 cases of optic atrophy due to a fracture of the optic canal "by irradiation." Immediate loss of vision, wide dilation of the pupil and the loss of direct and consensual reflexes are noted, with complete integrity of the fundus.

Indirect injuries of the eyeball make up over 6 per cent. of all battle injuries of the eyes in present-day warfare, and are of two forms:

1. Injuries which are purely the result of *air-contusion* or *air-decompression*, consequent upon the bursting of high-explosive shells in the near neighborhood. It is now generally recognized that many of the severe wounds of the eyeball in which there is no trace of the influence of a foreign body are the direct result of the play between

the enormous increase in pressure produced by the giant explosion and the consequent atmospheric thinning which causes violent suction. The lids may be torn, and the globe be actually dragged out of the orbit (Steindorff—*Berl. klin. Wchnschr.*, Nov. 9, 1914) and all forms of intermediate injuries may be produced. The explosive action which hurls men into the air and to the ground may cause severe injuries of the skull by this trauma, with secondary injuries to the optic nerves as a result. Steindorff states that small arms may produce a similar effect on the eye and instances a case of hemorrhage into the vitreous with secondary ablatio retinæ following the discharge of a rifle, the muzzle of which was held close to the cheek of a soldier in a front rank. Darier (*La Clinique Ophtal.*, Oct., 1914) and v. Grósz (*Wien. klin. Wchnschr.*, Nov. 11, 1915) report choroidal tears and retinal dullness following shell explosions, and the latter makes the interesting note that traumatic cataract from this source may be spontaneously absorbed and require only an appropriate lens to restore full vision. Lagrange (*Bull. de l'Acad. de Méd.*, May 18, 1915, p. 599) instances a case of subluxation of the lens from this source of trauma and gives the rather remarkable case of a soldier who was rendered unconscious for about ten minutes by the nearby explosion of a shell. Although he suffered some pain in the right eye, he continued on duty until incapacitated by another, though obvious wound. The vision of his right eye failed rapidly and examination showed a posterior staphyloma, M of —13.00 D, a pronounced chorio-retinitis about the macula and a large uveal detachment. V. O. D. with + 0.50 sph. = 4/10. The patient had always used his right eye for shooting and was considered an excellent shot at the time of his first injury. Lagrange believes that the myopia was either the direct result of the displacement of air communicated to the deep tissues, or that the elongation followed the inflammation and detachment and consequent thinning of the choroid. He concludes that a routine examination of the eyes should be made in every case of wounds of the face or skull. Pagenstecher (*Muench. med. Wchnschr.*, Nov. 16, 1915) has noted deep corneal opacities, rupture of the zonula, Berlin's opacity, retinal hemorrhages, choroidal tears and acute glaucoma with corneal murkiness on the same side as results of this form of trauma. He reports the case of a soldier who was felled to the ground by the explosion of a shell 3 meters distant. He fell back down, but without striking his head. After 15 minutes of unconsciousness he noticed that he did not see well. The retina was hazy, the margins of the disks were indistinct and a fine, red-brown discoloration was apparent in the maculæ. In both eyes the fields were at first contracted, the left showing a central scotoma for all colors using a 3 mm. disc, though 5 mm. discs of red and green were identified. Atrophic changes remained in the left macula, this eye seeing 6/18 and Jaeger 2 against 6/6 and Jaeger 1 for the right eye. Pagenstecher found the ''Heurteloup'' artificial leech, by which ½ to ¾ of a cylinder of blood was withdrawn from each temple every 6th day, of much value, as were hot foot-baths. These cases were of a sort which would easily have passed for ''simulation'' or ''hysterical amblyopia'' without the exact examination of a trained ophthalmologist. Schreiber (*Münch. Med. Wchnschr.,* Nov. 23, 1915) gives tears of the lids, intraocular hemorrhage, irido-dialysis, subluxation of the lens and retinal detachment as results of shell explosions. Vitreous hemorrhage is often absorbed very slowly and its effects often endure with permanent visual reduction. In practically all cases of commotio retinæ from shell concussion, an immediate examination of the fundus, whenever the absence of intraocular hemorrhage permits, discloses the characteristic milky haziness of the retina which disappears in a few days but leaves permanent defective central vision in about a third of the cases. Transitory paralysis of accommodation is not uncommon and complete separation of the iris has been observed, with the iris seen as a formless mass at the bottom of the blood-filled anterior chamber.

Bennett (*Brit. Med. Jour.,* Dec. 11, 1915, p. 848) describes a case of bilateral iridodialysis with amblyopia and contracted fields following the explosion of a shrapnel in the mud about 4 feet to the left and in front of the soldier. He was completely blinded for the time but the vision gradually returned to 6/9 and 6/12. A half-moon detachment of the iris from its ciliary origin was found nasally and above in both eyes. The fundi showed the characteristic pallor and edema of commotio retinæ, and both disks were paler than normal and had ill-defined margins. The fields were strongly contracted, especially for red and green, and showed no improvement after several months. The eccentric pupils caused slight but not inconvenient monocular diplopia. Lumps of wet clay probably caused the trauma and it is likely that this case should be considered one of direct rather than indirect injury. Bernhardt (*Berl. med. Wchnschr.,* No. 9, 1914), Zade (*Münch. Med. Wchnschr.,* Nov. 22, 1915) and Hertz and Ormond (*Lancet,* Jan. 1, 1916, p. 16) report cases or discuss the subject. In cases such as are reported by Evans (*Brit. Med. Jour.,* Dec. 11, 1915, p. 848) where multiple ruptures of the choroid are found, with multiple retinal and vitreous hemorrhages, the disks later become atrophic and vision is reduced to barely enough for locomotion. The atrophy is of the type seen after the retrobulbar passage of high-velocity projectiles. Butler (*Brit. Med. Jour.,* Dec. 11, 1915) observed three cases of optic atrophy after shell concussion and vitreous hemorrhage. Atrophy of the optic nerve, presumably from hemorrhage into the sheath, has also followed this form of trauma. Genet (*Lyon Chir.,* Nov. 15, 1915) reports a case of luxation of the lens into the vitreous after the explosion of a large-calibred bomb. Photophobia, blepharospasm and chronic accommodative spasm, with the creation of artificial myopia, have been frequently observed, and the fact is now well-established that shell shock is capable of making manifest many previously unsuspected latent ocular defects such as squint, strabismus and the entire range of refractive errors and muscular imbalances.

Identical injuries are produced by the accidental explosion of percussion caps while being handled.

The effect of the terrific explosions of artillery missiles upon the cortical visual centers and the optic pathways in the brain is discussed under the heading of *traumatic ocular psychoses of battle.*

2. Another group consists of indirect lesions in which the ocular coats have been detached, ruptured or otherwise seriously injured by contusion, penetration or perforation of the orbital cone by projectile or other injury, with no possibility of contusion of the globe, either directly or through the lids, or secondarily by fragments of bone driven from the orbit. The first recorded injury of this sort appears in an early edition of Senn's *Surgery,* in which a case of rupture of the iris noted during the Mexican war was ascribed to contraction of the eye muscles caused by the shock of the nearby impact. Most of such lesions result from oblique perforations of the fronto-malar region and antrum and form a type of injury which parallels the unique cases of pulpification of the base of the brain when the path of the bullet has been purely facial, the cases of indirect intestinal rupture where the pelvic girdle alone has been hit or the abdominal wall perforated tangentially, and those cases of hemorrhage into the spinal cord which often follow the mere passage of bullets through the cervical muscles without touching bone. The impact of the missile upon any part of the orbital cone is transmitted to the globe by a certain amount of spring of the bone and condensation of the soft tissues and the usual type of injury produced may be regarded as a form of contrecoup, for the eye, being an incompressible sphere, and consequently occupying the minimum space, is peculiarly liable to absorb sharp changes of pressure and to transmit them to the least resisting parts of the ocular coats.

The clinical evidences show that this deflected energy is most effective for trauma in the region about the posterior pole, where

Berlin's opacity, retino-choroidal hemorrhage, retinal detachment, choroidal rupture and retinal tears occur in about this order of frequency and in nearly every combination possible. The characteristic form of healing of the torn surfaces is that of retinitis proliferans and the visual defect is often grave and permanent, even though the condition be recognized and treated early. The fact that while concentric tears of the choroid are not uncommon in this type of injury, yet that the lesions may assume all manner of forms, may be horizontal, vertical, branched, stellate or cruciform and so located as obviously to exclude impact of the optic nerve upon the globe as a factor in their production, leads Mills to believe (*Ophthalmic Record,* June, 1916) that the main factors which localize most of these injuries in the posterior segment of the eye are the usual backward direction of the trauma, and the greater susceptibility of the posterior polar region to trauma from its structural weakness and the greater thickness of the retina and the fluid choroid in this situation. The resisting and inelastic retina sustains the impact of the transmitted force, as in direct contusion of the globe, and the transitory retinal edema which follows is found in practically every indirect injury when seen sufficiently early and not obscured by hemorrhage into the vitreous. The retinal changes in this commotio retinæ parallel the course of commotio cerebri very closely. The milky retinal haze reaches its height in from several hours to two days and in the lighter cases disappears in from two to three days more, without leaving a macroscopic trace of its existence, although scotomata are frequently found without corresponding gross retinal changes, as in direct contusion. In the more intense cases macular pigmentation may appear after a varying interval and is always associated with marked loss of vision and even with late optic atrophy, into any given case of which, however, the question of hemorrhage into the sheath of the nerve or ultramicroscopic retinal changes as suggested by von Merz (*Klin. Monatsbl. f. Augenh.,* Beilag., 1907) may enter. As in commotio cerebri, capillary hemorrhage occurs frequently and is not uncommonly limited to the macula in the form of the cherry-red spot seen in embolism of the central artery. Butler (*Brit. Med. Jour.,* Dec. 11, 1915) and others report cases of this sort. Local atrophy and grave functional changes invariably follow. Hemorrhage into the vitreous is the natural accompaniment of every tear of the retina and choroid. In most cases this is fairly rapidly absorbed. In some cases, however, absorption is very slow or not at all, and in these, if not in all cases of intraocular hemorrhage where the tension is not too low, the use of eserine in place of the commonly-employed atropine, as suggested by Feilchenfeld

(*Deutsch. med. Wchnschr.*, Dec. 2, 1915) seems to be logically indicated. In some cases the vision improves slowly, in others it diminishes progressively and in still others, the cause of blindness may finally be shown by the absorption of the effused blood, to be a rupture of the choroid in the macula region or some other irrevocable injury. Ormond (*The Practitioner*, London, May, 1916) is of the belief that any method whereby the blood can be prevented from or delayed in forming a solid, clotted mass in the vitreous, makes for its absorption, and to that end he suggests that the eye be permitted the freest movement, that digital massage—pneumatic would seem preferable—and ionic medication with iodine be used. Elschnig (*Med. Klinik*, May 16, 1915) has treated several cases of this sort with gratifying results by his method of substitution of the vitreous and, as it has been shown by Mills (*Ophthal. Record*, June, 1916) that the careful introduction of warm normal saline into the vitreous is a harmless procedure, the substitution of part of the blood-filled vitreous by this solution or by sterile distilled water, to promote diffusion and disintegration of the blood globules is worthy of trial, especially in eyes where vision is at a standstill or is steadily failing.

Retinal detachment occurs in a surprisingly large proportion of these indirect injuries and from a study of his cases and of those reported by Rollet and Mangini (*Lyon Chir.*, Oct. 1, 1915), Mills (q. v.) concludes that: 1. spontaneous reattachment of detached retina produced by indirect injury occurs in from one-third to one-half of the cases; 2. the fact that practically all of these cases are ambulatory lends weight to the opinion that there is actually less intraocular movement and more chance for adhesion with ambulatory treatment than by prolonged and often restless confinement to bed; 3. that a distinction must be made between the prognosis of these traumatic retinal detachments in young, healthy individuals and that of purely exudative origin and; 4. that the treatment of election of these traumatic indirect, as well as the direct form, is complete aspiration of the subretinal fluid, repeated if necessary, through a trephine opening placed low in the sclera. If this is ineffectual in preventing reaccumulation of subretinal fluid, with its consequent redetachment, the slow, deep intravitreous injection of warm, repeatedly filtered and fractionally sterilized normal saline solution, given under tonometer check until normal tension is restored, or the retinal detachment pressed into place and subsequently anchored, is suggested as the result of animal experimentation and unpublished clinical work. Further unpublished work shows that the temporary introduction of a fine seton subretinally may be of substantial aid in lessening the frequency of subretinal reaccumulations, or in preventing them. Attempts to deflect the subretinal exudate or transudate by local measures of forced elimination such as a dry, restricted diet, sweating and the use of dionin and other suitable subconjunctival injections are not contraindicated by the operative procedures, although repeated subconjunctival injections somewhat increase the operative difficulty by finally causing more or less tight adhesion of conjunctiva and sclera. Higgens (*Lancet*, Jan. 29, 1916) produced reattachment in two cases of retinal detachment resulting from shell explosion, by galvano-puncture between the external and inferior recti, posterior to the equator, gaining practical vision thereby in otherwise worthless eyes.

Bonnefon (*Bull. de 18 Acad. de Méd.*, May 2, 1916; abstr., *Jour. A. M. A.*, p. 2042) strongly advocates ignipuncture in the region of the equator as soon after the injury as it is possible to operate, on the ground that the retina loses its vitality so very rapidly after detachment that by the time the patient reaches a base hospital permanent damage to the retina has resulted. For this reason Bonnefon states that treatment of retinal detachment is the only intervention on the eyes which should be undertaken at the front. He has cured completely three cases of extensive detachment in which vision was reduced to light perception, by cutting a rectus muscle as for an advancement and exposing the sclera back to the equator, which he then punctured deeply at one or two points with the fine tip of an actual cautery heated to red heat. The tissue flap was sutured and immobilization in bed and atropin used. Six days after operation on one case there was no visible trace of detachment and vision had risen to 3/10, becoming and remaining 8/10 finally. This method is of course applicable only to cases in which retinal detachment can be recognized early, for in many instances, if not in most, the diagnosis cannot be made until the hemorrhage into the vitreous which so frequently accompanies traumatic detachment clears to an extent which makes the fundus visible.

Rollet and Mangini (q. v.) present an elaborate article on the subject, embracing observations upon 96 cases. Retinal detachment was present in 18 per cent. of the cases, spontaneous reattachment of the retina had occurred in 18 per cent., rupture of the choroid in 23 per cent. and retino-choroidal hemorrhage in 34 per cent. Not all of these cases, however, were purely indirect lesions. They remark that it is impossible to establish the least relation between the type of projectile, the force of penetration of the bone and the fundus changes, and further, that only a thorough examination of the visual fields to their extreme peripheries will give an adequate idea of the extent of functional loss, particularly in the cases of retino-choroidal hemorrhage. They also draw attention to the fact that the healed lesions of hemorrhage from this source show no difference from those due to general causes and to its possible medico-legal significance in later civil life.

While the posterior segment of the eye is much more often involved in indirect injury to the globe than the anterior segment, and nearly always with graver functional loss resulting, numerous cases of lesions of the anterior segment are seen. Rupture of the sclera, tears of the iris, partial and complete iridodialysis or cyclodialysis, paralysis of the musculature of the iris, and anterior or posterior dislocation of the lens, nearly always with terminal cataractous changes, occur not infrequently and are subject to the same treatment which similar lesions receive in civil life.

It is not always easy to determine whether a given lesion is indirect or direct, especially where the orbital margin has been driven in towards the globe, but in this instance palpation, obvious deformities or the roentgenogram detect the bony defect and show its relation to the ocular injury. The distinction, apart from the increased likelihood of intraocular infection in direct injuries, is mainly academic.

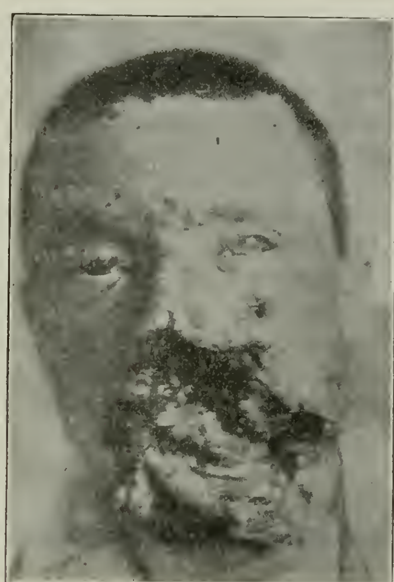
In most cases of indirect injury there is no pain referred to the eye, which nearly always retains its normal external appearance and as the uninjured eye retains its normal vision, the patient is seldom aware of the gravity of the damage sustained. The discovery, if made at all, is usually accidental or follows injury of the sound eye, but the constancy with which choroidal rupture and retinal hemorrhage follow projectile wounds of the bones of the upper face make ophthalmoscopic examination an imperative routine in all such injuries. DeWecker (*Centralbl. f. prak. Aughk.*, 1899, p. 104), Adam (*Eye Injuries in War and Their Treatment*, Berlin, 1914), Velhagen (*Münch. med. Wchnschr.*, 1915, No. 9), and Oloff (*Deutsch. med. Wchnschr.*, Sept. 30, 1915) among others have also contributed valuable clinical data dealing with this form of injury.

Direct injuries of the eyes are obviously less frequent than injuries of the adjacent parts of the face with their broader area of exposure. Out of 600 cases of ocular disorders of all forms, Uhthoff (*Berl. klin. Wchnschr.*, Jan. 3, 1916) found 252 cases of direct injury, of which 46 per cent. were blind eyes, 10 per cent. had vision less than 1/10 and 35 per cent. required enucleation. Undoubtedly the most frequent direct lesions of the eyes in modern warfare are caused by the enormous numbers of secondary missiles which arise from every explosion of an artillery projectile. The great majority of these injuries are slight, however, and bullets are responsible for the most consistently severe immediate lesions, while the lesser injuries are remarkable for the frequency with which infection and late and chronic complications follow.

Most *bullet wounds of the globe,* and those caused by larger pro- smashing of the eyeball, the explosive effect of bullets in particular jectiles, result in immediate and more or less complete rupture or upon the fluid globe being very apparent where the front of the bulb has been shot away completely, leaving radial fissures of the sclera running backward and with extreme changes about the posterior pole. In some cases there is a large, stellate, corneal rupture, and accompanying ruptures of the sclera in the anterior or posterior hemispheres. The retina is nearly always more or less completely detached in these cases and the globe is always filled with clotted blood. Most often, however, nothing but scattered bulbar shreds remain and lesions of the lids, the bony orbit, the upper maxilla and frontal bone, with vast destruction of soft parts, make the orbital condition one of but secondary interest, and the majority of such cases die almost immediately, being beyond the power of surgical aid. Shots which pass tangential to the globe do not always result in rupture, as shown by Terrien (*Paris Médical,* Sept. 25, 1915), who reports two exceptional cases where projectiles barely grazed the face of the cornea, in one case abrading the skin of the nasal bridge and causing a small paracentral ulceration of the left cornea without other disorder. Further, that tangential shots do not necessarily mean rupture of the eyes and death when antero-posterior in direction is clear from the evidence of Schuster (*Berl. klin. Wchnschr.,* Jan. 3, 1916, p. 24), who records two cases of bullet wounds where perforation of the skull from orbit to occiput resulted in general recovery. In the first case the bullet entered the left eye at the inner canthus, passed tangential to the eyeball, and emerged through the occiput about 6 cm. from the midline at the height of the external meatus. At an examination made six months later, the 5th, 6th, 7th and 8th left cranial nerves were shown to have been injured. The left eye was insensitive and presented healed lesions of a neuroparalytic keratitis, the left temporal and masseter muscles were paralyzed and atrophied and the left abducens was paralyzed, although both the optic and oculo-motor nerves were intact. The whole left face was paralyzed and there was left-sided deafness, together with slight symptoms of cerebellar injury. In the second case the bullet entered below the right external canthus, passed tangential to the globe and emerged in the left occiput about 6 cm. from the midline at the level of the external meatus. Injury to the cranial nerves was limited to the left side, the 3d, 7th and 8th being involved. Two months after injury there remained left ptosis, immobility of the left eye, paralysis of its pupil, absence of the corneal reflex, slight nystagmus on attempting to look down and complete left facial and auditory paralysis. In this case, also, only slight signs of cerebellar injury existed, as vertigo, especially on moving the head, a slight uncertainty of gait and the feeble nystagmus.

Uhthoff (*loc. cit.*) remarks that when bullets strike stones or the metal shields now so commonly used for protection in trench fighting, the mantle becomes torn and the lead core extrudes as a fine cloud of leaden particles which may literally spatter into an eye. In one of his cases both eyes were penetrated, one by many such particles and the other by a single fine fragment which remained in the vitreous without visual reduction. Four eyes similarly wounded were enucleated. In one, infection had produced an iridocyclitis and retinal detachment and in two others the foreign bodies were surrounded by circumscribed abscesses, more chemical than bacterial in type, which accords with the interesting results of Lewin's studies and observations (*Med. Klinik*, Jan. 9, 1916) that fragments of lead, lodged in the tissues, are a possible constant source of local and general poisoning by lead hydroxide. Fragments of the mantles of bullets, in the form of pieces of copper, aluminum or zinc alloys frequently penetrate the globe and usually lead to enucleation.

Wounds of the globe by fragments of artillery projectiles, and especially those produced by the various forms of trench and hand grenades and by the explosion of mines, so constantly associated with the caving in of trenches and earthen shelters and more or less complete entombment, are almost invariably complicated by the presence of more or less numerous secondary missiles set in motion by the explosive force. In fact the secondary missile effect of these violent explosions is often more far-reaching for trauma of the ocular regions than are the primary fragments themselves. Mud, dust, sand, gravel, sharp slivers and irregular fragments of rock, especially seen in mountain warfare, splinters of wood, metal and glass of all kinds and forms are the usual secondary missiles and, in common with the fragments of the projectiles, they contuse, lacerate, penetrate or perforate the eyeball, and greatly increase the risk and the incidence both of superficial and of deep infections. Often not only the corneas but the entire face of the patient is discolored as if stained or tattooed brownish-black by the numbers of fine foreign particles which have been driven into the tissues. Fragments of stone and metal splinters besprinkle or are lodged to greater or lesser depth in the corneas and in many cases similar fragments or particles have passed into the interior of the eyes, where their presence may be recognized only after repeated X-rays, by the irritation which they provoke, the infection which they introduce, or not at all. In eyes which have sustained this form of injury and in which prompt and copious irrigation of the conjunctival sac and mechanical removal of the larger imbedded foreign bodies have been impossible, the picture quickly becomes alarming. The lids are swollen to a degree where it is often scarcely possible to retract them, thin dirt-stained mucoid secretion fills the sac and gums the palpebral



Showing Great Mutilating Effect of Grenade Wound of Face with Loss of Right Eye.

fissure and, on forced separation of the lids, irregular, phagadenic forms of necrosis may be seen about the imbedded particles, the forerunner of a process which may go on to simple perforation or, more rarely, to single or multiple corneal abscesses and to destruction of the eye. Very frequently serpent ulcer results and eyes are often lost from this condition which the use of free irrigation, of optochin and the actual cautery fail to check. With slighter degrees of corneal involvement, the finer, superficial foreign bodies which are not removed mechanically, slough out and usually leave but faint nebulæ to mark their site. Most of the larger particles, such as earth and fine pebbles, even if they penetrate the cornea deeply, may be easily washed or picked out of their beds. Some of them, however, have to be actually cut out, and in all of these deeper foreign bodies the earliest possible removal is imperative, unless their number is excessive, for the deep corneal necrosis which otherwise occurs is of the type which most often leads to corneal abscess and perforation. Healing is usually prompt after early removal, followed by frequent and free irrigations of normal saline or dilute sodium hyperchlorite solution, the use of atropine as indicated and of 2 per cent. holocain or cocaine to control the often intense irritation, although in this connection it must be remembered that the latter substances are anesthetics and not analgesics, and that the use of heat, aspirin and the less potent derivatives of opium often give more satisfactory analgesia. Both here and particularly in case of intraocular foreign bodies vigorous doses of urotropin are indicated.

In all perforating wounds of the anterior segment of the eye the first indication is to close the wound and to protect the eye against infection by covering the wound with a conjunctival flap after as thorough a conjunctival toilet as possible. A conjunctiva which has been freely sprinkled with foreign bodies and dirt and which may even be decidedly chemotic may still be used for this purpose, although more reaction is to be expected. Cords (*München. med. Wchnschr.*, Aug. 31, 1915) reports the use of this conjunctival plastic operation, originally proposed by Kuhnt, in 37 cases of perforation and rupture of the anterior segment, disregarding the existence of amaurosis or collapse of the bulb from loss of vitreous. Several times he found that eyes which could not distinguish intense light from dark regained this sense and he states that the fact that sight remains in many of these cases is ascribable directly to the conjunctival plastic, which not only prevents secondary infection, but leads to more rapid healing and to firmer cicatrization. "The living conjunctiva is the best antiseptic and the best antisepsis, and, provided with such a bandage, the wounded soldier can be safely transported, reaching a specialist within a few days at the most and in time for enucleation should purulent inflammation have begun." In this method the conjunctiva is dissected from about the limbus to a circumferential extent proportionate to the amount of cornea to be roofed over. Wide, gaping lesions may require that the entire cornea be covered. In time the flaps retire, remaining adherent only to the wound itself. The particular sphere of this procedure is in prolapse of the iris and in the lesser corneal and scleral tears, especially when associated with intraocular conditions such as traumatic cataract and intraocular foreign bodies, which must be sent to the rear for operative treatment, with no assurance of the length of the journey before they are again in skilled hands.

[A more detailed account of this useful procedure is given, with illustrations, on p. 3508, Vol. V, and p. 6263, Vol. VIII, of this *Encyclopedia.*]

Simple scleral and conjunctival sutures suffice to protect the lesser scleral tears, but in the small corneo-scleral perforations about the limbus with or without injury to the lens, prolapse of the iris nearly always occurs. If seen immediately after injury, the iris may be excised, reposition of the pillars of the coloboma attempted by corneal massage through the lid and the judicious use of eserine, and the tear covered by a flap of conjunctiva. If suitable toilet of the conjunctiva is impossible or infection has already begun, the conjunctival flap is merely sewn into place above the undisturbed prolapse, or it may be previously cauterized with iodine.

Bahr (*München. med. Wchnschr.*, May 18, 1915) strongly recommends painting all the wounded tissues of the face, the lids and the anterior segment of the globe, with full strength tincture of iodine as the first treatment, in order to lessen the probability of infection. After thorough cocainization, the edges of the wound, the iris, vitreous and other prolapsed parts are touched with iodine until they are dark-brown, and a layer of cotton is interposed between lid and eye for a short time, to prevent needless contact with the iodine. The pain is severe and persistent, but infection is usually avoided, although naturally intraocular infection which has been introduced at the time of injury or has occurred between the time of injury and treatment cannot be influenced. Orechkin (*Russk. Vrach,* XV, No. 8, pp. 169-192) is equally convinced of the value of tincture of iodine.

The treatment of *traumatic cataract,* which, according to Cords (*loc. cit.*) occurs in about one-seventh of all cases of perforation of the cornea and the anterior portions of the sclera, depends upon the amount of inflammation or infection of the eye, the size of the capsular rent and the degree of swelling of the lens. In unskilled hands the only justifiable treatment is the immediate use of a conjunctival covering, eserine according to the tension, and immediate despatch of the patient to the nearest specialist center. Where conditions permit, however, a sufficient conjunctival flap may be prepared, and sutured in place over the wound after careful expression of all possible lens substance with or without enlargement of the original corneo-scleral and capsular wounds. Infection is frequent in this condition and, unless made imperative by the dangerous tension, operation should be delayed until conjunctiva and sac are in normal condition. Sympathetic ophthalmia has been reported after operation on this form of cataract. (Abstr. *Jour. A. M. A.*, June 17, 1916, p. 2000.) In the after-treatment of these cases, as well as in all ocular injuries where atropine is indicated and the patient must suffer transport, the use of atropine in the uninjured eye as well is of much benefit. At best, the prognosis of traumatic cataract following battle wounds is far graver than that after industrial injury. The violence is greater, the associated trauma usually far more extensive and infection far more frequent. The greater length of time elapsing between injury and its care still further lessens the chance of good recovery. The prognosis of the two forms of *contusion cataract,* those due to air pressure or decompression consequent upon the explosion of high-powered shells, and those produced by direct or indirect contusion of the globe through the lids or the bony orbit, is naturally far better than that of the ordinary traumatic cataract, absence of infection being the main factor in this difference of outcome. Not a few cases of this sort are seen which have been invalided as blind, but who merely require needling of the residual capsule, or at times simply the addition of the necessary convex lens to restore useful or normal vision.

Routine radiographic examination may show the presence of foreign bodies in the lens and in these cases extraction by magnet or operation is to be done only under ideal operative conditions. Contrary to general belief, where healing of the rent in the anterior capsule has occurred and the foreign body or bodies remain imbedded in the capsule or lens substance, intracapsular extraction of the lens is often successful, for the capsular cicatrix is far firmer than is supposed. The vision is not sufficiently disturbed in all cases to make extraction necessary. von Grosz (*loc. cit.*) reports a case in which a fragment of shrapnel remained imbedded in the lens for 6 months without the production of opacity and with a vision of 6/12.

Valude (*Jour. Amer. Med. Assc'n,* March 27, 1915, p. 1089) believes that soldiers suffering from traumatic cataract of one eye should not be operated on when the remaining eye is sound. Nothing is gained from the military standpoint even with the most successful result, while the risk of loss of the eye, or of reduction or loss of the vision which had been retained, increases the liability of the government for pension without the least possibility of compensatory benefit. After the patient has been discharged he will be at liberty to have such an operation performed at his desire and personal responsibility. Valude (*Jour. Amer. Med. Assc'n,* June 17, 1916, p. 2000) is confirmed in his opinion that traumatic cataract in one eye is not operable from the standpoint of the government, unless urgent symptoms demand, by the case of a young soldier with traumatic cataract of the right eye which followed a contusion of the orbital region. The left eye was normal. Operation for the removal of this cataract, done two months later, was followed by cyclitis and severe sympathetic ophthalmia of the left eye, making ultimate total blindness inevitable. "The result from the point of view of the state is a military unit lost and the highest pension to be paid to the patient, all because of an attempt to restore the vision, which in any case would have been very imperfect and which would have been useless for military purposes."

Where the ciliary body has prolapsed through the scleral wound, it should be replaced, without excision if possible, beneath a scleral suture of fine silk. The most difficult cases are those of injury of the ciliary body and lens with much loss of vitreous. Such eyes are nearly always lost from infection or from later atrophy, but occasionally a surprising amount of vision may be saved to them by the prompt application of the conjunctival covering and by expectant treatment.

Terrien (*loc. cit.*) states that the influence of commotio oculi on light trauma of the anterior segment of the globe is such that superficial foreign bodies of the cornea or conjunctiva frequently produce the gravest consequences, despite the vigorous use of antiseptic measures, and may lead to grave irido-cyclitis and to persistent corneal and conjunctival inflammations. Many of the most stubborn cases of conjunctivitis and of keratitis follow the tattooing of the conjunctiva and cornea by earth, combined with the effects of cerebral and ocular commotion in lowering local and general resistance. In these cases the conjunctivitis is of moderate intensity, there is often but little bulbar chemosis, pus secretion is slight or absent and a bacterial examination is nearly always negative. Photophobia exists out of proportion to the signs observed and suggests simulation, but is really a morbid entity, produced by the distant explosion. A light pericorneal injection often exists, with contracted pupils due to fulness of the iris veins and spasm of the pupillary sphincter and ciliary muscles which often occurs with crises and remissions of pain. This muscular spasm produces an artificial myopia, which disappears with the dilation of the pupil by atropine, although this dilation is difficult to accomplish. Under the influence of atropine the visual acuity improves in proportion to the dilation. The addition of a concave sphere produces the same result and the amount of sphere necessary to restore vision indicates the degree of accommodative spasm. Orbicular spasm accords with the intensity of the photophobia. Pseudo-paralytic ptosis may occur and may be unilateral or bilateral, presenting all the features of a functional palsy, but always in association with local conjunctival and pericorneal irritation. Feilchenfeld (*loc. cit.*) believes that some forms of orbicular spasm and photophobia are simulated in an endeavor to escape active duty at the front. Turner, Osler and others (abstr. *Jour. A. M. A.*, June 12, 1915, p. 2001) report cases of "blinking tic," a constant quivering blepharospasm and of monocular amblyopia without visible changes in the fundus or the reflexes. In one such case the vision of the left eye was lost except for a very small area in the temporal field, and in another the monocular amblyopia was combined with ptosis. Monocular diplopia has been reported in this connection.

At times fine, tenuous linear opacities of the cornea are observed, caused, undoubtedly, by the violence of the explosion. Their fineness is so extreme that they are often overlooked at the first examination.

The conjunctival and pericorneal irritation, as well as the characteristic photophobia, seen in this condition often persist for months without the least apparent reason for its chronicity, and the degree of reduction of visual acuity which remains during this time corresponds to the degree of photophobia and to its basic ciliary and iridic spasm. Terrien believes that all these inflammatory, sensorial and nervous disorders, so irregularly associated, are part of a single "hystero-traumatic entity," or syndrome, in which the idea of simulation has no rightful existence. Foreign particles are not found in all these cases, to explain the syndrome on the basis of direct mechanical trauma.

Intraocular foreign bodies have occurred in such relatively enormous numbers during the present war that more definite conclusions as to their removal and the treatment of their associated conditions are beginning to shape themselves more definitely than has ever been possible from their semi-occasional incidence in civil practice.

Intraocular foreign bodies are mainly the result of the explosion of artillery projectiles and are less frequently produced by bullets. Secondary missiles of every conceivable nature and form have penetrated the eyes and, in common with primary missiles, have caused the loss of vision, or of the eye by infection, in the majority of cases.

Pieces of the steel mantle of shells, grenades, and mines, as well as the mantle of certain bullets, notably the German, are magnetic and recoverable. Splinters of copper, zinc, lead and aluminum, or with these metals predominating, are non-magnetic; while fragments of aluminum, fine particles of earth, sand, gravel, or flint and of glass, excepting that of heavy lead content, often make no register upon the X-ray plate, or are so dim or so tiny that their shadows are overlooked. The larger fragments of stone usually lead to chronic inflammation and to blindness and enucleation, although the smaller fragments are often without the least reaction. Cords (*loc. cit.*) reports two cases of this sort, in which small fragments were seen floating in the vitreous of an otherwise normal eye.

No intraocular search for a foreign body is justifiable without a careful roentgenographic study of the eye and orbit from different angles, and its early use may determine the success of the treatment. The value of the X-ray in these and in other ocular wounds lies not only in the recognition and localization of foreign bodies, but in the detection, as well, of important lesions in the adjacent tissues. Fractures of the orbit are shown and suggest preventive therapy aimed against infection from the accessory sinuses; inconsequential looking wounds of the eyes, orbits and the frontal regions are found to conceal fractures of the orbital roof, depressions of the tables of the skull, deeply-lodged splinters of bone, and metal fragments, and even beginning brain abscesses, in ambulatory cases. Single, small wounds of the anterior segment, which would indicate the entrance of a single foreign body into the eye, may be shown by the X-ray that it had separated into smaller fragments, often so tiny as to preclude localization or recognition at operation. Some of the finest recognizable splinters measure but a fragment of a millimeter and weigh but a few tenths of a milligram, and their recognition demands not only the most painstaking technic, but it leads, in many instances, to no practical results, as most of these finer fragments are non-magnetic or too fine to be recognized by touch. In more favorable cases the missiles may be found to have passed through the eye and to be lying in the orbital tissue and, especially where foreign bodies have entered the orbit at or near the fornix, large retrobulbar fragments may be found in the retrobulbar tissues, of a size wholly disproportionate to the size of the wound of entry, owing to the elasticity of the conjunctiva in this situation.

Wounds in this situation are often particularly difficult to detect, and this is the route taken by the fine intraocular particles, whose existence has been unsuspected because of an obvious wound, but whose presence has been disclosed in consequence of routine X-ray examination. Mills (*Jour. Amer. Med. Ass'n,* Oct. 23, 1915, p. 1427) mentions a case of the sort where the only possible path for two small shrapnel fragments found by X-ray in the upper, posterior inner quadrant of the vitreous, was to have passed between the bridge and lens of the patient's glasses, entering the tissues just at the inner canthus, passing behind the transitional fold in this situation and entering the sclera at, or just behind the equator. It is of importance that in the absence of an X-ray the deviation of the magnetic compass may be used to detect the presence of magnetic foreign bodies which are not too deeply placed.

As the interpretation of plates is often uncertain because of false projection, or the superposition of objects, Duken (*München. med. Wchnschr.*, Aug. 17, 1915) suggests that the findings of two-plate localization pictures be further fortified by a study of the eye and orbit with the screen, in the attempt to project the foreign body out of the eye by viewing it carefully from various directions. Even with this additional aid it is often impossible to decide whether part of the fragments lie within or outside the globe, although it may be possible to localize one or more fragments by their size and contour and thereby indicate the position of the others. With the deeper fragments it is sometimes of value to take two plates from the same position of the tube but with the eye in two positions, when but a single shadow results if the foreign body is retrobulbar or in the orbit.

The removal of these foreign bodies from the anterior segment of the eye is of no great difficulty as a rule, though the position of the fragments in the iris or on the anterior capsule may demand much ingenuity on the part of the surgeon. Removal from the posterior segment, however, is always a serious matter in such battle lesions, and the results which follow extraction by the giant magnet and the operative extraction of non-magnetic bodies are so discouraging as to limit the use of the magnet and of operation to those cases where the position of the foreign body assures an uncomplicated removal and where the missile may be made to retrace its course through a still open wound. In those where a scleral incision must be made it should be placed as near as possible to the foreign body, which is extracted by this route rather than forward, in which direction of magnetic extraction cataract is not infrequently produced. von Liebermann (*München. med. Wchnschr.*, Oct. 12, 1915, p. 1413) successfully removed foreign bodies by the magnet in only 2 out of 275 cases of penetration. Detachment of the retina often follows magnetic extraction through the sclera, particularly where the foreign body has become lodged in the retina or has been bound to it by bands of fibrin or newly-formed fibrous tissue. The removal of a foreign body naturally does not prevent infection which it may have introduced, and every operator has seen infection follow extraction and make enucleation obligatory.

The presence of one or more small foreign bodies in the eye does not mean, of necessity, the loss of the eye or great reduction in its vision. Often, in fact, a surprising tolerance to foreign bodies is seen, particularly in the case of fine particles of dust and stone, or similar chemically indifferent bodies, and the enormous experience of this war seems to show that *the presence of any kind of a sterile foreign body in the eye has no relation to the production of sympathetic ophthalmitis.* As a result of this present war there are literally thousands of men going about with apparently innocuous particles of metal and of various forms of rock in one or both eyes and with useful vision or vision ranging up to 6/9 or even better. While a duration of a year or more may justly be said to make the final results in these cases still a matter of uncertainty, yet their number is so great and the clinical evidence so promising, that there is every likelihood that we are to revise our ideas relative to the treatment of apparently innocuous intraocular foreign bodies and shape our attitude according to the clinical course alone, i. e., according to the presence or absence of a traumatic chronic iridocyclitis. The rigid adherence to the rule of immediate prophylactic enucleation with the first evidence of sympathetic irritation in all the combatant armies has led to the almost complete disappearance of sympathetic ophthalmitis. von Grósz (*loc. cit.*) out of a large clinical experience did not see a single case during a year and attributed it to better initial treatment and to early enucleation of useless or possibly dangerous eyes, and Jessop (*Brit. Med. Jour.*, May 13, 1916) states that he has "neither seen nor heard of a single case of sympathetic disease." Ormond (*The Practitioner*, London, May, 1916, p. 491) declares the almost entire absence of the condition "remarkable, considering the large number of foreign bodies, often metallic, which are known to have remained inside the globe." Another factor has been the invariable thoroughness with which uveal and scleral shreds are removed after complete rupture of the globe, the lack of removal of these tissues having been responsible for more cases of sympathetic ophthalmia in the war of 1870 and in the American Civil war than were the cases of panophthalmitis.

The earliest evidences of plastic or suppurative uveitis, such as pain, tenderness, ciliary injection, disordered accommodation, failing vision, lowered tension, an inactive pupil or a discolored iris in the injured eye, associated with any degree of contraction of the field, enlargement of the blind spot or hyperemia of the optic disc or congestion of the retinal veins in the uninjured eye, should indicate prompt enucleation. A relative increase in the large mononuclear leucocytes is a further indication. Evisceration should not be considered in these perforating wounds because of the recorded occurrence of not a few cases of sympathetic ophthalmia following evisceration in civil practice.

In connection with the unhappy cases of perforation of both eyes by foreign bodies, it may be of cosmetic value to remember that in many eyes which have been thus blinded, an early reduction in the inflammatory reaction is often seen, with no late change or atrophy. Even in cases of unilateral blinding of this sort the eye may be left, if the conditions are such that enucleation will not be delayed at the first sign of disturbance.

Panophthalmitis is said to follow penetrating wounds of the globe in about 1/7 of the cases, and evidences of the infection appear usually about three days after the injury. Increasing tenderness and marked pericorneal injection, with the initial signs of plastic iridocyclitis are sufficient for operative interference. In neglected cases a vitreous abscess, with its characteristic yellow reflex on oblique illumination, is likely to ensue. Experience teaches that it is wiser to enucleate upon the first signs of beginning infection, thus sparing the patient the dangers of sympathetic involvement or the long process of atrophy with its attacks of pain and inflammation.

The most effective method of enucleation of these cases yet devised is that proposed by Lister (*Brit. Med. Jour.,* March 6, 1915) who, in order to prevent septic meningitis due to infection of the meningeal ramifications upon the optic nerve which has followed the usual enucleation in the presence of panophthalmitis and an open wound in the globe, leaves the optic nerve intact and surrounded by a small ring or cuff of clean sclera. His procedure is to first eviscerate the globe, carefully curetting away all traces of the retina and choroid to avoid all possibility of sympathetic ophthalmitis. The muscles are then divided, after which the sclera is pulled forward and cut away from about the optic nerve, leaving merely a frill of scleral tissue.

With a small or healed opening in the globe, the conjunctiva and the muscles are divided first, after which the cornea is cut away and the evisceration done, but where the rupture is unhealed the evisceration is done first and the remaining scleral shell is thoroughly washed out before the muscles and sclera are divided. When the globe is split open in all directions, the separation of the uveal fragments and the muscles from the sclera is done piecemeal, the dissection and later recognition and division of the scleral fragments being facilitated by clamping each piece with an artery clamp.

To avoid the risk of meningeal infection in these cases, simple evisceration has often been done, or primary evisceration followed by careful washing of the scleral shell and then by removal of the sclera. Healing is usually complete in from three to four weeks. Deutschmann (*München. med. Wchnschr.,* Oct. 26, 1915) proposes thorough evisceration followed by immediate suture of the scleral shell in a horizontal line with drainage. He states that much reaction follows.

In any form of enucleation, suture of the conjunctiva is useless, but particularly where the conjunctiva has been lacerated, suture after enucleation is likely to still further reduce the size of the conjunctival cul-de-sac.

A freshly shattered eye is best enucleated by the surgeon in the field, the bulbar tissues removed while easily recognized and the muscular and conjunctival relations restored in so far as possible, with a view to use them as the bed for a future prothesis. This immediate treatment is often of the greatest value in preventing great shallowing and deformity of the conjunctival sacs. Often, however, the busy surgeon at the front is unable to attend to this comparatively minor procedure and most of the cases reach the base or civil hospitals a few days to several weeks after injury. Usually within ten days after rupture the corneal, scleral and uveal remains are completely buried beneath the vigorous growth of conjunctiva and an exploratory search is often necessary to reveal their presence, even when the larger part of the globe remains. These cases should be X-rayed without exception, in order to detect the possible presence of sizeable deeply-placed fragments of projectiles which might otherwise be overlooked until late complications disclosed them under less favorable conditions.

In eyes shattered by bullets the uveal shreds are not retained within the collapsed sclera, as is the rule in industrial perforations, but are found scattered about the orbit. Unless carefully removed, they may be the cause of sympathetic inflammation of the other eye. At times it is necessary nearly to exenterate the orbit before removal of the remains is completed.

In all neglected cases, as well as in instances of gross laceration, the conjunctival sac is so shallow and so deformed by adhesions between the conjunctiva, torn muscles and their aponeuroses and their fascial sheets, that in spite of free dissection a good result with regard to protheses is seldom obtained. The cosmetic difficulty is often further exaggerated by the encroachment of comminuted fragments of the orbital rim upon the orbit.

Protheses are usually inserted three or four weeks after uncomplicated enucleation, and five to eight weeks after uncomplicated exenteration, but where tears of the lids and conjunctiva coexist, small protheses are used as soon as possible and are increased in size as rapidly as possible up to their final form. By this means the cicatricial contraction which so often makes wearing of an artificial eye impossible, even after repeated plastics, may be prevented or at least lessened. Not infrequently the use of a prothesis seems to be contraindicated by a persistent, purulent discharge from the socket, but the cause of this is usually found to be irritation of the conjunctiva of the lower lid by the inverted lashes of the upper, and the discharge ceases upon insertion of the glass eye. Often the blindness is made infinitely more tolerable by the use of carefully matched protheses. A genuine paralytic ptosis not infrequently accompanies the loss of an eye. Operations are of slight value for this form of ptosis, which can usually be held in check by a suitably planned prothesis.

While the orbital tissues soon become intolerant of the larger foreign bodies in the orbit, very often single or multiple small fragments are retained without the slightest irritation, and their removal will depend upon the clinical course which follows. Orbital hematoma, all grades of orbital cellulitis and orbital abscess, exophthalmos from the presence of the larger missiles, limitation of motion of the globe and, not rarely, fatal meningitis, are the main disturbances to which they give rise, and nearly always with associated lesions of the adjacent tissues and the eye. Bullets, both rifle and shrapnel, and pieces of shell, often of surprising size, can usually be extracted by orbitotomy, although, rarely, the Krönlein extraction must be employed. Dauthuile (*Paris Médical,* March 11, 1916) removed a metal fragment weighing 56 grams from the orbit by the former method.

In not a few cases bullets lodge partly in the orbit and partly in the orbital wall, and in some instances the first diagnosis of an intraorbital bullet has been made by the rhinologist, who has found the nose of a rifle bullet projecting from the orbit into the nasal fossa, or this condition has first drawn attention by limitation of movement of the eye in one direction. At operation the bullet is found lodged partly in the substance of one or more extrinsic muscles and partly in the adjacent bone. Frequently the presence and the nature of orbital foreign bodies are first made evident by the routine use of the X-ray in every case of evident or suspected orbital and ocular injury.

A peculiar injury to the eyes and orbital tissue, which has been seen a number of times during every recent war, but more frequently in this, is that due to the secondary missile effect of a bullet passing through binoculars, the numerous fragments of the binoculars entering the eye, the orbit, the face and the hand or hands with which they have been applied to the eyes. Usually one eye is lost.

Possibly the most spectacular case of the sort is that reported by von Grósz (*loc. cit.*) where the unbroken proximal lens of a field glass was driven into the officer's eye, which, with the contained and intact lens, was enucleated eight days afterward. The large number of spectacle wearers in the great modern armies, estimated by Weigelin (abstr. *Jour. A. M. A.*, July 31, 1915, p. 441) at 1,750 men per army corps in the German army, has been responsible for the considerable increase in similar, though usually less severe, injuries from broken spectacle glass. Unless the form of injury makes immediate enucleation imperative, these cases can usually be sent to the rear, because of the comparative innocuousness of glass as a foreign body, and here the treatment is carried out along the lines commonly followed in civil practice. Ormond (*Ophth. Review,* August, 1915) mentions a case where glasses deflected a bullet which would otherwise have entered the orbit and probably the brain.

Orbital cellulitis of nearly every possible type and degree follows the introduction of foreign bodies into, or their passage through, the orbit, as well as communication with the accessory sinuses through fissures or fractures.

Possibly the most common form is that of the low-grade, brawny induration of the tissues of the face and the orbital fat which follows the penetration by numerous small, infected shrapnel and secondary fragments. This is often mildly erysipeloid in type and has the peculiarity that it may recur weeks or months after the original inflammation has subsided and after most or all of the infecting fragments have suppurated out or have been removed. Often these low-grade infections flare into acute abscess formation which leads to extrusion of the foreign body or even to fatal meningitis, a not rare sequel, unhappily, of any of these orbital infections which follow. battle injuries. Meningitis following orbital infection is more often the result of retrobulbar perforation of an orbit by a bullet than of penetration of the orbital tissue by shell or shrapnel fragments. The difference is probably to be found in the greater amount of dirt, hair or other grossly infected material introduced by the larger missile, in the closer relation of its path to the meninges, the arachnoidean expansion of which upon the optic nerve is freqently lacerated and opened by this injury, and in the greater opportunity which the infection, nearly always streptococcic, has for becoming vigorously active in the depths of the orbit before its existence and situation become fully apparent. Both orbits occasionally become infected simultaneously after through-and-through shots.

In one form of perforation of the globe, viz., when it is shattered by the missile and with more or less accompanying laceration of the adjacent orbital tissue, infection, although usual, is generally mild, exemplifying the surgical rule that the freer the drainage, the less the risk of infection, and suggesting that in the cases of intense streptococcic cellulitis of the orbit it is wiser, in the face of increasing sepsis, to risk enucleation, even in the presence of the dread cellulitis, if adequate drainage is thereby established. Enucleation has been performed for drainage in a very few of the cases of grave orbital infection, and while cases in which a meningeal extension or a sinus thrombosis has already occurred naturally have not been bettered, this more radical procedure seems to have raised the average of recoveries in these fulminating infections beyond that which follows simple orbital incision, and decidedly beyond the results obtained by mere expectant treatment. After such enucleations the conjunctiva is never sutured but is continuously irrigated with hypertonic saline or full-strength Dakin's solution, or is washed out every three or four hours and freely drained during the intervals by rubber tissue wicks. The use of streptococcus vaccine is a valuable adjuvant in nearly every case of orbital cellulitis.

The cases of localized *orbital abscess* usually develop in orbital hematoma and less often about retained foreign bodies, and may begin a few days after the injury or may be delayed for several weeks. The lids become hot, swollen and tender, the eye protrudes and is immobile and the conjunctiva is very chemotic. Wherever there is any evidence of pointing, a free incision is made at the most dependent part, but more often the signs of localization are vague or non-existent and in all of these cases the best results are obtained by a broad incision through the base of the lower lid, parallel with the orbital margin and carried back nearly to the apex of the orbit, keeping close to the floor, in which situation nothing of importance is divided. In the majority of cases the origin of the infection in a hematoma is shown by the quantity of broken-down clot which is discharged, mixed with more or less thick pus. The strong tendency of all orbital wounds to close is overcome by the use of broad, flat rubber-tissue drains carried well back into the orbit and used until convalescence is assured. Hot fomentations over a wide area and the persistent use of Bier's suction cups are valuable aids.

Recovery from the more intense orbital infections is often, though not invariably, followed by a reduction or even a total loss of vision from toxic changes, post-inflammatory fibrosis or pressure atrophy.

Traumatic exophthalmos, both of the simple and pulsating varieties, is not seldom seen as an ante-mortem result of bullet perforations of the middle fossa. The surviving cases of unilateral protrusion, in which the line of perforation is so clearly within the orbit as to exclude the probability of arterio-venous aneurysm in the cavernous sinus or other post-orbital vascular lesions, should be incised and the cavity of the hematoma freed of clot and drained as soon as possible. This often favorably anticipates the troublesome if not dangerous infection which so commonly follows localized orbital hemorrhage. A number of cases of unilateral exophthalmos have been the result of bullets which have entered the skull obliquely from behind forward and which, lacking power to emerge through the external orbital wall, have remained in the retrobulbar tissue until removed by a Krönlein resection or an orbitotomy.

In unilateral pulsating exophthalmos, which, as the result of battle wounds, is rarely survived because of the gravity of the accompanying lesions, ligature of the common carotid is demanded as soon as operative surroundings justify, in order that vascular borne infection be limited as far and as promptly as possible.

Because the opportunity for autopsies is rarely given on the battlefield, any determination of the relative frequency of the various forms of vascular injury which result in pulsating exophthalmos is impossible. In connection with fracture of the orbital plate or of the middle fossa, or as the result of a direct laceration by projectiles, traumatic aneurysm of the ophthalmic artery, a wound of the internal carotid in the cavernous sinus, a sacculated aneurysm of the carotid without venous connection, a wound of the cavernous sinus or ophthalmic veins or their thrombosis may lead to a pulsating exophthalmos. In any case, if the initial shock and coincident injuries or infection are survived, the treatment of these conditions is undertaken in the base or civil hospitals and differs in no way from that of the similar cases seen after accidental wounding or attempted suicide in civil life.

Lesions of the upper cranial nerves, and particularly of the ocular nerves as a group, are far more common in projectile injuries of the head than is seen in industrial traumata. The increased power of penetration of the modern bullet, which is largely responsible for these lesions, is the chief factor in the comparative frequency with which these injuries are seen to follow wounds of the cranium and the basilar fractures and fissures which accompany them. Direct injury to or destruction of the nuclear centers or of the nerves in their course to or within the orbit, may result from the penetration of bullets or of fragments of shell or shrapnel into the cranial cavity, or indirectly by the intense cerebral edema and serous meningitis which follow the severer grades of cerebral contusion, or by the capillary or grosser hemorrhages which result from air concussion.

Recovery from projectile fractures of the base of the skull is not common, because of the widespread trauma of the nearby soft tissues and the impossibility of draining such wounds. A surprising number of recoveries do occur, although these are mainly cases of fracture or fissure of the anterior cranial fossas, or through-and-through perforations of the skull by undeformed bullets at ranges well over a thousand yards. Transitory stunning or unconsciousness, headache and slight mental confusion may be the only effect of these amazing vagaries of bullet-action. Von Brunn (*Deutsch. med. Wchnschr.*, Nov. 11, 1915) reports eight cases of spontaneous recovery following complete perforation of the skull by bullets, and Mills (*Jour. Amer. Med. Assoc'n*, April 10, 1915) gives a case of perforation of both petrous bones, with signs simulating the meningitis of an infected basilar fracture, but which recovered after a phlegmon of the wound of exit was detected by the X-ray and opened.

Of most direct relation to the eye are those fractures and lesions produced in the lateral course of bullets directly through the bones or along the floor of the middle fossa where the nerves and vessels in their passage along the cranial floor are divided, are lacerated by splinters of bone or metal, are emmeshed in the consequent hematoma, or possibly are caught in the momentary gaping of a fracture at the moment of impact. Apart from lesions of continuity, the final results of these injuries depend upon infection and upon the absorption or organization of clots or extravasations of blood. Inclusion of nerves in callus following fracture of any part of the base of the skull seldom, if ever, has to be considered, because of the exceedingly light callus formation in this part of the skeleton. In most adults, in fact, fractures or fissures of the base do not unite but are closed or bridged over by fibrous tissue. Muscular paralyses in every conceivable combination occur, although their presence is often unsuspected until the initial shock and the unconsciousness following the injury are well past, or until detected in the routine ocular and neurological examinations which are now recognized as essentials by all experienced surgeons in every projectile wound of the cranium.

Paralyses which follow the injury immediately usually indicate complete crushing or tearing of the nerves either in their course or at their point of emergence from medulla or pons. When delayed for some hours, the paralysis suggests compression from hemorrhage, but if it starts on the second or third day an infective neuritis from a complicated fracture may be diagnosed and a grave prognosis is indicated. Changes in the extent of these paralyses often form the main index of the progress of deep hemorrhage or inflammation. The involvement of single cranial nerves in these lesions is far less common than in basilar injuries of civil life. The 7th, 8th, 6th, 3d, 4th, and rarely the optic nerves at the chiasm, are involved in about that order of frequency and in any combination, and these pareses or paralyses are nearly always unilateral, being more commonly due to fractures which involve the base in the region of an orbital apex.

The 6th, 4th and 3d nerves are occasionally involved with the optic nerve in apical fissures and fractures of the orbit, producing a total ophthalmoplegia.

Lesions of continuity or destruction of the optic nerve in front of the chiasm naturally produce changes in or absence of the field of the involved side. Shots through the chiasma itself, because of the partial decussation of the nerve fibres, may blot out both inner or both outer fields, though total blindness nearly always is the fate of those who survive injuries through this region. Lesions behind the chiasm produce defects in the visual fields of both sides, the portions of the fields opposite to the side injured being those obscured. All these defects may be of half or merely of parts of the fields and the hemianopic areas may be vertical or horizontal. Terrien (*loc. cit.*) also depicts a case of homonymous hemianopsia with conservation of central vision due, as shown by radiogram, to a piece of metal near the sella turcica.

Aid in the more exact localization of lesions may be given by the focal or hemianopic pupillary reaction. The reflex path of the pupillary light reaction runs in the optic nerve to the region of the corpora quadrigemina, from which point it branches to the nucleus of the third cranial nerve, the centrifugal arc beginning here. Accordingly, if the lesion of the visual tract lies within the pupillary reflex zone, the reaction of the pupil must be found modified or lost if the portion of the retina corresponding to the defective visual field is stimulated by light. Lesions of the optic radiations or of the cortical visual centers have no influence upon the pupillary reaction, as they are outside of the reflex arc. Thus with a right-sided hemianopsia the left visual tract has been injured behind the chiasm and upon focal illumination of the right side of the retina the pupil reacts normally, while no pupillary response follows focal illumination of the left half of the retina. The lesion in this case must lie behind the left primary optic ganglia. Oloff (*Deutsch. med. Wchnschr.*, Sept. 30, 1915) demonstrated the practical value of this exact localization in a case of bullet wound of the brain, controlled by X-ray findings, and further demonstrated that defects of the field placed somewhat eccentrically also gave the characteristic hemianopic pupillary defect, despite von Hess' conclusion that the pupillary light reaction area of the retina extends only from a limited macula area.

Hemorrhagic and inflammatory foci, abscesses and post-traumatic cysts must often be localized by the changes in the visual acuity, in the visual fields and in the condition of the optic nerve head, by variations in the pupillary reactions and particularly by the extent and progress of the muscular pareses or paralyses.

Dupont and Troisier (*Bull. Soc. méd. d. hôp. de Paris,* 1915) record the case of a soldier whose skull was perforated by a bullet which entered above and behind the left ear and emerged behind the right ear. Complete motor paralysis of the eyes resulted, together with dysphagia, a weak and muffled voice, tachycardia, polyuria, and later, typical cervical herpes. The symptoms gradually subsided after two weeks and recovery ensued except for defective distant vision. The symptoms were probably the result of the pressure of extravasated blood.

Noehte (*Deutsch. med. Wchnschr.,* Oct. 7, 1915) reports two cases of paralysis of the 6th cranial nerve after projectile wounds of the parietal bone of the same side.

Schieck (*München. med. Wchnschr.,* Oct. 19, 1915, p. 1435) describes a case of injury of the left pontine region by a shrapnel fragment which showed clinically left-sided abducens and facial paresis, together with conjugate deviation to the right. The site of the lesion was corroborated by a later roentgenogram.

Stern (*Neurol. Zentralbl.,* No. 11, 1915) gives the changes which followed a lesion in the neighborhood of the optic thalamus as a transitory paresis of the 6th nerve, hemianopsia with preservation of the central field of vision, hemianopic loss of pupillary reaction and atrophy of the optic nerve. The pupil on the side of the hemianopsia was the larger and reacted slowly.

Uhthoff (*Klin. Mon. f. Aug.,* 54, p. 391) details a case of injury of the first and second divisions of the 5th nerve and functional disturbance of the third division, produced by a fragment of shrapnel which lodged in the Gasserian ganglion. The right eye remained very irritable, with easily produced, though transitory, corneal erosions and with complete loss of emotional crying, ascribed by Uhthoff to a lesion of the facial nerve during its course through the great superficial petrosal nerve and the spheno-palatine ganglion into the 5th nerve. In lesions of the 5th nerve at or near the origin of its divisions, keratitis, usually central, is the principal symptom. It may be so checked by a prompt median tarsorrhaphy that only a mild central scar results; otherwise the best that can be expected from the trophic changes is the formation of a dense central leucoma with complete loss of practical vision. Uhthoff states that trigeminus injury occurs in numerous cases of projectile wounds of the orbit.

Facial paralysis with lagophthalmus is a common consequence of shell or bullet wounds of the 7th nerve at its point of emergence from the skull, and if care is not taken, corneal inflammations usually result. Terrien (*loc. cit.*) saw a dozen cases with the symptoms of peripheral facial paralysis and with inability to close the palpebral fissure on the affected side, yet in no case was he obliged to perform temporary tarsorrhaphy in order to protect the cornea from the consequences of trophic disorder. As soon as the paralysis is seen to be irrevocable, however, it is wiser to lessen the danger by narrowing the fissure by operation, and by protecting the cornea from light and dust during the day by large, full curved lenses and by the use of 2 per cent. boric acid ointment at night, to keep the exposed cornea from drying.

Paralyses of the third and fourth nerves are usually most disagreeable because of the distressing diplopia which they suddenly produce. The most comforting treatment is the immediate use of a ground-glass lens or other cover over the affected eye. v. Liebermann (*München. med. Wchnschr.*, Oct. 12, 1915, p. 1414) describes a case of isolated paralysis of an internal rectus. The two roentgenograms taken at right angles disclosed one end of a rifle bullet projecting through the mesial orbital wall into the nasal cavity, while the butt was lodged in the body of the affected muscle.

Mills (*Jour. Amer. Med. Assn.*, April 10, 1915) reports a case of perforation of the occiput and cerebellum by three irregular shrapnel fragments which lodged among the nuclei of origin of the nerves of the ocular muscles. The whole right side of the trunk was paralyzed, apparently from pressure upon the left pyramidal tract before its decussation. The left eye was totally ophthalmoplegic, the right superior oblique and external rectus were paralyzed and the right pupil was dilated and unresponsive. The effect of the pressure upon the nucleus of the 7th nerve was a complete paralysis of the left side of the face and a deep and broadly infiltrated ulcer of the left cornea. Involvement of the 8th nerve made it necessary to shout in order to attract the patient's attention, and affection of the 9th was apparent in the constant drooling, dysphagia, especially for fluids, and an almost unintelligibly thick articulation. The corneal ulcer extended in this case to loss of the eye from iridocyclitis, in spite of closure of the palpebral fissure, the use of heat, atropine and the greatest cleanliness. As it is the best present surgical judgment that the trauma produced in the removal of such foreign bodies is so severe and of itself exaggerates the old paralyses and causes new ones, there is seldom more in store for such unhappy cases than a lingering existence, with death from intercurrent infection.

Lesions of the cervical sympathetic ganglia and fibres are not uncommon results of projectile injuries of the lower cervical and upper dorsal region, where crushing by a fractured transverse process or strangulation in an intervertebral foramen from edema or pachymeningeal hemorrhage, may be as often the cause as is the direct injury by the projectile. While Horner's syndrome is usually incomplete in these cases, the eye is always concerned to some extent in the vaso-motor, secretory and trophic reactions which result. Holmes (*Brit. Med. Jour.*, Dec. 4, 1915, p. 815) noted disturbances of the function of the cervical sympathetic in 36 cases of lesions of all spinal segments between the second cervical and second dorsal, inclusive. In the majority of these, injury to the sympathetic fibres in the neck could be excluded. Miosis was the most common and prominent symptom or, in unilateral lesions, inequality of the pupils, the smaller being on the side of the lesion and usually failing to dilate, or dilating less rapidly and less completely on shading the eyes. Instillations of adrenalin were without effect on the paralyzed pupils. A narrowing of one or both palpebral fissures and some enophthalmos was also pronounced in most of the cases, and ptosis was frequently observed, especially with lesions of the lower cervical and the sixth dorsal segments. In some unilateral lesions lessened lacrimal secretion was observed on the affected side, the eye being obviously drier and more staring and glassy than normal. In a few such cases the complaint was made of the lids being "stuck" or difficult to open in the morning, owing to the adhesion caused by the thickened conjunctival secretion. The excretion of sweat is diminished or absent on the affected side in most of these cases and the degree of inhibition seems to parallel the lessening of tear secretion.

"The cilio-spinal center lies in the lowest cervical and first dorsal segments, while the spinal center of the other components of the cervical sympathetic is found in the two upper dorsal segments and these are influenced or controlled by efferent bulbar fibres which descend uncrossed through the cervical cord. Disturbances of the latter must have occurred, therefore, when the lesion lies above the eighth cervical segment, while the spinal centers themselves are injured when the lesion lies below this."

Both the ocular and secretory disturbances appear to be more prominent and permanent when the spinal sympathetic centers are damaged than when the bulbar efferent fibres are involved, for in the latter case the symptoms usually subside quickly. Symptoms of irritation of the cervical sympathetic did not occur in any of Holmes' cases in which the spinal cord only was injured.

Russeff (*Zeitschr. f. Aug.*, 33, p. 291, 1915) discusses two cases of paralysis of the cervical sympathetic, in one of which a hematoma caused compression of the cervical cord, a circumscribed myelitis and Horner's syndrome. The left brachial plexus was injured at its place of exit from the foramina in both cases. Russeff believes that the type of sympathetic disorder which may result depends upon the development of a circumscribed myelitis which may involve the central paths. In one of three cases reported by Terrien (*loc. cit.*) the sympathetic syndrome complicated a carotid arterio-venous aneurysm. De Lapersonne (*Archiv. d'Ophtal.*, 1915, p. 580) and Uhthoff (*Berlin. klin. Wchnschr.*, Jan. 3, 1916) report cases caused by bullet wounds of the neck, and Ausch (*Wien. klin. Wchnschr.*, Oct. 21, 1915, p. 1139) discusses in detail a case of bullet wound of the superior cervical sympathetic ganglion which exhibited classical symptoms. In De Lapersonne's case the paralytic syndrome, which had lasted several weeks, disappeared within a few hours after lamination and removal of the bullet from the sixth cervical vertebra. Holmes (*loc. cit.*) discussing the spinal injuries of warfare, states that nystagmus has been described as the result of lesions in the higher cervical region and reports a transitory and intermittent nystagmus in 3 out of 63 cases of projectile wounds of the second, fifth and seventh segments.

In these cases of spinal injury where the X-ray discloses gross wounds, the benefit of the chance of surgical relief of pressure by missiles, fragments of bone, hemorrhage, edema, secondary thickenings or secondary serous cysts should be given, not forgetting in the after treatment, as well as in the unoperated cases, that because of lack of skeletal and muscular support, injuries of the cervical region require more than usual immobility and rest.

Concussion blindness, produced by the condensation or rarefaction of air in the explosion of shells, has become one of the outstanding ophthalmological features of modern war. It is a type of commotional syndrome which has long been recognized as following severe accidents or violent emotions in railroad, mine or factory accidents and in earthquakes.

A study of the distant effects of high explosives upon the buildings of a town shows that almost unbelievable damage is produced even at considerable distances, and this strikingly illustrates the effects which the atmospheric disturbances created during the terrific explosions must have upon the human body, whether standing, lying, waking or asleep. Numbers of men have been found dead in lifelike attitudes after the explosion of a shell just above or beyond them, and as these cases are nearly always found behind some protecting barrier, such as a wall, tree or trench, M. Arnoux, writing in *Le Journal,* July 6, 1915, considers the direct cause of death to be the static decompression of the atmosphere, for direct dynamic pressure has not come into play. The latter form of force is, however, unquestionably the cause of many, if not most, deaths without external injury, and autopsies upon cases of either nature have shown the existence of widespread petechial hemorrhages in the brain and spinal cord and of extensive and lethal damage to other organs, notably the hollow viscera such as the lungs, a case of rupture of which was reported to the Société de Chirurgie by M. Sencert. In a discussion on "Shell Shock" abstracted in the *Lancet,* Feb. 5, 1916, p. 306, a case showing typical symptoms of disseminated sclerosis after shell shock was reported, and Mott stated that autopsy upon a man who died 48 hours after a severe shock disclosed scattered hemorrhages throughout the brain, which, had the man survived, would have resulted in areas of sclerosis, possibly sufficiently severe to occasion definite symptoms. "Small scattered hemorrhages may well be at the root of some of the slighter cases where symptoms obstinately persist."

Mott (*Lancet,* Feb. 12, 1916; *ibid.,* Feb. 26, 1916; *ibid.,* March 11, 1916) includes among the sources of trauma to the nervous system as the result of the effect of high explosives, the physical trauma of the aerial compression which blows the body into the air or against the side of a trench or dug-out; which blows down the parapet or roof upon the soldier, causing concussion; or which hurls sandbags against his head or spine without causing visible injury. Again, he may be buried and partially asphyxiated or suffer from deoxygenation of his blood by CO poisoning, for these high explosives generate considerable quantities of CO, which is inodorous, which would be effective under the conditions of air stagnation in the depths of trenches or shell holes, and which would not easily be recognized. Mott illustrates the pathological similarity of cases of industrial or suicidal CO deaths to those following shell shocks without visible lesions.

Shuster, quoted by Gaupp (*Beitr. z. klin. Chir.,* April, 1915) has noted that when a shell explodes near a sleeping person it does not induce the mental and nervous disturbances otherwise observed, showing the relation of fright as a factor, and Forsyth, in his able paper on "Functional Nerve Disease and Shock of Battle" (*Lancet,* Dec. 25, 1915), states that for the more highly-strung, waiting for an oncoming shell to explode is well-nigh unsupportable. "The detonation, the flash, the air-concussion, the upheaval of the ground, and the acrid, suffocating fumes combine in producing a violent assault on all the senses simultaneously and the effect is immediately intensified by the shrieks and groans and the sight of the dead and injured." Forsyth states the commonly-held opinion that the reaction depends upon: 1. the state of mind at the time of the exposure to the trauma, an exhausted nervous system feeling the effect of the explosion more than when fresh or well-rested; and, 2. upon the psychopathic or psychogenous tendencies existing prior to the shock, for the traits which are responsible for early physical exhaustion exaggerate the emotional factors of the situation. Some men are apparently undisturbed by days of heavy fighting under shell fire; others who weaken at first soon become accustomed, while others break down. Clearly, therefore, the strain, however severe, is not the only causal factor in these cases and the inquiry of Mott (*loc. cit.*) localizes the main factor as an acquired or inborn tendency to neurosis. Out of 156 cases, 152 gave a history of previous nervous breakdown or disordered emotivity.

Mott (*Lancet,* March 11, 1916) suggests that because "shell shock" is now recognized as a definite entity and injury and therefore is subject to pension, the notion of never recovering may become a fixed idea and, as such, a *conscious* fraud, the detection of which may be difficult.

Mairet *et al.* (*Bull. de l'Acad. de Méd.,* 1915, 3s, lxxiii, 654) conclude that while some single disorder such as blindness, aphasia or epilepsy may dominate the clinical picture, yet all these instances of nervous shock should be grouped under the single heading of a "Commotional syndrome," the nervous signs and symptoms of which they divide into six groups; viz.,

1. *Disorders of sensation.* These are most common, usually as a diminution or abolition of function. Blindness, deafness and loss of taste and smell, partial or complete anesthesias are most often seen and the disturbances are usually symmetrical. Various degrees of hypesthesia, hypoalgesia, loss of sensitiveness to pressure, heat or cold limited to zones or areas of the body or more commonly affecting one side only, perhaps with the loss of the superficial reflexes, are all more frequently seen than the hyperesthesias, which involve as a rule, the existence of areas painful on pressure.

2. *Motor disturbance* is most widely shown by increased reflex irritability of tendons and muscles, often unilateral and in rare cases going on to the production of hysterical or epilpetiform attacks and

less often to paresis or paralysis of groups of muscles with or without contractures.

3. *Vasomotor disorders* are general. Chilliness, "goose flesh," cyanosis, which may be unilateral, and cardiac irregularities are common. The last may have connection with disturbance of the thyroid secretion. Headache is almost constant, perhaps accompanied by nausea or vertigo.

4. *Affective functions* such as altruism and family affection are lost and egoism comes boldly to the fore in the shape of causeless irritability or rage, causeless fear or even terror.

5. *Associative disturbance of the intellectual faculties* is frequent. Retrograde amnesia is very common, the patient forgetting his name, his home and the faces of his friends and relatives. Speech may be lost or halting and intellectual inertia may exist to the degree of stupor. The imagination is unduly active, making the patient the victim of dreams, nightmare, hallucinations, sleep-walking and even delirium, in which bygone battle-scenes are re-enacted.

6. *Disturbance of perception.* Often there is no recollection of the shock itself or of the events following for a shorter or longer period and the patient is left with a permanent lacuna in his memory. He is easily fatigued and is unable to concentrate on any subject, such as reading.

It is probable that most of the ocular symptoms of shell shock have a real organic basis in which cortical capillary hemorrhage, damage to the lymph tributaries of the nervous system and mechanical injury to the cortical nerve cells and basal ganglia are the cerebral factors, while gross or subtle interference with or damage to the retinal nervous structure, often evident clinically in different degrees of retinal opacity, indicate the probable ocular foundation. Ravaut (*Brit. Med. Jour.*, Aug. 14, 1915, p. 265) found that the spinal fluid of some cases of "acute neurasthenia" following shell shock, both with and without visual and aural disturbance, was blood-stained or contained increased quantities of albumen and that there was complete parallelism between the evolution of the symptoms and the condition of the spinal fluid. From these results it seems impossible to exclude central damage as a factor of importance in a given case unless one can demonstrate a normal spinal fluid.

In the most accentuated form of concussion blindness, the patient is totally blind; in other cases the vision is a little reduced and between these two extremes occur all forms of variations. Parsons (*Lancet*, April 3, 1915) deals with the clinical picture of these cases in such graphic detail that much of his article is here reproduced:

A man, more or less fatigued after prolonged marching and nervously unsteadied by prolonged exposure to shell fire in the trenches, or by seeing one of his friends killed beside him, is knocked down or thrown into the air, is more or less completely buried in earth and débris by a nearby explosion, or showers of dirt are thrown into his face and eyes. Although any degree of unconsciousness up to deep stertor ending in death may ensue, consciousness is not usually lost to an extent where automatic movements are prevented, so that the man may walk in a dazed condition to a dressing station, or may be so confused as to walk or attempt to fire in the wrong direction. The mental equilibrium at this stage is much disturbed and all memory of this phase is usually lost. The most striking feature is that of instantaneous blindness, which is often accompanied by deafness and loss of smell and taste. Such intense blepharospasm, photophobia and lachrymation may occur that the lids are opened only with the greatest difficulty, if at all, and examination of the globe must often be made by the forced use of a speculum. In most of these cases sand, dust or mud which have been blown into the eye are found free in the conjunctival sac or imbedded in the cornea, sclera or conjunctiva and furnish the physical basis for hypersensitiveness to light, orbicular spasm, ptosis and for the belief of blindness. In some cases blindness is not immediate, but the vision gradually becomes more and more defective, until the patient is just able to detect light from darkness.

In uncomplicated cases the eyes appear normal, although the pupillary reactions are often sluggish; one may react differently from its fellow, and it may be weeks before accommodation has recovered enough to permit large print to be read. By this time light may be perceived and large objects distinguished. As improvement occurs the patient becomes able to grope about with outstretched hands, but it is noticeable that he does not usually stumble against objects in his path. When possible to take them, the fields of vision are found greatly contracted, usually to a degree which seems inconsistent with the avoidance of obstacles in walking. The recovery of vision is slow, but eventually it improves to a point where only some cloudiness of vision remains, with much difficulty in fixing objects and often with accompanying retinal hyperemia of long duration. Final visual recovery follows perseverance and encouragement in most cases. Some patients frankly admit their fear and disinclination to return to the front. "It is too easy to jump to the conclusion that these men who have faced the music and come battered out of the ordeal are shamming, and these cases may rather be regarded as injuries or wounds of consciousness. This does not imply that there is no neural lesion to account for the psychological disorder, but merely that it has hitherto escaped observation.''

