ble to account satisfactorily for the action of the sympathetic nerve on the iris. The view that these nerves change the size of the pupil, through their action upon the muscular walls of the blood-vessels of the iris, is not well supported by the facts.

Their course toward the eyeball is partly along the walls of the arteries, partly along anastomoses which join the fifth cranial nerve. Section or paralysis of the sympathetic nerve of the neck is followed by contraction of the pupil, while its irritation dilates that aperture. These fibres can be traced through the rami communicantes of the last two cervical and the first two dorsal nerves into the spinal cord (Budge and Waller). The reflex centre of these fibres is partly in the corresponding region of the spinal cord, and partly in the medulla oblongata. Reflex dilatation of the pupil through this nerve channel can be readily induced by any sensory impression through almost any sensory nerve, at least when the pupil is not contracted by strong light, especially during sleep and incomplete narcosis. The pupil, indeed, is very sensitive to irritations of sensory nerves. It is not known that this reflex dilatation is of any utility.

It has recently been asserted by Tuwim[7] that the superior cervical sympathetic ganglion maintains a slight tonus of the dilator nerves of the iris, independently of, and even after, its separation from the central nervous system. Although his experiments seem conclusive, the question should be further investigated, since this would be the first instance known of tonic activity of nerves maintained by a sympathetic ganglion.

The fifth cranial nerve is the sensory nerve of the iris, endowing it with very great sensibility. Irritation of this nerve contracts the pupil very energetically in some animals, for instance the rabbit. Section of the nerve has the same effect, temporarily, the fibres being evidently kept in a state of transitory irritation by the injury, as occurs as well in certain other nerves. This influence of the fifth nerve upon the pupil does not exist in carnivorous animals. The observations in disease of that nerve in man are too conflicting to be decisive. The study of eye diseases attended with irritation renders it very likely that in man the fifth nerve is the vaso-dilator nerve of the iris, and that its reflex excitation congests the iris and contracts the pupil mechanically by the engorgement of the vessels. This is also the most plausible explanation of the intense pupillary contraction obtained on puncturing the anterior chamber, which result does not occur on operating on the dead eye.

BIBLIOGRAPHY.—The optic properties of the eye were not understood until Kepler, in 1602, evolved the theory of optical instruments in general. The importance of the various parts of the eye in refraction was further elucidated by the Jesuit Scheiner in 1619. Minor additions were successively brought out by the labor of different authors, but it was only after Gauss had published his mathematical investigation of the cardinal points ("Dioptrische Untersuchungen," Göttingen, 1841) that the complete theory of the refraction in the eye could be deduced. This was done successfully by Listing, in the article "Dioptrik des Auges" in Wagner's "Handwörterbuch der Physiologie" (1853), who, by a critical selection of the older measurements of the refractive indices of the eye by Chossat and by Brewster, of the anatomical measurements of dimensions and curvature by Kraus, Kohlrausch, and others, determined the position of the ocular cardinal points with considerable accuracy. The most marvellously accurate methods, however, for measurements of the living eye, were first introduced by Helmholtz, who, in his "Handbuch der physiologischen Optik" (1867; 2d edition, revised, 1896), has produced a masterly treatise of rare originality, which every student of the subject must consult in the original. Since the publication of his large work, the first part of which on refraction appeared in 1856, Helmholtz has pursued these studies with the aid of numerous students, most of whose articles have appeared in the running numbers of the *Archiv für Ophthalmologie*. In an article by Reich (*Arch. f. Ophth.*, 1874, vol. xx., 1), Helmholtz corrects some of his former measurements and figures, and accepts as more nearly representing the values of the cardinal points in the average eye the figures which we have reproduced in the text of this article. Extensive measurements, especially of the curvature of the cornea, have also been made by Donders ("Anomalies of Accommodation and Refraction," 1864) and by Mauthner ("Vorlesungen ueber d. optischen Fehler des Auges," 1872), and more recently by Reuss (*Arch. f Ophthalmologie*, xvii., 1, p. 27). The entire theory of the formation of images in the eye, including physiological optics in general, is most exhaustively treated in Aubert's "Grundzüge der phys. Optik," in vol. ii. of Graefe and Saemisch's "Handbuch der gesammten Augenheilkunde" (1876), while important recent additions are to be found in Nagel's "Anomalien der Refraction," in vol. vi. of the same work. Very complete is also the treatise of Fick in vol. iii. of Hermann's "Handbuch der Physiologie."* All of these works must be consulted for the complete literature of the subject. In the English language the most extensive but older treatise is the work by Donders on "Anomalies of Accommodation and Refraction" (1864), which book marked quite an era in our knowledge of the physics of the different refractive conditions of the eye. In connection with this latter subject the work of Jaeger ("Einstellungen d. dioptrischen Apparats," 1861) must also be mentioned.

