CHAPTER I.

Remarks on the Anatomy of the Eye—Mechanism of the Accommodation of the Eye.

ANATOMY OF THE EYE.

Orbito-Ocular Sheath.—The eyeball is encased in a fibrous sheath, which commences at the apex of the orbit, and embracing the optic nerve, passes forwards and becomes interwoven with the sclerotic a few lines behind the margin of the cornea. This sheath is known as the orbito-ocular sheath, or capsule of Tenon; it is perforated by the tendons of the obliqui muscles near the equator of the eye, and anteriorly the tendons of the recti muscles, in passing through it, give off a number of fibres, which are incorporated into those of the capsule of Tenon; in fact, these muscles may be said to be inserted not only into the sclerotic, but also into the orbito-ocular sheath (Fig. 1). The posterior surface of the globe of the eye, therefore, glides over the inner layer of the capsule of Tenon, somewhat in the same way as the head of the femur does in the acetabulum, a small quantity of serous fluid intervening between the eyeball and the orbito-ocular sheath. In extirpation of the eye, care should be taken not to

CAPSULE OF TENON.

FIG. 1.

a, *b*, *c*, *d*, sections of the recti muscles; *e*, *e*, capsule of Tenon; *g*, *g*, sclerotic, the capsule of Tenon having been removed; *f*, section of optic nerve.

Facilitates motion.

Preserved in extirpation of the eye.

injure the barrier formed by this fibrous membrane, the operation is thus rendered less dangerous than when the capsule of Tenon is cut through, and the contents of the orbit external to it are wounded, for inflammation may under these circumstances be set up among the soft tissues contained within the orbit, and be propagated backwards to the cranial cavity.*

Importance of, in operations for strabismus.

The connexion of the capsule of Tenon with the tendons of the recti muscles has an important bearing on the operation of tenotomy for the cure of diplopia. Evidently, if the tendons of the muscles only are divided close to their insertion into the sclerotic, the processes given off from them to the capsule of Tenon will prevent the tendons from suffering too great a retraction, and allow of their forming adhesions to the sclerotic near their normal point of insertion, often a matter of the first consideration in operations for the cure of strabismus.

Form of the eyeball.

If the eyeball is carefully separated from its attachments, it will be found to be nearly spherical; the cornea, being the segment of a smaller sphere, is more convex than any other portion. The eyeball varies in size in different individuals—its mean diameter being about seven-eighths of an inch.

THE SCLEROTIC.

The Sclerotic is the most external of the proper tunics of the eyeball, forming a dense, opaque, fibrous casing, which gives shape and support to the delicate structures within; its texture is modified anteriorly, where it forms the cornea, so as to become transparent and admit the passage of light to the interior of the eye. The optic nerve, ciliary vessels and nerves, pierce the sclerotic from behind: it is thickest posteriorly, where it corresponds to the situation of the retina, and becomes gradually thinner in front, until within a short distance of the cornea, when the sclerotic again increases in thickness, the capsule of Tenon being here fused into its substance: it is thinnest immediately behind the insertion of the recti and obliqui muscles. The sclerotic is in relation externally with the capsule of Tenon, and internally, in front, with the ciliary muscle, and behind with the choroid.

THE OPTIC NERVE.

The Optic Nerve passes through the sclerotic, together with the retinal vessels, at a spot about one-tenth of an inch internal to the antero-posterior axis of the eye. The passage through which the nerve enters the eyeball is funnel-shaped—being smaller towards the inner than the outer surface of the sclerotic: this opening is crossed by numerous decussating fibrous bands, which constitute the *lamina cribrosa*—in fact, it would be more correct to say that the sclerotic is pierced by a number of small openings for the transmission of the component fascicles of the nerve, rather than by a single one for the nerve itself.

Disposition of its sheath.

The optic nerve is encased in a dense fibrous sheath, a portion of which, on reaching the sclerotic, becomes fused into its structure, strengthening it posteriorly. In addition to this, the neurilemma of the various bundles of which the nerve is composed, is not prolonged into the eye, but quitting the nervous elements (which are further deprived of their white substance), it terminates in the fibrous meshes of the lamina cribrosa and anterior layers of the sclerotic.

