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Кафедра оториноларингологии с курсом офтальмологии

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АНАТОМИЯ ЗРИТЕЛЬНОГО АНАЛИЗАТОРА

**Учебно-методическое пособие по офтальмологии
для студентов 4 курса лечебного факультета
и факультета по подготовке специалистов для зарубежных стран
медицинских вузов**

ANATOMY OF THE VISUAL SYSTEM

**Teaching guide in ophthalmology for 4th year
of the faculty of general medicine
and faculty of general medicine for overseas students**

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Учебно-методическое пособие предназначено для проведения практических занятий по офтальмологии в медицинских вузах и составлено в соответствии с учебной программой, требованиям образовательного стандарта.

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CONTENTS

1. DEVELOPMENT OF THE EYE

The eye develops from both neural and surface ectoderm and from mesoderm. Surface ectoderm forms the lens and the epithelium of the cornea and conjunctiva and contributes, together with the neural ectoderm, to the vitreous body and zonule. Neural ectoderm forms the retina, ciliary epithelium, iris epithelium and its sphincter and dilator muscles, and the neural part of the optic nerve. Mesoderm gives rise to the corneal stroma and endothelium, the iris stroma, the choroid and the sclera.

In the formation of the embryo from the embryonic plate of ectoderm and endoderm, at the area of contact of the amnion and the yolk sac a midline primitive groove appears in the dorsal ectoderm and anteriorly at each side an optic groove appears which is the primordium of the retina. This is best followed diagrammatically. At the five week (7 mm) stage the spherical optic vesicle has by differential growth changed to a structure like an egg cup with part of the lower side missing. Through this foetal fissure the hyaloid artery enters the concavity of the cup. By the end of the sixth week (15 mm) the fissure has closed.

The lens forms by an ingrowth of surface ectoderm in front of the optic vesicle. The hyaloids artery ramifies on the back of the lens at the beginning of the sixth week (10 mm). Meanwhile on the outer surface of the optic vesicle a network of vessels appears in the mesoderm which will eventually develop into the choroid at the end of the sixth week (15 mm). Outside this the mesoderm forms the sclera and the extraocular muscles, which are differentiated and receive their nerve supply as early as five weeks (7 mm).The lens becomes enclosed by the edge of the developing optic cup. Its anterior cells form the lens epithelium while the posterior cells elongate. Later new lens fibers formed at the equator so that they comprise the nucleus engulf the posterior cells of the lens. The hyaline capsule of the lens is formed as a secretion of the lens cells.

The inner neural layer and the outer pigmentary layer of the optic vesicle form the retina, the ciliary epithelium and the iris epithelium which extends on the posterior surface of the iris to the pupil margin. The vitreous is originally the primitive tissue between the lens and the inner layer of the optic cup. This is invaded by the hyaloid vessels. Secondary vitreous then forms from the retina which displaces the primary vitreous forwards to the ciliary region and inwards to occupy a tubular space around the hyaloid vessels. The hyaloid system regresses leaving only its retinal branches. The hyaloid artery proximal to these branches becomes the central retinal artery. Tertiary vitreous which forms the lens zonule is partly made up of tissue from the primary vitreous and partly from fibres which develop in conjunction with the basement membrane of the ciliary body.

The retinal neural layer of epithelial cells divides and an outer nuclear layer and an inner non-nuclear marginal layer can be distinguished. From about the sixth week (15mm) the ganglion cells are formed by nuclear zone cells invading the inner layer. Nerve fibers grow out from them and run to the optic stalk and then to the brain. By 9 weeks (40 mm) the chiasma has formed and the optic tracts develop. Medullation of the nerve fibers takes place from the brain distally and reaches the lamina cribrosa just before birth. The outer layer of the optic vesicle becomes pigmented at the beginning of the sixth week (10 mm) and becomes flattened to form the retinal pigment epithelium. Further differentiation of the retina takes place next in the central region. The outermost cells of the nuclear layer form the rod and cone cell bodies, they bear cilia projecting into the cavity of the optic vesicle which develop into the photoreceptors, the rods and cones. Other cells of the nuclear layer form the amacrine, the horizontal and the bipolar cells. Processes from all these cells and from the ganglion cells form the plexiform layers. The macular area forms at the 20th week (150 mm) as a thickening of the ganglion cell layer and the fovea appears in the center of this area in the 24th week (200 mm).

The development of other ocular structures:

Mesodermal cells grow in between the lens and the surface ectoderm to form the corneal endothelium which secretes Descemet's membrane at about the 16th week (100 mm). Other mesodermal cells form the stroma and the surface ectoderm becomes the epithelium of the cornea. The sclera and Tenon's capsule are condensations of mesoderm around the optic cup. This process commences anteriorly where it is associated with the developing extra ocular muscles. The anterior chamber appears as a slit in the mesoderm between the cornea and iris.

The canal of Schlemm is present at 12th weeks (70 mm). Cleavage of the structures in the angle of the anterior chamber takes place but some tissue remains to form the trabecular meshwork allowing communication between the anterior chamber and the canal of Schlemm.

The posterior part of the mesoderm between the surface ectoderm and the lens forms the iris stroma where it lies anterior to the rim of the optic cup, the central part being the pupillary membrane. The posterior ciliary arteries supply them both. There is no true iris up to the 12th week (70 mm) but then there is a forward growth of neural ectoderm at the rim of the optic cup which extends to the pupillary margin by the 16th week (100 mm) as the two layers of the iris. At about the 30th week (250 mm) the sphincter and dilator pupillae form from the pigment epithelium. The posterior layer of the iris epithelium becomes pigmented at this time and later the pupillary membrane regresses leaving a circular ring, the collarette, peripheral to the pupil. Incomplete regression may leave strands of persistent pupillary membrane arising from the collarette and crossing the pupillary aperture, sometimes still adherent to the front of the lens. The iris epithelium is continuous behind with the two layers of the ciliary epithelium and mesoderm forms the stroma of the ciliary body and the ciliary muscle. At about the time of the formation of the iris epithelium, vascularized ciliary processes appear and between 20 and 24weeks (150–200 mm) the main arterial circle of the iris, situated in the ciliary body, arises from the two long posterior ciliary and seven anterior ciliary arteries (figure 1).

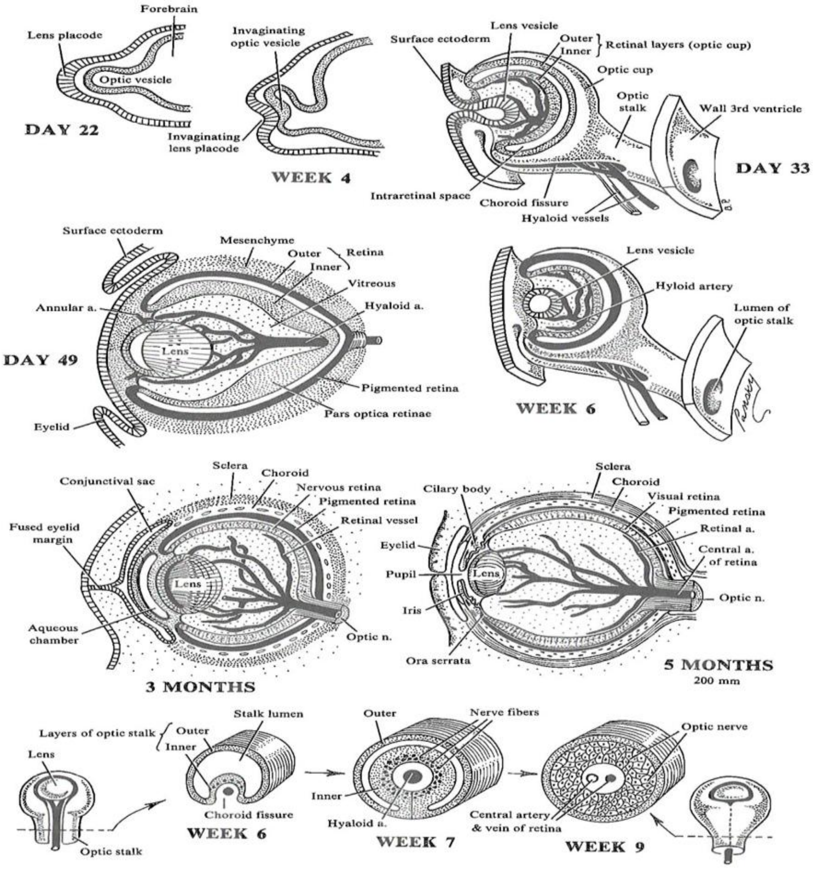

Figure 1 — Embryology of the eye

2. ANATOMY OF THE EYE AND ORBIT

The eye

The eye lies in the front half of the orbit surrounded by fat and connective tissue and is supported by a fascial hammock. The optic nerve, which connects the eye with the brain, leaves the orbit at its apex through the optic foramen in which it lies close to the ophthalmic artery. Attached to the eye are six extraocular muscles, four rectus and two oblique. They take origin posteriorly from the orbital walls or from a tendinous ring which bridges the superior orbital fissure and includes the optic foramen. They are innervated by the 3^{rd},4^{th} and 6^{th} cranial nerves which enter the orbit at its apex through the superior orbital fissure. The branches of the ophthalmic division of the 5^{th} cranial nerve also pass through the superior orbital fissure to convey sensory impulses from the eye and the upper part of the face.

The exposed front of the eye consists of a central transparent convex portion, the cornea, surrounded at the corneo-scleral limbus by opaque white sclera which is covered by the loose bulbar conjunctiva continuous at the fornixes with the more adherent palpebral conjunctiva which linesthe eyelids.

The lacrimal gland is situated just behind the upper outer angle of the bony orbit and its ducts discharge tears into the upper fornix. The front of the eye isprotected by the eyelids which form an elliptical opening, the palpebral aperture. The area of the outer and inner angles of the palpebral aperture are known as the lateral and medial canthi. The free margin of each lid bears the eye lashes and the mouths of sebaceous glands and, near the medial end of the upper and lower lids, on a small eminence will be found the openings of the upper and lower lacrimal canaliculi. Each upper lid is raised by the levator palpebrae superioris muscle supplied by the 3rd cranial nerve and the sympathetically innervated palpebral muscle of Muller. The lids are closed by the orbicularis oculi muscle supplied by the 7th cranial nerve.

The axial length of the normally sighted eye is approximately 24 mm (22–27 mm). Measuring posteriorly along the surface from the limbus, the anterior termination of the sensory retina lies at 8 mm, the equator at 16 mm and the posterior pole at 32 mm. The globe has three main layers. The outer **fibrous** supporting coat in front is the clear cornea which is continuous with the white opaque sclera behind. The middle **vascular** coat or uvea consists of the choroid, the ciliary body and the iris which has a central opening or pupil. The inner sensory coat, **the retina**, has a many cell layered neural membrane and a single celled outer membrane, the pigment epithelium. A fenestrated opening in the sclera 1.5 mm in diameter and 3 mm medial to the posterior pole transmits the fibres of the optic nerve, mainly the axons of the ganglion cells of the retina. The lens is a transparent structure, suspended immediately behind the iris by fine fibres, forming the zonule or suspensory ligament, which runs from the surface of the ciliary body to the periphery of the lens. The anatomy of all these structures is considered in more detail in the relevant sections (figure 2).

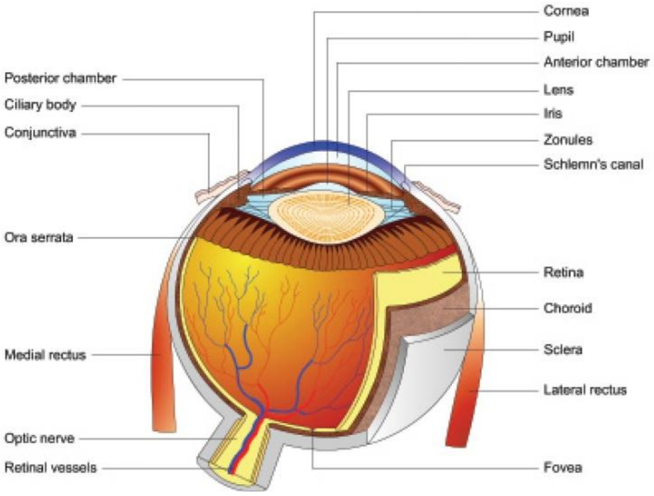

Figure 2 — The eye in horizontal section

2.1. ORBITAL CAVITY

The eyes rest in two bony cavities, the orbits, on either side of the nose.

The orbital cavity is the protective bony socket for the globe together with the optic nerve, ocular muscles, nerves, blood vessels, and lacrimal gland. These structures are surrounded by orbital fatty tissue. The orbital cavity is shaped like a funnel that opens anteriorly and inferiorly. The six ocular muscles originate at the apex of the funnel around the optic nerve and insert into the globe. The globe moves with in the orbital cavity as in a joint socket.

Bony socket. This consists of seven bones (figure 3):

1. Frontal.
2. Ethmoid.
3. Lacrimal.
4. Sphenoid.
5. Maxillary.
6. Palatine.
7. Zygomatic.

The bony rim of the orbital cavity forms a strong ring. Its other bony surfaces include very thin plates of bone.

The bones of the anterior margin of the orbit are thick and strong but may be fractured by severe direct blows. Because the rest of the walls are thin 'blow out' fractures occur when the intraorbital pressure is suddenly increased as the result of a blow from the front by a rounded object such as a small stone or a squash racquets ball. Usually the fracture occurs in the floor or medial wall with prolapse of the orbital contents.

On the anterior margin of the lateral wall there is a thickening, the lateral orbital tubercle. This gives attachment to the hammock-like suspensory fascia of the eye (the ligament of Lockwood), which on the medial side is attached to the bone behind the lacrimal sac. Anteromedially in the roof of the orbit is the trochlea which forms the pulley for the tendon of the superior oblique muscle.

