B D Chaurasia's Human Anatomy

for Dental Students

Fifth Edition

As per the Syllabus prescribed by the Dental Council of India

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Wall Chart on Head and Neck

Edited by

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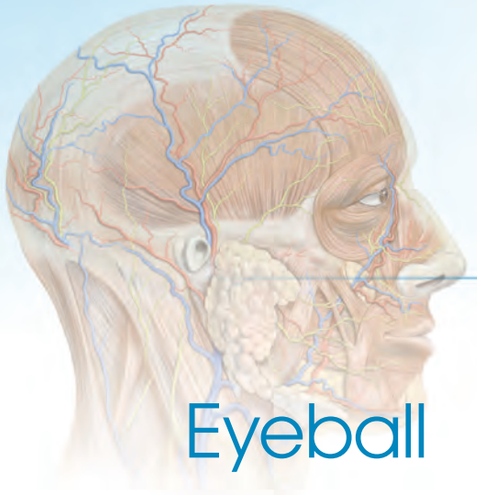


Chapter

27

Eyeball

"Our eyes are placed in front because it is more important to look ahead than look back."
—Anonymous

INTRODUCTION

Sense of sight perceived through retina of the eyeball is one of the five special senses. Its importance is obvious in the varied ways of natural protection. Bony orbit, projecting nose and various coats protect the precious retina. Each and every component of its three coats is assisting the retina to focus the light properly. A lot of advances have been made in correcting the defects of the eye. Eyes can be donated at the time of death, and a 'will' can be prepared accordingly.

About 75% of afferents reach the brain through the eyes. Adequate rest to eye muscles is important. A good place for rest could be the 'classroom' where palpebral part of orbicularis oculi closes the eyes gently.

The eyeball is the organ of sight. The camera closely resembles the eyeball in its structure. It is almost spherical in shape and has a diameter of about 2.5 cm.

Eyeball is made up of three concentric coats. The outer or *fibrous coat* comprises the sclera and cornea. The middle or *vascular coat* also called the uveal tract consists of the choroid, the ciliary body and the iris. The inner or *nervous coat* is the retina (Fig. 27.1).

Light entering the eyeball passes through several *refracting media*. From before backwards, these are the cornea, the aqueous humour, the lens and the vitreous body.

OUTER COAT

SCLERA

The sclera (*skleros* = hard) is opaque and forms the posterior five-sixths of the eyeball. It is composed of dense fibrous tissue which is firm and maintains the shape of the eyeball. It is thickest behind, near the

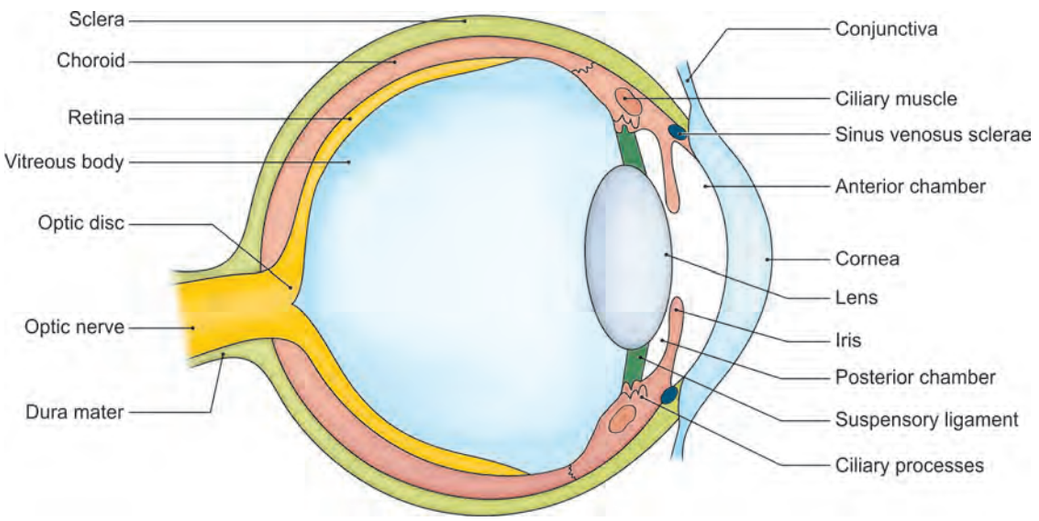


Fig. 27.1: Sagittal section through the eyeball

entrance of the optic nerve, and thinnest about 6 mm behind the sclerocorneal junction where the recti muscles are inserted. However, it is weakest at the entrance of the optic nerve. Here the sclera shows numerous perforations for passage of fibres of the optic nerve. Because of its sieve-like appearance, this region is called the *lamina cribrosa* (*crib* = sieve).