Donders' views.

Donders* describes the sheath of the nerve as consisting of two parts; the larger, external portion, leaves the nerve as it is about to enter the eye, and passing outwards, becomes incorporated with the sclerotic; the inner, more delicate portion, follows the nerve as far as the lamina cribrosa, which it helps to form, and then bends outwards to join the sclerotic towards its inner surface. The two portions of the sheath, in the normal condition of the parts, are united by a thin intervening layer of connective tissue, but the interval between them is continuous with the arachnoid cavity; and in persons predisposed to the affection known as *staphyloma posticum*, the outer sheath diverges prematurely from the inner one, leaving a considerable interval between them, which in section appears triangular, and is occupied by an increased growth of connective tissue. In this condition of the parts, the sclerotic immediately around the optic disc is represented by the thin layer of the inner sheath, deprived of the support it usually receives from behind, and is therefore prone to yield to intraocular pressure giving rise to staphyloma (see Fig. 33).

Relation to Post. staphyloma.

* "Atlas of Surgical and Topographical Anatomy," by B. F. Beraud; translated by R. H. Holme, pl. 15, fig. 2.

* "Accommodation and Refraction of the Eye," by Donders, p. 378 (New Sydenham Society).

The Conjunctiva. *The Conjunctiva* is essentially a mucous membrane, composed of an external stratum of epithelial cells resting on a basement membrane, beneath which the capillary vessels are situated. It lines the eyelids, and is continued over the anterior part of the eyeball; in the former situation it is known as the tarsal or palpebral conjunctiva, and in the latter as the orbital, or ocular conjunctiva. At its line of reflection from the lids to the eyeball, the membrane forms a loose fold, called the tarso-orbital fold; at the inner angle of the eye is a vertical fold, the plica semilunaris.

Palpebral portion. The palpebral conjunctiva is extremely vascular and thick, and its free surface is elevated into numerous papillæ, each of which encloses one or more fine capillary loops, and a terminal nervous apparatus, the whole being encased in connective tissue. *Papillæ and glands.* Beneath the basement membrane is a loose connective tissue, in which a number of solitary glands are imbedded; and besides these, there are a row of some eighteen or twenty conglomerate glands, opening by as many ducts on the free surface of the tarso-orbital fold of the conjunctiva; they pour out an abundant watery secretion, which helps to lubricate the eye.

Ocular portion. The ocular conjunctiva is void of papillæ, and is bound down to the capsule of Tenon by connective tissue; anteriorly it is united with the sclerotic. *Its vascular supply.* It is supplied with a superficial and deep set of vessels, the former being derived from branches of the palpebral and lachrymal arteries, and the latter from the muscular and ciliary; these anastomose with one another, forming a zone of vessels round the circumference of the cornea, and from this circle small branches pierce the sclerotic and anastomose with the vessels of the iris and choroid. In consequence of this arrangement, *The "sclerotic zone."* when the latter structure is congested, the zone of vessels round the cornea becomes turgid also, forming the "sclerotic zone of vessels," the "arthritic ring" of which we shall have to speak so frequently, as a most important indication of disorder in the intra-ocular circulation.

Venous anastomoses. The veins of the conjunctiva empty themselves into the cavernous sinus through the muscular and lachrymal veins, and also into the angular vein of the face, by the nasal arch; so that if from any cause the passage of blood through the vasa vorticosa of the choroid into the ophthalmic vein is impeded, as in glaucoma, a collateral circulation is established through the veins of the conjunctiva—hence the enlarged and tortuous superficial vessels noticed in chronic diseases affecting the choroid.

The Cornea. *The Cornea* is a modification of the sclerotic so constructed as to receive its nutriment by endosmosis, thus preventing the necessity for a vascular system, which would interfere with its transparency. The circumference is bevelled in such a manner that the sclerotic overlaps it; but, with this exception, it is of the same thickness throughout.