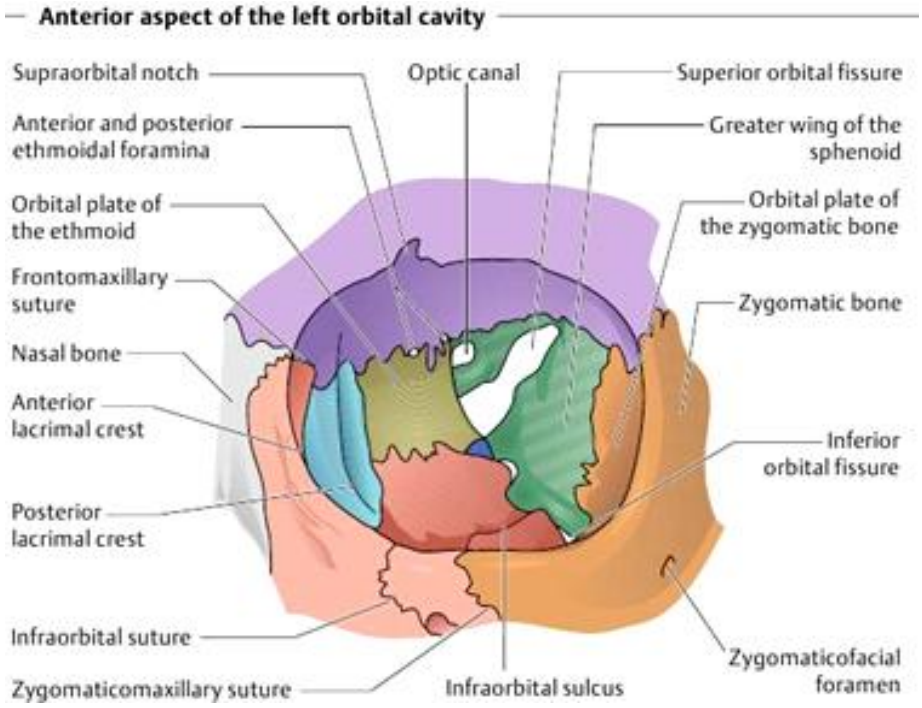

Figure 3 — Orbital bones

Table 1 — Orbital Measurements

Volume	30 ml
Globe volume	6.5 ml
Width	45 mm
Height	35 mm

Table 2 — Bones Forming the Orbital Walls

Orbital Wall	**Bones**	**Borders**
Superior (roof)	Frontal Sphenoid (lesser wing)	Anterior cranial fossa Frontal sinus
Lateral	Zygoma Sphenoid (greater wing)	Temporalis fossa Pterygopalatine fossa
Inferior (floor)	Maxilla (medial), zygoma (lateral), palatine (posterior	Infraorbital canal Maxillary sinus
Medial	Maxilla, lacrimal, ethmoid, sphenoid (anterior to posterior)	Ethmoid, sphenoid sinuses Cribriform plate at level of frontoethmoidal suture

Table 3 — Openings into the orbital cavity and the structures that pass through them

Orbital openings	**Structures**
Optic canal	Optic nerve Ophthalmic artery
Superior orbital fissure	Oculomotor nerve Trochlear nerve Abducent nerve Ophthalmic nerve Lacrimal nerve Frontal nerve Nasociliarynerve Superior ophthalmic veins
Inferior orbital fissure	Infraorbital nerve Zygomatic nerve Inferior ophthalmic vein
Infraorbital canal	Infraorbital nerve

Superior orbital syndrome (Rochon-Duvigneaudssyndrome) is a neurological disorder that results if the superior orbital fissure is fractured. Involvement of the cranial nerves that pass through the superior orbital fissure may lead to diplopia, paralysis of extraocular motions, exophthalmos and ptosis. Blindness or loss of vision indicates involvement of the orbital apex, which is more serious.

ORBITAL TISSUES

The orbital contents are supported by connective tissue which is thickened in places to form definite layers and compartments which are important in surgery and in the spread of hemorrhage and inflammation:

Periosteum of the orbit is continuous with the dura mater which also provides at the margin of the optic foramen the dural sheath of the optic nerve.

Orbital septum stretches from the bony margins of the orbit to the tarsalplates and prevents orbital fat from herniating into the lids.

Tenon's Capsule Tenon's capsule, or the fascia bulbi, is a layer of delicate connective tissue that completely envelops the globe from the limbus to the optic nerve, forming a potential space free of any tissue attachments that might restrict globe rotation. Posteriorly, extremely fine connective tissue filaments to the sclera loosely attach it. This episcleral space contains no fluid or endothelium and is not a full-fledged ball-and-socket joint in function. The globe can rotate some within the capsule; however, beyond small rotations, the globe and capsule move together, deflecting the orbital fat attached behind. This is to be expected, since the capsule is attached firmly to the eye at the limbus and to the muscles at their points of entrance.

The optic nerve, the extraocular muscles, and the blood vessels and nerves serving the globe penetrate tenon’s capsule. About the optic nerve the capsule is penetrated and broken up by multiple posterior ciliary arteries and nerves, and some have considered it to cease a few millimeters away from the optic nerve. There is no sheath continuing backward around the optic nerve.

2.2. EXTRAOCULAR MUSCLES

There are four rectus and two oblique’s muscles in the eyeball.

The four rectus muscles arise from the annulus of Zinn at the apex of the orbit. The medial rectus inserts onto the medial side of the globe at approximately 5.3 (B ± 0.7) mm from the corneoscleral limbus, whereas the lateral rectus inserts onto the lateral side of the globe at approximately 6.9 (B ± 0.7) mm from the limbus. Because the origins and insertions of the horizontal rectus muscles are symmetric and lie in the horizontal meridian of the globe, their functions are relatively simple and are antagonistic; contraction of the medial rectus adducts the globe, whereas contraction of the lateral rectus abducts the globe.

The superior and inferior recti also originate from the annulus of Zinn. The superior rectus inserts onto the globe superiorly at approximately 7.9 (B ± 0.6) mm from the limbus, and the inferior rectus inserts inferiorly at approximately 6.8 (B ± 0.8) mm from the limbus. In addition, their insertions onto the globe subtend a 23B° angle with the visual axis when the eye is in primary position, straddling the vertical meridian of the globe. Thus, in addition to its primary action of elevation, the superior rectus has a secondary action of incyclotorsion and a tertiary action of adduction. The primary action of the inferior rectus is depression, its secondary action is excyclotorsion, and its tertiary action is adduction. The relative importance of the primary and secondary actions depends on the direction of the visual axis. When the eye is abducted 23B°, the superior rectus acts solely as an elevator, and the inferior rectus acts solely as a depressor. When the eye is adducted 67B°, the superior rectus acts solely to incyclotort the globe, and the inferior rectus acts solely to excyclotort the globe.

The superior oblique also arises from the annulus of Zinn; however, its functional origin is the trochlea in the super medial of the orbit. The superior oblique is tendinous after it passes through the trochlea. This tendon then assumes a posterolateral direction and inserts onto the superior posterotemporal quadrant of the globe behind the center of rotation. This vector plane subtends a 54B° angle with the visual axis when the eye is in primary position. Thus, in addition to its primary action of incyclotorsion, the superior oblique also has a secondary action of depression and tertiary action of abduction. When the eye is adducted 54B°, the superior oblique acts solely to depress the globe, and when the eye is abducted 36B°, it acts solely to incyclotort the globe.

The inferior oblique arises from the anterior medial orbital floor, and thus it is the only extraocular muscle that does not arise from the annulus of Zinn. It inserts onto the inferior posterotemporal quadrant of the globe behind the center of rotation and subtends a 51B° angle with the visual axis when the eye is in primary position. Thus, in addition to its primary action of excyclotorsion, the inferior oblique has a secondary action of elevation and a tertiary action of abduction. W0hen the eye is adducted 51B°, the inferior oblique acts solely to elevate the globe, and when the eye is abducted 39B°, it acts solely to excyclotort the globe (figure 4).

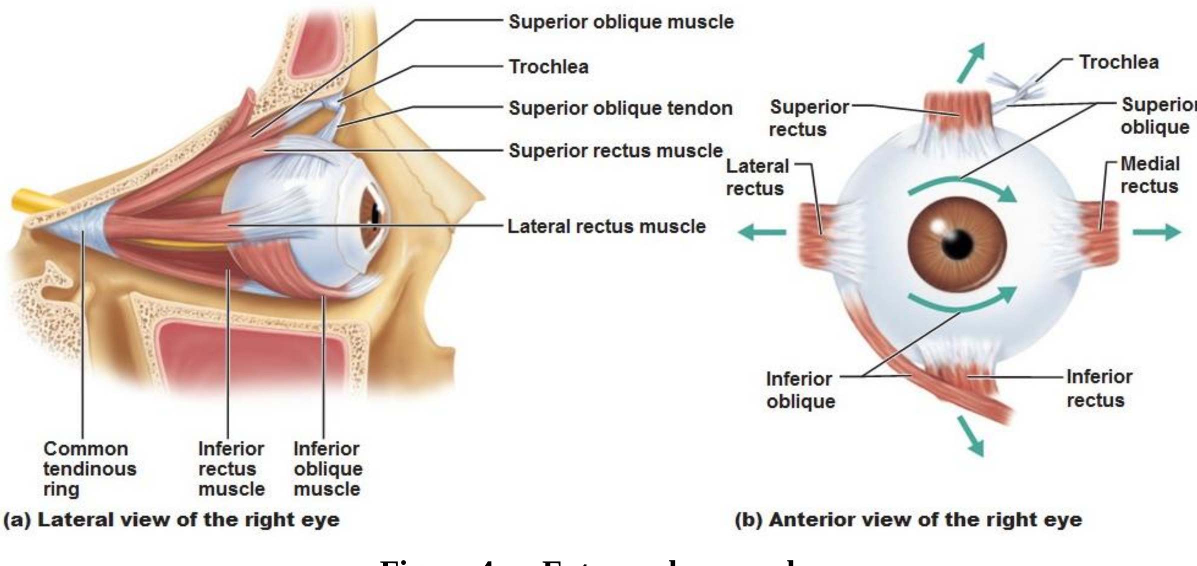

Figure 4 — Extraocular muscles

Eye Rotations

To understand how eye muscles move the eyeball, it is necessary to understand the geometry of the eye and the functions of the muscles. The eyeball rotates about three axes: horizontal, vertical, and torsional. These axes intersect at the center of the eyeball. Eye rotations are achieved by coordinated contraction and relaxation of six extraocular muscles four rectus and two obliques attached to each eye. The point of rotation of the globe, as well as the origin and insertion of each muscle determines the action of the muscles on the globe. Recent evidence suggests that the muscles also exert their effects on the globe via the extraocular muscle pulleys.

The eyeball rotates about three axes: x-axis (naso-occipital or roll axis), y-axis (earth-horizontal or pitch axis), and z-axis (earth-vertical or yaw axis).

Ductions refer to monocular movements of each eye. They include abduction, adduction, elevation (sursumduction), depression (deorsumduction), incycloduction or incyclotorsion, and excycloduction or excyclotorsion.

Versions refer to binocular conjugate movements of both eyes, such that the visual axes of the eyes move in the same direction. They include dextroversion, levoversion, elevation(sursumversion), depression (deorsumversion), dextrocycloversion, and levocycloversion.

Vergences refer to binocular disjunctive movements, such that the visual axes of the eyes move in opposite directions. They include convergence, divergence, incyclovergence, and excyclovergence (figure 4(b)).

2.3. EYELIDS

The eyelids are folds of muscular soft tissue that lie anterior to the eyeball and protect it from injury. Their shape is such that the eyeball is completely covered when they are closed. Strong mechanical, optical, and acoustic stimuli (such as a foreign body, blinding light, or sudden loud noise) “automatically” elicit an eye-closing reflex. The cornea is also protected by an additional upward movement of the eyeball (Bell’s phenomenon). Regular blinking (20–30 times/min) helps to uniformly distribute glandular secretions and tears over the conjunctiva and cornea, keeping them from drying out.

In the young adult the interpalpebral fissure measures 10 to 11 mm in vertical height. In middle age this is reduced to only about 8 to 10 mm (1) and in old age the fissure may be only 6–8 mmor less. The horizontal length of the fissure is 30 to 31 mm. The upper and lower eyelids meet at an angle of approximately 60 degrees medially and laterally. In primary position of gaze the upper eyelid margin lies at the superior corneal limbus in children and 1.5 to 2.0 mm below it in the adult. The lower eyelid margin usually rests at the inferior corneal limbus or just slightly above it. The margin of each eyelid is about 2 mm thick.

The skin covers the external surface of the body and provides significant protection against trauma, solar radiation, temperature extremes, and desiccation. It also allows for major interaction with the environment. The skin of the eyelid is the thinnest in the body owing to only a scant development of the dermis and subcutaneous fat.

The epidermis is the outer layer of the skin averaging about 0.05 mm in thickness on the eyelids, compared to the palms and soles where it can attain a thickness of 1.5 mm. It contains no blood vessels and is dependent upon the underlying dermis for its nutrients.

Beneath the epidermis is the basement membrane and below that the dermis. The stratum basale is connected to the basement membrane by protein fibers. The dermis lies beneath the basement membrane and on the eyelids is about 0.3 mm in thickness compared to other parts of the body where it may be up to 3 mm thick. It contains three types of tissues that are not layered: collagen, elastic tissue, and reticular fibers. The upper papillary dermal layer contains a thin arrangement of collagen fibers. The lower reticular dermal layer is thicker and contains thick collagen fibers arranged parallel to the surface. The reticular layer also contains fibroblasts, mast cells, nerve endings, lymphatics, and epidermal appendages surrounded by a ground substance of mucopolysaccharides, chondroitin sulfates, and glycoproteins. The fibroblast is the major cell type in the dermis. These secrete elastin and a procollagen that is then cleaved by proteolytic enzymes into collagen which becomes cross-linked. Collagen makes up nearly 70 % of the dermis by weight.

Sebaceous glands contain epithelium that is an outgrowth of the external root sheath of the hair follicle. These are holocrine glands that shed the entire epithelial cell along with secretory products of complex oils, fatty acids, wax, and cholesterol esters called sebum. A large sebaceous gland is associated with each hair follicle and empties its secretions directly in to the follicle. The hair follicle along with the sebaceous and Moll glands form the pilosebaceous unit. Additional small sebaceous glands called glands of Zeis are present between follicles and discharge their contents directly onto the skin surface. Eccrine sweat glands are also present in the dermis but they are not associated with the hair follicle. They open directly onto the epidermal surface via a long straight ductule. Eccrine glands secrete a clear fluid composed of water, salts, glycogen, and sialomucin.

Blood vessels and nerve endings course throughout the dermis where they derive from similar structures in the sub-dermis and deep fascia. Specialized sensory structures called Meissner’s and Vater-Pacini corpuscles within the dermis transmit sensations for touch and pressure.

Beneath the dermis is a subcutaneous layer of fat and connective tissue. Subcutaneous fat is very sparse beneath the preseptal portion of the eyelid skin, and absent from the more distal pretarsal portions. Beneath the skin within the eyelid are also found other structures that can be the focus for disease processes. On the subconjunctival side of the eyelid these accessory structures include the accessory lacrimal glands of Krause and Wolfring beneath the conjunctiva and are concentrated on the lateral side, and the meibomian glands which are modified sebaceous glands within the tarsal plates (figure 5).