The *outer surface* of the sclera is white and smooth, it is covered by Tenon's capsule (*see* Fig. 21.3). Its anterior part is covered by conjunctiva through which it can be seen as the white of the eye. The *inner surface* is brown and grooved for the ciliary nerves and vessels. It is separated from the choroid by the *perichoroidal space* which contains a delicate cellular tissue, termed the *suprachoroidal lamina* or *lamina fusca of the sclera.*

The sclera is continuous anteriorly with the cornea at the *sclerocorneal junction or limbus* (Fig. 27.1). The deep part of the limbus contains a circular canal, known as the *sinus venosus sclerae or the canal of Schlemm.* The aqueous humour drains into the anterior scleral or ciliary veins through this sinus.

The sclera is fused posteriorly with the *dural sheath of the optic nerve.* It provides insertion to the extrinsic muscles of the eyeball: The recti in front of the equator, and the oblique muscles behind the equator.

The sclera is pierced by a number of structures:

a. The *optic nerve* pierces it a little inferomedial to the posterior pole of the eyeball.
b. The *ciliary nerves and arteries* pierce it around the entrance of the optic nerve.
c. The *anterior ciliary arteries,* derived from muscular arteries to the recti, pierce it near the limbus.

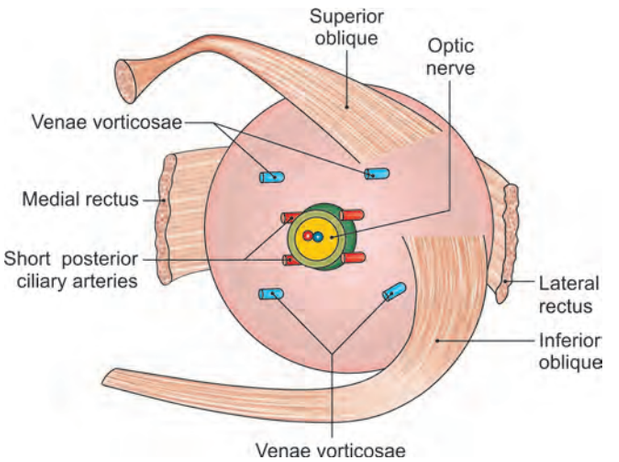


Fig. 27.2: Structures piercing the posterior aspect of the eyeball

d. Four *venae vorticosae* or the choroid veins pass out through the sclera just behind the equator (Figs 27.2 and 27.3).

The sclera is almost avascular. However, the loose connective tissue between the conjunctiva and sclera called as the *episclera* is vascular.

DISSECTION

Use the fresh eyeball of the goats for this dissection. Clean the eyeball by removing all the tissues from its surface. Cut through the fascial sheath around the margin of the cornea. Clean and identify the nerve with posterior ciliary arteries and ciliary nerves close to the posterior

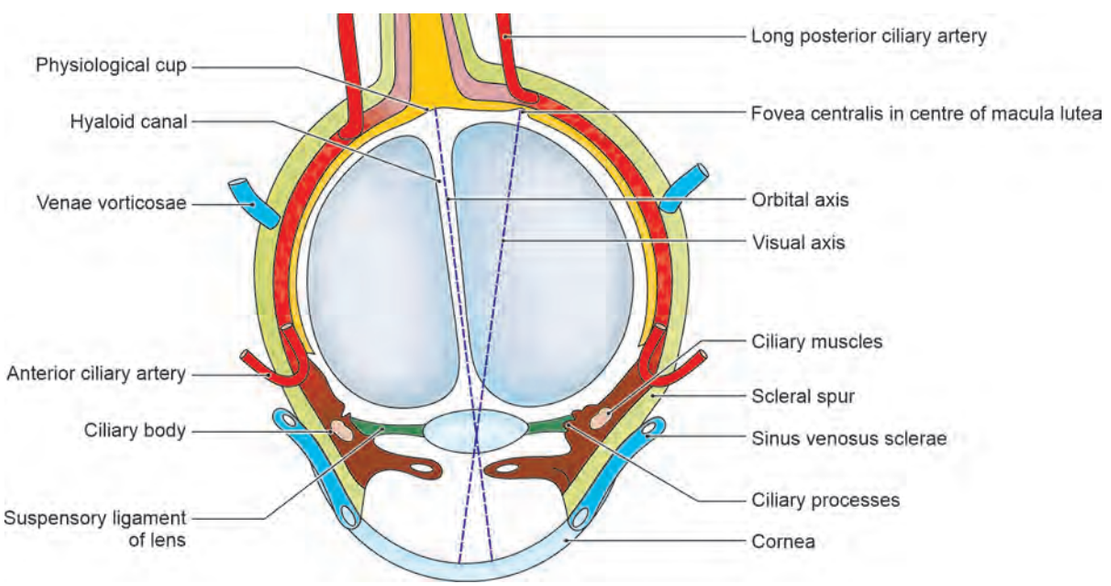


Fig. 27.3: Structures piercing the eyeball seen in a sagittal section

pole of the eyeball. Identify venae vorticosae piercing the sclera just behind the equator *(refer to BDC App)*.