Its anterior lamina. The cornea is divided into three laminæ; the external or conjunctival is an apparently structureless membrane, its anterior surface being covered by several layers of epithelial cells; posteriorly it sends processes inwards, interlacing with the fibrous elements of the lamina beneath it. *Middle lamina.* The middle lamina constitutes the principal bulk of the cornea, and consists of fibrous tissue, so arranged as to form strata superimposed one over the other; frequent communications, however, exist between contiguous layers, so that they are intimately connected one with another. In the intervals between the bundles and layers are innumerable interspaces or fissures, which contain elongated branching cells and a nucleus; these cells are probably filled with nutrient fluid during life. Branches of the long ciliary nerves may be traced into the cornea, where they appear to form a very abundant and intricate network.

Internal lamina. The internal lamina of the cornea is composed of an homogeneous membrane, and is lined internally—that is, towards the aqueous humour—by epithelial cells. Bowman describes it as "a transparent homogeneous membrane. Though very hard and capable of resisting pressure, giving a crisp sound when divided with scissors, yet it is very brittle and easily torn, fragments showing a remarkable tendency to curl up on all sides into rolls."*

Anatomical relations of internal lamina. A part of the fibrous structure of the middle lamina unites with the internal at the circumference of the cornea, and their union gives rise to three sets of

* "Lectures on the Parts concerned in the Operations on the Eye," by W. Bowman, p. 19.

fibres; one passing backwards towards the ciliary processes, form a point of attachment for the ciliary muscle, another bending forwards in an arched manner, unite with those of the sclerotic, leaving a small space between the two, called the circular sinus; and a third set of these fibres curve backwards to the iris, and are inserted into its anterior circumference.

THE CHOROID. **Structure and relations.**

The Choroid is essentially a vascular structure, serving the primary purpose of a reservoir of blood for the nourishment of the vitreous and lens. It is prolonged anteriorly into the ciliary processes; externally it is in contact with the sclerotic and ciliary muscle, and internally with the elastic lamina of the choroid, a fine hyaloid membrane upon which the hexagonal cells of the choroid rest; these two limiting structures being united by bands of connective tissue, in the meshes of which are situated the vessels, nerves, contractile tissue, and pigment cells, which collectively constitute the choroid. The innermost layer of cells—that is, those nearest the elastic lamina—are almost devoid of colouring matter, and are very much smaller than the pigment cells. The choroid contains a considerable quantity of contractile tissue prolonged from the ciliary muscle. Its nerves are derived from the short ciliary branches of the ophthalmic ganglion.

Arrangement of its vessels and pigment cells.

The vessels of the choroid and ciliary processes have been divided by anatomists into several layers, which it is unnecessary for me to describe. The arteries are derived from the posterior short ciliary divisions of the ophthalmic artery, which, piercing the sclerotic near the lamina cribrosa, divide into numerous branches; these are directed forwards, following a somewhat meandering course among the pigment cells of the choroid, and they give origin to a dense capillary network situated immediately behind the elastic lamina.

Capillaries internal.

The larger vessels of the choroid, therefore, are nearer the sclerotic than their capillaries, and in their meshes are lodged the stellate pigment cells of the part; whereas many of the capillaries are internal to the pigment cells, and consequently when these vessels are congested, if the eye is examined with the ophthalmoscope, they will be found almost to conceal the larger vessels of the choroid and its pigmentary structures.

Hidden by pigment in dark races.

Among dark-skinned people, so long as the hexagonal cells of the elastic lamina remain *in situ*, it is impossible to see the choroid with the ophthalmoscope; but in the fairer races, the hexagonal cells being free from pigment allow the passage of light to the choroid, and the reflection from this vascular layer causes the scarlet colour of the fundus of the eye as seen with the ophthalmoscope.

Some of the branches of the short ciliary arteries pass forwards through the ciliary muscle, and enter the iris.

Veins "vasa vorticosa" external.