The mechanism of accommodation has been extensively discussed by former authors, by whom, however, no facts were brought forth beyond those taught by every-day observation. By some the accommodative changes were referred to the variations in the size of the pupil, while others even denied the existence of any accommodation. The most complete mathematical discussion was furnished by Th. Young in the "Philosophical Transactions" of 1801, in which it was shown by experiments and by deductions that the accommodation cannot depend on any changes except those in the form of the lens. The experimental proof that such changes do occur was furnished simultaneously and independently of each other by Cramer (in various publications in the Dutch language, between 1851 and 1855) and by Helmholtz (*Monatsberichte d. Berliner Academie*, February, 1853). The mode of action of the ciliary muscle was first explained by Helmholtz theoretically, and has since been confirmed experimentally by Hensen and Voelkers, who have likewise studied the innervation of the accommodative apparatus ("Experimentaluntersuchung über den Mechanismus der Accommodation," 1868, and *Archiv f. Ophthalmologie*, 1873, vol. xix.). Important measurements of the changes in the curvature of the lens during accommodation, and a mathematical inquiry into their efficiency were published by Knapp (*Archiv f. Ophth.*, 1860, vols. vi. and vii.).† Our knowledge of the range of accommodation in health and disease is due mainly to the researches of Donders ("Anomalies of Accommodation and Refraction").

On the innervation of the iris there exists an extensive literature, scattered throughout numerous physiological and ophthalmic serials. The older literature is exhaustively compiled in Budge's "Bewegungen der Iris," 1855. The present writer presented likewise a full review of the physiology of the iris in the Chicago *Journal of Nervous and Mental Diseases* (April and July, 1874), in which the complete literature up to that date can be found. Whatever has been done since 1874 is explicitly referred to in the text.

H. Gradle.

1 Nagel: Anomal. d. Refraction, in Graefe and Saemisch's Handb. d. ges. Augenheilkunde, p. 461.
2 Ueber schiefen Durchgang von Strahlenbündeln durch Linsen, Gratulationschrift an C. Ludwig, 1874.
3 Archives of Ophthalmology, vol. ix., p. 29.

* The most recent compilation with many original measurements is Tscherning's "Physiological Optics," trans. by C. Weiland.

† Various doubts raised concerning Helmholtz theory of accommodation have been satisfactorily answered by confirmatory researches published by C. Hess in von Graefe's Archiv f. Ophthalmologie in a series of articles from 1897 to 1901.

4 Proceedings of the International Congress at Copenhagen, 1884, Ophthalmic Section.
5 Report of the Heidelberg Ophth. Society in Deutsche med. Wochenschrift, October 9th, 1884.
6 Archiv f. Ophthalmologie, 1866, xii., p. 95.
7 Archiv f. d. gesammte Physiologie, Bd. xxiv., p. 115.

EYE DISEASES. See under *Cataract, Choroid, Conjunctiva, Cornea, Glaucoma, Hypermetropia, Myopia*, etc.

EYE, INJURIES OF.—It will be proper, in writing on injuries of the eye, to take for granted that the reader is well acquainted with the anatomy and physiology of that organ, and such of its appendages and surroundings as, on account of structure, function, or situation, are likely, in case of injury, to require treatment differing in any way from that which would be suggested by the principles of general medicine and surgery.

It is understood, too, that the reader has acquired the art of using easily and well all the instruments and methods needed by the oculist for the diagnosis and treatment of those affections which are not traumatic. One requires, in handling cases of injury, not only to have at command an ophthalmoscope and a full case of surgical instruments, but to be well drilled in their use, and to possess also a certain adaptability to the situation and independence of thought and action, which will allow him to depart occasionally from conventionalities, and in emergency to use instruments for what they are worth, not necessarily for what they are made. For, though the results of violence may be routined off and classified as to the kind of operative interference that they may require, it is oftener in this branch than in any other that the surgeon will discover new and unprecedented situations or conditions which occur so infrequently as to have existed in literature only as forgotten curiosities.

PHYSICAL CONDITIONS.—A word or two relative to the physical conditions which exist in the healthy eye may be of service in helping to appreciate those which are likely to exist in the injured organ, or in one in which inflammatory changes following injury have not been met by the necessary surgical interference.