The disorder of the consciousness varies with the nature and severity of the injury and with the organization of the individual's character, that is, the degree to which he is capable of controlling and modifying his instinctive reactions to fright and shock by his intelligence and training. ''The anatomical basis of an isolated psychological function is to be sought rather in a unified system of widely-spread neuronic paths, afferent, associational and efferent, rather than in any so-called 'centre.' A blinding flash of light, especially if it occurs in the dark and is accompanied with a terrific detonation. will produce certain definite reflex results, such as sudden closure of the eyes, retraction of the head and perhaps recoil of the whole body.'' Actual damage may be done to the delicate retinal structures, resulting in the temporary or permanent defect of vision. F. de Lapersonne (*Arch. d'Ophtalmologie,* Feb., 1915) and others report detachment of the retina and retinal hemorrhage and other grave intraocular damage after shell concussion and show that under the influence of the commotion, even the slightest traumata have far more serious consequences than usual. The strong light stimulus, with its sudden and unexpected visual sensations, arouses an emotional state which varies from mere surprise to actual fear. The response of an individual to such a shock depends therefore upon all the functions of education, experience, patriotism and self-esteem which make up intellectual control in a man. Bodily fatigue and acute excitement have usually impaired the man's control and upset his judgment, so when the shock comes which renders him unconscious there is an abrogation of function of the highest level cortical cells and volitional control remains abrogated for some time after consciousness is regained. Now, although so far as objective evidence goes, the lower visual paths are intact and function normally, the patient is psychically blind. The optic nerves carry their impulses, at least as far as the pupillary reactions are concerned, the condition resembling uremic amaurosis as well as that seen in children after post-basic meningitis. It has also been suggested that the visual defect may be considered as an anesthesia of the perceptive elements of the retina, in correspondence with the loss or perversion of sensation exhibited by the skin and mucous membranes in shell shock. The block probably occurs, however, somewhere above the so-called primary optic centers, presumably in the course of the fibres of the optic radiations. Sometimes such a block occurs physiologically when it is probably subject to similar explanation, as a type of apperception. ''The first loss of vision undoubtedly has a definite neural basis but in the later stages the neural basis is of that undefined nature which we associate with functional conditions. It is neurotic, but it is not 'shamming.' The behavior in the early stages is a passive hysteria, quite unlike the active hysteria induced by some preponderant ideational impulse."

As recovery progresses, the outward manifestations of loss of voluntary control become less marked or are suppressed and the self-regarding sentiment gradually again becomes dominant, but the restoration and its completeness are in accordance with the innate disposition of the individual and this must be studied in each case, and encouragement and stimulus given along the lines of individual need. Injudicious forcing may completely and permanently wreck the morale of the patient. Parsons hints at the use of suprarenal extract in these cases. Ormond reported a case to the Congress of the Ophthalmological Society of the United Kingdom, 1915, in which recovery was greatly impeded by an error of refraction which gave the patient the idea that complete recovery had not taken place. Harwood (*Brit. Med. Jour.,* Apr. 15, 1916) believes that uncorrected errors of refraction not only are largely responsible for many prolonged convalescences from this condition, but that these errors may be the inciting cause of the condition.

The intimate relation of syphilis to refractory cases of shell shock has been recognized, and striking results have followed the use of galyl and similar antiluetic remedies in cases which have not responded to rest and psychic treatment.

Procter (*Lancet,* Oct. 30, 1915) details the curative employment of general anesthesia in a case of concussion aphasia with blepharospasm.

Ormond declares that all means of treatment of the condition are comparatively ineffective until suggestion or hypnosis are used, and Hertz and Ormond (*Lancet,* Jan. 1, 1916), out of a large experience with concussion blindness report in detail several of the many cases cured or improved by hypnotism after the failure of the usual treatment of rest, tonics, persuasion, encouragement, counter-irritation, and deprivation or punishments such as isolation or confinement. Full hypnosis was shown to be unnecessary. Merely sleepiness and relaxation of the patient's mind and muscles were needed in order to overcome his unconscious resistance. In one case, psychically deaf, mute and blind, the patient was given an anesthetic and suggestion was employed during the stage of semi-consciousness with marked success. The first case reported was quite blind and there was a constant flicker of his lids which were held almost closed. On forcibly opening his eyes, they were turned so far upward that it was difficult to see even the iris. A few fragments of sand were still imbedded in the conjunctiva but not in the cornea, but were causing no inflammation. The patient was easily hypnotized and while asleep was told that he would be able to see when he awaked and this suggestion was very forcibly repeated at the moment of waking, the eyes being held open. He cried out that he could see, tears ran down his cheeks and he fell on his knees in gratitude, as he had believed himself to be permanently blind and considered the restoration of vision to have been miraculous. Three days later the external appearance of the eyes was normal, vision O. D. = 6/6; O. S. = 6/36, the low vision in the left eye being due to vitreous opacity produced by bleeding from a retinal vessel. Myers (*Lancet*, Jan. 8, 1916) cured or benefitted 13 out of 23 cases of shell shock by hypnosis.

The acceleration of the pulse rate and increased perspiration observed in some of these cases may represent a phase of hyperthyroidism, which finds its most pronounced expressions as Graves' disease or irritable heart after battle shock.

That true Charcot's hysteria does occur not infrequently is asserted by Nonne (abstr. *Jour. A. M. A.*, Febr. 5, 1916, p. 440), and Uhthoff (*Berl. klin. Wchnschr.*, Jan. 3, 1916) reports two cases of genuine hysterical amblyopia with concentric contraction of the visual fields. Nonne succeeded in curing 51 out of 63 cases of "grand hysteria" by hypnosis and by waking suggestion. He claims that the value of hypnosis in this condition is that: 1. Cures are frequent and rapid, although all his cases had been previously and ineffectually treated in hospitals by other methods; 2. Hypnosis differentiates organic and functional cases; 3. Stubborn tremors, tics, including ocular tics of long duration, and severe vaso-motor disturbances yield promptly to suggestion, proving their purely functional origin; 4. Hypnosis is of great value in determining the actual disability, its degree, and its duration.

Feilchenfeld (*Deutsch. med. Wchnschr.*, Dec. 2, 1915) reports a case of true hysteria in a veteran officer centering symptomatically about the remaining eye.

It must not be forgotten that sudden blindness without physical injury while on active duty need not mean simulation, of necessity. Instead it may be the expression of some disease like cerebral tumor, or renal disease which was inactive or not vital at enlistment.

Among the ocular disorders largely or wholly evoked by physical and nervous exhaustion *military night-blindness* has been reported by a number of observers. In eyes which have moderate to considerable degrees of refractive error, even without pigment changes in the fundus, there is often an abnormal diminution of light perception under conditions of relative absence of light. This is measured by comparing the distance at which Förster's photometer, Nagel's adaptometer or the hands of a watch made phosphorescent by rubbing with the moist tip of a sulphur match, can be recognized in varying degrees of darkness and the promptness of recognitions with that of normal eyes. This slight anomaly, unrecognized under peaceful conditions, at times becomes a disabling factor under the tense physical and mental strain of continuous military service, often with insufficient and poor food.

Braunschweig (*München. med. Wchnschr.,* March 2, 1915) reported 22 cases of this disorder as an epidemic condition, its true relation to diet, to refractive errors and to mental and physical stress becoming apparent later, when the condition was more widely observed and studied by others. In most of Braunschweig's patients the condition had lasted for weeks or months before anxiety or depression had forced the men to report. They were unable to see or to drive horses in the dark, they stumbled into holes made by shells and felt insecure and helpless. The men often traced their symptoms to the strain of peering through the darkness while on duty in the trenches. Bitot spots were never found. In nearly every case the correction of the existing errors of refraction, and the slight conjunctivitis and blepharitis gave such relief as to make these organic abnormalities appear as the source of the condition. Paul (*Munchen. med. Wchnschr.,* Nov. 9, 1915) considers that the military form of night-blindness is the result of nerve exhaustion and psychic depression. His cases, like those of Braunschweig, occurred mostly during the long nights of the depth of winter, while no case was observed from May to August. Best (*Munchen. med. Wchnschr.,* Aug. 17, 1915) examined in detail the causes of night-blindness among 36 soldiers on active duty at the front, some of whom it was found necessary to disqualify from active service on the firing line. He found the condition due to, 1. Refractive anomalies; 2. Hunger and emaciation, usually in association with errors of refraction; 3. Night duty in the trenches; 4. Sun-blinding or dazzling; 5. Congenital hemeralopia, discovered incidentally; 6. Disturbances of the liver, caused by a shrapnel injury. Best believes that the condition is not one of a particular war nyctalopia. Feilchenfeld (*loc. cit.*), von Grosz (*loc. cit.*) and Weeker (*Bull. de l'Acad. de. Méd.,* March 28, 1916) refer at length to the condition, and Zade (*Munchen. med. Wchnschr.,* Nov. 2, 1915) calls further attention to the effect of active military service in seriously reducing the visual acuity of men with uncorrected or imperfectly corrected anomalies of refraction.

Attention is drawn (*München. med. Wchnschr.*, Aug. 31, 1915, p. 1207) to the relation existing between scorbutus and hemeralopia in the Austrian army in times of peace, owing to the absence of fresh vegetables from the diet, a lack which often exists for considerable periods under actual war conditions. Wietfeldt (*München. med. Wchnschr.*, Dec. 14, 1915) also believes that the lack of vitamins in the food may be an important factor in causing night-blindness.

Except in congenital hemeralopia, treatment by rest, good and plentiful food and the correction of the refractive errors promptly relieved the eye symptoms and the associated headache, dizziness, sleeplessness, disquiet and emaciation.

THE RELATION OF INJURIES OF THE SKULL AND BRAIN TO OCULAR AND VISUAL DISORDERS

1. *General consideration of projectile injuries of the skull and brain.* Projectile wounds of the cranium have long been divided into *tangential wounds,* which are notable for the amount of cortical destruction which they produce and the relative frequency with which they are survived; *penetrating wounds,* with lodgment of the missile, and *perforating wounds,* in which the missile, practically always a rifle bullet, has passed through and emerged from the skull.

The experiences of recent wars, but more particularly of the present colossal conflict, have been so enormous, however, and the effects of wounds of certain cortical regions so constant in their symptomatology, that subdivisions of cranial wounds according to the region involved or the symptoms produced are necessary.

The great number of points in the brain at which the optic centers and connections may be wounded or involved makes necessary a brief study of cranial wounds in general, their treatment and results.

The signs and symptoms of projectile injuries of the cranium are identical with those of all similar skeletal injuries (bleeding, pain, dislocation and functional disturbance resulting), but being kept more or less in the background by the symptoms of injury of the brain or its envelopes. Every projectile wound of the cranial vault, whether this is fractured or not, affects the underlying brain, which reacts to insult like all other tissue and to a degree corresponding to the extent of the trauma. Where no fracture, or merely a slight depressed fracture, has occurred, the reactive edema of the meningeal tissues, the cortex and the subcortex causes the brain to swell and to tend to become too large for the skull, even in the absence of local hemorrhage. This is further exaggerated by the presence of an actual serous meningitis when the reactive inflammation becomes excessive. With severer trauma this edema is complicated by arterial hemorrhage, laceration of the venous sinuses with hemorrhage, thrombosis and obstructive edema of the cortex, and mechanical damage of all degrees to the nerve elements and their mutual associational connections. Intracranial suppuration is the cause of death or of further disablement in nearly all cases which survive the initial injury.

The amount of immediate functional disturbance depends upon the location of the injury not less than upon its extent, for certain portions of the brain, notably the frontal regions, are amazingly tolerant of physical insult, while the array of recoveries, as to life and to a lesser degree as to vision, after tangential shots of the occipital region, is already formidable.

The absence of deficit phenomena after extensive destruction of brain tissue has been another surprising feature of projectile injuries of the brain and wide cranial gaps, and although Horsley's statement that there is no evidence of compensation, by education or substitution of function in other parts of the brain, for function lost by reason of permanent destruction in given areas, is apparently a truism, yet every active surgeon in the present war has witnessed relatively enormous amounts of injury to and destruction of brain tissue, followed by temporary and frequently by permanent improvement to an almost normal condition of life and intelligence. Thiemann (*München. med. Wchnschr.*, May 4, 1915) saw no deficit signs in a case in which a third of the right frontal brain had been shot away, in another in which most of the right half of the cerebellum had been destroyed, and in a third where large portions of the parietal lobe and central convolutions had been lacerated. In a case reported by Manasse (*München. med. Wchnschr.*, Oct. 26, 1915), a soldier was struck above the left eye by a flying fragment of his own ram-rod. On the following day he vomited repeatedly, complained of headache, was dulled mentally, taking little notice of surrounding objects, and the pulse was 50. A month later, when improvement permitted transportation to a base hospital, examination showed a small scar at the inner angle of the left eye, pulse 70, highest temperature 99, and his sole complaints, headache and slight dizziness. Roentgenograms taken in sagittal and frontal directions showed the presence in the frontal brain of a long, thin shadow, one extremely pointing parietally and the thin end toward the eye. At operation, 6½ weeks after injury, enlargement of the small bony defect at the inner angle of the orbit by chisel led to a large abscess of the frontal brain, enclosing a fragment of ram-rod 8 cm. long. Recovery ensued.

A number of cases of complete recovery after through-and-through perforations of the skull have been reported and the cases of penetration and lodgment in nearly all parts of the brain by all sorts of missiles and which have recovered to a more or less good condition, without or after operation, are legion.

The study of the late results in these cases of brain injury is disappointing but it is altogether probable that the present era of finished plastic surgery in the closure of cranial defects and the prevention of large cerebral scars will go far towards averting the constant headaches and the undue sensitiveness to sunshine which are the common and enduring results of nearly all these injuries. It will also radically lessen the frequency of cortical and subcortical softening, cyst formation, unduly large cerebral scars, the various forms of Jacksonian epilepsy and the chronic, diffuse or localized meningo-encephalitis which appears so insidiously within a few weeks or months and which may lead to death through sudden and unheralded coma, or gradually, after a prelude of sphincter troubles and mental disturbance. Psychological research after this form of cranial injury often discovers latent psychic defects in surprising ways.

Lapointe (*Jour. Amer. Med. Ass'n,* July 31, 1915, p. 441) declares that the immediate seriousness of cranial wounds in cases that survive to reach hospital care depends upon the continuity of the dura. If this is intact, the immediate mortality is about 7 per cent., as opposed to a mortality of 56 per cent., due to infection in nearly every case, where the brain substance is involved. Joseph (*München. med. Wchnschr.,* Aug. 31, 1915) is so much of the same opinion that he divides cranial wounds into those with intact and those with perforated dura. In this connection it is astonishing to see the extent to which the dura can withstand destruction of the overlying bone, which may be completely comminuted over wide areas and yet without dural laceration, although the brain beneath may or may not be extensively destroyed.

Viewed from the combined clinical, anatomical and operative standpoints, the most significant classification of projectile cranial wounds in general seems to be:—

1. Scalp wounds, without definite external signs of fracture of the skull;

2. Depressed fracture, without injury to the dura;

3. Fracture involving the dura, but without infection or lodgment of foreign bodies;

4. Fracture involving the dura, with infection and with foreign bodies in the brain;

5. Fractures and fissures of the cranial fossas, either complicating fracture of the vault or as the result of direct injury.

When the skull is fractured the inner table suffers far more severely than the external. As a rule, and accordingly, every fracture of the skull, regardless of its apparent triviality, should be considered as associated with comminution and depression of the inner table and with the consequent damage to the dura, the meningeal vessels and the venous sinuses.

The immediate consequences of fracture of the vault are exemplified by concussion, compression and irritation of the brain. Patients with depressed fractures are often, though not always, unconscious for a few moments immediately after the injury, but are often able to walk considerable distances within a short time. Headache, in all instances due to a pathological rise in intracranial pressure as the result of the traumatic edema of the bruised brain, is an almost constant and frequently distressing symptom which may demand one or repeated lumbar punctures for its relief.

Progressive hemorrhage is a condition of great rarity among cranial wounds where the initial injury is survived, and when it does occur, its cause is not uncommonly found in the existence of fissures running to parts of the skull remote from the point of direct injury.

Very often the only sign of intracranial damage in these cases of projectile wounds is persistent injection of the optic discs, without swelling, and the exact nature of the damage is disclosed by an exploration or revision of the scalp wound, after the X-ray findings have corroborated the ophthalmoscopic ones.

Both pulse and temperature curves are notoriously unreliable after cranial injuries. Early absence of frank fever is common in secondary brain abscesses, and on the other hand a pulse of normal rate may actually be a pressure pulse concealed by the toxic effects of complicating infection.

Whenever possible, therefore, every case of projectile injury of the head—of any nature whatever—should be subjected to a searching and often repeated routine study of the eye grounds, the pupillary reactions and ocular movements, of the cerebellar and labyrinthine functions, of the spinal fluid and a thorough neurological examination should be made. Of all the routine examinations the X-ray findings are of the greatest importance, and without them no formal cranial operation is justifiable.

The care of these cases, whether with operation or without, should be continued until the highest possible physical and social capacity has been recovered.

Every injury of the skull is, for a long time, a source of potential danger and the persistence of any sign or symptom, however trivial, is to be looked upon with suspicion. Further, persistent cranial fistula means the definite existence of a cranial or intracranial foreign body of some sort, which must be removed if possible, because of the danger, if not the certainty, of a late abscess of the brain, or meningeal infection.

Roberts (*Brit. Med. Jour.*, Oct. 2, 1915, p. 498) discussing *latent grave injuries with apparently minor external wounds,* states that "The number of patients who arrive at the base hospitals with bullet wounds of the scalp is large, but as their injuries are apparently superficial and their symptoms few or none they are frequently transported as 'sitting' cases and on arrival there is a tendency to overlook the fact that a fairly high per cent. have definite lesions of the skull, or of the skull and brain."

Roberts' analysis of these lesions found at operation in 140 cases of this order demonstrates that any projectile wound of the scalp, however slight, should be subject to early exploration to determine the presence or absence of a fracture. The 140 cases included:

Scalp wounds only	82
Fracture of outer table only	19
Fracture of inner table only	1
Fracture of both tables, dura uninjuried	18
Fracture of both tables, dura lacerated	1
Fracture with laceration of dura and brain	19

The excision of the scalp wound down to and including the pericranium, as practised by Roberts and many others as the first step in the exploration under novocain-adrenalin or general anesthesia, has to recommend it that

1. The diagnosis of fracture is usually established with absolute certainty;

2. If no bony injury is found, the wound is sutured without drainage and heals by primary union in over 95 per cent. of the cases;

3. Time, trouble in attendance and expense in dressings are saved.

Cushing (*Mil. Surgeon*, June, 1916, p. 601) expresses the present situation with regard to the treatment of cranial injuries: "There is no unanimity of opinion as to what should be the routine treatment of cranial wounds at first line hospitals. Some, owing to sorry experience, advocate leaving all except the minor injuries alone; some advise immediate trepanation only of the tangential wounds in which the dura has presumably escaped injury; but by far the larger number, basing their views on the experiences of earlier wars, recommend the prompt treatment of every case at the earliest possible moment. The operation usually consists of enlarging the wound, the elevation of depressed fragments, the removal, so far as possible, of the spicules driven into the brain, and direct drainage.'' Although approximately 55 per cent. of the cases of cerebral injury operated on within a few hours after injury under the necessarily primitive conditions of the usual field hospital, die from meningo-encephalic infection and from the remote fatalities due to secondary complications months afterward, Cushing believes that, ''if a field hospital is perfectly equipped in personnel, and X-ray apparatus and a thorough neurologic study can be made, immediate operation may be desirable,'' but under any less ideal conditions he is deeply convinced that, ''The likelihood of ultimate perfect recovery is seriously lessened, if preliminary and necessarily incomplete measures are there undertaken.'' He further states ''I believe that though an immediate operation might save 1 or 2 per cent. which could not reach a suitable base, 10 or 20 per cent. could be spared the late sequelæ of these injuries if their primary operation, even with a delay of 2 or 3 days, could be done under ideal auspices.''

In strong opposition to this opinion are Wilms (*München. med. Wchnschr.*, Oct. 19, 1915, p. 1437), Gray (*Brit. Med. Jour.,* Febr. 19, 1916), Bárány (*Wien. klin. Wchnschr.*, Nov. 20, 1915), Fritsch (*Hamb. med. Ueberseehefte,* Nov. 14, 1915), Makins (*Surgical Experiences in South Africa*), von Oettingen giving his experiences in the Manchurian campaign (*München. med. Wchnschr.,* 1906, p. 218) and Velter (*Presse Médicale,* Febr. 10, 1916).

Wilms recommends immediate removal of the indriven hair, bone and metal fragments and the crushed and softened brain in tangential shots, on the principle that early operation removes the foci of infection before the reactive edema becomes well established and lessens both the traumatic edema of the missile and operation by adequate drainage. Gray states that septic wounds of the scalp and skull are particularly easy to deal with by complete and early excision, and healing takes place by primary union, after suture, unless sepsis has obtained a firm hold in the lacerated brain. ''Edema and so-called shock are no bar to operative success. Indeed, it seems likely that both pass more quickly the sooner and more thoroughly the foreign material is removed, pressure and edema due to the circulatory obstruction relieved and adequate drainage established.''

Velter, after a year's experience with skull wounds seen within six hours following injury, is convinced that immediate operation in these, perhaps more than in any other wounds, is essential to a favorable outcome, for there is less chance of infection, less need for drainage and more opportunity for primary healing of the operative field. He believes that the mechanical disinfection of a wound within a few hours of its incidence, with the removal of foreign bodies and the excision of dead, disintegrated tissue is nearly always sufficient to ensure secondary reunion.

Skull wounds stand travel fairly well, even in the stage of concussion, but not at all well after operation, and the opinion of Haury (*Presse Médicale,* Nov. 18, 1915) that in the early treatment of the wounded more attention is given to the wound than to the soldier's mental and physical state, and that time should be given the brain, "the trophic center," to rally and steady itself, lest even a slight operation prove fatal from lack of recuperative power, is the belief held by most of the military surgeons of widest experience. The patient, when seen shortly after injury, is usually more or less collapsed, is suffering little, is often asleep and not easily roused and is not usually in a suitable condition to resist the depressing effects of prolonged anesthesia and the thorough opening, disinfecting and drainage of the wound necessary in these formal cranial operations. Practically all these initial phenomena are due to the general concussion of the brain and not to the local injury, and in the earliest stages the effect of operation is to exaggerate the trauma and shock. Sargent and Holmes (*Brit. Jour. of Surg.,* Jan., 1916) state "The immediate results of a gunshot wound are general disturbances of cerebral function and those due to local injury. In the former the whole cerebral and bulbar mechanism is affected in varying degree. Loss of consciousness of varying depth and duration, general muscular flaccidity and disturbance of cardiac, respiratory and vaso-motor action are most striking symptoms and yet, in case the danger is not immediately or shortly fatal, recovery can take place spontaneously. Associated with these are symptoms due to the abnormal increase of intracranial pressure from the reactive edema of the traumatized brain, aggravated by the presence of effused blood and by the frequent presence of multiple cortical capillary hemorrhages. This severe cerebral edema may last for several days and, in the absence of infection, subsides spontaneously, both the subsidence and the pressure symptoms being often greatly hastened by lumbar puncture. Hemorrhages occur, but are rarely large enough to threaten life or to demand operative interference. When considerable hemorrhage does occur, it is often basal, contralateral or inaccessible, manifesting itself after many hours or days and almost always by definite localizing symptoms added to those of general compression.

"The disturbances due to local injury are those of motor, sensory, reflex, mental and visual functions, according to the region involved, the extent or amount depending upon actual destruction of brain tissue and partly upon contusion, localized edema or local concussion. No operation relieves the former and the latter may recover without surgical aid. Only when progressive loss of function ensues is exposure and drainage of the affected areas indicated."

Relative to the *time of operation,* the degree of shock, the hospital facilities and the type of surgical skill available and the necessity for more or less prompt transportation are deciding factors. In general the safest time for operation is from two to four days after the injury, when the patient has reached a permanent and well-equipped base hospital where X-ray examinations can be made and the scalp adequately prepared. Sargent and Holmes (*loc. cit.*) state that delay lessens the danger of infection of the subarachnoid space by allowing the formation of adhesions and further lessens the danger of formation of hernia cerebri. Operative reactive inflammation, added to the traumatic edema already existing, increases the tendency of the brain matter to protrude, hernia cerebri, of course, being a symptom of abnormal intracranial pressure. "Further, the lining of the ventricular cavity tends to herniate, first into the overlying softened brain and then into the base of the hernia cerebri: ultimately it may rupture and discharge cerebro-spinal fluid"; ventricular infection following rapidly. The formation of a cerebral hernia is therefore not only dangerous to life, but to the function of the protruded brain and of that in the neighborhood of its base, the finer cortical and subcortical structures being unable to withstand the dragging strain placed upon them.

"The respective dangers, those of meningitis and of hernia formation attendant upon early operations, and those of infective encephalitis due to retained, infected foreign bodies, and of ventricular infection, which beset delay, must be balanced against each other, experience seeming to show that the dangers of early operation are the greater."

As serious wounds of the skull have been overlooked by neglecting the complete clearing of the scalp of hair, this is the first step in the local preparation for operation. This is best and most quickly done by clipping the hair as close as possible with a clipper and applying a depilatory such as a fresh mixture of 2 parts of barium sulphide, 5 parts of starch and 1 of orris root, made into the consistency of a thin paste with warm water, and rubbed well into the whole scalp. Within ten minutes the hair can be entirely scraped away with any dull instrument and the excess of paste removed by washing with water, the razor cuts so common to the usual shaving preparation being thereby avoided.

The scalp is best cleansed with alcohol and both scalp and wound thoroughly painted with strong tincture of iodine. In using a rubber tourniquet about the head to control bleeding, pressure upon the eyeballs is to be avoided.

The first step of the exploration is the complete excision of the contused and septic scalp wound down to and including the pericranium. If no evidence of deeper injury is found either locally or symptomatically, the wound may be sutured at once and usually heals by primary union. If the skull is fractured, however, it is seldom necessary to trephine, but the fragments of bone may be carefully elevated and removed until room is created for the insertion of a rongeur, by which all soiled and depressed fragments are gently gnawed away until the gap in the skull is rounded off. There is positive danger in allowing free buttons or fragments of bone to remain over the dura, for later depression and epileptiform symptoms occur from such sources. Fissures should be rongeured up, especially if the dura beneath them is torn. Space for these more extensive manipulations is given by the creation and reflection downward of a broad flap, with its pedicle downwards, in the middle of which is placed the original excised scalp wound, which is later closed by sliding a layer of aponeurosis over the defect.

Opinion is greatly divided as to the best treatment of an intact but non-pulsating dura. Under the dura in most of these cases dead, pulped brain matter exists, with or without a hematoma. Sargent and Holmes (*loc. cit.*) believe it unjustifiable to incise the dura, unless for extensive subdural hemorrhage, on the ground that the increased extent of dural adhesion which they believe results from the procedure is more likely to lead to epilepsy, and on the further ground that dangerous degrees of intracranial pressure are best treated by lumbar puncture or contra-lateral decompression. Roberts, (*Brit. Med. Jour.*, Oct. 2, 1915, p. 498) states that although it is inadvisable to open the dura in the presence of a septic wound, yet where the septic tissues have been excised by a surgeon who is sure of his technic the result of allowing exit to disintegrated tissue is excellent. In over 30 cases so treated, there were no deaths, while in 4 cases where this was not done, cerebral abscesses or meningo-encephalitis occurred, followed by death. He declares that this disintegrated brain substance and blood, whether superficial or deep, is of no use, that it acts as a foreign body, causing further destructive changes in the surrounding brain and that it is replaced by fibrous or glial tissue, forming a scar with its later potentiality for irritation. Gray (*loc. cit.*) and Arnaud (*Jour. A. Med. Ass'n,* March 25, 1916, p. 970) are of similar opinion, the latter stating that there is no need to fear infection from without, or cerebral hernia, and that patients recover without complication much better than if the dura mater had not been incised.

Where the brain has been lacerated, a continuous flow of hot normal saline during the operation washes away much softened brain and foreign matter and keeps the field free from blood.

Every fragment of bone and foreign body should be removed the moment it is felt, taking care not to enlarge the dural tear too much, lest the limiting adhesions be torn. As the symptoms seen with foreign bodies in the brain are mainly the result of injury done at the time of their introduction, if they are deep in the brain tissue and are causing no particular irritation it is wiser to allow them to remain, lest during their removal, not only will no improvement be effected in the original damage, but an increase in the extent of tissue injury and symptoms result. Many foreign bodies "lie in positions inaccessible to legitimate surgery; or the relative positions of wound and foreign body, taken together with the symptoms, show that in its passage such damage must necessarily have been done as to render hopeless the chances of recovery." Often multiple fragments are found by X-ray, scattered in various parts of the brain, making removal out of the question. "The removal even of easily accessible pieces of metal must be done with every precaution, for such cases not infrequently die apparently as a direct result of the operation, while similar cases, in whom expectant treatment was adopted, have recovered completely, temporarily at least." Bier has suggested that the patient be laid on the wounded side and gently and repeatedly rapping the head in this direction in order to start the foreign body outward.

Numerous observers have removed metallic foreign bodies, such as fragments of bullets and shrapnel from the brain with a minimum of trauma by the use of a giant magnet and at times under direct Roentgen-ray control. Sargent and Holmes (*loc. cit.*) use soft iron rods 12 to 18 cm. long and 1 to 1½ cm. in diameter. These are passed along the track of the missile after previously removing the fragments of bone under a stream of hot saline. At the desired distance the nose of the magnet is applied to the end of the rod and a current having a pulling equivalent of several pounds applied, this being enough to attract metal fragments an inch or more distant from the point of the rod. After a few seconds, during which the click of an attracted foreign body may be heard or felt, the apparatus is gently withdrawn and the attached foreign body dropped into a sterile test tube, for cultural purposes, by turning off the current.

Where thorough cleansing of the wound has been possible and the existence of sepsis does not gainsay, the denuded dura or brain is covered and protected by scalp or by sliding a pericranio-aponeurotic flap after the ingenious manner devised by Sargent, (*Brit. Jour. of Surg.,* Jan. 1, 1916), the wound being drained at its angles by rubber tubes, or better by rubber tissue wicks, carried down to but not into the bone defect.

Drainage is indicated in the presence of pus, of infected blood clot, of definitely infected but inaccessible foreign bodies and where there is free oozing from an extensive laceration of the brain. A gauze drain is never justifiable in wounds of the brain because of the certainty and the density of the adhesions which result. Small, fenestrated rubber tubing, or preferably rubber tissue wicks, give the best drainage, while the latter are most efficacious and have the least possible effect of a foreign body. Sargent and Holmes (*loc. cit.*) use glycerin in the lumen of the drainage tubes for its hygroscopic effect, its inhibiting action upon the growth of pyogenic cocci and its apparent effect in emulsifying disintegrated brain and thus aiding its escape. The drainage tubes are surrounded by gauze soaked in glycerin and a large dressing of gauze and wool applied. If afterward reactive edema tends to extrude the tube, lumbar puncture is done.

Perforating wounds of the skull in which immediate death has been escaped usually recover without operation, although in some of the more severe cases it is necessary to trephine both the wound of entry and that of exit, where wide fissures and extensive contusion of the brain may exist.

Fractures of the base of the skull from direct projectile injury are seldom operable and must be treated expectantly or, upon the signs of beginning infection, suboccipital decompression and drainage of the subarachnoid space may be done, according to the method of Cushing.

Lumbar puncture is one of the most valuable aids in the diagnosis and treatment of projectile injuries of the skull. By the character of its cellular and the amount of its albuminous content spinal fluid gives important information as to the extent and severity of the injury and by its immediate effect in reducing the intracranial pressure, the operation often gives prompt relief to the severe and continuous headache, to the paralytic phenomena, melancholia, stupor or even to the epileptiform attacks which not infrequently follow simple contusion of the skull and concussion, without focal injury of any sort. In simple commotion and in most non-penetrating wounds of the skull it is the only rational treatment. Fifteen to 45 cc. may be withdrawn daily, as indicated, and the procedure, even repeated in this way, seems harmless unless the pressure in the fluid is below normal to start with. The optic neuritis, so constantly associated with all these forms of intracranial pressure, is benefited in proportion with other symptomatic improvement.

In air concussion the intracranial pressure often remains high for days after the injury and these cases appear to suffer almost none of the consequences of lumbar puncture seen in civil life when done for diagnostic purposes or for the relief of diseased conditions.

Lumbar puncture is also of particular value in penetrating wounds, where it lessens the tendency to the formation of cerebral hernia and aids in its control, if already developed. If done before the subarachnoid space about the wound has become closed by adhesions, it must be used with care lest it be the means of introducing meningeal infection, which may also result from withdrawing too much fluid, thus causing the brain to sink back from the dura and tearing the adhesions. Medullary strangulation in the foramen magnum has also resulted from excessive withdrawal of fluid. The diagnosis of rupture into and of infection of the lateral ventricle also may be aided by examination of the spinal fluid.

Where lumbar puncture fails to relieve increasing pressure symptoms a contra-lateral subtemporal decompression may be indicated.

As a further aid, the use of urotropin in doses of 1.0 to 2.0 grams every three or four hours is indicated in every projectile injury of the skull with accompanying fracture, and is to be continued until danger of immediate infection is past. Bromides in full doses are necessary for months after every cerebral injury.

An additional, but very rare condition which may follow a projectile injury of the skull and create heightened intracranial pressure, with the optic nerve indicating its degree, is intracranial pneumatocele, due probably to opening of the frontal or ethmoidal sinuses into the anterior fossa. The symptoms are those of pressure on the frontal lobe. Duken (*München. med. Wchnschr.*, Nov. 17, 1915) and Kredel (*Zentralb. f. Chir.*, Nov. 30, 1915) report cases.

The relations of projectile injuries of the skull and brain to the eyes are established especially through increased intracranial pressure from many sources through actual destruction of or injury to the visual cortical centers or the visual pathways and through local and general meningeal or encephalic infection. The ocular expressions of these injuries appear in the form of papilledema and optic neuritis of all grades; muscular pareses, paralyses and conjugate deviations; and defect phenomena in the visual fields, ranging from total binocular blindness to tiny unilateral relative scotomata.

It is estimated that from 50 to 75 per cent. of projectile wounds of the skull show papilledema or genuine optic neuritis at some stage of their existence, the surprising frequency with which this sign is witnessed during the present war being due in large measure to the more rapid transportation of the injured to hospitals where special examination is available.

Fully two-thirds of these cases are limited to a slight and transitory blurring of the margin of the disc, or to slight edematous rather than inflammatory swelling of the disc and its immediate periphery. In most of these cases, the visual acuity and color sense are unaffected, and no changes in the visual fields are found. Hemorrhage is rare, and in most instances the condition disappears without leaving any permanent residue.

Where there has been no fracture of the skull and the symptoms are the result of a hematoma or of cerebral bruising and reactive edema, intense papillitis is seldom seen and when it does occur under these conditions, it usually subsides within a few days after lumbar puncture is instituted. In about four-fifths of all penetrating wounds, however, strong vascular engorgement and swelling of the disc are observed, in complete accord with the intensity of the intracranial damage and particularly of the degree of heightened intracranial pressure.

The cases of papilledema following depressed and splintered fractures of the skull are interesting, in that the neuritis usually subsides quickly after trepanation and removal of the fragments and all traces of its presence are usually lost within two or three weeks. A. von Szily (*Deutsch. med. Wchnschr.*, Aug. 19, 1915) believes that optic neuritis occurs less often after penetrating wounds and after those where bullets have become lodged, than after tangential shots with their more or less deep-reaching destruction of the cortex. There seems to be, in fact, a direct relation between the optic neuritis and the extent of destruction of the brain tissue, with the physico-chemical effect of the attendant hemorrhage and edema.

Shell and shrapnel fragments cause optic neuritis more frequently than bullets, because of the commonly greater extent of cerebral laceration and the constancy with which infection and abscess results. In infected wounds optic neuritis is always present and the grade of papillary swelling is proportionate to the degree of meningeal infection or, less constantly, to the degree of abscess formation and its location. The severest form of papillitis seems to be reached in large brain abscesses, particularly in many frontal though less often in cerebellar abscesses. In many of these abscesses the vascular engorgement and edema of the brain caused by the infection are often accompanied by prolapse of the brain, which further exaggerates the intracranial tension and consequently the degree of papillary engorgement. Upon the establishment of early and efficient drainage the cerebral prolapse usually subsides promptly and the discs clear. Lee (*Brit. Med. Jour.*, March 25, 1916, p. 447) working under an X-ray screen, removed a fragment of shrapnel from a deep occipital abscess, by forceps, after magnetic removal had failed owing to the impaction of the missile against the brain tissue. This case had an intense bilateral neuro-retinitis, with swelling of both discs, though all changes were more marked in the left fundus. The neuritis had subsided considerably though not completely a month after the operation. Although the small superficial cerebral abscesses which form in about 2 per cent. of the tangential injuries seldom find their index in papillary changes, yet when these changes do exist, they are usually more intense on, or are rarely limited to, the side of the injury.

Optic neuritis after cerebral injury, becoming progressively more severe, is to be considered as a grave sign, and the observation of changes in the disc by a trained ophthalmologist will often decide for the surgeon as to the advisability of reopening the wound, *the significant factor in these cases being the increase in the optic neuritis, not the mere fact of its existence.* Adams, writing of his experiences in the Balkan war (*Military Wounds of the Eye and Their Treatment*, Berlin, 1914), states: "With many surgeons papillitis is an indication for operation. This is a mistake, however, for these cases are not comparable with those of brain tumors, and the change in the optic nerve here simply means that something is wrong with the brain. Often it is merely the expression of a subdural hematoma and not uncommonly becomes more pronounced after the operation and may remain long after the cranial wounds are healed, facts which should be appreciated, lest the increase be interpreted into an unfavorable prognostic sign." *If, therefore, no other symptom furnishes an indication for trephining, that of choked disc alone should not be an indication for opening the skull.*

After shot wounds of the skull, if slow, or relatively slow, pulse occurs in connection with irregular changes of temperature and increasing vascular engorgement or swelling of the disc, the diagnosis of abscess of the brain becomes highly probable. Hayward (*Berl. klin. Wchnschr.,* Nov. 22, 1915), who gives a very extensive bibliography of military wounds of the skull, reports a case of multiple abscesses of the brain, in which autopsy disclosed a second and older abscess, deeper than the one which had been evacuated at operation. This had caused death by perforation of the ventricle.

von Szily (*loc. cit.*) reports a case of acute choked disc with a large preretinal hemorrhage, due to an ampulliform subdural hemorrhage into the sheath of the optic nerve, the result of fracture of the base of the skull from being unhorsed.

In many cases the optic neuritis retrogrades, but reappears later; in these cases at section, basilar meningitis or chronic abscess cavities, often formed about foreign bodies, are found. Abscesses, if of appreciable size, are often revealed and localized by the X-ray, for often localizing symptoms are not marked.

Conjugate deviation and nystagmus not infrequently occur as late pressure signs, the latter not to be confused with the nystagmus of cerebellar or of frontal origins.

In spreading meningitis, neuro-retinitis comes on early and is intense. Free opening of the dura, counter-incision and irrigation of the subdural space with salt solution, repeated large lumbar punctures, the aspiration of pus from the ventricles, as suggested by Chiray (*Presse Médicale,* Dec. 2, 1915) and the liberal use of autogenetic vaccine may, but rarely, lead to recovery. Residual paralyses of the ocular muscles rarely if ever result. That it is a grave error to consider wounds of the skull as healed merely on the ground that the wounds have closed, and that statistics relative to projectile injuries of the skull are grossly imperfect which do not include evidence dealing with the *late results of skull injuries* is apparent from the frequency with which fatal late infections, or permanently disabling defects of mind and body result. It is the exception when the injured man remains free from distress of some sort, and nearly all complain of headache for months after the injury and are seldom free from it. Warm days and exposure to the sun so greatly increase this complaint that such patients often cannot accept work which exposes them to the direct sunlight. The coal-tar products relieve this form of headache. Few of these patients are ever again capable of active military duties, and Holbeck (*Projectile Wounds of the Skull in Battle,* Berlin, 1912), who investigated 65 cases of projectile wounds of the skull two years after injury, found that only 8 were fully capable of work, while 7 had died.

Hayward (*loc. cit.*) presented a case of cerebral cyst formation four months after injury and one of serous meningitis, in which the relief of the pressure led to complete cessation of headache, and melancholia. This suggests the possibility that lumbar puncture may be of palliative value, at least, in some of these chronic disturbances, and many of the numerous methods of closure of traumatic or operative gaps in the cranium have the relief of these chronic and distressing symptoms as their main object. Mariau (*Paris Médicale,* April 1, 1916) describes the use of thin gold plate which fills the defect exactly and is held in place by three projecting arms. The Jacksonian seizures in 16 patients upon whom the method was used stopped completely and in a number of cases in which severe headache, throbbing and epileptiform attacks had made existence a matter of sheer misery, their symptoms were permanently relieved.

That it is safe to rule that all projectile wounds of the skull be kept under occasional observation for many months is well exemplified in the case reported by Casey Wood (*Ophthal. Record,* Aug. 1, 1915) of a soldier who sustained a depressed fracture of the skull in the median line, just behind the vertex. This was elevated 3 days after the injury. Nearly a month later an extensive infection of the scalp and neck occurred, requiring free incision and tubal drainage. A large, irregular fragment of shrapnel was removed from the neck at this time. Three weeks later the patient had a sudden attack of vertigo while walking. He was obliged to sit on the edge of his bed, felt very "queer" and noticed that his left arm began to jerk and his feet to dance. He grasped his left wrist with his right hand and then lost consciousness. He was afterwards told that he had had a convulsion, with some sort of "left-sided symptoms." This was the only convulsive attack which occurred.

About ten weeks later, the only subjective symptoms were morning frontal headaches and "blurred sight," the latter referred to the left eye and increased by over-exertion. These headaches disappeared before sailing for America, but returned after the ocean voyage. The blood count at this time was erythrocytes 4,800,000; leucocytes 16,900 and hemoglobin 85 per cent. The ocular examination made by Dr. Wood follows:

The patient's pupillary reactions, ocular tension, muscle balance and the external appearances of the eye are all normal. On dilating his pupils and scanning the fundi he presents a few white, very small dotted exudates scattered over both fundi, in addition to slight myopic changes. On the right side, just above the disc, is what appears to be the remains of an old hemorrhage. The important alterations in the fundi are, however, a definite blurring of the outlines of both nerve-heads, with obscuration of the physiological cups and loss of transparency in and swelling of the papillary tissues. The retinal vessels, both veins and arteries, are engorged and slightly tortuous. In fact, the picture is that of a recent, though receding, mild, bilateral papillitis. The fields of vision (two examinations at a week's interval gave almost identical charts) are shown in the accompanying illustrations. The areas, especially on the left side, for white, red and green, are decidedly contracted.

The treatment was entirely hygienic, following the definite instructions of the patient's oculist, Mr. Arnold Lawson, except that frequent very hot fomentations followed by very cold applications to both temples and ocular regions, ordered by the writer, appear to give relief to the headaches.

Dr. Archibald Church reported that the functions of the cranial nerves showed nothing abnormal, "aside from the restriction of the fields above mentioned. There is also no evidence of disturbance of innervation in the distribution of the cord and spinal nerves. Reflexes, sensation, trophic conditions, are everywhere normal. The knee-jerks are brisk, but on repeated examinations prove to be equal, as are the deep and superficial reflexes elsewhere.

"Evidently the young man received an injury to the occipital lobes affecting the right cuneus more than the left. Whether this is entirely traumatic in character or in some sense dependent upon a secondary infection, I am unable to state. I would suggest that he be carefully watched for rise of temperature, and that his blood be searched for any evidence of leucocytosis."

Whether the damage to the optic nerves will result in further invasion of the fields and go on to optic atrophy remains to be seen. If the eye symptoms are entirely due to the traumatism, as such, the youth and good health of the patient will probably bring about recovery with no additional damage to sight. If, on the other hand, the papillitis results from an infective meningitis the usual results of a post-neuritic atrophy of this character are to be feared.

In a personal communication about two months after this examination, Dr. Wood reports that "the patient developed an abscess of the brain, with operation and—so far—complete recovery."

In common with all forms of *injuries of the frontal lobes*, complete recovery occurs more frequently after abscess of the frontal than of other regions.

A case reported by Roberts (*Brit. Med. Jour.*, Oct. 2, 1915, p. 500) illustrates the apparent harmlessness of the loss of considerable frontal brain matter. A bullet entered over the left brow and emerged through the right upper lid. Both wounds were septic and the brain protruded from each. Severe wounds of both feet and one knee were also present. The patient was deeply unconscious, with incontinence of urine and absent reflexes in the lower limbs. The right eye was destroyed and the left fundus wholly obscured by vitreous hemorrhage. The right eye was enucleated and both wounds excised and enlarged. Both orbital plates, nasal processes of the frontal bone and ethmoid were comminuted. The fragments were removed and several deeply-placed pieces of bone were taken from the brain. The wound of entry was sutured and the wound of exit was drained after a partial closure. The patient eventually recovered, returning home in apparently normal mental condition. Vision began to return in the left eye after four or five days and finally became 6/12.

It is well to remember, in this connection, that the cortical innervation centers for the pupils, for the vaso-motor functions and for the control of conjugate ocular movements lie in the frontal lobe.

Brodmann (*Munchen. med. Wchnschr.*, Aug. 17, 1915) reports a case in which spasm of the sphincter of the iris remained as a residual symptom after perforation of the tips of both frontal lobes. Differences in the size, regularity and activity of the pupils occur very often in lesions of the cortex, but they are to be interpreted rather as the reflex effect of meningeal laceration than as the effect of local cortical injury. Immediately after injury the pupils are usually contracted, but widen later and become dilated and unreacting in the higher degrees on intracranial pressure.

Noehte (*Deutsch. med. Wchnschr.*, Oct. 7, 1915) has further reported 8 cases of *nystagmus after injury of the foot of the second frontal convolution* by projectile or by bone, reactive or hemorrhagic compression, and Oppenheim (*Berl. klin. Wchnschr.*, Nov. 8, 1915) refers to a form of nystagmus independent of any lesion of the cerebellum and its connections.

Nystagmus is often produced by injuries of the occipital region, a fact explained by the nearness of the labyrinth, the cerebellum and the medulla, but nystagmus following parieto-frontal injury can be understood only on the ground of the direct injury of a frontal center of coördinate movement, for the numerous cases of gross lesions of the brain without nystagmus seems to exclude the only other possible factor, that of transmission of the force of the projectile to the medulla through the cerebral lymph channels, this possibility being made more remote by the fact that no loss of consciousness occurred in several of these cases reported by Noehte.

The first case was that of a tangential shot through the left parietal region, with the anterior portion of the indriven bone pressing upon the foot of the second frontal convolution. There had been no loss of consciousness. The depressed bone was elevated at once. The right patellar reflex was stronger than the left and the right pupil was wider than the left. Nystagmus was induced by looking to the left and to the right as well. Three weeks later the general condition was excellent. On looking to the left the eyes wavered slowly back to the midline; there was slight weakness of conjugate motion, but no true nystagmus existed. The rapid disappearance of the nystagmus after operation excludes the possibility of its having been the sign of an earlier disease.

Case 2 was a bullet wound of the soft tissues over the left parietal bone, without bony injury. The patient was unconscious for five minutes after injury, and apart from lateral and superior nystagmus had no neurological symptoms. In case 3, a bullet fired at about 300 meters injured the soft tissues behind the left frontal protuberance, without fracturing the bone. After a short interval of unconsciousness, the man walked with help, but speech control was temporarily lost. Movements of the fingers of the right side were weaker than those of the left. Nystagmus to right and left existed and remained as the sole symptom of the injury nine days later, though it was evoked then only by looking to the right.

Case 4 received a bullet wound of the right brow, followed by transitory insensibility and later giddiness. Eight days later nystagmus upon looking to the right was accompanied by increasing headache, and by vertigo on raising the head. Finger orientation was poorer on the left side than on the right. The fact that these symptoms came on late and disappeared fifteen days after the injury would indicate a delayed hemorrhage or edema which gradually spread to the conjugate center which lay slightly posterior to the point of injury.

Case 5 was a shell wound of the left frontal boss, with a small wound of entrance. The patient was somnolent. Looking to the left evoked tremor of the eyes. Finger movements were weaker and less powerful on the right than the left. The pulse was 50. Four days later the patient still slept much and it was noticed that the right angle of the mouth was less readily raised than the left and movements of the tongue were influenced. Two weeks after injury the patient was well.

In case 6 a tangential bullet wound of the left parietal bone 2 cm. from the midline developed marked nystagmus to the left eight days after injury, the symptom clearing in two weeks, in common with paralysis of the right hand and reduced hearing, after depressed fragments of bone were removed. Paralysis of the right foot remained. As the hearing was reduced, the possibility of a labyrinthine nystagmus cannot be excluded here, although nystagmus did not exist at the first examination and was apparently produced by the pressure of hemorrhage.

Case 7 developed an abscess of the motor center for the left leg, after a bullet wound of the right parietal bone with prolapse of the brain. Coincident with the formation of the abscess an increasing paralysis of the left arm and the right side of the face, with an increasingly intense nystagmus, appeared.

Case 8 was a tangential shot of the right parietal region, with paralysis of the left extremities and reduced superficial and deep reflexes of the left side of the body. Nystagmus was evoked on looking to the right. The symptoms showed the cerebral injury to be located in a region bounded above by the leg center, below by the arm center, in front by the precentral and behind by the postcentral convolution, or approximately the region of the conjugate center.

In these cases there was no uniform relation between the side of injury and the direction of ocular movement, and Noehte is of the opinion that each center consists of several parts, lesions of which lead to right or left nystagmus, or the combined involvement of which produces nystagmus in all directions. He compares this disturbance of ocular motility to the ataxia of the extremities seen in lesions of the postcentral convolutions and believes that injury of the frontal center for combined ocular movements should be considered as a possibility in every case of post-traumatic ocular tremor.

Stack (*Bristol Med.-Chir. Jour.*, Dec., 1915), while not particularizing as to the region of injury, remarks the frequency with which nystagmus follows head injuries.

That not all wounds of the region anterior to the center for speech produce nystagmus is shown by a case of Henneberg's (*Deutsch. med. Wchnschr.*, Oct. 7, 1915) in which a perforating wound of both second frontal convolutions gave the picture of an acute dementia, with loss of ability for complicated motion, but without nystagmus.

An interesting group of ocular disorders centers around wounds of the sinuses, and particularly around *wounds of the superior longitudinal sinus* and its tributary lacunæ. Rupture of, or pressure upon the walls of the longitudinal sinus is common after tangential shots with depressed fracture or fissures of the skull in the midline, although much less often observed in through-and-through perforations. Many of these cases recover without symptoms, but where the sinus or its lacunæ, the intermediary channels between the sinus and the superior cerebral veins, becomes occluded by thrombosis or by the pressure of dislocated bone, widespread thrombosis, cortical venous stasis and resultant cerebral edema occur to such extent that dangerous or fatal degrees of pressure and characteristic and profound motor and sensory disorders ensue. The characteristic neurological symptom-complex, first described by Holmes and Sargent (*Brit. Med. Jour.,* Oct. 2, 1915, p. 493) under the title of the "longitudinal sinus syndrome," is that of an immediate bilateral spastic paraplegia which resembles the birth palsy of Little and affects the lower more than the upper extremities. The symptoms are attributed wholly to the circulatory stasis.

In these cases the eyes respond directly to the increase of pressure. Holmes and Sargent (*loc. cit.*) state: "As a rule the functions of the cranial nerves remain unaffected, but in several patients the ocular movements were disturbed. In one group there was either temporary weakness or paralysis of the associated movements of the eyes with ptosis or affection of the pupils; one patient in whom all four limbs were affected, was unable to move his eyes to order in any direction except slightly downwards, but he could follow, though not fully, a finger which was moved to either side or upwards. The visual axes always remained parallel. Within a fortnight, however, all movements had returned and only upward deviation was at all defective. There was a similar inability to perform conjugate ocular movements in another patient in whom all four limbs, except the fingers, were paralyzed, and this persisted until his death, five days after injury. More commonly, however, there was only weakness of the lateral conjugate movements of the eyes to one or both sides, or much effort was needed to perform them. It seems probable that this palsy of the conjugate movements is due to a temporary paralysis of the centers for ocular movements in the posterior part of the second frontal convolutions. We have occasionally observed a similar defect in local lesions of this region.

"In other cases, eight in all, we found an isolated palsy of one or other oculo-motor nerves, generally of the 3d, or of the 3d and 4th cranial nerves. This proportion is very striking when we consider the comparative rarity of ocular palsies in other types of gunshot wounds of the head; it seems probable, therefore, that it is related to the lesion we are considering. On the other hand, it might be due to a fracture of the base of the skull, to basal meningitis or hemorrhage, or to the effects of the considerable rise of intracranial pressure which is so often present in these cases. In some cases, however, in which a post-mortem examination was made, we could exclude basal lesions and in only two of the cases was the 6th nerve affected, although it is, of course, known that this nerve is much the most liable to suffer from a pathological increase of intracranial pressure.

"In five cases there was also definite optic neuritis, with considerable swelling of the discs and not merely such congestion and blurring of their edges as is seen in a large proportion of all gunshot wounds of the head. In four of these cases we could exclude meningitis and secondary cerebral abscesses and must consequently attribute the ophthalmoscopic changes to the edema and swelling of the brain."

Uncomplicated cases show a remarkable tendency to improve, probably owing to the free venous anastomosis. If operation is necessary, it is advised "to remove bone all around the depressed portion and only then to elevate this," for if hemorrhage occurs, the surgeon is then in a more favorable position to control it "by using Horsley's method of the 'postage stamp' operation, in which a piece of tissue, cut from the under surface of the skin flap, is pressed over the laceration and allowed to adhere, thus avoiding the exaggerated and grave thrombosis which inevitably follows the use of gauze tampons in this situation." Cushing suggests the use of vulcanized fibrin films.

Where these sagittal injuries occur posterior to the lateral lacunæ, sensory disturbances and the loss of the stereognostic sense may result from concomitant contusion of the superior parietal lobes.

The most characteristic and possibly the most striking of all cranial injuries are the *contusions and the tangential wounds over the occipital poles which cause central blindness and all manner of permanent and transitory defects in the visual fields.* Penetrating shots which enter between the occipital protuberance and the occipito-parietal sutures almost inevitably produce visual disturbances.

Uhthoff (*Klin. Monatsbl. f. Augenh.*, July-August, 1915) estimates that about 9 per cent. of all injuries of the optic apparatus are gunshot wounds of the skull with hemianopic disturbances, wounds of the occipital regions and of the optic radiations forming by far the larger part of these cases, and Best (*loc. cit.*) reports hemianopsia in over 15 per cent. of his cases of penetrating wounds of the skull, and mind-blindness in over 13 per cent. Marie found defects of the fields in 10 per cent. of cranial injuries. Genet, who made a systematic examination of all projectile wounds of the head, regardless of their apparent triviality, found that changes in the fields occurred in 11 per cent. of 82 cases and concludes that *research of the visual field is necessary in all cases of occipital trauma, regardless of their apparent triviality,* for certain wounds which would otherwise attract no attention, by the demonstration of a hemianopsia would demand trepanation, regardless of an intact external table, and would show important cerebral lesions. Further, many of these modifications of vision pass unperceived, as they are without subjective disorder, and in many instances are discovered only when sought.

Wounds of the occipital region are subject to the same conditions of surgical procedure as in other parts of the brain, with the possible exception that the removal of foreign bodies from this region is to be undertaken only with the most extreme caution and only through the wound of entry, for additional trauma merely augments the visual defect. The rule of trephining all cases where the bony skull has been so much as grazed by a projectile applies here, and the excision of the wound, trephining, elevation of the depressed inner table, the extraction of obvious and easily accessible fragments of bone and metal, or incision of the dura, with the evacuation of clot and pulped brain, and primary suture are all as imperative as in the motor areas. The external table is often intact in occipital shots and the true bony lesions often are disclosed only after trephining, when the inner table is found fractured or even fragmented into small splinters which may press into the dura with or without rupture. Laminæ of clotted blood form between bone and dura and over the occipital cortex, which is always more or less edematous, the site of capillary or more extensive bleeding, or in the severer injuries, irreparably destroyed.

Genet (*Lyons Chir.*, Nov., 1915) reports 3 cases of tangential occipital shots with bony lesions limited to depression of the inner table, found at operation. In all three cases the dura was intact, although it did not pulsate in two. The dura was incised and a jet of black blood, or of blood mixed with pulped brain, issued. These cases were completely cured, although one presented a right unilateral hemianopsia, another bilateral hemianopsia with conservation of macular vision only, while the third had complete cortical blindness due to considerable bruising and pulping of the occipital cortex on the right side, the left being found normal. Two days after operation upon the last case, vision began to return and in four days he could read headlines, though with rapid visual fatigue. Complete visual recovery ensued. Genet further reports a depressed fracture of both tables with concentric contraction of both visual fields, which cleared after elevation of the fragments and evacuation of blood through a dural incision. Hemianopsia has been found to disappear by Tillmann (quoted in the *Brit. Med. Jour.*, July 31, 1915, p. 190) after the removal of fragments of bone from the occipital lobe.

Marie and Chatelin (*Révue Neurol.*, 1915, xxii, 882-925) dissent from this opinion as to operation and, from their study of 56 cases of occipital injury with careful perimetric observations, conclude that apart from the question of abscess formation and certain cases of retained foreign bodies, surgical intervention appears to be contraindicated in most cases.

The striking feature of occipital injuries is that the principal defect is visual rather than nervous. Immediate unconsciousness, of momentary or of considerable duration, follows the injury, but when control returns, blindness of all degrees remains. Unless there has been a direct bilateral lesion of both visual cortical centers, the early more or less complete blindness which follows so many of these occipital injuries gradually resolves into one or another form of hemianopsia, or, as in a few reported cases, into complete restoration of vision, without discoverable defects in the visual fields. In these cases of initial total or relative blindness, the later restoration of vision depends upon the subsidence of the constant reactive edema of the contused cortex and subcortex, the absorption of cortical capillary hemorrhage, the contraction and organization of meningeal clots, or it may be explained on v. Monakow's last theory of diaschisis. According to Jessop (abstr. *Ophthalmoscope,* May, 1915, p. 247) in this conception the shock of the injury to one side of the occipital area of the brain is transmitted by commissural fibres to the corresponding area on the opposite side, and as each area represents the cortical projection of half the field of vision in each eye, the immediate effect is blindness When the shock and its physical effects pass off, the center on the side opposite to the lesion generally recovers completely, leaving permanent and usually more or less symmetrical residual defects in the visual fields.

The hemianopsias of civil differ from those of military life, in that they are nearly all directly or indirectly of vascular origin, and the occipital cortex and subcortex affected include a wedge or cone of tissue all of which becomes functionless and involved in the final massive atrophy; in the wounded, however, after the disturbances of commotion, bleeding and reactive exudation have passed, the final lesion usually remains very circumscribed. It seems wholly probable, however, that projectile or other traumatic lesions of the same vessels or vascular systems, the involvement of which produces the hemianopsia of disease, may be instrumental to a large, if not preponderant degree, in the causation of many of the cases of vertical hemianopsia, the essential civilian hemianopsia, which are not rarely seen in these battle injuries, though particularly after the deeper lesions. Further, the relative frequency of horizonal hemianopsia, a form of visual defect characteristic of battle lesions but practically unknown in civil life, unlike the vertical hemianopsias, seems to have no particular vascular relation, but to represent direct injury to the occipital pole.

The intracerebral optic fibres pass backward deep in the substance of the temporal lobes and along the internal face of the occipital. In the form of vertical laminæ of white substance, about 2cm. broad, they follow the external wall of the lateral ventricle into the occipital lobes, where they terminate about the calcarine fissure and the adjacent portions of the cuneus above, and the lingual lobule below.

With reference to *the cortical projection of the retina,* Uhthoff (*Klin. Monatsbl. f. Augenh.,* July-Aug., 1915) states and Pierre Marie (*Bull. de l'Acad. de Méd.,* Nov. 16, 1915) reaffirms that the upper quadrant of the retina of one side projects itself upon the superior margin of the calcarine fissure of the other side, the destruction of this producing a hemianopsia in the lower visual fields, and that a lesion limited to the visual cortical center of one side is detected by a hemianopic scotoma in corresponding portions of the visual fields of the opposite side, the systematization of the optic fibres necessary to accomplish this probably occurring in the optic radiations. Lister and Holmes (*Brit. Med. Jour.,* April 1, 1916, p. 485) come to somewhat similar, though not yet positively established, conclusions:

"1. The upper half of each retina is represented in the dorsal, and the lower in the ventral, part of each visual area.

"2. The center for macular or central vision lies in the posterior extremities of the visual areas, probably on the margins and the lateral surfaces of the occipital lobes.

"3. That portion of each upper quadrant of the retina in the immediate neighborhood of, and including the adjacent part of, the fovea centralis is represented in the upper and posterior part of the visual area in the opposite hemisphere, and vice versa.

"4. The center for vision from the periphery of the retina is probably situated in the anterior end of the visual area, and the serial concentric zones of the retina are probably represented in this order from behind forwards in the visual area."

Lister and Holmes, however, believe the hypothesis of bilateral representation of the macula to be incorrect, for in the hemianopsia produced by penetrating wounds which involve one occipital lobe, the macula is usually involved, unlike the cases of hemianopsia due to vascular injuries. They ascribe the difference to the fact that the tip of the occipital lobe in which the macula is represented is a watershed area which may draw its blood from either the middle or posterior cerebral arteries, the variations in this arterial distribution probably accounting for the involvement or the escape of vision in the neighborhood of the fixation point. They further state that the fact that "in over 2,000 cases of head injury, a central scotoma was never seen when a direct injury of the occipital poles could be excluded, must be regarded as striking evidence that central vision is represented in either or both the mesial or the lateral surface of the posterior borders of the occipital lobes." Their observations conform to the general view that the visual area corresponds with, or at least includes, the area striata. They found no evidence which would allow them to conclude that achromatopsia, with intact vision for white, is the result of central lesions which involve either the cortex or the optic radiations.

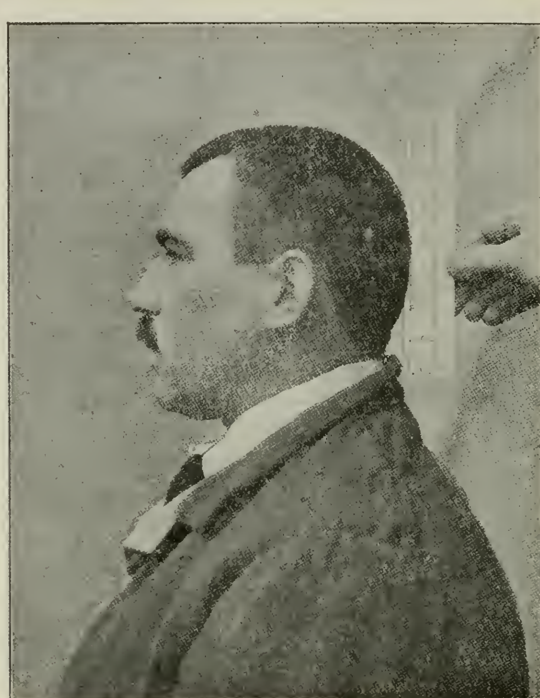
The common subjective symptoms which accompany these occipital injuries have been headache and vertigo, and in some cases visual irritant phenomena such as scintillating scotoma, ophthalmic migraine, disorders of visual orientation, loss or damage of the optical memory-pictures and hallucinations with closed eyes.

The terminal objective disturbances include: 1. cortical blindness, 2. horizontal hemianopsia, 3. vertical hemianopsia, 4. quadrant hemianopsia, and 5. hemianopic scotomata; the defects being nearly always symmetrically placed and, in the cases of the hemianopsias, being usually on the side opposite to the injured visual center.

In all of these cases any involvement of the papilla is merely evidence of secondary complications, such as hemorrhage, abscess formation, infection or other causes of continued and increasing pressure. Uhthoff (*Berl. klin. Wchnschr.*, Jan. 3, 1916) reports two cases of this form of intercurrent papillitis which were the first signs of deep and eventually fatal abscess.

The fields should be examined at short intervals, for particularly in the cases of hemianopic scotomata the increasing size of the scotoma may be the first index of the presence and the enlargement of an occipital abscess. v. Szily (*loc. cit.*) records a case of incomplete left-sided hemianopsia due to a chronic abscess cavity in the right occipital region, and Marie and Chatelin (*Rév. Neurol.*, 1915, xxii, 882-925) report careful perimetric studies of similar cases among the 56 cases of occipital lesions observed by them.

Cortical blindness is the direct result of a bilateral lesion of the visual cortical centers, usually a perforation of both centers by a bullet. It usually persists unmodified, and if vision of any sort remains or returns, it seldom exceeds a vague sense of luminosity or at best an exceedingly contracted field of distinct vision. Waddy (*Ophthalmoscope*, April 1, 1915, p. 175) details a case of destruction of the cortical visual centers by an undeformed rifle bullet which penetrated the occiput. The wound on the right side was 5¾ inches posterior to the outer boundary of the orbital margin, on a line 1½ inches horizontally posterior to the tip of the mastoid process, and 3½ inches superior to that point. The wound of the left side was 5½ inches, 1¼ inches and 3 inches upon the same lines as those given for the right side. The interval between the wounds was 5½ inches. As the line of the wound demonstrates, corresponding areas of each hemisphere were not destroyed by the shot, but as no radiogram was made and no operation performed, it is impossible to exclude wider destruction by fragments of bone depressed from the inner table. The soldier was unconscious for nine days following the injury,



1.

A Case of Destruction of the Cortical Visual Centers by a Rifle Bullet. Central Blindness.

and on regaining consciousness was able to distinguish light from darkness and to perceive coarse movements of the hand. No improvement resulted during four months of observation. The pupils reacted vigorously to light, both by consensual and direct stimulation, the reactions to convergence and accommodation were very poor, though demonstrable. The media were normal. Both optic discs were slightly indistinct at the margins, more pronounced over the upper third, and their surfaces were hyperemic. The maculæ were normal. The

2.

3.

A Case of Destruction of the Cortical Visual Centers by a Rifle Bullet. Central Blindness.

patient's general condition was excellent and remained so. There was no loss of memory or, as far as could be determined, of the higher associational functions.

The following cases of lesions of the cortical visual centers, and comments thereon, are from Harvey Cushing "Cranio-Cerebral Wounds of Modern Warfare" (*Mil. Surgeon,* June, 1916, p. 601):

"An Algerian zouave, 18 years of age, was wounded, presumably by a rifle ball, at 9 a. m. on April 26, and was admitted on April 30, 1915. On recovering consciousness immediately after the injury, the patient was found to be blind, but without motor paralysis. The wounds evidently remained untouched except for the external dressings which had been changed at various stations.

"Examination disclosed in the occipital region wounds of entrance and exit, about 12 cm. apart, equidistant from the midline and on a level with the occipital poles. Between these wounds the tissues were somewhat swollen and edematous, pressure gave pain and there was bony crepitus.

"Though there was some return of vision, he was unable to count fingers. (No perimetric observation.) He complained of headache and there was a low grade of papilledema. The neurological examination was otherwise negative. There was no fever.

"April 30.—Operation.—Ether. He was anesthetized face down on the cerebellar table. A curvilineal incision was made through the scalp to the bone above the line of injury and the flap was reflected downward. The occiput was found greatly comminuted, the dura badly torn and many bone fragments and spicules were scattered widely throughout the lacerated occipital poles. The fragments were carefully dislodged and removed. One of them was found to have perforated the sinus and hemorrhage was checked by the pressure of fingers until a piece of muscle could be secured from low down on the occipital flap, and this was implanted over the opening. The wound was carefully cleansed with pledgets of cotton, wet in saline solution, until all the clots and disorganized cortex were removed. All points of bleeding were checked by bits of implanted muscle and the flap was replaced and sutured in layers (galea and skin). A small cigarette-drain of rubber protective was left at each angle and the wound dressed with silver foil.

"All of the symptoms except the partial amblyopia rapidly subsided. The incision healed *per primam* and at the first dressing on May 3 the skin sutures were removed. By May 10 the drains had been withdrawn and he was up and about the ward. There was still some limitation of the fields.

"By May 18 his vision had greatly improved and on May 25 he was discharged, apparently well, with normal visual acuity and fields, so far as could be determined without a perimeter.

"In marked contrast to this result, there was admitted a few days later a precisely similar case, also wounded in the occiput 4 days before admission, and showing central blindness. He had been operated upon at a first line hospital; the wound was left open and packed and through the lacerated dura disorganized cortex protruded. The wound was cleaned as well as possible, many neglected fragments of bone, as well as the ball, being removed. The ball had lodged in the right mastoid after traversing the occiput. It was of course impossible to close the wound as a protection to the brain, as should have been done at a first stage operation, and the man succumbed to the almost inevitable meningitis 3 weeks later.

"These two cases form an excellent contrast, and I have little doubt but that, had it not been for the preliminary and incomplete operation in the second patient, he would have done as well as the first. The same thing holds true for some other cases in our service operated on in my absence—namely, good results after primary operation with closure even four or five days after the injury; poor results, with death from meningitis, in the cases treated at the front in the usual way and packed with gauze.

"The single exception to this was in the case of a man who had evidently had a severe shell wound of the left occipital region and after a prompt and effective operation was immediately evacuated and reached us on the same day. The large wound had been closed except at one end, where there was the usual gauze pack, at the base of which the brain was exposed. The X-ray showed no fragments of the projectile. He had a large defect in the skull and a right homonymous hemianopsia which was permanent. Otherwise there were no symptoms and he was discharged well, with the wound closed at the end of seven weeks." Moore (*Lancet*, Aug. 21, 1915) reports apparently complete recovery from total blindness in 22 days after a perforating bullet wound of both occipital lobes. No operation was performed, despite a pulse of 44, extreme drowsiness, total blindness and a subnormal temperature.

Superior hemianopsia is much more rare than inferior hemianopsia, because of the relatively rare injury of the lower margin of the calcarine fissure, which is much less exposed than the upper margin, the cortical projection area of the upper half of the retina.

These horizontal hemianopsias have more or less assumed the place of the typical hemianopsias of modern war. In the Transvaal and the Russo-Japanese wars twelve cases were reported by Critchett (*Ophthalmic Review*, 1901), by Inouye, by Makins and Fisher (*Surgical

Experiences in South Africa, 1899-1900), by Oka, Ono and by Haga, in the Boxer rebellion. Barbazan (*Thèse de Doctorat,* Paris, 1914, No. 400) gives an excellent bibliography of the subject. Uhthoff (*Klin. Monastbl f. Augen.,* July, 1915) and Axenfeld (*ibid.*) each report cases of this form of visual defect. In one of Uhthoff's cases total color-blindness existed, and in another, besides the defect in both lower fields, the left upper quadrant was partially blotted out, the probable lesion being an injury to both lips of the right calcarine fissure and of the upper margin alone on the left. A distressing occipital neuralgia occurred in one case, due to the pressure of the scar upon the occipital nerve, and was relieved by alcohol injections. Uhthoff ascribes the terrifying hallucinations which occur in the hemianopic cases upon closing the eyes, to cortical irritation, to which he further ascribed the continuous pain over the whole side of the head which resulted in one case. Four of Axenfeld's cases showed nearly complete defects of the lower fields. He draws attention to the necessity of excluding changes in the eyeballs or the optic nerves themselves as the result of a fall or contusion of any sort. One of the cases displayed hallucinations in the defective halves of the visual fields. Bruns (*Berl. klin. Wchnschr.,* Sept. 30, 1915) reports 2 cases and Marie (*loc. cit.*), Terrien (*loc. cit.*), Genet (*loc. cit.*) and others each report several cases. Roberts (*Brit. Med. Jour.,* Oct. 2, 1915, p. 499) gives the history of inferior transverse hemianopsia following immediately upon a gutter shot of the occiput just above the inion. At operation the depressed inner table was found pressing upon both occipital lobes over an area 2½ inches in diameter. The dura was intact. Bleeding from the longitudinal sinus was controlled by applying a piece of muscle. The wound was sutured. Vision became normal two days later. Ginestous and Bernard (*Paris Médical,* Sept. 25, 1915, p. 349), Cantonnet (*Archiv. d'Ophtal.,* June, 1915) and Rosseau (*Archiv. Méd. d'Angers,* July 20, 1915) each report a case of inferior hemianopsia.

In the horizontal hemianopsias the patients usually have more visual disturbance than is seen in the vertical defects. They not infrequently declare that their view is obscured by a film. (Probably the frequent involvement of the macula in the defect is partly, at least, responsible.)

The classical *lateral or vertical hemianopsias* are most often caused by deep and usually oblique perforation of the posterior temporoparietal region, by which the optic radiations deep in the temporal lobe are divided or injured. These cases are not usually preceded by cortical blindness, the hemianopsia exists definitely from the moment of injury and visual disturbance is sensed. According to Marie (*Bull. de l'Acad. de Méd.,* Nov. 16, 1915) it is rare that this type of lesion results from direct lesions of the visual center in occipital wounds, for in that case, if the trauma is extensive, the lesion is bilateral and cortical blindness or inferior hemianopsia results, or if the trauma is slight, the visual lesion is only partial and the homonymous lateral hemianopsia incomplete. In one of Marie's cases a *hemiachromatopsia* was demonstrated, the color-sense being absent in symmetrical parts of the left lateral fields. Uhthoff (*loc. cit.*), Terrien (*loc. cit.*), Marie (*loc. cit.*), Axenfeld (*loc. cit.*), Bruns (*loc. cit.*), Villaret and Rives (*Paris Médical*, Jan. 1, 1916) and others report hemianopsias of this form, all associated with more or less deep penetration of the optic radiations. In two of Uhthoff's cases the visual fields became perfectly normal, enabling one soldier to return to active and the other to less severe duty. Uhthoff states that these hemianopic defects are strongly symmetrical except when the eyes have become fatigued by the examination, but that *the intensity of the functional disturbance is both absolutely and relatively different in the two eyes.* In some cases a functional concentric contraction of the less affected field occurred, but soon disappeared.

Boettiger (*Deutsch. med. Wchnschr.*, July 15, 1915) describes the case of a soldier wounded by a bullet which entered the skull slightly behind the left mastoid and emerged just to the left of the middle line of the occipital bone, close to the upper border of the tabular portion. At first he was speechless and the right arm was slightly paretic, but these focal signs disappeared in six weeks, although the wound still suppurated. Six weeks later total alexia and right hemianopsia were found. He could only write his name spontaneously, and while fairly long words could be written upon dictation, he could not read them. Ten weeks after this the wounds were enlarged and loose fragments of bone were removed from both wound and brain. No improvement ensued until a large portion of the skull between the two wounds was rongeured away, when six large sequestra were found. Soon after the operation, reading became fairly easy, although never perfect, because of the persisting hemianopsia, which was undoubtedly due to destruction of a part of the optic radiation. The alexia is explained by the pressure of the sequestra upon the angular gyrus.

Genet (*Lyon Chir.*, Nov., 1915, p. 696) pictures the lesions which occurred in a case of left homonymous hemianopsia following depressed fracture of the occiput. Death occurred five hours after injury.

Hayward (*Berl. klin. Wchnschr.*, Nov. 22, 1915) reports three cases, in one of which vision began to return three days after the removal of a depressed fragment of bone from the occipital region, until only a small defect remained in the outer quadrants. This case was wounded by an infantry bullet at 200 meters. At the base hospital an oblique, granulating wound existed to the left of the midline of the occiput. Here bone was detected, shattered into small fragments. A right homonymous hemianopsia existed. Both discs were blurred at their inferior margins. Roentgenograms and operation showed fractures and depression of the inner table. The sequestra were removed, as were some splinters of bone which were imbedded in dural granulations. The dura pulsated well. Four days after operation the right upper quadrants of the visual fields were restored and at the last examination, aside from the slight defect in the lower right quadrants, the fields were completely normal. The single remaining complaint was headache upon exposure to the sun.

Lesions of the optic radiations often produce incomplete or *quadrantic hemianopsia,* the lower fields being nearly always the fields involved, and the actual direct and residual injury being limited to the superior lip of the calcarine fissure or to the portion of the optic radiations terminating there. Frequently permanent defects of this nature evolve out of initial total blindness, as reported by Bruns (*loc. cit.*), Terrien (*loc. cit.*) and others. F. Dimmer (*Wien. klin. Wchnschr.,* May 20, 1915) describes two cases of this nature in which the chief defect remaining at the end of a few months was a scotoma in the lower right quadrant of each visual field, the defect having an area of about 20 degrees and being almost identical in the two eyes. Milner (*Lancet,* July 24, 1915, p. 129) also reports two similar cases with complete restoration of vision save for identical defects in the left lower quadrant of each field. Axenfeld (*loc. cit.*) reports the unique case of residual right upper quadrantic hemianopsia due to a bullet lodged close beneath the occipital cortex.