The veins of the choroid form a vascular stratum external to the arterial network; they are arranged in curves (vasa vorticosa), converging to four large branches, which perforate the sclerotic midway between the optic nerve and the cornea and ultimately empty themselves in the cavernous sinus.

Ciliary processes.

Beyond the ora serrata the inner surface of the choroid appears striated; anteriorly the striæ become deeper, forming the *ciliary processes*, which pass forward and overlap, but do not actually touch the edge of the lens. These processes, amounting to about sixty in number, are received into as many folds of the vitreous body: they are lined internally by the suspensory ligament of the lens; externally they are in contact with the ciliary muscle. The structure of the ciliary processes is similar to that of the choroid, but anteriorly the vessels bend round upon themselves, each process being formed, as it were, of a club-shaped mass of vessels imbedded in fibro-cellular tissue and pigment cells; these processes are situated immediately behind the iris, forming the ciliary body.

THE IRIS. **Its attachments and structure.**

The Iris, as has been already stated, arises from the fibres proceeding from the margin of the inner lamina of the cornea, some of which may be traced into it. A second set, arising from the margin of the cornea, were mentioned as passing posteriorly towards the ciliary processes; some of these, too, may be followed into the iris. In addition to its fibrous structure, the iris contains an outer longitudinal and an inner circular set of contractile fibres, connective tissue, pigment cells, vessels and nerves. Its anterior surface is free, and bathed by the aqueous humour; its posterior surface rests against the capsule of the lens, and it inner margin forms the circumference of the pupil. It contains a vast number of pigment cells; those on its posterior surface being continuous with the epithelium covering the elastic lamina of the ciliary processes.

Contractile elements. The contractile (muscular) fibres of the iris may be divided into two sets; the outer, or radiating, which are described as running in fasciculi from without inwards, forming the dilatator pupillæ, and the internal circular fibres, which constitute the constrictor pupillæ.

Vessels. The vessels of the iris pursue a similar course; they are of a small size, and are derived from the long ciliary arteries, which perforate the sclerotic posteriorly; they pass along in the ciliary muscle till they reach the outer margin of the iris, when they divide and form a zone round its circumference, sending off branches to the iris and ciliary muscle.

Nerves. The iris derives its nerves from the ciliary branches of the ophthalmic ganglion, which connect it with the third, fifth, and sympathetic nerves, and also from the long ciliary branches of the nasal nerve; these uniting form a plexus round the outer margin of the iris, and from thence send off branches to supply the dilatator and constrictor muscles.

Reflex action of the pupil. The contraction of the pupil, in obedience to the stimulus of light, is evidently a reflex action depending upon excitation of the retina, the impression being transmitted to the circular muscle of the iris through the third nerve; for it is through the action of the **Motor fibres.** motor fibres of this nerve that the circular muscle of the iris contracts, for when the retina or the third nerve is destroyed the pupil remains dilated. If the optic nerve is divided, the iris still contracts when the portion of the nerve connected with the brain is irritated; and when the third nerve is divided, the irritation of its distal portion will still excite contraction of the iris. It is well known that through means of this reflex action, both irides will contract their pupils under the influence of light falling on one retina. Thus, in amaurosis of one eye, its pupil may contract when the other eye is exposed to a stronger light. The iris also contracts in association with certain other muscles supplied by the third nerve: thus, when the eye is directed inwards, or upwards, by the action of the recti, the iris contracts, as if under the action of the will; the contraction of the iris may under these circumstances occur in cases of total blindness. The contraction of the pupils, when the

eyes are inverted as in looking at near objects, serves the purpose of excluding the extraneous rays of light which are too divergent to be refracted on the retina.* The sympathetic nerve brings the radiating fibres of the iris into action, and hence division of the sympathetic in the neck is followed by contraction of the pupil, whereas its irritation causes the pupil to dilate. Donders remarks, that the action of the sympathetic causes a persistent exaltation of the tone of the radiating fibres of the iris; thus the dilatator pupillæ is with constant force the antagonist of the sphincter muscle.† It seems very possible, however, that the sympathetic fibres in this, as in other situations, are chiefly distributed to the vessels, and unless by altering their calibre hardly influence the movements of the iris.