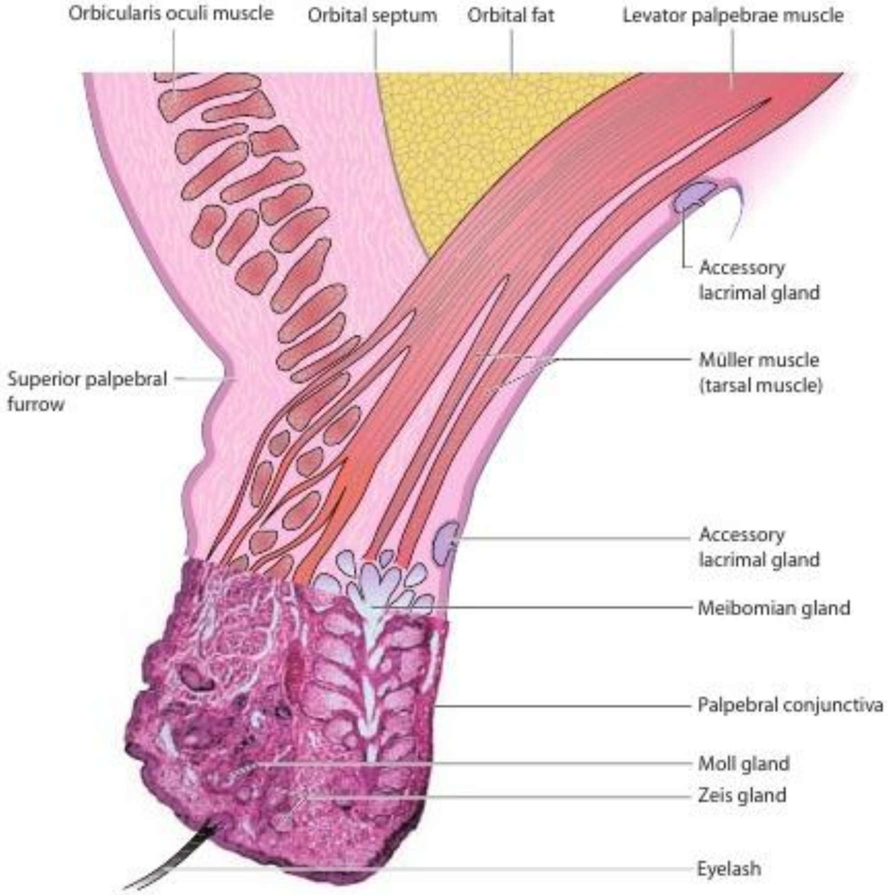

Figure 5 — Sagittal section through the upper eyelid

The orbicularis muscle

The orbicularis oculi is a complex striated muscle that lies just below the skin. It is divided anatomically into three contiguous parts — the orbital, preseptal, and pretarsal portions (figure 6).

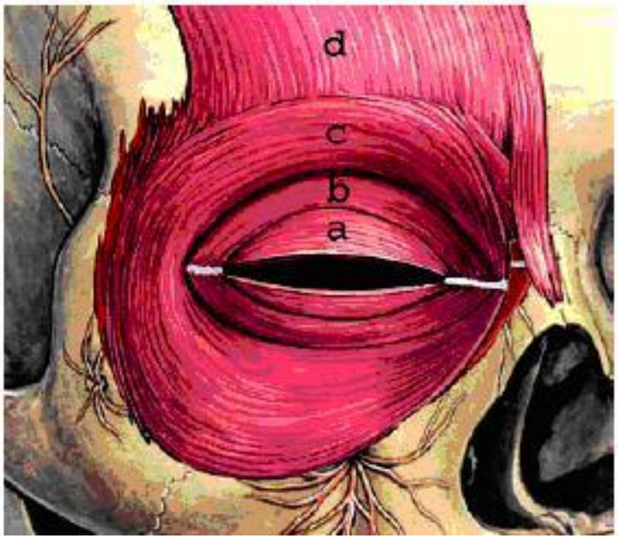

Figure 6 — Orbicularis and frontalis muscules:
a — pretarsal portion; preseptal portion; c — orbital portion; d — frontalis muscle.

The orbital portion overlies the bony orbital rims. It arises from insertions on the frontal process of the maxillary bone, the orbital process of the frontal bone, and from the common medial canthal tendon. Its fibers pass around the orbital rim to form a continuous ellipse without interruption at the lateral palpebral commissure, and insert just below their points of origin.

The palpebral portion of the orbicularis muscle overlies the mobile eyelid from the orbital rims to the eyelid margins. The muscle fibers sweep circumferentially around each lid as a half ellipse, fixed medially and laterally at the canthal tendons. Although this portion forms a single anatomic unit in each eyelid, it is customarily further divided topographically into two parts, the preseptal and pretarsal orbicularis.

The preseptal portion of the muscle is positioned over the orbital septum in both upper and lower eyelids, and its fibers originate perpendicularly along the upper and lower borders of the medial canthal tendon. Fibers arc around the eyelids and insert along the lateral horizontal raphé. The pretarsal portion of the muscle overlies the tarsal plates. Its fibers originate fromthe medial canthal tendon via separate superficial and deep heads, arch around the lids and insert onto the lateral canthal tendon and raph.

The main eyelid retractors

The retractors of the upper eyelid consist of the levator palpebrae and Müller's muscles. The levator palpebrae superioris muscle arises from the lesser sphenoid wing just above the annulus of Zinn. The muscle runs forward in the superior orbit just above the superior rectus muscle.

In the lower eyelid the capsulopalpebral fascia is a fibrous sheet arising from Lockwood'sligament and the sheaths around the inferior rectus and inferior oblique muscles.

The sympathenic eyelid retractors

Smooth muscles innervated by the sympathetic nervous system are present in both upper and lower eyelid and serve as accessory retractors. In the upper eyelid, the supratarsal muscle of Müller originates abruptly from the under surface of the levator muscle just anterior to Whitnall's ligament. Disruption of sympathetic innervation to these muscles results in Horner's syndrome. The classic triad of ptosis, miosis, and ipsilateral anhidrosis of the face characterizes this.

Specific clinical findings vary according to the location of the lesion along the polysynaptic pathway. The upper eyelid ptosis and elevation of the lower eyelid result from loss of sympathetic smooth muscle tone and accessory retraction.

The tarsal plates

The tarsal plates consist of dense fibrous tissue approximately 1 to 1.5 mm thick that give structural integrity to the eyelids. Each measures about 25 mm in horizontal length, and is gently curved to conform to the contour of the anterior globe. Within each tarsus are the Meibomian glands, approximately 25 in the upper lid and 20 in the lower lid. These are holocrine-secreting sebaceous glands not associated with lash follicles. Each gland is multilobulated and empties nto a central ductule that opens onto the posterior eyelid margin behind the gray line. They produce the lipid layer of the precorneal tear film.

The conjuctiva of eyelids

The conjunctiva is a mucous membrane that covers the posterior surface of the eyelids and the anterior surface of the globe except for the cornea. The palpebral portion is closely applied to the posterior surface of the tarsal plate and the sympathetic tarsal muscle of Muller. It is continuous around the fornices above and below where it joins the bulbar conjunctiva. Small accessory lacrimal glands are located within the submucosal connective tissue.

Nerves of the eyelid

The motor nerves to the orbicularis muscle derive from the facial nerve (N. VII) through its temporal and zygomatic branches. The facial nerve divides into two divisions, an upper temporofacial division and a lower cervicofacial divisio. The upper division further subdivides into the temporal and zygomatic branches that innervate the frontalis and orbicularis muscles. The lower cervicofacial division gives rise to the buccal, mandibular, and cervical branches innervating muscles of the lower face and neck.

The sensory nerves to the eyelids derive from the ophthalmic and maxillary divisions of the trigeminal nerve. Sensory input from the upper lid passes to the ophthalmic division through its main terminal branches, the supraorbital, supratrochlear, and lacrimal nerves. The nfratrochlear nerve receives sensory information from the extreme medial portion of both upper and lower eyelids. The zygomaticotemporal branch of the lacrimal nerve innervates the lateral portion of the upper eyelid and temple.

Vascular supply to the eyelids

Vascular supply to the eyelids is extensive. The posterior eyelid lamellae receive blood through the palpebral arterial arcades. In the upper eyelid a marginal arcade runs about 2 mm from the eyelid margin and a peripheral arcade extends along the upper border of tarsus between the levator aponeurosis and Muller’s muscle. These vessels are supplied medially by the superior medial palpebral vessels from the terminal ophthalmic artery, and laterally by the superior lateral palpebral vessel from the lacrimal artery. The lower lid arcade receives blood from themedial and lateral inferior palpebral vessels.

The venous drainage system is somewhat less well defined than the arterial system. Drainage is primarily into several large vessels of the facial system.

2.4. LACRIMAL SYSTEM

The lacrimal system consists of two sections (figure 7):

- Structures that secrete tear fluid.
- Structures that facilitate tear drainage.

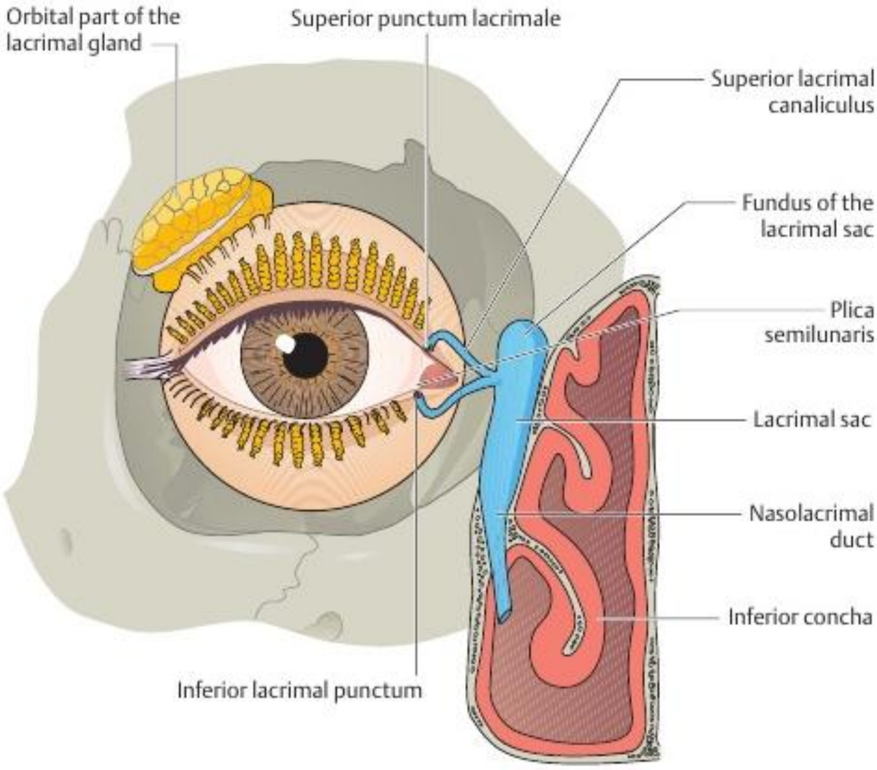

Figure 7 — Anatomy of the lacrimal system

Position, structure, and nerve supply of the lacrimal gland.

The lacrimal gland is about the size of a nut; it lies beneath the superior temporal margin of the orbital bone in the lacrimal fossa of the frontal bone and is neither visible nor palpable. A palpable lacrimal gland is usually a sign of a pathologic change such as dacryoadenitis. The tendon of the levator palpebrae muscle divides the lacrimal gland into a larger orbital part (two-thirds) and a smaller palpebral part (one-third). Several tiny accessory lacrimal glands (glands of Krause and Wolfring) located in the superior fornix secrete additional serous tear fluid.

The lacrimal gland receives its sensory supply from the lacrimal nerve. Its parasympathetic secretomotor nerve supply comes from the nervus intermedius. The sympathetic fibers arise from the superior cervical sympathetic ganglion and follow the course of the blood vessels to the gland.

Tear film

The precorneal tear film is approximately 7 µL thick with a volume of 6.2 B ± 2 µL during normal tear production. Tear fluid is typically produced with a major portion drained from the palpebral fissure through the nasolacrimal duct and a smaller volume lost through evaporation from the ocular surface. Tear chemistry is complex; ingredients include various electrolytes, metabolites, proteins, enzymes, and lipids. The functional significance of the tear film is broad. It provides lubricating qualities and a smooth optical interface with the air. It also protects the epithelium from airborne contaminants and provides natural immunity to infectious agents through secretory immunoglobulin molecules.

There are three layers in tear film (figure 8). The anterior-most layer is the lipid or oily layer derived from secretions of the meibomian glands located in the eyelid. The aqueous lacrimal tear layer is thick, depending on tear production by the lacrimal glands located in the superiotemporal margin of the orbit. The posterior mucous layer derived from secretions of conjunctival goblet cells. The hydrophilic nature of mucus substantially reduces surface tension and provides a smooth, wettable surface for the aqueous tear layer.

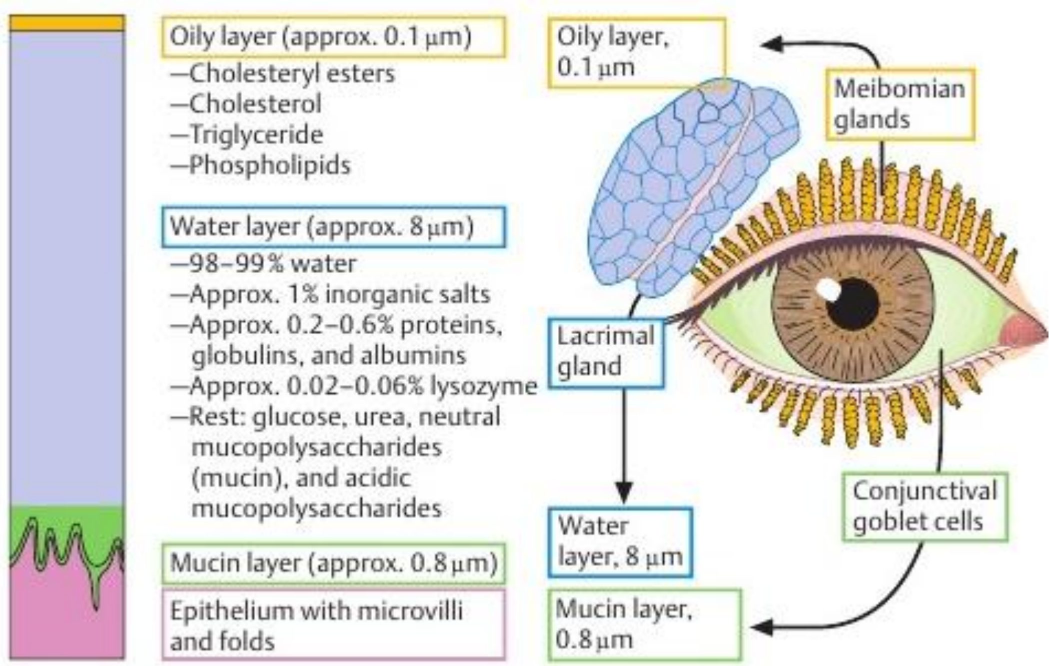

Figure 8 — Structure of the tear film

Tear drainage. The shingle-like arrangement of the fibers of the orbicularis oculi muscle (suppliedby the facial nerve) causes the eye to close progressively from lateral to medial instead of the eyelids simultaneously closing along their entire length. This windshield wiper motion moves the tear fluid medially across the eye toward the medial canthus. The superior and inferior puncta lacrimales collect the tears, which then drain through the superior and inferior lacrimal canaliculi into the lacrimal sac. From there they passt hrough the nasolacrimal duct into the inferior concha.