Hemianopic scotomata are the most common visual defects found after occipital wounds. Where they are sought for in a routine manner they are found in about 1 per cent. of the projectile wounds of the skull. Although the visual defect is absolute, they are nearly always ignored or are unrecognized, unlike the inferior and quadrantic hemianopsias, where a vague sense of visual modification exists. Their topography is variable: they may be macular, paramacular or peripheral. While they are usually single, Marie has demonstrated the existence of multiple homolateral or heterolateral defects, and in one case a triple scotoma of the right field, associated with a left hemianopsia. The characteristic of these scotomata is that they are practically always homonymous, comparable in form and unmodified by time, facts which, in common with the accompanying occipital wounds, serve to distinguish them as the product of lesions of the central optic pathways rather than of the optic nerves or the retina.

By plotting these hemianopic scotomata exactly and by repeated careful examinations of the fields, a valuable and early index of abscess formation is given.

Smith and Holmes (*Brit. Med. Jour.,* March 25, 1916) report in interesting detail a case of bilateral motor apraxia with *disturbance of visual orientation* which followed the passage of a 12 mm. shrapnel bullet through the skull and brain, involving the supramarginal gyri. By plotting its apparent course, the authors conclude that the bullet entered the brain in the posterior and upper part of the right supramarginal gyrus, passed through the dorsal part of the right hemisphere, perforated the falx 1½ cm. dorsal to and 1 cm. in front of the posterior margin of the splenium, where it entered the left hemisphere, passing just dorsal to Wernicke's field in front of the knee of the optic radiations, and emerging in the lower part of the left supramarginal gyrus, in front of the posterior end of the Sylvian fissure. The man presented an apraxia of the oculo-motor movements similar to his loss of ambulatory and tactile orientation. Visual localization and orientation were defective and objects moved into the periphery of the nearly intact visual field neither excited attention nor provoked the appropriate ocular movements. The inability of the patient to find his way about is attributed mainly to loss of spatial orientation, and to a sort of apperception both of directions and of the spatial relations of objects which he can see and recognize by direct visual effort. The optic discs were normal, and central vision was 6/10 in each eye. In both lower right quadrants a relative scotoma reached to within 10 degrees of the fixation point. The fields for red and green were normal.

In the *battle injuries to the skull from blunt weapons* like clubbed rifles and in accidental fractures of the skull caused by falling walls, cavalry accidents, artillery crushes and falls into trenches, the ocular lesions and ocular complications which arise in the course of infections or thrombosis of the large basilar venous sinuses are naturally identical to those which so frequently follow blunt violence and related accidents in civil life and need no elucidation here. Fractures and fissures of the base of the skull are the almost invariable lesions, and paralysis or paresis of the sixth cranial nerve the most common ocular disturbance. It is of interest that if the freely moving head is struck by a clubbed gun and the head is moving away from the blow, the force is usually so lessened that while concussion, and at times cerebral contusion, occur, fractures rarely result.

It not infrequently happens in close, bitter melees, that after guns can no longer be clubbed or rifles shortened, fighting degenerates into a series of desperate hand-to-hand encounters, and when these savage conflicts are survived, torn lids, deep sclero-corneal lacerations or traumatic enucleations are not unknown.

OCULAR DISORDERS AND INJURIES OF AVIATION

Of all forms of military service, aviation makes an intense, exacting and prolonged demand upon the eyes which is approached only by the strain put upon the observers and to a less degree upon the sighters of the anti-air-craft gun crews. The mental and ocular strain, the exposure and the noise of the engines combine in producing such an effect upon the aviator that it is estimated that nearly a fourth of the men lose their nerve and have to change to some other branch of the service.

It is obvious that only eyes which have the best possible vision and in which the muscle balance is normal can be of service in this form of military activity. Precipitation upon and the frosting of glasses which result in every flight to any considerable altitude, would at once incapacitate the flier, or even fatally handicap him against an opponent who was not equally hampered. Further, as the eye strain is multiplied many times beyond that of any civil activity, it is equally obvious that even moderate degrees of muscular imbalance would be exaggerated into serious and disabling strains. It is, in fact, assumed that a considerable part of the sleepiness which long flights produce comes from strain upon the ocular muscles and that the cases where men have dropped momentarily, or have dropped to their death, without engine trouble, have been due partly to the combined monotony of the engine, the effects of dazzling and the strain of intense visual effort upon imperfectly balanced eye muscles.

Wells (*Jour. Roy. Nav. Med. Service*, London, 1915, i, 55, and 1916, ii, 65), discussing the "Injuries and Diseases of Aviators," tells of a man who had full vision in each eye and with both eyes together, but who could make a landing only by closing one eye and even then his landings were difficult. The cause of his faulty judgment of distance was found to be a "concomitant squint." Wells states that "the accidents of aviation are due mainly to sudden stoppage of the aeroplane, which falls headlong to the ground, or lands at too sharp an angle," the aviator being thrown violently forward. As his body is usually strapped firmly to his seat, his head and neck are jerked forward and his face and forehead may be injured by striking the structures in front of him, the muscles of his neck may be strained excessively or a cervical vertebra may be fractured without displacement. In a few instances eye injuries have been caused by the loosening of some nut or bolt in a tractor aeroplane, the metal being blown back into the aviator's face by the draught of the screw.

Zade (*München. med. Wchnschr.,* Nov. 2, 1915), among 162 cases of *dazzling* which occurred mainly among men in the anti-air-craft service, found scotoma following retinal dazzling in 31 cases. This scotoma was always peripheral and was usually found in the lower part of the visual field, around meridians 40° to 50°. Zade states that the effects of the dazzling upon the retina can be prevented by a suitably tinted glass.

Irritative, corrosive and asphyxiating gases have been reintroduced into warfare during the present conflict, the gases of chlorine, bromine, sulphurous anhydrid, sulphur dioxide, nitrogen tetroxide, ammonia and formol having been employed deliberately, while lethal quantities of carbon monoxide appear to be set free in the chemical action produced by the explosion of high-explosive shells.

Chlorine gas, which has an air pressure of at least 90 pounds per square inch, i. e., about two and one-half times heavier than air, and which drifts with the wind, has been particularly used as a drift poison-gas and from its ease and cheapness of production has been most widely employed and may be considered the prototype of these corrosive weapons. Chlorine is irritative in concentrations of 1 to 100,000 and unbearable in concentration under 1 to 10,000. In contact with moist mucous membranes chlorine and its compounds appear to produce nascent H Cl, in which form it is most destructive. Similarly the sulphurous anhydrid content of certain bombs, after bursting, produces a wide-spread, dense fog of sulphuric acid by absorption of H_2O from the air.

The irritant and corrosive effects of all of these liquids and gases is comparable with their destructive action so rarely observed in industrial accidents and depends upon the concentration of the gas. Even the lighter concentrations of most of these irrespirable gases put a man completely out of effective action by their *specific irritating action upon the conjunctiva.* In the lighter degrees of this action only profuse lachrymation and moderate injection of the conjunctiva occur. With denser concentration of gas the eyes cannot be opened, they are exceedingly painful and the mucous membrane takes on a peculiar violaceous cyanosis, the combined product of the irritative and asphyxiating effects of these irrespirable gases. Intense conjunctival chemosis occurs, and corneal and ocular corrosion in cases where the gas or liquid has been literally sprayed into the eyes by the nearby explosion of a bomb. In the cases which recover from the grave constitutional effects of "gassing" and in which the irritant action upon the eyes has been severe, clouded vision may persist for some time, although no definite corneal changes may be observed. Prophylaxis against these gases is attained by the use of suitable head and face masks and respirators combined, a solution of sodium hyposulphite being employed as a chemical neutralizer.

Cargill (*Brit. Med. Jour.*, Dec. 4, 1915, p. 822) reports a case of retinal hemorrhage in each eye which followed "gassing." It cleared in a few weeks. Hill (*Brit. Med. Jour.*, Dec. 4, 1915, p. 801) discusses the general pathology of gas-poisoning.

Finch (*Lancet*, Nov. 6, 1915) reports a case of optic neuritis after "gassing." According to the patient, the gas was invisible and was first noticed by the irritation it caused to the eyes, nose and throat. Though the eyes watered freely the pain was not severe, nor was sight much affected. On the following day severe headaches set in and within three or four days the sight began to fail and continued to become steadily worse for about two months. At examination three months after the irritant injury, no constitutional cause for the condition of the eye could be found. Gonorrhea and syphilis were denied and a Wasserman test of the blood was negative (no spinal test reported). The only previous illness had been typhoid some years previously. In civil life the patient had been a stoker in a lead-smelting works but he had never come in contact with red or white lead nor had he ever showed the signs and symptoms of lead-poisoning. The urine contained neither albumen nor casts.

O. D. : V = light perception only. Fundus: secondary atrophy of the disc, the summit of the papilla being + 7.00 D and the retina + 5.00 D. The physiological cup was filled. Organizing striæ radiated from the disc in all directions and the swelling of the papilla extended one disc diameter beyond the margins of the disc.

O. S. : V = 1/60; with + 6.00 D = 6/36. The changes in the fundus were similar to those in the right eye, though less intense. A rough test of the field showed it to be not reduced. The suggestion is made that the condition may have been an infective neuritis, possibly associated with an ethmoiditis, due to the gas.

In time of war an enormous amount of non-operative work is thrown upon the ophthalmic surgeon both in the care of local ocular disease, or of ocular disease as a symptom of general disease, and in detecting and correcting refractive errors and ocular abnormalities among recruits and soldiers.

From one-sixth to one-third of the ocular diseases seen by the military ophthalmologist are those in which the strain and necessary filth of hard campaigning with insufficient food and with exposure to all sorts of weather, have led to the same *ocular diseases or recrudescences of old general and ocular diseases* which might be expected to follow similar strain or exposure in civil pursuits or avocations. Among these conditions the most frequently seen are fresh and recurrent cases of dendritic, eczematous and parenchymatous keratitis; serpent ulcer; rheumatic, syphilitic and gonorrheal iritis, the latter usually associated with old, unhealed urethritis; chronic conjunctivitis and trachoma, acute conjunctivitis in nearly all its bacterial and clinical forms and the intraocular changes characteristic of general toxic diseases.

Among 600 eye cases seen by Uhthoff (*Berl. klin. Wchnschr.,* Jan. 3, 1916) dendritic keratitis formed about 1/4 of the inflammatory corneal affections. These herpetiform ulcerations were seldom traumatic and demanded prompt and thorough cauterization. 20 per cent. zinc sulphate, radiant heat and the actual cautery are efficacious against the condition if used sufficiently early. Serpent ulcers are usually post-traumatic and would probably occur more often and be more severe were it not for the healthy tear ducts and good general health of young soldiers.

Gonorrheal conjunctivitis is reported by von Grosz (*loc. cit.*) as not infrequent and as leading to total blindness in several cases.

Jefferson and Armstrong (*Brit. Med. Jour.,* March 4, 1916) report the treatment of 50 cases of acute conjunctivitis with Dakin's solution of sodium hypochlorite, diluted to 1/5 strength, and used freely three times daily. They state "many valuable men in excellent general health are rendered incapable of service for considerable periods owing to the state of their eyes" and they undertook the use of this solution because of the need for more effective and rapid treatment. The cases were cured in six days of treatment on the average, compared with an average of nearly nine days in cases where boric acid and zinc solutions were employed.

In the continental armies, as was predicted by Mills (*Jour. Am. Med. Ass'n*, Oct. 23, 1915) and reported by von Grosz (*Wien. klin. Wchnschr.*, Nov. 11, 1915) and Feilchenfeld (*Deutsch. med. Wchnschr.*, Dec. 2, 1915), trachoma has made considerable and spreading inroads, both in the field and after infecting the soldiers' native villages.

Exophthalmos, as a part of the syndrome of neurogenous exophthalmic goiter has become known as one of the rarer products of the severe strain and the great emotional disturbances of modern warfare, Rothacker (*München. med. Wchnschr.,* Jan. 18, 1916) being among the latest reporters of the condition. The excessive smoking to which soldiers on active duty are prone may be a factor in this as in all the neurogenous conditions of warfare, such as the hemeralopias.

Since the report of cases of "epidemic nephritis" by various observers in the *Wien. med. Wchnschr.,* Oct. 30, 1915, a formidable number of cases has been seen and reported from all the combatant armies. The condition seems peculiar to men who have been on active service in the trenches for some months and is believed by most observers to be of an infectious nature. Moore (*Lancet,* Dec. 18, 1915), discussing "Renal Retinitis in Epidemic Nephritis," reports the existence of "exudative albuminuric retinitis" in 4.2 per cent. of 119 cases of this form of renal disturbance. He considers this to be a general index of the severity of the disease and although it is more likely to be present in cases of eight or nine week's duration, it may be present quite early in severe cases. Abercrombie (*Brit. Med. Jour.,* Feb. 19, 1916, p. 279) states that no fundus changes were observed in 500 acute cases during the first three weeks of the disease. Amaurosis occurred in 3 of these 500 cases. Moore (*loc. cit.*) and Jessop (*Brit. Med. Jour.,* May 13, 1916) believe the condition to be purely toxic in origin and to partake of the nature of a retinal edema. The retinitis usually disappears completely with full restoration of vision.

Aside from the more urgent ocular disturbances all sorts of abnormalities and pathological changes are discovered among the soldiers. Elschnig (*Med. Klinik,* May 16, 1915) in remarking the variety of the ocular injuries, expresses surprise that in so large a proportion of his patients the eyes had been defective before the injury. In two of his cases, choked discs from brain tumor were found in men who had been serving for months on the firing line. In 2 per cent. of Uhthoff's non-traumatic cases, pupillary evidence of cerebral syphilis, tabes and progressive paralysis existed, and he saw cases of choroidal sarcoma and carcinoma of the tear sac. von Grosz (*loc. cit.*) discovered cases of sarcoma of the iris and of the choroid, a gumma of the tear sac, a case of "metastatic rheumatic choroiditis" which led to atrophy of both eyes, tubercular choroiditis and a case of emphysema of the lids following violent sneezing.

Malingering occurs in all armies and the detection of simulated defects of vision is usually simple. In the endeavor to give the impression of nephritis, egg albumen has been introduced into the urine and the pupil repeatedly dilated by homatropine. Soldiers with slight cranial wounds ("Correspondent," *Brit. Med. Jour.,* Jan. 8, 1916, p. 65) have been known to prolong their convalescence indefinitely by provoking inequality of the pupils by the judicious use of atropine and men have delayed being sent to the front by inducing acute conjunctivitis by means of snuff or powdered ipecac and have caused "facial erysipelas" by an application of croton oil. The ingestion of picric acid in order to simulate jaundice is a fairly common subterfuge, and Guillain *et al.* (*Bull. de l'Acad. de Méd.*, Febr. 22, 1916) report an extreme case of this sort where bilateral ophthalmoplegia externa occurred twenty days after taking picric acid in an attempt to escape active service. Pseudo-icterus and gastro-intestinal symptoms existed. The pupillary reflexes to light and distance remained normal. The ocular paralyses are ascribed to the fixation of picric acid in the oculomotor nuclei or in the nerve trunks at their origin. Picrates and picramates were found in the urine and the spinal fluid yielded traces of picramic acid. Damage to the eyes from *methyl alcohol poisoning* is reported from all the armies in the field. Birch-Hirschfeld's account of the conditions (*Med. Klinik,* Febr. 27, 1916) is both typical and comprehensive.

THE RELATIONSHIP OF VISUAL ACUITY TO MILITARY EFFICIENCY

In times of peace refractive errors of more than moderate degree exclude men from military service, but it has been the history of every country in which compulsory service is not maintained, that shortly after the outbreak of war of any magnitude, the visual standards, in common with all the other physical standards, have been reduced and, for many men who have not the requisite minimum of vision but are capable of excellent service of some sort, reduced more than once. von Grosz (*Wien. klin. Wchnschr.*, Nov. 11, 1915) reports the case of a man who saw less than 5/20 but who won both medals for bravery, and urges that men with a maximum vision of 6/18 are capable of good and often full active service. Save in the special lines of sharpshooting, aviation, navigation and artillery observers and pointers, the majority of soldiers have no particular need for especially keen vision.

The visual standards used in the medical examination of recruits were founded, in the continental armies at least, upon the idea that their entire effective manhood might be made available for some form of active military service. Their standards were the result of exhaustive study and experience and the uniformity of their requirements indicate their common conclusion from this experience that effective visual acuity, i. e., visual acuity of a degree which enables a soldier to shoot effectively, is equally of value whether obtained through the use of glasses or without them. As Paterson and Traquair state (*Lancet,* May 6, 1916, p. 954) "Continental authorities have found that, on the average, soldiers who see best shoot best, and that those who wear correcting spectacles shoot better than those who do not." "In every case it is the vision with glasses or corrected vision which determines the acceptance or rejection of a recruit." Where it may become necessary to utilize every available man for military service, it is surely inconsistent to maintain a standard such as has been maintained in the United States and Great Britain whereby men who, in spite of very defective vision in one eye, have never been conscious of or incapacitated for industrial pursuits by this, because of excellent vision in the other eye, should be rejected, while others who are actually visually unfit, from cataract, optic atrophy, hypermetropia of moderate degrees and corneal opacities, are still able to pass the visual tests. It has been common experience in all the engaged armies that "hypermetropes who pass the test while they are well and strong, but who, after some months of trench life and perhaps a wound, find that their visual acuity is seriously reduced owing to difficulty in maintaining accommodation." Paterson and Traquair (*loc. cit.*) refer to an extensive bibliography which deals with the relationship of visual acuity to military efficiency.

TABLE SHOWING THE VISUAL STANDARDS FOR RECRUITS IN THE CHIEF EUROPEAN ARMIES *

	Amount of myopia allowed		Standard of corrected vision		
	Combatants	Non-combatants	Combatants	Non-combatants	Remarks
Germany	6.5D. For Landsturm no limit if standard of corrected V. attained.		½ in better eye. Minimal in other eye. Landsturm ¼. If V. = ½ one eye, other may be blind.		Vision with glasses i. e., corrected vision counts.
Austria	6D	Above 6D no limit if standard of corrected V. attained.	Group 1. ½ in each eye. Group 2. ½ in one; ¼ in other.	¼ in one; 1/10 in the other.	Vision with glasses counts.
France	7D	Above 7D no limit if standard of corrected V. attained.	½ in one eye; 1/20 in the other.	¼ in one eye; 1/20 in the other.	Vision with glasses counts.
Italy	7D		⅓ in each eye or ½ in one eye if the other has 1/1 (full vision).		Vision with glasses counts.
Great Britain	About 2.5D	About 2.5D in better eye; 3.5D in worse.	Uncorrected V. must be ¼ in each eye, or ¼ in right, with 1/10 in left. No correction allowed for general service.	Uncorrected V. must be ¼ in better eye, 1/10 in worse. The better eye may be the left.	Vision without glasses counts.

Notes.—The standards in the table are peace standards, except that of Great Britain, which is a war standard and by far the highest. 2. The regulations in continental armies as to forms of refractive error other than myopia follow similar lines.
* From Paterson and Traquair. Lancet, May 6, 1916, p. 954.

The visual requirement for enlistment in the United States army is 20/40 in the right eye and 20/70 in the left.

In connection with the question of errors of refraction among conscripted soldiers, of enough degree to make them dependent upon glasses, Weigelin (*Jour. Am. Med. Ass'n,* July 31, 1915, p. 341) found that 386 men, or 3.5 per cent., out of a division of 11,000 troops were thus dependent and that but few of these had a reserve pair of glasses. Estimating the number in a whole army corps at this rate would give 1,750 wearers of spectacles. Of the 386 soldiers, 214 were myopic, 74 hyperopic, 12 had senile visual defects, 81 astigmatism and 5 had ocular defects impossible of correction.

Nystagmus occurring in miners, which becomes apparent when the visual line is raised above the horizon, often makes service at the front impossible. Ormond (*Ophthal. Review,* Aug., 1915) states that the strain of military training has brought on a recurrence of the so-called "miners' nystagmus" in several cases which had been previously cured after working above ground for some months.

Harford (*Brit. Med. Jour.,* March 4, 1916) believes it is a serious mistake to subject men who have any tendency to this disorder "to the arduous strain of military service, which not only involves exertion of all the powers of body and mind, but particularly of the eyesight." This should be borne in mind when examining recruits from a mining community. Harford further points out that as the vision in these cases may be reduced suddenly to the minimum without obvious cause and attacks of giddiness may come on at any time, the presence of such a man might prove a source of serious danger to his unit. Most of these men have refractive errors, temporary giddiness, more or less photophobia of a type suggesting that seen in albinos, headache, perverted visual impressions and are often mentally introspective and oppressed.

The *loss of sight in one eye,* particularly of the right eye in a right-handed man, and the left in a left-handed man, usually incapacitates a private from active service, though not necessarily so in the case of an officer. The private need not be discharged but may be given some clerical duty in connection with the service, provided, as is not infrequently the case, that no permanent mental defect has resulted from a coincident lesion of the adjacent brain. Undoubtedly men who have lost one eye while in service and who, after their discharge, lose the remaining eye from a non-military cause without connection with the original injury, are entitled to pension on the ground that the first injury directly doubled their risk of subsequent blindness. Unilateral blindness occurs about ten times as often as bilateral blindness.

The chapter of *the totally blind* and of those with such reduced vision that their independent economic existence is precluded is at once the saddest and the most hopeless of military ophthalmology.

While total blindness and the loss of practical vision in such an unprecedented number of cases as this war has shown, are due in great measure to the increased penetration of the modern bullet, the employment of high-explosives in artillery missiles has nevertheless been an important factor. The most frequent cause of total blindness is lateral perforation of both orbits, but, aside from this there is a long array of injuries to the eyes or to the intracranial optic apparatus which are directly responsible for appalling numbers of blind. Large leucomata following corneal abrasions, with or without infection, simultaneous penetration of both globes by metal fragments or secondary missiles; rupture of the tunics, retinal detachments, retinal and vitreous hemorrhage, disease, injury to or destruction of the intracranial optic pathways and the cortical percipient centers, all have been the mediate lesions of blindness in many cases.

So great has been the number of these young unfortunates blinded during the present war, that large organizations have been formed in all the combatant countries for solving the problem of their care and education, and for providing for their employment, distraction and the maintenance of their families.

Such victims deserve the highest pension-recompense in the power of a nation and the efforts of the Germans along this line are worthy of serious emulation in all countries with due regard, of course, to the prevailing standards of living. The German government has decreed (*Jour. Am. Med. Ass'n,* March 4, 1916, "Berlin letter") that every blinded private shall receive an annual pension of $342.00, non-commissioned officers receiving $15.00 to $90.00 additional. The annual pension of a blinded officer is at least $1,000.00. Many of these men are also entitled to the invalids' pension provided for by the workingmen's compensation laws. Every blinded soldier who, previous to his admission to the army, was engaged in an occupation coming under the compensation act, may demand the legal pension, which is not less than $37.50 nor more than $75.00 annually. Private donations have helped to raise the funds necessary to meet these expenditures.

The obligation of a nation to these blind soldiers does not cease with the mere payment of a pension however. Such men are not almoners but are rather to be considered as potentially able workmen, who are to be encouraged to a new vocation, which it is their choice to select from many, and to engage in its practice where they please.

Uhthoff (*Berl. klin. Wchnschr.,* Jan. 24, 1916), E. Krückmann (*Deutsch. med. Wchnschr.,* June 24, July 1 and July 8, 1915) and Monprofit (*Bull. de l'Acad. de Méd.,* Nov. 30, 1915) have written at length on the matter of welfare work for the blind soldiers. Uhthoff places especial stress upon not allowing the patient to return home before his training is well advanced, for at home he nearly always loses his self-reliance and, from motives of love, sympathy or greed on the part of his family who have not seldom been willing to turn his misfortune into a means of gaining additional charity, he is often never permitted to regain it.

"Some men, and particularly those of the low-powered group, or men who have led hard lives, view the prospect of dependence with equanimity and at first absolutely refuse to face the long tedium of instruction. In time, however, by careful suggestion and infinite patience, even they can practically always be induced to learn some vocational task.

"The principle involved in the instruction is to encourage the blind to the fullest sense of their ability to lead independent and self-supporting existences, depending upon their own strength and intelligence, and the earlier after injury that training to that end can be undertaken, consistent, of course, with the state of health, the prompter the response. Cohn (*Berl. klin. Wchnschr.,* Jan. 24, 1916) shows the value of the blind as teachers and caretakers of the newly-blinded, stimulating them by the knowledge that others have acquired proficiency and a means of independent livelihood. Some sort of premium should be placed upon the relative willingness and exertions of the men and this is manifestly best done in the form of financial and moral backing during the early days of their independent career in the practice of their newly-acquired vocations.

Insofar as possible this training should be along practical vocational lines, for most of the men are strong and young and have been engaged in a calling for some years, and wherever possible the training should follow the lines of prior training and occupation, or tastes. Among other vocations the following are being successfully practised by these recently blinded men: 1. Music; organist, pianist, singer, music teacher, piano-tuner, violinist; 2. Intellectual calling; teacher, tutor, secretary, instructor in languages, instructor to the blind, elocutionist, entertainer, mathematician, geographer; 3. Massage, typewriting, telephony; 4. Hand labor and craftsmanship; weaving, broom-, chair-, basket-, mat-, and boot-making, rope and hammock-making; poultry farming, market gardening, bee-keeping, engraving in fine metals, and cigar-making. Dubois, quoted by Gerald Ames in the *Illustr. Lond. News,* March 11, 1916, suggests and employs fencing as an ideal recreation and exercise for blinded soldiers, the instinctive "feel of the blade" being attained by them with surprising rapidity.

Uhthoff further emphasizes the fact that any duplication of plants for the education of these blind is a needless waste and has proven a failure in Europe where the established institutions for the blind have merely been enlarged. The standardization of apparatus, of methods of instruction, and the placing of all these institutions under a centralized direction are additional means for economy and efficiency of expenditure no less than for uniformity and excellence of the results in terms of human output. See **Blind, Occupations of the.**

Naturally the fact that the optic cripple has gained the ability to earn offers no just foundation for attempting the least reduction or limitation of his pension. Uhthoff declares the payments of lump sums of money to the men, save in the form of a pension, to be nonsense, for while a few of the more thrifty bank this for the future support of themselves and family, in many more instances the money has been quickly wasted in various excesses. Uhthoff counsels the early marriage of these blind men, otherwise strong and healthy, to good and considerate women as the surest way of present happiness, and of later contentment in their children. The semi-dependence creates an additional bond of common devotion. The ease of marriage in youth, particularly where the previous existence of comely features without deformity has been known, is far greater than later, and mutual sympathy, aid, understanding and love more easily created from the first.

The accumulation of a great central library of literature for the blind is of the greatest importance.

The question of the employment of these men alongside of men with normal vision and the fear that such union may slow down the normal man by a tendency to aid the cripple, can be settled only by the demonstration that these men are equally capable and, in some vocations, more capable than men with full vision.

While blindness is possibly the greatest of physical misfortunes, it is not altogether a calamity, for through the visual failure, the senses of touch, hearing and particularly of orientation may achieve so fine a schooling that their only limits under modern training are the open streets and unknown places.—(L. M.)

Milium. A small, white tumor of the eyelids or their neighborhood. See **Cyst, Sebaceous, of the eyelid**; p. 3693, Vol. V of this *Encyclopedia.*

Milk. Cow's milk. In acute eczema of the lids, or in any other disease of the external eye where it is undesirable to use watery solutions warm cow's milk is a good detergent. In phlyctenules of the conjunctiva or cornea, especially if associated with facial eczema, the parts should not be washed with water but with a cleansing oily emulsion.

In such cases milk forms an admirable application. It is also a soothing liquid ready to hand for washing out the sac in burns of the conjunctiva from acids and other chemicals.

Milkstone. Galactites. A stone, no longer identifiable, employed in ancient Greco-Roman ophthalmology. This stone, under friction, is said to have yielded a milky fluid, of value in various diseases of the cornea and lids.—(T. H. S.)

Milk, The, of a woman. Woman's milk was highly esteemed as a remedy in various diseases and wounds of the eyes throughout antiquity and the middle ages and much of the present period. Even at the present day it is highly in favor among the laity of almost every land, and indeed is possessed of a modicum of actual virtue. Scribonius Largus esteemed it very highly in corneal ulcers and all severe ocular inflammations, while Pliny and Dioscorides employed it frequently for the removal of foreign bodies, and in ocular injuries generally. Pliny believed that woman's milk possessed an especial efficacy if the woman had borne either a boy or twins. Best of all, however, as a prophylactic, was the milk of a mother mixed with that of her own daughter. Once well anointed with such a powerful preservative, the eyes would be most thoroughly protected from all injury, as well as from all diseases, throughout the entire remainder of the owner's life.—(T. H. S.)

Milky cataract. A soft cataract in which the opacity is very white, like milk, in color.

Milliampere. One-thousandth part of an ampere.

Milliamperemeter. An instrument for measuring the strength of an electric current in milliamperes.

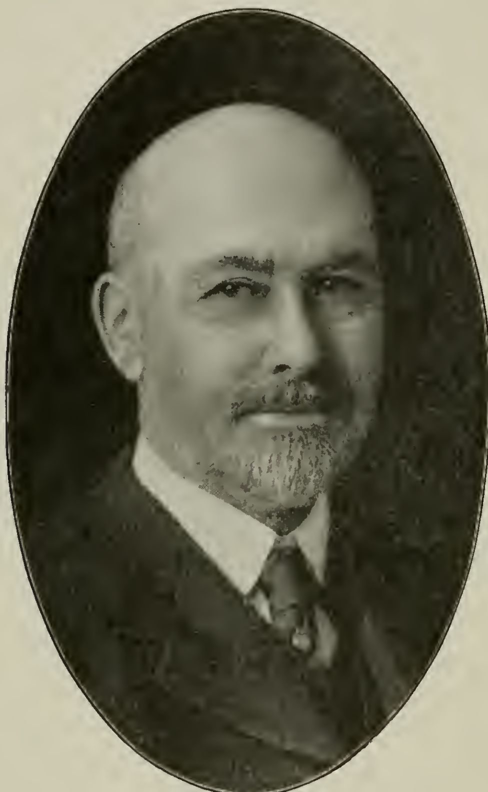
Millicurie. A unit of radio-activity which is the amount of radium emanation equal to that of a milligram of radium.

Milligram. One-thousandth part of a gram.

Millikin, Benjamin L. One of the most distinguished ophthalmologists of the Middle West. Born at Warren, O., son of Christopher and Mary Millikin, Dec. 24, 1851, he received the degree of Bachelor of Arts at Allegheny College in 1874, and that of M. D. at the University of Pennsylvania in 1879. After a year or more of graduate study abroad, he returned to this country, and served for a time as resident physician in the University of Pennsylvania, later in the Philadelphia Children's Hospital and the Wills Eye Hospital.

In 1883, having been appointed professor of diseases of the eye in the medical department of Western Reserve University, he removed to Cleveland, O. The following year he was appointed visiting ophthalmologist to St. Vincent's Hospital. From 1892 to 1912 he was visiting ophthalmologist to Lakeside Hospital, and, from 1912 until his death, senior visiting ophthalmologist. In 1900 he was made dean and executive officer of the medical faculty of Western Reserve University, retiring in 1912. Throughout his entire career he never ceased to take an interest in general medicine, though practising ophthalmology exclusively.

Dr. Millikin, in all his professional relations, was a power for good. Thus, it was chiefly owing to his persistent endeavors that the entrance



Benjamin L. Millikin.

to the medical course at Western Reserve was limited to college graduates. When he became dean, the endowment of the medical department was only $50,000; at the time of his retirement it had arisen to more than $1,500,000. One of his intimate acquaintances wrote: "In the twelve years that I have been associated with Dr. Millikin, I have not heard him utter a word of complaint concerning himself, or a word of criticism against another. Of a kindly and sympathetic nature, he has not only been most generous in his free professional service, but without the knowledge of anyone but the agent to whom he entrusted the beneficence, he assisted many of the medical students in their struggle for an education."

Dr. Millikin married, in 1891, Miss Julia W. Severance, by whom he had five children: Severance A.; Dudley Long; Helen E.; Marianne E., and Louise S.

For nine or ten years Millikin's health had been slowly failing, but even his intimate friends were not aware of the seriousness of his condition. He died Jan. 8, 1916, survived by his wife and all his children.

Doctor Millikin was a man of middle height, a blond, brown-haired, blue-eyed, and full of quiet, patient energy. He was a member of the Presbyterian Church, and a devout believer, but without the faintest trace of bigotry or slavery to creed. He was active in all good causes. He was fond of the country, spending his few vacations with his wife and children in the woods and fields, studying the markings of the trees and the calls of birds. Altogether, a pleasant, genial scholarly man, a true friend, an all-round physician, a skilful ophthalmologist; indeed, a type to be remembered.—(T. H. S.)

Millilambert. One candle-power per square inch equals 486.7 millilamberts. See **Illumination.**

Millimeter. One-thousandth part of a meter.

Millingen (or Milligen), Edwin van. A well-known Anglo-Turkish ophthalmologist, son of Dr. Julius van Millingen, physician to Lord Byron in the Greek war of independence. He was present with Byron when that celebrated poet died (at Missilonghi), and was subsequently physician to four sultans.

The subject of this sketch was born in England about 1848. He received an excellent education in the arts and sciences, and became a well-known linguist, writing and speaking French, German, Arabic, Greek and English with almost equal ease. His medical education was received chiefly in Germany, especially under Professor Julius Hirschberg, in Berlin. He practised in Constantinople, and there wrote numerous articles, the most of which appeared in the *Centralblat f. pkt. Augenheilkunde.* He invented a number of ingenious operations, one of which consisted in the insertion of a collar-button-shaped glass into the cornea, in cases of double corneal leucoma. This inserted glass was, of course, not tolerated very long, but the object was to enable the completely blind from leucoma to see again, for a very short time at least, just before they died, or else for the purpose of enabling the patient to identify some person, document, or other visible object, in an important case at law.

van Millingen was, for years, professor of ophthalmology at the

Constantinople Military School, and, for even a longer time, was ophthalmologist and otologist to the Sultan Abdul Aziz and to the harem. "In this capacity," writes a correspondent, "van Millingen proved so useful that His Majesty never wished him to leave the Capital, as there was always some eye or ear trouble in the large Imperial family needing attention. Once when I wanted him to visit Egypt with me, he was not permitted to leave, because one of the Sultan's numerous wives had an acute middle ear suppuration."

van Millingen was tall, slender, handsome, and, in a word, of very impressive presence. His complexion was dark, and he wore a pointed beard, "which, along in the '90s, was, like his hair, becoming gray." His favorite theme, in conversation, was England: he was always, in fact, on the very point of going back to England. But it seems that he never received permission to depart for his native land, and he died, without again beholding it, some time in the year 1900.—(T. H. S.)

Milne-Edwards, Henri (1800-85), naturalist, was born at Bruges, Belgium. His father was an Englishman. After having for many years taught natural history at the Collège de Henri IV., he was elected in 1838 member of the Académie des Sciences in the place of Cuvier. In 1841 he filled the chair of entomology at the Jardin des Plantes, and in 1844 became also professor of zoology and physiology. He published numerous original memoirs of importance in the *Annales des Sciences Naturelles,* a journal he himself assisted in editing for fifty years. His *Eléments de Zoologie* (1834), reissued in 1851 as *Cours Elémentaire de Zoologie,* was a great success. His *Histoire Naturelle des Crustacés* (1834-40) and *Histoire Naturelle des Coralliaires* (1857-60) were almost equally noteworthy. The *Lectures on the Physiology and Comparative Anatomy of Man and the Animals* (14 vols. 1857-1881) have a great permanent value for their immense mass of details, and copious references to scattered sources of information.—(*Standard Encyclopedia.*)

Milton, John. One of the greatest poets of all time, who, in his later years, was blind from glaucoma. Born at the Spread Eagle, in Bread Street, Cheapside, London, on Friday, Dec. 9, 1608, the son of John Milton, a scrivener, he received his early education from a domestic tutor named Thomas Young, a graduate of the University of St. Andrews, and a man of considerable ability. From his seventeenth year to his twenty-fourth, he pursued an academic course at Cambridge, being a "lesser pensioner" of Christ's College, and receiving the degree of Master of Arts in July, 1632. During his career at Cambridge Milton wrote numerous poems, among them the lines *"On the Death of a Fair Infant"* (1625-26), the well known Christmas ode, *"On the Morning of Christ's Nativity"* (1829), and the sonnet, *"On Arriving at the Age of Twenty-Three"* (Dec., 1631).

Milton took lodgings in London, first at the foot of Fleet street, shortly afterwards in Aldersgate Street, where he established a small private school. In 1643 he married a Mary Powell, who, soon after the wedding ceremony, departed for a visit to her father's house, and, then, for about two years, would not return to her husband's. In 1645, however, when Milton, by reason of political changes, might be of assistance to her parents, she returned to him. Milton, an ardent supporter of the cause of Cromwell, was, in 1648, when forty years of age, appointed to the secretaryship for foreign tongues to the Council of State in the newly established Commonwealth. He now had "official rooms" in Whitehall.

For a number of years, the poet had been suffering from ill health, especially "a certain dimness of the eyes," and, in May, 1652, when the affection had been upon him for about ten years, he became, at the age of forty-four, absolutely blind. A letter of the poet's written to a friend, who had "offered to lay his case before an eminent Continental ophthalmic surgeon," narrates the history of this case in considerable detail. The relevant portion of the letter runs as follows: "Known to you only by my writings, and widely separated in our abodes, I was first honored by your kind correspondence, and afterwards, when an unexpected occasion brought you to London, with the same kindness you came to see me, who could see nobody; one laboring under an affliction which can entitle him to little observation, and may perhaps expose him to some disregard. As, however, you entreat me not to abandon all hopes of recovering my sight, and state that you have a medical friend at Paris (M. Thevenot), particularly eminent as an oculist, whom you would consult upon the subject, if I would transmit to you the causes and symptoms of the disease, that I may not neglect any means (perhaps divinely suggested) of relief, I will hasten to comply with your requisition.

"It is now, I think, about ten years since I first perceived my sight to grow weak and dim, and at the same time my spleen and other viscera heavy and flatulent. When I sat down to read as usual, in the morning, my eyes gave me considerable pain, and refused their office till fortified by moderate exercise of body. If I looked at a candle it appeared surrounded with an iris. In a little time a darkness covering the left side of the eye (which was partially clouded some years before the other) intercepted the view of all things in that direction. Objects, also, in front, seemed to dwindle in size whenever I closed my right eye. This eye, too, for three years gradually failing, a few months previous to my total blindness, while I was perfectly stationary, everything seemed to swim backward and forward; and now thick vapors appear to settle on my forehead and temples, which weigh down my eyelids with an oppressive sense of drowsiness.

"I ought not, however, to omit mentioning that, before I wholly lost my sight, as soon as I lay down in bed, and turned on either side, brilliant flashes of light used to issue from my closed eyes; and afterwards, on the gradual failure of my powers of vision, colors proportionally dim and faint seemed to rush out with a degree of vehemence and a kind of noise. These have now faded into uniform blackness, such as ensues on the extinction of a candle; or blackness, only varied and intermingled with dimish gray. The constant darkness, however, in which I live day and night, inclines more to a whitish than a blackish tinge; and the eye turning round, admits, as through a narrow chink, a very small portion of light. But this, though perhaps it may offer a small glimpse of hope to the physician, does not prevent me from making up my mind to my case, as one evidently beyond the hope of cure; and I often reflect that, as many days of darkness, according to the wise man, are allotted to us all, mine (which, by the favor of the Deity, are divided between leisure and study) are recreated by the conversation and intercourse of my friends, and far more agreeable than those deadly shades of which Solomon is speaking. But if, as it is written, 'Man shall not live by bread alone, but by every word that proceedeth out of the mouth of God,' why should not each of us likewise acquiesce in the reflection, that he derives the benefit of sight, not from his eyes alone, but from the guidance and providence of the same Supreme Being? Whilst he looks out, and provides for me as he does, and leads me about, as it were, with his hand, through the paths of life, I willingly surrender my own faculty of vision, in conformity to his good pleasure; and with a heart as strong and steadfast as if I were a Lynceus, I bid you, my Phalaris, farewell."

It was, however, during his blindness that Milton produced the loftiest epics of all the ages, excepting alone, perhaps, the *Iliad* and the *Odyssey* of Homer—and Homer, too, is said to have been blind—namely, the "*Paradise Lost*" and the "*Paradise Regained.*" By installments of twenty or thirty lines a day, this wonderful blind man, through the aid of chance acquaintances or amanuenses who would set down his unappreciated lines for the trifling sums which the poet could bestow—in this sad way, this great, undaunted sufferer, managed to make permanent those lofty, those immortal epics, which, today, are known and loved by all the world of letters. The *Paradise Lost*—the greater poem of the two—is said to have been sold to a publisher for five pounds sterling, with a promise of two additional sums of five pounds each, after the sale of a rather large number of copies.

What remains to be said of Milton's blindness had better be expressed in his own undying words. Here, then, is his touching sonnet to Cyriac Skinner, written, as the sonnet itself declares, three years after the blindness was practically complete:

Cyriac, this three years' day these eyes, though clear,
To outward view, of blemish or of spot,
Bereft of light their seeing have forgot,
Nor to their idle orbs doth sight appear
Of sun, or moon, or star throughout the year,
Or man, or woman. Yet I argue not
Against Heaven's hand or will, nor bate a jot
Of heart or hope; but still bear up, and steer
Right onward. What supports me, dost thou ask?
The conscience, friend, to have lost them overplied
In liberty's defence, my noble task,
Of which all Europe talks from side to side.
This thought might lead me through the world's vain mask
Content, though blind, had I no better guide.

The following sonnet is no less touching, and is even more sublime:

When I consider how my light is spent
Ere half my days, in this dark world and wide;
And that one talent which is death to hide,
Lodged with me useless, though my soul more bent
To serve therewith my Maker, and present
My true account, lest he returning chide;
Doth God exact day-labour, light denied,
I fondly ask? But Patience, to prevent
That murmur, soon replies, God doth not need
Either man's work or his own gifts; who best
Bear his mild yoke, they serve him best: his state
Is kingly; thousands at his bidding speed,
And post o'er land and ocean without rest;
They also serve who only stand and wait.

Then, too, we cannot omit (since Milton has written of blindness as no one else in any age or clime) the very pathetic

LINES BY MILTON IN HIS OLD AGE.

I am old and blind;
Men point to me as smitten by God's frown
Afflicted and deserted of my mind,
Yet I am not cast down.

I am weak, yet strong:
I murmur not that I no longer see:
Poor, old, and helpless, I the more belong,
Father supreme! to Thee.

O merciful One,
When men are farthest, then Thou art most near
When friends pass by, my weakness shun,
Thy chariot I hear.

Thy glorious face
Is leaning towards me, and its holy light
Shines in upon my lonely dwelling place,
And there is no more night.

On my bended knee
I recognize Thy purpose clearly shown
My vision Thou hast dimmed that I may see
Thyself, Thyself alone.

I have naught to fear;
This darkness is the shadow of Thy wing,
Beneath it I am almost sacred—here
Can come no evil thing.

Oh! I seem to stand
Trembling where foot of mortal ne'er hath been,
Wrapped in the radiance of Thy sinless land,
Which eye hath never seen.

Visions come and go;
Shapes of resplendent beauty round me throng;
From angels' lips I seem to hear the flow
Of soft and holy song.

It is nothing now,
When heaven is opening on my sightless eyes,
When airs from Paradise refresh my brow,
The earth in darkness lies.

In a purer clime
My being fills with rapture; waves of thought
Roll in upon my spirit; strains sublime
Break over me unsought.

Give me now my lyre!
I feel the stirrings of a gift divine;
Within my bosom glows unearthly fire,
Lit by no skill of mine.

Finally, and most important of all perhaps, are the celebrated lines from Paradise Lost, Book III:[1]

Thus with the year
Seasons return; but not to me returns
Day, or the sweet approach of even or morn,
Or sight of vernal bloom, or summer's rose,
Or flocks, or herds, or human face divine;
But cloud instead, and ever-during dark
Surrounds me, from the cheerful ways of men
Cut off, and, for the book of knowledge fair,
Presented with a universal blank
Of nature's works, to me expunged and rased
And wisdom at one entrance quite shut out;
So much the rather thou, celestial light,
Shine inward, and the mind through all her powers,
Irradiate; there plant eyes, all mist from thence
Purge and disperse, that I may see and tell
Of things invisible to mortal sight.

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[1] Milton's lines descriptive of Samson's blindness, which occur in his "*Samson Agonistes,*" will be found, in this *Encyclopedia,* under the heading "**Samson.**"

The rest of Milton's life is quickly told. Milton's first wife having died in 1652,* leaving him with three small children, he married a second time in 1656. This wife died at the end of fifteen months, leaving no children of her own. On Feb. 24, 1662-63, Milton for a third time married, being in his fifty-fifth year, and his bride, an Elizabeth Minshull, being only in her twenty-fifth. Strangely enough, this marriage was the happiest of the three. The great blind poet was loved, appreciated, cared for, and his latter days were days of peace.

Physically, Milton was somewhat under middle height, as well as slight and delicate of build. His face was a beautiful oval. His complexion was almost absolutely white, his eyes dark gray, his hair very light brown. His voice was low and sonorous. At college he was called "The Lady," but he was very active and strong, as well as manly and courageous. He was a most excellent swordsman. In his later years he became quite sluggish (as a result of his many infirmities) and content to sit beside the fire, or, in the summer, in a kind of swinging chair in the garden.

Milton died at his home in Bunhill on Sunday, Nov. 8, 1674, aged 65 years and 11 months. He had long suffered terribly from gout; in fact for many years his hands and feet had been most horribly knotted and swollen, and so we are not surprised to learn that the cause of death is "gout-fever," or "gout struck in." He was buried in the Church of St. Giles, Cripplegate.—(T. H. S.)

Milzbrand. (G.) Anthrax.

Mind-blindness. Visual amnesia. See p. 1131, Vol. II of this *Encyclopedia;* as well as **Neurology of the eye.**

Mineral waters in eye diseases. Health resorts, sanitaria, as well as "Springs" of various kinds, have their uses in the treatment of eye diseases. Apart, however, from the treatment of those general conditions that influence ophthalmic diseases, it cannot be said that there are many mineral springs, or sanitaria connected with them, either in this country or abroad, that are particularly efficacious in ocular therapy *per se.*

The change of air and scene, the outdoor life, the freedom from business cares and household worries that a sufficient sojourn at some comfortable health resort produce are of value (apart from the medicinal effect of the waters, either internal or external) in many eye affections, notably in phlyctenular diseases, glaucoma, accommodative asthenopia, ocular headache, and other symptoms following eyestrain. A course of antilithemic and antisyphilitic treatment is particularly appropriate to those affections—scleritis, iritis, choroiditis, optic

* According to some authors. According to others, 1653-4.

atrophy—when dependent upon these systemic maladies. Hot Springs, in both Virginia and Arkansas, as well as the springs at Saratoga and French Lick, Indiana, are well adapted for the treatment of these conditions and, when judiciously carried out under the care of a competent internist, are to be recommended. In the same way there are, throughout the United States and Canada, similar, though perhaps less known, resorts whose value in the conduct of gouty, rheumatic, syphilitic, anemic, tubercular and neurasthenic states is quite equal to those just named.

A. Trousseau (*La Clinique Ophthal.*, July 25, 1908) has discussed this matter, chiefly so far as the French mineral springs are concerned. Quite naturally, perhaps, he ignores the justly celebrated baths of Carlsbad, Marienbad, Wiesbaden, Baden-Baden, Homburg, Kissingen and other German resorts, and speaks more particularly of the French and Spanish sanitaria.

Trousseau suggests that cases of iritis, irido-choroiditis and scleritis due to rheumatism—especially if of the recurrent type—be sent to Aix-les-Bains. He believes that the interval of the acute attacks is the proper time for sanitarium treatment, and he would not permit the continued use of even the water of Aix while an acute attack is in progress.

In the plastic form of iritis Bourbon-l'Archambault is the place; Royat for the "quiet variety," while Luchon is excellent for the recurrent type in the rheumatic and anemic. He thinks Contrexville a good place for these diseases when of gouty origin; if very chronic Vittel affords the most relief.

Vichy is also an appropriate resort for patients with iritis and scleritis for the "after cure" when the acute stages have passed. He suggests Vichy, also, for diabetes and thinks a season spent there is a good preparation for extraction of diabetic cataract.

In paresis of the eye muscles he advises Bourbon-l'Archambault and Néris; the latter place, also, for the after treatment of herpes zoster ophthalmicus.

For neuropaths and those suffering from the eye troubles of intestinal toxemia, he advises Plombiéres and Chàtel-Guyon.

Tabetic affections, including optic atrophy, if taken early enough are benefited by the waters of Lamalou.

Evian, Thonon, or better, Bourbon-Laney, are the best localities for those subject to vitreous or retinal hemorrhages.

In cases where conjunctivitis and recurrent attacks of keratitis are produced by diseases of the nose or nasopharynx, Luchon, Mont Doré or Satins-du-Jura is to be recommended.

In phlyctenular disease of the conjunctiva and cornea, Trousseau advises a sojourn at and treatment by the waters of Saint-Gervais, Royat, Luchon or la Bourboule according to the state of the patient.

Asthenopia, due to diseases of the reproductive organs, as well as iritis and irido-choroiditis of genito-urinary origin, are benefited by a course of treatment at Luxeil. For those ocular troubles encountered at the menopause, the writer recommends Bagnoles de l'Orne.

Scrofulous children affected with recurrent keratitis, should be sent to the seaside; to Berck during the intervals of freedom from the attacks, and to Biarritz as the acuity of the attack is declining. Owing to its freedom from wind and dust Trousseau thinks Arcachon is a desirable resort in these cases at any period of the disease, because of its protected situation amid the pines.

The writer advises Bourboule as a resort for spring catarrh, and has known several cases that did not exhibit their customary annual recrudescence after treatment there.

Syphilitic eye affections that did not improve elsewhere, he has known to get well under the active treatment practised at Aix and Uriage; optic nerve diseases due to lues are generally sent to the latter place.

Patients with interstitial keratitis of the hereditary syphilitic type, Trousseau sends to Uriage and Biarritz; to the former place even during the progress of the disease unless the case requires constant supervision. He advises Biarritz only at the end of the disease or if there are congestive symptoms. Should Biarritz be found too much exposed he exchanges its sea air and waters for Arcachon.

In addition to the mineral waters already mentioned as valuable in eye diseases the following springs are to be recommended, particularly if the patient, leaving behind him as many of his cares and worries as possible, will repair to the Hauptquelle prepared to remain as long as is necessary under the care of a competent local physician and to enjoy, so far as he can, the drives, walks and scenery, as well as the musical and other entertainments that most of these resorts afford.

Baden-Baden; Baden (Switzerland); Bath (England); Bethesda (Wisconsin); Mecklenberg (Va.) or "Buffalo Lithia"; Cheltenham (England); D'Orezza (Corsica); Ems (Germany); Fiuggi (Italy); Friedrichshall (Germany); Harrogate (England); Hunyadi Janos (Hungary); Kreuznach (Prussia): Neuheim (Germany); Montreux (Switzerland); Ragatz (Switzerland); Reichenhall (Bavaria); Rubinat (Spain); St. Moritz (Switzerland); Salzbrunn (Austria); Tarasp (Switzerland) and Wiesbaden (Germany).

The following British health resorts are especially valuable in gouty, rheumatic, autotoxic, neurasthenic and angiosclerotic eye diseases: Blackpool (Yorkshire); Bournemouth; Braemar (Scotland); Buxton; Channel Islands (tuberculosis and neurasthenia); Bray (Ireland); Cheltenham; Hastings; Kingstown (Ireland); Ilkley; Malvern (Wales); Torquay (Devonshire); Tunbridge Wells; Ventnor; Mallow (Ireland). See, also, **Hydropathy,** p. 6080, Vol. VIII, of this *Encyclopedia.*

Miners' nystagmus, An occupational disease of the nervous system, found only among workers in coal mines. It was pointed out by Shufflebotham (*Brit. Med. Jour.,* Mar. 21, 1914, p. 648) that the disease was first recognized by Gillett, of Sheffield, about 1854, although no case was mentioned in medical literature until 1861, when the symptoms were described by De Conde, a Belgian physician. Cases were reported as early as 1860, by Müller, by von Graefe in 1873, and by Taylor and Nieden in 1874. Snell in England and Dransart in France were among the first to contribute valuable observations regarding this many-sided disease, while among recent writers, J. Lister Llewellen (*Miners' Nystagmus, Its Causes and Prevention*) has added the most important contribution to our knowledge of the disease which has appeared for a considerable time.

The physical signs of the disease are: Involuntary and irregular movements of the eyeballs, chiefly of a rotatory character, tremor of the eyelids, eyebrows, head, and, in some cases, even of the neck and shoulders. A backward inclination of the head with drooping eyelids is characteristic and common. The first symptom is failure of sight, especially at night, or when the sufferer is called upon to perform the more skilled portion of his work. He next complains that the lamps dazzle his eyes, and sooner or later that the lamps and all surrounding objects dance before him. Headache, varying from slight pain between the temples to attacks of extreme severity, giddiness on exertion and stooping, inability to see at night, and dread of a bright light, are often present. Dransart and Famechon (*Ophthalmoscope,* Aug., 1908) insist upon two symptoms in the affection: blepharospasm and amblyopia.

There are two distinct varieties of the disease. In the first the symptoms are absent or latent, and the man, suffering no disability, is unaware that he has nystagmus; in the second the disease is manifest, and the man is more or less incapacitated and aware that his eyes are affected. Among 750 consecutive cases, reported by Llewellen (*Brit. Med. Jour.,* June 28, 1913) 150 latent cases were observed. Rutten (*Klin. Monatsbl. f. Augenheil.,* July, 1908) states that non-active miners' nystagmus may be made manifest by (a) having the patient look up and sideways; (b) by imitating work in a mine; (c) by throwing light into the eye with the ophthalmoscope, and (d) by rapidly turning the head. It has not been possible up to the present time to arrive at any conclusive data in regard to the relative frequency of this disease. Different investigators have found it occurring in the proportion of 3 per cent. in certain mining districts, and as high as 18 per cent. in others. In the United States the proportion is probably considerably under 5 per cent.

The factors contributing to the production of nystagmus in miners are not numerous, though several theories have been brought forward. Snell (*Lancet,* Aug. 1, 1908) argues that the affection is due to weariness of the elevators induced by the strained position of the body and eyes, and that it is totally independent of the poor illumination. This theory is not now generally held. Gower's view (*Ophthalmoscope,* July, 1913) is that it is caused by disease in the equilibration center. Based on the consideration of 100 consecutive cases, Browne, Mackenzie, Ross and Abertillery (*Brit. Med. Journ.,* Oct. 5, 1912) arrange the causes in the order of relative frequency and importance, (1) inadequate light, (2) errors of refraction, (3) straining of ocular muscles, (4) neurotic temperament.

That inadequate light is an important cause is conclusively proven by the fact that 99 per cent. of these cases had been using the lock-lamp for a number of years.

Ninety per cent. of the cases had errors of refraction; of these, 48 per cent. had astigmatism, 27 per cent. myopia.

The straining of the extrinsic muscles of the eyeball is the result of the two foregoing factors, the workman had his eyes fixed in a staring, strained position for long periods, either downwards and laterally, as in narrow seams, or upwards, as in wide seams.

They regard the inability, on the part of a very large number of men with nystagmus, to concentrate their physical or mental powers in any particular line of action much more as the cause than as the effect of nystagmus. The severe headaches and aching eyes of which these men complain are accounted for by errors of refraction and straining of the eyes; the vertigo, by inco-ordination of the ocular muscles; the conjunctivitis and photophobia by the sudden frequent change from darkness into dazzling light.

Regarding prevention, the writers contend that this resolves itself into medical examination of all men engaged to work underground, and the periodical examination of all underground workers, for (a) the presence of refraction errors, (b) any signs of incipient nystagmus, (c) physical or nervous debility. To this must be added the importance of adequate light. In this connection it appears surprising that even in the most up-to-date collieries there is, as yet, no indication of electric light being used throughout the workings. They are satisfied that if such precautions were taken and electric light installed in all working places in collieries, or electric lamps capable of giving light for at least eight hours supplied to all underground workers, miner's nystagmus would soon be unknown, while serious accidents to workmen and consequent loss to employer would much more rarely occur.

Edridge-Green (*Brit. Med. Jour.*, May 18, 1912) believes the cause of this condition to be the necessity for movements of the eye in order to be able to see with the fovea. He has shown that the fovea is blind when there is no visual purple in it, and this diffusion of the visual purple into the fovea is caused either by light falling on an adjacent portion of the retina containing rods or by movement of the eye. In the conditions usually obtaining in a mine sufficient light does not fall upon adjacent portions of the retina and so the eye is in continual movement. It is easy to see how the repetition of this unnatural movement may cause nystagmus.

Dransart, Somain (*Trans. Belg. Oph. Soc.*, November 24, 1912), believes that the predisposing cause of nystagmus in miners is paresis of the internal recti. The fatigue of the elevator muscles, due to the defective position of the worker, being the primordial factor. The internal recti are paralyzed in 97 per cent. of cases. The wearing of prismatic lenses, base out, may perceptibly diminish the nystagmus; in severe cases, advancing the internal recti has shown some good results.

In discussing this paper, Coppez said that in comparing the tracings obtained by the nystagmograph with those obtained by the myograph, it was remarked that the nystagmographic tracing resembled the tracing of incomplete tetanus; therefore, the nystagmus of miners could only be a fatigue. Fatigue is not exclusively shown in the superior recti muscles, but in the automatic act represented by the visual direction of the worker in the mine.

Benoit believes that the cause of miner's nystagmus is to be found in the various positions assumed by the worker: stooping, reclining or semi-reclining. Nystagmus then exists almost invariably, but accompanied by other symptoms (dizziness, scintillations, anxiety, nausea, blepharospasm, etc.) and in a certain number of grave cases these symptoms may become very intense whilst the nystagmus is very slight. The nystagmic oscillations are the same phenomena of vertigo which can be produced in a healthy subject by irritating the internal ear, by rotation, injections of cold or hot water, electricity and by pressure upon the tympanum, but they are slight and cease when the cause is removed.

In miners there is produced, as time goes on, a lesion of the internal ear (semi-circular canals, saccule and utricule) which is transmitted to the centers of Bechterew and Deiters. This lesion alters the direct physiological relations which exist between these centers and the different bulbar centers and the brain (oculi-motors, glosso-pharyngeal, pneumogastric, etc.) and there follows a break in the bulbar automaticity which imparts to the normal man the sensation of well being, of equilibrium; vertigo follows. Nystagmus is the first symptom of vertigo. The nystagmographic tracings of the pendular type are not characteristic of miner's nystagmus; the author has found a number of cases of the active type which indicate the direct action of the labyrinth upon the oculi-motor; the pendular type is rather the sign of unequilibration.

Moret does not think that an increase in the barometric pressure acts as a factor in nystagmus. The nervous trouble in slight forms of nystagmus is localized at the centers of association of ocular movements; in bad cases the disturbance extends to the neighboring centers of co-ordination.

An inspector of injured workmen in one of the English coal mines, H. S. Elworthy (*Brit. Med. Jour.,* Nov. 19, 1910), informs us that miners in tin and lead mines are not afflicted with miner's nystagmus; it is a disease peculiar to coal miners. He has come to the conclusion that the absence of color is responsible, believing that the cause is fatigue of the eye, resulting from working by artificial light with a black background and nearly black surroundings. Matters are made worse by the fact that the majority of miners prefer to work in the day, and thus the greater part of the year it is dark when they get up and go to work and dark when they leave off work; they get a minimum of daylight and the opportunity of seeing a variety of colors by daylight, which means physiologic relief to the eye. Another cause of fatigue to the eye is when miners have to walk a mile or more underground to reach the "face" where they work. They proceed more or less in single file, each carrying a lamp which gives out light in every direction. The result is that the miner walking behind another gets the glare of that lamp in his eyes all the time.

He confesses that he can give no opinion as to the theory that nystagmus is produced by working while lying down; but this theory is weakened by the fact that other underground workers, such as haulers, timbermen and repairers also suffer from this anomaly.

The only class of workers in coal mines that seems immune is the hostlers, and that is because the stables are whitewashed. That it is not due to imperfect fusion is shown by its occurrence in one-eyed men. This is in agreement with the observations of Ohm, who reports (*Ophthalmology,* Apr., 1913) that of 15,096 coal miners, 504 cases, or 3.3 per cent., were seen in four years, and it was found in no case in which one eye had been lost, but it was observed in cases where one eye was blind or had extremely poor vision. Regarding treatment he says that working underground in daytime is a mistake, as the miner in doing so loses his opportunity of refreshing his eye by looking at colors in daylight, and so, in a measure, compensating himself for working by artificial light without color relief.

To prevent unnecessary fatigue to the eyes removable shades should be provided for the lamps, so that they give out light in front only. These should be used in going in and out. When at the "face" they could be taken off, so the light would not be interfered with. With the shade on, the man simply wants to see the ground in front of him and the roof to prevent him knocking his head.

Finally he suggests an original method of prevention in the shape of some sort of a color scheme in coal mines, substituting by artifice sufficient color to make good the deficiency. He proposes that the roof, the leeward sides of the posts and collars, the cogs and sides of the alleyways be colored with some light but inexpensive wash—whitewash, or preferably, green or other varied colors. The coloring would have to be done daily, and would cost money; but nystagmus costs money.

Butler (*The Ophthalmoscope*, Vol. X, p. 680, 1912) raised the question whether the disease can be present without nystagmus. He demonstrated three patients, in only one of whom were traces of nystagmus discovered at a late stage. The men were colliers, and each complained of being dazzled by lights, and of the lights of the mine dancing or jumping up and down. Hemeralopia, night-blindness, and photophobia were severe in the cases without nystagmus. Twitching of the lids was present in each case, and one had nodding of the head and another had twitching of the neck muscles. Visual acuity was diminished without obvious cause. He considered the muscular twitching and tremor as the essential symptom in the cases. Indeed, it is the only objective sign, as the other symptoms were entirely subjective. The complaint of lights dancing might have been due to a nystagmus occurring in the mine, or simply to the rapid twitching of the eyelids.

Pollock (*Glasgow Med. Jour.*, Sept., 1913) reported another case, the patient seeking advice because of severe vertigo. He complained of being dazzled by lights and of staggering when in the street after dark. He also complained of hemeralopia. The vertigo came on at all times, but especially on coming into the light. Careful search failed to elicit nystagmus, but unfortunately the special methods of rotation in a dark room, or putting the patient into the miner's posture while at work, were not employed. He was well nourished, muscular, and a sportsman, with no signs of a nervous disposition. Diplopia was absent, the optic nerves were normal, and there were no signs of brain tumor. He was a banker, and after correcting his astigmatism, complete rest from business and a trip to the south of France was advised. He improved rapidly, but while passing through London on his return a relapse occurred, and he was taken to a London oculist, who sent him away for another three months. After an interval of four and a half years he was again seen and at this time he said that although the giddiness had not recurred, he still had trouble in the dark at night. In the town the lights made him stagger and go, as he said, as if he were drunk. On inquiring if he had ever been down a mine, he said that he had been for a number of years a mine manager and had been constantly in the pits, but that he had scarcely been down a mine during these last four years.

There is little doubt this patient suffered from a type of miners' neurosis, and that if he had had to continue working in the mines nystagmus would have developed. In fact, it is probable that it did occur when he saw the lights jumping up and down in the mine.

Several writers have suggested that, as this disease is confined to the collier, and as the associated symptoms point to the involvement of higher centers of co-ordination, the disease should be termed coal miners' neurosis. Weekers (*La Clinique Ophthalmologique,* Tome XVI, p. 538, 1910) holds that nystagmus is not a symptom of neurosis, but that the neurosis is superimposed on the nystagmus. He considered nystagmus to be the essential symptom.

Pollock concludes that these several cases are evidence that the disease occurs without nystagmus and that they represent the stage prior to the development of nystagmus. He supports the view, published a few years ago, that the lesion is situated in the cerebral centers: probably the nucleus of the third and associated nerves.

Preventive treatment of this disease resolves itself into medical examination of all men engaged to work underground, and the periodical examination of all underground workers for (a) the presence of refractive errors; (b) any signs of incipient nystagmus; and (c) physical or nervous debility. It is most important that there should be adequate light in the mines, which can be obtained by the use of electric lights in place of oil lamps. The advantage of the electric light is somewhat offset, however, by the fact that it cannot be used in gaseous mines for the essential purpose of determining the presence of fire damp.

As stated, the only curative treatment prescribed is rest, the use of strychnin, and the correction of refractive errors.

Percival (*Ophth. Review*, Aug., 1910) has reported encouraging results from the administration of formic acid even in patients who continued their work underground. He administered m. v. of a 25 per cent. solution of formic acid, in water three times a day, gradually increasing the dosage to m. x. Ohlemann (*Ophthalmic Review*, November, 1910) gives his observations on this subject based upon his experience in the mining districts of Bochun, Westphalia. He chose 12 cases, all men who were off work, and treated all of them with formic acid in doses similar to those mentioned by Percival, for a period of three weeks; but the treatment was unsuccessful in every instance. He believes that in every case in which improvement is noted in this anomaly the change is due to the giving up of underground work, and the enjoyment of a period of rest, followed by work above ground. In examining patients in this stage (after a complete cessation of mining work) the nystagmus may not be noticeable except when the eyes are directed upwards, and sometimes only in a darkened room.

After a rest of varying duration depending on the length of time the disease has been present, the age and strength of the patient, and perhaps his habits as to alcohol and tobacco, some patients are able to resume work underground. Generally, however, a return to work in the mine is followed by a relapse of the disease. The writer has also treated these cases with strychnine, but without success, and he believes that no drug has yet been shown to be capable of curing the condition, and that rest is the real cause of the improvement noted in many cases.

As in other occupational diseases, there are certain medico-legal aspects in connection with miner's nystagmus which, because of the workmen's compensation laws, should not be overlooked.

The impairment of vision prevents prompt recognition of the "cap" flame in the safety lamp, which gives warning of the presence of dangerous gases. An inspector suffering from nystagmus had shown his inability to thus detect the presence of gas promptly. Men had been fined for such failure to detect it, and probably explosions had occurred on account of such failure. The existence of nystagmus increases the risk of certain diseases, and delays healing, as in corneal ulcer, or wounds of the eye. The lowering of visual acuteness may also interfere with the miner's judgment of position, and be a cause of injury to himself or a fellow workman. See, also, **Nystagmus.**

Minim. One-sixtieth part of a fluidram; often used (incorrectly) as a synonym of *drop.*

Minimal luminosity. The weakest illumination that will permit the eye to recognize the form of a letter or other test object.

Minimum deviation. In *optics,* the least deviation sustained by a ray of light in passing through a prism. See also **Angle.**

Minimum-sensible. The smallest or weakest impression which can be perceived by a given sense.

Minimum thermometer. A thermometer which can be set to record the lowest temperature to which it is exposed.

Minimum visible. In *physiologic optics,* the smallest angular measure of which the eye can distinguish the parts. It is about ½ a minute.

Minin light. A therapeutic lamp for the administration of violet and ultra-violet light.

Minze. (G.) Mint.

Miosis. Incorrectly written *myosis* (q. v.). Contraction of the pupil. See **Pupil in health and disease.**

Mirage. The density of the air generally diminishes with the height; rays of light proceeding obliquely upwards from an object then become more and more nearly horizontal, but generally pass away into space. Under certain conditions, however, the obliquely ascending rays may become quite horizontal and then bend down towards the earth, reaching it at a distant point. The observer at that point sees distant objects at an unusual elevation, or sees above the true horizon erect images of objects which may or may not be beyond the horizon. If the layer of air near the earth, say 50 or 100 feet thick, be uniformly dense, as in the cold air over a frozen sea, and a warmer stratum lie above it in which the density rapidly diminishes, so that the rays are brought back to the earth as above, we find, on tracing the path of the rays reaching the observer from the top and the bottom of the distant object respectively, that these rays have crossed one another in the hot stratum; the observer therefore seems to see the object suspended in the air, magnified and upside down. In the mirage of the Sahara and other arid deserts the conditions are reversed; the air is hottest nearest the hot sand; rays descending become bent upwards; and the eye receives an impression resembling that produced by the reflection from water.—(*Standard Encyclopedia.*)

Miram, Eduard. A Russian comparative anatomist and embryologist, of some importance in ophthalmology. Born at Mitau (Kurland)

Aug. 4, 1811, he studied at St. Petersburg and settled in Dorpat. In 1838 he lectured there on comparative anatomy, and in 1839 on zoölogy. In 1841, he traveled in Germany, France and England, for the purpose of studying the universities and museums of those countries. In 1842 he received his degree in medicine at the Königsberg University. Shortly afterward he was appointed extraordinary professor of physiology at Kiev. In 1843 he became the full professor of this subject, and retained the title until his resignation in 1862. He died at Kiev in 1886.

His only ophthalmologic writing is entitled "Beschreibung einer Bildungshemmung des Sehorgans und Betrachtung über die Entwicklung des Auges" (von Ammon's *Monatsschrift,* 1839).—(T. H. S.)

Mirault, G. M. An ophthalmologist of d'Angers, France, the first to describe (very faultily) inflammation of the cornea (keratitis) as distinguished from corneal ulceration. Mirault graduated at Paris in 1823, presenting as dissertation "Sur l'Anatomie et l'Inflammation de la Cornée Transparente." He was for a time professor at the Surgical Hospital. Besides the dissertation above-mentioned, he wrote a number of articles on keratitis, retinitis, capsular cataract, capsular after-cataract, and the cure of ectropium.—(T. H. S.)

Mirbanöl. (G.) Nitrobenzol.

Mire. The object on the arc of the ophthalmometer whose reflection from the cornea is employed in determining the amount of corneal astigmatism. See p. 7140, vol. VI, of this *Encyclopedia.*

Mirmol. A mixture of phenol and formaldehyd: used as an application to ulcers and cancerous growths.

Miroir concave. (F.) Concave mirror.

Miroir de la choroïde. (F.) A portion of the choroid in which (in most mammals) the black pigment is wanting and which possesses a metallic lustre.

Mirror. A reflecting surface, usually made of glass lined at the back with a brilliant metal, so as strongly to reflect the image of any object placed before it. When mirrors were invented is not known. We read in the Pentateuch of mirrors of brass being used by the Hebrews. Mirrors of bronze were in very common use amongst the ancient Egyptians, Greeks, and Romans, and many specimens are preserved in museums. Praxiteles taught the use of silver in the manufacture of mirrors in the year 328 B. C. Mirrors of glass were first made at Venice in 1300. Since the latter part of the 19th Century, mirrors are usually made by silvering glass with an ammoniacal solution of a silver salt to which tartaric acid and sugar-candy have been added.

The *parabolic mirror* is one which converts a pencil of rays parallel to its axis into a pencil through its focus, i. e., rays from a source of light placed at its focus are converted into a parallel beam. Such mirrors are used in search lights and similar devices.

Heat is reflected like light; so that a concave mirror may be used to bring rays of heat to a focus. Thus used, a mirror is called a *burning mirror.*

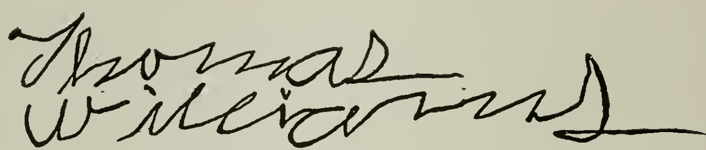
By using a curved glass instead of a flat one, the reflected image of an object will become distorted; a concave cylindrical mirror lengthens the object at the expense of the width, while a convex mirror has an opposite effect.—(*Standard Encyclopedia.*)

Mirror-galvanometer. A galvanometer of which the index is a beam of light reflected from a mirror attached to the needle.

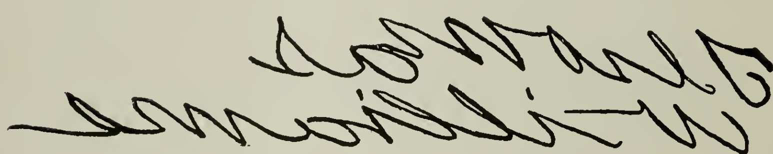
Mirror sight. An attachment to firearms, involving an ingenious application of a well-known principle in optics. The ordinary rifle fore sight is replaced by a mirror with a black disc and pointer, while the back sight consists of a white disc which can be illuminated by a small pocket battery for night work. The size of the white disc is so calculated that its image always appears larger than the black point on the upper edge of the mirror. As Schanz (*Ophthalmology,* Oct., 1913) explains, the mirror sight has the following advantages over the usual sights: The back sight is transferred to a greater distance from the eye and lies at a distance where no accommodation is necessary. (As regards target-shooting, in England at any rate, the aperture sight also renders accommodation for the back sight unnecessary.) The base line between the two sights is longer. It is claimed that the rifle may be brought into position more rapidly and held there more easily.

Mirror test. This is a test for strabismus applicable even to the youngest infants. Worth (*Squint,* p. 80) recommends the patient be in the dark room, with a lamp placed behind him. The light is reflected from the mirror of an ophthalmoscope, from a distance of about two feet, into the patient's eyes. An infant will immediately look at the mirror; an older patient should be told to do so. A tiny image of the ophthalmoscopic mirror is formed on the patient's cornea. Owing to the angle gamma, this reflection of the mirror is usually slightly to the nasal side of the center of the pupil. By flashing the light rapidly from one eye to the other, any want of symmetry in the position of the reflections is at once detected. It may easily be seen, too, which is the deviating eye, and, with practice, a very good guess as to the extent of the deviation may be made.

Mirror-writing. Reversed writing. Inverted writing. In addition to the remarks under **Inversion, Visual,** p. 6560, Vol. IX of this *Encyclopedia,* it may be added here that all cases of visual inversion are not due to the same causes. This fact is brought out by Buchanan (*Ophthalmoscope,* March, 1908) who reports the case of a boy seven and a half years of age who had a peculiar tendency to write reversed letters and figures. His vision was poor on account of hyperopic astigmatism. When he began to learn writing he was given a copy and began at the top of the right-hand corner of the page and wrote with his left hand toward the top left corner. The letters were re-



Calhoun's Case of Mirror Writing.—Normal script with left hand.



Calhoun's Case of Mirror Writing.—Mirror script with left hand.

versed. The tendency was combated by the care of the teachers, and soon the boy was able to write with either hand. Still he had a tendency to reverse his letters, and it was only by constant watchfulness that he kept from doing it. Specimens of mirror writing submitted to him were read off easily, and he saw nothing peculiar about them. Buchanan notes that the peculiarity is more frequently seen in left-handed children; also that there are many well authenticated instances of individuals who have suffered from right hemiplegia (lesion on left side of brain) who have learned to write with the left hand and have had a distinct tendency to write mirror-wise.

Hughes (*Lancet,* Jan. 18, 1909) reports his own case. He wrote some with the left hand from right to left, when first learning to write. But the habit was repressed, and from the seventh to the sixteenth year never practised. Then he noticed that he had especial difficulty with written examinations, and lack of connection of thought and pen when using the right hand. He tried mirror-writing again with his left hand, found it easy, rapid, perfectly performed, and that thought followed the pen more easily.

F. Phinizy Calhoun (*Ophthalmic Record,* p. 455, Sept., 1915) gives a complete review of the subject and reports a well-marked case of his own. (See the figures.) He agrees with those who believe that there is a tendency in certain children to write mirror-script instead of normal left-right script, and the reported cases show the conditions under which spontaneous mirror-writing appears and prove that mirror-writing is the normal writing of the left-handed or of the left hand in general when the right hand becomes incapacitated. Spatial displacements are common occurrences in the early drawings and attempts at writing of the right-handed child as well as of the left-handed one. For example, a child in attempting to make numerals may turn them upside down or turn them upon the side. It is not uncommon to see a child enjoying a picture book upside down or turned from the normal position. This indifference to position can be understood only in the light of the development of space perception, but there exists in the child a perception of form with an apparent indifference to position, which is only developed by an outgrowth of experience. In the child the fusion sense of form and position has not resulted, hence the ease with which he produces and interprets given form in any position.

Misadjust. To adjust imperfectly or put out of adjustment.

Mischfarben. (G.) Mixed or compound stains.

Mise au point. (F.) Focusing.

Missbildungen des Auges. (G.) Malformation of the eye.

Missgebildet. (G.) (a). Affected with a deformity. (b). Having the characteristics of a monster.

Mistura oleoso-balsamica. A popular German mixture used in 5 to 10 per cent. strengths as a stimulating collyrium. The formula is: Acid. boric., 2.25 grm. (gr. xxxiv); aq. amyg. amar., 5.0 c.c. (f℈jmxv); aq. rosæ, 100.0 c. c. (f℥iii, f℈j).

Misura dell'accomodazione. Measurement of the accommodation.