The fifth is the sentient nerve of the iris; its motor action can only be explained by supposing that, when irritated, reflex action takes place from the Gasserian ganglion, for its influence in causing contraction of the pupil continues after division of the oculo-motor and the sympathetic nerves.‡ **Sentient.**

The Retina is essentially a nervous structure, spread over the inner surface of the back of the eye. It extends from the optic disc forwards as far as the ora serrata, its posterior surface being in contact with the hexagonal cells of the choroid; internally it is separated from the hyaloid by the membrana limitans. **The Retina. Extent and relations.**

The vessels of the retina are derived from the arteria centralis retinæ, which enters the eye through the centre of the lamina cribrosa, and passing through the optic disc, sends out branches in different directions; they form, however, two principal groups as they leave the disc—one ascending, the other descending. These vessels are at first situated immediately beneath the membrana limitans, but ultimately they dip down into the nervous elements of the retina, terminating in a system of delicate and by no means numerous capilla- **The central artery and vein.**

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* "Handbook of Physiology." By W. T. Kirkes. Eighth Edition, p. 540.

† *Vide* Donders on "Accommodation and Refraction," published by the New Sydenham Society, p. 579.

‡ Id. p. 581.

ries. The veins commence in a circle round the ora serrata, and converging from thence, end in the vena centralis retinæ, which passes out of the eye through the centre of the optic disc.

Independent vessels of the disc.

The optic disc is described by Galezowski, Clifford Allbutt, and other authorities, as having a separate source from which it derives its blood-vessels, consisting of branches from the pia mater to the chiasma of the optic nerve, a branch from the middle cerebral to the optic tracts, as well as vessels from the choroid plexus and central artery of the retina: by means of the former (branches from the pia mater) there is an unbroken vascular network from the optic tracts to the papilla. In consequence of this arrangement, we can understand how anomalies in the cerebral circulation may extend to the papilla of the optic nerve, and how, from disease of the vessels supplying the papilla, this structure may be converted into a perfectly white disc (atrophy), its rose colour depending upon the supply of blood from the above-mentioned sources. On the other hand, the condition of the vessels of the optic papilla may indicate the degree of repletion or anæmia of the cerebral vessels, of which they are the prolongation.* But we must bear in mind that the blood supply of the disc is also maintained by vessels given off from the central artery of the retina, and from a vascular circle which surrounds the disc, formed from branches of the short ciliary arteries. In addition to these vessels the optic disc receives arteries and veins directly from the choroid, these anastomose with branches from the central vessels of the retina.

Intimate connexion with the brain.

The yellow spot.

A deeply-tinted yellow spot, called the *macula lutea*, may be observed in the retina, situated exactly in the axis of vision; it is therefore about the one-tenth of an inch to the outer side of the entrance of the optic nerve (optic disc); in its centre will be seen a small depression, the fovea centralis. The retinal vessels will be noticed curving above and below this spot in an arched manner, but they do not cross it. The

* "Etude Ophthalmoscopique sur les Altérations du Nerf Optique," par X. Galezowski, p. 33, Paris, 1866; also "On the Use of the Ophthalmoscope," by T. Clifford Allbutt, p. 30, London, 1871.

macula lutea is the most sensitive part of the retina.

Entrance of the optic nerve.

As I have already mentioned (p. 3) the fibrous sheath of the optic nerve is divided into two layers, the outer one being fused with and strengthening the posterior and middle layers of the sclerotic; and the internal sheath, which represents the neurilemma, passing forwards to the intra-ocular surface of the sclerotic to become fused with its anterior layers. Consequently, at the optic foramen of the sclerotic, a more or less projecting border is formed, to which the edge of the posterior opening of the choroid is attached by filamentary tissue. The scleral opening is filled by the anterior part of the optic nerve.

Scleral opening.

The lamina cribrosa is constituted by processes from the neurilemma of the optic nerve, strengthened by a network of elastic elements from the sheath of the central artery of the retina, and by fibres from the sclerotic.