The blood supply of the lacrimal sac region is derived from the superior and inferior palpebral branches of the ophthalmic artery, the angular artery, the infraorbital artery and the nasal branch of the sphenopalatine artery and drains to the angular, infraorbital and nasal veins. The lymphatics drain into the submandibular and deep cervical glands. The nerve supply is from the infratrochlear branch of the nasociliary nerve and the anterior superior alveolar nerve.

2.5. CONJUNCTIVA

The conjunctiva is a thin vascularised mucous membrane consisting of a non keratinising, stratified, columno-squamous epithelium and a substantia propria. It leaves the posterior surface of the eyelids from which it is reflected forwards at the fornices, to cover the anterior sclera. The conjunctiva thus forms a potential space, the conjunctival sac, which is open at the palpebral fissure. The conjunctival epithelium is continuous with the corneal epithelium at the limbus and a muco-cutaneous junction is formed at the eyelid margins.

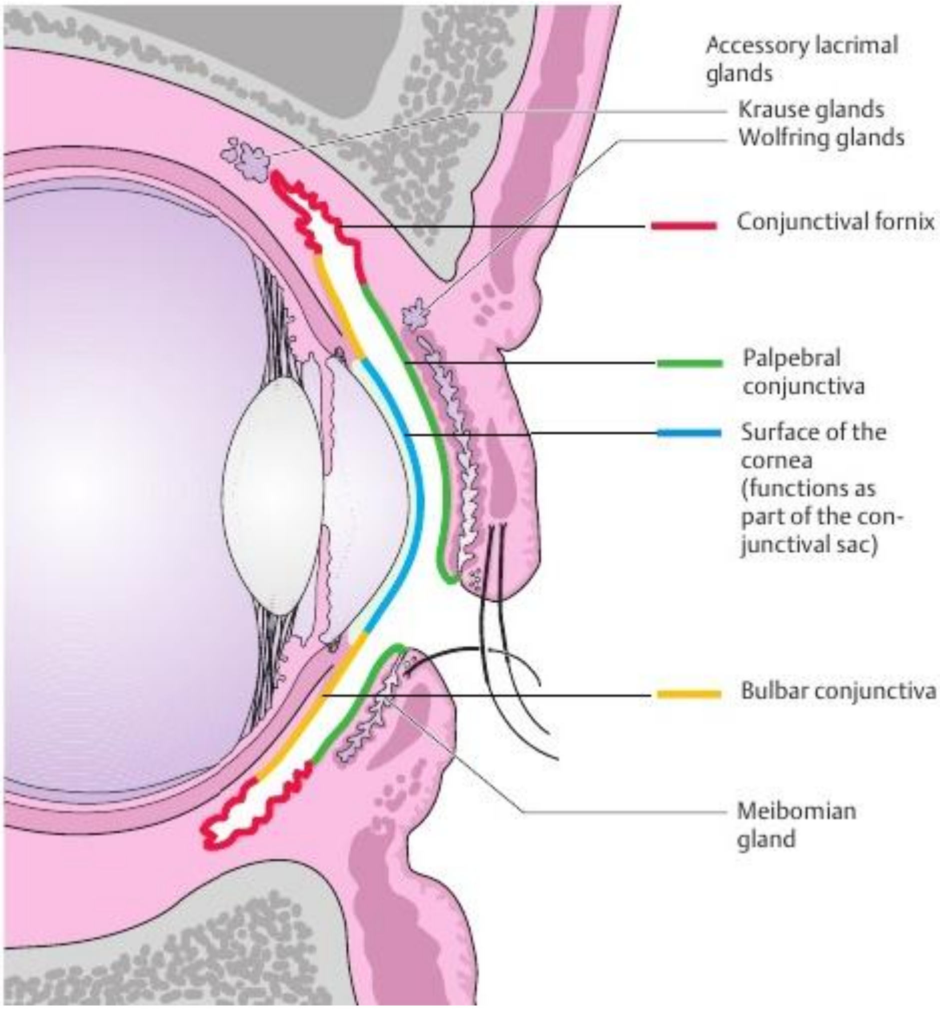

Figure 9 — Conjuctiva

Anatomically the conjunctiva has five regions which are continuous with each other: palpebral, conjunctival fornix, bulbar, limbal and the plica semilunaris (figure 9). The palpebral conjunctiva lines the posterior surface of the eyelids being transitional in the conjunctival fornix with the bulbar conjunctiva which covers the anterior sclera to which it is loosely attached. About 3 mm from the cornea it is attached more strongly forming the limbal conjunctiva. The corneo-scleral limbus is the junction between sclera and cornea whereas the conjunctiva! limbus lies l mm anteriorly. At the limbus the substantia propria ends leaving only an epithelial layer which is continuous with the corneal epithelium.

The conjunctival epithelium. Most of the conjunctiva has a non-keratinised stratified columnar epithelium. The epithelial cells at the limbus include alocal reservoir of cells which can migrate to cover any acquired corneal epithelial defects.

The conjunctival substantia propria, is a layer of fibrovascular tissue underlying the epithelium. The fibroblast is the structuralcell of the substantia propria, but the extrinsic cells present in this layer provide it with great potential in combating infection. In addition, a variety of extracellular immunoglobulins (IgG, IgA, and IgM) have been identified in normal conjunctiva.

The blood supply is from the lacrimal and terminal ophthalmic artery branches which form arcades supplying the bulbar conjunctiva to within 4 mm of the limbus where they anastomose with the anterior ciliary arteries which are the principal supply of the limbal region. Conjunctivitis mainly causes dilatation of the bulbar vessels (conjunctival injection) whereas scleritis, keratitis and uveitis cause dilatation of the deeper anterior ciliary vessels (ciliary injec-tion). The conjunctival veins drain into the ophthalmic, angular and lacrimal veins. Aqueous veins are also present in the conjunctiva, emerging from thesclera and draining aqueous into the episcleral veins in which a laminar blood column can be seen with the slit lamp before the aqueous mixes with the blood. The lymphatics are arranged in a superficial and deep plexus in the conjunctival substantia propria and are important in the mediation of immune reactions. They drain medially to the submandibular glands and laterally to the preauricular nodes.

Nerves of the conjunctiva. Sensory nerves are derived from the 1 st and 2nddivisions of the trigeminal nerve and form plexuses below and between thecells of the epithelium.

2.6. FIBROUS TUNIC OF EYEBALL

Cornea

As a portion of the ocular tunic, the cornea protects the delicate intraocular contents with its tough, yet pliable, collagen structure. It is remarkable that a tissue with this ability to resist injury can provide the essential optics and transparency to focus an image on the retina.

The cornea is elliptical in shape, measuring aproximately 12 mm in the horizontal diameter and 1lmm in the vertical. The radius of curvature is 7.8 and 6.5 mm. It is approximately l mm thick at the limbus reducing to 0.52 mm +/- 0.02

mm centrally. It is the most important refracting surface of the eye, the dioptric power being approximately 43 dioptres, and numerous refractive surgical techniques rely upon altering the curvature of the corneal front surface.

Cornea comprised of five layers: epithelium, Bowman's layer, stroma, Descemet's membrane and endothelium (figure 10).

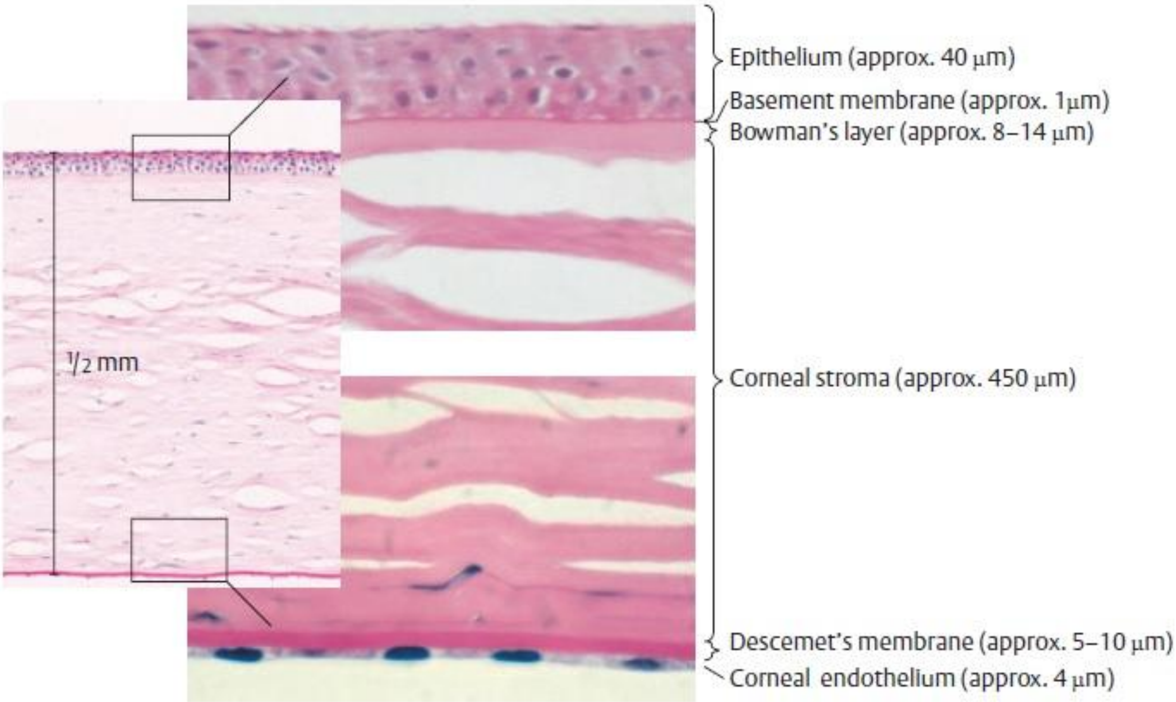

Figure 10 — Layers of the cornea

The epithelium is a stratified non-keratinised squamous epithelium consisting of about five layers of cells which are columnar at the level of the basement membrane but become progressively flattened towards the surface. Cells regenerates quickly when injured. Within 1 hour, epithelial defects are closed by cell migration and rapid cell division. The epithelial cells are continually replaced by mitosis in the deeper layers. Regular corneal regeneration will no longer be possible when these cells are compromised. An intact epithelium protects against infection; a defect in the epithelium makes it easy for pathogens to enter the eye.

Bowman's membrane is a thin structure less layer which is an irregular condensation of the superficial layers of the stroma. This layer is highly resistant but cannot regenerate. As a result, injuries to Bowman’s layer usually produce corneal scarring.

Beneath Bowman’s layer, many lamellae of collagen fibrils form the corneal stroma. The stroma is a highly bradytrophic tissue. As avascular tissue, it only regenerates slowly. However, its avascularity makes it an immunologically privileged site for grafting. Routine corneal transplants.

Can be performed without prior tissue typing. An increased risk of rejection need only be feared where the recipient's cornea is highly vascularized, as may be the case following chemical injury or inflammation. Such cases require either a tissue-typed donor graft or imunosuppressive therapy with cyclosporin.

Descemet's membrane and the corneal endothelium lie on the posterior surface of the corneal stroma adjacent to the anterior chamber. Descemet's membrane is a relatively strong membrane. It will continue to define the shape of the anterior chamber even where the corneal stroma has completely melted (descemetocele). Because it is a genuine basement membrane, lost tissue is regenerated by functional endothelial cells. The corneal endothelium is responsible for the transparency of the cornea. A high density of epithelial cells is necessary to achieve this. The corneal endothelium does not regenerate; defects in the endothelium are closed by cell enlargement and cell migration.

Transparency. This is due to two factors.

• The uniform arrangement of the lamellae of collagen fibrils in the corneal stroma and the smooth endothelial and epithelial surface produce by the intraocular pressure.

• The water content of the corneal stroma remains constant at 70 %. The combined action of the epithelium and endothelium maintains a constant water content; the epithelium seals the stroma off from the outside, while the endothelium acts as an ion pump to remove water from the stroma.

The cornea derives its nutrition and oxygenation from the tears, from the aqueous and from the limbal capillary arcade. It is richly supplied with sensory nerve endings from the nasociliary branch of the first division of the trigeminal nerve, making it exquisitely sensitive.

Sclera

Function. The sclera and the cornea form the rigid outer covering of the eye. All six ocular muscles insert into the sclera.

The sclera is the white outer coat of the eye which is continuous anteriorly with the cornea at the corneoscleral limbus. It is thin in children and in some disease processes e.g. osteogenesis imperfecta, so that uveal pigment can be seen through it giving it a bluish appearance. It is composed of dense bands of fibrous tissue mainly parallel to the surface which cross each other in all directions, the orientation and thickness of the bands is such that they give maximum strength where required e.g. muscle tendons enter the sclera and fan out to give strong attachment. Elastic fibres appear after birth, are situated on the surface of the fibrous bands and help the sclera to resist permanent distension by intraocular pressure.

The sclera is thickest (1 mm) anteriorly at the limbus of the cornea, where it joins the corneal stroma, and at its posterior pole. It is thinnest (0.3 mm) at the equator and beneath the insertions of the rectus muscles. The site where the fibers of the optic nerve enter the sclera is known as the lamina cribrosa. This is the weakest area and tends to stretch in the face of raised intraocular pressure being one factor in cupping of the optic disc and by this distortion, strangulating the blood vessels and nerve fibres.

In the angle of the anterior chamber, the sclera forms the trabecular network and the canal of Schlemm. The aqueous humor drains from there into the intrascleral and episcleral venous plexus through about 20 canaliculi.

Vortex veins and the short anterior and posterior ciliary arteries penetrate the sclera. Behind the equator the four vortex veins draining the choroid, leave the eye and form the ophthalmic veins and about 4 mm from the limbus the sclera is traversed by 7–8 anterior ciliary arteries which are a continuation of the muscular arteries supplying the rectus muscles, which then anastomose with the long posterior ciliary arteries to form the major arterial circle of the iris.

2.7. UVEAL TRACT

The uveal tract (also known as the vascular pigmented layer, vascular tunic, and uvea takes its name from the Latinas (grape) because the dark pigmentation and shape of the structure are reminiscent of a grape. The uveal tract consists of the following structures:

- Iris.
- Ciliarybody.
- Choroid.

The iris

Iris is the anterior most part of the uveal tract. It is a thin circular disc corresponding to the diaphragm of a camera. In its centre is an aperture of about 4-mm diameter called pupil which regulates the amount of light reaching the retina. At the periphery, the iris is attached to the middle of anterior surface of the ciliary body. It divides the space between the cornea and lens into anterior and posterior chambers.