Mitbewegung. (G.) The involuntary contraction of some muscles in consequence of the intentional contraction of others.

Mite. A minute insect; an acarid.

Mitigated caustic. Mitigated stick. Silver nitrate weakened by an excipient or diluent.

Mitin. This is a white, neutral, soft substance like petrolatum that easily blends with most drugs used in ophthalmology. It was introduced by Jessner and is now recommended by Haas and others as a valuable excipient for eye salves and as a satisfactory vehicle for resorcin, mercurial salts, thigenol, etc.

Mitte. (F.) A disease of the eyes caused by sewer-gas poisoning.

Mittelpunkt. (G.) Center.

Mittelsalz. (G.) Neutral salt.

Mixed cataract. An opacity of the lens which begins as a cortical cataract in sharply-defined lines or streaks or triangular patches. It affects at first both the anterior and posterior layers of the lens, the nucleus, also sooner or later becomes hazy, and the whole lens eventually becomes opaque.

Mixed contrast. That form of contrast of colors in which the retina, having received the impression of a certain color for a length of time, conveys the sense of the complementary color, or, on being directed to a new color, receives the mingled impression of that color and of the color complementary to the first.

Mixture cathérétique. Collyre de Lanfranc. A preparation (French *Codex*) consisting of 5 parts each of aloes and myrrh, 10 of copper subacetate, and 15 of purified arsenic trisulphide, powdered and mixed with 1,000 parts of white wine, to which 380 parts of distilled water of roses are subsequently added.

Miyashita, Shunkichi. A celebrated Japanese ophthalmologist. His original name was Kuniya, but he was adopted in early childhood by the Miyashita family. Born in Tajima province, Japan, May 5, 1860, he entered the Tokyo Imperial University in 1872, from which institution he received his medical degree in 1882. Proceeding to Europe he studied ophthalmology for five years in the University of Freiburg, and, still later, received the degree of M. D. from the University of Würzburg.

Returning to Japan in 1887, or '88, he established in Tokyo the Miyashita Ophthalmic Hospital, and was appointed chief of the Ophthalmic Department in the Tokyo Charitable Hospital in 1888. In 1891 he was made a director of the Ophthalmic Polyclinic of the Tokyo Charity Medical College. He published about this time, a work entitled *Ophthalmic Diagnosis.* He died in Tokyo Dec. 29, 1896.

Dr. Miyashita was a versatile man, a great linguist, and an excellent public speaker. In the words of Prof. M. Takayasu, of Kanazawa Medical College, Kanazawa, Japan, in a personal letter to the writer: "He was a man of small but quite stout type with white skin and thick-haired beard. He was always cheerful, of undaunted spirit and prompt in decision. All of the assistants were influenced by his excellence in morality, as he was very kind and polite to everybody who came in contact with him. In conversation he was so ingenious that all, man and woman, young and old, were never tired of him. Habitually he was fond of walking, riding and hunting. He was also a good friend of dogs and birds."—(T. H. S.)

Mmm. An abbreviation for micromillimeter.

mm. An abbreviation for millimeter.

Mn. The symbol of manganese.

Mnemonics. The science of memory.

Möbius' sign. Inability to keep the eyeballs converged in exophthalmic goiter: due to insufficiency of the internal recti muscles. See p. 903, Vol. II, and p. 4807, Vol. VI, of this *Encyclopedia.*

Modalities. In homeopathic parlance, the causes, conditions and times of symptoms, what aggravates or ameliorates, and when they are better or worse, their location, character and direction. See **Homeopathy in ophthalmology.**

Models of the eye. See **Pedagogy, Ophthalmic.**

Modus operandi. The method of performing an operation or action; the steps of an operation.

Moebius disease. Paralysis of the motor oculi nerve, periodic or recurrent.

Mohaddab ad-din b. Ad-Dahuar. A son of Ali of Damascus, born in Damascus in 1169 A. D. He became official oculist to the Bagdad Hospital and a teacher of the famous Usaibia.—(T. H. S.)

Mohammed Ebn Zakarijah Abu Bekr. See **Ar-Razi.**

Mohrenheim, Joseph Jacob Freiherr von. A distinguished Austro-Russian surgeon, obstetrician and ophthalmologist, inventor of the compressor bandage for the subclavian artery—a dressing which still bears his name. For him, too, was named "Mohrenheim's fossa," a depression below the clavicle, and between the pectoralis major and deltoid muscles, which serves as a guide in the ligation of the subclavian artery. At first he practised in Vienna, but later (1783) was called to St. Petersburg, where he filled the chair of obstetrics and operative surgery. He was widely known as a cataract operator. He died in 1799.

His more important writings are the following, of which the second contains a number of interesting ophthalmologic observations, and the third an excellent exposition of cataract:

1. *Wienerische Beytrage zur Arzneikund, Wundarzneikunst und Geburtshilfe.* (2 vols. Wien, 1781; Dessau, 1783.)

2. *Bilbachtungen Verschiedener Chirurgischer Vorfälle.* (2 vols., Vienna, 1780.)

3. *Abhandlung von der Entbindungskunst, Verfasst auf Höchsten Befehl Ihro Maj. der Kaiserin, u. s. w.* (St. Petersburg, 1792; Leipsic, 1803. Described by Gurlt as "a sumptuous affair, published at the expense of the Empress Catherine.")—(T. H. S.)

Mohrrüben. (G.) Carrots. When roasted and used as a substitute for coffee this vegetable has produced eye symptoms.

Mold infection. MOULD INFECTION. See the various **Fungus** headings,

p. 5319, Vol. VII, of this *Encyclopedia.* To these observations may be added the case reported by Dimmer (*Klin. Monatsbl. f. Augenh.*, p. 194, August, 1912), in which there was corneal and scleral infiltration. The eye was enucleated and the mold formation was found on the surface of the sclera, under the conjunctiva, and in the superficial layers of the sclera.

Molecule, Refringent. Minute bodies or corpuscles that possess the property of bending rays of light (e. g., the highly refractive spores of the fission-fungi and some other cryptogams).

Mole, Eyes of the. According to J. R. Slonaker (*Report of Indiana Academy of Science*, p. 146, 1899) it is a widespread belief that the mole does not have eyes. This is possibly due to the fact that the eyes are not readily seen and that an animal living habitually in the ground would have little or no use for organs of sight. Nevertheless, the mole has not only a well-defined eye, but one which is readily observed, on parting the fur at the right place, as a dark area covered by the skin and true eyelids. The latter, however, are rudimentary and the cleft between them so small that it is practically never open enough to admit light.

From this fact alone one could safely conclude that the power of sight in the mole is no more than to distinguish between light and darkness, and when the eye itself is examined this conclusion is well substantiated.

Comparing the mole eye with a normal mammalian eye it is found to be quite degenerate. The stages of degeneration seem to have been as follows:

The eye has decreased materially in size. This reduction diminishes the size of the aqueous and vitreous chambers until in some eyes they are wholly wanting. It also allows the retina to collapse, causing the inner layers to become more or less jumbled together. Each of the layers may, however, be made out.

The lens is much modified in size and shape in different eyes. Owing to the great diversity of pressure exerted by the shrinking eye the lens takes a variety of forms which may be different in eyes taken from the same animal. On magnifying the lens the cells are seen to resemble cartilage more than typical lens cells. The histological degeneracy of the lens has thus gone much farther than one would at first suspect.

C. Ritter (*Arch. f. Micr. Anat. u. Entwl.*, Bd. 53, Heft III, p. 397) and Carl Rabl (*Zeitschr. f. Wis. Zool.*, Bd. 67, Heft I, 1899, p. 63) in describing the development of the mole lens say that it is similar to the mammalian type in its early stages, but the later stages are arrested, and in the adult the typical lens cells have degenerated to a form as above described.

The function of such an eye as this may be reasonably conceived when we consider the composition and shape of the lens, the almost closed lids and the closely crowded condition of the retina. The power of sight would doubtless extend little if any beyond the ability of distinguishing between light and darkness. See, also, p. 2617, Vol. IV, of this *Encyclopedia*.

Mole of the eye. This lesion is generally seen as a pigmented nævus of the lids. It is congenital and occurs either singly or in numbers. It is of oval or circular form, varying in size from that of a pin-head to large tumor-like masses. The upper lid is more often involved than the lower. There are smooth, warty, fatty, and hairy moles. The larger ones are to be treated by excision; for the smaller ones electrolysis is the best method.—(J. M. B.)

Molinæus. A botanist-physician of Lyons, France, who flourished in the 16th century. See **Desmoulins.**—(T. H. S.)

Molinelli, Pietro Paolo. An Italian surgeon, of some ophthalmologic importance. Born in Bombina, Italy, Mar. 2, 1702, he became the first incumbent of the chair of operative surgery at the University of Bologna. For a time he resided in Paris, but very soon returned to Bologna, where he continued to live, and also to teach in his former position, until his death, Oct. 15, 1764. He was known in ophthalmology for the numerous operations which he performed on the fistula lacrymalis, and for an article which he wrote on this subject (*Comment. Acad. Bonon. Scient. et Artium,* Vol. II, 1775).—(T. H. S.)

Mollescuse. (F.) Softening.

Mollities. (L.) Softness; abnormal softening.

Mollosin. An ointment-base made of liquid petrolatum (4 parts) and yellow wax (1 part).

Moll's glands. Modified sweat-glands found at the free margin of the eyelids, thought by some to empty into Zeiss's glands. See **Histology of the eye.**

Molluscum contagiosum. A contagious disease of the skin, characterized by small whitish or pinkish, pearl-like, elevated tumors, occurring singly or in groups, with smooth, rounded surfaces slightly umbilicated at the summit, and often with a small, dark point or minute central orifice, yielding on pressure a soft, whitish, greasy, consistent body or semi-fluid material resembling sebum. The disease was first described in 1817 by Bateman, who, in his *Delineations of Cutaneous Diseases,* gave an admirable clinical account of it.

The disease is not common in the United States, where, according to Hyde, the statistical frequency of the disease equalled at 1901 but 1.65 per 1,000. In England, on the contrary, it may be said to be extremely common. It affects both sexes and it may be found at all ages, but by far the greatest number of cases occur among children and the poor, especially in asylums and in institutions, and, because it may thus affect communities or families or prevail in schools, it should be considered as contagious. Mittendorf observed its occurrence in two Homes, in one of which there were 27 cases, in the other 41, and Knowles, in one year among 350 inmates in a Home for children, observed 59 cases, in 22 of which the lesions were located on the eyelids. It has been found among the frequenters of Turkish baths, as was noticed by Hutchinson, who believed the media of contagion to be through the use of towels and gloves. It frequently co-exists with warts. Exactly comparable growths have been found on the eyelids and beaks of chickens and pigeons, but so far no direct causal relation has been established between their presence on birds and their occurrence in man.

The affection is due, probably, to an organism, but so far none has been isolated. The disease has been successfully inoculated, and from such experimental, as well as from clinical, evidence, the period of incubation may be said to last from several weeks to a few months.

In the beginning the lesions are rounded and resemble minute warts, but as they increase, often attaining the size of peas, the top becomes flattened and later depressed or umbilicated, while in the center is a darkened point representing the mouth of a follicle. The base of the tumor is broad, occasionally they are found pedunculated, and while at first they are firm, they become opaque, yellow and tend to soften and from the central orifices a semi-cheesy substance resembling sebum exudes, which peculiar matter Bateman believed to be "the secretion" of the tumor. Sometimes, as was noted in a case of my own, the slightly-hardened substance projects from the opening. At times they may become red, inflamed, and even suppurate, yet they heal without a trace. As a rule, the lesions are sluggish in their general character and present no active signs of inflammation, and usually the tumors disappear by absorption and by desiccation. Because the elevations may sometime resemble the pre-pustular lesions of variola, the French have applied to this disease the term *acne variola forme.*

The course of a single lesion varies, sometimes it disappears by the end of a few weeks or months, yet others may last two or three years; also, while older growths are disappearing, new ones may present, so that all sizes and stages of the tumor formation may be seen in a given case.

Ten or twelve lesions only may be present as a rule, although occasionally, as many as fifty may be counted on the face and eyelids. The molluscum are usually discrete, but exceptionally two or three may be bunched together, a solid mass even may be formed; and they may become gigantic, though commonly they are only of pin-head size or that of a fat pea.

While molluscum may occur anywhere on the body surface, their usual seat is on the face, but particularly the eyelids, and frequently along the brows and among the eyelashes, even the lid borders, in which situation they may excite considerable irritation and exceptionally conjunctivitis, which may become marked, as in a case in Knowles' series, and in others reported by Steffan and by Muetze. Ballaban recorded a unique case of molluscum of the bulbar conjunctiva.

There are no subjective symptoms accompanying their eruption nor during their course, the lesions appear and disappear without pain, itching or burning, except in the case of those which become inflamed, when there may be soreness and pain; neither are there any constitutional symptoms.

Much mystery surrounds the origin of molluscum, and the greatest pathologists have not despised speculating over the probable cause and pathology of these tiny tumors. The lesion was formerly supposed to have its seat in the sebaceous glands, but at present it is believed that it bears no relation to the glands. It is now generally agreed that the growth arises within the epithelium and develops as a hyperplasia of the rete and is in fact a benign epithelioma. Opinion differs as to whether or not it takes its start from the epithelial lining of the hair follicle or in the rete layers proper.

The molluscum growth is made up of wedge-shaped lobules comprising the rete separated by fine connective tissue septa formed by the papillæ. Extraordinarily varied cells are found. The degeneration is in the principal cells of the upper or lower layers of the rete. The elements are pressed together at the outlet where the mass is composed of changed epithelial cells, which accumulate at the mouth of the lobule in a homogeneous mass containing rounded, opaque, fatty bodies, the "molluscum bodies of Patterson," and the tumor may be emptied by squeezing it out. The bodies are so called because Patterson, who studied the secretion, mentioned, in his report in the *Edinburgh Med. and Surg. Journal* for 1841, the finding of strange nuclear bodies, which he considered to be the molluscum "corpuscles" or "bodies." The epithelial cells in the lower part of the lobules proliferate and then degenerate and soften, although others may harden and become cornified. The whole lesion, except on the surface, is enclosed in a fibrous capsule the base of which rests on the corium, the border being continuous with the epidermis; it therefore is surrounded by connective tissue cells which never present the signs of inflammation unless secondary changes occur. The changes within the epithelial cells consist in the production of small, clear, hyaline bodies, the molluscum body, oval in shape, which rest close to the nucleus of the cells and contain their own nucleus. Further changes are noted in the granulation of the cells followed by degeneration and cornification of the protoplasm.

Molluscum is a singular disease, and although undoubtedly contagious, the specific bacteriologic body has not yet been isolated. By some observers, the Patterson bodies have been supposed to be the irritant which gives rise to the formation of the tumors, but such a supposition cannot be supported. The conclusions to which White and Robey arrived, after their study of several hundred sections cut from tumors, were that "the changes are not those of a colloid or hyaline degeneration, but rather a very extraordinary metamorphosis of rete cells into normal keratin."

In the diagnosis the special points to be considered are, the size of the lesions, their waxy or glistening appearance and the presence of the central depression or orifice, all are sufficiently characteristic to prevent mistakes, and from which Hutchinson aptly likened the appearance of the tumors to small pearl buttons. Molluscum is to be differentiated, however, from fibroma, milium, warts, and acne.

Molluscum masses are smaller than fibromata, and they are superficial, being seated in the upper skin and epidermal tissues, whereas fibromata are rounded and are deeply-situated, reaching even into the subcutaneous tissues, and they have no central orifice or depression.

Though milia resemble molluscum, they are whitish and lack the peculiar pearly or waxy appearance, as well as the central orifice. which is so distinctive of molluscum. So also as to warts, which are hard and solid; while acne shows many stages of papulation and pustulation.

Spontaneous cure is not always certain, and, exceptionally, traces may continue indefinitely, yet on the whole, the prognosis is favorable, as most lesions disappear in the course of several weeks or in a few months, although others may require active treatment. But all molluscum tumors should be promptly treated to prevent the spreading of the disease; therefore the contents of each tumor should be pressed out immediately, and a deep application of strong nitrate of silver, carbolic acid, or trichloracetic acid, on a stick, should be made through the orifice, or the globule may be incised and then cauterized, while in others speedy cure may be effected by the electric needle.

When seated on limited regions like the lid borders, mild stimulating or parasiticidal ointments should be used before operating. White precipitate, or sulphur, 20 to 40 parts, applied vigorously once or twice a day may prove of great benefit, or calamine, zinc oxide lotion, or boric acid, applied twice a day and allowed to dry, may be sufficient, yet care must be taken to prevent irritation of the conjunctival structures in applying such substances. Compression of the tumors situated on the eyelids is painful; so also are the applications of acids, which, in addition, are tedious procedures. It may be best to operate promptly, and when the tumors are pedunculated they can be snipped without hesitation and their bases cauterized with the prospect of speedy healing. In the case of children and nervous adults, it may be necessary to administer a general anesthetic.

Consult:—Stelwagon, *Diseases of the Skin;* Parson's *Pathology of the Eye,* Vol. 1; Mittendorf, *Trans. Am. Oph. Soc.* 1886, p. 262; Knowles, *Jour. Am. Med. Assoc.* 1909, Vol. 53, p. 671; Muetze, *Arch. f. Augenhk.* 1896, Vol. 33, p. 302; Ballaban, *Arch. f. Augenhk.* 1903, Vol. 47; Salzer, *Muench. Med. Woch.* 1896; Steffan, *Klin. Mon. f. Augenhk.* 1895, p. 457; White and Roby, *Jour. Med. Research,* 1902, p. 255.—(B. C.)

Molluscum epitheliale. A name for molluscum contagiosum.

Molluscum fibrosum. This neoplasm is, according to Parsons, generally a neurofibroma, and as such occasionally attacks the lids. Weeks (*Diseases of the Eye,* p. 178) describes it as a rather soft, elastic and diffuse growth; it usually affects the upper lid on one side throughout its entire thickness, extending into the brow and onto the temple. This form of tumor occurs in children and young adults. In a case observed by Friedenwald the growth was congenital. The lid is much thickened, rendering it impossible to open the eye. The skin presents the appearance of slight venous congestion, its surface is irregular, as is also the conjunctival surface. The conjunctival surface is often suggestive of trachoma. Pain at intervals, often very severe, is characteristic of these growths. They are often congenital. The growth is composed of numerous, loosely placed connective-tissue fibers, interlaced with a network of nerve fibers and bundles, medullated and non-medullated. In some cases the vessels are increased in number and in size. Excision gives the best results.

Molybdamaurosis. (L.) Amaurosis due to lead poisoning.

Molybdamblyopia. (L.) Amblyopia due to lead-poisoning.

Momordica elaterium. The juice of the squirting cucumber is very irritating to the eye tissues. Moissonier (*Clinique Ophtal.*, p. 266, 1901) reports a case in which an inflammatory swelling of the lid and a slight corneal abrasion followed the entry of the juice of the fruit into the eye. The active principle elaterin, does not seem to possess as irritating qualities.

Monakow's fibers. A bundle of nerve fibers connecting the eyeball with the anterior corpus quadrigeminum.

Monaster. The single star-shaped figure in karyokinesis.

Monaxial. Monaxonic. Monoaxal. Having but one axis; uniaxial.

Mondblindheit. (G.) Moon-blindness.

Mondeville (or **Amondaville**) **Henri de.** A French surgeon and ophthalmologist of the 13th and 14th centuries, concerning whom but little is now known. He was born in Normandy, at Mondeville, or Amondaville, taught and practised for a considerable time at Montpelier, in 1301 became surgeon to the King, and in 1306 removed to Paris in order to accept a chair of surgery in that city. A few years later he had written a work on surgery, a Latin edition of which was issued by Pagel, at Berlin, in 1892, under the title *Die Chirurgie des Heinrich von Mondeville*, while a French translation by Nicaise appeared at Paris in 1893, called *La Chirurgie de Maître Henri de Mondeville.*

Henri de Mondeville did not live to finish his book, which, in consequence, lacks all its ophthalmic divisions, saving and excepting only the bare rubrics. He died of consumption at some time between 1317 and 1320.—(T. H. S.)

Mongolian imbeciles. Mongolian idiots. The ocular conditions of these unfortunates are discussed both on p. 6138 and on p. 6176, Vol. VIII, of this *Encyclopedia.*

Mongolism. Mongolian idiocy.

Moniconostereoscopic glasses. Optical glasses giving a stereoscopic effect to single pictures.

Monilethrix. A very rare disease, of unknown causation, affecting the eyebrows and lashes, as a result of which the hairs and cilia have a beaded appearance, the narrow parts being unpigmented. The disease runs in families, and is (apparently) due to periodic, increased activity in the *rete mucosum.*

Mono-. A prefix denoting one or single; limited to one part; in chemistry, combined with one atom.

Monoblepsia. Monoblepsis. A condition in which the vision is confused when both eyes are used, but distinct, or more distinct, when only one eye is employed.

Monocentric rays. In *optics,* rays which emanate from the same point or focus. Same as homocentric rays (q. v.).

Monochloracetic acid. See **Acid, Monochloracetic,** p. 70, Vol. I of this *Encyclopedia.*

Monochlorophenol. Paramonochlorophenol. The compound is made from para-aminophenol by means of chlorine. It occurs as colorless crystals, slightly soluble in water; soluble in ether and alkaline fluids. It is a decided antiseptic and is recommended especially in syphilitic iritis and keratitis in subconjunctival injections of a 1 to 2 per cent. aqueous solution.

Dolganoff claims that in corneal ulcer subconjunctival injections of parachlorophenol (one per cent. in water) are quite as effective as mercuric cyanide or bichloride and not nearly so irritating and painful. The phenol compound really acts as an analgesic and the discomfort following the injection is small or lasts only a few minutes.

Monochroic. Monochromic. Having but one color.

Monochromasia. Monochromasy. That condition in which differences of color are not perceptible. The only differences such people perceive are differences of brightness, almost as on an engraving. The whole color table is narrowed to a single point. The spectrum seems to them simply a luminous band, the brightness of which reaches its maximum, not in the yellow, as is the case in the normal eye, but in the green. While color-blindness implies no other abnormality, monochromatic eyes manifest all other signs of weakness: photophobia, albinism, diminution of the visual acuity, etc.—(C. P. S.)

Monochromat. A totally color-blind subject.

Monochromatic. In *optics,* consisting of light of one wave-length, and in that sense of one color only, as the light produced by a Bunsen flame in which sodium is being volatilized. The light of the flame is then almost entirely the light of the two sodium lines, the colors of which are barely distinguishable from one another, and consequently objects viewed by this light are all yellow, and differ only in form and illumination. A monochromatic light gives a single bright line when viewed with a *spectroscope* (q. v.)

Monochromatic aberration is the totality of all optical defects of a lens, or any optical system which brings the light rays coming from a point sending out only monochromatic light, not to a point again but to produce an irregular image. Into this class of aberrations fall: spherical curvatures of refracting surfaces (*vide* **Aberration spherical**), defective centration, regular and irregular astigmatism (*vide* **Astigmatism**).

Monochromatic lamp. A lamp emitting rays of only one wave-length.

Monochromatophil. Stainable with only one kind of stain; any cell or other element that will take only one stain.

Monocle. A figure-of-eight bandage so applied to the head as to cross over one eye; a one-eyed animal; also, a glass for one eye; a single eye-glass, held before the eye (by the skin at the margin of the orbit) between the cheek and brow.

After remarking that nobody "takes the monocle seriously," and that its wearing is generally a subject of mock and jest for the daily press and the comic periodicals, R. Halben (*Ther. Monatsheft.*, p. 189, March, 1913) draws attention to the slight mention made of it in surgical literature. The author believes, however, that it has a definite place in ophthalmic therapy and recommends it highly, especially in cases where there is only one eye or but one useful organ; when only one eye requires an ametropic correction, either because the other eye is normal or in cases where it is desirable to correct the defect in one eye only. Halben also claims that, when it is thus indicated, the monocle is to be recommended because, compared with spectacles and noseglasses, it is cheaper, remains better *in situ*, is easier to remove and is in every way more simple and convenient. The writer says nothing, however, about the asthenopia and other symptoms set up by the use of the monocle when, in obedience to the dictates of fashion, etc., binocular vision is neglected or prevented; nor does he dwell much upon the fact that foolish fops, young and old, furnish food for jest by wearing before a single eye a lens of one-eighth of a diopter or simply a plane glass, and thus bring ridicule upon a serious and important form of ocular therapy. See, also, p. 4949, Vol. VII of this *Encyclopedia*.

Monoclinal. Dipping in one direction.

Monocular diplopia. UNIOCULAR DIPLOPIA. In addition to the matter found on p. 4006, Vol. VI, of this *Encyclopedia*, E. Woelfflin (*Archives of Ophthalm.*, Sept., 1912) gives a full account of the subject, which has been reviewed by Rosa Ford in the *Ophthalmoscope* for June, 1914.

The author summarizes the causes of monocular diplopia as follows: Cases without physical basis, which are explained by the formation of a double fovea, such as is not uncommon in squinting eyes. He reminds us of Bielschowsky's interesting case in which the monocular diplopia disappeared, when the normal fovea finally excluded the pseudo-fovea from function.

Cases with a physical basis. Of these there are the following varieties: (a) diplopia which may be explained by Scheiner's test, e. g., in cases of traumatic iridodialysis; (b) cases which are due to irregular or regular astigmatism of the cornea, or, more often, of the lens. These are the most common. (A corneal fold produced by compression of the lids results in a rare form of diplopia due to corneal changes.) Woelfflin explains this form by assuming that, as the result of an irregular lental astigmatism, a point of light is seen as an irregular star, which is divided into two points of light by the addition of a regular corneal astigmatism. Sometimes the phenomenon appears only with a dilated pupil, when more markedly astigmatic portions of the cornea or lens are included in the pupillary area. A curious case is instanced as occurring in Dufour's clinic in which, following a paralysis of accommodation due to diphtheria, a diplopia was present only in the center of the pupil (the center of the lens showing an irregular refractive condition, the peripheral portions being normal), and was observable only at a certain distance from the eye (28 cm). One would expect cases of this kind to be present in keratoconus or lenticonus, but in three cases of keratoconus examined for diplopia, it did not exist. (c) Cases caused by asthenopia. These are probably due to accommodative changes. The diplopia only lasts a few hours in these cases. An interesting instance of this is the diplopia which has been observed in two cases after the prolonged use of one eye, as in microscopy, in the other eye. Woelfflin explains this by partial ciliary contractions adapted to give clearest vision in the eye in use and produced sympathetically in the other, resulting in an artificial lenal astigmatism. Cases of hysterical diplopia are probably due to improper accommodation, the increased nervous sensitiveness making the sensory impressions more marked. A unique case is quoted in which diplopia came on after an injection of morphia, and disappeared after eight hours. The weak miotic power of morphia is blamed for this. (d) Cases due to hysteria which can be cured by suggestive treatment. (e) Cases due to cerebral trauma. The diplopia usually disappears after a few weeks or months. (f) Diplopia which occurs in normal eyes, as the result of double reflection of the rays in the cornea, from the posterior surface to the anterior and back to the fundus (Snellen), or as the result of decentration of the refracting media. The latter explanation seems the more likely, since Rochat, who observed the phenomenon on himself, found that with his pupil dilated, he could make the one or the other image disappear by screening the upper or lower half of his pupil.

Monoculäres Doppeltsehen. (G.) Uniocular or monocular diplopia.

Monocular exercise. One of the best means of exercising the weaker eye in squint is to attach to the corresponding lens worn by the patient a black rubber disc or blinder, so devised as to clamp easily but firmly upon the spectacle or eyeglass lens. See the figure.

Blinder for Monocular Exercise of the Squinting Eye.

Monocularly. By means of one eye.

Monocular vision. Seeing with one eye only. See **Physiological optics**; as well as the discussion of the medicolegal relations of the subject under **Legal relations of ophthalmology.**

Monoculate. Monoculous. Having only one eye.

Monoculus. Simplex oculus. A bandage used to keep in place a topical application to one eye. See. p. 871, Vol. II, of this *Encyclopedia.*

Monodiplopia. Double vision in either eye alone.

Monoglenous. A bandage for one eye.

Mono-infection. Infection with a single kind of organism.

Monoiododioxybenzol-formaldehyd. See **Iodofan.**

Monolepsis. The transmission to the offspring of the characters of one parent, to the exclusion of those of the other.

Monoluminous. Referring to a single source of light.

Monomethylcatechol. See **Guaicol.**

Monometric. See **Isometric.**

Monophthalmus. Having but one eye; generally applied to a unilateral anophthalmus. Round-eyed, one-eyed; a monster having but one eye, placed in the middle of the forehead; a cyclops. A bandage for one eye.

Monops. A fetus having but a single eye.

Monoptotype. (F.) A term applied to a form of test type for visual examination.

Monoscopter. A synonym of *horopter* and *isogonal circle.* See p. 2253, Vol. III of this *Encyclopedia.* See **Muscles, Ocular.**

Monostereoscope. An instrument producing stereoscopic effects by means of a single lens.

Monostoma. A genus of trematode worms. One species has been discovered in the crystalline lens.

Monoyer's test. This pseudoscopic apparatus (for the detection of feigned blindness), one of the modifications of the Fles box, is described on p. 1185, Vol. II, of this *Encyclopedia.*

Monro, Alexander. Also called *"Primus,"* because of his son—A. M., *"Secundus,"* and grandson—A. M., *"Tertius."* He was born at London, Sept. 8, 1697, the son of a military surgeon, and later removed with his father to Edinburgh. He studied with Cheselden, and settled in Edinburgh, where he taught anatomy and surgery for forty years. His most important writings relate to anatomy and surgery, but he wrote also an article on diseases of the lachrymal passages in which, in certain cases, he advises the removal of the lachrymal sac, and was one of the earliest to do so. His principal works are *Osteology* (1726), *Essay on Comparative Anatomy* (1744) and *Observations, Anatomical and Physiological* (1758).—(T. H. S.)

Monro, Alexander, Secundus. Son of Alexander Monro, *Primus*, and father of Alexander Monro, *Tertius*. A distinguished Edinburgh, Scotland, anatomist, of a slight ophthalmologic importance because of his *Three Treatises on the Brain, the Eye, and the Ear* (Edinburgh, 1797). He was born Mar. 20, 1733, in Edinburgh, where he received his medical degree in 1755, and became professor of anatomy in that city until his death, Oct. 2, 1817.—(T. H. S.)

Monsters, Ocular conditions in. This subject has been fully discussed under **Congenital anomalies,** especially on p. 2834, Vol. IV of this *Encyclopedia*.

Montain, Gilbert Alphonse Claude. A younger brother of Jean François Frédéric Montain, a surgeon and obstetrician of some note and a man of special prominence in ophthalmology. Born at Lyons, Dec. 21, 1780, he graduated at Paris in 1808, his dissertation being "Quelques Propositions sur les Maladies Laiteuses." He became surgeon-in-chief at the Charité in Lyons, and professor of materia medica at the Secondary School in that city. He invented a number of ophthalmic instruments, and was widely known as a depressor of cataract. His most important literary work was performed in collaboration with his brother, and was entitled *Traité de l'Apoplexie* (Paris, 1811). He also wrote a number of independent books and articles pertaining to general medicine, as well as the following compositions of an ophthalmologic character: 1. *Traité de la cataracte et des Moyens d'en Opérer la Guérison* (Paris and Lyons, 1812). 2. Considérations de la Tumeur et de la Fistule Lacrymale (*Jour. Gén. d. Méd.*, 1813).—(T. H. S.)

Montain, Jean François Frédéric. A French physician, of some importance in ophthalmology. Born at Lyons, France, May 2, 1778, he graduated at Montpellier, presenting as thesis "Quelques Propositions sur la Méthode Expectante Appliquée à la Chirurgie." In 1809 he became physician to the Hôtel Dieu at Lyons. Imprisoned for a political conspiracy, he escaped by the assistance of his brother, and fled to Belgium. Later he returned to Lyons, and became a military physician, in which capacity he accompanied a number of expeditions to Africa. Though widely known as a coucher of cataract, he left no writings of an ophthalmologic character; his special procedure in depression, however, was described by his brother Gilbert. The subject of this sketch died at Paris in 1851.—(T. H. S.)

Monte, Michele del. An Italian ophthalmologist, author of the greatest Italian text-book on ophthalmology in his day. Born at Moliterno in July, 1838, he studied at Naples and Berlin, at the latter institution receiving the personal instruction of Albrecht von Graefe. Settling in Naples, he was made extraordinary professor of ophthalmology in that place. He was a good operator and an extraordinarily good teacher. In 1872 he published Part I of the above-mentioned text-book, *Manuale Pratico di Ottalmologia,* and, four years later, Part II. Even then the work was not complete, nor was it completed at the time of the author's death, in 1885.—(T. H. S.)

Monteath (or Monteith), George Cunningham. A distinguished Scotch physician, the first in the city of Glasgow to devote himself exclusively to diseases of the eye. Born Dec. 4, 1788, at Neilston, Renfrewshire, Scotland, he studied at Glasgow and in London, receiving the M. R. C. S. in 1809. For a time he was surgeon in the English army, but in 1813 settled as physician in Glasgow, where, shortly afterward, he began to devote himself exclusively to the study and treatment of ocular diseases. He was widely and favorably known throughout the west of Scotland and the North of England. In the prime of life he died, Jan. 25, 1828, being but forty years of age.

Monteath translated Karl Heinrich Weller's *Handbuch der Augenkrankheiten,* with the English title *Manual of the Diseases of the Human Eye;* translated from the German, Illustrated with Cases and Observations (2 vols., Glasgow, 1821). This book is declared by Gurlt to have been "das populärste *Handbuch jener Zeit.*"—(T. H. S.)

Monteggia, Giovanni Battista. A distinguished Italian surgeon, who devoted some attention to ophthalmology. Born at Laveno, on Lake Maggiore, Aug. 8, 1762, he studied chiefly at the Milan General Hospital. In 1790, he was made assistant surgeon and prosector of anatomy at this hospital, in 1791 prison physician, and, four years later, professor of anatomy and surgery, as well as surgeon. He died Jan. 17, 1815.

Monteggia's writings are all on general surgery. In his masterpiece, however, *Istituzioni di Chirurgia* (Milan, 1802-1803) he devotes a single chapter to the pathology of the eye—a chapter which was valued very highly by so great a man as Scarpa.—(T. H. S.)

Montessori method, Ocular relations of the. A method of teaching allied to the kindergarten system, chiefly applicable to children between 3 and 6 years of age, the most important period of sensory education, and found to be of great use to backward children, including those partially or totally blind. Even in normal children most of the exercises are done blindfolded, so as to exercise the tactile muscular and stereognostic senses. By this system vision plays but a small part in learning to write; the art is acquired almost as a by-product during the training of the tactile muscular sense, including the discrimination of various sounds and rhythm. The method enables children to perform by the assistance of these senses many complex acts accurately. A difficulty with English children, however, is the fact that English is perhaps the least phonetic of European languages, while Italian is almost purely phonetic. This left the child, as Leslie Paton (*The Lancet,* Mar. 20, 1915) has observed, to develop its inherent capacities, in opposition to the usual method of inculcating from outside truths in the form of dogma. Children seemed to be unconscious that they were doing more than playing at a most absorbing game, yet they were undergoing self-discipline and a social recognition of duties to others.

Moon-blindness. A rare condition of retinal anesthesia said to be due to exposure of the eyes to the moon's rays in sleeping. This popular belief (or delusion) is referred to by Weeks (*Diseases of the Eye,* p. 536) as follows:—There is a popular belief that sleeping exposed to moonlight may cause a dimness of vision which may last some hours or months. This has been observed most frequently among sailors. The condition is apparently due to torpidity of the retina, causing night-blindness; but changes in the crystalline lenses apparently due to exposure to moonlight have been reported (Ole Bull). The patient was a sailor, twenty-six years of age, who slept with two companions on the deck of a ship in the bright moonlight. On waking all had great difficulty in seeing, which condition lasted two months. Small opacities were scattered throughout the crystalline lenses of the patient examined by Bull. It is very probable that this form of amblyopia is largely dependent on impaired nutrition and that the influence of exposure to moonlight is exaggerated.

Moon-blink. A local, vulgar name for moon-blindness (q. v.).

Moonites, The. A fabulous race of people which Lucian (*circa* 150 A. D.) pretends, in his *The True History* (a kind of ancient "Baron Munchausen's Travels") to have discovered on the moon. Concerning these people's eyes he remarks as follows: "It is with some hesitation that I describe their eyes, the thing being incredible enough to bring doubt upon my veracity. The fact, however, is that these organs are removable. Any one can take out his eyes and do without until he needs them; then he has merely to put them back in. I have known of numerous persons who lost their eyes, and borrowed the eyes of others. Some—the rich—kept a very large stock." For another example of removable and interchangeable eyes, see **Graiœ.**—(T. H. S.)

Moon, William (1818-94), was born at Horsemonden, Kent, England, and gave up all hope of a career in the church when he became totally blind at the age of twenty-two (1840). He afterwards devoted his energies to the care of those afflicted like himself with loss of sight, and started a school for the blind. Finding previous alphabets for the blind too complicated, he invented an embossed type, consisting of eight Roman letters unaltered and twelve with parts left out, which made reading easy, and established societies for searching out the blind in their homes, teaching them to read, and lending them books free of cost. He also devised pictures and maps for the blind. In 1882 he visited the United States. His philanthropic efforts have produced 80 schools in Great Britain and 14 in other countries. (*Standard Encyclopedia.*) See, also, **Alphabets for the blind,** p. 259, 260, Vol. I, of this *Encyclopedia.*

Mooren, Albert von. A famous German ophthalmologist and privy medical councillor. Born July 26, 1828, at Oedt, near Kempen on the Nether Rhine, he studied medicine at Bonn and Berlin, at the latter institution receiving his degree in 1854. It was under the stimulus of A. v. Graefe that he decided to occupy himself with ophthalmology. From 1855 till '62 he practised as a general physician in Oedt, then was called to the headship of the Ophthalmic Hospital at Düsseldorf. In addition to the numerous duties of this position he also fulfilled those of the directorship of the Ophthalmic Institute at Liège. He resigned the latter position in 1878; the former in 1883. He continued, however, to practise ophthalmology until his death, and with an ever-widening reputation. Numerous honors were conferred upon him in the course of the years. His life, however, was greatly saddened by an accident which occurred to a member of his family. His eldest son, at Marburg, saved a child from drowning, but, in so doing, lost his own life. Von Mooren died Dec. 31, 1899.

Concerning the personality of this man, we reproduce the words of Prof. Julius Hirschberg in *Centralblatt für pkt. Augenheilkunde* (quoted in the *American Journal of Ophthalmology*): "Those who knew him from literature only cannot fully appreciate him; he had to be seen at the operating table; he was one of those blessed artists who are born but rarely; aside from this he was a noble man, deeply religious, full of warm love for humanity, one who naturally imbued his patients with the greatest confidence. Of course, on account of his successes, he was envied by some, but to his friends he was a warm friend. Our professional friendship has lasted for 32 years, without the slightest disturbance. His memory will remain fresh, not only in science, but also in the hearts of those whom he benefited.''

The most important of von Mooren's ophthalmologic writings are as follows: 1. *Ueber Retinitis Pigmentosa.* (Düsseldorf, 1858.) 2. *Die Gehinderte Tränenleitung.* (*Ibid.*, 1858.) 3. *Die Verminderten Gefahren einer Hornhautvereiterung bei der Staarextraction.* (Berlin, 1862.) 4. *Die Behandlung der Bindehauterkrankungen.* (Düsseldorf, 1865.) 5. *Ophthalmiatrische Beobachtungen.* (Berlin, 1867.) 6. *Ueber Sympathische Gesichtsstörungen.* (*Ibid.*, 1869.) 7. *Ophthalmologische Mittheilungen.* (*Ibid.*, 1874.) 8. *Gesichtsstörungen und Uterinleiden.* (*Ibid.*, 1881; 2d ed., 1898.) 9. *Zur Pathogenese der Sympathischen Gesichtsstörungen.* (Zehender's M.-Bl., XI.) 10. *Fünf Lustren Ophthalmologischer Thätigkeit.* (Wiesbaden, 1882.) Who, among ophthalmologists, has not read and admired this book? The following encomium which was passed upon it in a personal letter to the present writer by Dr. J. A. Spalding, of Portland, Me., is well-nigh typical: ''Much in it now is antiquated, but it reads like a novel. It is one of the most remarkable books that the world ever saw.'') 11. *Hauteinflüsse und Gesichtsstörungen.* (*Ibid.*, 1884.) 12. Einige Bemerkungen über Glaucomentwicklung. (*Arch. f. Augenhlk.*, XIII.) 13. *Die Sehstörungen und Entschädigungsansprüche der Arbeiter.* (1891.) 14. *Die Indicationen der Cataractdiscission.* (1893.) 15. *Die Operative Behandlung der Natürliche und Künstlich Gereiften Staarformen.* (1894.)—(T. H. S.)

Mooren's ulcer. See p. 3405, Vol. V of this *Encyclopedia;* also **Ulcus rodens (Mooren).**

Moorfields. The name (from the London Metropolitan District) by which the Royal London Ophthalmic Hospital, now on the City Road, E. C., is best known. See, among other captions the biography, in this *Encyclopedia*, of **John Cunningham Saunders,** the founder; also **Ophthalmic hospitals and clinics.**

Mops. In the place of sponges formerly employed by the modern ophthalmic surgeon he now uses small pieces or ''dabs'' of (moist) sterile gauze or cotton to mop up blood and other secretions.

Morand, Sauveur François. This surgeon was the son of Jean Morand, chief surgeon of the Hôtel des Invalides, Paris, he married a daughter of Maréchal and studied surgery at Paris. In 1724 he became Demonstrator of Surgery at the Garden of the King, in 1730 surgeon to the Charité and chief-staff-surgeon of the French garden. One of the founders of the French Academy of Surgery, he gave an immense impetus to his beloved art. He himself invented a number of operations, but was the means of introducing many others from foreign countries into France.

He wrote a very large number of works and articles of a general character, which need not here be named. Ophthalmologically interesting are the *Eulogy on Cheselden* and the *Eulogy on Daviel.* In these two eulogies has been preserved much of the personal information we possess today about these two great masters. He was one of the first to show that membranous cataracts do not exist, except as opacifications in the capsule of the lens.

He seems to have been a very friendly man and almost universally liked. He was, however, possessed of much vanity. Thus, Daremberg declares: ". . . his scientific baggage was neither considerable nor important, and he compromised his merit by his vanity."—(T. H. S.)

Morax-Axenfeld bacillus. This very common cause of conjunctivitis, is a large Gram-negative bacillus, which generally occurs in pairs. See p. 796, Vol. II, of this *Encyclopedia.*

Morax-Axenfeld conjunctivitis. See **Conjunctivitis, Morax-Axenfeld,** p. 3121, Vol IV, of this *Encyclopedia.*

Morbilli. (It.) Measles.

Morbus Addisonii. See p. 96, Vol. I of this *Encyclopedia.*

Morbus, bullosus. (L.) Pemphigus.

Morbus ceruleus, Eye signs of. See p. 3607, Vol. V of this *Encyclopedia.*

Morbus maculosus Werlhofii. A name for purpura.

Morcellation. The division of a tumor, followed by its removal piecemeal.

Morchelvergiftung. (G.) Mushroom poisoning.

Moreau, Peter. A French notary who, in 1640, succeeded in casting leaden letters for the blind. See **Alphabets for the blind.**

Morelle furieuse. (F.) The belladonna plant.

Morgagnian cataract. An over-mature cataract in which there are degenerative changes, a softening or liquefying of the cortex, while the nucleus remains hard. Sometimes the nucleus sinks through the liquefied cortex to the bottom of the intra-capsular space. See p. 1560, Vol. III, of this *Encyclopedia.*

Morgagnian globules. Same as **Morgagni, Spheres of.**

Morgagni, Giovanni Battiste. One of the greatest anatomists of all time. He was born at Forli, Italy, Feb. 25, 1682, was professor of anatomy at Padua for fifty-nine years, and died Dec. 6, 1771.

His chief service was in the field of pathological anatomy. His most important works are: *Adversaria Anatomica* (Bologna, 1706-19); *De Sedibus et Causis Morborum per Anatomiam Indicatis. Lib. V* (Venice, 1761).

Ophthalmologically, Morgagni should be remembered because he was one of those who succeeded in securing the acceptance in Italy of "the new teaching about cataract," which had originated in Germany. The history of this teaching is, in brief, as follows: Throughout antiquity and the middle ages, as well as in the first few centuries of our present period, the belief was universal that a cataract consisted of a deposit of corrupt and inspissated "humor" in a (wholly imaginary) space between the pupil and the lens. About 1643, Quarré, a Frenchman, taught that a cataract is really the lens itself in a hardened and opacified condition. Rolfinck, a German, in 1656, made actual anatomical demonstration of the truth of this theory. The matter attracted but little immediate attention, and, indeed, was soon forgotten absolutely. Thirty or forty years later, however, two Frenchmen, Brissean and Maître Jan, took up the cudgel for the new doctrine, and, after a bitter fight, succeeded in securing its acceptance. To the great Heister belongs the credit of having introduced "the new teaching about cataract" into Germany. To the subject of this sketch—Morgagni—(as well as to a number of others) is given the honor of having introduced the new teaching about cataract into Italy.—(T. H. S.)

Morgagnian humor. Liquor of Morgagni. The fluid supposed to exist in small quantity in normal lenses between the lens proper and the inner surface of the posterior capsule on the one hand, and between the lens proper and the so-called capsular epithelium on the other.

Morgagni, Spheres of. Granular masses that form among the other detritus of a disorganized Morgagnian cataract (q. v.).

Morgan, John. A celebrated English surgeon, of considerable importance in ophthalmology because of his having founded Guy's Eye Infirmary and of having written *Lectures on Diseases of the Eye*, long a favorite work among ophthalmic students in England and America. Born at Stamford Hill, England, Jan. 10, 1797, son of William Morgan, an actuary, he became an apprentice to Sir Astley Cooper in 1813, and received the diploma of the Royal College of Surgeons either in 1818 or 1820.

In 1824 he was elected surgeon to Guy's Hospital, and in 1843 to the Council of the College of Surgeons. Mr. Morgan, in his earlier years, was chiefly interested in comparative anatomy, later, however, he devoted himself almost exclusively to the surgery of the eye. His *Lectures on Diseases of the Eye* (not "Lectures on Ophthalmic Surgery" as given by the *Medical Gazette*, Vol. XL, p. 779) was published in 1839, a very large second edition appearing in 1848.

Mr. Morgan married, in 1831, Miss Anne Gosse, of Poole, in Dorsetshire. He resided at Tottenham for the greater portion of his life, lecturing and practising in the city until about two months before his death. He died of Bright's disease * Oct. 4, 1847, aged 51.

Mr. Morgan was especially famous as an accurate observer, and the story is told of him that "when very young he was taken into his mother's bedroom, soon after one of her confinements, to be reproved for mischief, and on coming out he remarked, 'How savage she is now she has got a little one!' thus proving his keen notice of *one* habit of the female animal." In later life his interest in comparative anatomy and physiology developed almost into mania—as in the case of John Hunter—until he became a surgeon at Guy's Hospital. His house, like Hunter's, was full of beasts and birds, living, dead and in various stages of suspended animation. He kept for months a number of female kangaroos, "so as to be able daily to examine them, by the hand put into the pouch, to find out when, or how, the little immature creature came to hang attached, as if organically, to the first-used nipple." After his appointment as surgeon to Guy's, Mr. Morgan to some extent relinquished his comparative investigations, remarking that "he must either be a showman or a surgeon, and suspected that the latter would *pay* the best."

Mr. Morgan left a widow and a number of children, "none of whom," he remarked to a friend, "should ever enter our Profession." Two of his sons, however, became physicians.—(T. H. S.)

Moringa polygona. (L.) An East Indian species, in properties like *Moringa pterygosperma.*

Moringa pterygosperma. MORINGA ZEYLANICA. Horse-radish (or drumstick) tree; an Eastern species introduced into the West Indies. The juice of the leaves is used to promote suppuration in abscesses, is applied with pepper over the eyes in (ocular) vertigo.

Morioplasty. The restoration of a lost part by material belonging to the same organism usually by transplantation from a neighboring or a remote part.

Morison's pills. An empirical (British) laxative remedy supposed to

* "During the time that Dr. Bright, with the assistance of Dr. Addison, and, though last not least, with the assistance of Mr. Morgan's *other* most intimate and trusted friend, Dr. Hodgkin, whose indefatigable industry and patient investigations have never, to my mind, been properly acknowledged—I repeat, during the time Bright was making out the disease, now called after his name, and watching its symptoms, Mr. Morgan was marking the approach of the same symptoms in his own body. With the courage natural to him, he said little or nothing about it, till one day he found himself on the floor of his consulting-room; and when he came to himself (as I have been informed) he went to his solicitor and told him to make his will while he staid there and could sign it—knowing only too well, from the course of that disease, that such an attack might recur."—*Anon.*, in "*Med. Times and Gazette,*" Vol. I, 1871, p. 50.

contain, among other agents, aloes and stramonium capable in large doses of producing temporary loss of vision.

Moro's reaction. This is an inunction test for tuberculosis, of some importance to the ophthalmologist. Moro (Wood's *System of Ophthalmic Therapeutics,* p. 203) found that he obtained results approximating in accuracy those of the v. Pirquet method. A salve composed of equal parts of lanolin and old tuberculin is rubbed into a small area of skin, preferably the chest or abdomen. Within a few hours a diffuse redness appears, with later development of papules, the reaction remaining a week or 10 days.

Kanitz tried the reaction in a series of cases, and compares the results with those obtained with the Calmette and v. Pirquet reactions in the same patients. His figures given in the table below are not so favorable to the inunction method as are those of Moro.

	Cases	Calmette or V. Pirquet Reaction		Moro Reaction	
		+	—	+	—
Tuberculosis	78	72 = 92.5%	6 = 7 5%	28 = 35.9%	50 = 64.1%
Suspected tuberculosis	16	14 = 87.5%	2 = 12.5%	9 = 56.2%	7 = 43.8%
Not clinically tuberculosis	53	27 = 50.9%	26 = 49.1%	7 = 13.2%	46 = 86.8%

See, also, **Calmette,** p. 1361, Vol. II of this *Encyclopedia.*

Morphia. MORPHINE. MORPHIUM. This alkaloid (white prisms with a bitter taste, slightly soluble in water) is obtained from various kinds of opium, some of which may contain as much as 10 per cent. of the drug. It is a well known poison with marked hypnotic, narcotic and analgesic properties in doses of from 1/12 to ½ grain. The freely soluble *sulphate* is usually prescribed but the *acetate, chloride* and *meconate* are also widely employed. For an account of its employment in ophthalmic surgery see **Opium.**

The *oculotoxic* effects of morphia and morphinism are of slight importance. The miosis, the slight spasm of accommodation and the dulled cornea pass off when the drug is discontinued.

Morphœa. MORPHŒA ALBA PLASSA. This trophoneurosis has been reported as affecting the lid skin. It appears as a well-defined, smooth, hard and sometimes slightly-elevated patch. Later on, atrophy of the skin ensues and the patch becomes slightly sunken beneath the surrounding parts.

Morpho metellus. The systematic name of one of the numerous caterpillars whose hairs produce conjunctivitis nodosa.

Morphometry. The art of measuring or ascertaining the external forms of objects.

Mörtel. (G.) Mortar.

Morton-Oliver operation. See **Enucleation of the eyeball,** pp. 4448 and 4451, Vol. VI, of this *Encyclopedia.*

Morton ophthalmoscope. See **Ophthalmoscope,** as well as p. 4749, Vol. VI, of this *Encyclopedia.*

Morvan's disease. See **Syringomyelia.**

Mosaic law regarding blindness. Twice the Mosaic law inculcates respect and consideration for the blind. The first of these passages (*Lev.*, xix, 14) runs as follows: "Thou shalt not curse the deaf, nor put a stumbling-block before the blind, but thou shalt fear thy God: I am the Lord." The second of the passages (*Deut.*, xxvii, 18) is decidedly more emphatic: "Cursed be he that maketh the blind to wander out of the way. And all the people shall say, Amen."—(T. H. S.)

Mosche volanti. (It.) Muscæ volitantes.

Mosetig's method. An operation for the formation of a pad of "artificial bone," intended to relieve the deformity caused by an *orbital exenteration.* See **Orbit, Operations on the.**

Mosquito. (Dim. of Span. *mosca, "a fly."*) This name is applied to various troublesome gnats, of the family *Culicidæ*, belonging to the order *Diptera.* Mosquitoes are distinguished by long, slender antennæ, composed of fourteen or fifteen joints; long and slender proboscis; wing veins clothed with tiny scales, and ten veins or subdivisions thereof reach the margin of the wings. The wings have no distal cell, and at the apex on the inner side of the tibiæ there are spurs. In separating the Culicidæ into genera, attention is usually concentrated on the characters derived from the scales on the three divisions of the body and on the wings. Mosquitoes are very widely distributed, but it was only about the commencement of the 20th century that separate species began to be well known to entomologists and to be adequately described. The discovery that the species of the genus *Anopheles*, and allied genera, had an undoubted connection with the transmission of malaria was exceedingly important. The discovery is generally attributed to Dr. Ronald Ross, a Scotchman in the Indian Civil Service. However, several Italians were close on his heels. In all probability mosquitoes are connected with the propagation of other tropical diseases. Ross worked the problem out for malaria, demonstrating first on birds and later on human beings. The adult mosquito may be recognized by the fact that the antennæ have plumes or whorls or hair, often long and dense in the male, while the head bears a long projecting proboscis. As in the allied midges, the blood-sucking habit is confined to the female. Blood is apparently not the sole or even the chief food, and there seems no doubt that millions of individuals live and die without ever tasting it. The larvæ are always aquatic, and it is shallow standing water which seems especially to suit their habits. The common gnat of England and other comparatively cold countries is *Culex pipiens,* the same species which in warmer countries constitutes the much-dreaded "mosquito." It does not appear that this species ever carries malarial infection, the mosquitoes of malaria, so far as is yet known, being always species of *Anopheles.*

Members of the species *anopheles,* which is the species, as has been said, mainly instrumental in carrying malarial fever, differ from other species in that the palpi in both sexes are hardly less long than the proboscis; this latter is straight, and the body is colored with a brown and yellowish tint. When at rest the body inclines at an angle from the surface on which it is resting, and beak, thorax, and abdomen are all in the same plane; this is a convenient way of distinguishing the *Anopheles* from the hump-backed posture assumed by other species. Species of *Anopheles* do occur in this country, but there is an infinitely more plentiful variety to be met with in the tropics. The commonest American species is A. *maculipennis,* which occurs also in S. Europe.

The yellow-fever mosquito (*Stegomyia calopus* or *Stegomyia fasciata*) belongs to tropical and sub-tropical parts. It is a domestic mosquito and does not breed in the swamps or away from civilization, and its eggs, like those of the *Anopheles,* are laid separately. During the severe outbreak of yellow fever at New Orleans in 1905 measures were taken as far as possible to ward off the danger which is now generally agreed to lie in these insects. Another disease, filiariasis (see **Filaria**), is also transmitted by one or more species of mosquito, particularly *Culex ciliaris.*—(*Standard Encyclopedia*). The direct ocular injuries inflicted by *Culex giganteus* are considered on p. 3528, Vol. V, of this *Encyclopedia.* See, also, **Malaria.**

Moss, Ceylon. Jaffna moss. See p. 1982, Vol. III, of this *Encyclopedia.*

Motais' operation. For the relief of ptosis. See **Ptosis.**

Motility of the eye. See **Muscles, Ocular.**

Motilitätsstörungen des Auges. (G.) Disturbances of the ocular movements.

Motion-distortion. Modification of the spectrum due to the motion or motions of the source of light.

Motor asthenopia. The eye symptoms—photophobia, blurring of print, temporary diplopia, vertigo, car sickness, panorama phenomena, etc. —due to *heterophoria* and *heterotropia.* See these captions, as well as **Muscles, Ocular.** A very good account of the matter is also given by Landolt (*Klin. Monatsbl. f. Augenheilk.*, p. 110, 1911).

Motorius. (L.) A motor nerve.

Motor nerves of the eye. See **Anatomy of the eye**; as well as **Muscles, Ocular.**

Motor oculi. (Motores oculi). OCULOMOTORIUS. The third pair of cranial nerves, distributed to all the muscles of the eye, except the superior oblique and external rectus.

Motor spirit. See **Petrol.**

Mottled degeneration of the macula. See **Macula, Diseases of the.**

Mouches volantes. (F.) Muscæ volitantes.

Mounting of eye sections and specimens. See p. 6886, Vol. IX of this *Encyclopedia.*

Mouse, The. The mouse was employed in various ways in ancient ophthalmic therapy. According to Pliny, the ashes of the head and tail, mixed with honey, was useful to clarify the sight. A salve made of a young mouse bruised in old wine was highly esteemed as a means of promoting the growth and vigor of the eyelashes. So, too, were the ashes of the dung of this animal, when mixed with antimony, wool fat, or the dung of the goat.—(T. H. S.)

Mouse-ear. *Asperugo procumbens.* The root of myositis, or myosoto, mixed with a porridge of chestnut meal, was employed in the days of Pliny and Dioscorides as a remedy for ocular phlegmon (any acute inflammation, accompanied by swelling) and for various diseases of the inner corner of the eye, especially dacryocystitis.—(T. H. S.)

Mouth, Diseases of the. Apart from dental affections (see p. 3817, Vol. V, of this *Encyclopedia*) oral sepsis may affect the eyes by continuity by way of the blood stream, especially through the veins of the pterygoid plexus, but this process is probably very rare. When it occurs orbital cellulitis or cavernous sinus thrombosis may result.

Mouth-glass. A hand-mirror used by dentists.

Mouvement circulaire. (F.) Rotary movement.

Movable cheeks. In certain of the *Crustacea,* the lateral movable portions of the cephalic shield, which bear the eyes.

Movement, Associated. A movement of parts which act together, as of the eyes. See **Muscles, Ocular.**

Movements, Ocular. See **Muscles, Ocular**; and such headings as **Convergence,** p. 3294, Vol. V of this *Encyclopedia;* also, under **Divergence,** p. 4051, Vol. VI.

Moving pictures. CINEMATOGRAPH. The strain upon the eye muscles and the brain fag produced by the efforts of the eyes to fix and interpret the swiftly moving images of the cinematograph and particularly when the films are defective, has been a subject of comment both by the laity and ophthalmologists since the introduction of these pictures. For instance, the Superintendent of Public Schools in Chicago requested (1913) that the City Council pass an ordinance based on the Massachusetts law requiring a five-minute intermission between reels, so as to mitigate the eye strain of the motion picture.

Ferree and Rand (*Bryn Mawr Coll. News,* Oct. 15, 1914) made an investigation of the effect of moving pictures on the eyes. They fitted up a room at the Bryn Mawr theater and made tests there after watching the pictures for periods of two hours. The results of these tests show that if the observer sits well back from the screen, after two hours there is no more strain on the eyes than there is after the same period of reading by the greater part of the direct lighting and much of the semi-indirect lighting now in actual use. This is interesting in view of the fact that a great many people object to moving pictures on the ground that they are bad for the eyes, and yet these same people are content to read for two or three hours at a time with bright light sources in the field of vision. See, also, p. 2249, Vol. III, of this *Encyclopedia.*

Mowat, Daniel. A well known English ophthalmologist, a graduate of the University of Edinburgh, a member of the Ophthalmological Society of the United Kingdom, and a clinical assistant at Moorfields for more than twenty years. He died in 1910.—(T. H. S.)

Mowers' mite. The *Leptus autumnalis.*

Moxa. A form of cautery, (counter irritant much used in India, China and Japan) produced by burning on the skin the leaves of *Artemesia moxa.* It is often applied to the temple to relieve ocular pain and inflammation. Hence, any cauterizing agent, even including the galvanocautery. See, also, p. 6417, Vol. VIII, of this *Encyclopedia.*

Moyne, Giuseppe Damiano. A well known Italian ophthalmologist. Born in 1803 in Piedmont he studied at Turin, and settled in Naples in 1826. Here he became the successor of G. B. Quadri. He was an excellent teacher, and a very celebrated operator, having an especial reputation as an intracapsular cataract extractor. He was a very modest, unassuming man, pleasant and courteous to all, and was universally esteemed. He died in 1873.—(T. H. S.)

Muavin. An alkaloid from muawi-bark, an East African drug. Its hydrobromid, a yellowish powder, acts somewhat like digitalin. It is identical with *erythrophlein.* See p. 4518, Vol. VI, of this *Encyclopedia.*

Müchensehen. (G.) Muscæ volitantes.

Mucicarmin. A stain for mucin consisting of 1 gm. of carmin, 0.5 gm. of aluminum chlorid, and 2 c.c. of distilled water.

Mucilages. MUCILAGINES. Mucilage is an artificial viscid paste of gum or dextrin: used in pharmacy as a vehicle or excipient, or in therapy as a demulcent. The principal mucilages are those of acacia, elm, salep, sassafras-pith, starch, and tragacanth. They are used in prescriptions to suspend some insoluble substances, or as excipients for forming masses for pills, troches, etc. The mucilages are soothing to inflamed mucous membranes; e. g., mucilage of sassafras-pith is largely used in eye-washes.

Mucin. This, the chief constituent of mucus, is a compound protein insoluble in water and precipitated by alcohol, acids and alum. It is found, among many other situations, in the goblet-cells of the conjunctiva. Its presence is usually revealed by the thionin and mucicarmin. See, also, p. 6916, Vol. IX, of this *Encyclopedia.*

Mucitis. Inflammation of a mucous membrane.

Mucocele. A distension and bulging of the lachrymal sac, canaliculi, ethmoidal, or frontal sinus or other cavity, from an excessive secretion and collection of mucus. See **Dacryocystitis, Catarrhal,** p. 3717, Vol. V, of this *Encyclopedia.*

Paunz (*Zeitschr. f. Augenh.,* Sept., p. 272) has reported a case in which the *ethmoidal cells* on the left side and the *frontal sinus* had been converted into a single, smooth-walled cavity filled with dark-brown mucous fluid which had eroded the lateral walls of the ethmoid (lamina papyracea) and the posterior and inferior walls of the frontal sinus. The dura formed the upper and the periosteum of the orbit the external wall of the cyst. A Killian operation brought about a cure. Chance reports that a supposed osseous tumor of the orbit was found upon operation to be a mucocele of the ethmoidal and frontal sinuses. In Zentmayer's case (*Oph. Record,* June, p. 287, 1908) proptosis occurred suddenly, and the optic nerve was veiled by exudation and extravasation. Both of these conditions were suddenly reduced by purulent discharge from the nose, from the rupture of a mucocele of an accessory sinus.

Calderaro (*Arch. f. Augenh.,* LXI, 4, 1908) finds atypical forms of mucocele of the *frontal sinus* difficult to recognize; and due to variability of the sinus itself. The latter may consist in an extension into the outer and posterior portion of the orbit, as far as the small wing of the sphenoid or to the foramen opticum, or to the outer portion of the frontal bone. The symptoms prior to destruction of the bony wall are those of any retrobulbar growth, exophthalmos, etc. Treatment should consist in evacuation of the contents of the sinus, excision of the sinus, excision of the depressed orbital arch and obliteration of the cavity of the mucocele.

Mucoid. Resembling mucus. As a noun, any one of a group of mucus-like compounds of animal origin. The mucoids differ from mucins in solubility, they are precipitated by acetic acid; and they include colloid and ovomucoid.

Mucoid degeneration. See **Mucin.**

Muco-lachrymal spectrum, The. The diffraction of light dependent on tears, mucus, fat globules and bubbles of air moving over the cornea by the action of the sharp lid margins and appearing in front of the pupil.

Mucor. A genus of saprophytic mold-fungus, some orders of which affect—but rarely—the ocular structures.

Mucor cornealis. A term applied by Cavara to the mold parasite responsible for certain forms of aspergillus infection. See **Keratomycosis.**

Mucor corymbifer. A pathogenic species of mold-fungus that has been observed on the eyelid. It has umbrella-like, branching sporophores.

Mucor rhizipodiformis. This is a pronounced pathogenetic mold-fungus with a doubtful history of having attacked the eye. It has been found in white bread and on the mucosa of the mouth.

Mucor stolonifer. This form of mold-fungus is said by Knapp (Berlin) (*Klin. Monatsbl. f. Augenh.*, Febr., p. 180, 1908) to have been found as fungoid masses as a secondary infection of a tubercular ulcer of the conjunctiva.

Mucosa. The mucous membrane.

Mucous patches. These lesions, not always luetic, are seen—but rarely—on the conjunctiva. They resemble the same alterations on other mucous membranes. When they are syphilitic in character they readily disappear under general and local treatment.

Mucuna pruriens. COWHAGE. The hairs of this (Brazil) leguminous plant are extremely irritating and were formerly a popular remedy for intestinal worms. No well-established account has been published of their producing any serious lesion of the eye.

Mucusan. A trade name for diboron-zinc-tetra-orthooxybenzoate, used in gonorrhea, leucorrhea and mucopurulent forms of conjunctivitis.

Mud-bath. A bath in the mud of certain mineral springs or in the mud of a salt marsh.

Mueller's operation. See **Retina, Detachment of the.**

Muhammed b. Halaf b. Musa al Ansari al-Auasi. A Spanish-Arabian physician of the 12th century, who is said to have written a number of works on ophthalmology, none of which, however, is extant.—(T. H. S.)

Mulder's angle. The angle between the facial line of Camper and a line from the root of the nose to the spheno-occipital suture and intersecting the first line.

Mules' operation. See **Enucleation of the eye and its substitutes,** p. 4428, Vol. VI, of this *Encyclopedia.*

Mules, Philip Henry. A well-known English ophthalmologist. Born in 1843, he was for many years surgeon to the Royal Eye Hospital in Manchester. He invented Mules's sphere and Mules's wire operation for ptosis—both of which are described at length under other rubrics in this *Encyclopedia.* Late in life he removed to Gresford, Denbighshire, where he became ophthalmic surgeon to the Wrexham Infirmary. He died suddenly Sept. 1, 1905, aged 62, leaving a widow and six children.—(T. H. S.)

Mullein. *Verbascum thapsus.* Mullein leaves, boiled either in water or in rose-oil and vinegar, were used in the days of the elder Pliny as a local application for epiphora.—(T. H. S.)

Müller, Heinrich. A well-known German anatomist and physiologist, who contributed much to our knowledge of the human retina. Born Dec. 17, 1820, at Castell, Unterfranken, he became in 1852 extraordinary professor of topographical and comparative anatomy, and six years later full professor of the same subjects. For a number of years he lectured on the anatomy, physiology, and pathology of the eye, and gave instruction in the use of the ophthalmoscope. He died May 20, 1864.—(T. H. S.)

Muller, Johannes. This eminent physiologist was born at Coblenz, Prussia, in 1801. He studied at Bonn and Berlin, chiefly anatomy and zoology, and in 1826 was appointed professor of physiology and anatomy at Bonn; and in 1833 succeeded Rudolphi as professor of anatomy and physiology at Berlin, and held that post until his death. He is regarded as the founder of modern physiology. His *Handbuch der Physiologie des Menschen* (2 vols. 1833-40; Eng. trans. 1840-49) exercised a great influence as a textbook of the science. He died in 1858. He was an intimate friend, student and collaborator of Helmholtz.

Müller-Lyer paradox. An experiment in physiologic optics intended to illustrate ocular space-judgments and their defects.

Müller'sche Flüssigkeit. (G.) Müller's fluid.

Müller'scher Ringmuskel. (G.) The ciliary compressor lentis.

Müller'sche Stützfasern. (G.) Müller's fibers.

Müller's fibers. (1) Finely striated fibers whose bases form the internal limiting membrane of the human retina, and which pass vertically to the external limiting membrane and give off numerous small branches which by their anastomoses form a matrix for the retinal elements. See **Histology of the eye.** (2) Large longitudinal nerve-fibers on each side of the central canal in the myeline of *Petromyzon fluviatilis.*

Müller's fluid. A weak solution of potassium dichromate and sulphate: used in fixing, hardening, and preserving anatomic specimens. It is now superseded by the Formol-Müller fluid. See p. 5275, Vol. VII, of this *Encyclopedia.*

Müller's muscle. See **Anatomy of the eye**; as well as **Histology.**

Multiaxial. Having several or many axes.

Multicolor. MULTICOLOROUS. Of many colors.

Multifamilial. Affecting the several successive generations of a family.

Multifid. Cleft into many parts.

Multilaminate. Having many layers or laminæ.

Multi-lens objective. An objective comprising a large number of lenses.

Multiple images. Images due to repeated reflection in two or more mirrors.

Multiple eyes. See **Insects, Eyes of**; p. 6370, Vol. VIII, as well as p. 2530, Vol. IV, of this *Encyclopedia.*

Multiple neuritis. See **Neuritis, Multiple.**

Multiple puncture. Under the heading *Multiple retino-choroidal puncture,* Wood (*System of Ophthalmic Operations,* Vol. II, p. 1373) remarks that among the numerous operative procedures for the relief of detached retina advocated by that inventive surgeon, Galezowski, is multiple puncture of the choroid and the separated membrane.

The instrument he employed for the purpose had the shape of an arc of a circle—a stout curved needle—not unlike that he used for the introduction of his catgut suture. A number of punctures and counter-punctures were made in the eyeball, the needle at each insertion passing through the detached retina. In this way he hoped to push or pull the membrane towards the choroid, making a number of retino-choroidal cicatricial points sufficient to keep the replaced retina in its normal position. He reported 17 cases treated in this way, five with partial and two with signal success.

Pagenstecher, according to Scheffels, also used a common steel needle for multiple puncture of the sclera, choroid and detached retina, an operation that was followed by good results.

Elschnig says that Pagenstecher used also a Knapp's knife to make multiple puncture of the sclera, choroid and retina, and that Galezowski tried multipuncture of the sclera and retina in the area of the detachment with a pointed knife which he called his ophthalmotome.

August Brück describes in detail the method of H. Pagenstecher. The post-retinal fluid is drawn away by means of a simple puncture. Afterwards, with a discission needle, four additional sclerotomies are made in the region of the detachment, rather close to one another and through the sclera, choroid and retina. The post-operative treatment consists in the application of a pressure bandage and complete rest. The essayist gives the results of treatment in several cases and concludes that where multiple puncture with the knife or knife-needle does not bring about a complete cure, it at least prevents a spread of the separation.

Multiple sclerosis. See **Sclerosis, Multiple.**

Multiplying camera. A photographic camera fitted with a number of lenses.

Multiplying glass. Multiplying lens. A facetted lens that furnishes a number of images of the object.

Multirotation. A phenomenon presented by a number of optically active substances according to which the rotating power of a freshly-prepared solution is about twice as great as the final constant rotation.

Multocular. Having numerous eyes.

Mumps. This is the popular name for *parotitis,* a specific inflammation of the parotid glands. The disorder usually begins with a feeling of stiffness about the jaws, followed by pains, heat, and swelling beneath the ear. The tumefaction begins in the parotid, but the other salivary glands may become implicated, so that the swelling extends along the neck towards the chin, thus giving the patient a deformed and somewhat grotesque appearance. There is seldom marked rise of the temperature. The inflammation is usually at its highest point in three or four days, after which it begins to decline, suppuration of the glands being rare. The disease is infectious; and the infection probably remains for at least a fortnight after apparent recovery.

The *ocular relations* and symptoms of this disease are important.

Major Worthington (*Ophthalmology,* April, 1913) finds but little written on the subject of ocular conditions that may be directly due to parotitis, yet they may be of such severity as to cause considerable anxiety on the part of the patient and doctor alike. Among these conditions may be mentioned abscess of the eyelids, dacryoadenitis, iritis, keratitis, and even retrobulbar optic neuritis, optic atrophy and, possibly, blindness. To the present time no satisfactory explanation of the mode of production of the ocular or other metastases of parotitis has been advanced. The toxin theory seems the most logical, but has not yet been thoroughly proven.

The ocular complications of mumps most frequently come on when the usual symptoms of the disease have begun to subside, at the beginning of convalescence or within a few weeks subsequent to the attack.

The first recorded observations of this condition were made in 1872 by E. Ryder, who reported two cases of dacryoadenitis due to epidemic parotitis. Hatry in 1876 published ten cases of neuro-retinitis due to this disease.

J. W. Charles reported a case of keratitis interstitialis anterior, coincident with mumps, patient male, age 28. Recovery from mumps one week previous. First noticed redness and slight pain in right eye. Vision reduced to 8/240, iris hyperemic. Cornea steamy, with faint stain with fluorescein. Antecedent history was muscular and articular rheumatism prior to this attack which confined him to bed. In two weeks from date of onset vision in right eye was 15/12 with correction, some opacity remaining below.

Villard reports a case of bilateral iritis, subsequent to a double parotitis, patient a woman, aged 30. Eye involvement came on during the last few days of the disease, eyes reddened, painful, pupils sluggish, vision normal. Complete recovery in eight days.

H. V. Würdemann made an exhaustive report of a case of thrombophlebitis of the central retinal vessels occurring in a boy aged 8, two weeks after the onset of an attack of mumps, in which sudden and total blindness of the left eye occurred. The fundus appearances showed very extensive thrombophlebitis, with many retinal hemorrhages as greyish-white discolored patches. Nearly one year later acute fulminating glaucoma set in; eye enucleated. Microscopic sections showed thrombus filling lumen of artery and clots in vein.

J. H. Woodward has written a complete article on this subject in which he reports in detail his case of unilateral (left) optic neuro-retinitis due to parotitis in a girl 11 years old, resulting in blindness of the affected eye—and enucleation of the eyeball three and a half years later for proptosis caused by anterior staphyloma. In this case the condition developed four or five weeks after convalescence. He also gives a resumé of the subject on ocular complications of mumps, as follows:

Twenty-three cases of neuro-retinitis. Vision more or less impaired in 12, recovery in 11. Three cases of retrobulbar neuro-retinitis, with complete recovery. Six cases of optic nerve atrophy, with blindness in 4, nearly complete blindness in 2. Keratitis complicated with iritis in one eye. Made imperfect recovery. Six cases of iritis. Three complete recovery, 3 imperfect recovery. Fourteen cases of dacryoadenitis. Three cases each of paralysis of accommodation, and of extraocular muscles.

Worthington's own case was one of keratitis with, however, rapid recovery to normal. The patient, a male, aged 23, had been having a severe double parotitis for the past eight days, complicated with an orchitis. Examination of the eyes revealed the following: Right eye slightly injected, there was excessive lachrymation; cornea appeared steamy and dull, with central cloudiness; the pupil of this eye was not contracted, but was quite sluggish and hyperemic fundus was seen but indistinctly. Vision was quite reduced, fingers at 10 feet.

Lehmann (*Jour. Am. Med. Assocn.*, Apr. 1, 1916) also remarks that ophthalmologists have had their attention called to an eye affection, an *iritis* or *uveitis*, resembling that of syphilitic origin in some respects but absolutely rebellious to specific treatment, and remarkable further, in that it is accompanied by inflammation of the parotid glands, slight fever and facial paralysis. Lehmann has encountered two cases himself and knows of ten others in Denmark—a total of twelve cases of what he calls febris uveoparotidea. It represents a definite syndrome of bilateral uveitis, bilateral parotitis, low, continuous fever, and, in half the cases, facial paralysis. The uveitis runs a chronic course and may eventuate in blindness in one or both eyes in the severer cases. In a few cases other glands besides the parotid were affected likewise. The prodrome is protracted; the first symptom may be the facial paralysis, which may keep up for three or four weeks before the uveitis or parotitis develops. The latter resembles mumps to a certain extent, but its long persistence, the absence of any known source of infection, the absence of any contagion from these cases, and likewise the fact that orchitis was never known in any instance, seems to exclude epidemic parotitis. The parotitis may develop as an indolent tumor, persisting for two years. In all the cases, however, the parotid lesions and the facial paralysis entirely retrogressed in time. A number of points differentiate this affection from Mikulicz' disease of the lacrimal and salivary glands, as Lehmann describes in detail. In nine of the twelve patients there was nothing to suggest tuberculosis or a predisposition thereto, no traces of scrofula, and the skin and subcutaneous tuberculin tests applied to three elicited a negative response. But the other three patients were undoubtedly tuberculous; the microscope revealed tuberculous tissue in the iris of one and in a gland in the neck of another. Uhthoff of Breslau described an analogous case in 1909 which he explained as a case of tuberculous meningitis with tuberculous iridochoroiditis.

Münze. (G.) Mint.

Mural circle. A graduated circle fixed in the plane of the meridian and used, in connection with an astronomical telescope, for measuring the declinations of celestial bodies.