LIGAMENT OF THE LENS.

The Suspensory Ligament of the Lens (zonula of Zinn) is a fibro-cellular structure internal to the hexagonal cells of the choroid; it passes forwards from the ora serrata and along the ciliary processes, and dipping down over the margin of the lens, it is incorporated with the anterior surface of the capsule of the lens. In leaving the ciliary body to pass to the lens, the suspensory ligament forms the anterior wall of the canal of Petit, to be presently noticed.

THE HYALOID AND VITREOUS.

The Hyaloid constitutes the membranous bag in which the Vitreous is contained; it is a most delicate and fragile structure, and is in immediate contact with the membrana limitans as far forwards as the ora serrata: anteriorly it is in apposition with the suspensory ligament of the lens, until, advancing close up to the margin of the lens, it dips down behind it, so that the edge of the lens is contained in a canal, first described by Petit, which is formed by the suspensory ligament in front and by the hyaloid behind.

Enclosed in this sac (the hyaloid) is the *Vitreous humour*, consisting of mucous tissue—the gelatinous connective tissue of Kölliker. It is structureless, without nerves or vessels, but contains nuclei and cells, which are principally found in its peripheral layers, and near the hyaloid. The nutrition of the vitreous is carried on through the vessels of the retina and choroid.

The Lens. The *Lens* is a transparent double-convex body, about the sixth of an inch thick, more curved behind than in front; it is composed of a numerous series of fibres, united so as to form plates or laminæ, having a very complex arrangement. **Capsule of lens.** It is contained in an elastic homogeneous capsule; on the posterior surface of the anterior capsule is a layer of polygonal cells, otherwise the capsule has no epithelium. The lens with its capsule may be said to rest posteriorly in the anterior part of the vitreous, the hyaloid intervening, and in front it is attached by the suspensory ligament to the ciliary processes, and is in contact with the posterior surface of the iris, and aqueous humour.

The Ciliary Muscle; The last structure I have to notice is the *Ciliary Muscle;* it consists of two sets of smooth muscular fibres, one having a meridional direction, the other a circular course; **Its connexions.** the former arise from the point of junction of the cornea and sclerotic, and pass backwards beneath the sclerotic as far as the ora serrata; they are attached to the sclerotic. These bundles of muscular fibre have an intimate connexion with the connective tissue of the ciliary processes and choroid. The circular fibres of the ciliary muscle are chiefly found near the boundary of the iris, and are attached to the fibres proceeding from the inner layer of the cornea towards the iris.

Vessels and nerves. The source of the vessels supplying the ciliary muscle is the same as in the case of the iris. Its nerves are derived from the ciliary, naso-ciliary (a nerve of sensation), and also from the sympathetic; these unite and form an abundant plexus in the muscle; it is also supplied with ganglionic cells.

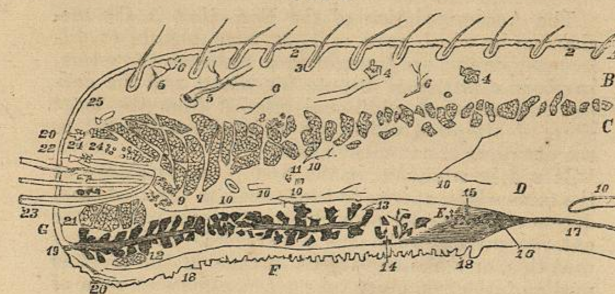
Anatomy of the Eyelids. *The Eyelids* serve a most important function in protecting the eye. Their anatomy will be readily understood by reference to the diagram on the opposite page, after M. Moll, which represents a vertical section through the middle of the upper eyelid, treated with acetic acid, and magnified.*

The surface of the skin of the lid (A) is covered with fine hairs, and is continuous with the palpebral conjunctiva (18-18). The cilia (22, 23) emerge from about

* "Archiv f. Ophth.," Bd. iii. p. 258. 1857; and H. Power, "Illustrations of Diseases of the Eye," p. 84, 1867.

the centre of the free margin of the lids, their follicles extending backwards into the eyelid above the tarsal cartilage: several sebaceous glands open into each hair follicle. The centre of the lid is occupied by the palpebral portion of the orbicularis muscle (C), a small portion of it (21) [Horner's muscle] passing beneath the cilia; through these contractile fibres the duct of the Meibomian glands is seen to pass. The tarsal cartilage (E) is situated immediately beneath the conjunctiva, the levator palpebræ is attached to its upper border (17). The Meibomian glands (12) are imbedded in the tarsal cartilage, and open (19) near the inner margin of the edge of the lid.