Macroscopic appearance. Anterior surface of the iris can be divided into a ciliary zone and a pupillary zone by a zigzag line called collarette.

1. Ciliary zone. It presents series of radial streaks due to underlying radial blood vessels and crypts which are depressions where superficial layer of iris is missing. Crypts are arranged in two rows — the peripheral present near the iris root and thecentral present near the collarette.

2. Pupillary zone. This part of the iris lies between the collarette and pigmented pupillary frill and is relatively smooth and flat (figure 11).

Microscopic structure. The iris consists of four layers which from anterior to posterior are:

1. Anterior limiting layer. It is the anterior most condensed part of the stroma. It consists of melanocytes and fibroblasts. Previously this layer was called endothelial layer of iris which was amisnomer. This layer is deficient in the areas of crypts. The definitive colour of the iris dependson this layer. In blue

iris this layer is thin and contains few pigment cells. While in brown iris it is thick and densely pigmented.

2. Iris stroma. It consists of loosely arranged collagenous network in which are embedded the sphincter pupillae muscle, dilator pupillae muscle, vessels, nerves, pigment cells and other cells which include lymphocytes, fibroblasts, macrophages and mast cells. The sphincter pupillae muscle forms one millimetre broad circular band in the papillary part of the iris. It is supplied by parasympathetic fibres through third nerve. It constricts the pupil. The dilator pupillae muscle lies in the posterior part of stroma of the ciliary zone of iris. Its myofilaments are located in the outer part of the cells of anterior pigment epithelial layer. It is supplied by cervical sympathetic nerves and dilates the pupil.

3. Anterior epithelial layer. It is anterior continuation of the pigment epithelium of retina and ciliary body. This layer gives rise to the dilator pupillae muscle.

4. The posterior pigmented epithelial layer. It is anterior continuation of the non-pigmented epithelium of ciliary body. At the pupillary margin it forms the pigmented frill and becomes continuous with the anterior pigmented epithelial layer.

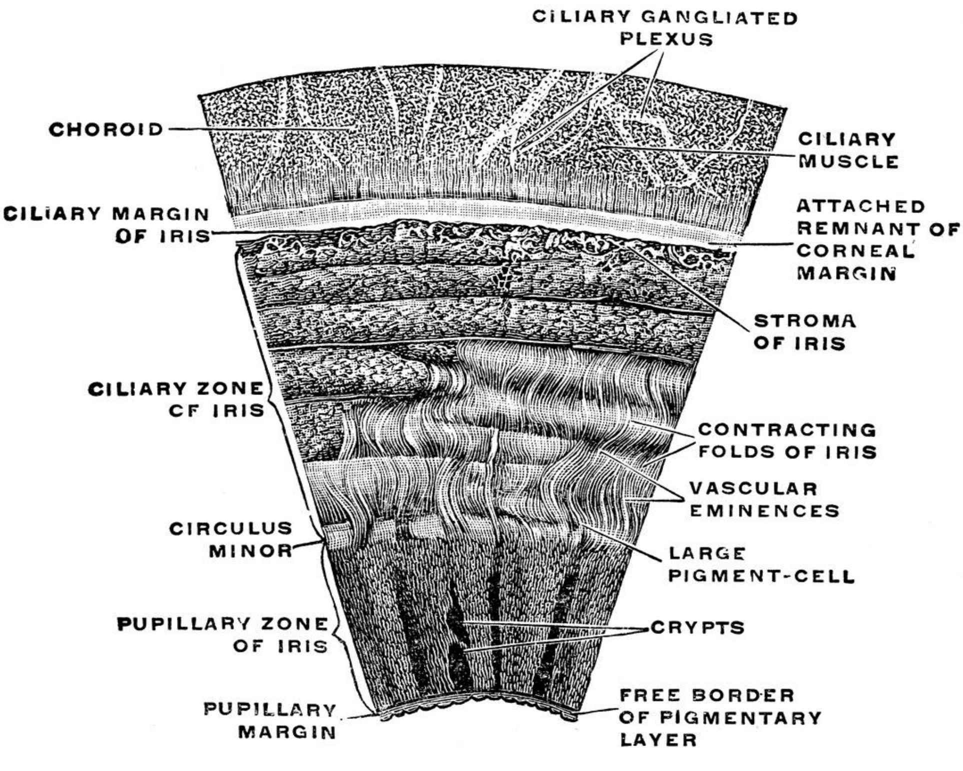

Figure 11 — Surface anatomy of the front of the iris

The ciliary body

This is the part of the uvea between the iris and choroid. It is triangular in antero-posterior section and the anterior surface into which the root of the iris is inserted forms part of the angle of the anterior chamber. The outer surface is in relation to the sclera and the anterior part of the inner surface is plicated to form the ciliary processes, about sixty in number.

Where the inner surface is smooth posteriorly it is called the pars plana. The junction between the retina and the pars plana is scalloped and is described as the oraserrata. At the oraserrata the neural layer of the retina abruptly changes to a single layer of non-pigmented epithelium lying immediately within the continuation of the pigment epithelium of the retina. Together the two epithelial layers constitute the ciliary epithelium which covers the heavily vascularised ciliary processes and secretes aqueous. The ciliary processes enormously increase the secreting area.

Microscopic structure. From with out in wards ciliary body consists of following five layers:

1. Supraciliary lamina. It is the outermost condensed part of the stroma and consists of pigmented collagen fibres. Posteriorly, it is the continuation of suprachoroidal lamina and anteriorly it becomes continuous with the anterior limiting membrane of iris.

2. Stroma of the ciliary body. It consists of connective tissue of collagen and fibroblasts. Embedded in the stroma are ciliary muscle, vessels, nerves, pigment and other cells. Ciliary muscle occupies most of the outer part of ciliary body. In cut section it is triangular in shape. It is a non-striated muscle having three parts: (1) the longitudinal or meridional fibres which help in aqueous outflow; (2) the circular fibres which help in accommodation; and (3) the radial or oblique fibres act in the same way as the longitudinal fibres. Ciliary muscle is supplied by parasympathetic fibres through the short ciliary nerves.

3. Layer of pigmented epithelium. It is the forward continuation of the retinal pigment epithelium. Anteriorly it is continuous with the anterior pigmented epithelium of the iris.

4. Layer of non-pigmented epithelium. It consists mainly of low columnar or cuboidal cells, and is the forward continuation of the sensory retina. It continues anteriorly as the posterior (internal)pigmented epithelium of the iris.

5. Internal limiting membrane. It is the forward continuation of the internal limiting membrane of the retina. It lines the non-pigmented epithelial layers.

Ciliary processes. These are finger-like projections from the pars plicata part of the ciliary body. These are about 70–80 in number. Each process is about 2-mm long and 0.5-mm in diameter. These are white in colour.

Structure. Each process is lined by two layers of epithelial cells. The core of the ciliary process contains blood vessels and loose connective tissue. These processes are the site of aqueous production.

Functions of ciliary body. (1) Formation of aqueous humour. (2) Ciliary muscles help in accommodation.

The muscle is mesodermal and non-striated and is supplied by the short ciliary nerves which convey postganglionic parasympathetic fibres from the ciliary ganglion. Preganglionic fibres originate in the Edinger-Westphal nucleus in the midbrain and pass via the inferior division of the third cranial nerve to the ciliary ganglion. There is also a weak reciprocal sympathetic innervation of the ciliary muscle. Contraction of the ciliary muscle draws the suspensory ligament of the lens forwards and slackens it. The lens becomes more convex by contraction of its elastic capsule and focuses the eye for near distances. This is the act of accommodation.

The choroid

The choroid is in contact on its inner surface with the pigment epithelium of the retina. It is entirely mesodermal except for the innermost layer, the cuticular part of the membrane of Bruch, which originates from the retinal pigment epithelium. The choroid can be subdivided into three distinct parts from internal to external: (1) Bruch's membrane; (2) the vascular layers; and (3) the suprachoroid (figure 12).

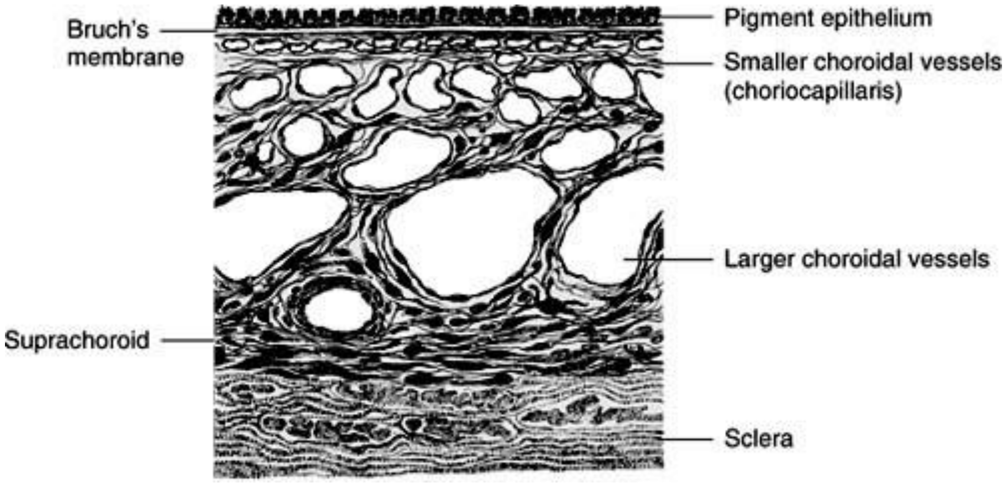

Figure 12 — Choroid anatomy

Bruch's membrane, also called the lamina vitrea, is the inner layer of the choroid. This thin, acellular, well-delineated zone between the retina and choroid extends from the optic nerve to the ora serrata. Composed of elements from both the retina and the choroid, Bruch's membrane is an integral part of the choroid. From internal to external, the membrane is formed of five layers: the basement membrane of the RPE, the inner collagenous zone, the elastic tissue layer, the outer collagenous zone, and the basement membrane of the choriocapillaris.

The blood supply of the uveal tract

The blood supply of the uveal tract comes from the short and long posterior ciliary arteries and the anterior ciliary arteries. The short posterior ciliary arteries, which are variable in number, supply the choroid and important branches to the vascular circle surrounding the optic nerve head. The two long posterior ciliary arteries pass forward in the horizontal meridian within the suprachoroidal space. The anterior ciliary arteries are continuations of the arteries of the rectus muscles which continue in the episclera and perforate the sclera 4 mm from the limbus to join the long posterior ciliary arteries. These form the major arterial circle of the iris which lies in the ciliary body supplying both ciliary body and iris. One anterior ciliary artery emerges from the lateral rectus and two from each of the other rectus muscles. Veins from all the uveal tract drain posteriorly to form four large vortex veins which traverse the sclera behind the equator to join the superior and inferior ophthalmic veins (figure 13).

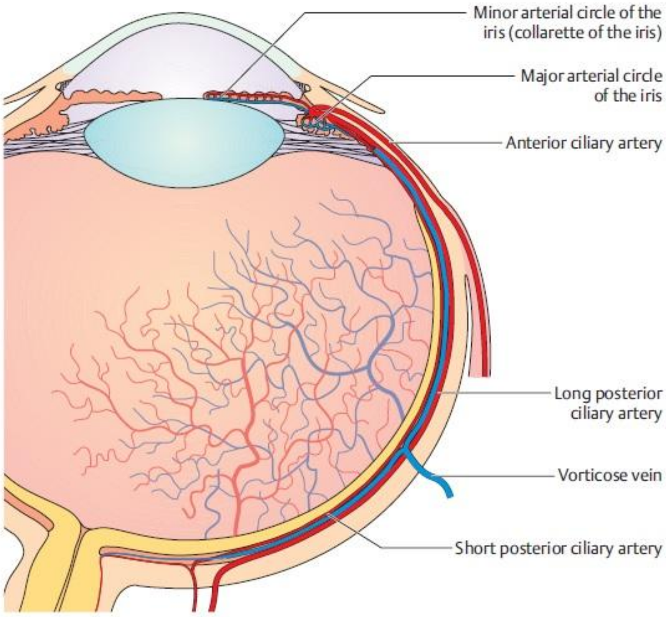

Figure 13 — The blood supply of the uveal tract

Physyology of aqueous production

The ciliary body consists of the anterior pars plicata (2 mm wide) and the posterior pars plana (4 mm wide). The pars plicata bears 70 radially orientated ciliary processes wich project into posterior chamber. Each ciliary process is lined by a pigment epithelial layer continuous with the retinal pigment epithelium and a non-pigment epithelial layer continuous with neuroretina. Each process also has a central arteriole ending in a rich capillary network. Tight junctions between adjacent non-pigment epithelial cells constitute the blood-aqueous barrier. Aqueous humor is a actively secreted by the non-pigment epithelium as a result of a metabolic process that depends on several enzyme systems, especially the Na/K ATPase pump, which secrets Na ions into the posterior chamber. Water follows passively along the osmotic gradient. Carbonic anhydrase also pays a role, but the precise mechanism is uncertain. Aqueous secretion is diminished by factors that inhibit active metabolism such as hypoxia and hypothermia but its idepend of the level of intraocular pressure.

Aqueous outflow.

1. The trabecular meshwork (trabeculum) is a sieve-like structure at the angle of the anterior chamber, through which 90 % of the aqueous humor leaves the eye. It consists of the following three portions.

a) the uveal meshwork is the innermost portion, which consists of cord-like meshes that extend from the root of the iris to Schwalbe line. The inter trabecular spaces are relatively large and offer little resistance to the passage of aqueous;

b) the corneoscleral meshwork forms the larger middle portion which extends from the scleral spur to Schwalbe line. The meshes are sheet-like and the inter trabecular spaces are smaller than in uveal meshwork;

c) the endothelial (juxtacanalicular) meshwork is the outer part of the trabeculum which links the corneo-scleral meshwork with the endothelium of the inner wall of Schlemm canal. The juxtacanalicular tissue offers the major portion of normal resistance to aqueous outflow.

2. Schlemm canal is a circumferential channel in the perilimbal sclera, bridged by septa. The inner wall of the canal is lined by irregular spindle-shaped endothelial cells which contain infoldings (giant vacuoles). The outer wall of the canal is lined by smooth flat cells and contains the openings of the collector channels which leave Schlemm canal at oblique angels and connect directly or indirectly with episcleral veins.

Aqueous flows from posterior chamber via the pupil into the anterior chamber , from where it exits the eye by two different routes:

1. Trabecular (Conventional) route accounts for approximately 90 % of aqueous outflow. The aqueous flows through the trabeculum into Schlemm canal and is than drained by the episcleral veins. This is a bulk-flow pressure-sensitive route so that increasing the pressure head will increase outflow.

2. Uveoscleral (unconventional) route accounts for the remaining 10 % of aqueous outflow. The aqueous passes across the face of the ciliary body into the suprachoroidal space and drained by the venous circulation in the ciliary body, choroid and sclera.