Mural quadrant. A graduated quadrant used as the mural circle.

Murdoch, Russell. A well-known surgeon and ophthalmologist of Baltimore, Md., renowned for his researches in comparative ophthalmology, especially of the ophthalmology of the larger carnivora. A graduate of the Medical Department of the University of Virginia, at Charlottesville, he was a surgeon in the Confederate army through the civil war, and one of the founders of the Baltimore Eye, Ear, and Throat Hospital, after returning to civil life. For a time he was lecturer on diseases of the eye and ear at the University of Maryland, and professor of diesases of the eye, ear, and throat in the Woman's Medical College, at Baltimore, Md. He was a member of the Medical and Chirurgical Faculty of Maryland, of the American Ophthalmological and the American Otological Societies. He died Mar. 19, 1905, at Johns Hopkins Hospital, Baltimore, Md., of cerebral hemorrhage.—(T. H. S.)

Muriatic acid. See **Acid, Hydrochloric.**

Murine. An empirical and much advertised (American) eyewater enjoying (at this writing) considerable popularity among the laity.

Murrell, Thomas E. A well-known American ophthalmologist, professor of ophthalmology at the Barnes Medical College, of St. Louis, Mo. Born in 1850, he received his medical degree at the University of Maryland in 1873. After two or three years of graduate study and hospital work he settled at Little Rock, Ark. In 1890 he became the Secretary of the Ophthalmic Section of the American Medical Association, and in 1893 one of the vice-presidents of the association. In 1894 he removed to St. Louis, that he might occupy the chair of ophthalmology at Barnes Medical College. In 1896, however, he retired, because of ill health, and died at Denver, Colo., June 26, 1898, of pulmonary hemorrhage.—(T. H. S.)

Murrina. A form of trypanosomiasis among mules and horses in the Canal Zone. It is thought to be caused by the *Trypanosoma hippicum*, and is marked by anemia, weakness, emaciation and edema, conjunctivitis, pyrexia, and some posterior paralyses.

Mursinna, Christian Ludwig. A famous 18th century Prussian surgeon, of especial renown in the extraction of cataract. Born Dec. 17, 1744, at Stolp, in Pomerania, he became a military physician, and saw much active service in both field and hospital. He later (in 1799) received his diploma from the University of Jena, returning shortly afterward to his duties as a military surgeon. He finally settled in Berlin, where he became professor of surgery and a prolific writer on surgical and medical subjects. He is said to have performed the cataract operation (extraction) 908 times, with only 41 complete failures. A man of robust health and great physical strength and endurance, he was also remarkable in the matter of longevity, dying May 18, 1823, almost 90 years of age.—(T. H. S.)

Muscæ volitantes. The dioptric media of the eye are not perfectly transparent, as is shown by the presence of small, bead-like bodies (muscæ volitantes) which are seen when one looks through a microscope. They are due to translucent bodies in the vitreous humor. *Pathological* vitreous opacities (especially of the floating variety) also give rise to the sensation that specks, motes or other "dancing" bodies are floating in the air in front of the eyes. The so-called normal muscæ are not constantly seen while, of course, the sensation due to fixed alterations is constant. The whole subject should be studied in relation to **Uveitis** as well as **Hyalitis** and **Choroiditis in general.**

Muscarin. A deadly poisonous alkaloid from the mushroom *Amanita,* that gives rise to eye-symptoms. See p. 282, Vol. I, of this *Encyclopedia.*

Muscegenetic. Giving rise to muscæ volitantes.

Muschelgläser. (G.) Shell-shaped glasses. Coquilles.

Muscle, Bowman's. The ciliary muscle.

Muscle, Choanoid. See p. 2072, Vol. II, of this *Encyclopedia.*

Muscle-balance. See **Muscles, Ocular.**

Muscle, Brücke's. Tensor choroidæ. See p. 1319, Vol. II of this *Encyclopedia.*

Muscle, Ciliary. See p. 2237, Vol. III, of this *Encyclopedia.*

Muscle, Corrugator supercilii. See p. 3541, Vol. V of this *Encyclopedia.*

Muscle exercise, Ocular. This important subject has been discussed under several rubrics in this *Encyclopedia;* e. g., under **Dyerizing,** p. 4098 and p. 4797, Vol. VI. In addition attention is drawn here to the paper of A. Duane (*Ophthalmic Record,* June, 1911) who gives his patient *printed directions* regarding this, to him, often complex matter. The Editor has followed this printed plan for many years and strongly recommends it. The following appliances are required, in following Duane's system:

Square unmounted prisms of 10°, 16°, and 20°.

A round white pasteboard target at least one foot in diameter, with a central black bull's eye, one-third of an inch in diameter.

A round white pasteboard target 6 inches in diameter, with a dot in the center not more than $\frac{1}{32}$ of an inch in diameter on one side, and a narrow vertical line, one inch long, in the middle of the other side.

Duane tells the patient that only the prisms need be bought, or as the Editor arranges, *rented* as the targets can be made at home. There are four varieties of exercises. 1. Practice in converging with prisms when eyes are fixed on distance. 2. Practice in converging with prisms when eyes are fixed on a near object. 3. Practice in diverging with prisms. 4. Practice in converging on an approximating point.

The instructions for each exercise are given in detail so that the patient can make no mistake.

For exercise 1 the large target is used at least 15 feet away, whereas in 2 the small target is used, the dot side being used as a rule, except when there is much hyperphoria, when the line is used instead. The prisms of course are used base out before each eye in increasing strengths.

In exercise 3 the small target is used with reading glasses, if worn. Here the prism is used base towards the nose. If fusion cannot take place the target must be moved towards the eye and then back again till the dot doubles. When the weak prism can be overcome easily a stronger one is tried.

For exercise 4, the reading glasses are put on and the small target is used, the patient looking at the dot. It is held at arm's length and moved up to the face till it doubles. Any small object such as a pin with a white head can be used equally well.

Order, duration, and frequency of exercises. Practice 3 times a day, 9 a.m.; noon; and 5 p.m. Exercises to be done in order given above. If pain or more than temporary discomfort results the exercises must be stopped for that time. The exercises must be modified in duration according to the patient's feelings. The exercises will be prescribed according to the symptoms of the patient. Thus 1, 2 and 4 for cases of exophoria. If this is more marked for distance and converging power good, then exercise 1 is specially indicated. For convergence insufficiency exercises 3 and 4 should be used. The reviewer can speak of the value of these from his own experience. When diverging power is low exercise 1 should be omitted as it may do harm. This is especially the case in pure convergence insufficiency.

Exercise 1 and 2 should be avoided if there is any tendency to spasm of accommodation. They are, on the contrary, of much value in cases of subnormal accommodation.

Exercise 3 is used for practicing the divergence in cases of convergence excess. It may also be employed in cases of spasm of accommodation.

The duration of the exercises will depend upon the case, and it is necessary to see the patient from time to time to see what progress is being made. As a rule four or five weeks are required to produce the best results in cases of convergence insufficiency, and the patient should be able to overcome prisms, base out, of an aggregate amount of at least 46°. If this is done Duane omits the practice for four weeks and if he can still overcome the strong prism tries him again in another four weeks. Should the patient go back the exercises must be done again.

All the exercises may be used to modify the effect of operations on the eye muscles. Exercises 1, 2 and 3 are particularly useful after a tenotomy of the externus done for divergence excess. In such cases measurements of the deviation for distance and near are taken daily after the operation, and the exercises are pushed, omitted, or modified according to the findings thus obtained.

Muscle hook, Stroschein's double. This instrument, a modification of de Wecker's (see p. 5999, Vol. VIII of this *Encyclopedia*) is fully described in the *Klin. Monatsbl. f. Augenheilk.*, Jan., 1910. See, also, the cut.

Stroschein's Muscle Hook.

Muscle, Horner's. See p. 6023, Vol. VIII of this *Encyclopedia.*

Muscle-humble. (F.) The inferior rectus muscle.

Muscle, Müller's. See **Müller's muscle**; as well as **Anatomy of the eye,** and **Muscles, Ocular.**

Muscle, Naso-palpebral. Orbicularis palpebrarum.

Muscle, Orbicularis palpebrarum. See **Anatomy of the eye.**

Muscle power, Ocular. See an account of the *ergograph,* p. 4698 Vol. VI of this *Encyclopedia.*

Muscle, Riolan's. A muscular slip from the orbicularis palpebrarum, running along the free border of the eyelid.

Muscles, Extrinsic eye. See **Muscles, Ocular.**

Muscles, Injuries of the extraocular. Traumatism of the orbital muscles and their nerve supply may be due to contusions from blunt objects as well as to penetrating injuries of various kinds. The muscles may be directly contused and rendered functionless by blows on the eye especially the levator of the lid, whose exposed tendon is most often bruised. Such isolated injuries to the levator may come from stones, shots and other missiles without specially showing swelling or the production of scar tissue.

The muscles may be indirectly affected by the pressure of a hematoma, or fragments of bone in the orbit following a blow from a blunt object, or torn out of their insertions, or in two, by luxation and avulsion of the globe. Fire-arm injuries may both directly and indirectly contuse or rupture the muscles.

Injuries to the muscles through the entrance of pointed objects, shot and foreign bodies into the orbit, is somewhat common. In many cases it is impossible to determine whether the resulting paralysis is due to direct injury to the muscle or to its supplying nerve, or whether it be from hemorrhage or laceration from bone fragments. The levator of the lid is most often cut through, causing ptosis. Commonly several muscles are injured at the same time, especially where a luxation of the globe has been produced where the tendons are dragged out of the body of the muscle.

The wound of entrance in the conjunctiva or lids, and characteristics of a penetrating wound of the orbit, are to be observed. The subconjunctival ecchymosis, chemosis and swelling of the lids are usually prominent. In isolated ruptures or wounds there is loss of motion towards the injured side and the eye is pulled the other way on account of the action of the antagonist.

Double vision is complained of or readily elicited. If several muscles be injured the eye protrudes from loss of their tension and from the hematoma in Tenon's capsule and the orbit, and the ocular movements in all directions are diminished thereby. The motility of the globe is permanently damaged from solution of continuity of the muscles or nerves, but may return if the loss of motion be due to hemorrhage. As a rule the globe remains intact, but it may likewise have been opened by the injury.

Following hemorrhage and laceration of the eye muscles and the capsule of Tenon these structures, as well as the orbital cellular tissue, fat and periosteum, may become inflamed and end in abnormal adhesions and cicatricial contraction of tissue whereby the movements of the eyeball may be impeded. Such conditions are apt to follow orbital phlegmon, periostitis and other inflammatory conditions, especially in the case of retarded foreign bodies in the orbit. Cicatricial enophthalmus with atrophy of the globe results.

The diagnosis depends upon the history and the kind of injury. Wounds over the insertion or belly of the muscles are characteristic. If over the tendon, shreds of tendon tissue may protrude or the lacerated tendon be seen in the depths of the wound. Partial laceration is difficult to diagnose on account of the bleeding and the contused nature of the wound.

The prognosis of isolated injury to muscle or tendon is good if an operation be done to correct the accidental tenotomy. Where much scar tissue forms, especially after the retention of foreign bodies, the prognosis is unfavorable as to recovery of function. Complete separation of the muscles entails lasting paralysis with secondary contracture of the antagonists. Partial lacerations may, like partial resections, heal after some time with perfect restoration of function.

The therapy is surgical. The ends of the divided muscle or tendon should be brought together by two or three interrupted sutures, or if the tendon has been divided, the Worth or other advancement operation may be made, especially where the injury has happened some time before. It is worthy of remark that a partial division of the tendon or muscle may not produce permanent disturbance of motility, for it heals rapidly. In some cases it may be necessary to perform a graduated tenotomy on the antagonist in order to secure muscle equilibrium.—(H. V. W.) See, also, **Military surgery of the eye.**

Muscles, Insufficiency of eye. See **Muscular insufficiency.**

Muscles, Ocular. [As the length of this extremely important section may make it difficult for the reader to locate some of the numerous subsections into which the major heading is divided the following table of contents has been prepared. It is by no means intended to be an index of all the matter included in this caption, but will be useful to the reader searching for information under the principal heads into which the whole subject is divided. The physiology and pathology of the extrinsic ocular muscles has been written by Dr. G. C. Savage, while an account of the operative measures for the relief of the various forms of oculo-muscular imbalance has been contributed by Dr. Edward Jackson—both well-known authors on the subjects they discuss.

PHYSIOLOGY AND PATHOLOGY OF THE OCULAR MUSCLES—SAVAGE

OPERATIONS ON THE OCULAR MUSCLES—JACKSON.

my—Partial Tenotomy—Advancement with Anchor Stitch—Special Forms of Suture for Muscular Advancement—Advancement with Folding of the Tendon—Folding the Tendon with Special Instruments —Shortening a Muscle with Section or Resection—Operations to Enable One Muscle to Take up the Functions of Another—Transplantation for Paralysis of External Rectus—Transplantation for Oculomotor Paralysis—Exsection of Tendons.—Ed.]

The muscles of an human eye are divisible into two classes, the *intrinsic* and the *extrinsic*. The muscles belonging to the first class, as the name would imply, are within the eye-ball. They are four in number, two being found in the ciliary body, and two in the iris.

Ciliary muscles. The two muscles in the ciliary body are muscles of accommodation and correction. The one is a circular muscle which has been named after its discoverer, Mueller. The other muscle, also named after its discoverer, Bowman, has its fibers running parallel with the meridians of the eye.

Bowman's muscle was first to be discovered and was thought by him to be the only muscle in the ciliary body and, therefore, the muscle of accommodation; that is, the muscle that gives to the perfect eye the power to see as well near as far. Later, Mueller discovered the circular muscle, and justly claimed for it the function of accommodation. This claim of Mueller is now universally conceded. The existence of Bowman's muscle is not doubted, but it is not claimed by any one to take a part in the act of accommodation.

Nerve supply of ciliary muscles. The nerve supply of these two muscles must be different. It is well known that Mueller's muscle gets its power through the third cranial nerve, by way of the ciliary ganglion. The cortical brain center, the tenth conjugate, controlling the Mueller muscle in the one eye also controls the Mueller muscle in the other eye, each muscle receiving the same quantity of neuricity in every accommodative act. If one muscle needs more neuricity than the other, the excess must come from tenth basal center of the corresponding side. This muscle is not only accommodative, but it is also corrective when the eye, to which it belongs, is hyperopic, and to some extent is corrective when there is astigmatism. In hyperopic eyes this muscle is capable of perfect correction. In astigmatism the best that this muscle can do is to place the focal interval on the retina; that is, cause the one focus to be as far in front of the retina as the other focus is behind it. It can not bring the two foci any nearer together than they stand when this muscle is not in action. The corrective power of Mueller's muscle in astigmatism is so slight as to be almost negligible. Whatever this power may be, in extent, it can be suspended by a cycloplegic, as can the power residing in it for the correction of hyperopia, and the power of accommodation. There is an astigmatic corrective agent residing in the eye whose power can not be suspended by atropine or any other cycloplegic or mydriatic. That agent must be Bowman's muscle, and its nerve supply can not be the same as that giving power to Mueller's muscle. Its source of power must be the sympathetic, probably the superior cervical ganglion. Over this source of power no known medicinal agent has any control. The one discovering such an agent would confer a great boon on humanity, and all oculists would rise up and call him blessed. Up to this moment time alone is able to suspend the chief power that is corrective of astigmatism.

Under the influence of the superior cervical sympathetic ganglion, or a higher center through this ganglion, the function of Bowman's muscle is to tilt the crystalline lens on an axis lying in the plane of the corneal meridian of greatest curvature. This tilting would not change the position of the anterior focus, but it would make the posterior approach towards, or merge into, the anterior focus—if the former, the astigmatism would be only partly corrected, but if the latter, the correction would be complete. It is clear that this power would not be exercised in myopic astigmatic eyes, in distant vision, for the reason that seeing would be made less sharp; but in near vision this function would be exercised to some extent, unless the myopic astigmatism were associated with 3 D. or more of myopia. Bowman's muscle would be active in both distant and near vision in all cases of hyperopic astigmatism, whether simple or compound, and in mixed astigmatism to some extent.

Not the whole of Bowman's muscle would act in any given case, but only those fibers at the one end or the other of the corneal meridian of least curvature. The bundle of fibers at either end of this meridian, acting alone, could cause an equal tilting of the lens on the axis lying in the plane of the meridian of greatest corneal curvature; and it is possible that these two bundles may alternate in rest and activity, at longer or shorter intervals. The tilting of the lens would increase its refractive power everywhere, except in the plane of the axis of tilting, but most of all in the meridian at right angles to the axis of tilting. All other parts of Bowman's muscle would be forever inactive. In emmetropic, hyperopic and myopic eyes Bowman's muscle is functionless. Since Bowman's muscle does not act in the distant vision of myopic astigmatics, the correcting minus cylinder should—and does—correspond with the ophthalmometric reading within .50 D, regardless of the age of the patient.

Accumulating years bring disability alike to both the Mueller and the Bowman muscles, so that, in time, the former loses both its accommodative and corrective powers, while, at the same time, the latter loses its corrective power.

The total hyperopia is shown when the Mueller muscle has been put at rest by either age or atropine. The total astigmatism of the hyperopic kind is shown only by advancing years, or as the result of the teasing power of cylinders of ever increasing strength. Myopic astigmatism, whether simple or compound, is total, regardless of age, hence a full correction can be given at once. If some agent could be found that could influence the Bowman muscle, as atropine controls the Mueller muscle, the full correction of hyperopic astigmatism could be given at once. There being no such known medicine, only the hyperopic astigmatism not corrected by Bowman's muscle, or made manifest by the Mueller muscle's loss of control of the focal interval, can be corrected. Future observation may disclose the fact that in hyperopic astigmatism, the corneal astigmatism as shown by the ophthalmometer, when according to the rule, should be corrected within .50 D, and when against the rule, should be fully corrected, or even over-corrected to the extent of .50 D. Under such correction it is likely that Bowman's muscle would soon cease its corrective activity, just as Mueller's muscle soon learns to quit its corrective work, after hyperopia has been fully corrected, under a cycloplegic.

Muscles of the iris. The circular muscle of the iris, located near the pupilary margin, has for its function the contraction of the pupil. For this work it is supplied by the third cranial nerve, by way of the ciliary ganglion. The eleventh conjugate cortical brain center controls the sphincter of the iris in the two eyes, as is shown by the fact that the pupil of a totally blind eye will contract in harmony with the pupil of the good eye, when the latter is exposed to the light. The pupil of such an eye will not contract at all when light is cut off from the good eye, however bright may be the light thrown into the blind eye. The same agents that will put at rest the Mueller muscle will also suspend activity of the sphincter of the iris, so that a cycloplegic is also a mydriatic.

The radiating muscular fibers of the iris have for their function the dilatation of the pupil, when unopposed by action of the sphincter muscle. These fibers are, doubtless, supplied by the sympathetic nerve, through the superior cervical sympathetic ganglion. The Bowman muscle and the radiating muscle of the iris doubtless have a common nerve supply. If an agent is ever discovered that will put at rest the Bowman muscle, so that total astigmatism may be shown, that same agent will doubtless also put at rest the pupil dilator. The combination of such an agent with a mydriatic would effect a fixed semi-dilatation of the pupil. The same combination would put at rest both the Mueller and Bowman muscles of the ciliary body. Such a condition would be most favorable for easy and perfect correction of errors of refraction.

Although the Mueller muscle and the sphincter of the iris are supplied by the same nerve, they differ widely in the duration of their activity. The former begins to lose its power before the meridian of life has been reached and becomes actionless at fifty-five to sixty years of age; while the latter retains its power throughout life. The explanation of this is probably in the fact that each of these muscles has its own inervation center. Likewise the Bowman muscle and the pupil dilator muscle differ in the duration of their activity, although both are supplied by the sympathetic. Age puts at rest the former, while the latter always retains its power to act. Each of these muscles, doubtless, has a center of its own.

Weak sphincters. The sphincter muscle of the iris is sometimes weak, as shown by the fact that the pupil, under ordinary light, is disposed to be dilated. Bright light will cause such pupils to contract, but the contraction cannot be kept up long without discomfort more or less marked. Relief for this condition may be had by the wearing of amber tint glasses, when in bright light. Better still, the sphincter may be made strong by an exercise that can be easily resorted to. The patient should sit in front of a bright artificial light and with a dark screen in his hand he should hold it between his eyes and the light for three seconds, and then should remove it for three seconds, continuing this for one to ten minutes. The pupil dilates behind the screen and contracts when it is removed. Thus contraction and relaxation alternate. This continued not longer than ten minutes and repeated two or three times a day will make weak muscles strong.

Weak Mueller muscle. The Mueller muscle is not infrequently weak in young people. This is shown in two ways: First, there is esophoria in the near when there is none in the distance, or there is greater esophoria in the near than in the distance, or there is less exophoria in the near than in the distance; second, the muscle cannot overcome a — 3.00 sphere held in front of the correction of any existing focal error—often cannot overcome a — 1.00 sphere. Such eyes cause symptoms, more or less severe, which can be relieved by proper treatment. This consists of exercise by means of weak minus spheres—a — .50 or even a — .75. The patient should be seated eight or ten feet from some object which he can see distinctly with, or without, the minus spheres. He should raise and lower these minus spheres every three seconds. Looking through them the muscles contract, looking without them the muscles relax. Thus is effected alternate contraction and relaxation which, if discontinued short of fatigue, must develop power in the muscles exercised. Beginning with two minutes, the period of exercise should be gradually lengthened to ten minutes. The exercise should be resorted to once or twice daily and should be continued until the muscles can easily overcome a pair of — 3.00 spheres, by which time all symptoms will have disappeared.

EXTRINSIC OCULAR MUSCLES.

These muscles, as the name implies, are on the outside of the eyeball. They are six in number for each eye, and are divided into two classes, the recti and the obliques.

The recti muscles. The four recti have their origin at the apex of the orbit, from the margin of the optic foramen, thus completely encircling the optic nerve as it enters the orbital cavity. Diverging they pass through the orbital fat so as to encompass the eyeball, to which they attach themselves between the equator and the corneo-scleral margin, usually about one-quarter of an inch from the latter. These muscles take their name from the relationship they bear to the globe: the superior rectus, above; the inferior rectus, below; the external rectus, temple-ward; the internal rectus, nasal-ward. The newer names for the last two are mentioned only to be condemned: rectus lateralis and rectus medialis.

From origin to insertion these muscles are ensheathed by the capsule of Tenon, thus making their contractions most easy. In their course they are pierced by blood vessels to give them nourishment, and by nerve fibers through which they may receive power.

The oblique muscles. The superior oblique arises, also, at the apex of the orbit just above the origin of the superior rectus. Coming forward in a covering of Tenon's capsule, in the anterior part of the orbit, at the upper-inner angle, its rounded tendon passes through a fibrous ring, in which it has freedom of movement; thence, changing its course, the expanding tendon passes between the superior rectus and the eyeball to finally insert itself into the sclera behind the equator and between the vertical and horizontal meridians of the globe. The inferior oblique arises from the floor of the orbit immediately beneath the fibrous ring through which passes the rounded tendon of the superior oblique. Thence it pursues the same direction as the expanded tendon of the superior oblique, passing beneath both the inferior rectus and the globe to become inserted into the sclera behind the equator, near the horizontal meridian of the eye. The space between the two insertions of the two obliques is never very great.

Each is supplied by blood vessels for nourishing it, and nerve fibers for imparting power to it.

The law governing ocular motions disregards the rotation plane of any single muscle. Before studying this law, and the nerve centers for executing the same, it will not be unprofitable to study the action of each muscle, independent of all the other muscles.

The muscle plane and axis. The axis of rotation of the eye by any one muscle must be at right angles to the plane of rotation for this muscle. This plane must bisect the muscle at its origin, in its course, and at its attachment, and must also pass through the center of rotation of the eye. As to the internus or externus, the relationship that the muscle plane bears to the horizontal plane of the eye indicates the exact rotation that will result from its action. If the rotation plane of the internus coincides with the horizontal plane of the eye, then this muscle will have only one result from its contraction; that is, the eye will be turned directly in (adversion), the rotation taking place around the vertical axis of the eye. This action of the internus may be termed its principal action; and under such condition there can be no subordinate action of the muscle. Some may prefer the terms used by Maddox, viz., pre-eminent and subsidiary action.

If the plane of rotation of the internus does not coincide with the horizontal plane of the eye, the simple rotation is impossible. Let this muscle plane be inclined down and out, as it must be when the internus is attached too high, then the axis of rotation cannot be the vertical axis of the eye, for the former must bear the same relation to the latter that the muscle plane bears to the horizontal plane of the eye. The unopposed action of this muscle cannot rotate the eye directly in, but associated with the adversion there will be superversion and inward torsion or declination, both of which are subordinate actions. Let the internus be attached too low on the globe, then its plane of rotation will have an inclination down and in, forming a definite angle with the horizontal plane of the eye. The axis of rotation will form the same angle with the vertical axis of the eye. Unopposed, the internus thus attached cannot rotate the eye directly inward, but, associated with the adversion (principal), there will be subversion and an outward torsion or declination. It is reasonable to suppose that the plane of rotation of the internus does not always coincide with the horizontal plane of the eye. Thus it is shown that, by error of attachment (too high or too low), an internus may be one factor in a hyperphoria or a cataphoria, and in a minus or a plus cyclophoria.

In like manner rotation by the external rectus muscle may be studied. If the plane bisecting the origin and insertion of this muscle, and passing through the center of rotation, coincides with the horizontal plane of the eye, its action will result in abversion (principal, without any kind of subordinate, action). If the muscle be attached too high, its plane of rotation must be inclined down and in, its axis of rotation making the same angle with the vertical axis that its plane makes with the horizontal plane. The action of the externus thus attached will have a triple result: (a) abversion (principal); (b) superversion (subordinate); and (c) an outward torsion or declination (subordinate).

If the externus be attached too low, its plane of rotation will be tilted down and out, forming a definite angle with the horizontal plane, and its axis of rotation will form an equal angle with the vertical axis. In contracting, the eye will be abverted (principal action); it will also be sub-verted, and there will be an inward torsion (subordinate actions). Thus it is shown that an externus attached too high or too low will be one factor in the production of a hyperphoria or a cataphoria, and just as certainly a factor in the production of a plus or a minus cyclophoria.

It will be observed, from the foregoing, that either an internus or an externus attached in greater part above the horizontal plane, will have the super-verting effect of a superior rectus; and that either muscle attached in greater part below the horizontal plane of the eye, will have the sub-verting effect of the inferior rectus. The torsioning effect of an internus attached too high will be in, while that of an externus with a too high attachment will be out. An internus attached too low will produce a plus cyclophoria, while an externus attached too low will cause a minus cyclophoria. Thus it will be seen that an internus will have the same kind of verting and torsioning effects as the superior or inferior rectus towards which its attachment is displaced. The external rectus will have the super-verting or sub-verting effect of the superior or inferior rectus towards which its attachment is displaced, but the opposite torsioning effect. The practical nature of these observations will be shown in the study of operations on the lateral recti muscles.

The correctness of what has been said about the action of the internus or externus, when the plane of rotation does not coincide with the horizontal plane of the eye, can be easily demonstrated by the use of the rubber ball and the knitting needles, and in the same way can be studied the individual action of the superior and inferior recti and that of the obliques. The rotation plane of an individual muscle bisects the muscle and cuts the center of rotation. Only in properly attached lateral recti muscles does this plane correspond with a meridional plane. The axes of rotations by the other four muscles cannot lie in the equatorial plane, because their rotation planes are not meridional planes.

The origin, course, and insertion of the superior rectus, also of the inferior rectus, make it impossible for the plane of rotation for either one of these muscles to coincide with the vertical antero-posterior plane of the eye, when in the primary position. The plane of rotation for either one of these muscles is made to pass through the center of the origin of the muscle, the center of rotation of the eye, and the center of the insertion of the muscle. It is only when either muscle has a very definite attachment that its plane of rotation can be vertical. A displacement in or out of the attachment of either the superior or the inferior rectus will not change the kind of rotation to be effected, but it would modify the extent of the three effects of its contraction. For simplicity of study it may be considered, therefore, that there is a common plane of rotation for both the superior and the inferior recti, and that the plane is vertical, forming an angle of 27° with the vertical antero-posterior plane of the eye, the plane of the vertical meridian. The axis of rotation must be at right-angles to the muscle plane, and consequently must form an angle of 27° with the transverse axis, but in the horizontal plane with it. The superior rectus, unopposed, has for its principal effect superversion, and for its subordinate results, adversion and an inward torsion or declination. The inferior rectus will have, for its principal action, sub-version, and for its secondary actions, adversion and outward torsion. Thus the superior rectus, while being the chief factor in a hyperphoria, may be also a secondary factor in the production of an esophoria, and of a minus cyclophoria. The inferior rectus, while the chief factor of a cataphoria, may also be a secondary factor both in esophoria and in a plus cyclophoria.

An oblique muscle, when unopposed, is incapable of a simple rotation. Its plane of rotation must be constructed in the same way as have been constructed the planes for the recti. In the case of the superior obliques, the point of origin through which the plane must pass is the pulley at the upper-inner angle of the orbit, and not at its real origin at the apex of the orbit. Since the inferior oblique arises beneath this pulley, and since the superior oblique may be supposed to pass directly above, while the inferior passes directly beneath, the center of motion of the eye, to be inserted directly opposite each other in the outer-posterior quadrant, they may be said to have a common plane of rotation, which means, also, that they have a common axis, around which each must revolve the eye when unopposed by any other muscle. This plane is at an angle of 39° with the vertical transverse plane of the eye. The axis must be, therefore, at an angle of 39° with the visual axis. When the superior oblique contracts, its principal action is to tort the eye in; but always accompanying this are the subordinate actions, sub-version and abversion. When the inferior oblique is unopposed and unaided, its principal action is outward torsion, and its secondary effects are superversion and abversion. Thus it may be seen that the obliques may be a factor in three forms of heterophoria: (a) cyclophoria, (b) hyperphoria and cataphoria, (c) exophoria.

The rotation plane of the eye. In passing from the study of the action of individual muscles, it may now be stated that every rotation plane of an eye is a meridional plane. Therefore, in every rotation from one point of view to another, these two points must lie in the plane of one and the same meridian. This is true whether the start be made from the primary, or direct, point of view to some secondary point, or from a secondary point back to the primary; or from one secondary point back to another secondary point. The point of fixation is the point looked at whether it be direct or indirect (secondary). Its image falls on the macula, and the line connecting the point and its image is the visual axis. In this line the planes of all retinal meridians cross, and therefore it is the line which is common to the planes of all the retinal meridians. The point of beginning of this line (the visual axis) is the posterior pole of the eye, which is the central point of the macula—the fovea centralis. Since every meridian must cut the center of retinal curvature, the visual axis, common to all the meridians, on its way forward must cut the center of the retinal curve, which is the center of rotation of the eyeball. The point of the cornea pierced by the visual axis, on its course out into space, is the anterior pole of the eye, whether it be the center of the cornea or not. (The true anterior pole is just inside the cornea, a point as far removed, anteriorly, from the center of the retinal curve, as the posterior pole is distant from it posteriorly.) Since the visual axis fixes the poles of the eye and is common to all retinal meridians, all corneo-retinal meridians must pass through these poles.

The retinal and spacial meridians. The planes of the retinal meridians projected into space constitute the planes of the spacial meridians. The point of fixation in space is the spacial pole, and through this spacial pole pass all spacial meridians, the center of whose curves is the center of retinal curvature. The retinal and spacial meridians, having a common center of curvature, correspond, point for point, everywhere. The spacial pole corresponds with the retinal pole, and the two are connected by a visual line which, because of its importance, is distinguished by the name *visual axis.* All other corresponding spacial and retinal points are also connected by visual lines, distinguished from the visual axis, the direct line of vision, by being named *indirect visual lines.* All lines connecting corresponding spacial and retinal points must cross each other at the center of the retinal concave, which is the center of rotation of the eye.

Since all objects and their respective images are connected by visual lines which cross at the center of retinal curvature, whenever the visual axis is to be moved from one point to another, the two points always on the same spacial meridian, the rotation must be around the central point of the retinal curve, for it is only by such rotation that the visual axis can be made to take the position of an indirect line of vision. The center of rotation, therefore, is the center of retinal curvature.

The monocular field of vision. To facilitate the study of monocular rotations, Figs. 1 and 2 are here introduced. The white space in Fig. 1 represents the field of vision of the left eye; and in Fig. 2 the white space represents the field of vision of the right eye. The point of crossing of the meridians, in either figure, is the spacial pole for that eye. At the spacial pole is that object which throws its image on the macula, and therefore it is on the visual axis—the line of most acute vision. If any other object, within the rotation space of that field, is to be fixed without a movement of the head, this must be accomplished by the moving of the spacial pole to that point, from the point which had been at this pole. The second point cannot be anywhere in this field without being on some one spacial meridian. The spacial pole, the crossing point of all spacial meridians, must be moved along that meridian on which lies the object to which the gaze is to be directed. Since the spacial pole is on the visual axis, the former cannot be moved except when the latter is in motion. The latter can be set in motion only as the eyeball is made to revolve around its center of rotation. This movement of the eye must be effected in obedience to the law governing monocular rotations.

Law of monocular motion. The law governing monocular rotations may be formulated as follows: (1) *The visual axis, which is the line of intersection of the planes of all meridians, must be rotated in the plane of that meridian on which lie the first and second points of view and their retinal images.* (2) *In the plane of the horizontal, or that of the vertical, meridian, the rotation must be effected around a single fixed axis, at right-angles to the rotation plane and cutting it at the center of rotation—if in the horizontal plane, around the vertical axis of the eye; if in the vertical plane, around the transverse axis of the eye.* (3) *In the plane of an oblique rotation, whatever the degree of the obliquity, the rotation must be accomplished around two moving*

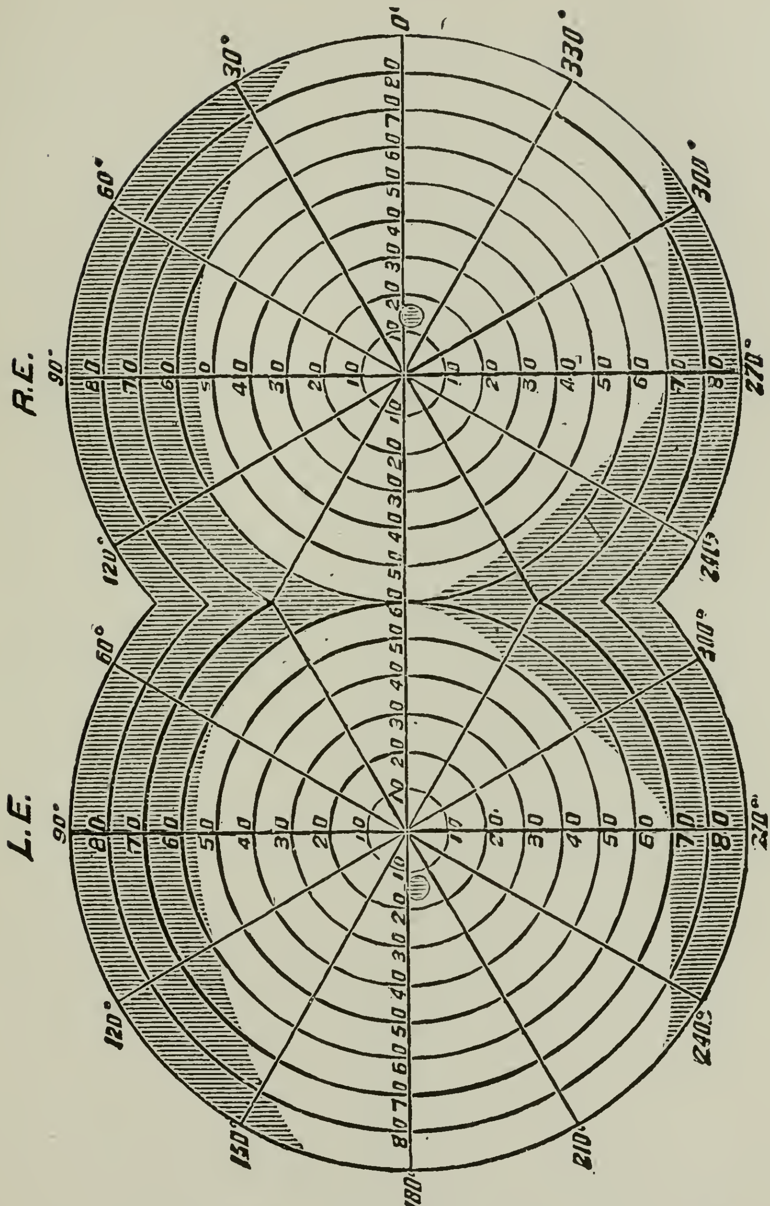


Fig. 2.

Fig. 1.

axes by two forces acting simultaneously, these axes being the transverse and vertical, both at right-angles to the visual axis, but neither one at right-angles to any oblique rotation plane; while a third force prevents any rotation around the visual axis.

The only part of the above law open to controversy pertains to oblique rotation. These rotations are accomplished by three forces in simultaneous action; and they are so applied as to make it impossible for such a rotation to be around a resultant fixed axis, as would be the case if only two forces were acting. If a resultant axis for the three forces be possible, the axis would be a moving one, for, in any oblique rotation of the eye there are no two fixed points directly opposite or otherwise related, on its surface, hence there could be no fixed diameter. If there be a resultant moving axis for an oblique rotation, it would be hard to locate. It is so easy to grasp the thought that, in an oblique rotation, one oblique muscle prevents rotation around the visual axis, while one rectus muscle is moving the eye around the vertical axis, and one other rectus muscle is moving the eye around the transverse axis, it seems to the author that the wording of the third (3) section of the law of monocular rotation must be correct.

The purpose of the above law is that, while the visual axis is being rotated in a fixed plane, the vertical axis of the eye shall never lose parallelism with the median plane of the head, for on this parallelism depends correct orientation.

A single muscle can obey this law only when the rotation is in the horizontal plane, and then only when the externus or the internus is bisected by this plane. In vertical and oblique rotations, an oblique muscle prevents rotation around the visual axis, hence performs the task of keeping the vertical axis of the eye parallel with the median plane of the head, while one rectus (as in vertical rotations), or at most two recti (as in oblique rotations), moves the visual axis from point to point in space.

In the light of this law the six extrinsic ocular muscles should be studied as they are related to each other in performing their tasks.

Synergism and antagonism. The helping of one muscle by other muscles is synergism; the opposing of one muscle by other muscles is antagonism. The old method of studying these is set forth in the following

TABLE.

Internus	Synergists	Superior rectus Inferior rectus	Tonicity.
	Antagonists	External rectus Superior oblique Inferior oblique	Tonicity.
Externus	Synergists	Superior oblique Inferior oblique	Tonicity.
	Antagonists	Internus Superior rectus Inferior rectus	Tonicity.

Superior rectus in superversion	Synergists	Inferior oblique A too high internus, or A too high externus	Contractility. Tonicity.
	Antagonists	Inferior rectus Superior oblique A too low internus, or A too low externus	Tonicity.
Inferior rectus in sub-version	Synergists	Superior oblique A too low internus, or A too low externus	Contractility. Tonicity.
	Antagonists	Superior rectus Inferior oblique A too high internus, or A too high externus	Tonicity.
Superior oblique	Synergists	Superior rectus A too high internus, or A too low externus	Tonicity.
	Antagonists	Inferior oblique Inferior rectus A too low internus, or A too high externus	Tonicity.
Inferior oblique	Synergists	Inferior rectus A too low internus, or A too high externus	Tonicity.
	Antagonists	Superior oblique Superior rectus A too high internus, or A too low externus	Tonicity.

It will be noticed that in the above table each ocular muscle has one more antagonistic muscle than synergistic.

Another point to be noted in the study of the table is that synergism more often comes from tonicity than from contractility, and that the antagonism shown comes entirely from tonicity. In this table the synergistic muscle, either by tonicity or contractility, aids a contracting muscle in the performance of its principle function only; and the antagonistic muscle, by its tonicity, hinders the contracting muscle in the performance of its principal function only.

A single muscle may be both synergistic and antagonistic. To illustrate: Rotation directly up is accomplished by two muscles, the superior rectus and the inferior oblique. The principal action of the superior rectus would be to elevate the eye, but the secondary results would be to tort the eye in and to turn it in. The inferior oblique, in its principal function, prevents the intorting, and the subsidiary result is to prevent the inturning and to help the upturning. The inferior oblique is, therefore, both synergistic and antagonistic to the superior rectus.

In the truest sense a synergistic muscle, by contractility, should be one helping another muscle in the performance of its task of rotating the visual axis correctly; while an antagonistic muscle, by contractility, should be one to prevent an error in the relationship of the vertical axis of the eye with the median plane of the head.

It would seem, therefore, that a new table of synergism and antagonism should be constructed, in which no mention of muscles not contracting should be made. Since this is a study of monocular rotation, the following table may be considered a study of the right eye:

TABLE.

(1) Rotation directly to the right:	Externus	Synergist: None.	Antagonist: None.
(2) Rotation directly to the left:	Internus	Synergist: None.	Antagonist: None.
(3) Rotation directly up:	Superior rectus	Synergist: Inferior oblique.	Antagonist: Inferior oblique.
(4) Rotation directly down:	Inferior rectus	Synergist: Superior oblique.	Antagonist: Superior oblique.
(5) Rotation obliquely up-and-right	Externus and	Synergist: Superior oblique.	Antagonist: Superior oblique.
	Superior rectus	Synergist: None.	Antagonist: Superior oblique.
(6) Rotation obliquely down-and-left	Internus and	Synergist: None.	Antagonist: Superior oblique.
	Inferior rectus	Synergist: Superior oblique.	Antagonist: Superior oblique.
(7) Rotation obliquely up-and-left	Internus	Synergist: None.	Antagonist: Inferior oblique.
	Superior rectus	Synergist: Inferior oblique.	Antagonist: Inferior oblique.
(8) Rotation obliquely down-and-right	Externus	Synergist: Inferior oblique.	Antagonist: Inferior oblique.
	Inferior rectus	Synergist: None.	Antagonist: Inferior oblique.

Points fixing the rotation planes. There are three points on the same line through which every rotation plane must pass: the fovea centralis of the macula, the center of the retinal curve, and the point of direct view. The straight line connecting these three points is the visual axis. This line is common to all rotation planes, for it is the line of crossing of all meridional planes. For any given rotation there must lie in its plane two other points: the second point of view in space and its retinal image, the former having the same relationship to the special pole as the latter has to the retinal pole, the two being on opposite sides of the visual axis. The line connecting these two points lies in the rotation plane and crosses the visual axis at the center of rotation. The second spacial point is removed from the spacial pole through the same arc as the retinal point is removed from the retinal pole, each arc having its angle at the center of rotation, the angles being opposite; therefore in the rotation the visual axis is made to take the place of the indirect line of vision—the spacial pole has been made to move from the first to the second point of view, and the retinal pole has been made to move from the first to the second image.

The two axes of rotations. The moving of the spacial and retinal poles in either of the four cardinal directions; that is, directly to the right and left, and directly up and down, the rotation plane is such as to require a single fixed axis of rotation. In the horizontal cardinal directions the first and second points of view, and the images of these points, lie in the plane of the horizontal retinal meridian, and the fixed axis of the rotation from the one point to the other is the vertical axis of the eye, shown as a–b in Fig. 3. In the vertical cardinal directions, the first and second points of view and their retinal images lie in the plane of the vertical meridian, spacial and retinal, and the fixed axis of the rotation from the one point to the other is around the transverse axis of the eye, shown as d–e in Fig. 3.

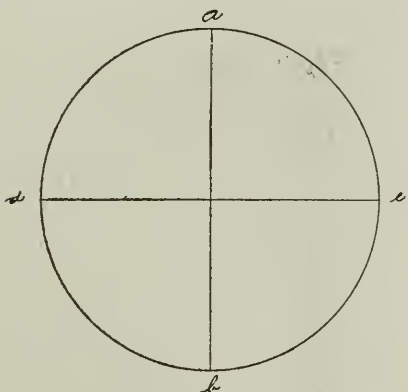


Fig. 3.

In oblique rotations the oblique muscles make impossible the existence of a fixed axis of rotation at right-angles to the rotation plane. There are only two axes of rotation, around one or both of which every possible ocular motion takes place. These axes are fixed and at right-angles to the rotation plane only when the rotations are in the four cardinal directions, and then the given motion is around only one axis. There is no torsion in such a cardinal rotation. In Fig. 3 these two axes are shown. The circle a–d–b–e represents the equator of the eye, the line a–b is the vertical axis, and the line d–e is the transverse or horizontal axis of the eye. These are at right-angles to each other, the one in the plane of the vertical meridian and the other in the plane of the horizontal meridian, and both lie in the plane of the equator. They are both at right-angles to the visual axis. Around a–b the visual axis rotates directly to the right or left and without torsion. Around d–e the visual axis moves directly up or down and without torsion. These cardinal rotations can be shown easily by means of a rubber ball to represent the eye, and two knitting needles, one to represent the visual axis and the other to represent one or the other of these two axes of rotation. The rubber ball and the knitting needles are worthless in the study of oblique rotations, for the reason that there can be no fixed axis for any one of these rotations. Any and every oblique rotation is around both the vertical and the horizontal axes, a–b and d–e, which are always at right-angles to the visual axis, but not at right-angles to any oblique rotation plane. These axes are not fixed, but are themselves in motion as the eye rotates around them in any oblique plane. As in cardinal rotations, so in oblique rotations, the rotation plane is a fixed plane. The duty of each of the three muscles concerned in an oblique rotation is well defined, and each does its duty well in the interest of correct orientation. The oblique muscle

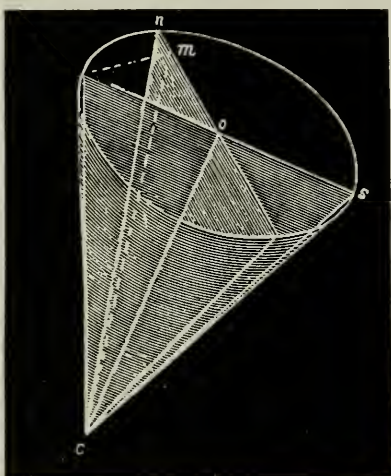


Fig. 4.

prevents the loss of parallelism of the vertical axis of the eye with the median plane of the head. The superior rectus elevates the eye by rotating it on the transverse axis, d–e; while the external rectus, acting simultaneously and harmoniously with the other two muscles, rotates the eye to the right around the vertical axis, a–b. As these two rotations begin, the axis of each is made to move by the power that is making the eye rotate around the other, hence they cannot be fixed axes. At the end of such an oblique rotation (up and to the right), there is no more torsion than if the eye had been first rotated outward on the fixed axis a–b, and then directly upward on the fixed axis d–e. In every possible monocular rotation the vertical axis of the eye must be kept parallel with the median plane of the head, and this is the task that is set for the oblique muscles.

Would-be torsion. The study of torsion in oblique rotations on a fixed axis, at right-angles to the rotation plane, is given here as a matter of mathematical interest, but not as a physiological truth.

The accompanying cut, Fig. 4, was designed by Maddox for solving "false torsion." It is taken from his very interesting book on "*The Ocular Muscles*," published in 1898. The following is the solution in his own words:

"Taking VC as unity—

Since $OV = \sin I$

and $\frac{OM}{OV} = \cos R,$

$\therefore OM = \sin I \cos R.$

Moreover $OC = \cos I;$

$\therefore \frac{OM}{OC} = \frac{\sin I \cos R}{\cos I} = \tan I \cos R.$

But $\frac{OM}{OC} = \tan (I - X);$

$\therefore \tan (I - X) = \tan I \cos R.$

Or $X = I - \tan^{-1} (\tan I \cos R)$

"Putting this into language: The false torsion is equal to the angle from the vertical, or from the horizontal, of the axis about which the eye rotates, less the angle whose tangent is the multiple of the tangent of the inclination of the axis of motion with the cosine of the angle traversed by the line of fixation.

"The short table overleaf will give an idea of the amount of false torsion which takes place on looking in any diagonal direction midway between any two of the cardinal directions.

"Since the greatest false torsion of which the eye is capable occurs at the extremity of these diagonals, we may see at once that it does not ever much exceed 10°."

Rotation about an axis 45° from the horizontal.

Degrees	5°	10°	15°	20°	25°	30°	35°	40°	45°
Torsion	6½′	26′	1°	1°47′	2°49′	4°6′	5°40′	7°33′	9°44′

The above table was taken from Maddox.

At the author's request, Prof. John Daniel, of Vanderbilt University, designed Fig. 5 with the view of determining the amount of torsion that would occur as the result of oblique rotation of the eyes, if it were not prevented by the oblique muscles. The following is the solution by Professor Daniel:

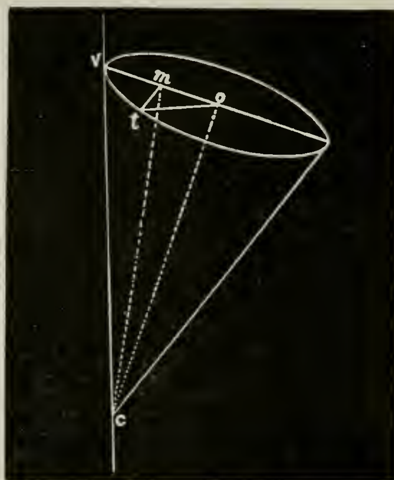


Fig. 5.

"Make $vo =$ unity.

$I =$ angle between the vertical and the axis of rotation, $= ocv$.

$R =$ angle through which the eye is turned on said axis, $= vot$.

Then $X =$ angle of torsion, vcm.

$$= \sin^{-1}\left(\frac{\cos I \text{ vers } R}{\sqrt{\cos^2 R + \cot^2 I}}\right)$$ (for, in the triangle vcm, we have $\sin X \div vm = \sin ovc \div mc$).

$$\sin X = \sin ovc \frac{vm}{mc} = \sin (90° - I) \frac{vm}{mc}$$

$$\frac{\cos I \text{ vers } R}{\sqrt{\overline{mc}^2 + \overline{oc}^2}} = \frac{\cos I \text{ vers } R}{\sqrt{\cos^2 R + \cot^2 I}}$$

$$X = \sin^{-1}\left(\frac{\cos I \text{ vers } R}{\sqrt{\cos^2 R + \cot^2 I}}\right)$$

"That is, starting from a primary position, when the eye is rotated R degrees on axis inclined I degrees to the vertical (or horizontal) the resulting torsion, X, is an angle whose sine is equal to cos I times the vers R, divided by the square root of the sum of the squares of cos R and cos I. The numerical value of the torsion, X, when the inclination of the axis is 45°, is as follows for angles of rotation, R, as follows:

Angle of rotation = R =	5°	10°	15°	20°	25°	30°	35°	40°	45°
Torsion	6½′	26′	1′	1°47′	2°49′	4°6′	5°40′	7°33′	9°44′

"This was worked out independently of the simpler formula given in Maddox, but the two are equivalent."

The mistake made by Maddox was in supposing that no effort was made by the obliques, to correct the torsioning that otherwise would occur.

The work of mastering the study of ocular rotations is greatly simplified by a knowledge of the fact that a cardinal rotation is around one of two axes, and that oblique rotations are around both these axes simultaneously, and that no other axes are possible. Rotation planes are innumerable, but the axes of rotation are only two, the vertical and the transverse axes of the eyes.

Helmholtz' method of finding all axes of rotations. The two axes, shown in Fig. 3, around one or both of which all ocular rotations take place, can be easily found to be the vertical and horizontal axes of the eye. Helmholtz' method of finding the fixed axis of any given rotation is fairly set forth in Fig. 6. In this cut, a–b is the first position of the visual axis and a′–b′ is the second position of the visual axis. The plane a–a′–b–b′ is constructed through five fixed points—the first point of view b and its image a, the second point of view b′ and its image a′, and the center of rotation c. With b as the primary or direct point of view, a–b is the visual axis, a being the center of the macula. With b′ as a secondary or indirect point of view, a′–b′ is a secondary or indirect line of vision, a′ being the retinal image of b′. The lines a–b– and a′–b′, each connecting two points lying in the plane, and crossing each the other at the common point c in the plane, must, therefore, lie wholly in the plane. The retinal images a and a′ are the same distance apart in degrees as are the spacial points b–b′, for the arc a–a′, and the arc b–b′ subtend angles that are equal, for they are opposite, as shown at c. That b′ may become the direct point of view, the macula must move from a to a′ and the visual axis must rotate from b to b′, to take the place or position of what was an indirect line of vision before the rotation began. This turning has been about the point c. The former direct point of view b has become an indirect point of view, and its image a is on the retina to the left of the new position of the macula. The line a–b is a new indirect line of vision. Truly the first position of the visual axis was a–b, but this position is now occupied by an indirect line of vision which followed the visual axis from right to left through an arc equal to the arc b–b′. Just as truly the second position of the visual axis is a′–b′, for b′ is now the direct point of view; but it now occupies the position of what was an indirect line of vision before the rotation began, which line has been rotated to the left through an arc equal to that connecting b′ and b. The new and the old indirect visual lines have been rotated around the point c in perfect harmony with the rotation of the visual axis. If the plane a–a′–b–b′ were extended right and left, it would include the line that was the indirect visual line a′–b′ before the rotation began, and that other line which has become the indirect visual line a–b, as a result of the change of point of direct view from b to b′. The rotation of all lines has been around the common point c, and in the plane a–a′–b–b′. This point is the rotation center and this plane is the rotation plane.

Helmholtz found the axis of this rotation by constructing two other planes, each at right-angles to the plane of rotation, one of them including the visual axis in its first position, the other including the visual axis in its second position. The first of these two planes, as shown in Fig. 6, is a–b–f–e, and the second is a′–b′–h–g. The line of intersection of these two planes is c–b, and this line is the axis of rotation. Since the planes a–b–f–e and a′–b′–h–g are at right angles to the plane a–a′–b–b′, their line of intersection c–d must be at right angles to the rotation plane, and, as shown in the figure, if extended upward, would cut the center of rotation.

In Fig. 6 the horizontal retinal meridian of the eye is represented as lying in the rotation plane a–a′–b–b′ with its center of curvature at c. In the first position of the visual axis the solid-line curve, representing the cornea, shows the eye looking at b; in the second position of the visual axis the broken line representing the cornea shows the eye looking at b′. In either case the visual axis goes from the central point of the macula, through the center of rotation, c, on to the point of direct view.

Fig. 6 represents the rotation of Helmholtz' ideal eye, one in which the visual axis and the optic axis coincide. If Helmholtz had constructed Fig. 6 and had given it a close and clear study, he would have seen that, at least in the ideal eye, all indirect lines of vision must cross the visual axis at the center of retinal curvature, which is the center of rotation, and not at the nodal point; that they are radii of retinal curvature prolonged, and not the axial rays of cones of light. He would have seen that, in the non-ideal eye—the eye whose visual axis cuts the optic axis at N, with the macula at o—the line a–b could not be the visual axis in the first position, nor could the line a′–b′ be the visual axis in the second position. The visual

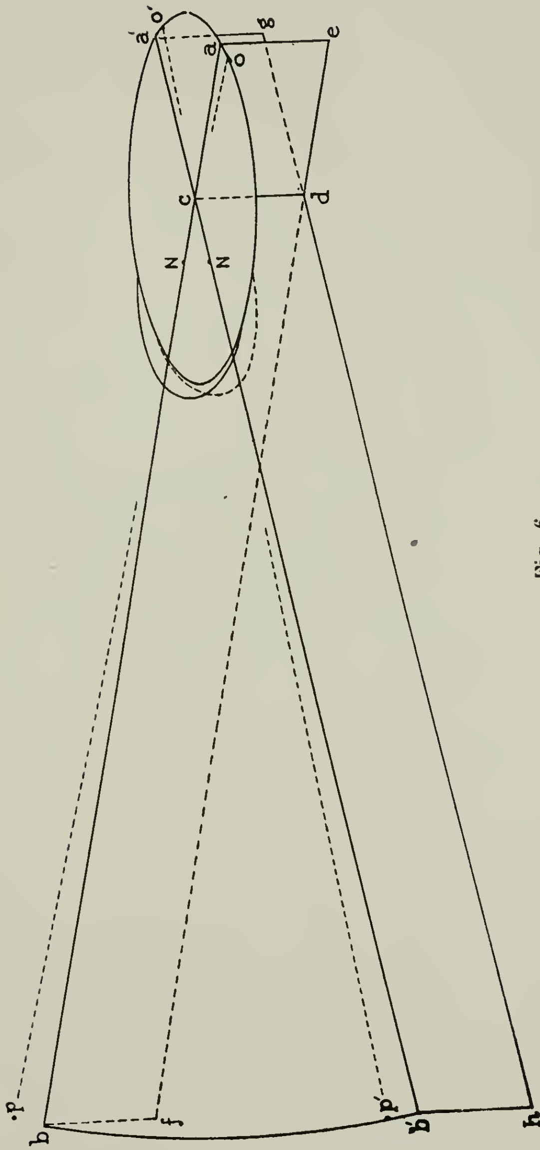


Fig 6.

axis in the first position would be a line drawn from o through N to p, a point in space 5° to the right of b, as shown by the unfinished dotted line o–p; and the visual axis in the second position would be a line drawn from o′ through N′ to p′, a point 5° to the right of b′, as shown by the incomplete dotted line o′–p′. He would also have seen that, according to his own teaching, the lines a–b and a′–b′ must be indirect lines of vision, as well as optic axes, for each crosses its respective visual axis at the nodal point. He would have seen that in this non-ideal eye there could be no point on the visual axis that would be stationary in any rotation except the one directly up or down, for only in such a rotation would the misplaced visual axis cross the axis of rotation; and even in the vertical rotation that part of the visual axis within the eye would not be bisected by the axis of rotation. Such a visual axis could not be called a "rotating line," for there is no fixed point on the line around which it can turn. All lines bisected by the axis of rotation have on them a point around which they can rotate, and that point lies on the axis of rotation. Only those lines that are bisected by the axis of rotation at its center—mutual bisection—can be lines of direction, or visual lines—lines connecting objects in space with their retinal images.

Reverting again to the study of Fig. 6, Helmholtz could have seen that the plane of the horizontal retinal meridian, being in the rotation plane, itself became the plane of rotation, for the rotation plane in this figure is nothing more or less than the plane of the horizontal retinal meridian extended. He would also have seen that the axis of the given rotation, at right-angles to the meridional plane and cutting it at the center of rotation, must line in the equatorial plane.

Reversing Fig. 6 so that a′ shall be directly above a on the retina, and that b′ shall be directly below b, in space, then the part of the figure representing the ideal eye will be the vertical meridian, and its plane extended would be the rotation plane from b to b′. Then the direct and indirect lines of vision, lying in the plane of the vertical meridian, would cross each other at the center of rotation, as they are shown to do when lying in the plane of the horizontal retinal meridian; and the axis of rotation, at right-angles to the rotation plane and cutting it at the center of rotation, would be horizontal and in the equatorial plane.

Author's method of finding axes of cardinal rotations. The author's method of finding the axis of a cardinal rotation of the eye differs in every respect from the method of Helmholtz. The author's method found the fixed points on the surface which determined the axis of rotation; Helmholtz' method found the axis of rotation which located the two fixed points. By each method it was found that the two fixed points on the globe are in a plane with the rotating point and with the center of rotation; that the two fixed points are each 90° from the rotating point and 180° from each other, the three points lying on the same great circle; and that the line connecting the two fixed points is a diameter at right-angles to the rotating line, which is also a diameter. In each case the rotating point is the center of the macula. The rotating line is the visual axis, and that diameter lying in the rotating plane with the visual axis and at right-angles to it is the axis of rotation. By each method the visual axis is found lying in the plane of two great circles at right-angles to each other, and is the line of intersection of these two planes, the rotating plane and the rotation plane, each being a meridional plane; and the axis of rotation is found to lie in the plane of a great circle at right-angles to these two planes, which plane is undeniably the equatorial plane.

A sphere, in rotation around its center as a fixed point, has on its surface two points, and only two points, that do not move. These two points must be 180° apart, and the straight line that connects them must be a diameter of the sphere. This diameter is the axis of a given rotation. Every point on the surface of the sphere, other than the two fixed points, moves in a plane at right-angles to the axis of rotation, describing the circumference of a circle larger or smaller, on the surface of the sphere. The size of any one of these circles is determined by the distance of the given rotating point from the nearer of the two fixed points up to 90°. A point 90° from the two fixed points describes the circumference of a great circle, while all other rotating points describe circumferences of smaller circles. The planes of all the circles thus created are rotation planes, and each one is parallel with all the others. The planes of all these circles, except the plane of the one great circle, may be ignored, for the plane of any given rotation is the plane of the one great circle. This plane alone cuts the axis of rotation at its center—the center of the sphere—while the planes of all the small circles cut the axis at varying points from the center.

Only one of the infinite number of points lying on the great circle should be studied in any given rotation, but it should not be forgotten that all points on this great circle bear an unalterable relationship to the one chosen point. The line extending from the chosen point back through the center of rotation—the center of the sphere—to another point on its surface just 180° distant, is the rotation line, and all other moving lines, whether diameters or not, may be ignored, for all these lines must bear a fixed relationship to this one chosen line. Both the rotating line and the axis of rotation are diameters of the revolving sphere. They lie in the plane of the same great circle, and each is at right angles to the other. This is always true, regardless of the point of application and the direction of the force effecting the rotation. A change in the direction of the force only means a new axis of rotation, a new rotating point and rotating line, and a new rotation plane.

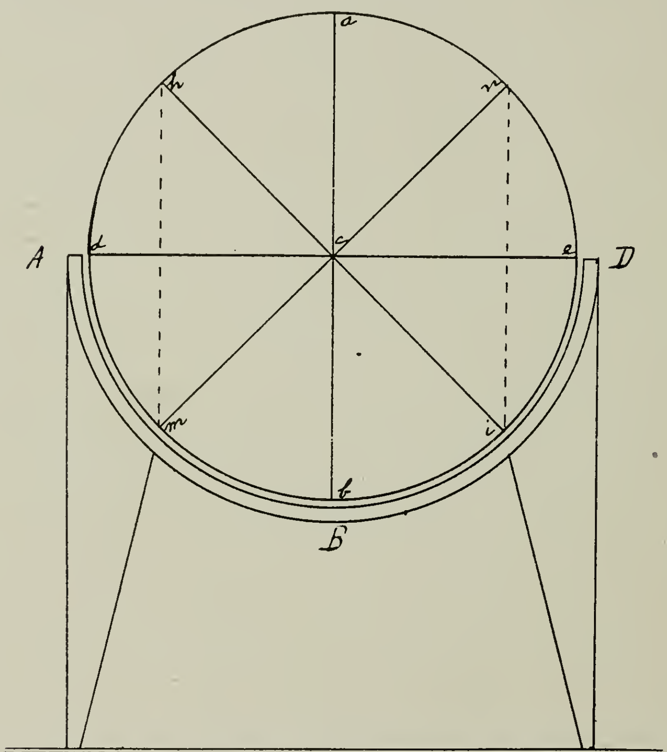


Fig. 7.

A careful study of Fig. 7 will serve to fix in the mind the truths that have been taught above. In this figure, A–B–D represents the cross-section of a concave hemisphere whose center is c, in which is set the convex sphere whose cross-section is a–d–b–e, and whose center is also c. The lines a–b and d–e are diameters of this sphere, at right angles to each other and in a plane common to the two. Since this sphere is loose in the concave hemisphere, any point on its surface may be chosen as the point for rotation. If a is to be rotated into the position of b, it must move in the plane of the great circle of which a–b is the diameter. The two fixed points on the surface of the sphere in this rotation are d and e, and the line connecting them is the diameter d–e, which is the axis of this rotation. It lies in the same plane with a–b and also in the plane of the great circle which is equally distant at all points from both a and b. The force so applied as to make a the rotating point and a–b the rotating line, fixes the axis of rotation as d–e, for d and e are the only two fixed points on the surface in this rotation. Any point on the surface between a and h and between a and n will rotate in a plane parallel with a–b, each circle growing smaller as the point recedes towards h or n. Likewise circles for revolving points between h and d and between n and e grow smaller as the rotating points recede from h or n, until at d and e the circle has become infinitely small, or, in other words, d and e do not move at all. The tangents at d and e are parallel with a–b, therefore these two points are 90° from both a and b.

Again referring to Fig. 7, it will be seen that the unbroken line a–b is the diameter of the great circle described by the rotating point a, the dotted line h–m is the diameter of the small circle created by the moving secondary point h, and n–i is the diameter of the small circle generated by the moving secondary point n. These three lines are parallel, and they all cut the axis of rotation, d–e, at right angles. In like manner, any point between a and d or between a and e might be studied. The point a moves most rapidly, while the points d and e do not move at all.

The force may be so applied to the loose sphere as to make n the rotating point and n–m the rotating line. Thus h and i would become the two fixed points, and h–i would be the axis of this rotation. By changing the point of application and the direction of the force on this loose sphere, any point on its exposed surface may be made the rotating point. The diameter extending from this point would become the rotating line, and the diameter at right-angles to this revolving line and in the plane with it would become the axis of rotation.

In any rotation of a sphere there are three points on its surface to be considered—viz., the rotating point and the two fixed points. There are two lines, each a diameter, to be considered—viz., the rotating line and the axis of rotation. There are three planes to be studied —viz.: (1) the rotation plane, a fixed plane, in which move the rotating point and the rotating line; (2) the rotating plane, in which lie the three points and the two lines (diameters); and (3) the plane containing the two fixed points and the axis of rotation, which also is a rotating plane. These three planes are each at right-angles to the other two, and the only point within the sphere common to all of these

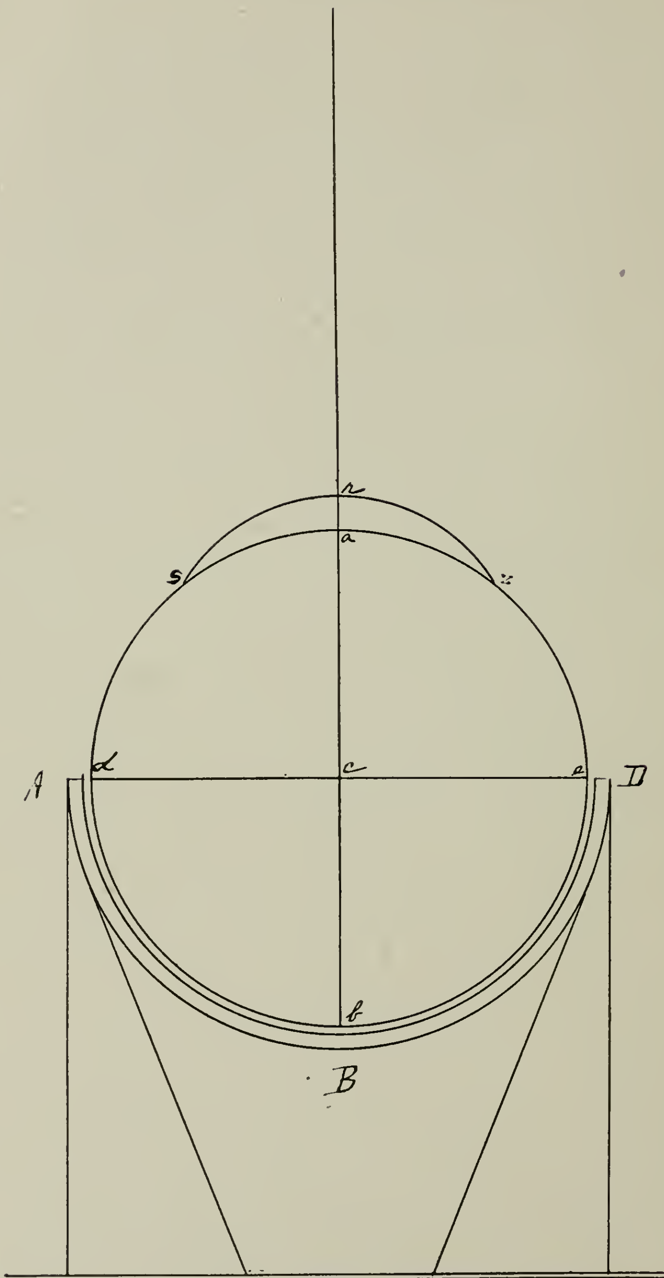


Fig. 7(b).

planes is the center of rotation. The intersection of the rotation plane (1) and the rotating plane (2) is the rotating line. The intersection of the two rotating planes (2) and (3) is the axis of rotation.

The eye is spherical, the posterior half, at least, being a perfect hemisphere. This is shown by Fig. 7(b), which is the same as Fig. 7 with the cornea s–r–x added and four lines with their letterings left out. The diameter b–c–a is prolonged into space as the visual axis. The center of the macula is b, the posterior pole; the center of the retinal curve is c; and the so-called anterior pole is r, but the real anterior pole is a, in the anterior chamber of the eye. It is not loosely set in the concavity, in the anterior part of the bed of fat, designed to receive it, but it is movably confined therein by the capsule of Tenon and the muscles in which reside the power for rotating it with mathematical precision and with wonderful frictionless speed. (These structures are not shown in the figure). In the eye, as in the loose sphere studied, every rotation plane is the plane of a great circle, and these planes may be many. The eye, unlike the loose sphere studied, has only one rotating point, and this point is not anterior, but posterior—it is the central point of the macula (b). The eye, having only the one primary rotating point, can have only one primary rotating line (diameter), and this line is the one extending from the central point of the macula forward through the center of rotation to the cornea at, or not far removed from, its center, thence to be prolonged into space (b–c–r). This is the direct line of vision. or the visual axis. In the study of the loose sphere, the primary rotating point was in the front, or in view, and the rotating line extended backward through the center of rotation. In the eye the primary rotating point is behind—is unseen—and the primary rotating line comes forward through the center of rotation to the cornea, where it does not stop, but extends on into space.

As in the loose sphere studied, so in the eye, there are two fixed points on the surface in any cardinal rotation, and these are connected by that diameter which is the axis of that rotation. All other points on the surface of the eye, not in the rotation plane, are rotated in planes of small circles that are parallel with the rotation plane, as shown in the study of Fig. 7 (lines h–m and n–i). All secondary points on the retinal surface bear an unalterable relationship to the one primary rotating point, the center of the macula, whether the eye be at rest or in motion; hence in the study of ocular motion, all points except the central point of the macula and one secondary point may be ignored. All secondary diameters of the eye bear a fixed relationship to the visual axis (the primary diameter), and all move in perfect harmony with it.

The diameters of the eye are divisible into two classes, the rotating and the fixed. The rotating diameters are divisible into two classes, the primary and the secondary. To the primary class belongs only a single diameter, and it lies in the plane of every meridian—is the line of intersection of all the meridional planes—and it alone connects the two poles of the eye. To the secondary class belong all other rotating diameters, each lying in the plane of only one meridian, but cutting the planes of all other meridians at the center of rotation. The fixed diameters are two, and they both lie in the equatorial plane of the eye. One of the two also lies in the plane of the horizontal meridian and is the axis of vertical rotations; the other lies in the plane of the vertical meridian and is the axis of lateral rotations. (See Fig. 3.)

The primary rotating diameter is the visual axis; all other rotating diameters are secondary lines of vision. The fixed diameter, always in the equatorial plane, is the axis of a cardinal rotation, and it, too, always lies in that meridional plane which is at right-angles to the rotation plane of a given cardinal rotation.

Secondary rotation lines are divisible into two classes: first, diameters which are secondary lines of vision, each bearing its own relationship, in degrees, to any given rotation plane; second, the lines that connect any two directly opposite points on the surface, lying on the same side of the rotation plane and equally distant from it, but on opposite sides of the equatorial plane. These two points, if they do not lie in the plane common to the visual axis and the axis of rotation, must be on opposite sides of this plane and equally far removed from it. Such lines are always bisected by the axis of rotation and are at right-angles to it, and each lies in the plane of its own small circle, which plane is always parallel with any given rotation plane. These planes of small circles, like the rotation plane with which they are parallel, are fixed planes in a cardinal rotation.

Lines connecting surface points not 180° apart on either a great or a small circle should not be considered as either primary or secondary rotating lines. Rotating lines of whatever class are lines bisected by the axis of rotation, but only those lines that are bisected at the center of rotation are lines of vision. All visual lines, whether direct or indirect, and the axis of any rotation mutually bisect each other, and hence all are diameters.

The author's method of finding the axis of any cardinal rotation, as set forth in the study of Fig. 7, is simple, and is applicable to all eyes. Helmholtz' method of finding the axis of rotation is not so simple, nor can it apply to his non-ideal eyes. It was only in the ideal eye that Helmholtz found the visual axis and his so-called "optic axis" to coincide. He taught that, in the larger number of eyes, the visual axis intersects his so-called "optic axis" at the nodal point. Since such a visual axis could not be a diameter, it could not become the primary rotating line in the Helmholtz method of finding the axis of rotation. By both methods the axis of any oblique rotation could be found if it were a fixed axis, and the center of the macula were taken as the beginning of that visual line which must pass through the center of rotation. But both methods fail here, for, since in oblique rotations there is no torsioning, such a rotation can not be around a fixed axis. The two axes of cardinal rotations, found by both methods with equal accuracy, are the double axes of all oblique rotations, but, as already shown, they are not now fixed axes.

Helmholtz made a fundamental mistake in his selection of the center of the cornea as the anterior pole of the eye, constructing therefrom his optic axis, which he carried backward through the center of rotation to a point on the retina, usually between the macula and the optic disc, which point he named the "posterior pole." He should have selected the center of the macula as the posterior pole; and if he had done so, his so-called "optic axis" would have been the visual axis of all eyes, and the anterior pole would have been that point on the cornea cut by the visual axis, whether it were its center or some other point slightly removed from the center. His method of finding the axis of rotation is proof of the error he made, for his method could apply only to that eye whose visual axis cuts the center of rotation. Because of this fundamental error, from which he was never able to free himself, he was unable to write clearly and convincingly about ocular movements. That he himself recognized the murkiness of his teaching in his chapter on "Movements of the Eyes," in his great work, "*Physiologic Optics,*" is shown in his conversation with Herman Knapp, as recorded in the letter reproduced herewith. When he advised Knapp to "leave this chapter aside," it was his fixed purpose to "make a more comprehensive presentation," in which work he declared himself then engaged. He lived and labored about twenty-five years after that conversation, but never rewrote that chapter, all because, no doubt, he was never able to rid himself of his fundamental error in locating the poles of the eye. If Helmholtz had grasped the truth that the center of the macula is the posterior pole of the eye, he would have made his discussion of the "Movements of the Eyes" the clearest and strongest chapter in his great book, and would have avoided other errors, the outgrowth of the fundamental error pointed out. Certainly his law of visible direction would not have been based on the "axial ray theory."

Truth looked at from many points of view will always appear as truth; error may appear to be the truth when viewed from one or two

I have read it for my instruction and interest into this fine subject, but it is very hard to conquer. Years ago, in Heidelberg, when Helmholtz's Physiol. Optik came out, I at once plunged in it, and somewhat after it, when we took a walk in the beautiful woods, I told him: I have no great difficulties with your "Phys. Optics", except the chapter: "Movements of the Eyes". O yes, he at once spoke in loudertone; "I do not wonder that you find it difficult. It was the chapter which have me given the greatest labor; but leave this chapter aside, I am at a different, ~~and~~ shorter and more comprehensive dissertation; this will please you more". Now when a Helmholtz so speaks, I may not be ashamed, if this chapter is difficult to me, and I have to resort to authorities when such problems present themselves in my practice.—

H. Knapp

standpoints, but it is sure to become manifest under the clearer light of many-sided investigation. Truth is always simple, and the greatest truths are the simplest. When an investigator finds himself beset with difficulties, he may be sure that error, either of his own creation or that has been handed down to him, shadows his pathway. Fundamental errors, until discovered and discarded, are dangerous things, for out of these come many other errors of greater or less magnitude. Helmholtz' fundamental error in his study of ocular motions was the selection of the center of the cornea as the anterior pole of all eyes. Because of this fundamental error, he was not able to write clearly and consistently about ocular rotations. Helmholtz' conclusions, based on his falsely located poles of the eyes, may here be contrasted with what the writer believes to be the truth.