Fig. 2.



Section of Eyelid.—After Moll.

A. External skin. B. Subcutaneous connective tissue.
C. Palpebral part of the musc. orbicularis.
D. Connective tissue containing fat between the orbicularis and the tarsus.
E. The tarsal cartilage. F. Mucous membrane.
G. Free border of the lid.
1. Epidermis. 2. Cutis, with papillæ.
3. Hairs with their follicles. 4. Sweat glands.
5. Bloodvessels in the subcutaneous connective tissue.
6. Nerves in the same.
7. Pars ciliaris } of the musc. orbicularis.
8. Pars palpebralis }
9. Fat.
10. Bloodvessels in the connective tissue between the musc. orbicularis and the tarsus.
11. Nerves in the same.
12. Lobuli of the Meibomian glands.

13. Termination of the same glands.
14. Section of an adjoining Meibomian gland.
15. Adipose tissue in the most superior part of the tarsus over the ends of the Meibomian glands.
16. Elastic tissue merging into the upper part of the tarsus.
17. Musculus levator palpebræ superioris, terminating in the above-named elastic tissue.
18. Papillæ of the mucous membrane.
19. Opening of the excretory duct of the Meibomian follicle.
20. Glands of small hairs near the free border of the lid.
21. Tarsal portion of the orbicularis (Horner's muscle).
22. Cilia. 23. Two cilia in one follicle.
24. Sebaceous glands of the cilia.
25. Cutis of the free border of the lid.

THE ACCOMMODATION OF THE EYE.

ACCOMMODATION OF THE EYE.

The Accommodation of the Eye—that is, the mechanism by which rays of light from objects at different distances are brought to a focus on the retina, has been a matter of dispute for years; and the subject has acquired additional interest from the large share of attention which has of late been directed to the disorders of accommodation.

Due to changes of curvature in the lens.

It will be advisable, in the first place, to glance at the facts which appear to prove that, in the accommodation of the eye for near objects, the convexity of the anterior surface of the lens is increased. It is evident that this, or some equivalent change in the dioptric media of the eye, must take place, otherwise rays of light from a near object (divergent rays) could not possibly be brought to a focus on the retina, upon which rays from distant objects (parallel rays) are also focussed; in other words, parallel and divergent rays cannot be brought to the same focus, unless the refracting medium through which they pass is capable of altering its power of refraction.

The necessary adjustment for the accommodation of the eye might be brought about by changes in the curvature of the cornea, or else by an elongation and contraction of the antero-posterior axis of the eyeball; it would seem, however, as if Cramer and Helmholtz had settled the matter in favour of an alteration in the curvature of the lens as the cause of the necessary changes in the dioptric media.

The experiments of Helmholtz.

Helmholtz, in his experiments, took advantage of the well-known fact that when a lighted candle is held in

front of a healthy eye, three reflected images of the flame may be seen apparently in the pupil—an anterior and posterior erect image, being the reflections from the cornea and anterior surface of the lens, and a middle but inverted image reflected from the posterior surface of the lens or vitreous. With his ophthalmometer he was able to measure the magnitude of these reflected images under varying circumstances, and he found that so long as the person under observation looked steadily at a distant object—that is, accommodated his eye for the far point—the three reflected figures of the flame of the candle remained unaltered in size; but the instant the accommodation of the eye was changed, and a near object was brought under observation, the reflected image from the anterior surface of the lens increased in magnitude, the other figures remaining unaltered in size.