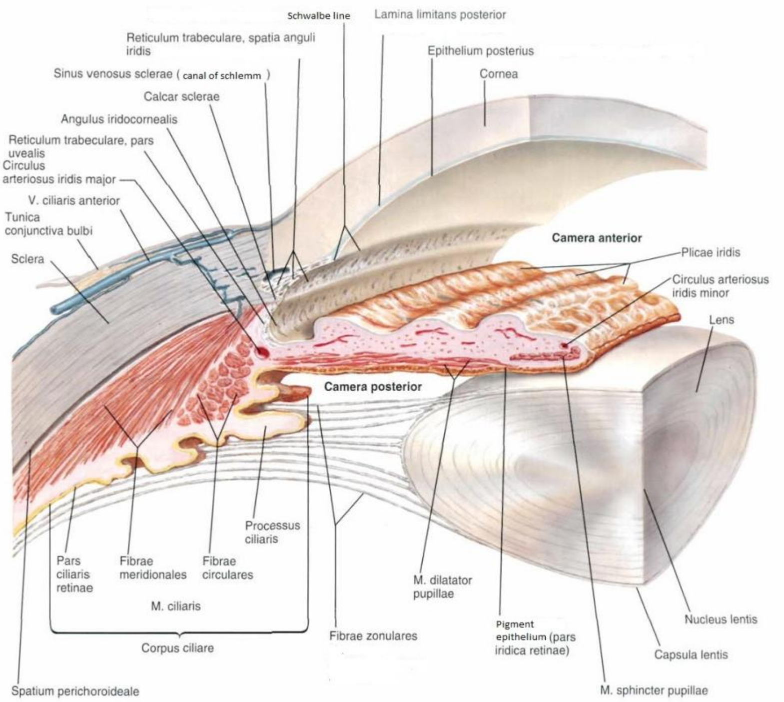

Figure 14 — Ciliary body

2.8. THE LENS

The lens is a transparent, bi-convex structure suspended from the ciliary body by the zonular fibres and situated between the iris and the vitreous. The lens is about 9 mm in diameter and about 4 mm thick at the centre. The thickness varies with accommodation. The anterior surface of the lens is less convex than the posterior surface. The lens is one of thes esential refractive media of the eye and focuses incident rays of light on the retina. It adds a variable element to the eye's total refractive power (10–20 diopters, depending on individual accommodation).

The most anterior part of the lens is called the anterior pole, the periphery is called the equator and the most posterior axial area is the posterior pole. The lens consists of capsule, epithelium and lens fibres. Under the anterior capsule lies a layer of epithelial cells. The rest of the lens consists of the lens fibres derived from other epithelial cells (figure 15).

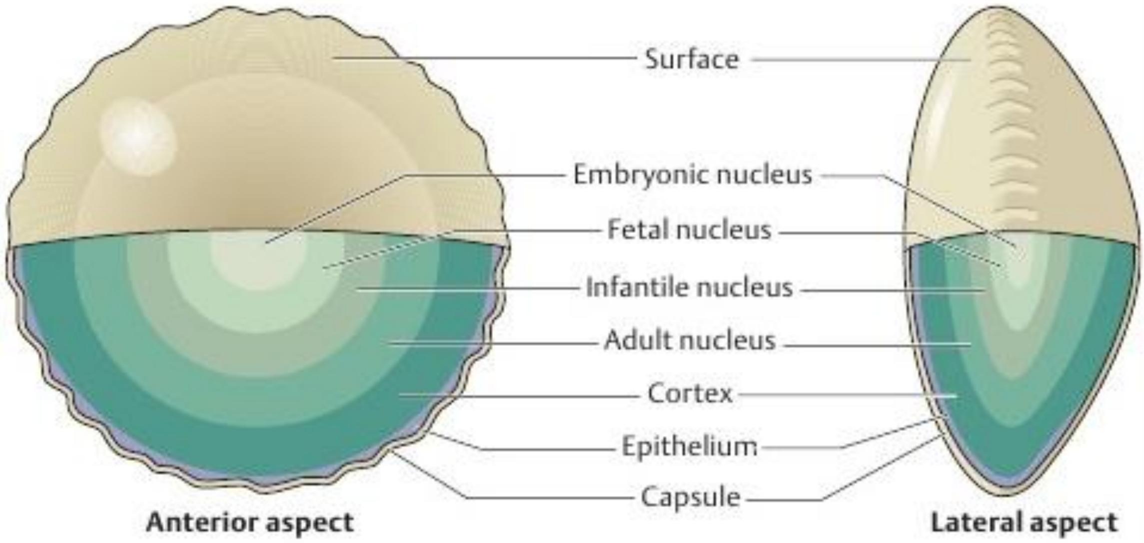

Figure 15 — Lens anatomy

The lens is a purely epithelial structure without any nerves or blood vessels. The normal direction of growth of epithelial structures is centrifugal; fully developed epithelial cells migrate to the surface and are peeled off. However, the lens grows in the opposite direction. The youngest cells are always on the surface and the oldest cells in the center of the lens. The growth of primary lens fibers forms the embryonic nucleus. At the equator, the epithelial cells further differentiate into lens fiber cells. These new secondary fibers displace the primary fibers toward the center of the lens.

The lens is nourished by diffusion from the aqueous humor. In this respect it resembles a tissue culture, with the aqueous humor as its substrate and the eyeball as the container that provides a constant temperature.

2.9. VITREOUS BODY

The gelatinous vitreous body consists of 98 % water and 2 % collagen and hyaluronic acid.

The vitreous is a hydrogel and the water which makes up 99 % of its volume is kept in a gel state by a collagen fibril framework and hyaluronic acid. It occupies the posterior segment of the globe bounded by the posterior surface of the lens and zonule, the pars plana of the ciliary body, the retina and the optic disc. The outer part of the vitreous (the cortex) has the greatest concentration of collagen fibrils. The majority of these run parallel to the surface of the retina, but a few turn at 90° to be inserted into the internal limiting membrane of the retina.

These collagen fibrils are responsible for the firm attachment of the vitreous gel to certain parts of the peripheral retina, the pars plana of the ciliary body and the optic disc. Less commonly, firm attachments also occur between the vitreous cortex and the retinal vessels and the macula.

These firm attachments are important because traction on the retina occurs at these points if the vitreous contracts, resulting in a retinal tear. The centre of the gel contains less collagen than the cortex and the collagen fibrils are condensed into tracts. These tracts run forward from the disc. There are three major tracts. The hyaloid tract inserts into the back of the lens. The other two major tracts insert into the ciliary body. One important attribute of these tracts is their ability to confine a vitreous haemorrhage between them rather than allowing the diffusion of haemorrhage throughout the whole gel. A blood/vitreous barrier is present, similar to the blood/aqueous or blood/brain barrier. This prevents free exchange of the larger molecules between the plasma and the vitreous gel. The barrier is due to the tight junctions that exist between the endothelial cells of the retinal vessels, the cells of the pigment epithelium and the inner endothelium of the ciliary processes. This barrier is impaired in disease of the retinal vessels, e.g. diabetic retinopathy. The barrier also influences the penetration of systemic antibiotics into the vitreous when the ophthalmologist is attempting to control intraocular infection.

2.10. RETINA

The retina is the innermost of three successive layers of the globe. It consists of two parts:

I. A photoreceptive part (pars optica retinae), consisting of the first nine of the 11 layers listed below.

II. A non receptive part (pars ceca retinae) forming the epithelium of the ciliary body and iris.

The pars optica retina emerges with the pars ceca retinae at the ora serrata.

Layers of the retina. Moving inward along the path of incident light, the individual layers of the retina areas follows (figure 16):

1. Internal limiting membrane (glial cell fibers separating the retina from the vitreous body).

2. Nerve fiber layer (axons of the third neuron).

3. Ganglion cell layer (cell nuclei of the multi polar ganglion cells of the third neuron; “data acquisition system”).

4. Inner plexiform layer (synapses between the axons of the second neuron. And dendrites of the third neuron).

5. Inner nuclear layer (cell nuclei of the bipolar nerve cells of the second neuron, horizontal cells, and amacrine cells).

6. Outer plexiform layer (synapses between the axons of the first neuron and dendrites of the second neuron).

7. Outer nuclear layer (cell nuclei of the rods and cones=first neuron).

8. Outer limiting membrane (sieve-like plate of processes of glial cells through which rods and cones project).

9. Layer of rods and cones (the actual photoreceptors).

10. Retinal pigment epithelium (a single cubic layer of heavily pigmented epithelial cells).

11. Bruch′s membrane (basal membrane of the choroid separating the retina from the choroid).

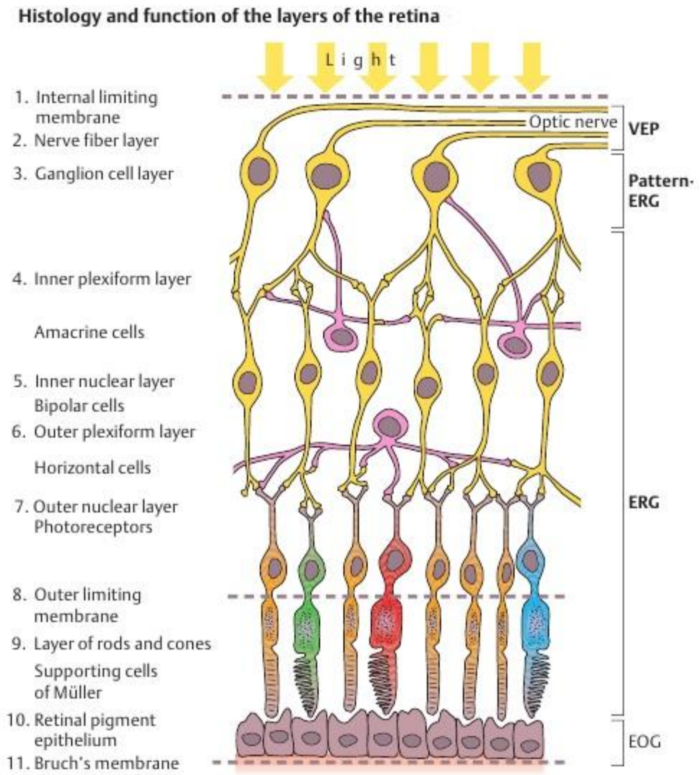

Figure 16 — Retina layers

When electromagnetic radiation in the visible light spectrum (wavelengths of 380–760 nm) strikes the retina, it is absorbed by the photo pigments of the outer layer. Electric signals are created in a multiple-step photochemical reaction. They reach the photoreceptor synapses as action potentials where they are relayed to the second neuron. The signals are relayed to the third and fourth neurons and finally reach the visual cortex. Light must pass through three layers of cell nuclei before it reaches the photosensitive rods and cones. This inverted position of the photoreceptors is due to the manner in which the retina develops from a diverticulum of the forebrain. Sensitivity of the retina to light intensity. The retina has two types of photoreceptors, the rods and the cones. The 110–125 million rods allow mesopic and scotopic vision (twilight and night vision). They are about 500 times more photosensitive than the cones and contain the photo pigment rhodopsin. The six to seven million cones in the macula are responsible for photopic vision (daytime vision), resolution, and color perception. There are three types of cones:

— Blue cones.

— Green cones.

— Red cones. Their photo pigments contain the same retinal but different opsins. Beyond a certain visual field luminance, a transition from dark adaptation to light adaptation occurs. Luminance refers to the luminous flux per unit solid angle per unit projected area, measured in candelas per square meter (cd/m^2). The cones are responsible for vision up to a luminance of 10cd/m^2, the rods up to0.01 cd/m^2 (twilight vision is 0.01–10 cd/m^2; night vision is less than 0.01 cd/m^2). Adaptation is the adjustment of the sensitivity of the retina to varying degrees of light intensity. This is done by dilation or contraction of the pupil and shifting between cone and rod vision. In this manner, the human eye is able to see in daylight and at night. In light adaptation, the rhodopsin is bleached out so that rod vision is impaired in favor of cone vision. Light adaptation occurs farmore quickly than dark adaptation. In dark adaptation, the rhodopsin quickly regenerates within 5 minutes (immediate adaptation), and within 30 minutes to 1 hour there is a further improvement in night vision (long-term adaptation). An adaptometer can be used to determine the light intensity threshold. First the patient is adapted to bright light for 10 minutes. Then the examining room is darkened and the light intensity threshold is measured with light test markers. These measurements can be used to obtain an adaptation curve.

Macula lutea

The macula lutea is a flattened oval area in the center of the retina approximately 3–4 mm (15°) temporal to and slightly below the optic disc.

Its diameter is roughly equal to that of the optic disc (1.7–2 mm). The macula appears yellow when examined under green light, hence the name macula lutea (yellow spot). Located in its center is the avascular fovea central is, the point at which visual perception is sharpest. The fovea central is contains only cones (no rods) each with its own neural supply, which explains why this region has such distinct vision. Light stimuli in this region can directly act on the sensory cells (first neuron) because the bipolar cells (second neuron) and ganglion cells (third neuron) are displaced peripherally.

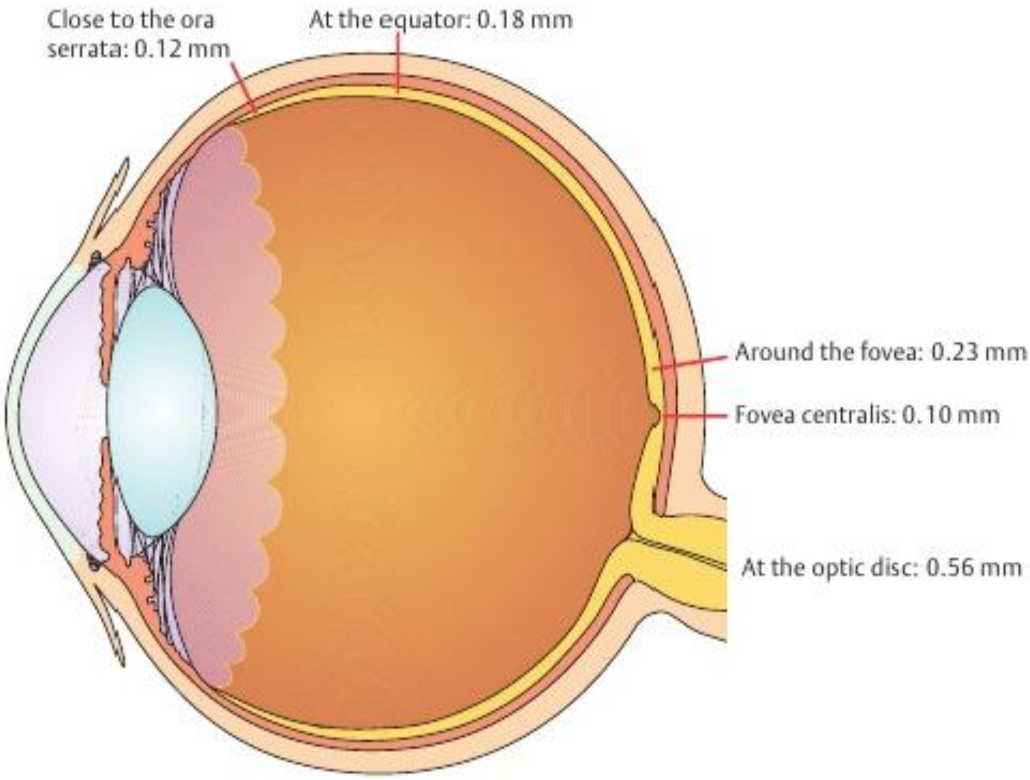

Fig 17 — Retina

Vascular supply to the retina. The inner layers of the retina (the internal limiting membrane through the inner nuclear layer) are supplied by the central artery of the retina. This originates at the ophthalmic artery, enters the eye with the optic nerve, and branches on the inner surface of the retina. The central artery is a genuine artery with a diameter of 0.1 mm. It is a terminal artery with out anastomoses and divides into four main branches.