HELMHOLTZ.	SAVAGE.
(1) The center of the cornea is always the anterior pole, and the center of the macula is the posterior pole only in ideal eyes.	(1) The center of the macula is always the posterior pole, and the center of the cornea is the anterior pole only in ideal eyes.
(2) The optic axis begins always at the central point of the cornea, passes backward through the center of rotation to the retina, rarely at the central point of the macula, but usually to a point between the macula and the optic disc.	(2) The optic axis always begins at the center of the macula, passes through the center of rotation and cuts the cornea, rarely at its center, but usually to the nasal side.
(3) The optic axis is the visual axis only in the ideal eye, and only then does the visual axis cut the center of rotation. Usually the visual axis misses the center of rotation by passing to the outer side of it, crossing the optic axis at the nodal point, and lying in only one meridional plane.	(3) The optic axis in all eyes is the visual axis and is the line of intersection of all meridional planes, hence it lies in the plane of every meridian.
(4) Visual lines are axial rays of cones of light, as is also the visual axis, and all these cross the optic axis at the nodal point. Even in ideal eyes the visual lines	(4) Visual lines are not axial rays of light, but are radii of retinal curvature prolonged, all of them crossing the visual axis at the center of rotation, which

do not cross the visual axis at the center of rotation.	is the center of retinal curvature.
(5) In passing from one point of view to any other, the visual axis of a non-ideal eye can not move in a plane of a meridian except when the rotation is directly to the right or left.	(5) In monocular motion every rotation plane is a meridional plane extended, and the visual axis always moves in this plane.
(6) In cardinal and oblique rotation starting from the primary point of view or returning to it, the axis of any rotation lies in Listing's plane; the axis of rotation from one secondary point to another secondary point lies in a plane bisecting the angle between Listing's plane and the equatorial plane.	(6) The axis of every rotation, whether cardinal or oblique, whether from a primary to a secondary point of view, or vice versa, or whether from one secondary to another secondary point of view, lies in the equatorial plane.
(7) The object in space and its retinal image are connected by a straight line which crosses all similar lines at the nodal point, and never at the center of rotation.	(7) The object in space and its retinal image are always connected by a straight line which crosses all similar lines at the center of rotation and at no other point.
(8) The spacial pole, if on the same straight line with the two poles of the eye, can not be the direct point of view for non-ideal eyes.	(8) The spacial pole is on the same straight line with the two poles of the eye and is the direct point of view for all eyes.

In drawing the above parallel, no attempt has been made to quote the exact language of Helmholtz, or any of his followers, on either of the eight points of difference; but that he has been fairly represented as to his teachings, no one will deny. His two fundamental errors were: (1) In not taking the central point of the macula for his posterior pole, and (2) in his axial-ray theory of direction. To be in agreement on the location of the posterior pole and on the law of direction would mean agreement everywhere. If on these points Helmholtz is right, the author is wrong; if the author is right on these points, then Helmholtz is wrong. The teaching of the one who is correct in the location of the posterior pole and in his conception of the law of direction will stand.

The rotation plane of an individual muscle, as already shown, must bisect the muscle from its origin to its insertion, and must cut the center of rotation. It may, or may not, cut the macula. It can cut the macula only when the muscle plane of an externus or an internus is none other than the plane of the horizontal meridian; that is, when one of these muscles at its origin, in its course and at its attachment, is neither too high nor too low. Every rotation plane of the eye must cut the center of the macula, and the center of rotation. even though it may not pass through a single muscle. Only an externus, or an internus, of ideal relationship to the eye, can act alone in rotating it. Vertical rotation requires the harmonious action of two muscles; while every oblique rotation requires the harmonious action of three muscles.

Brain centers controlling the ocular muscles. There are two sets of brain-centers designed for exciting and controlling the ocular muscles in rotating the eyes. One of these sets, or groups, of centers is alone active in monocular rotations. The same group of centers is also active in binocular rotations. These centers are located in the motor area of the cortex of the brain, and are under the control of volition. The cells of each of these centers are diaxonic, one axone going to a muscle of one eye, the other axone going to a muscle of the other eye, thus uniting the two in a pair. The centers of the other group are located in the base of the brain, and are under the control of the fusion faculty of the mind. The cells of each of these centers have only one axone, and therefore can be connected with only one muscle. The name indicates that these centers are used only in the interest of binocular single vision. When there is but one eye these centers are forever at rest. The volitional centers do the same character of work, whether there be one eye or two; hence, when one eye is lost, these centers go on as if there were still two eyes.

However perfectly balanced may be the ocular muscles, activity of two fusion centers is necessary in all oblique binocular rotations. In every form of muscle imbalance, whatever may be the direction of the binocular gaze, two or more fusion centers must be forever active. The fact that the loss of one eye forever releases the fusion centers from activity, affords an explanation for the statement made by so many, who have lost one eye, that the one eye is stronger than the two eyes ever were.

To help towards an understanding of the centers controlling the ocular muscles, in both monocular and binocular rotations, Fig. 8 is here presented.

Conjugate centers. The upper part of this figure represents the brain in which is arranged schematically the centers of the ocular muscles. In the cortex of each hemisphere is found eleven circles representing the volitional conjugate centers. Some of these circles are large, showing that they are the active centers, while the others

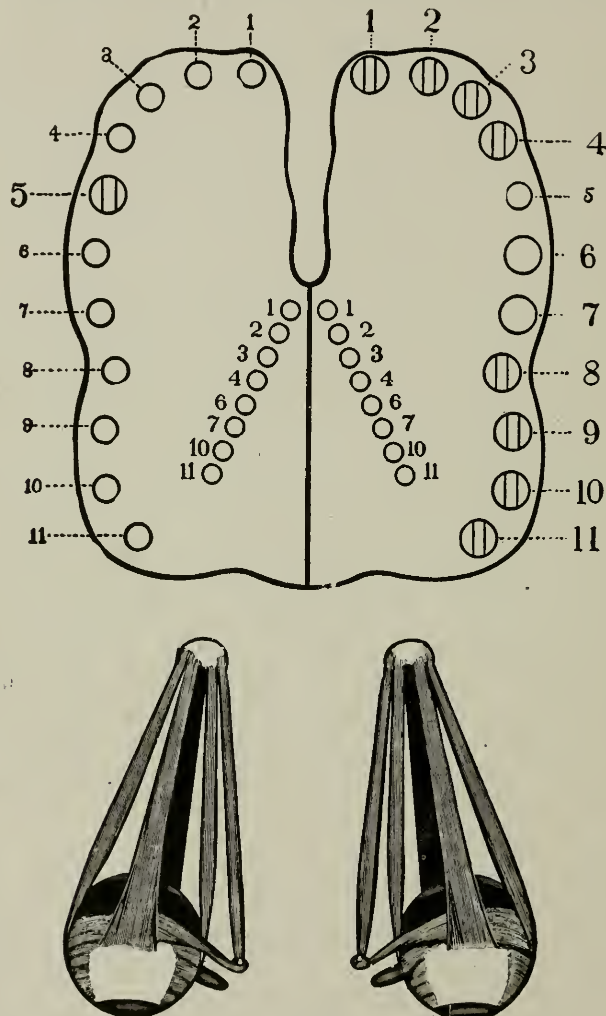


Fig. 8.

are small to reprcsent that they are inactive. Ten of the large circles are shown in the left hemisphere, while only one of the large circles is in the right hemisphere. The twenty-two centers, at birth, were all equally ready to become active. In right-handed people the active centers would be as shown in the figure, but in left-handed persons the ten active centers would be in the right hemisphere, and the lone active center in the left hemisphere would be the fourth. The active and inactive centers, when of the same number, are each connected with the same pair of muscles, but the fibers from the inactive centers are as dead wires and convey no neuricity to the muscles. The diaxones of every cell, in every center, part company at the base of the brain, one going to a muscle of the pair on the corresponding side, while the other, crossing to the opposite side, goes to the other muscle of the pair belonging to the opposite eye. The neuricity discharged from each of these centers is sent in equal quantity to each muscle of the pair under its control.

The large circles, according to their numbers, are connected with their respective muscles as follows: (1), with the two superior recti; 2, with the two inferior recti; (3), with the two interni; (4), with the right externus and the left internus; (5), with the left externus and right internus; (6), with the two superior obliques; (7), with the two inferior obliques; (8), with the right superior and left inferior obliques; (9), with the left superior and right inferior obliques. These nine conjugate centers are connected with the extrinsic muscles only; the tenth and eleventh centers are connected respectively with the two ciliary muscles and the two sphincters of the iris. They, likewise, are conjugate centers, all the cells composing them being diaxonic.

The six ocular muscles of one eye, as already shown, are grouped in three pairs. In the later study of tonicity this grouping must be still observed, although the tonicity test is impossible except when the two eyes are being used.

The twelve extrinsic muscles of the two eyes, in binocular single vision, must be grouped in nine pairs. Five of these pairs consist of recti muscles: (1) the two superior recti, (2) the two inferior recti, (3) the two internal recti, (4) the right externus and the left internus, (5) the left externus and the right internus. Four of the nine pairs consist of the oblique muscles: (1) the two superior obliques, (2) the two inferior obliques, (3) the right superior and left inferior obliques, (4) the left superior and right inferior obliques. In some of the rotations only one of the nine conjugate centers is active; in other rotations only two of the nine are active; and in still other rotations three of the nine must be active, but never more than three.

Fusion centers. The circles on either side of the median plane of the head, in figure 8, are all made the same size, for all of these must be ready for action in binocular vision, whenever a condition exists that would lead to diplopia, as in oblique rotations of all eyes, whether there is orthophoria or heterophoria; and in all heterophoric eyes, whether at rest or in motion of any kind. Of the twenty-two conjugate volitional centers, only eleven are active, and the location of the active centers is determined by the physical connection of the two maculas with the brain—ten in the left brain and one in the right, if the two maculas are connected with the left cuneus. Of the sixteen —eight on either side—fusion and corrective centers at the base of the brain, all stand ready for action in binocular vision, regardless of the connection the maculas may have with the brain, provided it is common-brain-cell connection—the fundamental fact of binocular single vision. In the cases, all too common, of antipathy to binocular single vision, the two retinas not having common brain-cell connection, the basal or fusion centers are forever at rest.

Twelve of the basal centers, six on either side, are connected with the twelve extrinsic ocular muscles, one center with one muscle. The six centers on the right side are connected with the six muscles of the right eye in the following order: 1, with the superior rectus; 2, with the externus; 3, with the internus; 4, with the externus; 6, with the superior oblique; and 7, with the inferior oblique. In like manner, the six centers to the left of the median plane are connected with the six muscles of the left eye. The center on the left side marked 4 might have been marked 5, since one of the two axones from conjugate center 5 goes to the left externus. The reason for not doing so is that in speaking of a pair of fusion or basal centers it is better to say right and left fourth, right and left third, etc. The two remaining centers on either side, marked 10 and 11, are connected with the ciliary muscle and sphincter of the iris on their respective sides. If the right ciliary muscle is weaker than the left and the refraction of the two eyes is the same, then the right tenth basal center must send supplemental neuricity to its weaker muscle to make it do a work equal to that of its fellow under the influence of the tenth conjugate center only.

Again, if the hyperopia of the right eye be greater than that of the left, since the tenth conjugate center sends equal neuricity to the two ciliary muscles, the right muscle, in order to accomplish its greater task, must receive supplemental neuricity from its individual tenth basal center. If the sphincter of one iris is weaker than that of the other, it must receive supplemental neuricity from its eleventh basal center in order to contract its pupil as the other is contracted by neuricity from the eleventh cortical center only.

The well insulated axones of all the cells of all these centers, both conjugate and fusional, are collected into three nerves at the base of the brain. One axone of every diaxonic cell crosses to the opposite side to help form a nerve of that side; while the other, remaining on the side to which its cell belongs, helps to form a nerve on that side.

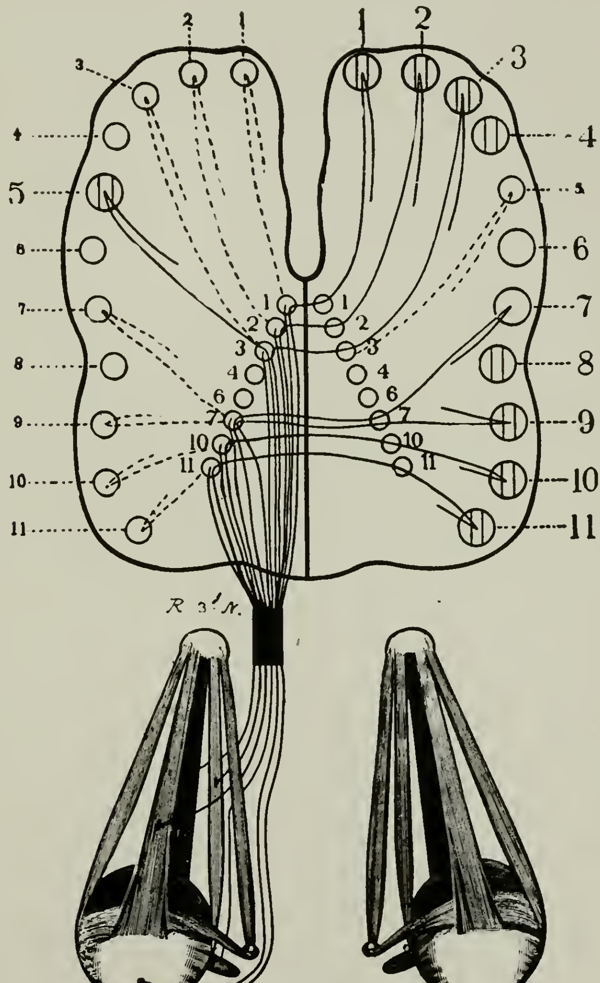


PLATE I

The two axones do not always help to form the two nerves of a pair, the exceptions being the cells in the following centers: the fourth, the fifth, the eighth and the ninth. Each cell in the fourth conjugate center has one axone in the left third nerve, and the other axone in the right sixth nerve; while the cell in the fifth conjugate center has one axone in the right third nerve, and the other axone in the left sixth nerve. The cells of the eighth conjugate center each have one axone in the right fourth nerve, and the other in the left third nerve; while each cell in the ninth conjugate has one axone in the right third nerve and the other in the left fourth nerve.

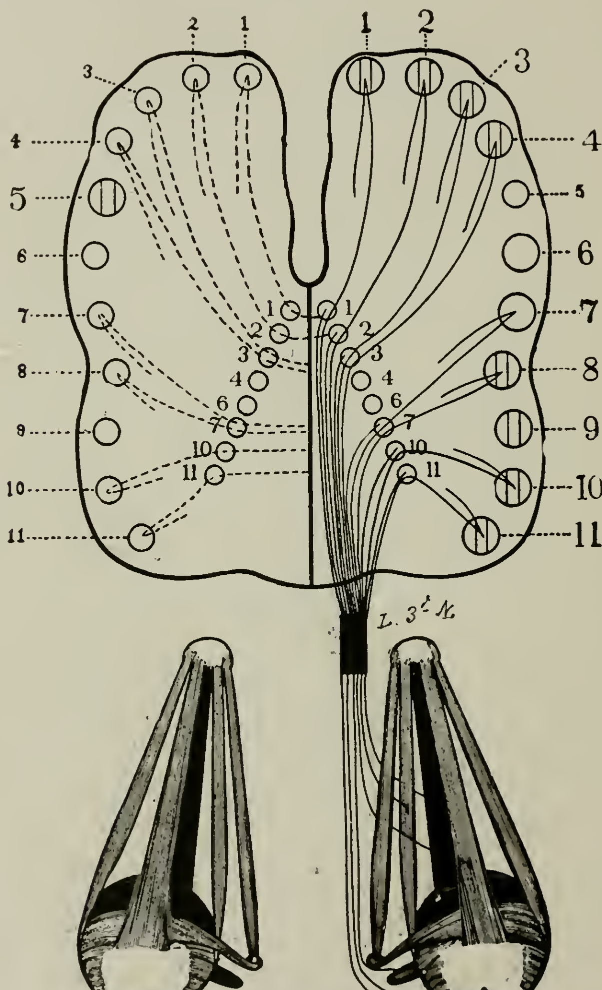


PLATE II

Plate 1 shows the cells and axones entering into the formation of the right third nerve of a right-handed person. All of the live-wire axones, represented by continuous lines, from the cortical centers have crossed save one. The single axone from each cell of six of the basal centers on the right side help to form the right third nerve. The continuous lines which are cut short a little way from the cortical centers are the axones that help to form some other nerve. The dotted lines from the inactive cortical centers represent the "dead-wire" axones which enter into the structure of one or other of the three pairs of

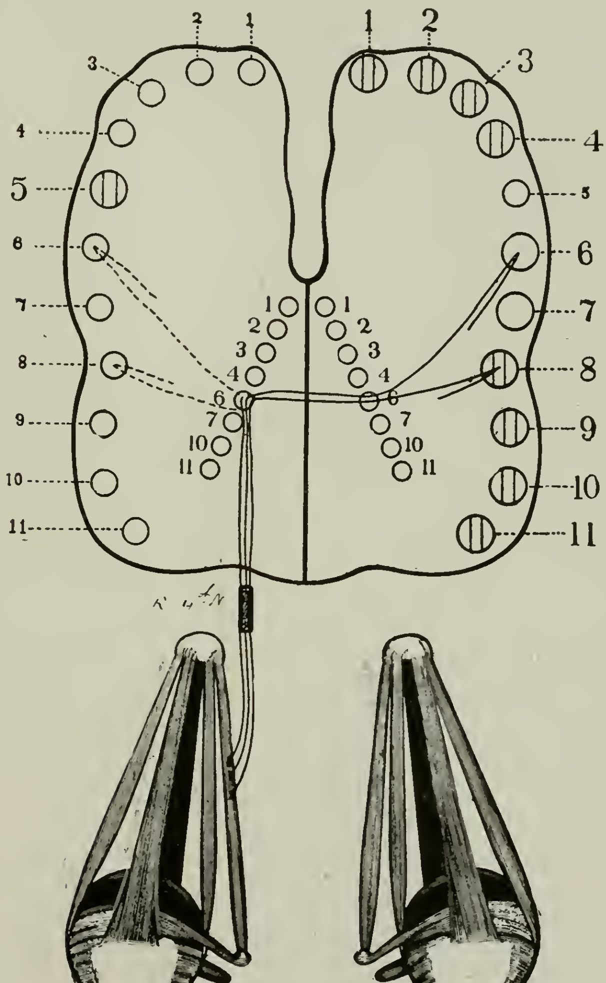


PLATE III

motor nerves of the eyes, but convey no neuricity to their respective muscles. The "live-wire" axones, from their central cells to their end-organs in the ocular muscles, are everywhere insulated that there may be no waste of neuricity intended for the control of a muscle. Hence each nerve is a cable of independent but associated axones.

Plate 2 represents the formation of the left third nerve of a right-handed person. All of the live axones forming this nerve remain on the same side of the median plane of the head, to which their cells belong.

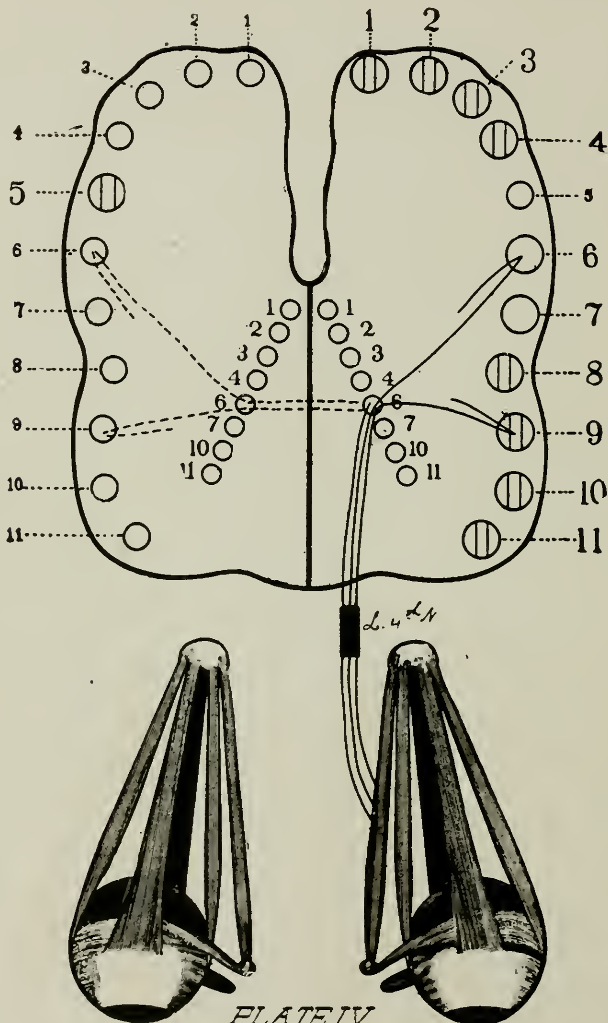


PLATE IV

Plate 3 represents the formation of the right fourth nerve, all of whose fibers have crossed from the left side of the brain.

Plate 4 represents the formation of the left fourth nerve, none of whose axones have crossed. Each of these nerves is composed of fibers from only two cortical centers and one basal center; while each of the third pair of nerves is composed of fibers from eight cortical and six basal centers.

Plate 5 shows the structure of the right sixth nerve, the "live-wire" fibers of which come from only one cortical center and one basal center, the cortical center being on the opposite side of the brain.

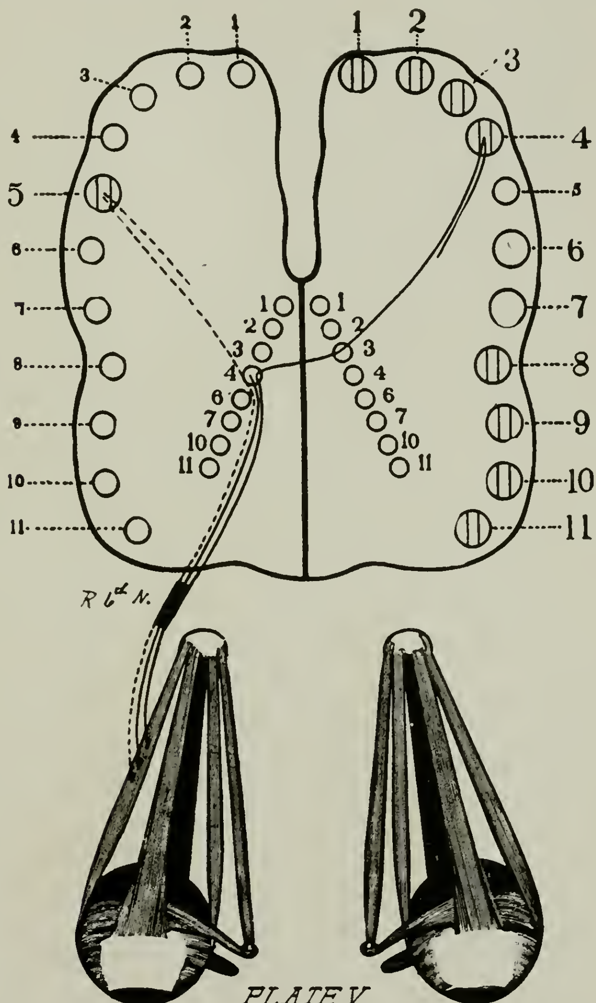


PLATE V

Plate 6 shows that the left sixth nerve is connected with one cortical and one basal center, the former in the right hemisphere. In each of the sixth nerves the axones from the conjugate center have crossed from the opposite side of the brain. In all of the plates the single axone from the cell of basal centers goes to a muscle of the corresponding side.

We have studied the individual extrinsic ocular muscles, their planes of rotation, and the cortical volitional centers controlling each; and

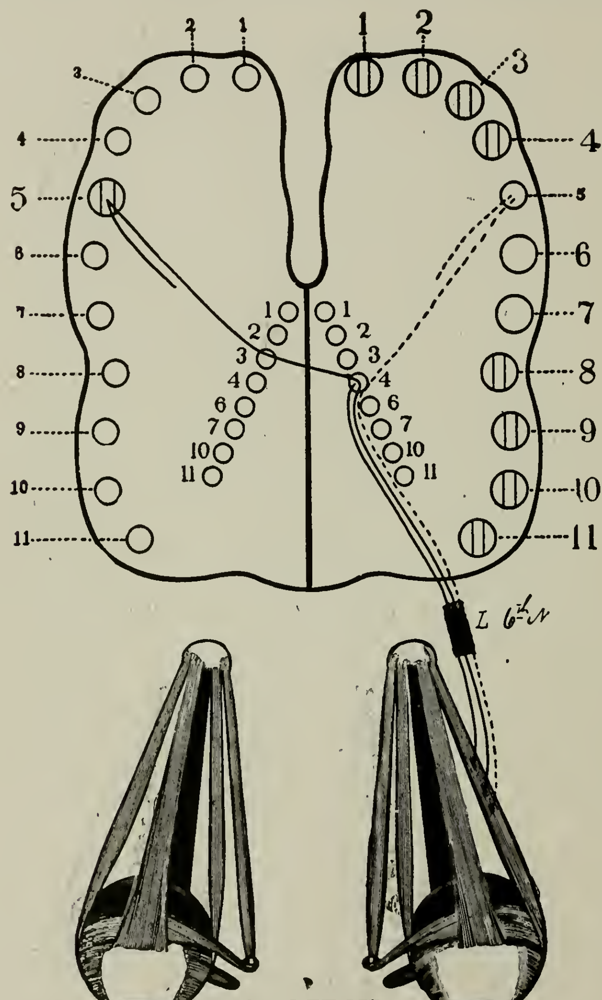


PLATE VI

have also studied the planes of monocular rotations, and how the rotations in these planes are around one of two fixed axes in cardinal rotations, and around both these axes (now movable) in oblique rotations. These studies constitute a good foundation for a comprehensive understanding of binocular rotations and the law governing them.

Binocular rotation. In the human being the two eyes are so placed and so adjusted as to make binocular single vision possible, in obedience to the supreme law of corresponding retinal points. To say that the macula of one eye must correspond, point for point, with the macula of the other eye; that the vertical meridian of one eye must correspond, point for point, with the vertical meridian of the other eye; that the horizontal meridian of the one eye, in like manner, must correspond with the horizontal meridian of the other eye, does not explain the fundamental fact which makes binocular single vision possible. There are eyes whose maculas and whose vertical and horizontal meridians do not correspond—eyes that have never had binocular single vision and can never be made to have it. This abnormal condition was known to Von Graefe and was by him named ''antipathy to binocular single vision,'' but he made no attempt to explain it. For such eyes there is no circle (horopter or monoscopter) of single seeing with the two eyes. There is no such thing as a binocular spacial pole, and over such eyes the law of binocular rotation has no power. For these eyes, and they are fairly numerous, the fundamental fact underlying binocular single vision does not exist.

''What is the fundamental fact of corresponding retinal points?'' is a question worth the asking. The author believes he uttered the truth when he taught, some years ago, that the secret of corresponding retinal points is common brain-cell connection; that one macula corresponds, point for point, with the other macula only because these corresponding points have, going from them, two fibers which meet in the optic tract and go, side by side, back into the same cuneus, to terminate in one common cell in the visual center. Corresponding points on the two vertical and the two horizontal meridians, likewise corresponding points on any two oblique meridians similarly related to the vertical and horizontal meridians and to the maculas, must have common brain-cell connection. This explains double impressions, yet a single sensation—two images, yet a single object. If the fibers from the right macula should go to the right side of the brain, and the fibers from the left macula should go to the left side of the brain, there would be two sensations excited, as certainly as that there have been two retinal impressions. Or, if the fibers going from retinal points that normally correspond, find their way back to the same cuneus, but terminate each in a separate brain-cell, there would be two sensations as certainly as that there have been the two retinal impressions. One or the other of these anatomic faults must exist in every person who has antipathy to binocular single vision—who has never seen singly with the two eyes and who can never be made to do so. A good illustration of common brain-cell connection may be had by one riding on a street car, when there are two individuals who wish to signal the conductor their desire to leave the car at the same crossing. The two press the buttons at the same moment of time with but one result, the ringing of one bell, just as if only one button had been pressed—a double impression with only one bell excited. If one button were connected with a bell at one end of the car, while the other button is connected with a bell at the other end of the car, or if the two bells be at the same end of the car, and even very near to each other, the pressing of the two buttons would make the two bells ring, but their sounds could not be blended into one.

The law of visible direction does not explain corresponding retinal points, for this law is violated in the interest of binocular single vision whenever a prism is placed before either of the two eyes. Duction is possible only in violation of the law of direction. When there are no corresponding retinal points, nothing can interfere with the law of direction: Every thing seen is on a line connecting the object and its image, which line passes through the center of rotation—"every line of direction is a radius of retinal curvature prolonged." Nor is this law ever violated when there is only one eye.

A person whose eyes have not corresponding retinal points is always strabismic, and while he may prefer to use almost constantly one eye, the other eye does not become blind from want of use, although mental suppression alone prevents diplopia. This crossing exists from the day of birth to the day of death, yet the crossed eye continues to see well, whenever permitted to do so by the temporary obstruction of the other eye. In ordinary strabismus, as is well known, the deviating eye becomes mentally blind.

Nature has two methods of preventing diplopia—(1) fusion of the two images by bringing the two corresponding retinal points into conjunction with the two images; (2) mental suppression of one of the two images. Fusion is possible only when there are corresponding retinal points. Suppression is a necessity, (1) when there are no corresponding retinal points; (2) when there are corresponding retinal points, but mal-adjustment of the ocular muscles makes it impossible to correctly relate these two points to the two images of the single object.

In strabismic (heterotropic) eyes, when the seeing eye is being rotated in obedience to the law of monocular rotation, the other eye moves, but not in the interest of either binocular single vision or correct orientation. The comitant verting of a squinting eye differs in nothing from the rotation of an eye that is stone-blind.

Binocular rotation, as it will now be studied, is the rotation of the two eyes in the interest of binocular single vision and correct orientation. Binocular rotations are either cardinal or oblique. They are effected by the same muscles that are concerned in monocular rotations, but not wholly by the volitional brain-centers, which alone are concerned in monocular rotations. Besides the nine conjugate brain-centers, all under the control of the will, and each connected with two muscles, one belonging to each eye, there are twelve centers controlled by the fusion faculty of the mind, each center being connected with only a single muscle. These fusion centers, as their name indicates, exist in the interest of binocular single vision; hence when there is a condition that would cause diplopia, whether the eyes be at rest or in rotation, one or more of these fusion centers must be in action. These fusion centers must be ready to act both independently of, and coördinately with, the conjugate centers. The conjugate centers furnish the neuricity that brings about all voluntary movements of the eyes, such as verting and converging. The single centers, in the sense of acting on only one muscle, are the centers that effect duction, the power that overcomes double vision, and planing, the power that prevents diplopia.

Fig. 8 shows, in a schematic way, the conjugate centers and the single fusion centers. This figure also shows the two eyes with their twelve muscles; but, in its study, the imagination must make the connections. In "*Ophthalmic Neuro-Myology*" there is a separate illustration for each conjugate brain-center and the muscles controlled by it, in which the connecting nerve-fibers appear; and the connection of each fusion center and its muscle is also shown.

As related to the volitional brain-centers which control them, the twelve muscles belonging to the two eyes are arranged in pairs as follows: (1) The two superior recti, (2) the two inferior recti, (3) the two interni, (4) the right externus and the left internus, (5) the right internus and the left externus, (6) the two superior obliques, (7) the two inferior obliques, (8) the right superior oblique and the left inferior oblique, (9) the left superior oblique and the right inferior oblique. For each of the nine groups of two muscles there is a conjugate innervation center from which go fibers to be distributed equally to the two muscles to be controlled by it. The internal recti and the four obliques are each connected with two conjugate innervation centers, while the remaining muscles are each under the control of only one conjugate innervation center.

Planes of reference. In binocular, as in monocular, rotations there are two—only two—planes of reference. These are shown in Fig. 9.

The necessity for the existence of both the conjugate volitional centers and the basal fusion centers, already studied and illustrated, is shown in Fig. 9 now to be studied. A careful study of this figure will bring many things into the light of the understanding. First of all, the figure shows three planes—(1) the fixed horizontal plane of the head, a–b–c–d; (2) the fixed vertical plane of the head, g–h–i–j; (3) Listing's plane, or the fixed transverse plane of the head, cutting the centers of the two eyes, this plane being k–l–m–n. Each of these

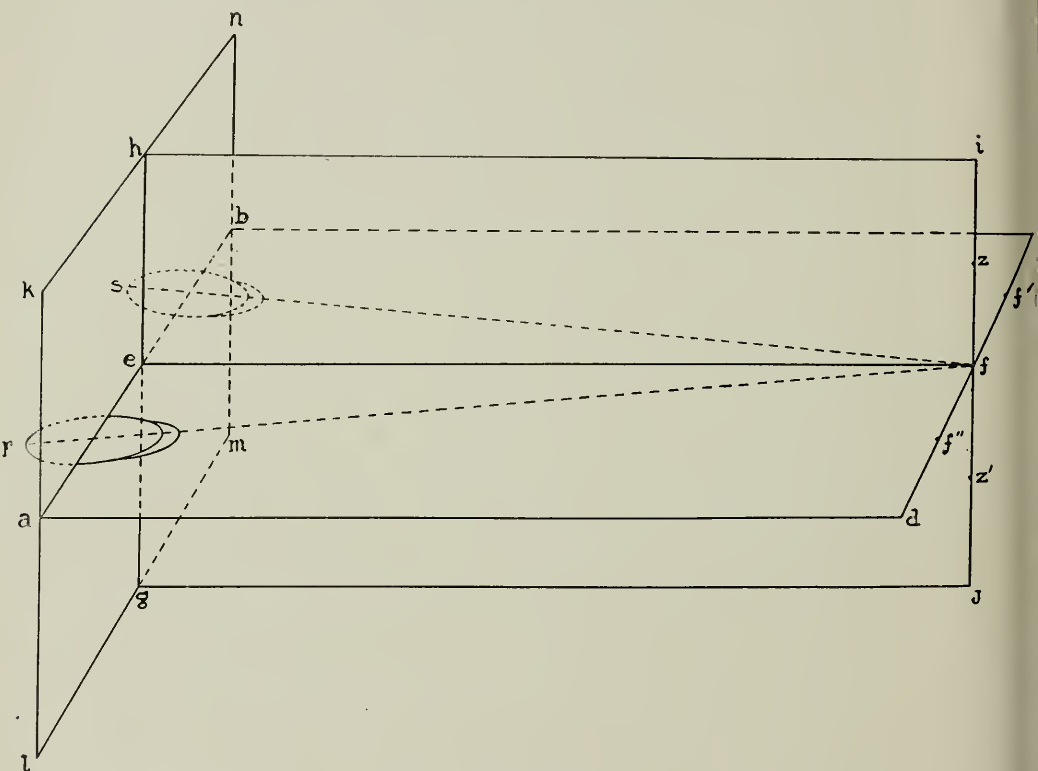


Fig. 9.

planes is at right angles to the other two planes, and the three lines of intersection are e–f, a–b, and h–g. In the horizontal plane are shown horizontal sections of the two eyes, r and s, and the two visual axes r–f and s–f.

The extended fixed vertical and horizontal planes of the head are planes of reference. With the head in the primary position, if a point is not in the horizontal plane, a–b–c–d, it is instantly known to be above or below it; if a point is not in the vertical plane, h–i–j–k, it is certainly known to be to the right or left of it; and an approximately correct estimate of the degrees of removal of such point from these planes can be made in obedience to the law of visible direction. In the primary position of the head, the plane a–b–c–d is horizontal, and the eyes are in their primary positions when the two visual axes lie in this plane, and are converged on some point, at practical infinity, lying on the line of intersection, e–f, of the horizontal and vertical planes. Converged on such a point, the visual axes are practically, though never really, parallel. To be perfectly parallel, the visual axis (r–f) of the right eye would have to be in the position r–f″, and the visual axis (s–f) of the left eye would have to be s–f′.

In locating the position of any point in viewable space, the words *right* and *left* would be used in reference to the vertical plane of the head, h–i–j–k; the words *above* and *below* would be used in reference to the horizontal plane, a–b–c–d; and the word *in* should be used in reference to both the vertical and horizontal planes. The points f′ and f″ are in the horizontal plane, the one to the right, the other to the left, of the vertical plane; the points z and z′ are in the vertical plane, respectively above and below the horizontal plane. All points lying on the line of intersection (e–f) of the two planes would be points directly ahead, and these would be primary points of view. All points off this line of intersection (e–f) would be secondary points of view. The four cardinal directions are f–i, f–j, f–c and f–d. All points not in the line c–d (or in the plane a–b–c–d) and not in the line i–j (or in the plane g–h–i–j) are obliquely related to these lines (or planes). The point of binocular view—whether direct, cardinal, or oblique—is the point of intersection of the visual axes, to be studied a little further on as the binocular spacial pole.

With the head fixed in the primary position, the point of binocular view may be changed from the primary point, f, to any secondary point, whether cardinal or oblique, in obedience to the law of binocular rotation. The absurdity of the claim that the axes of all binocular rotations, from the primary to a secondary point of view, or vice versa, must lie in Listing's plane, is made apparent by even a casual study of Fig. 9. In this figure k–l–m–n represents Listing's plane, which is at right-angles to the planes a–b–c–d and h–i–j–k. Listing's plane is, therefore, a transverse vertical plane of the head, and it cuts the centers of rotation of the two eyes. It has been shown that the axes of all rotations lie in the plane of the equator of the eye, and that the equatorial plane is always at right-angles to the visual axis. Therefore, with every change in the position of the visual axis, there must be a change in the relationship of the plane of the equator with Listing's plane. There is only one point in the plane of the equator that never leaves the Listing plane, and that is the center of rotation. Since the transverse and vertical axes of the eyes, alone or together, are the only axes of rotations, the relationship that these bear to Listing's plane is determined by the relationship that the visual axes bear to the fixed vertical and horizontal planes of the head. When the visual axes, r–f and s–f, lie in the plane a–b–c–d, the vertical axes of the eyes must be in Listing's plane. Any movement of the eye that compels the visual axis to remain in the plane a–b–c–d, as from f to f′ or from f to f″, must be around the vertical axis, which must lie in Listing's plane. Any rotation around the transverse axis will carry the point of fixation up to z or down to z′, but in these rotations the transverse axis of each eye forms the same angle with a–b that r–f and s–f form with e–f, hence the rotation from f to z or z′ is about an axis that does not lie in Listing's plane, any more nearly than is there parallelism of r-f and s-f with e-f. If the rotation upward were to start from f′, the axis of rotation of the left eye would lie in Listing's plane, for the visual axis, in position of s–f′, would be parallel with e–f; but the transverse axis of the right eye would form the same angle with Listing's plane as its visual axis, in the position of r–f′, forms with e–f. In a rotation starting upward from a point between f and f′ or beyond f′, neither of the two axes of rotation would lie in Listing's plane.

Listing's plane. The conclusion compelled by the above study of Fig. 9 is that Listing's plane cannot be a plane of reference, nor can it be a plane containing the axes of all rotations starting from, or returning to, the primary point of view. The equatorial plane of the eye contains both the vertical and transverse axes of the eye, and it is around one or the other or both of these that all rotations, cardinal and oblique, occur. Listing's plane, like Listing's law, should be forgotten in the interest of truth.

Horizontal rotations. The brain-centers, volitional and fusional, have already been named. The study of Fig. 9 will convince even a skeptic that these centers are real and not imaginary. The convergence of the visual axes, r–f and s–f, to any point on e–f, is effected by the third volitional center acting on both interni; turning the visual axes from f to f″ is accomplished by the fourth volitional center acting on the right externus and the left internus; sweeping the visual axes from f to f′ is made possible by the action of the fifth volitional center on the right internus and the left externus. The above centers have been pointed out first because they effect the simpler rotations.

Vertical rotations. More complicated are the rotations directly up and down. Elevating the visual axes from f to z is accomplished by the combined activity of two volitional centers—(a) the first conjugate acting on the two superior recti, and (b) the seventh conjugate acting on the two inferior obliques. Depressing the visual axes from f to z′ is effected by the harmonious activity of two volitional centers—(a) the second conjugate acting on the inferior rectus of each eye, and (b) the sixth conjugate acting on the two superior obliques.

Oblique rotations. More complicated still are oblique rotations, for each of these must be effected by the harmonious action of three volitional brain-centers; and, in addition to these, every oblique rotation requires activity on the part of two basal or fusion centers. If the visual axes are to be moved from f to any point above the horizontal plane and to the right of the vertical plane, this motion must result from the harmonious action of the first conjugate center on the two superior recti; the fourth conjugate, on the right externus and the left internus; and the eighth conjugate, on the right superior oblique and the left inferior oblique. In the right-sweep part of this rotation, since the left inferior oblique would hinder the left internus, while the right superior oblique would help the right externus, the hindered left internus must receive a supplemental impulse from the left third basal or fusion center, whose sole power pertains to that muscle. Since, in the upward part of this oblique rotation, the right superior rectus would be hindered by the right superior oblique, while the left superior rectus would be helped by the left inferior oblique, the hindered right superior rectus must receive supplemental neuricity from the right first basal center, else the right visual axis would lag behind the left visual axis.

Whatever the degree of obliquity and in whatsoever direction, the rotation of orthophoric eyes must be accomplished by the harmonious action of three conjugate volitional centers and two basal or fusion centers.

In order to bring into view the only remaining conjugate brain-center connected with the extrinsic ocular muscles while studying Fig. 9, the rotation may be considered as from f to a point above the horizontal plane and to the left of the vertical plane. This point can be reached only as the result of the harmonious activity of the first, fifth and ninth conjugate centers. The left superior rectus, hindered by the left superior oblique, must receive supplemental neuricity from the left first basal center; and the right internus, hindered by the right inferior oblique, must receive supplemental neuricity from the right third basal center. In like manner might be studied rotations from f to some point below the horizontal plane and to the left of the vertical plane, or to some point below the horizontal plane and to the right of the vertical plane, but in every such study the fact would become apparent that three volitional and two fusion centers have been acting in the interest of binocular single vision and correct orientation.

In every rotation above the horizontal plane, a-b-c-d, the first conjugate center participates; in every rotation below this plane the second conjugate center has a part. In every rotation to the right of the vertical plane, g–h–i–j, the fourth conjugate center is active, and in every rotation to the left of this plane the fifth conjugate center participates. The third conjugate center is concerned in the fixing of any point in space. Thus the five conjugate centers controlling the four recti muscles, become more real when studied in the light of Fig. 9.

Rotation from f to any point in space above or below the horizontal plane, a–b–c–d, must call into action some one of the four conjugate centers connected with the oblique muscles. In rotations from f to z, the seventh conjugate center keeps the vertical axes of the eyes parallel with the vertical plane, g–h–i–j; and in rotations from f to z′, the sixth conjugate center maintains this parallelism. In rotations up-and-to-the-right and down-and-to-the-left, the eighth conjugate center prevents torsioning toward the right; and torsioning towards the left is prevented by the ninth conjugate center when the rotations are up-and-to-the-left and down-and-to-the-right. Activity of the eighth and ninth conjugate centers arouses into action six of the right and left fusion or basal centers belonging to the recti, but only two of these at any one time. The two basal centers never excited in oblique rotations of eyes whose muscles are normal, are the right fourth and the left fourth. Cardinal rotations by normal muscles do not excite a single fusion center. Thus far the study of Fig. 9 has demonstrated the existence of all of the nine conjugate brain-centers belonging to the recti and obliques, and six of the eight right and left basal or fusion centers connected with the recti.

The fusion centers. The demonstration of the fact of the existence of the right and left individual fusion centers connected with the recti, and the four like centers connected with the obliques, is made easy by a further study of Fig. 9. Normal recti muscles, in a state of tonicity, would converge the visual axes at f, if that point were twenty feet distant, and would keep the two visual axes in the plane a–b–c–d; and the obliques of equal tonicity would confine the two horizontal retinal meridians in this plane. In such a condition of equal tonicity, neither volitional nor fusion brain-centers are active, when both the head and the eyes are in their primary positions. Convergence of the visual axes, and planing these axes and the horizontal meridians are conditions essential to binocular single vision; but the existence of single vision with the two eyes does not guarantee that all the muscles are normal in tone. If tonicity cannot effect binocular single vision, this must be accomplished by contractility of the muscles wanting in tone. The source of the required neuricity is not controlled by the will, but by the fusion faculty of the mind, itself dominated by the desire for single vision. Every ocular muscle has its individual fusion center, the neuricity from which acts on only the one muscle. These centers have already been individualized by numbers, and the existence of six of the right and left fusion centers for the recti has been proved in the study of oblique rotations, in the light of Fig. 9. By means of this figure the existence of all the fusion centers, eight for the recti and four for the obliques, can be demonstrated from two different vantage grounds—viz., the tests for heterophoria and the duction tests.

The proof, from the standpoint of heterophoric tests, will presuppose the uncomplicated existence of each of the several errors to be studied later. One eye must be taken off its guard in order that any one of these errors may become manifest. The placing of a 6° prism, base up, before the right eye in Fig. 9 would double f, the false f being thrown to the position of z′. The right eye, now off its guard, will assume the position that muscle tonicity would give it, and not a single muscle belonging to this eye will receive neuricity from any source, provided the mind uses the left eye for fixing the true f. If the false f be directly under the true f, it thus appears because the externus and internus of the right eye have equal tonicity, and the visual axis of this eye, notwithstanding the prism diplopia, will be pointing to the true f. By removal of the prism the diplopia is made to disappear without the turning of either eye. If the false f, instead of being at z′, stands directly under f″, it is so because the right eye, in assuming its position of rest, has its visual axis pointing to f′ (esophoria). On removing the prism the false f would jump into the position of f″ and would remain there so long as the right visual axis points to f′. This diplopia would not be tolerated. To overcome it, the fusion faculty would unlock the right fourth basal center and cause neuricity to flow to the right externus, whose contraction would pull the eye so as to quickly bring its visual axis from f′ to f. The left eye, throughout the diplopia, and during the recovery of binocular single vision, has remained stationary, for it has received no fusion impulse. The right fourth basal center alone has acted, and only the external rectus of the right eye has responded. Any impulse to any muscle of the left eye would have made its visual axis leave the point f. In the same manner the left eye could be tested, and by the test the left fourth fusion center could be found.

Placing the prism, base up, before the right eye, the false f would be thrown directly down to z′; but instead of appearing directly below f, it would seem to be under f′, and only because excessive tonicity of the externus of the right eye (exophoria) has turned it out so that its visual axis points to f″. On removing the prism the false f would jump to the position of f′ and would remain there, if no fusion effort were made; but instantly the right third fusion center alone would be excited, and its discharged neuricity would compel the right internus to pull the right eye so that its visual axis shall move from f″ to f. In this fusion effort not a muscle connected with the left eye has received any impulse, else its visual axis would have been carried away from point f. By applying the test to the left eye, the existence of the left third basal center could be demonstrated.

By placing a 10° prism, base in, before the right eye, a false f would be thrown to d. If the false f appears to be at d, it is because of the fact that the superior and inferior recti of the right eye are equal in tonicity; and notwithstanding the diplopia, the right visual axis continues to point to f. Removal of the prism makes the false f jump at once into the true f, and that, too, without any movement of either eye. But if the false f appears under d, on a level with z′, it is because the right superior rectus, endowed with an excess of tonicity (hyperphoria), has elevated the eye so that its visual axis points to z. On removal of the prism the false f would jump into z′ and would remain there, if no effort at fusion were put forth; but this effort at fusion will be made and the diplopia will disappear. The power this time comes from the right second basal center, and it acts only on the right inferior rectus, which at once turns the eye down so that its visual axis shall point to f.

With the 10° prism, base in, before the right eye, the false f may be made to appear above d, on a level with z, because of excessive tonicity on the part of the right inferior rectus (cataphoria). Now the visual axis will point to z′. On removal of the prism the false f will jump into z and will remain there, should the right visual axis continue to point to z′. To overcome this diplopia, the right first basal center calls into action the right superior rectus alone, and by this action the right eye is elevated so that its visual axis may point to f, the diplopia disappearing at that moment.

The existence of the right first and second basal or fusion centers has thus been proved from a second standpoint. Placing the 10° prism before the left eye, the fact of the existence of the left first and second fusion centers can be shown. The eight fusion centers, each controlling a single rectus muscle in the interest of binocular single vision, certainly exist.

A Maddox triple rod placed vertically before each eye, with a 6° prism, base up, behind the right rod, will make two streaks of light when a candle or gas jet is the test object. The upper streak should be fixed. If the lower streak is parallel with the upper one, it is because the right superior and inferior obliques are equal in tonicity. If the lower streak diverges from the upper at their left ends, it is because the right inferior oblique possessing an excess of tonicity, has tilted the horizontal retinal meridian down at the right (plus cyclophoria). Removing the 6° prism, the two streaks can be made to blend throughout only because the right sixth fusional or basal center compels the right superior oblique to restore the horizontal retinal meridian to its correct position in the horizontal plane, a-b-c-d. No other center has acted on any other muscle connected with either eye. If, with the prism behind the right rod, the lower streak has lost parallelism by leaning down to the right, this would be due to the fact that the right superior oblique, with excessive tonicity, has torted the right eye in (minus cyclophoria). On removal of the prism the two streaks could blend only because of activity of the seventh basal center compelling the weak inferior oblique to replace the horizontal meridian in the horizontal plane, from which it had been thrown when the eye was off its guard. Thus has it been proved that there are right sixth and seventh basal or fusion centers. By placing the prism behind the left rod, the fact of the existence of the left sixth and seventh basal or fusion centers is also provable.

No additional proof should be necessary in order to convince even the most skeptical concerning the twelve fusion centers, and the tasks they are set to perform. The one remaining method of proving their existence is the duction test. This must be studied in connection with Fig. 9 in order that the whole truth may be told about them.

Duction test. The best means for taking the duction power of the recti muscles is the Risley rotary prism of the monocular phorometer, shown in Fig. 25, but this test may be made by means of the loose prism in the refraction case. With the rotary prism, the fusion centers involved will discharge neuricity in increasing quantity, as the image is being gradually moved, up to the point when fusion is no longer possible. The placing of a loose prism before the eye excites suddenly, and to the full extent, the fusion center and the muscle under its control. In the former method the eye glides gently; in the latter method the eye jumps violently. Each method is as capable as the other in proving the existence of the individual fusion centers connected with the recti muscles. Since the author prefers the revolving prism, that method will be made to give evidence concerning the existence of these centers in the still further study of Fig. 9. The phorometer, without the supernumerary displacing prism, should be placed in front of the right eye in position for taking abduction and adduction with zero vertical. With the index at zero, the two orthophoric eyes will fix the point f as a result of muscle tonicity only. By turning the index in the temporal arc, the image of f on the right retina will be carried nasal-ward—that is, toward e—in that eye. The only way to prevent diplopia is for the macula to keep under the moving image. Since the image is moving nasal-ward on the horizontal meridian, the macula must move directly nasal-ward and in no other direction. This motion of the eye is accomplished by a discharge of neuricity from the right fourth basal center to the right externus alone. During this revolution of the prism, no other brain-center has been excited, and no other ocular muscle has contracted.

When the index has been returned to zero, there is easy binocular vision at the expense of muscle tonicity only. Revolving the index of the prism into the nasal arc will make the image of f move templeward—that is, toward a. At the very beginning of the rotation of the prism the right third fusion center becomes active, and the neuricity from it makes the right internus move the eye so that the macula may remain beneath the moving image. This action of the third right fusion center on the right internus alone has prevented diplopia. No impulse has gone from any other center to any other muscle belonging to either eye. Thus abduction and adduction of the right eye prove the existence of the right fourth and third fusion centers. In the same manner abduction and adduction of the left eye may be made to prove the existence of the left fourth and third fusion centers.

The prism should now be placed before the right eye for the taking of super-duction and sub-duction, with zero horizontal. With the index at zero, the two orthophoric eyes will have easy binocular single vision at the expense of muscle tonicity only. When the index is being rotated into the upper arc, the image of f on the right retina is made to move downward on the vertical meridian. The macula must remain under the moving image, else the object f will be doubled, the false f appearing directly above the true f. This moving of the macula is made possible by the contraction of the right superior rectus, in response to an impulse coming from the right first fusion center. No other muscle contracts, nor does any other center discharge neuricity for effecting this fusion. The slight torsion that would occur in sub- and super-duction is of course counteracted by the superior and inferior obliques respectively, controlled by their individual centers, the sixth and seventh conjugate, but this demand is so slight as to be negligible in this test. (In sub-version and super-version, the obliques and the centers controlling them cannot be ignored.)

Returning the index to zero relieves both the right first fusion center and the right superior rectus from further activity. If the index is now made to move downward, the image of f on the right retina will be moved upward on the vertical meridian. The macula must be kept under the moving image or a false f will appear directly below the true f. To prevent this diplopia, the right second fusion center will be made to discharge neuricity to the right inferior rectus alone. No other center and no other muscle will be brought into action for maintaining this fusion, and this center and its muscle cease activity the moment the index is returned to zero. Thus the taking of right super-duction and sub-duction proves the existence of the right first and second fusion centers. By placing the prism before the left eye in position for taking left super-duction and sub-duction, the existence of the left first and second fusion centers may be proved.

In all these duction tests it will be observed that fusion has been accomplished in violation of the law of direction as it applies to the right eye. As the macula moves in, the visual axis moves from f toward f″; as the macula moves out, the visual axis moves from f to f′; as the macula moves downward, the visual axis moves from f toward z; and as the macula moves upward, the visual axis moves from f toward z′. The fused point, f, is on the visual axis of the eye not under test, but is off the visual axis of the ducted eye. In the duction act of fusion, the line connecting the fused point and its displaced image is not a true line of direction, for it does not cut the center of the retinal curve.

The existence of the individual fusion centers for the obliques cannot be proved by prisms, but the Maddox rods give positive evidence. With a triple rod before each eye, set vertically, and with no prism behind either rod, the test candle will appear as a single streak of light. Turning the right rod toward the temple, within the arc of possible fusion for an oblique muscle, will not result in doubling the line, but this doubling will be prevented by the right seventh fusion center acting on the right inferior oblique. This activity of center and muscle places the horizontal retinal meridian under the inclined streak of light. If the right rod had been turned toward the nose, in the arc of possible fusion for an oblique muscle, the diplopia would have been prevented by the discharge of neuricity from the right sixth fusion center to the right superior oblique. In each of these efforts at fusion, only one center and one muscle have been active. By these tests the existence of the right seventh and sixth fusion centers has been proved. Leaving the right rod vertical and turning the left rod slightly out and in would prove, in like manner, the existence of the left seventh and sixth centers.

A final source of proof concerning the existence of the four fusion centers for the oblique muscles is oblique astigmatism of one eye, while the astigmatism of the other eye is either vertical or horizontal. In the latter eye a horizontal line will have a horizontal image, but in the former eye the image of the horizontal line will be displaced toward the meridian of greatest curvature, hence this image will be oblique. To fuse the oblique image with the one that is horizontal, an oblique muscle belonging to the oblique-astigmatic eye, under the influence of the sixth or the seventh center on the corresponding side, must force the horizontal retinal meridian under the displaced image. It would be the seventh center and the inferior oblique, if the most curved meridian is in the upper nasal quadrant; it would be the sixth center and superior oblique, if the meridian of greatest curvature is in the upper temporal arc, whether it be the one eye or the other.

The isogonal circle. There is now neither mystery nor complicated mathematics connected with the circle bearing the three names: horopter, monoscopter, and isogonal circle. The simplicity of this comes as the result of the discovery that the macula is the posterior pole of the eye, and that the center of rotation is the point of crossing of all visual lines. Fig. 12 is a photographic reproduction of the first correct horopteric figure ever published, and was constructed in 1892, immediately after the discovery of the true law of visible direction—viz., all lines of direction are radii of retinal curvature prolonged. Le Conte, in "*Sight,*" first edition (1882), thought he had correctly constructed Mueller's horopter. This is shown in his reproduced figure, Fig. 10, in which the circle is constructed through the two centers of rotation and the point of fixation; but he has ruined the figure by constructing his indirect visual lines in such a way as to make them cross the visual axis at the nodal points. Noyes evidently had the same conception of Mueller's horopter, for he said: "It is a circle which passes through the center of rotation of each eye and the point of fixation of the visual axes." If Noyes had drawn indirect visual lines, he would have made them cross the visual axes at the nodal points, as did Le Conte, in Fig. 10. At any rate, there was something that confused him, for he said: "This statement is not strictly correct, but will suffice for our purposes." No horopteric circle is correct that does not make indirect visual lines cross the visual axes at the center of rotation.

Le Conte, in his 1897 edition of *"Sight,"* published a new figure which he claimed as a true presentation of the Mueller horopter. This 1897 figure is reproduced in Fig. 11. This circle is constructed through the two nodal points and the point of fixation, and the direct and indirect visual lines are made to cross each other on the circle. Le Conte's two figures, as here reproduced, should be studied in contrast with each other. In Fig. 10 the visual axes, under the same angle of convergence, could move from point to point on the circle, each eye around the point common to the visual axis and the circle; but the visual axes A–c abd A–c′ could never be made to take the place of the indirect visual lines B–b and B–b′, for his indirect visual lines do not cut the visual axes at the centers of rotation, but at n and n′, the so-called nodal points. It will be further observed that the two eyes in Fig. 10 are ideal eyes of Helmholtz, in that the visual axes pass through the centers of rotation.

As erroneous as is Fig. 10, Fig. 11 is still worse. If the visual axes A–c and A–c′ should move from A to B, neither eye would rotate around a point common to its visual axis and horopter, hence the points n′ and n would be made to leave the circle; or if the circle should move with the nodal points, it would be forced to leave the points A and B. It is equally clear that A–c and A–c′ could never be made to take the positions of B–b and B–b′.

The true horopter, in the sense that it is the circle of binocular single vision, both direct and indirect, as shown in Fig. 12, is based on three great facts: (a) The macula of all eyes is the posterior pole, and the visual axis is the antero-posterior axis of the eye; (b) all indirect lines of vision cross the visual axis at the center of rotation; (c) corresponding retinal points have a common brain-cell connection, and these points bear identical relationship, in degrees, to their respective maculas. In this figure the circle is constructed through two fixed points and one changeable point, the former being the centers of rotation of the eyes, b and d, and the latter the point of direct fixation. This circle is b–d–e–c–a. Any point so situated on the circle as to throw light into the two eyes will be seen as a single point, for the images will be on corresponding retinal points. The direct point of view, c, and its images, h and g, will be connected by lines that cut the centers of rotation, b and d. The secondary point of view a and its images, j and f, will be connected by lines passing through the centers of rotation, b and d; and the secondary point e will be connected with its images, l and k, by lines that cut the visual axes at the centers of rotation. That all points on this circle, whether direct or indirect, will be seen under the same angle, is proved by the fact that each angle is measured by half the arc b–d, for each is an inscribed angle, with this common arc. If the visual axes should be moved from c to a, they will take the positions of the indirect visual lines, a–j and a–f; if the visual axes should be moved from c to e, they will take the positions of the indirect lines, e–l and e–k. The figure also shows that the direct and indirect points of view are related in degrees as are their respective images. The angle c–b–a is an

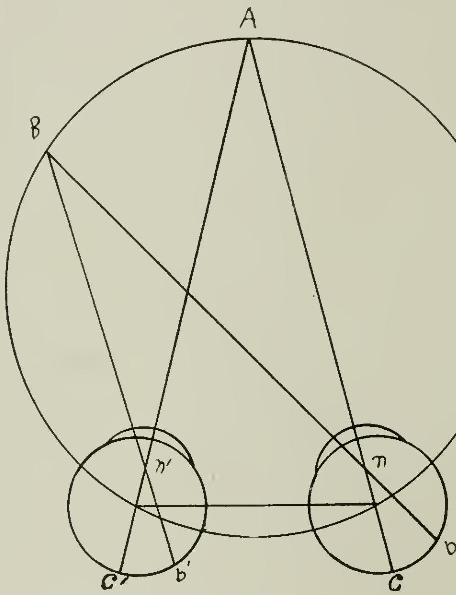


Fig. 10.

inscribed angle and is measured by half the arc a–c. The angle h–b–j is an angle at the center and is measured by the whole arc h–j. But these angles are opposite and are, therefore, equal. The angle a–d–c is equal to the angle a–b–c, for it, too, is measured by half the same arc, a–c; therefore the angle g–d–f is equal to the angle h–b–j. Since j and f are similarly related, in degrees, to the maculas, h and g, they are corresponding retinal points, for such points have common brain-cell connection. The statements made above are strictly correct, and, therefore, Fig. 12 will suffice for all purposes in the study of binocular single vision and binocular rotations.

Points on the circle whose indirect visual lines cross m–c at the same point are equally far removed from the direct point of view.

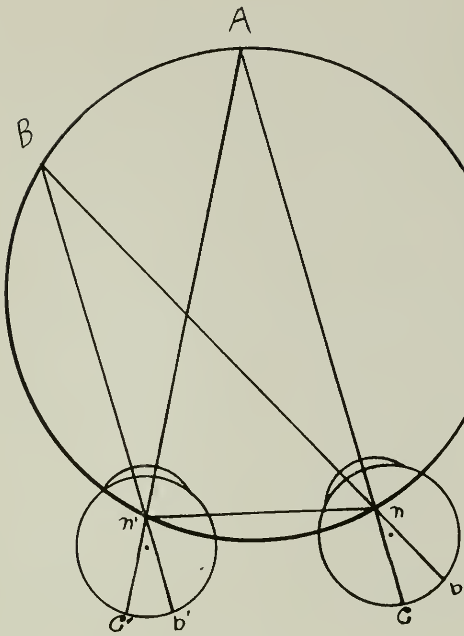


Fig. 11.

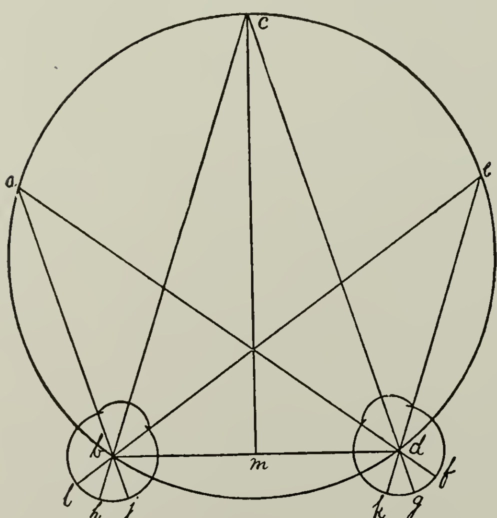


Fig. 12.

To show this, the line m–c was drawn. For a different purpose entirely, and one more practical, the line b–d was placed in the figure.

Isogonal surface. Having demonstrated the curved line of binocular single vision, it was only one step to the demonstration of the curved surface of binocular single vision. The author suggested to Dr. Manning Brown, now of Hopkinsville, Ky., then his private student, that this surface could be generated by revolving the circular plane, b–d–e–c–a, on the cord, b–d. Doctor Brown at once volunteered to have this peculiar surface of single seeing made in wood, by means of the skillful use of the turning lathe. This he succeeded in doing. This oddly, but beautifully, shaped piece of wood was then cut along a plane including the line b–d, into two equal parts, with a very delicate saw. Each of the two cut surfaces presented a plane the outlines of which were large segments of two circles, as shown in Fig. 13, which represents a vertical section of this model.

It is clear that the parts above and below b–d are precisely alike. In this figure, b and d represent the centers of the two eyes, and b–d is the line connecting these centers. The circular planes shown on either side of b–d each represents perfectly the plane of the horopter. A section made from any point on the surface of this model, along a plane including the line b–d, would have shown the two conjoined horopteric planes just as depicted in Fig. 13. As on the line, so on the surface generated, there is not a point so situated as to send light into the two eyes but that it would be seen as a single point with the two eyes. The concave area of binocular single seeing is clearly shown in the Brown model.

The section of this model should have led at once to the making of Fig. 14, but, in fact, it was fifteen years later (1907) before the author found the artist who could make this complicated figure, to be studied further on.

Referring again to Fig. 12, it may be stated that, since b–d–e–c–a is the line of binocular single vision, all points within and beyond it should be seen double. This is literally true as applied to small circles; and it is always true as to nearby points, however large the circle may be. If the horopteric circle has a diameter of thirty feet, objects beyond will not appear as double, though points, if they could be seen so far, would be double. Even the double appearance of nearby objects, when the circle is small or large, is not confusing, nor is it hurtful, for no attempt is made by the mind or eyes to fuse such images.

In 1898, Maddox published in his book, *"The Ocular Muscles,"* a cut which he named the "Isogonal circle." This circle he constructed through the centers of rotation and the point of fixation. In the cut he had no indirect visual lines, but only the two visual axes, converged first on the direct point on the circle, and then rotated to a secondary point. His purpose was to show that the angle of convergence was the same for the two points. If he had seen, he had not accepted, the

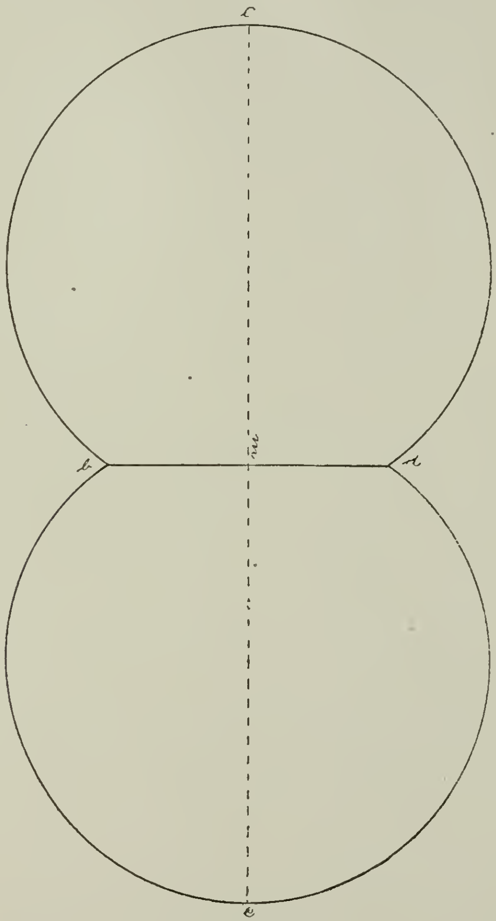


Fig. 13.

teaching of the author that all points on this circle, whether direct or indirect, were seen as single points and under a common angle. The author, some years before, had named Fig. 12 "the monoscopter," the meaning of which is "line of binocular single vision." Either one of the names is better than the older name, "horopter," which means "the limit of seeing." Since points, to be seen as single, must be under the same angle, and for other reasons, the name "isogonal circle" is preferable to the name "monoscopter." The name "isogonal circle" may be defined as follows: The circle on which all visual lines, lying in a common plane and coming from corresponding retinal points, converge, each two lines forming the same angle as do all other two lines. This has been shown to be true in the study of Fig. 12. The name "isogonal" may be made to apply to the surface of single seeing as well as to the circle. "Isogonal surface" may be defined as follows: The two visual lines, whether direct or indirect, from cor-

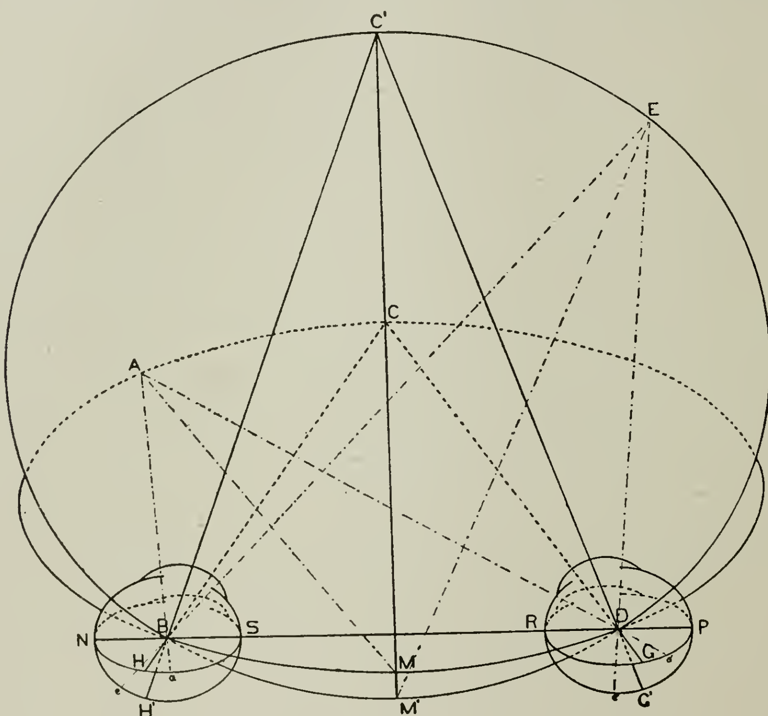


Fig. 14.

responding retinal points, converging at any point on this surface, form the same angle as the two visual lines converging at any other point on this surface.

The definition of the isogonal circle as given by Maddox, in connection with his figure of the circle constructed through the centers of rotation and the point of fixation, is as follows: "It is the curve of uniform convergences and of equal lateral ductions for the two eyes." A just criticism of this definition is that "versions" should be substituted for "ductions."

In the study of Fig. 14, published for the first time in 1907, the author accepts the name "isogonal circle" in its fuller meaning, in preference to either of the two other names—"horopter" and "monoscopter." Equal angles of all two visual lines from corresponding retinal points on a circle (isogonal) means binocular single vision; binocular single vision of points, on a circle (monoscopteric) means equal angles. Since the two terms mean practically the same thing, "isogonal" has the preference over "monoscopteric" when joined with "circle," because, if for no other reason, it is more easily pronounced and is more pleasing to both the ear and the eye.

The spherical concavity of the retinas, corresponding retinal points, and the law of visible direction, make possible the mathematical circle and surface of binocular single vision. In the light of Fig. 14, the isogonal circles will be studied as belonging to one of two classes. To the first class belongs only one circle, and there is no better way to distinguish it from the many members of the other class, than by naming it the *primary isogonal circle.* The circles of the other class should be known as *secondary isogonal circles.*

The primary isogonal circle. In Fig. 14 M–C represents the extended median plane of the head, and C is a point on the line of intersection of this plane and the horizontal plane of the head. With C as the point of fixation, the primary isogonal circle must pass through it. The other two points through which this circle must pass are the centers of rotation of the two eyes, B and D. The primary isogonal circle, B–D–C, thus constructed, presupposes that both the head and the eyes are in their primary positions. The distinguishing fact of this circle is that in its plane lie the two visual axes and the two horizontal retinal meridians, and that the visual axes are converged to a point on it. On either side of the point of fixation are many indirect points of view on this circle, and in its plane lie twice as many indirect lines of vision, for to each point belong two lines.

The secondary isogonal circles. The secondary isogonal circles are constructed through the two centers of rotation, B and D, and through indirect points of view lying in the extended vertical plane of the head, both above and below C, each and all of these points being the same distance from the point of intersection of M–C and B–D as is the point C. Fig. 14 shows only one of these secondary circles, B–D–C′. Lying on this circle—to either side of C′, itself a secondary point—are many other secondary points of view, and in its plane lie only indirect visual lines, two for each point. The plane of no secondary isogonal circle contains a retinal meridian, but it intersects the planes of all the retinal meridians. The number of secondary isogonal circles can be computed, if they should be considered as only 1″ apart. By reference to Fig. 21, it will be seen that the upper part of the field of binocular single vision is 55° and the lower part of this field is 70°. This would give 198,000 secondary isogonal circles above the primary circle, and 252,000 below it, making a total of 450,000 secondary circles to one primary isogonal circle.

All isogonal circles, whether primary or secondary, are alike in the following respects: (a) They are all constructed through two common points, the centers of rotation, B and D, of the two eyes; (b) they all have a common cord (B–D), the line connecting the centers of the two eyes; (c) they are all bisected by the extended median plane of the head; (d) all points on all of the circles, belonging to one group, so located as to send light into the two eyes, will be seen as single points; (e) the two lines of vision connecting any secondary point, on any circle of a given group, with its two images, have the same angle as that formed by the convergence of the visual axes on the point of direct view—angles B–A–D, B–C′–D, and B–E–D are equal to the angle B–C–D.

What has been said above in (a), (b), and (c) applies to all circles of all groups. What has been said in (d) and (e) applies to any single group of isogonal circles—circles that have the same diameter. An infinite number of points lie on the line of intersection of the extended vertical and horizontal planes of the head, and each of these points may become the primary point of view—the point of direct fixation. For each of these points there is a possible primary isogonal circle; hence the number of possible primary isogonal circles is infinite, but only one can exist at a time. Each new primary isogonal circle creates a new group of secondary circles, all of equal size.

There is no point in the space devoted to binocular single vision (see Fig. 21) that does not lie on some isogonal circle, or in the plane of one of these circles. The field of binocular rotations is a little smaller than the field of binocular single vision, but any secondary point within this smaller field may become the point of fixation, and that, too, regardless of the size of the circle on which the secondary point may be located.

The degree of convergence of the visual axes at a secondary point will be the same as if they were converged on the direct point of that primary circle which belongs to the same group. This is well shown in Fig. 14, in which the visual axes can be considered as moved, first from C to C′, and again from C′ to E. In either case the visual axes have been made to take the position of indirect lines, under the same angle of convergence.

If the point for indirect fixation is on a smaller or larger circle than is the primary point of view, the primary circle, which must change with the degree of convergence of the visual axes, must grow smaller or larger until it shall finally include the secondary point to be fixed. If, at the beginning of a rotation, the second point of view lies on the circumference of the primary isogonal circle, that circle neither enlarges nor does its plane move, while the visual axes move from one point of view to the other. If the second point is at a greater distance than the first point, but in the plane with it, the circle enlarges, but the plane does not move, as the visual axes pass from one point to the other. If the secondary point of view is in the plane of a secondary isogonal circle, of a given group, the plane of the primary circle moves into the position of the secondary circle, as the visual axes converge on the second point. No point in viewable space can be fixed until the plane of the primary isogonal circle is made to include it, as the visual axes converge upon it.

From the foregoing it will be seen that the plane of all isogonal circles are movable planes, and that the common axis around which they rotate is the line connecting the centers of the two eyes—the line B–D in Fig. 14. If the visual axes rise, the primary isogonal rises with them; if the visual axes must be depressed, the primary isogonal circle must go down with them. As the primary isogonal circle rotates, all secondary isogonal circles rotate with it, in the same direction and to the same extent. Thus, within the limit of vertical rotations, the plane of the primary circle may be made to assume the former position of the plane of any secondary circle. As the plane of the primary circle rises and falls, the visual axes move in the moving plane, if the second point is obliquely located, so as to converge on the second point of view at the moment that the plane reaches that point. In doing this the point of convergence moves along a binocular special meridian. (See Fig. 21.)

The isogonal circles are possible of construction only because: (1) the central point of the macula of all eyes is the posterior pole; (2) the visual axis of every eye is the antero-posterior axis of the eyeball; (3) all indirect lines of vision—lines connecting secondary objects and their respective retinal images—cross the visual axis at the center of the retinal concave, and therefore are radii of retinal curvature prolonged.