The eye is a globe; it is filled with fluid, semifluid, or gelatinous matter which is practically incompressible. Its walls, though elastic and flexible, cannot be stretched very much, and as the sphere is that form which will contain the largest amount of matter within a given area of covering, the result is, there being no outlet, that if pressure is put upon this globe it will not change its shape very much without rupture. The physical conditions are very much the same as those of a leather ball filled with water—not those that exist in a rubber ball filled with air. The walls of this globe are very flexible, and when the globe itself is emptied any part of the sclerotic or cornea can be bent on itself like cloth. Neither of these tissues, either with or without its lining membrane, is subject to fracture in the true sense of the word, and when there is any complete and violent solution of continuity in these parts it is due either to laceration, to puncture, to cutting from some sharp substance, or to tension, erosion, or chemical action. The particular part at which rupture takes place will be the part at which the enveloping material is the weakest, unless, perchance, that part, at the time of the stress, is better supported by the pressure of neighboring parts, or unless some other portion is made comparatively weak by the pressure of some foreign substance which bends or indents it, and so places on it a local strain that cannot be transmitted. Rupture by contre-coup is not possible in the eye, though it is sometimes spoken of as having taken place.

Before considering each separate tissue in order, it may be well to supplement what has already been said by calling attention to the fact that the enclosing tunics of the healthy eye are more than full, and once their integrity is broken a small part of the contents is likely to be forced out by the elasticity of the tissues; that the secretion of aqueous and vitreous, and the supply of blood to the interior of the organ, keep its elastic covering always in a state of tension, and when, by rupture, cut, or puncture, or by ulceration, or decay of injured tissue, there is any solution of continuity, a part of the contents will have a tendency to escape; and while the opening remains, the constant building up of material to supply the place of what has been lost often forms a serious obstacle to the rapid healing of the wound, or the successful return of any part of its contents, such as protruding iris or vitreous, to the eye.

Without having at hand any experiments which may be quoted as giving definite knowledge of the actual strength of the materials used in the structure of the eye, it is possible to state, from records kept in cases of injury, that the part which is least capable of resisting strain put upon it by external pressure is the sclerotic, 3 or 4 mm. from the sclero-corneal margin. This is by far the most frequent seat of rupture, which nearly always takes place in a direction parallel to the sclero-corneal margin. The fact that it is usually found to have broken through the meridional fibres in the upper and inner quadrant is probably explained by the position of the surrounding parts, which are such as to protect it from external pressure, and yet to give little or no support when the eye is pressed upon from some other direction. The cornea rarely ruptures, and when it does, it is from some ragged extension of an irregular sclerotic tear, and is not to be looked upon as primarily a corneal lesion. The thickness of the sclerotic and cornea in the accompanying cut is not to show the actual size, but to indicate diagrammatically the relative liability of different parts to give way whenever, from any cause, sufficient pressure is put upon the eye itself to make a rupture of its tunics inevitable. In the same figure the choroid is drawn as if it were attached to the inner side of the sclera only at the nerve, at the venæ vorticosæ, and at the ciliary processes (Nos. 1, 2, 3). This is not really the fact, but it is so much more loosely attached at the intermediate points that, whenever the choroid itself ruptures—as it sometimes does if pressure so distorts the eye as to pull this membrane away from the overlying sclera—the break

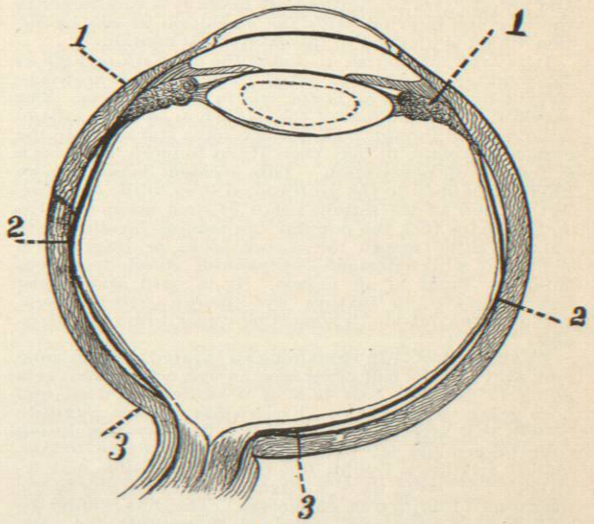

FIG. 2049.

does not ordinarily occur at any of the three points named above, but at some intermediate place. Such ruptures are most frequently seen, of course, in the posterior part of the eye, often nearer the nerve than the equator. They also do occur anteriorly to the venæ vorticosæ, and sometimes so far forward as to be unrecognizable during