Because the central artery is a terminal artery, occlusion will lead to retinal infarction

The outer layers (outer plexiform layer through the pigment epithelium) contain no capillaries. They are nourished by diffusion primarily from the richly supplied capillary layer of the choroid. The retinal arteries are normally bright red, have bright red reflex strips that become paler with advancing age, and do not show a pulse. The retinal veins are dark red with a narrow reflex strip, and may show spontaneous pulsation on the optic disc.

Pulsation in the retinal veins is normal; pulsation in the retinal arteries is abnormal.

The walls of the vessels are transparent so that only the blood will be visible on ophthalmoscopy. In terms of their structure and size, the retinal vessels are arterioles and venules, although they are referred to as arteries and veins.

Venous diameter is normally 1.5 times greater than arterial diameter. Capillaries are not visible.

2.11. OPTIC NERVE

The optic nerve is a unique part of the central nervous system (CNS). It lacks neuronal cell bodies and is isolated from the rest of the brain. The optic nerve consists of unbranched axons of the retinal ganglion cells and the glial cells. The number of axons can be considered a constant, whereas glia and myelin are present in variable amounts relative to the axons and the surrounding microenvironment.

The optic nerve extends from the posterior pole of the eye to the optic chiasm. After this characteristic crossing, the fibers of the optic nerve travel as the optic tract to the lateral geniculate body. Depending on the shape of the skull, the optic nerve has a total length of 35–55mm. The nerve consists of:

- An intraocular portion.
- An intraorbital portion.
- An intracranial portion.

The intraocular portion (optic nerve head) is approximately 1 to 1.5 mm long and 1.5 mm in diameter and traverses the sclera. The intraocular portion of the optic nerve is visible on ophthalmoscopy as the optic disc. All the retinal nerve fibers merge into the optic nerve here, and the central retinal vessels enter and leave the eye here. The complete absence of photoreceptors at this site creates a gap in the visual field known as the blind spot. The normal physiologic color is yellowish-orange. The temporal half of the optic disc is usually slightly paler. The margin of the optic disc is sharply defined and readily distinguished from the surrounding retinal tissue. On the nasal side, the greater density of the nerve fibers makes the margins lightly less distinct than on the temporal side.

Optic cup. This is the slightly eccentric cavitation of the optic nerve that has as lightly flattened oval shape corresponding to that of the neuroretinal rim. It is the brightest part of the optic disc. No nerve fibers exit from it. The size of the optic cup correlates with the size of the optic disc; the larger the optic disc, the larger the optic cup. Because enlargement of the optic cup means a loss of nerve fibers in the rim, it is particularly important to document the size of the optic cup. This is specified as the horizontal and vertical ratios of cup to disc diameter (cup–disc ratio).

Central retinal artery and vein. These structures usually enter the eye slightly nasal to the center of the optic disc. Visible pulsation in the vein is normal. However, arterial pulsation is always abnormal and occurs with disorders such as increased intraocular pressure and aortic stenosis.

Blood supply to the optic disc. The optic disc receives its blood supply from the ring of Zinn, an anastomotic ring of small branches of the short posterior ciliary arteries and the central retinal artery. Both groups of vessels originate from the ophthalmic artery, which branches off of the internal carotid artery and enters the eye through the optic canal. The central retinal artery and vein branch into the optic nerve approximately 8 mm before the point at which the optic nerve exits the globe. Approximately 10 short posterior ciliary arteries penetrate the sclera around the optic nerve (figure 18).

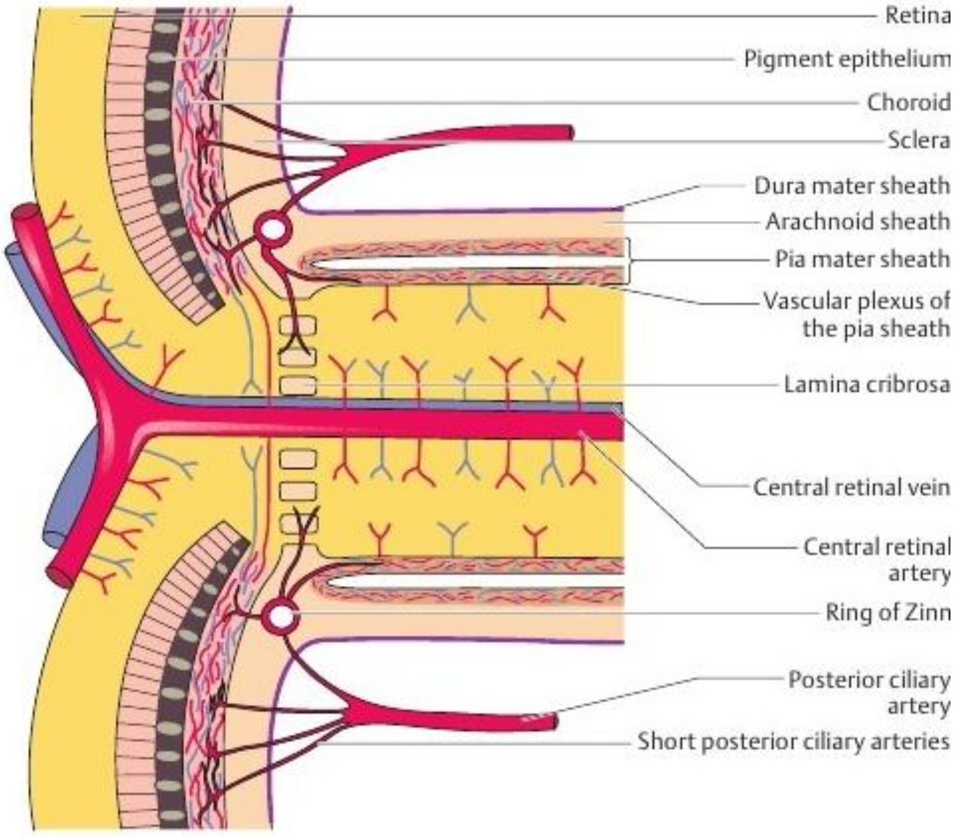

Figure 18 — Blood supply the head of the optic nerve

Intraorbital and Intracranial Portion of the Optic Nerve

The intraorbital portion begins after the nerve passes through a sieve-like plate of scleral connective tissue, the lamina cribrosa. Inside the orbit, the optic nerve describes an S-shaped course that allows extreme eye movements. After the optic nerve passes through the optic canal, the short intracranial portion begins and extends as far as the optic chiasm. Like the brain, the intraorbital and intracranial portions of the optic nerve are surrounded by sheaths of dura mater, pia mater, and arachnoid. The nerve receives its blood supply through the vascular pia mater sheath (figure 18).

Several important structures are situated close to the intracranial portion of the optic nerve. The frontal lobe of the brain lies above each optic nerve. The anterior cerebral and anterior communicating arteries separate the optic nerve from the olfactory tract. Laterally, the ophthalmic artery arises from the internal carotid artery and is located beneath the optic nerve near the optic canal. Because of the close anatomic relationship that exists between the proximal optic nerve, the chiasm, and the internal carotid artery and its branches, any space-occupying lesions that occur in this area may compress the optic nerve or chiasm, resulting in vision loss and visual field defects. Also, diseases of the sphenoid and posterior ethmoid cells, which are usually situated either inferiorly or inferomedially, may also affect the optic nerve and chiasm.

3. VISUAL PATHWAY

The anatomy of the visual pathway can be divided into six separate parts.

1. Optic nerve. This includes all of the optic nerve fiber bundles of the eye.

2. Optic chiasm. This is where the characteristic cross over of the nerve fibers of the two optic nerves occurs. The central and peripheral fibers from the temporal halves of the retinas do not cross the midline, but continue into the optic tract of the ipsilateral side. The fibers of the nasal halves cross the midline and there enter the contralateral optic tract. It was formerly thought that the inferior and superior nasal fibers traveled in a small arc through the contralateral optic nerve (anterior arc of Wilbrand) or the ipsilateral optic tract (posterior arc of Wilbrand), but the arcs of Wilbrand do not exist in a normal chiasm. It is only in cases of optic atrophy that the nerve fibers are drawn to the optic nerve, due to shrinking of the tissue.

3. Optic tract. This includes all of the ipsilateral optic nerve fibers and those that cross the midline.

4. Lateral geniculate body. The optic tract ends here. The third neuron connects to the fourth here, which is why atrophy of the optic nerve does not occur in lesions beyond the lateral geniculate body.

5. Optic radiations (geniculocalcarine tracts). The fibers of the inferior retinal quadrants pass through the temporal lobes; those of the superior quadrants pass through the parietal lobes to the occipital lobe and from there to the visual cortex.

6. Primary visual area (striate cortex or Brodmann’s area 17 of the visual cortex): The nerve fibers diverge within the primary visual area; the macula lutea accounts for most of these fibers. The macula is represented on the most posterior portion of the occipital lobe. The central and intermediate peripheral regions of the visual field are represented anteriorly. The temporal crescent of the visual field, only present unilaterally, is represented farthest anteriorly (figure 19).

Other connections extend from the visual cortex to associated centers and oculomotor areas (parastriate and peristriate areas). Aside from the optic tract there is also another tract known as the retinohypothalamic tract. This tract is older in evolutionary terms and diverges from the optic chiasm. It transmits light impulses for metabolic and hormonal stimulation to the diencephalon and pituitary gland system and influences the circadian rhythm.

Pupillary light reflex. This reflex arc consists of an afferent path that detects and transmits the light stimulus and an efferent path that supplies the muscles of the iris (figure 20).

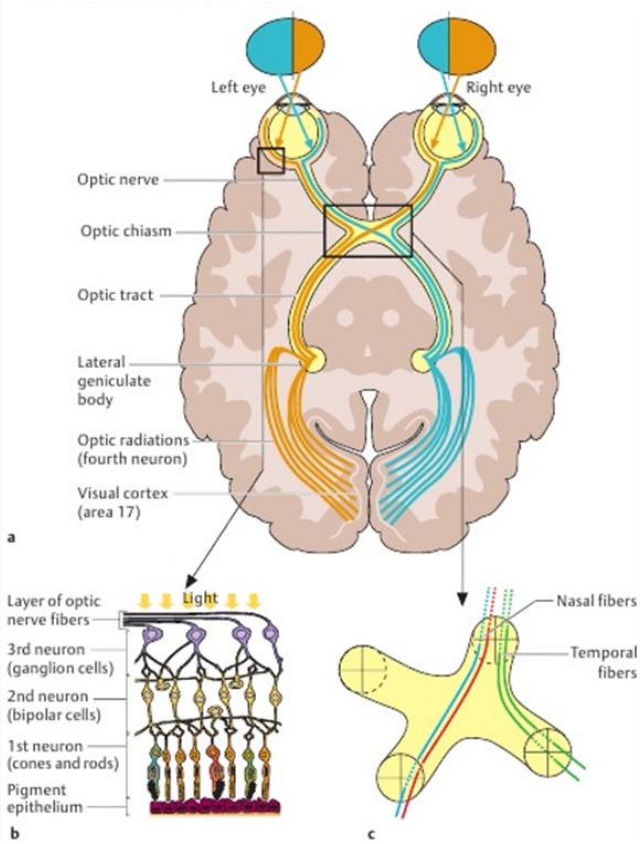

Figure 19 — Visual pathway

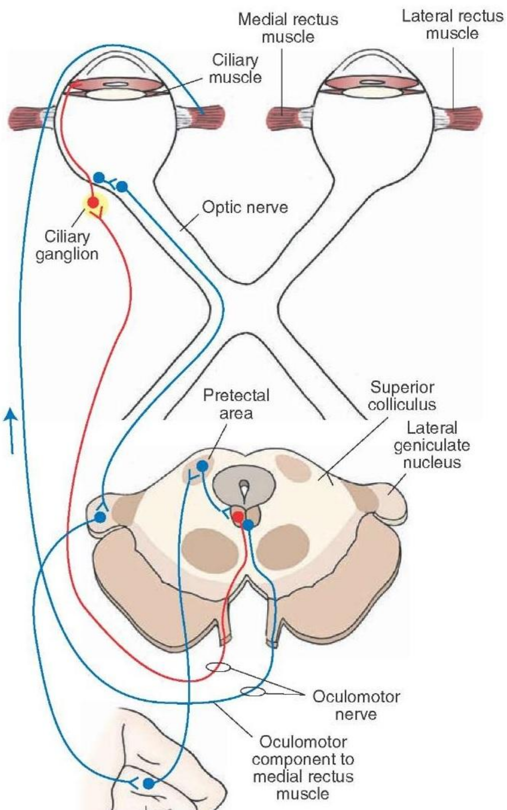

Figure 20 — The pathways mediating the pupillary light and accommodation reflexes

Afferent path.

This path begins at the light receptors of the retina, continues along the optic nerve, the optic chiasma where some of the fibers cross to the opposite side. The path continues along the optical tracts until shortly before the lateral geniculate body. There the afferent reflex path separates from the visual path way and continues to the pretectal nuclei and from there to both Edinger–Westphal nuclei. Each of the two pretectal nuclei conducts impulses to both Edinger–Westphal nuclei. This bilateral connection has several consequences:

- Both pupils will normally be the same size (isocoria) even when one eye is blind. Deviations of up to 1 mm are normal.
- Both pupils will narrow even when only one eye is illuminated (consensual light reflex).

Efferent parasympathetic path.

This path begins in the Edinger–Westphalnucleus. Its nerve fibers form the parasympathetic part of the oculomotor nerve and travel to the ciliary ganglion in the orbit. Postganglionic nerve fibers pass through the short ciliary nerves to the effector organ, the sphincter pupillae muscle. Perlia's nucleus and the Edinger–Westphal nuclei are also responsible for the near reflex, which consists of accommodation, convergence, and miosis.