Changes of curvature demonstrated.

It became evident, therefore, that in varying the accommodation of the eye from a far to a near object, the convexity of the anterior surface of the lens was augmented, the depth of the lens from before backwards being increased by the bulging forwards of its anterior surface. The increase thus observed in the curvature of the lens, has been shown, mathematically, to be sufficient to bring divergent rays from near objects to the same focus as that of parallel rays from distant objects without such alteration. In the latter case the lens is at rest, and it is only when we look at near objects that the accommodation is brought into play.

The same conclusion, as to the nature of the changes which occur in the adaptation of the eye to vision at different distances, has been arrived at in other ways; but the above experiments are sufficient for our present purpose.

Accommodation a voluntary act.

The accommodation of the eye appears to be a voluntary act, inasmuch as it is under the control of the will: we wish to see a near object, and on looking at it, the changes in the form of the lens above described take place, in the same way as the extensor muscles respond to the desire to open our hand when closed. In the infant we see how vague and uncertain the performance of those actions is, which for accuracy depend upon the accommodation of the eye; doubtless by repetition these actions afterwards become unconscious and automatic; the acquired faculties being organized in the constitution of the sensori-motor ganglionic nuclei, the movements follow as reflex effects of an external stimulus. Another point especially deserving attention in connexion with these focal adjustments, is the combined precision and incessant variation required: so long as a person is awake, alterations in the distance between the retina and objects under observation must be taking place at every instant, necessitating corresponding alterations in the curvature of the lens; for it has been proved that, for correct vision, not only must the rays of light be brought to a focus on the retina, but they must be accurately focussed on its bacillary layer.

Focal adjustments.

Attributed to the ciliary muscle.

The highest authorities of the day hold, that the accommodation of the eye is effected by the action of the ciliary muscle. Donders says—"It therefore remains only to attribute to the musculus ciliaris the important quality of accommodation muscle. But the mechanism whereby the contraction of this little muscle alters the form of the lens, to however small a compass the question may now be reduced, is not yet satisfactorily or convincingly brought to light."*

In support of this idea we cannot overlook the fact that in those animals whose range of accommodation is highest, as birds, the ciliary muscle is largely developed; in those, as fishes, in which accommodation is almost *nil*, the ciliary muscle is hardly developed.

At one time it was supposed, that in the accommodation of the eye the action of the ciliary muscle was much assisted by the iris; but Von Graefe's case has settled this point; for in this instance, the whole of the iris was removed and yet the focus of accommodation remained perfect.

* "Accommodation and Refraction of the Eye," by Donders, p. 26 (New Sydenham Society).

CHAPTER II.

Methods employed in examining the Eye, and testing the patient's Vision—The Ophthalmoscope: its Principle and Use—Ophthalmoscopic Appearances of the Healthy Eye.

EXAMINATION OF THE EYE.

Examination of the Eye.

The first and most essential point to attend to in examining the eye is, that it should be illuminated by a clear, bright light. The patient may conveniently be seated before a window, the surgeon standing in such a position, that no part of his person intercepts the rays of light from falling directly on the patient's eye, and yet enabling him to examine the part thoroughly.

Light.

Manipulation.

The next thing to be done is to open the eyelids, the upper one with the thumb of one hand, and the lower with the other. This manipulation, though simple enough, requires care; even slight pressure on the diseased eyeball frequently causing pain and irritation, followed by a gush of tears from the eye, which for the moment prevents us from proceeding with our examination. The lids having been separated as far as possible, the condition of the cilia, puncta, conjunctiva, sclerotic, cornea, and iris should be carefully noticed.

The two eyes to be compared.

If one eye only is diseased we must compare its condition with the sound eye; slight alterations in the colour and brightness of the iris, which may nevertheless be very significant, are often thus distinguishable, and any abnormal prominence or flattening of one cornea will be made more apparent by contrast with the other. It is, moreover, by a comparative examination of this kind, that we ascertain the nature of the various derangements that are met with in connexion with the muscular apparatus and movements of the eyeball.