That Le Conte did not accept the macula as the posterior pole of the eye, except in the case of the ideal eye, and that he denied that the crossing point of all visual lines was the center of retinal curvature, are made sufficiently clear in Figs. 10 and 11, his two horopteric curves, number 11 being the last one devised by him. In Fig. 10 the central point of the macula is the posterior pole, but in this figure, as in the other one, he has the secondary lines of vision crossing at the Helmholtz nodal point. In Fig. 11 the central point of the macula is not the posterior pole, for if it were the visual axis would cut the center of the retinal curve in this figure as in Fig. 10. Yet Le Conte in his book on *"Sight"* said two things: (1) "For every retinal point there is a corresponding spacial point;" and (2) "The rods and cones see end-on." The first statement could be true only because corresponding retinal and spacial points are on concentric retinal and

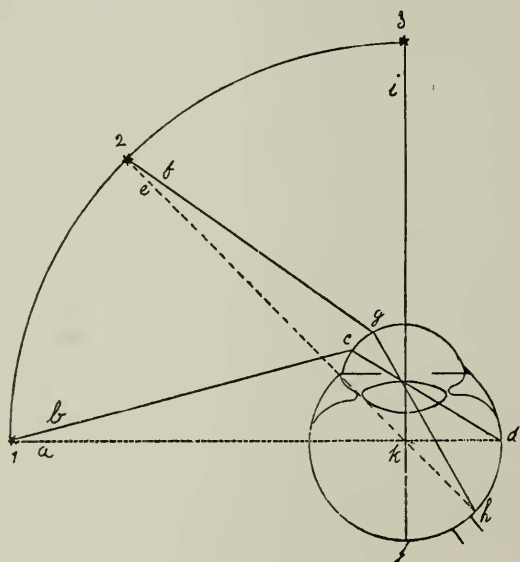
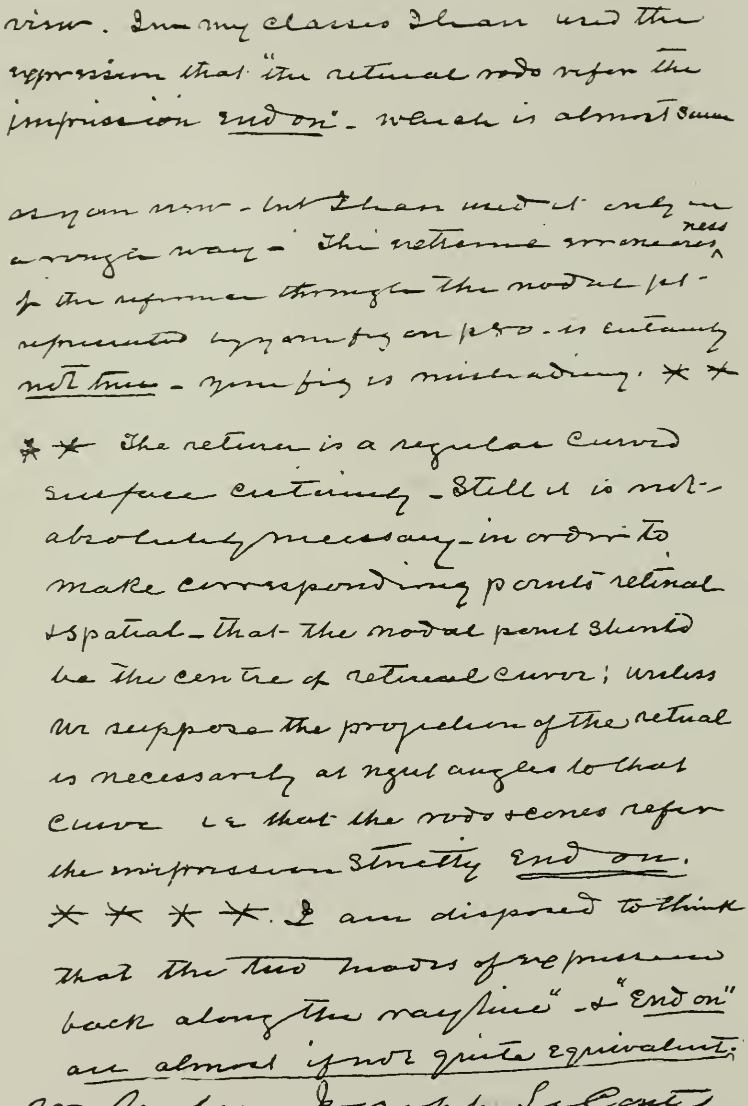


Fig. 15.

spacial curves, the common center being the center of the retinal curve, which is the center of rotation. The second statement would literally mean the same thing, for the rods and cones all point into space through the center of retinal curvature. In his letter herewith reproduced, in part, he denies that the lines connecting corresponding retinal and spacial points cross at the center of the retinal curve, but reaffirms his belief in the axial "ray-line" theory of Helmholtz. He further declares that the expression, "the retinal rods refer the impression end-on" was used by him in only a rough way. His two horopters, Figs. 10 and 11, and his reproduced letter show conclusively that he did not believe the three things essential for the construction of the true horopter, Fig. 12. Without the true horopter or primary isogonal circle there could be no correct law of binocular rotations.

The figure referred to in the seventh line of the Le Conte letter was on page 80 of the author's "*New Truths in Ophthalmology*" (first


view. In my classes I have used the expression that "the retinal rods refer the impression end on" - which is almost same as you now - but I have used it only in a rough way - The extreme erroneousness of the reference through the nodal pt - represented by you on p. 80 - is certainly not true - your fig is misleading. * *

* * The retina is a regular curved surface certainly - Still it is not absolutely necessary - in order to make corresponding points retinal & spatial - that the nodal point should be the centre of retinal curve; unless we suppose the projection of the retinal is necessarily at right angles to that curve i.e. that the rods & cones refer the impression strictly End on. * * * *. I am disposed to think that the two modes of expression back along the rayline" - & "End on" are almost if not quite equivalent. Very truly Joseph Le Conte

edition). The thing represented in that figure, and declared by Le Conte not true, is the crossing of the visual lines at the center of retinal curvature—the center of rotation—for this was the one truth taught by that illustration. That figure is reproduced here, as Fig. 15, to speak for itself in favor of the "retinal—radius" theory of visible direction, as against the "axial—ray" theory. In this figure the corresponding retinal and spacial curves, each an arc of 90°, are shown. The retinal curve is j–h–d, the spacial curve is 1–2–3, and the common center of these two curves is h.

For the special points 1, 2 and 3 to correspond with the retinal points, j, h and d, the lines connecting them in the order given must cut the center of rotation k. If a line were drawn from d through Helmholtz' nodal point, in the posterior part of the lens, it would strike the spacial curve about half-way between 1 and 2, which would miss the source of light, 1, by more than 20°.

The law of binocular rest and motion. The twelve extrinsic muscles of normal eyes, under the control of the nine conjugate, and the twelve fusion, brain-centers, must so relate the two eyes that their two visual axes and the two horizontal retinal meridians shall always lie in the plane of the primary isogonal circle, whether at rest or in motion, and that the two visual axes shall converge at some point on this circle, in the interest of both binocular single vision and correct orientation.

The two eyes, while obeying the law of binocular rotation, do not violate the law of monocular motion. Each visual axis moves in the plane of that individual retinal meridian projected into space, on which lie both the first and the second points of view, during which motion the vertical axis of the eye will be kept parallel with the median plane of the head. The fusion centers, not used in monocular rotations, are essential in binocular rotations. Without the fusion centers, even when muscles are normal in tone, all oblique rotations would be attended by diplopia; and without them, muscles of unequal tonicity would cause diplopia, whether the eyes be at rest or in motion, as shown in the study of Fig. 9.

The cord common to all isogonal circles—the line, B–D (Fig. 14) connecting the centers of the two eyes—should always lie in the horizontal plane of the head; but this cannot be, if one eye is set lower in the orbit than is the other. Even in such faulty eyes the horizontal retinal meridians must lie in the plane of the laterally inclined primary isogonal circle, when both eyes are being used. Should the plane be inclined to 5°, the vertical axes of the two eyes must be inclined through the same arc, toward the side of the lower eye. This would be effected by activity of either the eighth or ninth conjugate center, on the superior oblique of one eye and the inferior oblique of the other, the former if the left eye be lower, the latter if the right eye be lower. With one eye covered, as in the work of refraction, the conjugate center would cease its activity and the eye would then have its vertical axis normally related to the median plane of the head. On uncovering the eye, the two vertical axes would be tilted again toward the side of the lower eye. The practical point growing out of this observation is that such eyes would require the shifting of the axes of correcting cylinders toward the side of the lower eye, through arcs corresponding to the lateral displacement of the horizontal retinal meridians.

In the interest of binocular single vision, but against correct orientation, the horizontal retinal meridians of uncorrected oblique astigmatic eyes must be forced out of the plane of the primary isogonal circle. This subject has been given proper emphasis in the section on **Oblique astigmatism.** In that section the sixth and seventh conjugate centers are represented, respectively, as the source of power for converging and diverging the vertical axes of the eyes in the interest of fusion of displaced images. It probably would be more nearly correct to say that this work is accomplished by the right and left sixth, and the right and left seventh, basal centers, as has been pointed out in the study of Fig. 9. The fusion function must be under the control of the fusion faculty of the mind, and this faculty presides over the single basal centers, right and left.

Emmetropia and orthophoria make it easy for the ocular muscles to obey the law of binocular rotation. Hyperopia and myopia interfere with the act of convergence; oblique astigmatism, with meridians of greatest curvature diverging or converging, makes it impossible for the obliques to keep the horizontal retinal meridians in the plane of the primary isogonal circle; hyperphoria and cataphoria make it hard for the superior and inferior recti to plane the visual axes; exophoria and esóphoria make difficult the task of converging the visual axes to points on the circle, and the shifting of the visual axes in the plane of the circle by the lateral recti. In the light of these facts, it would appear that the eyes, not naturally emmetropic and orthophoric, should be made so by art.

The muscle indicator. This device is the primary isogonal circle put in material form, as shown in the half-tone picture, Fig. 16. The circle o–M–N–o passes through the centers of rotation, o and o, and through the direct point of fixation, shown at the intersection of the visual axes. The horizontal retinal meridians are represented by the two circles, E and E, each passing through two vertical slots, S and S. They both lie in the plane of the larger circle, and each is supported in that position by the two clips, C and C. Each visual axis, V–A, extends from the macula at E, through the center of rotation, o, on through the cornea, either at or near its center, thence across the circle to meet its fellow-axis at the point on the circle through which passes the extended median plane of the head. The visual axes, as well as the two horizontal retinal meridians, are lying in the plane of the circle. The clips, C and C, across the front vertical slot, S, prevent the visual axes from rising above or falling below this plane. Each visual axis is made of two pieces of copper wire and a tube, so as to make both lengthening and shortening possible, as the point of view may be changed. The horizontal slot, M–N, allows the moving of the point of fixation of the visual axes both to the left and to the right. The slot, M–N, does not quite reach the limit of lateral rotations, but

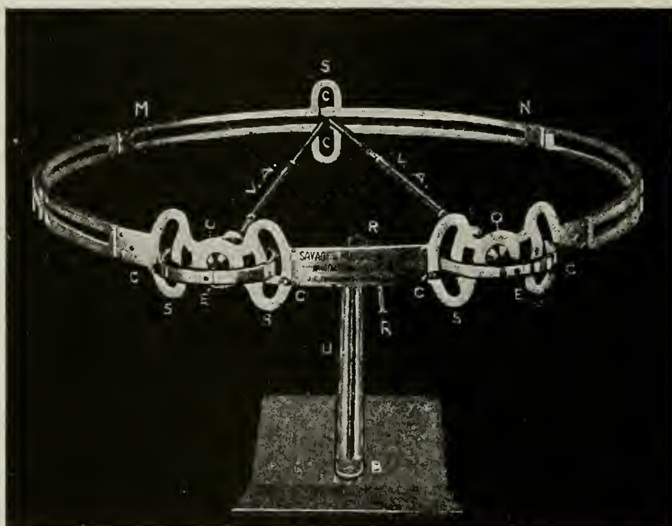


Fig. 16.

it extends far enough to show how the visual axes can be made to move in the plane of the circle, around the centers of rotation, o and o. The circle is supported by the upright, U, attached to the base, B. At the upper end of the upright there is a screw attachment for either fixing the circle in the horizontal position, or allowing it to rotate up or down, on the cord, o–o, the line that connects the centers of the two eyes. The screw is worked by the sliding rod, R–R. Imagining that the real circle in Fig. 16 has a diameter of twenty feet, then it will not be hard to conceive that the tonicity of the superior and inferior recti of orthophoric eyes has planed the visual axes, and that tonicity of the lateral recti has converged them; nor will it be a difficult matter to understand that the tonicity of the superior and inferior obliques has planed the horizontal retinal meridians. The clips, C and C, front slot, S, represent the power that keeps the visual axes planed, and that power resides in the superior and inferior recti. The four clips, C, across the vertical slots through which the horizontal meridians pass, represent the power that planes these meridians, and this power resides in the superior and inferior obliques. When the tonicity of either of these pairs of muscles is unequal, the planing of the visual axes or the horizontal retinal meridians, as the case may be, can be maintained only by contractility of the weaker muscle of a pair. Should the lateral recti muscles be unequal in tone, the visual axes would tend to cross, either within or beyond the circle, and only contractility of the weaker muscle of each pair would compel them to converge on the direct point of view.

If tonicity keeps the horizontal retinal meridians and visual axes in the plane of the ordinary isogonal circle, when lying in the horizontal plane of the head, and converges these axes at the direct point of view on this circle, the rotations will all be effected by the normal expenditure of neuricity. That the visual axes, when rotated from one point of view to any other point of view, assume the exact positions of the two indirect visual lines which connected the second point of view and its two images, before the rotation began, can easily be shown by a further study of Fig. 16, in connection with a glance at Fig. 17. Before rotating the visual axes from the primary point, shown in Fig. 16, to the secondary point, N, directly to the right, two wires should be made to extend from N, directly over the right end of the horizontal slot, M–N, the one wire back to the right retina and the other back to the left retina, each passing over the center of rotation, o, of its eye. These wires should be firmly held in their respective positions while the visual axes are rotated from the direct point of view to N, as shown in Fig. 17. At the end of the rotation it will be found that the two visual axes lie directly under the two wires which were made to represent the two indirect visual lines.

If each of the two wires representing indirect visual lines, going from N, were carried over the nodal point of its eye, back to a point directly above the supposed location of the image on its retina, and these wires should be firmly held while the visual axes are rotated from the direct point to N, it would be seen that the visual axes do not lie directly under these wires thus placed. This would show that, while the two visual axes have reached the second point of view, the maculas have fallen short of the two supposed images of that point. No man can make these two experiments with the muscle indicator and not be convinced that all lines of direction are radii of retinal curvature prolonged.

Fig. 17 shows that when the second point of view already lies on the primary isogonal circle, the visual axes move from the primary point, in the plane of that circle, to the secondary point, but the circle itself remains stationary.

Fig. 18 shows that when the second point of view is in the vertical

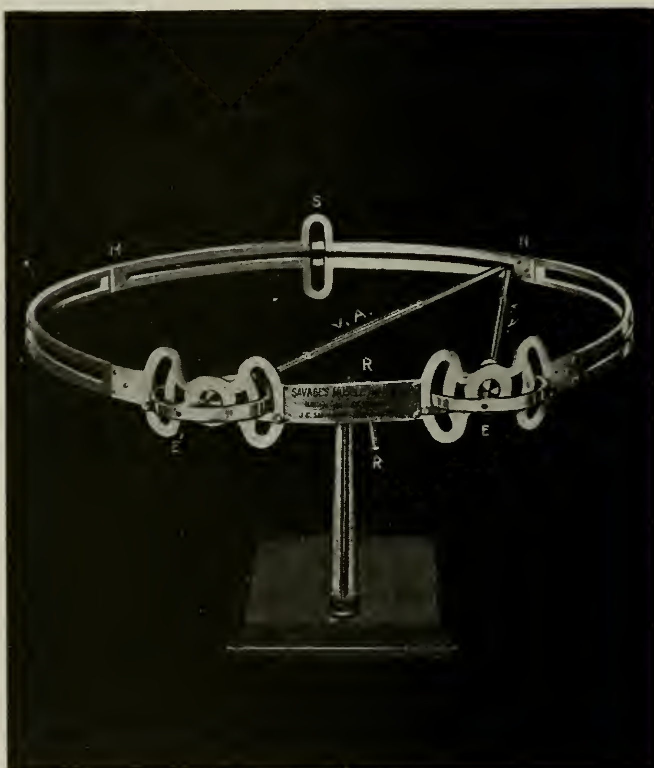


Fig. 17.

plane above the primary point of view, the visual axes are carried upward in the rotating plane of the primary isogonal circle, without change of position in that plane, to the second point of view. The primary circle has been made to take the position of that secondary circle on which rested the second point before the rotation began, and the visual axes have been made to assume the positions of the two indirect visual lines which connected the second point and its two images before the rotations started. In both Figs. 17 and 18 the point of convergence of the visual axes has moved along that binocular spacial meridian on which were lying both the first and second points of view. In the two cardinal directions right and left, the visual axes must move in a motionless plane; in the two cardinal directions up and down, the visual axes must remain motionless, in the moving plane, throughout the rotation. The rotations shown in Figs. 17 and 18 have been accomplished without either the horizontal retinal meridians or the

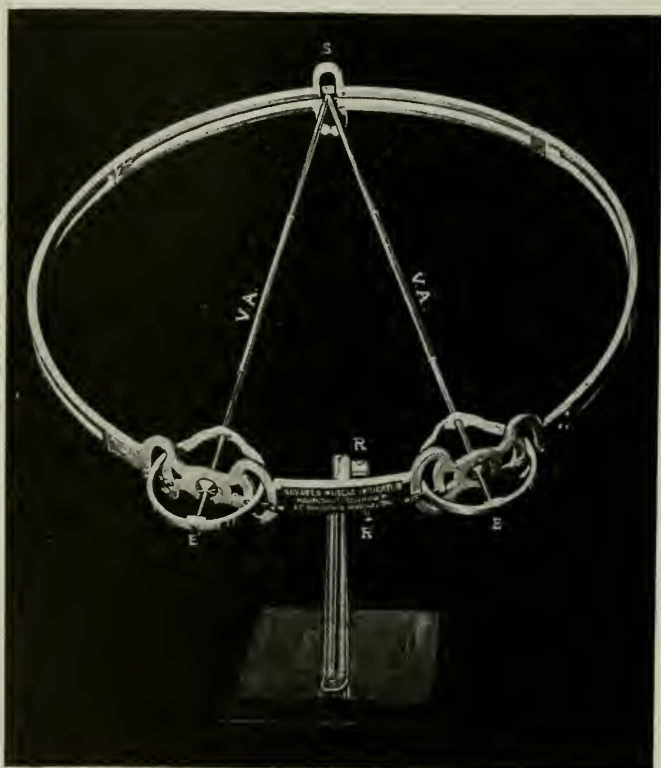


Fig. 18.

two visual axes leaving the plane of the primary isogonal circle, and the visual axes are still converged at a point on the circle. The rotation shown in Fig. 17 has been effected around the vertical axis of the eye, a fixed axis throughout the rotation. That shown in Fig. 18 has been accomplished around the transverse or horizontal axis of the eye, likewise a fixed axis for that rotation. In both of these rotations each eye has obeyed the law of monocular rotation, and the two eyes together have obeyed the law of binocular rotation.

Fig. 19 shows a rotation that has been effected from the primary point of view, as shown in Fig. 16, to a secondary point of view obliquely up-and-to-the-right. The primary isogonal circle has been so elevated as to take the place of that secondary circle on which rested the second point of view before the rotation began; and the visual axes have been made to assume the position of the two indirect visual lines which connected that second point with its two images while the eyes

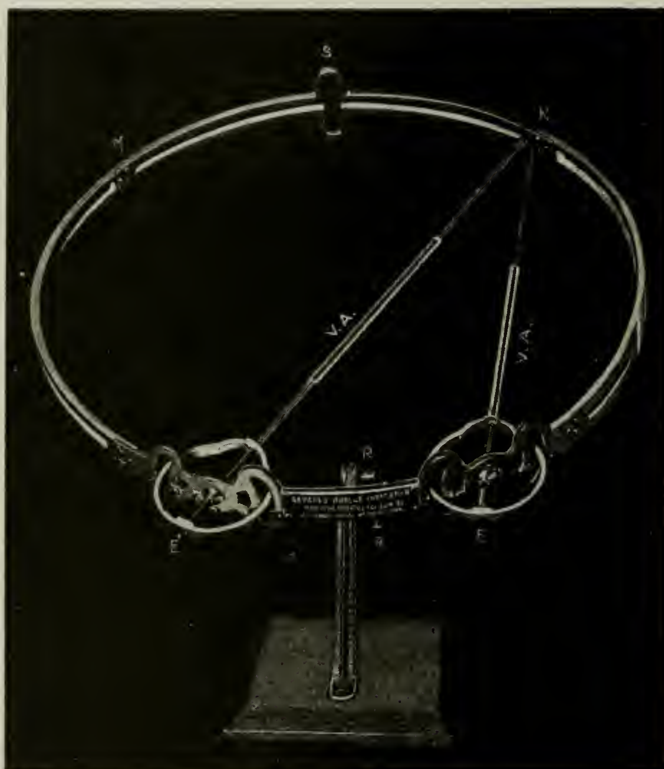


Fig. 19.

were yet fixed on the first point. To fix this obliquely-placed second point of view, the visual axes must rise with the plane, and must move in this plane to the right, as it ascends, so as to converge at the second point the moment the plane reaches it. In this motion with the plane and the other movement in the plane, the point of convergence of the visual axes has moved along that oblique binocular spacial meridian on which were lying both the first and second points of view.

Fig. 19 shows that this oblique rotation has been accomplished with the horizontal retinal meridians still lying in the plane of the primary isogonal circle; and it also shows that the visual axes have remained in that plane and are converged at the proper point on the circle. The plane of the primary isogonal circle has been carried upward with the visual axes of the two eyes, which have been rotated, each around its transverse axis, and the visual axes have been moved in the slot toward N by an accompanying rotation of each eye around its vertical axis.

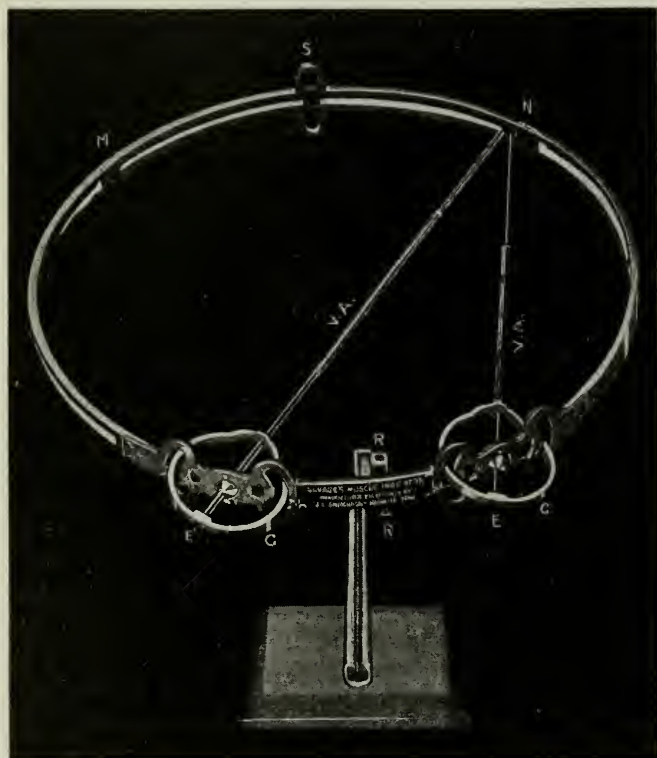


Fig. 20.

Each of these axes, the vertical and the transverse, have been themselves in motion throughout the oblique rotation. The perfectness of this double rotation about the two moving axes has been made possible by the obliques preventing any rotation of either eye around its visual axis. The clips supporting the two horizontal retinal meridians show that these meridians have not been allowed to leave the moving plane of the primary circle. Fig. 19 is representative of all oblique rotations.

In oblique, as in cardinal, rotations, as illustrated, each eye has obeyed the law of monocular rotation, and the two together have obeyed the law of binocular rotation.

If the oblique rotations, illustrated in Fig. 19, had been effected around fixed axes, at right-angles to their respective rotation planes, the horizontal retinal meridians would have been made to leave the plane of the primary isogonal circle, each tilting down-and-to-the-right, as shown in Fig. 20, introduced here to show *what does not occur* in any oblique rotation. Two clips are down.

The muscle indicator proves the existence of corresponding retinal points in that it would not be a possibility if there were no such points. It proves the correctness of the law of direction, as discovered by the author—viz.: All lines of direction are radii of retinal curvature prolonged; for if this were not the true law of direction, the muscle indicator could not have been made. It proves that the macula is the posterior pole of the eye; for if this were not true, the muscle indicator would be a muscle mystifier. Of a muscle mystifier this could not be said: "There is not a single phase of a single ocular muscle, or any combination of ocular muscles, normal, abnormal, or pathological, which the muscle indicator will not show." It is the embodiment of truth, condensed and clarified, concerning all muscle problems. With its aid the mediocre mind may become master of muscle questions which were baffling to the brightest intellects of other days. It is the only device that teaches "the truth, the whole truth, and nothing but the truth," concerning binocular rest and easy motions of orthophoric eyes, and concerning binocular unrest and uneasy rotations of heterophoric eyes.

In an early part of this section, Figs. 1 and 2 were introduced to make easier the study of monocular motion. These two figures are so familiar to all readers, having been seen in practically all books on the eye, it would seem superfluous to say anything more about them. In other books, however, Figs. 1 and 2 only represented the field of vision for the left and the right eyes respectively, as shown within the shadings above, below, and to the inner side. Heretofore the lines traversing the white space were not called spacial meridians, and the point of their crossing has not been known as the spacial pole.

From these two figures the author has been able to construct Figs. 21 and 22. He did this by dividing both Figs. 1 and 2 along the vertical meridians, and then pasting the divided parts together as follows: He transposed the right half of the left and the left half of the right fields, and, bringing these together, he formed Fig. 21, for which there is no name better than *binocular field of vision;* then, without transposing, he brought together the left half of the left field and the right

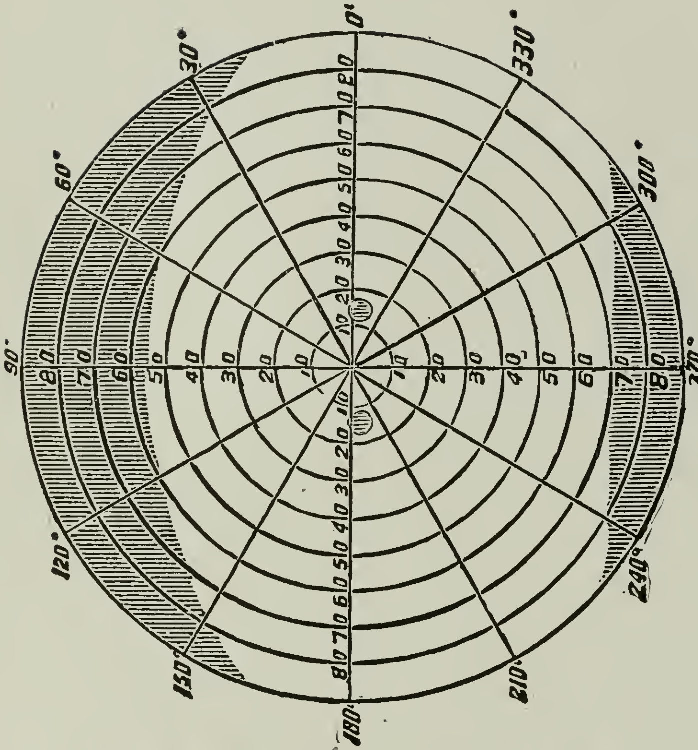


Fig. 22.

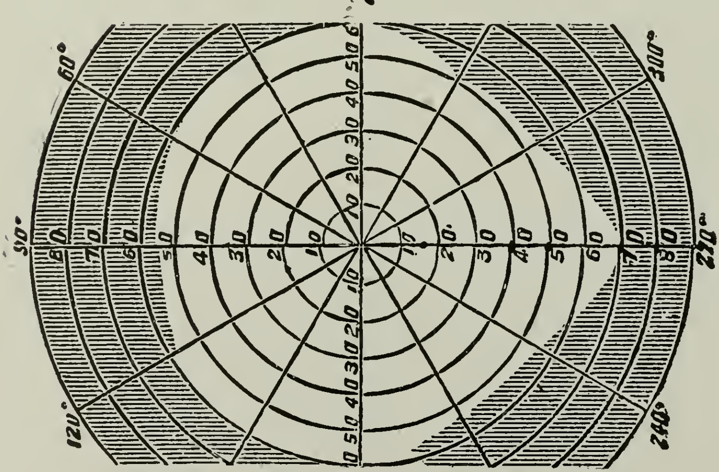


Fig. 21.

half of the right field, thus creating Fig. 22, which he has named the *binocular field of view.*

Fig. 21, although standing separate from, is, in reality, a part of Fig. 22. Fig. 21 represents the field of binocular vision when both the head and the eyes are stationary and in their primary positions. In this peculiarly shaped field every object is seen singly by the two eyes; and every object within this field, further removed than the point of fixation, is seen singly by the two eyes, if that point is distant thirty or more feet. The measurements of this field in the four cardinal directions are: 55° up, 70° down, and 60° to the right and left. In the center of this field is the binocular spacial pole, and passing through this pole are the binocular spacial meridians. Encircling the pole are the parallels, located 10° apart. Since the field of binocular rotations is only a little smaller than the field of binocular single vision, as shown in Fig. 21, practically all the points in this field may become points of fixation, by rotating the eyes, while the head remains stationary. There cannot be a point in this space which will not lie on one of the spacial meridians, except the point of fixation—the binocular spacial pole—which lies on every meridian, at the point of their crossing.

Two points in space are to be considered in every rotation—the first point of view, which is the point of fixation, and the second point of view, which is the point to be fixed. The changing from the one to the other is neither more nor less than the moving of the binocular spacial pole along that binocular spacial meridian on which lie both the first and second points. If the first point of view is the primary point, as in Fig. 21, the second point may be the point of crossing of parallel circle 40 and meridian 120-300, above (any other meridian and parallel might have been chosen). In this case the point of fixation—the binocular spacial pole—would move along this meridian until it reaches the point which was on circle 40. In every rotation the parallel circles move with the pole, so that when the pole (point of fixation) reaches the second point of view, the point of crossing of parallel 40 and meridian 120–300, below, will have moved up to the point which was the primary point before the rotation began. All points that were on that meridian before the rotation began will be on it when the rotation has ended, but they will be differently related to both the binocular pole and the binocular parallels.

In the binocular field of vision (Fig. 21), when the head and eyes are in their primary positions, every point will lie on three circles common, or belonging, to the two eyes—(1) a spacial meridian which determines the relationship (cardinal or oblique) that the point bears to the vertical and horizontal planes of the head; (2) a spacial parallel which marks its distance in degrees from the line of intersection of the two planes of reference; (3) an isogonal circle, primary or secondary, of some group, which determines the angle under which it is seen by the two eyes. Any one spacial meridian and any one spacial parallel can cut each other at only two points, which points are in opposite directions from the spacial pole and equally distant from it.

The easy coexistence of the binocular spacial pole, meridians, and parallels depends on normal conditions of the ocular muscles. There may be a binocular spacial pole and parallels, but no binocular meridians; but such a state can be established only by uncorrected oblique astigmatism, through abnormal work on the part of the obliques. Normal recti and oblique muscles easily create, and maintain, the binocular spacial pole, meridians and parallels, as shown in Fig. 21. Abnormal recti and oblique muscles make it either difficult or impossible to have the binocular spacial pole, meridians, and parallels. The treatment, surgical and otherwise, of abnormal muscle conditions has for its aim the easy creation and maintenance of the binocular spacial pole, meridians, and parallels.

Fig. 22 is a combination of both the field of binocular vision and the field of binocular view. Objects located anywhere within the white area of Fig. 22 will be seen with the two eyes—together if located within the space corresponding in shape and size with Fig. 21, but with one or the other eye only, if removed further from the spacial pole. Objects beyond parallel 60° to the left will be seen with the left eye only, and objects beyond the same parallel to the right will be seen by the right eye only.

The spacial pole of an eye must be on the same straight line with the anterior and posterior poles of the eye. The spacial pole of an eye can be the direct point of view, for that eye, only because the center of the macula is the posterior pole, for the center of the macula and the direct point of view must be connected by a straight line. If the spacial pole for each eye is the direct point of view for that eye, as in Figs. 1 and 2, the fixing of the two eyes on one point brings the two poles into one, as in Figs. 21 and 22. The perfect fusion of the two poles brings into practical fusion the spacial meridians and parallels of the two eyes, also well shown in Figs. 21 and 22.

The monocular spacial parallel is everywhere equally distant from the visual axis of the eye to which it belongs; therefore, strictly speaking, no two circles equally distant from the two poles could be perfectly fused, for their centers could not be made the same point. In the formation of the binocular pole, the two vertical spacial meridians would be perfectly fused, but the two horizontal spacial meridians would cross each other at the binocular pole, and they would then diverge, but so slightly that, at 90°, they would be just that distance apart corresponding with the measurement between the two eyes. At the extreme limit of lateral binocular rotation they would be much closer together, probably 1½ inches or less. For practical infinity, so slight a separation would amount to nothing.

Binocular visual axis. When the binocular spacial pole is at practical infinity, a line going from this pole to a point halfway between the two eyes may be considered as the binocular visual axis. This conception would give perfect binocular spacial meridians and parallels. Fig. 23 has been constructed on this conception, and the mathematics of the figure proves the value thereof.

In the study of the isogonal circles in Fig. 14, it has been stated that, for every point on the line of intersection of the vertical and horizontal fixed planes of the head, there is a new group of isogonal circles, all the members of any one of the infinite number of groups having the same diameter. The point of direct fixation not only creates an independent group of isogonal circles, but it also creates an independent group of binocular spacial meridians and an associated group of binocular parallels.

In Fig. 23, the primary isogonal circle is constructed through B and D, the centers of the two eyes, and the point of fixation, C. The horizontal binocular spacial meridian, 1–C–1, for that point of fixation, has been created by M–C, the binocular axis, as a radius. The vertical and oblique meridians of this group would be constructed with the same radius. Binocular spacial meridians, constituting any one group, are meridians with the same radius. The binocular parallels created by the point of fixation, C, are A′–E′, R″–S′, V‴–W‴.

If C had been chosen as the point of fixation, the primary isogonal circle would have passed through it and the two centers of rotation B and D. With C′ as the point of fixation, the binocular axis, M–C′, as a radius, would generate the horizontal binocular spacial meridian, 2–C′–2, for that point, and all the other members of that group of spacial meridians would have the same radius. The parallels for this new group of meridians and parallels would be A–E, R′–S′, and V″–W″.

If C″ had been chosen as the point of fixation, then the primary isogonal circle for that point would have passed through C″ and the two centers of rotation, B and D. M–C″ would have been the binocular axis and the radius of curvature for all the binocular spacial meridians for that point. The circle representing the horizontal binocular spacial meridian, with M–C″ as the radius, would be 3–C″–3. The associated parallels would be R–S and V′–W′.

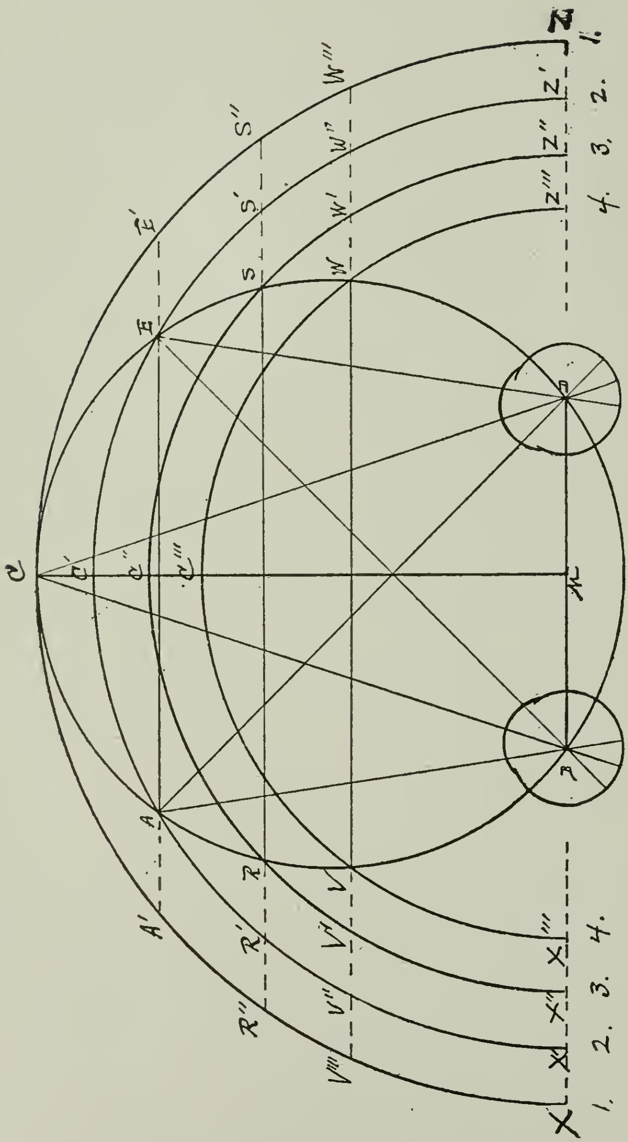


Fig. 23.

If C‴ had been chosen as the point of fixation, the primary isogonal circle for that point would have passed through C‴ and the two centers of rotation B and D, and M–C‴ would have become the binocular axis. With M–C‴ as a radius, the horizontal binocular spacial meridian would be 4–C‴–4, and all the other meridians belonging to the group created by the point C‴ would have M–C‴ as the radius. The parallel for this group of meridians and parallels would be V–W.

The equator of any one of these four groups of meridians and parallels would have the same radius of curvature as the meridians. The diameter of the equator of group C is X–Z, that of group C′ is X′–Z′, that of group C″ is X″–Z″, and that of group C‴ is X‴–Z‴. The diameter of each equator is the same as that of the meridians belonging to the same group. The diameters of the parallels belonging to group C are A′–E′, R″–S″, and V‴–W‴; the diameters of the parallels belonging to group C′ are A–E, R′–S′, and V″–W″; those for group C″ are R–S and V′–W′; and the one for group C‴ is V–W.

An interesting feature of Fig. 23 is that the two indirect visual lines drawn from A and E respectively, that from A through D, and that from E through B, intersect each other on the line M–C. Lines similarly drawn from R and S and from V and W, respectively, would intersect each other on the line M–C. Mathematically, A and E are equally distant from C′, R and S are equally distant from C″, and V and W are equally distant from C‴. The very definition of a parallel makes apparent the correctness of the above statement.

A binocular spacial parallel cuts the horizontal spacial meridian (and all other meridians) at only two points, and these points are equally distant from the binocular spacial pole. This is true of every parallel of every single group of parallels and meridians, as group C, C′, C″, and C‴. It is through a succession of such two points on diminishing horizontal spacial meridians that the primary isogonal circle passes, as A and E, R and S, and V and W.

Three other primary isogonal circles could be constructed in Fig. 23, all of which must pass through the centers of rotation, B and D. One of these, in going from B, would pass through V′, R′, A′, thence through a new point of fixation on M–C extended, and thence on through E′, S′, and W′ to D, thence to the beginning at B. Another isogonal circle may start from B and go through V″ and R″ on to a still more distant point of direct fixation on M–C extended, thence around to S″, through W″ and D, to the point of beginning at B. And again, a still larger isogonal circle may be started at B, carried thence through V‴, to a point of direct fixation, still further removed, on the line M–C extended, around to W‴, thence through D to B, the starting point.

Thus it is shown by Fig. 23 that any two points on any horizontal binocular spacial meridian cut by a parallel circle may become points of binocular single vision, for these two points either lie on a constructed primary isogonal circle or in the line of a possible primary isogonal circle.

There is no point in viewable space which is not at the crossing of a spacial meridian and a spacial parallel belonging to some group; and such points as lie in the rotation field (only slightly smaller than that represented in Fig. 21) are also on either the primary or some secondary isogonal circle of some group—the three groups of circles as related to any one point of direct view constitute one common triple group.

When the binocular spacial pole moves from point to point on the primary isogonal circle—the first point of view, whether direct or indirect, is always on the primary isogonal circle—it moves along the intervening arc of that circle, as from C to A, without change of angle of convergence; or if it moves along the chord of that arc, the angle of convergence increases as it moves from C to the middle of the chord, and thence on decreases until the pole arrives at A. The angle at the end of the rotation is the same as at the beginning. In this rotation the pole has moved from a point on the horizontal spacial meridian, 1–C–1, of one group, to a point on the horizontal spacial meridian, 2–C′–2, of another group, but the visual axes have not left the plane common to these two meridians and the retinal meridian on which were lying the two images; and the macula, in passing from one image to the other, has not deviated from that retinal meridian on which were lying the two images before the rotation began, nor does it ever deviate from such a meridian.

If the second point of view is A′, it will be seen that the two points, C and A′, lie on the same horizontal spacial meridian, 1–C–1. This rotation cannot be effected without a change of angle of convergence which will grow smaller, for the second point is on a larger isogonal circle. The spacial pole, in moving from C to A′, may go along the arc C–A′ or along the chord of this arc, but in either case the angle of convergence has continually changed. The maculas have moved from the images of C to the images of A′, along the horizontal retinal meridian. Thus might be studied rotations from any one point of view to any other point of view, cardinal or oblique.

Some one primary isogonal circle passes through the two points of intersection of all successively diminishing horizontal binocular spacial meridians and any one of the parallels belonging to the same group.

Every secondary isogonal circle cuts every parallel at two points similarly related to the spacial pole and the vertical and horizontal meridians; but at these points it cuts two different meridians which bear the same relationship to the vertical and horizontal meridians. This is made evident by the fact that the spacial part of every secondary isogonal circle is wholly either above or below the plane of the horizontal spacial meridian, while one-half of every oblique meridian, and the vertical meridian as well, is above, and the other half is below, the plane of the horizontal meridian.

Since the two points of intersection of a parallel and any oblique or the vertical meridian are on opposite sides of the plane of the horizontal meridian, it would not be possible for any secondary isogonal circle to pass through both points. The primary isogonal circle passes through a point common to all meridians of any one group, which point is the binocular spacial pole, and intersects the horizontal meridian of all diminishing groups at two points. The spacial part of no secondary isogonal circle cuts the horizontal spacial meridian at any point, but every secondary circle cuts all other meridians, each at only a single point.

If the maculas were not the posterior poles of the eyes; if the centers of the retinal concaves were not the centers of rotation; and if all lines of direction did not cross each other at the centers of rotation, then Fig. 23, with all of its mathematical beauties, could have no existence; nor would Figs. 21 and 22 have any true foundation.

Angle of convergence. In all binocular rotations the binocular spacial pole is made to move along the plane of the binocular spacial meridian in which lie the first and second points of view. The spacial meridians all accompany the motion of the spaial pole; but that meridian whose plane is the rotation plane, and it alone, has a wheel-like motion. All parallels also move with the rotating pole, but they have no wheel-like motion. As the spacial pole rises or falls, the planes of all the parallels look up or down; as the pole moves to the right or left, or obliquely up or down, the planes of the parallels face in a corresponding direction, but in no case does a parallel move in its plane.

Several interesting facts have already appeared in connection with the study of the isogonal circle. Another important feature growing out of the study of the isogonal circle is the easy determination of the angle of convergence, whatever may be the distance of the point of fixation. The mathematical formula for solving this problem is: As the circumference of the isogonal circle is to 360°, so is the arc extending from the center of one eye to the center of the other, divided by 2, to the angle of convergence.

The first member of this proportion is found by multiplying the length of the diameter of the circle, which is the distance of the point of fixation, by 3.1416. The third member of the proportion depends on the size of the circle and the distance between the centers of the two eyes. If the circle is large, the arc from the center of one eye to the center of the other is practically the same length as its chord, which is the straight line from the center of the one eye to the center of the other. If the diameter of the circle is in feet, then the arc must be expressed in a fraction of a foot, but if the one is expressed in inches, the other must be also. To illustrate: Let the diameter of the circle be 16 inches, and let the arc subtending the angle of the visual axes be 2½ inches, then the following is the formula expressed in figures:

$$50.26 : 360° :: 2\frac{1}{2} \div 2 : X°.$$

From this it will be found that $X = 8.9°$. If the first and third members of the proportion were feet and a fraction of a foot, and if the arc subtending the angle formed by the visual axes was always 2½ inches, or 1/5 of a foot, the work of determining the angle of convergence could be simplified as follows: Divide 36 (the result of multiplying 360 by $1/5 \div 2$) by the product of the distance of the point of fixation (the diameter of the isogonal circle) and 3.1416. To illustrate: Fixation is at 1 foot. Multiply 1 by 3.1416 and the product is 3.1416; with this number divide 36 and the quotient will be 11.35°. For any given length of the diameter of the isogonal circle, the visual axes will form a greater angle if the eyes are wide apart than if they are close together. For comparison, let the diameter be 16 inches and the arc 2½ inches; then the angle of convergence will be, as already shown, 8.9°; but let the arc be 2 inches, then the angle of convergence will be 7.16°; a difference of 1.74°. The following table is interesting and helpful, and is approximately correct. The point of fixation being 16 inches, the upper row of figures represents the pupillary distance and the lower row the angle of convergence of the visual axes for each:

2	2¼	2⅜	2½	2⅝	2¾	2⅞	3
7.16°	8.06°	8.5°	8.95°	9.4°	9.85°	10.3°	10.74°

As is well known, the metre-angle of Nagel is not formed by the intersection of the two visual axes, but it is the angle formed by the intersection of one visual axis with the extended median plane of the head, the head in the primary position, the point of fixation being at a distance of one meter. Under these conditions, the angle formed by the visual axis of the other eye and the extended median plane of the head, is also a metre-angle; the one exactly equal to the other. The sum of the two angles constitutes the angle of convergence, so that the angle of convergence is two metre-angles of Nagel. Both the metre-angle and the angle of convergence vary with variations of the distance between the centers of the two eyes. The angle of convergence is a thing to be measured, but not more certainly than that the metre-angle is also a thing to be measured. The metre-angle, therefore, cannot be taken as a standard of measurement, because a standard must never vary. A yard must be thirty-six inches, whether one is buying or selling, and whether the thing bought or sold is cloth or tape. The very word standard means unvarying. The unvarying standard for measuring angles is the arc of a circle in degrees, minutes, and seconds. This standard, for reasons to be shown, should apply to the angle of convergence. If Nagel had taught that the metre-angle is the angle formed by the intersection of the visual axes at a distance of one metre, and had given to it twice the value in degrees that he did give it, there would be less objection to it. Even then, the metre-angle would mean 3° 20′ with the distance from center to center of the two eyes 58 mm.; while it would mean 3° 40′ with the distance from center to center of the two eyes 64 mm. After having determined the value of the metre-angle (the angle formed by the intersection of the visual axes of the eyes at the distance of one metre, the head invariably in the primary position) in any given case it would be very easy to translate any fraction of a metre-angle or any number of metre-angles into degrees. Distances less than a metre, therefore a fraction of a metre, would increase the metre-angle in inverse ratio; for distances greater than a metre, the metre-angle would decrease in inverse ratio. To illustrate: Fixation at ½ a metre would give convergence of two metre-angles; ⅛ metre would give a convergence of 8 metre-angles; but fixation at 2 metres would give convergence of ½ metre-angle; fixation at 8 metres would give convergence of ⅛ metre-angle. Let the value of the metre-angle be 3° 20′, then the above would be translated: 2 ma = 6° 40′, 8 ma = 26° 40′, ½ ma = 1° 40′, ⅛ ma = 25′.

The value of the metre-angle (the angle of convergence) for various distances between the eyes is given in the accompanying table:

2	2⅛	2¼	2⅜	2½	2⅝	2¾	2⅞	3	Distance between the eyes in inches.
2°54′38″	3°5′33″	3°16′28″	3°27′23″	3°38′18″	3°49′13″	4°0′8″	4°11′3″	4°21′58″	Value of one metre-angle.

An interesting fact developed in working out the size of the metre-angle, is that, for every ⅛ of an inch increase of the distance between the eyes, there is an increase of the angle to the extent of 10′ 55″. Knowing the size of the metre-angle when the base-line (distance between the centers of the eyes) is 2 inches, the size of the angle with the base-line $2\frac{5}{8}$ inches is found by adding to the former 54′ 35″, which is five times 10′ 55″. This would give $2° 54' 38'' + 54' 35'' = 3° 49' 13''$, just the size of the angle shown in the table, when the base-line is $2\frac{5}{8}$ inches.

To find the size of the angle of convergence in any given case, when the point of fixation is less than one metre distant, divide the size of the metre-angle in degrees by that part of a metre that measures the distance of the point of fixation, which, of course, means that you are to invert the terms of the divisor and multiply. To illustrate: Fixation at 16 inches is fixation at $\frac{1}{2.46}$ metre. Let the base-line be $2\frac{1}{2}$ inches and we have the following:

$$30° 38' 18'' \div \frac{1}{2.46} = 3° 38' 18'' \times \frac{2.46}{1} = 8° 57' 1''.$$

Again, let the point of fixation be 3 m., and the base-line be $2\frac{1}{2}$ inches. We now have

$$30° 38' 18'' \div 3 = 3° 38' 18'' \times \tfrac{1}{3} = 1° 12' 46'',$$

the size of the angle of convergence at 3 m. The base-line remaining the same, the angle of convergence at a distance less or greater than one metre, is to the angle of convergence at one metre (the metre-angle), inversely, as the distance of the point of fixation is to one metre. The mathematical formula is that the tangent of half the angle of convergence varies inversely as the distance of the point of fixation from the middle of the line joining the centers of the eyes. But for small angles the above rule gives approximately the same results.

The reason for suggesting that the metre-angle be the angle formed by the intersection of the visual axes at one metre, and not the angle formed by the visual axis and the extended median plane, and that it be given a value double that given it by Nagel, is that the angle of convergence, or rather the nervous impulse from the third conjugate center, necessary to make this angle, is the chief factor in the formation of judgment as to distance. In fixing points to the right and left on the isogonal curve the angle formed by the intersection of the visual axis and the median plane of the head is confined to one eye, and is constantly changing in value, whereas the metre-angle, which is synonymous with the angle of convergence of the visual axes at one metre, remains the same everywhere when carried along the isogonal curve whose diameter is one metre.

Muscle nomenclature. If the muscles of all eyes were normal, much of the muscular nomenclature now to be studied could be eliminated. Early in the writings of George T. Stevens, he introduced terms that covered all conditions of the recti muscles save one. At that time he introduced no terms applicable to the obliques, and the terms that he later applied to them are not in harmony with his terminology pertaining to the recti, as will be shown further on. His more recent additions to the terminology of the recti are not as simple and serviceable as his original terminology, which has now become so well fixed in the ophthalmic literature of the world. In his original terminology he strangely omitted a name for the downward tendency of one eye, only supplying a term for the upward tendency of the other eye. He deserves great credit for his old nomenclature, but his later additions deserve to be forgotten, the reason for this to be given later. Up to 1891, it was the boast of some of his professional adversaries that no scientific body on earth had adopted his terms, in fairly general use up to that time. This boast was forever silenced by the Section of Ophthalmology of the A. M. A. at the Washington meeting in 1891, which voted unanimously, on motion of the writer, the adoption of the Stevens muscular nomenclature. The terms adopted by that resolution are as follows:

Orthophoria, heterophoria, esophoria, exophoria, hyperphoria, and the several combinations of the last three, as hyper-exophoria; also heterotropia with its subdivisions esotropia, exotropia, hypertropia, and the several compounds of the last three terms, as hyper-esotropia. Later the writer added the following terms in perfect harmony with the Stevens nomenclature in use up to that time: cataphoria for the downward tendency of an eye whose fellow eye was hyperphoric; cyclophoria for an unbalanced pair of obliques, the two forms being plus and minus; double hyperphoria when both eyes had a tendency upward, and double cataphoria when both eyes had a tendency downward; and cyclotropia plus and minus. Years after, when Stevens began to recognize that there was such a condition as a tendency to loss of parallelism between the vertical axes of the eyes and the median plane of the head, he strangely ignored the term "cyclophoria," which was in harmony with his original nomenclature, and coined the term "retinal declination," plus and minus. To distinguish a downward tendency of both eyes he has introduced the name kataphoria, differing in only one letter from the term introduced by another, many years before, to designate the downward tendency of one eye—cataphoria. Cataphoria is just as common as hyperphoria, and as richly deserves a name, for hyperphoria applies to only one eye while it is well known that the other eye has a downward tendency. "Kataphoria" is confusing, and there is nothing in the name that would point to the two eyes. "Double cataphoria" points distinctly to the two eyes as having a downward tendency. Besides, double cataphoria is exceedingly uncommon. Stevens' term for double hyperphoria, anaphoria, is objectionable for the reason that it does not point to the two eyes any more than does hyperphoria.

Some one has coined the term hypo-phoria to indicate the downward tendency of one eye, but it is not so good a term as cataphoria, for "hypo" means under while "cata" means down; and it too nearly resembles hyperphoria.

In the right of the two following parallel columns of terminology will be mentioned, but not endorsed, other terms which have been introduced from time to time, either to take the place of better terms, or to designate some condition with which it is better not to burden the mind of the reader. In both the right- and left-hand columns, the nomenclature introduced by Stevens will appear in plane letters, the writer endorsing those terms in the left column but condemning those in the right column. Terms introduced by others will appear in italics, the endorsed ones in the left column, the unendorsed in the right column. Terms, in the two columns, intended to mean the same thing will be placed opposite each other, the better one to the left, the worse one to the right. These columns will contain not only the "phorias" and the "tropias," but will also contain terms used to designate ductions and versions. Ductions and versions, distinct and different in fact, will not be confounded in name, in these columns.

PHORIAS.

Orthophoria.	
Heterophoria.	
Esophoria.	
Exophoria.	
Hyperphoria.	
Hyper-esophoria.	
Hyper-exophoria.	
Cyclophoria, plus.	Retinal declination, plus.
Cyclophoria, minus.	Retinal declination, minus.
Cataphoria.	*Hypophoria.*
Cata-esophoria.	
Cata-exophoria.	
Double hyperphoria.	Anaphoria.
Double cataphoria.	Kataphoria.

TROPIAS.

Esotropia.	*Internal strabismus, internal squint.*
Exotropia.	*External strabismus, external squint.*
Hypertropia.	*Upward strabismus, upward squint.*
	Downward strabismus, downward squint.
Catatropia.	*Hypotropia, downward strabismus, downward squint.*
Hyper-esotropia.	*Upward-inward strabismus.*
Hyper-exotropia.	*Upward-outward strabismus.*
Cata-esotropia.	*Hypo-esotropia.*
Cata-exotropia.	*Hypo-exotropia.*
Cyclotropia, plus.	
Cyclotropia, minus.	
Cyclo-hyper-esotropia.	
Cyclo-cata-esotropia.	
Cyclo-hyper-exotropia.	
Cyclo-cata-exotropia.	

DUCTIONS.

Adduction.	
Abduction.	
Superduction.	Sursumduction.
Subduction.	Deorsumduction.
Cycloduction, minus.	
Cycloduction, plus.	

INSTRUMENTS.

Cyclophorometer.	Clinoscope.
Tropometer.	*Perimeter.*
Muscle indicator.	

VERSIONS.

Right version.	Dextroversion.
Left version.	Sinistroversion.
Superversion.	Sursum version.
Subversion.	Deorsum version.
Up-and-right and Down-and-left oblique version.	
Up-and-left and Down-and-right oblique version.	
Convergence.	

Duction. Duction is not volitional but fusional, and is under the control of the guiding sensation, whose dominion is limited, and whose throne is the central point of the macula. If, in one eye, an image is displaced into any part of its domain, the guiding sensation will call on the fusion faculty of the mind to command its servants, the ocular muscles, to move the macula to it, that there may be binocular single vision. The field of binocular fusion is the peculiar kite-shaped area in each retina shown in Fig. 24.

While the field of binocular rotation is large, the field of binocular fusion is small. The former is measured by degrees of arc, and will be studied in connection with versions; the latter is measured by prism degrees. The field of fusion can be determined only by the use of prisms.

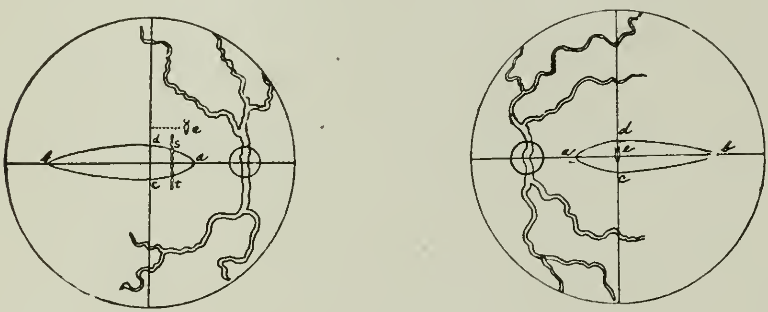


Fig. 24.

In this study again, it is not important to find the extent of the field except in the four cardinal directions. Authors differ as to the extent of this, while none of them sufficiently emphasize its importance in the study of heterophoria. When an image is displaced by a prism to any point within the field of fusion of one eye, while the image in the other eye remains on the macula, an effort at fusion will be made, and if the muscle that must respond is sufficiently strong, fusion will at once take place, caused by such a rotation as will bring the macula under the displaced image. When the image is thrown, by a stronger prism, entirely outside of the field of fusion, the guiding sensation, which seems to reside in this area only, will not call on any muscle to move the eye for the purpose of fusion. The nasal limit of this retinal area, as measured by a prism in front of the eye, is 8°; the temporal limit, 25°; the upper limit, 3°; and the lower limit, 3°. The line drawn through these four points marks the entire boundary of the field. This may be considered the normal size of the fusion area. In some cases it may appear to be smaller, while in still other cases it may be larger, as shown by actual measurement, but only in one, or at most two, directions.

It is by means of prisms which displace an image within this field that we can determine the fusion power of a muscle. This may be termed the intrinsic or lifting power of the muscle. A determination of this power is important, even in the study of orthophoria, but of much more importance in the study of heterophoria. A knowledge of the fusion power, associated with a knowledge of the verting power of a muscle, is indispensable in the formation of a judgment as to what ought, or ought not, to be done in an operative way, in any given case of heterophoria.

Three essential tests of the extrinsic eye muscles. There are three tests that should be made of every pair of eyes as a part of the work of refraction. To neglect the making of these tests will mark many failures against the oculist. Tonicity, duction and version are the names of these tests. The two first mentioned are indispensable; the last one named is of so much value as to command attention. In a very rude way the tonicity and fusion tests may be made with the loose prisms in the refraction case, but better far is the monocular phorometer. The binocular phorometer should not be used for either of these tests, for the fundamental reason that the image of the test object in one eye should be undisturbed. The principle on which all the tests possible to a phorometer rest, is that the image in one eye, throughout every test, shall be undisturbed; that the head shall be erect; and that both eyes and the object—better a white dot on a black background—shall be on the extended horizontal plane of the head. The false object must have its image thrown outside the area of binocular fusion in the eye under test, while the true object will have its image on the macula of the eye not under test, thus making it not only possible, but necessary, that this eye shall be in the primary position throughout the test, for it is not to have its image disturbed during any one of the several tests.

The monocular phorometer. An instrument based on the principle enunciated above is the monocular phorometer. It fulfills every essential condition, and is wholly reliable, and, except in rare cases, is invariable. The accompanying cut, Fig. 25, represents its appearance, but not its capabilities. The screw-and-spring arrangement, for regulating the spirit level, is as good as the best. In the base of the instrument there are slots on either side of the rotary prism, in one of which, towards the patient's face, is to be placed the displacing prism for causing the diplopia. If the instrument has been leveled, this prism, when placed in the slot, must have its axis either vertical or horizontal, and must produce a corresponding diplopia. The Risley rotary prism differs from the one in the Wilson phorometer in that it

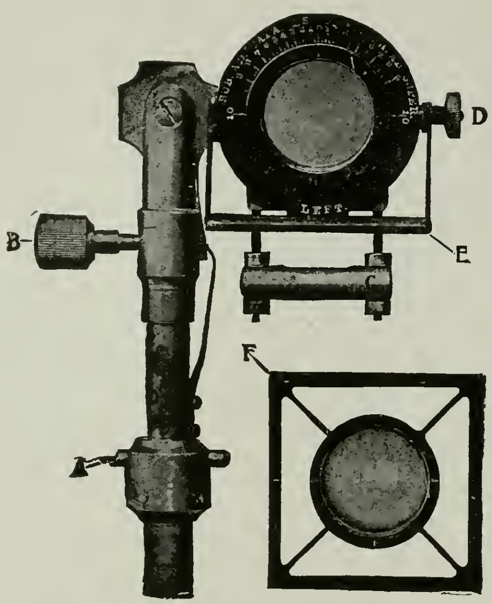


Fig. 25.

has a face correctly lettered and marked in degrees, for each eye, and is easily reversible.

Tonicity test. With the monocular phorometer properly leveled before the right eye, the axis of the rotary prism vertical, and the 6° prism base up, in the slot toward the face, the false object is made to appear below the true, and if directly under it there is lateral orthophoria. The rotary prism turned in either direction will make the false object go either to the right or to the left of the vertical line passing through the true object, which must be, at all times, the one looked at. Should the false object not be under the true, turning the rotary prism in the proper direction will place it there. On the face of the instrument toward the operator, can be read the kind and quantity of the error. The test for lateral orthophoria, in the near, is made by holding a card with a dot or cross in its center, at the reading distance.

To test the vertically-acting muscles, the rotary prism must be turned so as to have the revolving screw vertical, and the axis horizontal. The 10° displacing prism, base in, must be placed in the slot towards the patient's face, so as to displace the image, nasal-ward, beyond the area of binocular fusion. The false object should be in the same horizontal plane with the true, if there is vertical orthophoria. Any movement of the rotary prism will displace the false object, either raising or depressing it. When the false object is not found on a level with the true, there is a vertical heterophoria. Turning the rotary prism so as to bring the false object to a level with the true, shows, on the face towards the operator, the kind and quantity of the vertical error.

With the instrument in the adjustment for detecting vertical orthophoria, and without a displacing prism, the balance of the obliques is found by moving the rotary prism, first down, while the patient looks at a horizontal line until it doubles. The lines will be parallel if there is orthophoria of the obliques. Reversing the movement of the rotary prism, the false line appears above the true, but should be parallel with it. If there is not a perfect balance between the obliques it will be shown by a want of parallelism between the false and true lines. The kind of error will be indicated by the direction in which the lines converge, but the quantity cannot be measured by this instrument.

Duction. With the instrument in the adjustment for the tonicity test of the vertical muscles, sub-duction and super-duction may be quickly determined by rotating the index first up and then down. Normally these measurements are about 3° prism. Adjusting it as for testing the tonicity of the lateral muscles, abduction can be taken without the aid of a supernumerary prism, if the patient is orthophoric, by rotating the index towards the temple, the normal measurement being 8° prism. To take the adduction, one or two supernumerary prisms will have to be used to aid the rotary prism. If adduction is not above 25°, the 15° prism may be placed in the slot toward the face, with its base toward the temple. Turning the rotary prism nasal-ward will add to the effect of the supernumerary prism up to 10°. This added to 15° gives 25° of adduction, provided the doubling occurs only at the end of the rotation. If the adduction should be 30°, or more, it can be shown by placing the 5° or 10° prism, base out, in the slot in front, while the 15° prism remains behind, and again moving the rotary prism through the nasal quadrant. This instrument can measure adduction only up to 35°. In testing for the adduction with the monocular phorometer, the only muscle to respond is the one internal rectus.

By reversing the instrument all of these tests can be repeated on the muscles of the left eye. In every one of these tests the image in one eye remains undisturbed. The object seen by this eye must always be seen by direct vision, while the false object must be seen by indirect vision. All other methods of testing for orthophoria of the recti, even including the use of the Maddox rod, are faulty and should be discarded. The leveling part of a phorometer is an absolute necessity, for without it there can be no exactness in the placing of prisms before an eye. In testing for lateral orthophoria, slight errors, resulting from an improperly-placed prism, could be tolerated, but not so in testing for vertical orthophoria. The Maddox rod is objectionable in all tests of the recti, for the reason that a part of the streak of light, whether it be vertical or horizontal, will fall on the field of binocular fusion, unless the error be great. The false image, whatever may be its character, should never be on any part of this field; otherwise a greater or less effort at fusion will be made.

Tonicity test of the obliques. There is a legitimate use for the Maddox rod. It is in testing the oblique muscles, both as to their tonicity and their intrinsic strength. This instrument may be called the cyclo-phorometer, though Stevens has named the instrument he has invented for this purpose the clinoscope. The first of these instruments was invented by Price, in 1893, and was exhibited by him before the Section of Ophthalmology, at the meeting of the American Medical Association in San Francisco, in 1894. It consisted of a double prism, line of bases horizontal and a rod at right angles to this line of union, placed in a circular disc to fit the rim of a trial frame, and a Maddox rod only to be placed vertically in the other side of the frame. Looking at a candle, the patient would see two horizontal and necessarily parallel lines of light with the one eye, and a single horizontal line of light with the other, the latter appearing between the other two, and parallel with them in orthophoria of the obliques. This was for testing the obliques when the visual axes were approximately parallel. It was faulty in that there was no adjustment by means of which the frames holding the rods could be leveled. A little later, Baxter, of Boston, and Brewer, of Connecticut, each independently, invented a cyclophorometer with the error in the Price instrument eliminated. Brewer, not knowing of the Price invention when he made claim for himself, later wrote to the *Ophthalmic Record* as follows: "Dr. G. H. Price, of Nashville, Tenn., appears in your July (1898) issue as claimant to prior use of the Maddox rods in testing the position of the retinal meridians. Since he very clearly substantiates his claim, so far as I am concerned I tend him such laurels as I may have grasped, and trust he may wear them securely and gloriously." Dr. Brewer named his instrument the torsiometer. Later than this Stevens brought out his prism clinoscope, the construction of which is not very different from the instruments of Baxter and Brewer, and later still he invented his present clinoscope.

Cyclo-phorometer. The cyclo-phorometer must, of necessity, be a binocular instrument. The cyclo-phorometer, Fig. 26, made for use in connection with the monocular-phorometer stand, or the Wilson phorometer holder, consists of a base on which rest two graduated cells, in each of which is to be placed a triple Maddox rod with the axis vertical. Behind each of these circular cells is a rectangular cell for a displac-

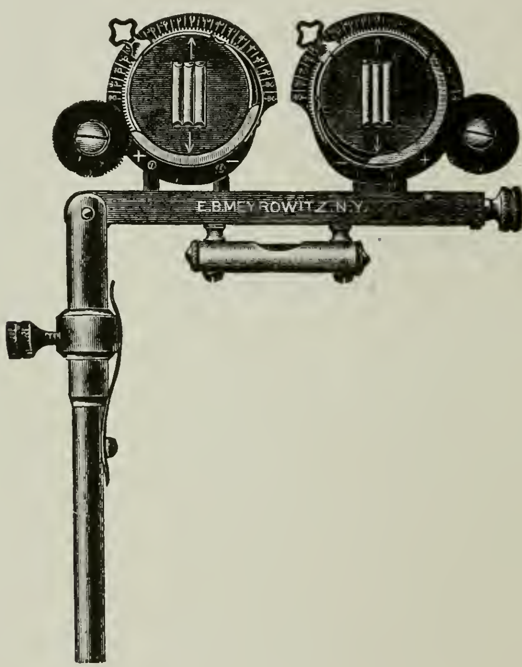


Fig. 26.

ing prism. There is an arrangement by means of which the pupillary distance can be easily regulated so that the one streak of light may be brought directly under the other. There is beneath the base of the instrument a spirit level for regulating the adjustment of the instrument. On each disc containing the rods is marked below a line continuous with the axis of the central rod. The rods placed vertically, with a prism of 5° base up behind one of them, will show two horizontal lines of light, when a candle is looked at. The lower one will be seen by the eye before which is the combination rod-and-prism. The lines should be parallel, and their ends even. The latter can be regulated by turning the screw that controls the pupillary distance. The slightest movement of either disc will cause a loss of parallelism of the streaks of light. If not parallel, there is want of orthophoria of the obliques, the kind and quantity of the error being shown by the rotation of either disc.

Cycloduction. By removing the displacing prism, the intrinsic power—the cyclo-duction—of each oblique muscle can be taken alone, and then the combined cyclo-duction of either both superior or both inferior obliques. This is done, when only one muscle is being tested, by revolving the one rod in the lower temporal arc for a superior, and in the lower nasal arc for an inferior oblique. If both superior obliques are under the duction test, then both rods must be revolved in the lower temporal arcs; if both inferior obliques, then both rods must be revolved in the lower nasal arcs. The moment the two streaks separate, the rotations must stop. On the arc of the cell the extent of cyclo-duction can be read. The normal cyclo-duction for a single oblique muscle is somewhere between 7° and 14°. The combined cyclo-duction of either pair of obliques is somewhere between 12° and 22°.

Clinoscope. The method of determining the perfect balance of the oblique muscles, or the imbalance when it exists, by the Stevens clinoscope, will be better understood after a description of the instrument itself. This description is given in the words of the inventor:

"The clinoscope (Fig. 27) is composed essentially of two hollow tubes, each of which has at one end a minute pin-hole opening through which the eye can look, and at the other end a translucent disc on which is drawn a line, in the case of one tube from the center straight up, and in that of the other tube straight down.

"These tubes are so adjusted on a standard that they can be placed and maintained in the same horizontal plane, which is indicated by a spirit level, but from end to end they can be directed horizontally or up or down. They can, as above intimated, be made to converge or diverge to meet certain contingencies.

"The tubes rotate on their long axes, and a pointer attached to each tube indicates on a scale the extent to which the tube is rotated. The small sight openings are so adjustable that the distance between them may be suited to the interpupillary distance of different persons. For the accommodation of those who, on account of presbyopia, myopia, or any high degree of refracting error, can not see at the distance of the test objects from the eyes, there are clips in which refracting glasses may be placed. The sight openings being very small and exactly in the same horizontal plane, there can be no doubt as to the erect position of the median plane of the head when the two eyes are seeing, each through its appropriate sight opening, any existing hyperphoria being corrected.

"The instrument is to be so adjusted in respect to height that the sight-holes will be on a level with the eyes of the examined person when sitting erect. This is best accomplished by the use of an adjustable table. The tubes may be exactly parallel or they may, in certain cases, be made to converge very slightly, thus making the distant point at 8 or 10 feet instead of infinite distance. Under other exceptional

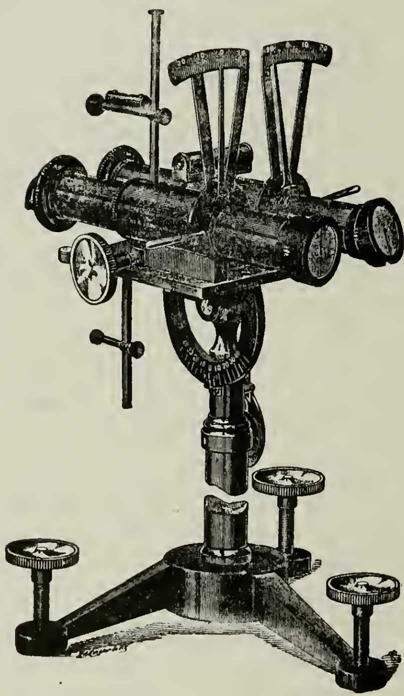


Fig. 27.

circumstances they may be made to diverge. The tubes must be brought to an exact level with each other as shown by the spirit level.

"Unless the subject of the examination is unable to see the test lines of the tubes, on account of presbyopia or high refractive error, no glasses should be used, and when glasses are necessary the weakest that will enable the person to see the lines clearly should be placed in the clips. A prism for the correction of hyperphoria may also be required. The glasses should not be worn, since, if a strong glass should not be held exactly at right-angles with the axis of the tube, the lens would itself induce a declination of the image.

"The examiner must be sure that the examined person sees through both openings simultaneously, and that the view of both images is maintained throughout the examination; otherwise, there can be no certainty that the head is precisely erect.

"When the examined person has secured a good view of both the test lines, he should endeavor, if they do not at once unite, to induce them to do so as in a stereoscope. Some people do not succeed in this, in which cases the examination may go on with the images separated, but it is less satisfactory.

"When the apparent vertical position of the lines has been attained, the examiner should move them more or less backward and forward, in order that the true position may be more positively located. Few people can arrive at a satisfactory conclusion regarding the position of the lines at the first trial, but after a day or two the tests become, for nearly all intelligent people, remarkably uniform."

With the clinoscope thus adjusted, the head of the pin with the point up should be fused with the head of the pin whose point is down, and both pins should be vertical if the oblique muscles are doing their full duty—if the vertical axes of the eyes are parallel with the median plane of the head. If the two pins are not now one vertical line, there is a cyclophoria. Whether the cyclophoria is plus or minus is easily determined, and its quantity is measured by revolving the tubes till the two pins become one vertical line.

In determining cyclo-duction by the clinoscope, the translucent discs with lines entirely across are to be used instead of those that have the lines only half way across. With the tubes properly adjusted the two lines would be seen as one. Revolving one tube would tend to displace the image of one line, which the eye would overcome by torsioning, as long as possible. The conclusion which Stevens has reached is that the image may be displaced as much as 14° in one eye before doubling occurs, and that the combined displacement, in opposite directions, of the images in the two eyes, may be as much as 22°. He also claims that a little greater displacement may be overcome by the inferior obliques than by the superior. In harmony with "phorometer," Stevens should have named this instrument "cyclophorometer," even if there was already in the field a different instrument constructed bearing that name.

Version tests. No test of the ocular muscles is complete until the verting power of the recti has been determined.

In the study of the field of fixation, or, better, the field of rotations, it must not be confounded with the field of binocular view (Fig. 22), which, in healthy eyes, is much larger than the former. It more nearly corresponds with the field of binocular vision (Fig. 21). The rotations in the four cardinal directions are those to be studied; and the best means at our command for this study is the tropometer, invented by Stevens. A fair degree of accuracy may be obtained by the use of the perimeter and a lighted candle, or a small electric light, in a dark room. This method, though not the better of the two, will be described first. The patient should be placed in front of the perimeter as for the taking of the field of vision. The eye to be tested must be in the center of the perimeter curve. The extent of the outward rotation is determined by asking the patient to fix the blaze of a small candle, or a small electric light, as it is moved behind the arm of the perimeter, toward the temporal side of the eye under test. When the patient can turn the eye no further out, the operator putting his open eye (one eye should be closed) in line with the candle and the center of the rotated cornea, observes the image of the candle reflected from the center of the cornea, and then reads the number of degrees marked at the point of location of the candle. In like manner the extent of rotation of the same eye in the opposite direction is determined and noted. The arms of the perimeter are now to be placed in the vertical position, when the extent of the upward and downward rotations can be measured in the same way. There is no necessity for other than these measurements in the four cardinal directions. Muscles found capable of making these rotations reach the standard, will be fully capable of doing the work of effecting any other rotation, which, after all, must be a combination of the forces effecting the cardinal rotations. Both eyes should be thus tested.

The Stevens tropometer, shown in the accompanying cut, Fig. 28, is an instrument of greater precision and is more convenient for use. The arrangement for fixing the head needs no description, since it is easily understood. At the base of the instrument is a thumb-screw by means of which the tropometer proper can be placed at varying distances from the patient's eye. The object of this arrangement is to so adjust the instrument that the reflected image of the cornea will extend from one of the darker lines in the scale to the other one, and this adjustment should be made at the beginning of every examination. Near the center of the upright piece there is a thumb-screw for elevating or depressing the mirror so that its center may be on a level with the patient's eye. At the top of this upright there is a flat base by means of which the mirror-box of the tropometer may be placed directly in front of the eye to be examined. This is effected by simply sliding the tropometer in either the one direction or the other. The horizontal part of the tropometer is a little more difficult to understand, and yet it is simplicity itself. It consists of a square box, closed completely by metal on all sides except the one facing the patient, and in the center of this side an opening which is filled with a disc of perfectly plain transparent glass, in the center of which is a white dot at which the patient is directed to look, at the beginning of the examination. Inside of this box is the mirror, placed at an angle of 45° on a vertical axis. From this mirror the patient's eye is reflected, an aerial image of which is formed on the graduated

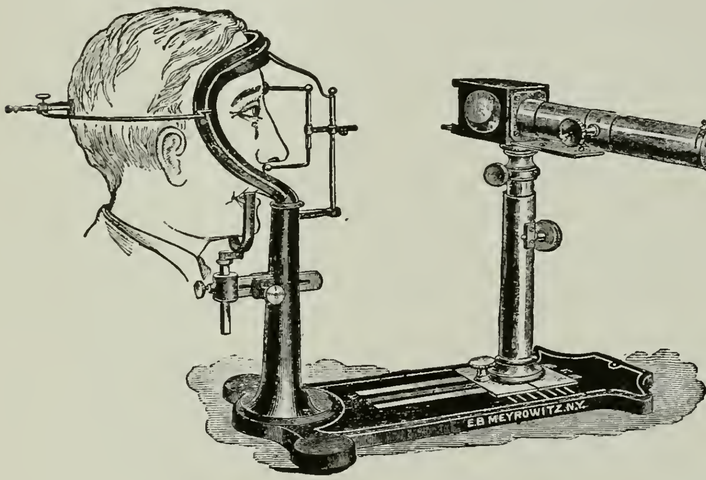


Fig. 28.

disc, so that the operator at the other end of the instrument may see it. The sharpness of the image is regulated by the thumb-screw in the center of the telescope part, by means of which the lenses contained in the tube are so adjusted as to enable the operator to get perfect sharpness of outline of the aerial image. The disc containing the graduated scale has been constructed with mathematical correctness. In the center of this disc there is a heavy line extending entirely across. At right-angles to this base-line there extends from each side a heavy line, the distance between the two being nearly 60°. On either side of the base-line there are lighter lines placed at points 10° apart. When the handle of this disc is vertical, the position is for measuring super-version and sub-version. With this instrument adjusted so the patient's cornea extends from one heavy line to the other, the base-line passing down through the center of the cornea, and the image itself being sharply focused, we take the super-version by asking the patient to look up as far as possible. In the reflected image the eye appears to move downward, for the image is inverted. The position of the lower margin of the cornea (upper of image) is now noted and the extent of the rotation is read off on the scale. In a normal condition the super-version should be 33°. This having been noted, the patient is asked to look straight forward again, when the image of the cornea will extend from one heavy line to the other as before, while the base-line will pass directly down through the center of the pupil. Now the patient is asked to look down as far as possible. Unless the upper lid is held up by external force, it will so cover the cornea that the measurement cannot possibly be taken. An assistant is necessary then to elevate the upper lid in order that sub-version may be taken. While the patient is looking down as far as possible, the position of the upper margin of the cornea (lower as it appears in the image) is noted, and the extent of the rotation is read off on the scale. This should be about 50°. The super-version and sub-version having been taken, the handle connected with the scale-disc is turned from the vertical to the horizontal. Now the instrument must be so adjusted that the base-line will coincide with the horizontal meridian of the cornea, while the cornea itself extends from one heavy line to the other. If the left eye be under test, abversion is taken by asking the patient to look as far towards the left as possible. The location of the nasal margin of the cornea, when the eye is in extreme abversion, is noted on the scale and the extent of the rotation is read off. This should be about 50°. This done, the patient is asked to look straight forward, when the instrument is adjusted as before. Now he is asked to look as far towards the right as possible, when the extent of the adversion can easily be determined. This should be about 50°. The power of rotation in the four cardinal directions having been found normal, it would be correct to conclude that rotation in any one of the oblique directions would also be normal. Any marked variations in the different versions from the standard, as noted above, should be considered a very important guide as to any surgical procedure to be resorted to, but this will be more clearly set forth in the study of heterophoria. Both eyes should be thus tested.