Efferent sympathetic nerve supply to the pupil.

Three neurons connected by synapses supply the pupil:

- The central first neuron begins in the posterior hypothalamus, passes the brain stem and the medulla oblongata to the ciliospinal center (Budge's center) in the cervical spinal cord (C8–T2).
- The preganglionic second neuron extends from the ciliospinal center through the white rami communicantes and sympathetic trunk to the superior cervical ganglion. It is vulnerable to certain lesions such as Pancoast tumors because it is immediately adjacent to the tip of the lung.
- The postganglionic third neuron extends from the superior cervical ganglion as a neural plexus along the internal carotid artery, ophthalmic artery, and long ciliary nerves to the effector organ, the dilator pupillae muscle.

4. BLOOD SUPPLY OF THE EYE AND ORBIT

Arteries

The main blood supply of the eye and orbit is from the ophthalmic artery (figure 21).There are contributions from the external carotid artery and many variations. The ophthalmic artery arises from the convexity of the curve of the internal carotid artery as it passes out of the cavernous sinus. It enters the orbit through the optic canal below and lateral to the optic nerve and then curves above the nerve with the nasociliary branch of the 5th cranial nerve and runs along the medial wall of the orbit to terminate by dividing into the dorsonasal artery, which supplies the lacrimal sac area, and the supratrochlear artery.

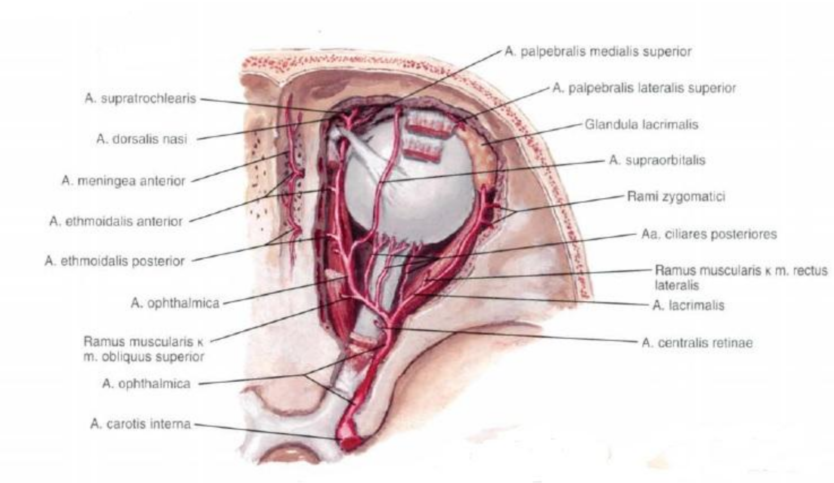

Figure 21 — Arterial blood supply of the left eye and orbit

The main branches of the ophthalmic artery are:

— the central retinal artery which runs forward under the optic nerve and enters it l cm from the globe;

— posterior ciliary arteries which give rise to a variable number of branches piercing the globe around the optic nerve and which supply the choroid and the intraocular portion of the optic nerve. Two branches in the horizontal meridian, the long posterior ciliary arteries, pass forward to the ciliary body near the base of the iris where they contribute to the major arterial circle of the iris;

— the lacrimal artery gives off a recurrent meningeal branch to anastomose with the middle meningeal artery and passes forward to end in the temporal and zygomatic branches after supplying the lacrimal gland;

— muscular arteries pass along the rectus muscles and continue forwards as the anterior ciliary arteries which end in the pericorneal arcade. They give off large branches which penetrate the sclera about 4 mm from the limbus and with the long ciliary arteries form the arterial circle at the base of the iris to supply the iris and ciliary body;

— the supraorbital artery passes around the margin of the orbit at the supraorbital notch to anastomose with the vessels of the scalp;

— the posterior and anterior ethmoidal arteries pass through the foramina of the same name and may have meningeal branches;

— the superior and inferior medial palpebral arteries anastomose with corresponding branches of the lacrimal artery in the lids.

Veins and lymphatics

There are three main veins within the orbit: (1) The superior ophthalmic vein receives the two superior vortex veins and drains into the angular vein. It connects posteriorly with the cavernous sinus. (2) The inferior ophthalmic vein drains to the pterygoid plexus through the inferior orbital fissure, having received the inferior vortex veins. (3) The central retinal vein leaves the opticnerve lcm behind the globe to join the ophthalmic veins. The cavernous sinus lies within a splitting of the dura mater on either side of the body of the sphenoid bone. Its important relations are shown in. Lymphatics from the medial part of the lower lid drain to the submaxillary lymph nodes, while those from the lateral part and most of the upper lid drain to the preauricular nodes.

5. NERVES OF THE EYE AND ORBIT

The 3^{rd} cranial (oculomotor) nerve

The nucleus of the 3rd cranial (oculomotor) nerve is situated in the midbrain beneath the aqueduct of Sylvius. Anteriorly is the nucleus of Perlia which is concerned with convergence, and antero-laterally are the nuclei of Edinger–Westphal from which parasympathetic fibres are derived. The nuclei of the 3^{rd}, 4^{th} and 6^{th} cranial nerves are linked by the medial longitudinal fasciculus. The 3^{rd} nerve leaves the midbrain between the cerebral peduncles passes anteriorly in the lateral wall of the cavernous sinus and enters the orbit through the lower part of the sphenoidal fissure dividing to supply the levator palpebrae superioris, medial and inferior rectus muscles and the inferior oblique. The branch of the 3^{rd} nerve to the inferior oblique muscle conveys the parasympathetic fibres which leave it as the motor root of the ciliary ganglion. From the ciliary ganglion arise the many short ciliary nerves which pierce the sclera around the optic nerve and supply the uveal tract and the ciliary and sphincter pupillae muscles (Figure 22).

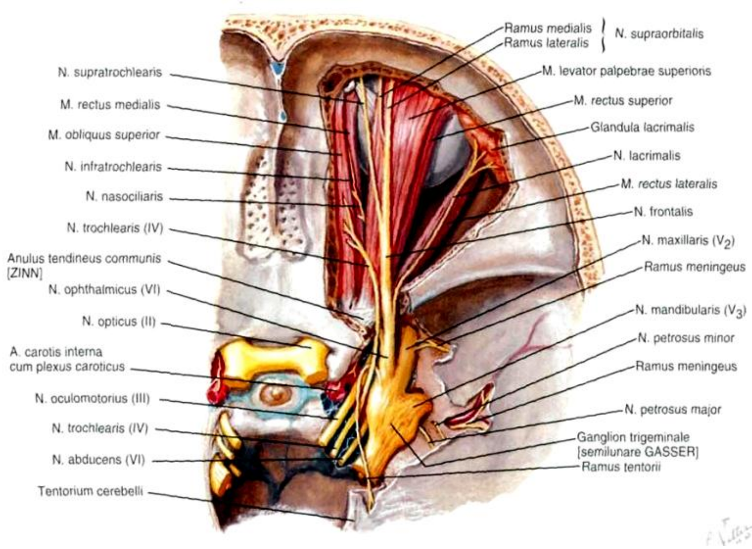

Figure 22 — Nerves of the eye and orbit

The 4^{th} cranial (trochlear) nerve

The 4^{th} cranial (trochlear) nerve nucleus is at the posterior end of the 3^{rd} nucleus. Its fibres decussate to emerge dorsally and run forwards in the wall of the cavernous sinus and through the sphenoidal fissure to supply the superior oblique muscle.

The 5^{th} cranial (trigeminal) nerve

The 5^{th} cranial (trigeminal) nerve is the sensory nerve of the head and face but is also the motor supply for the muscles of mastication. The nucleus of the motor part of the nerve is near the floor of the aqueduct of Sylvius and the principal sensory nucleus concerned with tactile impulses is in the pons near its lateral surface.

The trigeminal ganglion lies in a depression in the petrous temporal bone within a cleft of dura mater (Meckel's Cave) and anteriorly has three branches, ophthalmic, maxillary and mandibular. — The ophthalmic nerve runs forwards in the wall of the cavernous sinus divides into frontal, lacrimal and nasociliary branches which enter the orbit through the sphenoidal fissure.

- The, frontal nerve passes anteriorly near the roof of the orbit and emerges as the supraorbital and the supratrochlear nerves to supply the skin of upper lid, conjunctiva and scalp.
- The lacrimal nerve accompanies the lacrimal artery along the upper border of the lateral rectus muscle to supply the lateral parts of the upper and lower lids. It receives a twig derived from the maxillary nerve which conveys secretory fibres to the lacrimal gland.
- The nasociliary nerve conveys sensory impulses from the eyeball. After passing through the tendinous ring it crosses above the optic nerve with the ophthalmic artery and runs along the medial wall of the orbit which it leaves via the anterior ethmoidal canal, enters the anterior cranial fossa, runs in the roof of the nose emerging on the face as the external nasal nerve to supply the skin of the nose. In its course it contributes the sensory root of the ciliary ganglion and the two long ciliary nerves which accompany the long posterior ciliary arteries, conveying sensory fibres from the uvea and sympathetic fibres to the dilator pupillae.

— The maxillary branch of the trigeminal nerve passes from the cranial cavity through the foramen rotundum to the pterygopalatine fossa and distributes sensory nerves directly or via the sensory root of the sphenopalatine ganglion to the skin of the upper face and nose, the lower lid and its conjunctiva. It also supplies the mucous membranes of the nose, maxillary sinus and mouth; also the teeth, periosteum of the orbit and the dura mater of the middle cranial fossa. In addition it receives post-ganglionic secreto-motor fibres from the sphenopalatine ganglion which are distributed via the zygomatic nerve and its communication with the lacrimal nerve, to the lacrimal gland.

— The mandibular branch of the trigeminal nerve passes through the foramen ovale to emerge into the infratemporal fossa. It has motor and sensory roots. The motor root mainly supplies the muscles of mastication. The sensory rootis the sensory supply to the skin of the scalp and its auriculo-temporal branch receives secretomotor fibres from the otic ganglion for the parotid salivary gland. Its lingual branch near its origin receives from the chorda tympani both sensory taste fibres for the anterior two thirds of the tongue and secreto-motor motor fibres which relay in the submandibular ganglion and supply the sublingual and submandibular salivary glands (Figure 23).

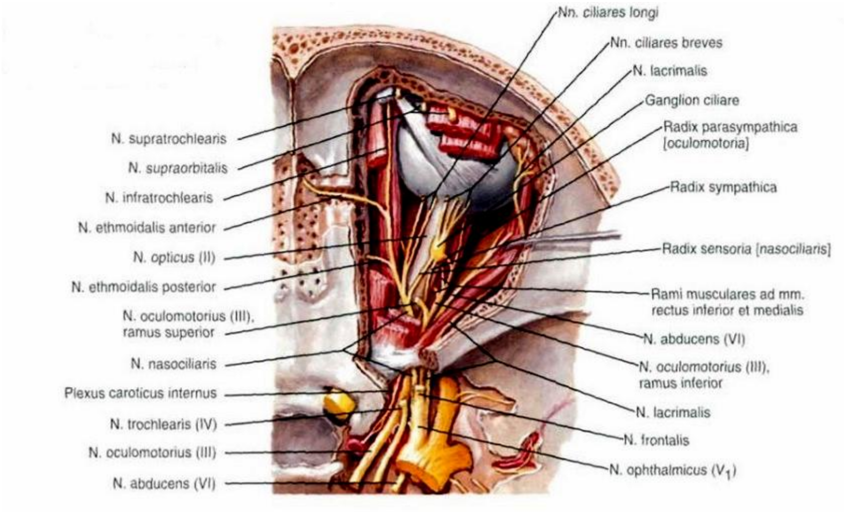

Figure 23 — Nerves of the eye

The 7th cranial (facial) nerve and its connections

The 7th cranial (facial) nerve consists of a motor component and the pars intermedia of Wrisberg which has both a sensory and secretomotor function.

Motor. The motor nucleus is located in the pons lateral to the fibres of the 6th nerve and medial to the spinal nucleus of the 5th nerve. The motor fibres ascend to loop medially and dorsally around the 6th nerve nucleus in the floor of the 4th ventricle and then run ventrally to emerge at the lower border of the pons lateral to the 6th nerve. The motor part of the nerve enters the internal auditory meatus in company with the 8th cranial nerve and with the nervus intermedius which then fuses with it. The facial nerve then makes a sharp backward bend to enter the facial canal, curves over the middle ear supplying the nerve to stapedius and leaves the canal at the stylomastoid foramen, it gives branches to the digastric and stylohyoid muscles and turns forwards and divides into upper and lower branches in the parotid gland to supply the mus-cles of the face. The upper branch comes from the upper part of the nucleus which has cortical connections to both hemispheres while the lower part does not. As a result the muscles supplied by the upper branch including those around the eye are spared in unilateral supra-nuclear lesions.

Facial nerve block to immobilize the facial muscles around the eye can be achieved by injecting local anaesthetic solution against the posterior aspect of the ramus of the mandible where the nerve curves around it, with the mouth widely open to protect deeper structures.

The efferent sympathetic nervous supply to the eye and orbit (adrenergic)

These nerve fibres originate in the hypothalamus. They pass down the brainstem and the cervical spinal cord to the level of the first and second thoracic nerves (Tl and T2) where, at the ciliospinal centre in the intermedio-lateral tract of grey matter, the first relay occurs, the axons of the second order neurones leave the spinal cord via the spinal root of Tl or T2 and enter the cervical sympathetic chain. The third relay takes place at the superior cervical ganglion where the third neurones' axons form the non medullated postganglionic fibres. These accompany the internal carotid artery into the skull and throughthe cavernous sinus and follow its branches into the orbit. They are also carried by the ophthalmic division of the fifth cranial nerve and its nasociliary branch and the long ciliary nerves to the dilator pupillae and ciliary muscles.

Other sympathetic fibres from the carotid sympathetic plexus pass via the levator palpebrae superior is branch of the third cranial nerve to the superior palpebral muscle of Miiller. This smooth muscle sheet arises from the inferior surface of the tendon of the levator to be inserted at the margin of the tarsal plate. There is a similar, less well defined muscle in the lower lid arising from the inferior rectus tendon.

The efferent parasympathetic nervous supply to the eye and orbit (cholinergic)

These nerve fibres originate in the hypothalamus. They then relay in the Edinger–Westphal nucleus of the third cranial nerve and are carried by the third nerve to the orbit. They accompany the branch to the inferior oblique muscle but leave it to relay to the third neurone in the ciliary ganglion. The postganglionic fibres enter the short ciliary nerves to supply the sphincter muscle of the pupil, the ciliary muscle and other smooth muscle in the eye. Lesions of the third cranial nerve, the ciliary ganglion (Holmes–Adie pupil) or the muscles themselves will result in a dilated pupil and weakness of accomodation.

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(на английском языке)

Учебно-методическое пособие по офтальмологии
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