The candle method of simply watching the eye as it rotates in each of the four cardinal directions does not commend itself as being at all accurate; and yet it is better than no examination to determine the extent of these rotations. Unless the temporal rotation carries the outer margin of the cornea to the external canthus, and the nasalward rotation carries the inner corneal margin to the internal canthus, it would appear that these rotations are too limited. In the upward and downward rotations there are only the lid margins, themselves movable, to give us an approximate judgment as to their extent. This method is of use in a case of paresis or paralysis, but it ought never to be relied on for other purposes.

The extent of these rotations (versions), as given by different authors, varies but little. Landolt makes the standard of these rotations as follows: Out, 46°; in, 44°; down, 50°; up, 33°. Stevens places the standard as follows: Out, 48° to 53°; in, 48° to 53°; down, 50°; up, 33°. The standard set by Stevens is probably more nearly correct. A knowledge of an excess of, or deficiency in, these measurements can but be helpful when the question of a muscle operation presents itself. The rotating power of a muscle should never be reduced by operation below the standard measurement for that muscle.

Orthophoria. Orthophoria is the term applied to a perfect balance of the ocular muscles when the head is in the primary position and the eyes are looking straight forward, into practical infinity, at a dot or a small light. This condition, in the strictest sense, includes the idea that the twelve extrinsic muscles have all been perfectly developed, that each has its correct origin, pursues its proper course through the orbit to the eye, and is rightly attached to the globe; and that the orbits themselves are perfectly formed. It also includes the idea that the nine conjugate innervations are wanting in nothing. When such a state of things exists the visual axes, regardless of the point of fixation, are easily kept in the same plane through the first and second conjugate innervations; are always perfectly converged through the third conjugate innervation; and by means of the first, second, fourth and fifth conjugate innervations, are made to sweep harmoniously along the vertical plane, in the horizontal plane, and in any oblique direction. Nor will the sixth, seventh, eighth and ninth conjugate innervations fail to keep the vertical axes of the eyes parallel with each other and with the median plane of the head, while the transverse axes lie in the plane of the primary isogonal circle, regardless of the location of the point of fixation. Such a condition would also include the idea that the verting and ducting power of all of these muscles is up to the standard. But for these eyes, thus well balanced, to be perfect, there must be no error of refraction. There are such eyes, and the happy possessor of them knows of their existence only for the joy they give him. The workings of such eyes never add anything to the sum of human ills.

The only accurate instrument for determining the existence of orthophoria is the monocular phorometer (Fig. 25). With this instrument properly leveled before the right eye, the axis of the rotary prism vertical, and the 6° prism base up, in the slot toward the face, the false object is made to appear below the true, and if directly under it, there is lateral orthophoria. The rotary prism turned in either direction will make the false object go either to the right or to the left of the vertical line passing through the true object, which must be, at all times, the one looked at. The test for lateral orthophoria, in the near, is made by holding a card with a dot or cross in its center, at the reading distance. The bottom dot will be directly under the true dot. This would be better called the convergence test, which is normal only when the bottom dot stands directly under the true.

To test the vertically-acting muscles, the rotary prism must be turned so as to have the revolving screw vertical, and the axis horizontal. The 10° displacing prism, base in, must be placed in the slot towards the patient's face, so as to displace the image beyond the area of binocular fusion. The false object should be in the same horizontal plane with the true, if there is vertical orthophoria. Any movement of the rotary prism will displace the false object, either raising or depressing it.

With the instrument in the adjustment for detecting vertical orthophoria, and without a displacing prism, the balance of the obliques is found by moving the rotary prism, first down, while the patient looks at a horizontal line until it doubles. The lines will be parallel, if there is orthophoria of the obliques. Reversing the movement of the rotary prism, the false line appears above the true, but should be parallel with it. The responses to the inquiries of the phorometer and cyclophorometer outlined above are possible only in orthophoria. In themselves they do not answer the question, "Is the orthophoria sthenic or asthenic?" This is answered only by the duction test. Variations from the normal in tonicity tests will be shown in the study of the several heterophorias.

Duction. With the instrument still in the adjustment for the vertical muscles, sub-duction and super-duction may be quickly determined, and each should be 3°. Adjusting it as for testing the lateral muscles, abduction can be taken without the aid of a supernumerary prism, if the patient is orthophoric, and this should be 8°. To take the adduction, one or two supernumerary prisms will have to be used to aid the rotary prism. If adduction is not above 25°, which should be considered normal, the 15° prism may be placed in the slot toward the patient's face, with its base toward the temple. Turning the rotary prism will add to the effect of the supernumerary prism up to 10°. This added to 15° gives 25° of adduction, provided the doubling occurs only at the end of the rotation. Since abduction, in sthenic orthophoria may be more than 8°, adduction may be correspondingly increased above 25°. The ratio of abduction and adduction may be safely placed at 1 to 3. If the adduction should be 30°, or more, it can be shown by placing the 5° or 10° prism, base out, in the slot in front, while the 15° prism remains behind, and again moving the rotary prism through the nasal quadrant. This instrument can measure adduction only up to 35°. In testing for the adduction with the monocular phorometer, the only muscle to respond is the one internal rectus. Only one basal center and one muscle respond to any duction test.

By reversing the instrument all of these tests can be repeated on the muscles of the left eye. In every one of these tests the image in one eye remains undisturbed. The object seen by this eye must always be seen by direct vision, while the false object, when it appears, must be seen by indirect vision.

While the rotary prism may show the existence of orthophoria of the obliques, as already set forth, it cannot take the duction power of these muscles. Without the displacing prism the cyclophorometer can be made to show the intrinsic power—the cycloduction—of each oblique muscle, and can be made to show the combined cycloduction of either the two superior or two inferior obliques. How to do this has already been shown in the study of the cyclophorometer (Fig. 26). The clinoscope (Fig. 27) will accomplish the same results. In sthenic orthophoria, cycloduction should be 10° or more. The duction power of an inferior oblique is usually a little greater than that of the superior oblique.

Version tests for orthophoria. In determining orthophoria, or even heterophoria, the tonicity and duction tests are far more important than are the version tests. If the ocular muscles are normal in tonicity and duction power, versions in the four cardinal directions should be found normal: right version, 50°; left version, 50°; sub-version, 50°; and super-version, 33°. While the duction power of one externus is only one-third of the duction power of an internus, the verting power of these two muscles is the same. In the study of orthophoria oblique versions need not be taken.

Normal tonicity, normal duction, and normal version show the existence of sthenic orthophoria. If such eyes are emmetropic, their possessor should know of their existence only through the joy resulting from their use.

Asthenic orthophoria. There is an orthophoria that is not in strength, but in weakness. The diplopia tests may elicit responses indicating orthophoria of all the pairs of muscles, but these muscles may show a want of duction power, also a want of verting power. Such eyes, though orthophoric, as judged by the tonicity tests, cannot be as strong as they would be if the muscles were possessed of full intrinsic power. If an externus perfectly balances its antagonistic internus and there is an abduction of only 4°, there must be a correspondingly low adduction. If there is harmony between the superior and inferior recti, and they show a super-duction and sub-duction of only 1°, there is weakness that demands attention. Such cases are often met in actual practice. The treatment is ceiling-to-floor and wall-to-wall exercise. The method of carrying out this exercise is both simple and efficient. The patient is directed to stand against one wall of his room, midway between the walls to the right and left. Having previously fastened, by pin or tack, a piece of paper on each wall to right and left, at an angle of 35°, approximately, and on a level with his eyes; and having placed some object on the floor immediately in front of him and at a distance equal to his height, he must stand with his head erect while he looks up at the ceiling where it joins the wall in front of him, then down at the object on the floor, and so on for six or eight movements in the vertical plane; then he must change his movements to the horizontal plane, looking first at the paper to the right, then at the paper to the left, and so on for six or eight movements in this plane. He then passes again to the vertical plane, changing the point rhythmically every three seconds; and, at regular intervals, alternating the vertical and horizontal movements. He should stop the exercise always short of fatigue, and should not continue it longer than ten minutes at a time. Once a day is often enough to resort to the exercise. The time of day may be suited to the convenience of the patient. The duction power should be taken at intervals of a few weeks, and the exercise should be continued until the recti show the normal lifting power. In this way an asthenic orthophoria may be converted into a sthenic orthophoria.

The alternate contraction and relaxation of the recti, under the stimulus of the first, second, fourth and fifth conjugate innervations, if not carried to excess, can result only in the upbuilding of the muscles. Since every muscle is exercised in the same way and to the same extent as its antagonist, there is no danger of interfering with the equal balance that existed between the muscles before the exercise was commenced.

There are cases in which there is a sthenic lateral orthophoria and an asthenic vertical orthophoria. In such cases the ceiling-to-floor exercise alone should be advised. There are other cases in which there is a sthenic vertical orthophoria and an asthenic lateral orthophoria. In these cases only the wall-to-wall exercise should be given.

Since the strength of opposing muscles is correspondingly increased, there is never any danger of accomplishing too much. A lateral orthophoria with an abduction of 12° and an adduction of 36°, is a better condition than when the abduction is 8° and the adduction is 25°. A vertical orthophoria with sub-duction and super-duction of 5° is better than if these ductions were only 3°.

The diagnosis between sthenic and asthenic orthophoria should always be made. In the former, duction is normal or super-normal; in the latter duction is always subnormal.

Heterophoria. Heterophoria is a generic term and includes all errors of tendency of all the extrinsic ocular muscles. It is the disposition on the part of a muscle, or muscles, to disobey the law governing it; that is, the supreme law of corresponding retinal points. To obey this law, the recti, in the final result of their action, are concerned only with the visual axes; the superior and inferior recti of the two eyes keeping these axes in the plane of the primary isogonal circle, the external and internal recti causing them to intersect at the point of fixation on this circle. The obliques must keep the vertical axes of the eyes parallel with each other and with the median plane of the head. In orthophoria the demands of this law are easily met; in heterophoria the demands are met, but not with ease; there is strain or overwork.

In heterophoria involving the superior and inferior recti, there is a disposition on the part of these muscles not to keep the visual axes in the same plane, the visual axis of one eye tending above the plane that ought to be common to the two axes, while the visual axis of the other eye has a corresponding tendency downward. The direction of this tendency gives name to the error: upward tendency, hyperphoria; downward tendency, cataphoria. In heterophoria involving the lateral recti, there is a tendency toward intersection of the visual axes between the observer and the point observed, or they tend to intersect beyond the point of view, or even to become divergent. The tendency to cross too soon is esophoria; the tendency to cross too far away is exophoria. In heterophoria, involving the obliques, there is either a tendency on the part of the inferior obliques to cause the vertical axes to diverge from each other above, or of the superior obliques to converge these above. The former is properly termed plus cyclophoria; the latter, minus cyclophoria.

Heterophoria has its causes, and just as certainly has its consequences. To exist in any one of its several forms, one muscle must have an advantage over its antagonist; or, what is the same thing, in reverse order, one muscle must be at a disadvantage as compared with its antagonist. The difference may be in the comparative sizes of the two muscles, the one being larger, and, therefore, stronger than the other. There may be a difference in the insertions of the two muscles, the one being too near the corneo-scleral junction and the other too far back. These muscles may be of proper size, but it is certain that the one with insertion too far forward will exert more power in rotating the globe than its antagonist not so favorably attached. Whether the one cause exists alone, or whether two or more of them combine in the production of heterophoria, the error is corrected by an extraordinary nerve impulse which is sent to the weaker muscle of a pair from its own fusion center, and thus, with the undue expenditure of nerve force, binocular single vision is maintained.

Orbital malformations. As has been claimed by Stevens, Risley, and others, malformation of the orbits may be a cause of heterophoria. Ideally-constructed orbits are such that the eyes they contain, when in the primary positions, will have their horizontal planes lie in the fixed horizontal plane of the head. However interesting may be the study of malformation of the orbits as causative of heterophoria, the treatment, whether operative or otherwise, must be directed to the muscles; since it would be utterly impossible, by manipulation or operation, to convert a malformed orbit into an ideal one. It stands to reason that prisms in positions of rest would be the ideal treatment of heterophorias dependent on orbital malformation, there being no muscle imbalance per se.

To Stevens, of New York, is due much credit for his pioneer work in the study of the ocular muscles. Before him, Graefe, in his study of insufficiency of the interni, gave us a glimpse of that light which Stevens afterwards turned on more fully. By means of the phorometer, imperfect because it is binocular, which he invented, he found it much easier to investigate the recti muscles. He prosecuted this study for many years, almost alone, and under fire of most severe criticism. The information given us by Graefe about insufficiency of the recti muscles is so incomplete, as compared with the results of Stevens' labors, that the latter may well be looked upon as the discoverer of these conditions. The remarkable feature of Stevens' work is that he so long ignored any study of the oblique muscles, which have a duty to perform no less important and exacting than that required of the recti. It has already been shown that the obliques, under the influence of four conjugate innervations, must always keep the vertical axes of the eyes parallel with each other and with the median plane of the head. As far back as 1891,* it was shown that the obliques were not always capable of accomplishing their work with ease; and a little later the method of exercising these muscles so as to strengthen them, was introduced.† In 1893 it was shown that one danger attending an advancement of a rectus muscle was that its new attachment might be so displaced as to throw unbearable work on one or other of the obliques.‡ Again, in 1893, following a suggestion by Swan M. Burnett that one or more of the recti might naturally be so attached that the obliques would be insufficient for the work demanded of them, an operation on a rectus for strengthening an oblique muscle was first performed by the writer.§ It was not until 1895 or 1896 that Stevens commenced his study of the obliques. Soon thereafter he invented his clinoscope, the capabilities of which have already been shown. His work in this direction, as might have been expected, has been helpful; but in his paper published in the January (1899) number of the *Archives of Ophthalmology,* he claims entirely too much credit for himself, as expressed in these words: "Anomalous declinations not related to disabilities of the muscles had, previous to my own contributions,|| obtained no recognition as a practical subject, if, indeed, it had been recognized at all, although it is probably one of the most practical of the various important phases of the adjustments of the eyes."

In the matter of nomenclature Stevens gave us perfect terms, but not a complete list. There should be a name for every deviating tendency, but he gave none for the downward tendency. In conformity with his nomenclature, the downward tendency of an eye has been named cataphoria.¶

Before Stevens began the study of the obliques, the name cyclophoria was given to insufficiency of the obliques, in conformity with the nomenclature applied to the recti. To distinguish insufficiency of the superior from insufficiency of the inferior obliques, the term plus cyclophoria has been applied to the former and minus cyclophoria to the latter. Maddox, for some reason, preferred the terms plus torsion and minus torsion. Still later Stevens gives to these conditions the names plus declination and minus declination. Unless there is a very special reason for doing otherwise, there should be uniformity in the nomenclature applied to the ocular muscles. As there appears no

* See *Archives of Ophthalmology,* Vol. XX., No. 1.
† See *Ophthalmic Record,* Vol. II., No. 1.
‡ See *Ophthalmic Record,* Vol. II., No. 9.
§ See *New Truths in Ophthalmology,* 1893, pp. 40, 41.
|| Not earlier than 1897.
¶ See *New Truths in Ophthalmology,* 1893, page 68.

valid reason against this uniformity, the term cyclophoria alone should be used in writing about errors of the obliques.

Terms should be multiplied only when there is absolute need for them. The terms anaphoria and kataphoria added to nomenclature by Stevens a while ago, and applied, respectively, to an upward tendency of both eyes, and a downward tendency of both eyes, would lead only to confusion. These conditions exist, but it is far better to say double hyperphoria and double cataphoria.

Maddox did good work when he offered as substitutes for sursumduction and deorsum-duction the simpler and easier terms superduction and sub-duction. But even these terms should be given only a single meaning. They should be made to apply only to the power the superior and inferior recti have for overcoming prisms in the interest of binocular single vision. Likewise adduction and abduction should be restricted in meaning so as to apply only to the interni and externi in their efforts to overcome the lateral displacing of images by prisms.

The fact that it is better to have two terms, each with a single meaning, than to have one term with two very different applications, must be the author's apology for adopting the following nomenclature for the turning of the eyes in the four cardinal directions: Abversion, turning the eye out; adversion, turning the eye in; super-version, turning the eye up; and sub-version, turning the eye down. These terms are shorter and better than outward rotation, inward rotation, upward rotation, and downward rotation. Right version and left version are better terms than abversion and adversion.

Duane deserves credit for his very careful study of the ocular muscles in his little brochure, *"Motor Anomalies of the Eye"*; but the terms hyperkinesis and hypokinesis, introduced by him, are not nearly so simple or easy as the terms sthenic and asthenic esophoria, sthenic and asthenic exophoria, and sthenic and asthenic hyperphoria, and so on for all the phorias. The meaning, however, is precisely the same.

The heterophoria that is purely innervational should be designated by the prefix pseudo as pseudo-esophoria, a condition depending on the relationship existing between accommodation and convergence, and not depending on any error inherent in the interni.

The following is a *list of the heterophorias:*

(1) Esophoria, of which there are two varieties, viz.: pseudo-esophoria and intrinsic esophoria. Of the intrinsic variety there are two kinds, sthenic and asthenic.

(2) Exophoria, pseudo and intrinsic. Of the intrinsic variety there are two kinds, sthenic and asthenic.

(3) Hyperphoria and cataphoria, which are always intrinsic when the superior and inferior recti are the only factors. These errors are either sthenic or asthenic. There are now and then to be found a double hyperphoria or a double cataphoria.

(4) Cyclophoria, plus and minus, both pseudo and intrinsic. The intrinsic variety may be either sthenic or asthenic.

Two or three of these errors may be found combined in many cases; but it is probably better not to have compound names for such combinations of errors, as it is important that the quantity of each error should be noted. It would be difficult to indicate the quantity of the two errors if the note was made hyper-esophoria or hyper-cyclophoria. Every individual error should be detected and measured independently, but the combined errors must be treated.

Cover test. There are some interesting tests for heterophoria that can be made, in a rough way, independent of the phorometer. One is the cover test. If there is an error of any magnitude, it will manifest itself on covering one eye while the patient is looking with both eyes at a test object twenty feet distant. The covered eye will immediately place itself in a state of equilibrium. When the cover is removed, it will return to the position of harmony with the fellow eye. This readjustment can be easily seen, in many cases, by the observer. The direction in which the eye moves when uncovered indicates the kind, but not the quantity, of the heterophoria. A patient of keen observation will be made conscious of the disturbance. This is better done by covering and uncovering the eyes alternately.

Red-glass test. In high degrees of heterophoria a plain red glass placed before one eye will suspend, to some extent, the effort at fusion, and diplopia will result. A candle should now be the test object. The position of the red blaze, the patient the while looking at the real candle, will indicate the kind of error. Only the higher errors respond to the red-glass test.

Phorometer test. The test by means of the monocular phorometer is the only one to be relied upon. By it the kind of error is quickly determined and the quantity is easily measured. In testing the interni and externi, the 6° prism is placed, base up, in the cell next to the eye. This will throw the false image above on the retina and entirely outside the field of binocular fusion, so that no attempt can be made at fusion. The false object will be below the true, and will bear that relationship to it determined by the existing imbalance. The handle of the rotary prism must be horizontal, the index at zero, and the instrument perfectly level. The true object must be the one looked at. If the false object is toward the opposite side, there is exophoria. Turning the controlling screw, the index * is moved toward the corresponding side until the patient says the false object is directly under the true. The number at which the index stands marks the quantity of exophoria for that eye.

If the false object, instead of being on the opposite side, shows itself on the corresponding side, the existing error is esophoria. The controlling screw is now turned so that the index moves toward the opposite side. The revolution is stopped when the patient says the false object is in a vertical line with the true one. The number at which the index stands shows the quantity of esophoria for that eye.

Convergence test. The test having been made for the distance, it should now be repeated at the reading point. The test object now should be a white card in the center of which is a black dot, and the card should be held directly in front of the eyes. There should be no line drawn vertically through the dot, as advised by Graefe, for the reason that this line would cross the area of binocular fusion, and would thus lead to an attempt on the part of the eye to correct its error. The kind of error is determined and its quantity is measured, as in the distant test. The result, not always the same as found in the distant test, should be noted. More properly speaking, this is the convergence test—a very important one.

The lateral error having been thus found and measured, the 6° prism should be removed and the 10° prism, base toward the nose, should be placed in the cell; the handle of the rotary prism should be placed vertically, and the index must be made to stand at zero. It is now of vast importance that the instrument be perfectly level; otherwise, a vertical error may be shown when none exists. The instrument thus adjusted, any vertical imbalance may be detected and measured. As in the test for lateral errors, the true object must be the one fixed. The false image will be thrown outside the retinal area of binocular fusion, toward the nose, while the false object will appear on that side of the true, corresponding to the eye under test. If the false object is below the horizontal line passing through the true, there is hyperphoria of that eye, the quantity of which is determined by revolving the controlling screw so that the index shall move upward. The number at which the index stands when the patient says the two objects are level shows the quantity of the error.

If in the test the false object is above the horizontal line passing

* The index of the rotary prism should be at the apex end of the axis. Unfortunately some rotary prisms are not thus marked.

through the true, there is cataphoria of that eye. The screw is now turned so that the index shall move downward. The number at which the index stands, when the patient says the objects are level, shows the quantity of the cataphoria. The test for vertical imbalance need not be repeated at the near point.

The one eye having been tested thus for imbalance of all the recti, the instrument should now be turned into position before the fellow eye, that the lateral and vertical imbalances it may have may be found and measured. Usually, if there is esophoria of one eye, the other will also show esophoria, the amount in the one is about equal to that in the other. Occasionally, however, there will be a difference of 1° or even more. The same may be said of exophoria. When there is hyperphoria of one eye, the other is usually cataphoric, and the one error is about equal to the other.

A double hyperphoria and a double cataphoria cannot so easily be shown, in the tonicity test, by the phorometer. The proof test, which is by means of the Maddox double prism, quickly shows either of these errors when they exist. The base-line of these prisms (4°) should be held horizontally before first one eye and then the other, having each eye look at the distant test object, first through the upper prism and then through the lower, observing that position which throws the double objects closer together. If they are closer for both eyes when the false object is seen through the upper prism, there is double hyperphoria; but if they are closer for both eyes when the false object is seen through the lower prism, there is double cataphoria.

It can be readily understood that, if there is hyperphoria of one eye and cataphoria of the other, the two objects will be closer together when the false one is seen, by the hyperphoric eye, through the upper prism, and by the cataphoric eye when seen through the lower prism. Hence the reason for calling this use of the double prism the "proof-test" of hyperphoria and cataphoria.

The next step in the testing is to determine the ability of the obliques to parallel the vertical axes of the eyes with the median plane of the head. This can be done rudely in any one of several ways: First, by means of the Maddox double prism, the object looked at being a horizontal line on a blackboard, twenty feet distant, or a horizontal line on a card held at the reading distance; preferably, both. The base-line of the double prism (4°) should be horizontal and so held before one eye as to double the test-line. The two lines seen by this eye must be parallel. The third line, seen by the other eye, should be between the other two and parallel with them. A dipping of the true line toward the opposite side would show a plus cyclophoria, while a dipping toward the corresponding side would show a minus cyclophoria. The quantity of the error thus shown, however, cannot be measured, with the prism.

The same test may be made by means of a single prism of 4°, base up or down, before the eye; but even still more easily it may be made by the revolving prism in position for taking the sub-ducting and super-ducting power. The rotation, of course, must be carried beyond the possibility of fusion. The false line is seen by the eye before which the single prism is held or the rotary prism has been placed, while the true line is seen by the other eye. The refracting angle of the prism points in the direction of the false line. When this line is seen below, by the right eye, and the ends of the two toward the right converge, there is plus cyclophoria; if they diverge toward the right, then there is minus cyclophoria. Neither the single or rotary prism can measure the error thus found. In revolving the rotary prism backward, or in turning the single prism, so as to make it possible for fusion to take place, it is interesting for the patient to watch the manner of fusing; if there is cyclophoria, the two lines will come together at one end first and then quickly fuse throughout.

The Stevens clinoscope will detect and measure any existing cyclophoria; but the best instrument for detecting cyclophoria and measuring the amount of the error is the cyclophorometer. It is much cheaper than the clinoscope, and, better still, it is simpler in construction and much more easily manipulated. The 5° prism, base up, behind one rod gives the second streak of light; the thumb-screw makes it easy to place the one streak directly under the other—ends even. If the axes of the rods are at zero and the two streaks are not parallel, cyclophoria is positively shown; if the lower streak is seen by the left eye and the two streaks converge at the left, there is plus cyclophoria; but if they diverge at the left, there is minus cyclophoria. The extent of the turning of the rod on the one side or the other, necessary for paralleling the streaks, measures the quantity of the cyclophoria. It is not necessary, with the cyclophorometer, to keep in mind the fact that the lower streak is seen by the eye that has the displacing prism before it, for the position of the axis of the rod at the time the streaks are made parallel names the error as well as measures its quantity: when the axis must be moved into the lower nasal arc, there is plus cyclophoria; into the lower temporal arc, there is minus cyclophoria.

The spirit level of the cyclophorometer enables one to determine if the cyclophoria is monocular or binocular. When the two streaks of light converge at one end or the other, if the error is binocular, neither of the lines will be horizontal. If one is horizontal while the other is oblique, the error is monocular; if both lines are inclined in the same direction, it shows plus cyclophoria in one eye and minus cyclophoria in the other.

Having followed out the tests already described—the tests for imbalance—one knows the kind of error or errors in the individual case, but remains ignorant of the character of these errors. The duction and version tests alone can reveal the fact that an error is sthenic or asthenic, just as the study of refractive errors alone reveals whether or not a given heterophoria is pseudo or intrinsic.

Duction. The duction test is to determine the power the recti muscles have for overcoming the displacing of images by means of prisms. To this meaning the word duction, with its several prefixes, should be restricted. The method of determining duction power by means of the monocular phorometer has already been set forth. It can be accomplished by means of the prisms in the refraction case, but not so quickly nor so accurately. Duction is wholly an involuntary act, and it is accomplished through the guiding sensation, in obedience to the law of corresponding retinal points; but it has its limitations. Abduction is the power of an externus to fuse with the image on the macula of the fellow eye, an image that has been displaced to the nasal side of the macula of its own eye. Less than 6° of such power is subnormal; more than 8° is supernormal. Adduction is the power of an internus to move the macula outward until it shall stand under the image that has been displaced templeward, so that it may be fused with the image on the macula in the fellow eye. It is certainly subnormal if less than 18° to 25°. The adduction stimulus is much greater than any other, and is much more variable. Its variableness makes it less reliable than any other duction; but, nevertheless, it must be known in dealing intelligently with esophoria.

Super-duction is the power the superior rectus has for fusing an image displaced below the macula, with the image on the macula in the fellow eye. Less than 2° is subnormal; more than 3° is supernormal.

Sub-duction is the power the inferior rectus has for fusing an image displaced above its macula, with the image on the macula in the fellow eye. Less than 2° is subnormal more than 3° is supernormal.

In all duction tests it is better that the image should be slowly moved away from the point occupied by the macula, when the eye is in the primary position, toward the boundary line of the field of binocular fusion which should be considered as immovably fixed. So long as this image is within this field there is binocular single vision, for the macula moves with the moving image as far as possible; but the moment it passes the border line there results diplopia. The index of the rotary prism marks the duction power of the muscle concerned. It should be noted. The field of binocular fusion is larger, if the muscles are stronger; smaller, if the muscles are weaker. Its size can be changed both by exercise and by operations. If it is too small, it may be increased by exercise and by shortening and advancement operations; if too large, it can be reduced only by tenotomies, which should always be partial, whether marginal or central.

Cycloduction, which is involuntary, can be taken only by the clinoscope or the cyclophorometer. With the former instrument the line as seen by one eye is turned by means of the proper screw up to the point of doubling. The index marks the torsioning power of the oblique involved. With the cyclophorometer the axis of one rod is moved from zero toward the nose in the lower nasal arc to test the torsioning power of the inferior oblique, and toward the temple, in the lower temporal arc, for determining the power of the superior oblique.

In determining the several ductions the tests should be monocular, except in cycloduction.

In any given heterophoric condition the duction test, aided by the version test, determines whether the error is sthenic or asthenic, and, therefore, the kind of operation, if any, that should be performed. No muscle whose duction power is normal or subnormal should be weakened by partial tenotomy; but the imbalance should be cured either by a shortening or an advancement of its weaker antagonist.

No examination of the recti muscles is complete without the taking of the verting power of every one. As already shown, this can be rudely done by simply watching the eyes while the patient looks as far as possible in the four cardinal directions. The objection to this test is that there is no accuracy in it, and yet it is better than no test.

The reason for introducing the terms adversion, abversion, superversion, sub-version has been given already, and the extent of each, considered as normal, has been shown in the same connection. Of all instruments for making the version tests, the Stevens tropometer stands first, because of simplicity, accuracy, and speed. The only part of the instrument that should be dispensed with is the head rest, and this for two reasons: First, it interferes with the manipulation of the upper lid, when the sub-version is being taken, for now the lid must be held up or it will entirely obscure the cornea; second, it obscures too soon the small electric light or other test object which the patient should fix as the super-version is being taken. The mouth-piece is necessary in order to insure that the patient's head shall not turn while the verting power of the eye is being taken.

A fairly good substitute for the tropometer is the perimeter, if properly used. There should be some means for preventing the movement of the head, and nothing could do this better than a mouthpiece, such as constitutes a part of the tropometer. The eye under test should be in the center of the perimeter curve. As with the tropometer, the rotations should be taken in the four cardinal directions only. With the arms of the perimeter in the horizontal plane, abversion and adversion can be easily taken; and if proper care is observed, the result will be practically accurate. The small electric light, shaded toward the observer, should be placed first directly in front of the eye while in the primary position. From this position, the light, while being kept in contact with the perimeter arm, should be moved in the temporal arc—the arc for abversion—slowly, the patient fixing the moving light, while the operator observes its image reflected from the center of the cornea, moving his own head harmoniously with the moving light. The patient should speak when he finds himself no longer able to fix the light. At the same moment the observer can see that the image is no longer reflected from the center of the cornea. Thus the patient serves as a check to the operator, while the operator also serves as a check to the patient. When 5° beyond the point of fixation, the small light becomes so blurred that the patient can easily detect the change; hence, if the patient is closely observant, there is small room for error. The operator cannot so easily detect an error of 5°, as shown by the reflected image. For these reasons the subjective part of the test is more reliable than the objective. The position of the light on the arc, when the patient can no longer fix it, and when the reflected image begins to leave the center of the cornea, indicates the degree of abversion. With the light moving along the nasal arc, adversion is taken in like manner, and its extent should be noted.

With the arms of the perimeter rotated into the vertical plane, superversion and sub-version are taken by moving the light along the upper and lower arcs, respectively, and their extent is noted. In taking subversion, the reflected image cannot be so easily watched, even when the upper lid is held out of the way. Here the subjective part of the test must be relied upon.

One eye having been thus tested, in the four cardinal directions, the other eye should be properly placed and the various verting powers should be determined and noted.

Unlike the duction power, which is involuntary, verting power is a thing of volition. Neither one should be depended on to the exclusion of the other. The result of these two tests (duction and version), should be compounded, if the surgeon would be safely guided in his operative work, or even in the non-operative treatment of heterophoria.

Cycloversion has no existence, since voluntary rotation around the visual axis is impossible.

No muscle whose ducting or verting power is normal or subnormal should be weakened by a partial tenotomy. No muscle should be increased in strength by an advancement or by a shortening when the duction and version are not subnormal.

Symptoms of heterophoria. That there are cases of heterophoria without symptoms must be conceded, but such cases are not often seen by the ophthalmic surgeon. It is a symptom, or symptoms, of eye-strain that drives the patient to the doctor. It may be that the symptoms, in a given case, are dependent in part, if not wholly, on errors of refraction; but it is a serious mistake to suppose, as some do, that eye-strain is always and only associated with the ciliary muscle. The ciliary muscle is only one of eight muscles connected with each eye; and each of the seven other muscles, when called on to do abnormal work, is just as capable of developing symptoms. People who have no symptoms, and yet have heterophoria, are possessed of a stable nervous system and are physically strong. The physically weak and the nervously unstable must be sufferers from eye-strain, of whatever character. The nervous centers of the one must be compared with the steady leaves of the oak, which are shaken only by a wind; while the nervous centers of the other may be compared to the leaves of the aspen tree, which quiver in the slightest zephyr. Or, again, the easily-disturbed nerve centers may be compared to the leaves of the trailing little vine seen in the old turned-out field, all of the leaves of which fold themselves up if but one leaf be touched by a human finger.

The strong, healthy person, with a stable nervous system, may never have had a symptom resulting from muscle or focal errors that have always existed. Let this individual have an attack of typhoid fever, measles, or other depressing disease, or let her pass through a pregnancy and confinement; now, on attempting, too soon, the use of her eyes in near work, she begins to be a sufferer. The suffering becomes a habit, and she gets no permanent relief until the focal or muscle error has been corrected.

A sudden shock to a nervous system that has been strong, brings about a change that ever after makes the patient feel the effects of errors whose existence before had made no impression.

Growing children, especially those that are delicate, when too hard pressed in their school work, almost invariably present some one of the many symptoms of strain. More women than men feel the effects of muscle and refractive errors, mainly because of the fact that the former are forced to spend a greater number of hours every day in near work than the latter. Bookkeepers, or men who are engaged in other continuous near work, are often forced to seek aids to vision.

Headache. The most common of all the symptoms caused by heterophoria is headache. The aching may be in the temple, brow, at the top of the head, over the parietal region, or in the back of the head. In some cases the suffering is in the back of the neck. The pain may be on both sides of the head, but often it is unilateral. It is periodic in character, and usually comes on as the result of prolonged, hard near-work. The headache which one has on awaking in the morning—or, more properly speaking, the headache which awakens the patient—is usually due to disturbances in the sinuses, or cells, that open into the nasal passages, brought about by mouth-breathing, the mouth-breathing depending, of course, on nasal stenosis, or adenoids. Rest in sleep usually relieves the headache of heterophoria and of refractive errors. Headaches due to eye-strain, that come on unassociated with near work, are usually heterophoric and not refractive. The headache that one has on bright days and when amid bright surroundings, as the white buildings and white walks of an exposition, is often due to overwork of a weak sphincter of the iris, which is compelled to keep the pupil small that the retina may be protected from the glare. The headache of eye-strain is usually of the nervous variety—that is, unassociated with nausea and vomiting. However, genuine sick headache—pure migraine—is sometimes caused by both refractive and muscle errors. The migraine which disappears as presbyopia comes on, proves itself clearly dependent on an error of refraction; and the same may be said of other headaches that disappear as one grows old. Indeed, this coincidence should have attracted attention to focal errors, as causative of headache, long before anything was known on this subject.

Not so with headaches that are dependent on heterophoria, for strain of heterophoria once, means strain of heterophoria throughout life, unless relieved by treatment, surgical or otherwise.

Vertigo and nausea. The kind of muscle error that is the most common cause of vertigo and nausea is insufficiency of the obliques or cyclophoria. The correctness of this teaching is emphasized in cases of paresis of an oblique or of a superior or an inferior rectus, either one of which would be attended by a torsioning of the eyes. The earliest and most marked symptoms presented by these cases are vertigo and nausea, which continue so long as the patient tries to use both eyes. Excluding the vision of the affected eye, the symptoms vanish. When cyclophoria is the cause, these symptoms will be periodic, and will present themselves only when the weak obliques are no longer able to maintain perfectly the parallelism between the vertical axes of the eyes and the median plane of the head. Overwork, worry, shock, ill-health, sleeplessness—all tend to make these symptoms worse.

Confusion of thought. Any one of the heterophorias, whether associated with errors of refraction or not, necessarily interferes with that clearness of comprehension one would have if his eyes were free from all errors. Reading becomes a burden to heterophorics for the reason that their thought centers work confusedly, through sympathy with the motor centers that are overtaxed in efforts at harmonizing the ocular muscles. How far confusion of thought may be carried toward insanity, because of continued existence of a muscle error, remains to be shown. Cases of undoubted insanity have been cured by operations on the ocular muscles. It has been a matter of common observation that school children who were counted as dull and incapable, not able to comprehend clearly either books or teachers, have been transformed into apt scholars by ocular treatment. In the race for an education, a child who has any form of heterophoria, or an error of refraction, is considerably handicapped.

Chorea. A spasmodic condition of the muscles of the face—a local chorea—in children with unstable nerve centers, is often caused by eye-strain, as is shown by the quick relief that follows a correction of the condition causing the strain. The cause continuing to act, the transformation of a local into a more general chorea is often effected. It cannot be denied that chorea, sometimes in a very aggravated form, is caused by visual errors; but it cannot be asserted that all choreas are caused by ocular defects. It is safe and proper to say that every child suffering with chorea should be examined by an ophthalmic surgeon, with the view of having any existing ocular error corrected. It is generally considered that, whatever may be the cause, chorea is a reflex neurosis, and that finding and removing the cause brings a speedy cure. Medical treatment, without reference to cause, is at best slow.

Epilepsy. There can be no longer any room for doubt that, in many cases, epilepsy, whether in the severe or in the light form, is often reflex in origin. If wax impacted in the ear can be the cause of epilepsy, is it unreasonable to suppose that hyperopia may cause this motor-psychic disturbance? But it is no longer a matter of supposition; for, beyond all question, many cases of epilepsy have been cured by the convex lenses that corrected the hyperopic error. If a phimosis can excite epileptic seizures, is it any wonder that the excessive tension of muscles, in cases of heterophoria, may now and then be the cause of these attacks? In fact, scores of epileptics have been cured by operations for the establishment of normal equilibrium between the ocular muscles. The proportion of cases of epilepsy caused by heterophoria may not be large—no one knows—but every case of epilepsy should be subjected to a most careful examination of the visual apparatus, by a competent investigator; and all focal errors found should be corrected and muscle imbalance should not be ignored. That Stevens, Ranney, and others have spoken their convictions, based on observation and practical experience, on this subject, the author believes. He himself has had and has cured some cases, while failing on others.

Catalepsy. If clonic muscular contractions, associated with unconsciousness, can be caused by errors of refraction and heterophoria, the same errors may cause tonic muscular contractions—rigidity—with mental oblivion. The cause should be sought and, when found, removed. Occasionally excessive tension of the ocular muscles is causative of catalepsy.

Hysteria. This disease is one of the functional neuroses, and, like the others already considered, may depend on focal errors and imbalance of the ocular muscles. The character of the hysteria in a given case does not point to any definite cause. Whether the manifestations are sensory, motor, psychic, visceral, or vaso-motor, a cure can be effected, if the cause can be found; hence the importance of a most thorough investigation of these unfortunates. In these cases no investigation is complete that leaves out the visual apparatus. Errors of focus should be corrected, imbalanced muscles should be adjusted, with the fair prospect that at least some will be cured.

Neurasthenia. This condition of weakness of the neuron elements is the very opposite of those just considered, and yet it may have the same cause. If errors of refraction and heterophoric conditions do not cause neurasthenia in certain cases, it must be conceded that they can perpetuate it in all cases. The results of the correction of errors of refraction, and the regulation of the tension of the recti muscles by tenotomies and shortenings or advancements, have been so marvelous as to justify the declaration that every subject of neurasthenia should have the visual apparatus investigated. The correction of any existing errors, to say the least, would tend to hasten a cure, whatever may have been the chief cause. Many cases have been speedily cured by these means alone, in which internal medication, electricity, and rest had been tried in vain. In any case in which but little nerve force is generated, the undue expenditure of that little should be prevented, thus giving medicine, food, and rest a better chance to have full regenerating power restored to the weak brain cells. In no case should the correction of visual errors be wholly relied on, but other organs and parts of the body should be investigated, and all local diseases found should be treated—such as those of the stomach, the rectum, the bladder, the ovaries, and the womb; for these may have been the chief cause of the prostration, the visual errors having served only to aggravate and perpetuate the neurasthenia.

Through the nervous system errors of refraction and heterophoria may cause functional derangement of the thoracic, abdominal, and pelvic viscera. Indigestion, torpidity of the liver, and constipation have disappeared, in some cases, as a result of the correction of visual errors. A case of stammering was unexpectedly cured by the wearing of prisms prescribed by a Denver oculist for an exophoria. The doctor was so astonished at the result that he decided to remove the prisms, so that he might determine whether the cure was a coincidence or a consequence, a *post hoc* or a *propter hoc*. The stammering returned, and was again relieved by the wearing of the prisms. Disturbed respiration and an irritable heart have been quieted by lenses and by operations on the eye muscles. Dr. Hale, of Nashville, once had a little patient suffering from a refractive error, whose bladder was so irritable that micturition in sleep was almost a nightly occurrence; but at the time of the examination of the eyes nothing was told about the irritable bladder. Later the parents reported that the glasses had done more than was contemplated, in that the bladder trouble had vanished. The doctor's astonishment was great. He decided to settle the question of relationship between the wearing of the glasses and the disappearance of the irritability of the bladder, by withholding the glasses. Almost immediately the bladder trouble returned, to disappear again, and permanently, when the spectacles were restored to the child.

It has been a matter of common observation that dysmenorrhea in girls and young women has been wholly, or in part, relieved by a correction of errors of the visual apparatus. These things are marvelous and can be explained only by assuming that these remote organs have sympathized with the eyes in their efforts to correct errors of adjustment and errors of focus. To claim that all cases like those referred to above have the exciting cause in the eyes would be absurd; but when the cause is so simple, how easy and rapid the cure! So far the symptoms considered have been in parts more or less remote from the eyes. In many cases the only symptoms of eye-strain are in the eyes themselves or in their appendages.

Asthenopia. This is a weakness of the eyes that may be shown in a sense of fatigue associated with more or less pain in the eyes, together with an excessive secretion of tears, whenever an attempt is made to do near work. Letters, while being looked at, may fade away for a moment, because of relaxation of weak ciliary muscles; the page may become blurred or mixed from side to side, because the imbalance of the lateral recti muscles momentarily increases the angle of convergence, as in esphoria, or by the temporary lessening of this angle, as in exophoria; or the blurring may be from top to bottom, caused by the sudden elevation of one visual axis above the other, as in hyperphoria.

The conjunctival vessels often become congested because of visual errors. Likewise the lid margins become engorged with blood, scales forming among the roots of the lashes, the nutrition of the lashes themselves suffering. In high degrees of muscle imbalance, objects in the distance sometimes become double momentarily. Not only may the external structures of the eyes become congested because of strain to overcome errors, but the structures within the eyes also may become congested. Functional disturbances without and within the eye, if long continued and much aggravated, may lead to organic changes and even result in the development of some of those diseases that bring blindness.

One of the most troublesome asthenopias presents itself when a patient is exposed to bright light, either natural or artificial, and is caused by a weak sphincter of the iris, which must keep the pupil small so as to protect the delicate retina.

Treatment of heterophoria. The treatment of heterophoria must be determined by the kind and quantity of the error. Small errors of the recti may be treated by prisms in positions of rest for the too weak muscles. The base of the prism must always point toward the muscle to be favored. In esophoria the base would be out, and prisms of equal strength should be placed before the two eyes. If the error is small and the interni are properly attached, or even if they are attached in greater part above the horizontal plane, in most cases they can be comfortably worn. If they do not give comfort, it becomes evident that the interni are attached too low, and that their forced action develops a plus cyclophoria, which becomes a source of discomfort. In exophoria the prisms should be of equal strength before the two eyes, and their bases should be in. If the error is small and the externi are correctly attached, the rest prisms would certainly bring comfort, at least for a time. If the externi are attached too low, the prisms, as a rule, can be comfortably worn; but if they are attached too high, the use of the prisms cannot bring comfort because of the plus cyclophoria developed.

In hyperphoria the correcting prism, in nearly all cases, should be worn only in front of the hyperphoric eye, the base being placed down, for the reason that the action of the superior rectus, for overcoming the prism, develops a minus cyclophoria, which, to a certain extent, neutralizes the plus cyclophoria which nearly always exists. In the rare cases in which there is minus cyclophoria, the rest prism should be placed, base up, before the cataphoric eye, that a neutralizing plus cyclophoria may be caused. Only when there is perfect balance of the obliques would it be correct practice to divide the prismatic effect between the two eyes, base down before the hyperphoric eye, base up before the cataphoric eye. The per cent. of cases accepting kindly the rest prism, base down before the hyperphoric eye, is very large; while only a very small per cent. of such cases would be improved by placing the rest prism, base up, before the cataphoric eye. A full prismatic correction of a hyperphoria should be given only when there is a marked complicating cyclophoria.

In uncomplicated cyclophoria the patient may be benefited by wearing a weak pair of cylinders, axes in the arcs of distortion for the stronger muscles, even when there is no astigmatism; or, if there is astigmatism, by displacing the axes of the correcting cylinders in the arcs of distortion for the stronger pair of obliques. The arc of distortion by plus cylinders for the superior oblique of the right eye has its center always at 45°, and for the left eye it has it at 135°; while the center of the arc of distortion by plus cylinders for the inferior oblique of the right eye is always at 135°, and for the left eye it is at 45°. The reverse is true of minus cylinders. These arcs are equal in extent only when the astigmatism is vertical or horizontal, but their sum is always 180°. The extent of the displacement of the axes of the cylinders, requisite for the relief sought, depends on the quantity of cyclophoria and the strength of the astigmatic correction—a weak cylinder, more displacement; a strong cylinder, less displacement. If there is no complicating hyperphoria, the displacing effect of the cylinder should be divided equally before the two eyes; but if there is a hyperphoria complicating a plus cyclophoria, only the cylinder before the cataphoric eye should be displaced; while the reverse would be true when a hyperphoria complicates a minus cyclophoria. It is clear that the enforced action of an inferior oblique would elevate the corresponding eye, to that extent neutralizing or correcting the cataphoria; while the enforced action of a superior oblique would correspondingly depress the eye to which it belongs, thus diminishing, if not correcting, the hyperphoria. The displaced cylinders do for the weak obliques what rest prisms do for the weak recti. In both instances the law of direction is infringed, which, in itself, is not good. For this reason it is better practice to relieve all forms of intrinsic heterophoria either by exercise or by operations. An objection applies to displaced cylinders that does not apply to prisms: by the former vision is rendered less acute, while by the latter there is no such interference.

Gymnastic exercise. In low degrees of heterophoria, of whatever kind, development of the weaker muscles by exercise is the best practice. The time necessary for curing these cases by exercise and the trouble involved in carrying it out regularly and systematically, constitute the chief objections to this method of treatment.

In a modified form the late Dr. Charles E. Michel, of St. Louis, persistently practiced the development of weak internal recti muscles by means of prisms, following 1877. The prisms used by him were not stronger than 4° nor weaker than 1°. Beginning with the weaker prism, he directed the patient to exercise frequently (ten to fifteen times) during the day, each period of exercise to last only four or five minutes for the first few days; later they were to be worn only four or five times daily, increasing the time of exercise by two to five minutes daily, until they could be worn comfortably one hour. When the patient, looking in the distance, became able to wear the 4° prism one hour without discomfiture, he was directed to commence reading. At first he must read only from three to five minutes at a time; but later he increased this time by two to five minutes daily, until he could read comfortably one hour, four times a day. Whenever this could be done, the patient was directed to continue for several months the reading-exercise practice for from a half to one hour, two or three times a day. To suit individual cases, modifications, as to strength of prism and length of time and frequency of exercise, had to be made.

Under Dr. Michel's treatment, fully 60 per cent. of his patients had full muscular power developed, and in this way were enabled to use their eyes with comfort; 25 per cent. had greater or less gain in comfort; while 15 per cent. derived no benefit from the treatment. As a preliminary step to the muscle treatment, the doctor always corrected any existing refractive errors, and had the patient wear these lenses behind the exercise prisms.

Michel's method of developing ocular muscles is given for the reason that it differs essentially from that set forth in the books, and for the additional reason that a high percentage of cures resulted from his method. Success was due to the fact that his weak prisms used made but little demand on the weak muscles, thus making it possible for the continuous contraction to be borne and the muscle strengthened.

In contrast with Michel's practice, the method of George T. Stevens, of New York, is here given in his own words: "Adduction may be greatly improved by gymnastic exercises of the interni, by means of prisms. In these exercises the eyes are required to unite images in overcoming gradually-increasing obstacles. A prism of a few degrees, perhaps 10°, is placed, base out, before one of the eyes, while gazing at a lighted candle at twenty feet distance, when an effort is at once made to prevent diplopia. As soon as the images are blended, another prism, of perhaps less degree, is placed in the same manner. The images being united, a stronger prism takes the place of one of those already in place, or one is added to those already in position. Thus, little by little, the eyes are required to overcome prisms until the images can no longer be united. Then all the glasses are removed and the process is repeated; with each repetition something may be gained. The exercise should not be continued, at a single sitting, more than five or six minutes; and only a single sitting daily is desirable. By this means the adducting power can, in most cases, be raised, after a few exercises, to the desired point.

"The effect of such exercise upon the eyes is very often extremely salutary. With greater freedom of muscular action comes a sense of relief from nervous strain, which is often of a most gratifying character. Such an exercise is in no way related to the practice sometimes adopted, and which should be condemned, of requiring the patient to gaze for a long time at a near object."

The virtue of Michel's method lies in the fact that, though he taxed the muscle for a long while, gradually reaching the maximum of time, he taxed them but slightly, using only weak prisms; while the virtue of Stevens' method lies in the fact that, though he taxes the muscles severely, using the strongest prisms possible, reaching the maximum strength by degrees, he does not continue the exercise very long and does not repeat the sitting again the same day. And, too, he almost strikes the right principle in his method of intermitting the exercise. In contrast with both of these methods, and with the methods laid down in the books, the method of *rhythmic exercise* will now be given, the author feeling confident that it is founded on sound principles and that it, therefore, can be carried out successfully in practice.

Contraction and relaxation, alternating in short and rhythmic order, and continued short of fatigue, is the kind of exercise that develops a muscle in any part of the body. It is the alternate contraction and relaxation that develops the muscles of the arm of the blacksmith. If the forearm should be flexed on the arm and held in that position ten minutes, no one would suppose that the muscles concerned could be developed thereby. There would be greater reason for believing that such action would enfeeble the muscle. This is precisely the kind of contraction effected by prisms in the old method of exercising the recti muscles. There can be no wonder that better results have not followed, and that the practice has been abandoned by almost all oculists.

It would be of little worth to condemn the old practice as bad without setting forth a new line of practice, based on sound principles, and one that must be successful, in suitable cases.

While rhythmic contraction and relaxation, regulated as to intensity and time, will develop any one of the recti muscles, as is developed the biceps of the blacksmith's arm, the writer would not be understood as believing that one of these muscles can be developed out of a low state of weakness into a high state of strength. There are cases of exophoria that will remain exophoric still, in spite of long-continued rhythmic and graduated exercise; and these cases, to be cured at all, must be cured either by partial tenotomies alone, or by these supplemented with rhythmic exercise. The same may be said of esophoria and of hyperphoria. Only low degrees (not more than 6°) of lateral heterophoria can be converted, by rhythmic exercise alone, into orthophoria; the higher degrees can be corrected by partial tenotomies, shortenings, and exercise combined. While, in suitable cases, the aim of partial tenotomies and shortenings should be to approach orthophoria, yet the greatest care should be exercised not to go beyond the "balance" line. The safest thing is to leave, for correction by exercise, some of the original condition.

Any one of the recti, and either of the obliques, weaker than its opposing muscle, the difference in corresponding strength not being too great, may be developed by rhythmic exercise into a state that will enable it to work harmoniously with its fellow.

The specific plan of exercise for any given case of heterophoria will be given in connection with the study of each heterophoric condition. Likewise the operative treatment will be mentioned in connection with the specific condition.

ESOPHORIA.

In this form of heterophoria there is a tendency of the visual axes to cross somewhere within the primary isogonal circle on which rests the point to be viewed binocularly—an inward tendency of the eyes. The crossing is prevented only by contraction of the externi, excited by neuricity sent to them by their respective fusion centers. There is an esophoria which, because of its nature, may be called "true," or "intrinsic"; while there is another form that should be termed "pseudo." The one kind is entirely distinct from the other, and yet the two often co-exist, the one being grafted onto the other.

Intrinsic esophoria. In this condition the interni have an advantage over the externi, which may be due to any one of several conditions. It may be that the interni are over-developed, or, what would result in the same thing, the externi may be under-developed. In either case there would be an imbalance in favor of the interni. That this is often true hardly admits of doubt; for every surgeon who has operated often will testify that, in operating on the internus to lessen its tension, he has frequently found it very large and strong, and that, in operating on the externus to increase its tension, he has found it small and weak.

The interni may not be over-developed, but abnormally short; or the externi may be abnormally long, thus giving an imbalance in favor of the interni. In operating on an internus to lessen its tonicity, it is sometimes found to be tense, as if stretched; while in operating on an externus to increase its tonicity, this muscle is found loose and flabby.

The interni may not be over-developed nor the externi under-developed, nor may the interni be too tense while the externi are too lax. The esophoria found in such a case would be due to the interni having their attachments too far forward while the externi have their attachments too far removed from the corneal margin.

If either of the conditions mentioned above should be the cause of an esophoria, it can be understood readily how the esophoria may be greater in the one eye than in the other, and that it may exist only in one eye, the lateral muscles of the other eye being perfectly balanced. This can be determined quickly and accurately by means of the monocular phorometer, the binocular phorometer being wholly unreliable for this purpose.

Whatever may be the cause, esophoria is usually about equal in the two eyes. Regardless of the existence of the one or the other of the four causes discussed, or that two or more of them may coexist, the treatment, as will be shown, must be directed either toward the interni with the view of lessening their tonicity by partial tenotomies, or toward the externi with the view of increasing their tonicity by means of exercise, or by shortening or advancing one or both of them. In low degrees of the error, prisms in positions of rest for the weak externi may be tried.

Unless one, or more, of the above mentioned causes exists, there can be no such thing as an intrinsic esophoria. The superior and inferior recti, when attached, in greater part, on the nasal side of the vertical meridian of the eye, act as a secondary cause of true esophoria.

Malformation of the orbits cannot have much to do, directly, with the causation of intrinsic or even pseudo-esophoria. The angle of convergence for eyes that are wide apart is but little greater than the angle of convergence when the eyes are close together, and yet that little may constitute one of the factors in the production of an esophoria, or, vice versa, of an exophoria. When the eyes are three inches apart and the point of fixation is sixteen inches, the angle of convergence is 10.7°, while the angle of convergence for the same point, the eyes being two inches apart, would be 7.16°, a difference of 3.54°. It is, therefore, reasonable to conclude that a muscle adjustment that would give orthophoria the base-line being two inches, would give exophoria if the base-line were three inches. Malformation of the orbit must play only a very small part in the production of an esophoria or an exophoria. There are two kinds of esophoria, sthenic and asthenic.

Sthenic esophoria. The quantity of esophoria does not determine its character with any certainty. If the error is sthenic in character, it can be told only by resorting to the duction and version tests. How to make these tests has been fully set forth already, and so important are these tests, from a therapeutic standpoint, that they can never be safely neglected. In sthenic esophoria adduction should be more than 25°, and adversion should be more than 50°. Abduction and abversion may be only little less than normal, and rarely would these exceed the normal. More dependence must be placed on abduction and abversion than on adduction and adversion in determining if an esophoria is sthenic. If, in a case of esophoria, abduction and abversion are nearly normal, it is of the sthenic type.

Asthenic esophoria. Here, again, it is not the quantity of the error that determines its character. It is only by the duction and version tests that the asthenic may be distinguished from the sthenic. In such a case the adduction power is less than 25°, and the adversion is less than 50°. Abduction and abversion will be correspondingly low.

If in responding to these tests a patient should show less duction and version power than he really has, the error will be on the safe side. In asthenic esophoria the interni should never be operated upon. What to do for such cases will be fully set forth under the head "Treatment."

Pseudo-esophoria. As its name implies, it is an esophoria that has neither of the above mentioned causes. It is wholly dependent on the relationship that exists between the third conjugate innervation center and the center controlling the ciliary muscles. It is never found in a myope; it is never shown in the distant test when the patient is an emmetrope. Even an emmetrope may show a pseudo-esophoria in the near, but only when the ciliary muscles are weak and must receive an abnormal impulse in order to focus near objects. Pseudo-esophoria always exists in cases of hyperopia, manifesting itself in one of three ways: first, lessening the quantity of an intrinsic exophoria; second, showing an esophoria when, in reality, there is no imbalance between the lateral recti; third, showing a greater quantity of esophoria than really exists. Though false in character, it is nevertheless harmful, unless it complicates an exophoria. Then, as will be shown in the study of exophoria, it is helpful in the absence of any treatment of the exophoria.

Donders was right when he emphasized the influence that accommodation has over convergence, though some have doubted that there is any truth in his teaching on this subject. He may have attached too much importance to it; doubtless he did go beyond bounds when he taught that hyperopia was the chief cause of internal strabismus. Some idea of the probable effect that accommodation has over convergence may be obtained by the study of eyes that are emmetropic and orthophoric. Such eyes accommodate 3 D. for a distance of 13 inches. The distance between the centers of the eyes being 2½ inches, the angle of convergence for 13 inches will be 11°. Each eye accommodates 3 D., and its visual axis is turned toward the median plane of the head through an arc of 5.5°, showing nearly 2° of convergence for 1 D. of accommodation, as the normal. This holds almost true when the accommodation is 1 D., the point of fixation being at a distance of 1 M. The base-line being 2½ inches, the angle of convergence will be 3.6°, half of which (1.8°) will show the converging of each axis toward the extended median plane of the head. To show how nearly the proportion holds good, the following is given: 3 D. : 5.5° :: 1 D. :1.8°. Thus it would appear that 1 D. of hyperopia would give 1.8° of pseudo-esophoria, the proportion practically holding good up to 6 D., there being a variation of only .1°. In 6 D. of hyperopia the pseudo-esophoria for each dioptre would be 1.9°.

A pseudo-esophoria may be chargeable, in some unaccountable way, to a complicating plus cyclophoria. This surmise becomes stronger since it is well known that an esotropia occasionally has for one of its causative factors a plus cyclophoria, which must be corrected to make it possible for the esotropia to be cured. There must be, however, an intrinsic esophoria, which is only aggravated by the cyclophoria.

In many cases of esophoria the distant test shows a greater error than the test in the near, and in some cases an esophoria is shown in the distant test and an exophoria in the near. Occasionally the esophoria shown in the near test is from 1° to 10° greater than that shown in the far test. This variation will not show itself when the esophoria is wholly intrinsic. If there is emmetropia, the esophoria in the distant test is intrinsic, and the same quantity of the error will be shown in the near test, if the ciliary muscles are ideal in structure and size and ready to give full response to the normal stimulus sent to them from the brain-center that controls their action, when accommodating for the near point. If the point to be fixed is 16 inches from the eyes, the impulse sent from the brain to the ciliary muscles will be a 2.50 D. impulse and the muscles will respond so as to increase the refraction of the lenses 2.50 D. The associated impulse sent to the interni, the distance between the eyes being 2½ inches, would be enough to make the two visual axes swing toward each other 4.5°, so that the angle of convergence would be 9° (a small fraction less). If the diplopia test in the distance shows 6° of esophoria, the near test will show the same, for nothing exists to break the evenness of the error. In another case of emmetropia, suppose the ciliary muscles to be subnormal in their development, so that more than a 2.50 D. impulse must be sent from the brain-center in order to make them respond sufficiently to increase the refraction of the lenses 2.50 D. For the sake of argument, let a nerve impulse of 5 D. be necessary to elicit a 2.50 D. response on the part of the ciliary muscles; the associated impulse sent to each internus would be double that of the normal ($4.5° \times 2 = 9°$) in the effort to accommodate at 16 inches. The distant test showing 6° of esophoria, the near test would show 10.5° of esophoria (6° intrinsic esophoria + 4.5° pseudo-esophoria = 10.5°).

In another case of emmetropia, suppose the ciliary muscles to be hyper-developed, so that only a 1.25 D. nerve impulse is necessary to elicit a 2.50 D. response by the ciliary muscles; the associated impulse sent to the interni would be just half the normal ($4.50° \div 2 = 2.25°$)

when accommodating for a point at 16 inches. The deficiency of associated impulse must be supplied by a corresponding amount of the inherent tension of the interni, diminishing the esophoria in the near test just to that extent. To the convergence impulse (2.25°) must be added 2.25° of the esophoria in order to have the visual axes from an angle of convergence of 9°. Then, the distance test showing 6° of esophoria, the near test would show 3.75° of esophoria ($6° — 2.25° = 3.75°$).

In still another case of emmetropia, there may be an intrinsic esophoria of 2° in the distance. The ciliary muscles may be such as to require only a 1 D. impulse to call forth 2.50 D. of activity on the part of hyper-developed ciliary muscles, in accommodating for 16 inches. The associated impulse sent to the interni would be only 1.8°, when an impulse of 4.5° is required for convergence at 16 inches. When the whole of the 2° of intrinsic tension of the interni is used in aiding convergence, the guiding sensation must make a special call on the right and left third innervation basal centers for .7° more of convergence on the part of each internus in order that the proper angle of convergence may be formed (associated impulse 1.8° + 2° intrinsic esophoria + .7° extra impulse from the right and left third fusion centers = 4.5°). The diplopia test in the near withdraws the extra impulse from the fusion centers and exophoria of .7° is shown.

It is not the response of the ciliary muscles in dioptre changes of the lenses that causes a definite associated contraction of the interni, but it is the greater or smaller impulse, measured in dioptres, generated by the brain-center controlling the ciliary muscles, that develops the associated action of the interni; for every 1 D. of ciliary impulse there is 1.8° of convergence impulse.

Experiments and observation do not show that an associated nerve impulse is sent to the ciliary muscles from the center controlling them because of an over-stimulation of the third conjugate innervation center. This would be shown in spasm of accommodation—pseudo-myopia—a condition never seen in cases of esophoria, and rarely seen at all, even in a case of exophoria. The condition so often spoken of as spasm of accommodation is not such, but is the temporary continuance of the manifestation of an acquired tonicity of the ciliary muscles, when one begins the wearing of convex lenses for the correction of hyperopia.

Whatever may be true of other associated brain-centers, it appears that the center of the ciliary muscles (the tenth conjugate) and the third conjugate innervation center can have the associated impulse run in only one direction; that is, from the former to the latter.

Tests for esophoria. No test for esophoria can be relied on when the eyes are under the influence of a mydriatic. Within an hour, and it may be for a much longer time, after the installation of a mydriatic, the third conjugate innervation center is excessively stimulated, either directly or indirectly, more likely the latter, so that an esophoria will be shown when there is none; existing esophoria will be increased more or less; and an exophoria will be made to appear less than it really is. All of these statements are certainly true, in both the far and the near tests, if the patient is a hyperope; they are true in the near, if not in the far, if the patient is an emmetrope; they are also true in the near, if not in the far, if the patient is a myope of less than 2.50 or 3 D.

The explanation for this phenomenon, given by the author in 1892, he still believes to be true. This explanation is as follows:

A very peculiar feature of the use of a mydriatic is that at first—probably from one to several hours—a mydriatic, in hypermetropic eyes, will increase the esophoria, will lessen an exophoria or convert it into orthophoria, or even into an esophoria. Until now this has been unexplained. The following explanation must be true: The mydriatic acts on either the endings of the accommodative nerve fibers or on the fibers of the muscle of accommodation, certainly not on the accommodative center, which, therefore, must remain in a state susceptible of excitation by the demands from the guiding sensation. As the muscles of accommodation pass into their forced rest, the retinal images become less sharp in outline, the blurring increasing up to the point of full suspension of accommodation. The guiding sensation calls on the accommodative center for sharper images, and the impulse is sent out, but finds the muscles unresponsive; the call is repeated more eagerly, and a stronger impulse is sent to the sleeping muscles, and still no change is effected in the images; and thus the calls and the responses are kept up for a longer or a shorter time. For every degree of activity thus excited in the accommodative center, there is a corresponding tendency to activity generated in the converging center. So long as the calls are made on, and responses are made by, the accommodative center, the center of convergence stands ready to call into unusual action the interni, which they do the moment the guiding sensation is robbed of its restraining power by the test for heterophoria, when an increased pseudo-esophoria is shown. But finally the guiding sensation ceases its calls, or, from exhaustion, the accommodative center ceases to respond, and now the normal muscular condition is again shown, and will remain manifest, although the mydriatic may be continued. From this observation on the mydriatic as a disturber of the salutary relationship of the centers of accommodation and convergence, we deduce the following conclusion: All tests for lateral heterophoria are wholly unreliable within the first few hours after eyes have been brought under the influence of a mydriatic.

Exclusion test. The exclusion test will always show an outward resetting whenever the card is removed. The resetting may be so slight as not to be detected objectively; but the patient will always be conscious of the apparent movement of the test object toward the opposite side, however slight may be the esophoria.

The red-glass test. Taking the eye slightly off its guard because of the change in the color of the image, will result in diplopia in many cases, the red light appearing on the side corresponding to the eye before which the red glass is held—homonymous diplopia. It will be distant from the true candle, more or less, depending on the quantity of the error. The diplopia developed by the red glass practically always indicates that an operation should be done, but it does not determine the muscle to be operated upon nor the kind of operation to be done. This can be shown only by the duction and version tests of both the interni and the externi.

The double prism. The double prism, held with the line of union of the bases horizontal, shows the middle, or true, object displaced toward the corresponding side; or, if the true object is fixed, the upper and lower false object will appear on the side corresponding to the position of the double prism. A prism from the refraction case that places the false and true objects in a vertical line, measures the error, but does not indicate the method of procedure to be adopted for effecting a cure. The duction and version powers must be taken.

The single prism. If the single prism be correctly held before the eye—that is, the axis vertical and the base up—the resulting diplopia will be homonymous; and the extent of the deviation can be measured by prisms, as when the Maddox double prism is made the means of producing the diplopia. The double prism has the advantage over the single prism, whether they are placed in a trial frame or held in the hand, in that the examiner can always be certain, with the double prism, that its axis is vertical, when the two resulting images are made to appear the one directly over the other. With the single prism there is no such means of knowing the exact position of the axis, hence the chance for the creeping in of an error that, on the one hand, may show more esophoria, while, on the other hand, it may show less, than really exists. The ease with which this source of error might be eliminated by the double prism was really the thought that led Maddox to invent it. Of the two means for developing diplopia by prisms, independent of the phorometer armed with the spirit level, the double prism is by far the better and more reliable.

The Maddox rod. The Maddox rod was invented because of a defect in the double prism as first made, and as made even now by some manufacturers. The grinding of both prisms on one piece of glass left a somewhat rounded line of union of the bases, so that not only would the candle blaze be doubled when the base-line passes across the pupil, but a streak of light, formed by the refraction of the rays passing through the rounded line of union, extends more or less completely from the one false light to the other. The streak served a good purpose, in that it led to the invention of the indispensable rod; but since it can no longer serve a good purpose, it should be eliminated by uniting two separate prisms, base to base.

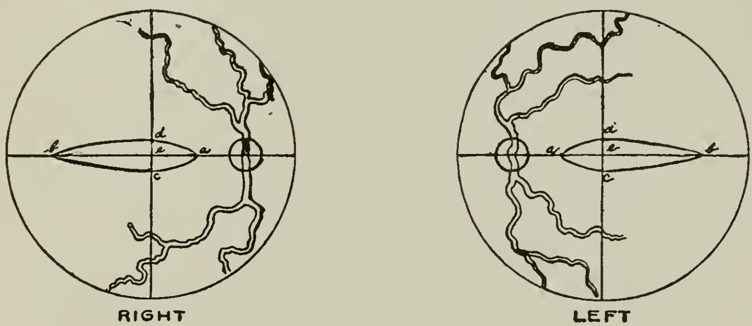


Fig. 29. Retinal Fusion Areas.

While there is but one certain, therefore legitimate, use for the Maddox rod—viz., in testing the oblique muscles—it is, nevertheless, frequently used in testing the recti.

When the rod is horizontal before the right eye, the vertical streak of light is seen to the right of the candle in every case of esophoria. The prism, base out, that causes the streak to pass down through the light measures, but not accurately, the quantity of the esophoria. The want of accuracy is due to the fact that the vertical retinal meridian is not turned so far out, by contraction of the internus, as to throw the streak entirely outside the retinal area in which resides the guiding sensation; therefore there would be some effort made at fusing the part of the much-changed image with the true and unchanged image in the other eye. Figure 29 shows this better than words can possibly portray. The figure also shows how a displacing prism, with base up, would throw the unchanged image of the candle blaze above and entirely beyond the fusion area, so that no effort would be made by the eye to disturb the position of equilibrium into which it has turned. It will be seen also that the rotary prism would carry the displaced image to the vertical meridian without having it infringe anywhere on the fusion area. The dotted line from e, in the right eye, represents the line of travel of the image while the measurement of the error is being taken with the rotary prism. At no time would a fusion impulse be excited. Not so with the streak of light which crosses the fusion area. The nearer this is carried by a rotary prism, or a simple prism, base out, to the vertical retinal meridian, the greater would be the demand made by the guiding sensation on the center controlling the external rectus. For this reason the rod test will give variable results from time to time, and will always show less esophoria than the patient really has. The same is true, even to a greater extent, when the rod is used for testing for exophoria and for hyperphoria and cataphoria. There is only one means for testing for esophoria that is less reliable than the rod, and that is the strong plus lens suggested by Stevens.

The monocular phorometer. From every standpoint the monocular phorometer constitutes the most desirable means for detecting esophoria and measuring it. The displacing prism should always be placed, base up, in the cell toward the patient's eye; the thumb-screw for the rotary prism should be in the horizontal; the index of the rotary prism should stand at zero; and the spirit level should be exactly regulated. The upper, or true, object should be fixed. The six-degree displacing prism will throw the false image above and entirely beyond the retinal area of binocular fusion, taking the guiding sensation of that eye entirely off its guard, so that the eye will at once be turned in. The lower, or false, object will be proportionately displaced from the vertical toward the corresponding side—homonymous diplopia. Revolving the rotary prism so that its index moves in the nasal arc, the false object is brought further and further toward the vertical line passing down from the true object, until at last the patient observes that the false object is directly under the true object. The point at which the index stops tells the degree of the error. The same result, practically, will be shown by any number of tests on the same day or on consecutive days, if the patient is always careful to "fix" the true object. This point is absolutely essential to the greatest accuracy; and if strictly observed, there is no other factor to bring in an error. Certainly at no time will the false image be within the retinal area of binocular fusion.

The one eye tested, the instrument should be reversed so as to test the other eye, for in this way only can it be determined if there is more esophoria in the one eye than in the other.

Pseudo-esophoria or intrinsic? To know how to proceed in the treatment of any given case, this question must be answered: Is it pseudo-esophoria? This is answered by a study of the refraction under a mydriatic a little later. If there is no hyperopia or hyperopic astigmatism, the answer is "No." If there is hyperopia or hyperopic astigmatism, the answer is, "Yes, at least in part," which part can be easily calculated, for it would be 1.8°, or nearly 2°, for every dioptre of the hyperopia, and as much for every 2 D. of hyperopic astigmatism. The quantity of the pseudo-esophoria thus determined, subtracted from the full error, as shown by the phorometer gives the amount of the true, or intrinsic, esophoria.

Duction and version. But before the mydriatic is used the duction and version power of both interni and both externi should be taken in order that the following two questions may be answered: Is the intrinsic sthenic? Is it asthenic? How to make these tests has been shown in the study of Fig. 9. These questions answered, the method of procedure becomes plain, as soon as complications have been found or eliminated.

Complications of esophoria. These are hyperopia and hyperopic astigmatism, hyperphoria and cataphoria, and plus and minus cyclophoria. The existence or non-existence of one or more of these complications must be known before it becomes possible to resort to the correct treatment of esophoria. It has already been shown how hyperopia and hyperopic astigmatism develop a pseudo-esophoria, which can be cured by proper lenses. A myopia and myopic astigmatism sometimes complicate an esophoria, and when they do, their correction increases the esophoria in the near, but not in the far.

A hyperphoria of one eye and a cataphoria of the other will increase an esophoria, as will also a double hyperphoria and a double cataphoria. How to deal with these complications in the treatment of esophoria will be shown under the head "Treatment."

As already stated, it is difficult to see how a plus or a minus cyclophoria can add to an esophoria, since the oblique muscles are abductors; but it can be seen readily how an esophoria might be lessened by a cyclophoria. It is possible, however, that a cyclophoria may excite the third conjugate innervation center in some way, so as to develop a spasm of the interni, such as is excited in cases of hyperopia; but there is not that definite relationship between the obliques and the interni that there is between the ciliary muscles and the interni. Nevertheless, when cyclophoria complicates an esophoria, the treatment of the esophoria must include the treatment of cyclophoria, if the best and quickest results are to follow; in fact, it is practically impossible to cure an esophoria while the cyclophoria remains uncorrected.

For the methods of detecting and measuring hyperphoria and cataphoria, and plus and minus cyclophoria, as complications of esophoria, the reader is referred to the study of those errors further on.

Symptoms of esophoria. These are any one or several of those mentioned as resulting from heterophoria, and the reader is referred to that part of this study treating of symptoms; but not all the symptoms resulting from abnormal nervous tension of the ocular muscles are mentioned in that section. It would be impossible to make a complete list. There is not a single brain-center controlling any one organ or part of the body that may not be disturbed, in sympathy with the fusion centers that control the ocular muscles, in the interest of binocular single vision; and, vice versa, the centers controlling the ocular muscles may be sympathetically disturbed because of excessive demands on the other centers. The difference between other centers and those controlling the ocular muscles, is that the former have not so severe a taskmaster as the guiding sensation which compels obedience, on the part of the ocular muscles, to the law of corresponding retinal points, in binocular vision. For this reason no other centers are so likely to be overworked as are the eight fusional innervation centers whose duty is to control the recti muscles so that the visual axes may always be in the same plane and may be converged at the proper point, and the four conjugate centers that force the obliques to parallel the vertical axes with the median plane of the head. The only exception is the center that controls the action of the ciliary muscles, which must also satisfy the guiding sensation of the retina.

In monocular vision, as when one eye has been lost, the possibility of the excitation of reflex nervous symptoms is greatly lessened. The centers not relieved of the necessity of over-excitation when there is but one eye are the center that sends impulses to the ciliary muscle and the centers that must make the obliques parallel the vertical axis with the median plane of the head. Posing the head in monocular vision would relieve the strain that may have been demanded of the recti in binocular vision. There is, therefore, truth in the statement that has been made by some people who have lost one eye—that "the one eye is stronger than the two ever were."

The symptoms of esophoria are not due directly to the abnormally high inherent tension of the interni, but to the abnormal nervous tension of the externi in their effort to prevent the esophoria from being transformed into an esotropia, or to the nervous tension of other weak muscles in their effort to counteract other errors that may complicate the esophoria.

[This subject continued in Volume XI.]