Incise only the sclera at the equator and then cut through it all around and carefully strip it off from the choroid. Anteriorly, the ciliary muscles are attached to the sclera, offering some resistance. As the sclera is steadily separated, the aqueous humour will escape from the anterior chamber of the eye. On dividing the optic nerve fibres, the posterior part of sclera can be removed.

CORNEA

Features

The cornea is transparent. It replaces the sclera over the anterior one-sixth of the eyeball. Its junction with the sclera is called the *sclerocorneal junction or limbus.*

The cornea is more convex than the sclera, but the curvature diminishes with age. It is separated from the iris by a space called the *anterior chamber of the eye*.

The cornea is avascular and is nourished by lymph which circulates in the numerous corneal spaces and by the lacrimal fluid.

It is supplied by branches of the ophthalmic nerve and the short ciliary nerves (through the ciliary ganglion). Pain is the only sensation aroused from the cornea.

DISSECTION

Identify the cornea. Make an incision around the corneoscleral junction and remove the cornea so that the iris is exposed for examination. Identify the middle coat comprising choroid, ciliary body and iris deep to the sclera. Lateral to iris is the ciliary body with ciliary muscles and ciliary processes.

Strip off the iris, ciliary processes, anterior part of choroid. Remove the lens and put it in water. As the lens is removed, the vitreous body also escapes. Only the posterior part of choroid and subjacent retina is left.

Histology/Microanatomy

Structurally, the cornea consists of these layers, from before backwards:

1. *Corneal epithelium* (stratified squamous non-keratinized type) (Fig. 27.4)
2. *Bowman's membrane* or anterior elastic lamina
3. The *substantia propria*
4. *Descemet's membrane* or posterior elastic lamina
5. Simple squamous *mesothelium*.

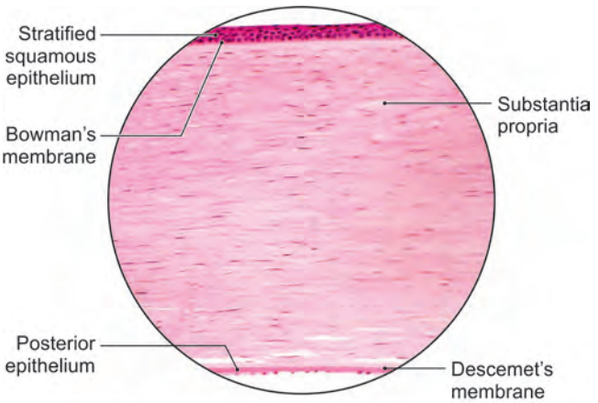


Fig. 27.4: Histology of cornea

CLINICAL ANATOMY

- Cornea can be grafted from one person to the other, as it is avascular.
- Injury to cornea may cause opacities. These opacities may interfere with vision.
- Eye is a very sensitive organ and even a dust particle gives rise to pain.
- Bulbar conjunctiva is vascular. Inflammation of the conjunctiva leads to conjunctivitis. The look of palpebral conjunctiva is used to judge haemoglobin level.
- The anteroposterior diameter of the eyeball and shape and curvature of the cornea determine the focal point. Changes in these result in myopia or short-sightedness, hypermetropia or long-sightedness (Fig. 27.5).

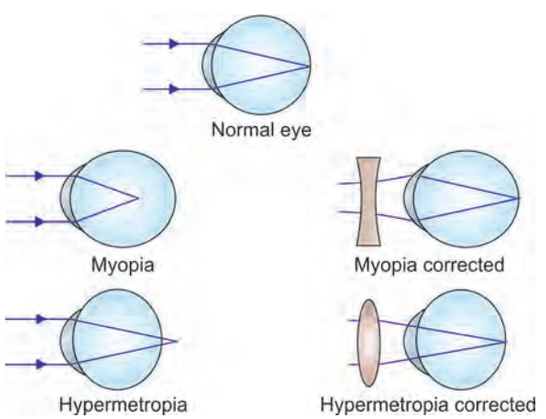


Fig. 27.5: Optical defects

MIDDLE COAT

CHOROID

Choroid is a thin pigmented layer which separates the posterior part of the sclera from the retina. Anteriorly, it ends at the *ora serrata* by merging with the ciliary body. Posteriorly, it is perforated by the optic nerve to which it is firmly attached.

Its *outer surface* is separated from the sclera by the suprachoroidal lamina which is traversed by the ciliary vessels and nerves. Its attachment to the sclera is loose, so that it can be easily stripped. The *inner surface* is firmly united to the retina.

Structurally, it consists of:

a. *Suprachoroid lamina*
b. *Vascular lamina*
c. The *choriocapillary lamina*
d. The inner *basal lamina* or membrane of Bruch.

CILIARY BODY

Ciliary body is a thickened part of the uveal tract lying just posterior to the corneal limbus. It is continuous anteriorly with the iris and posteriorly with the choroid. It suspends the lens and helps it in accommodation for near vision.

1 The ciliary body is triangular in cross-section. It is thick in front and thin behind (Fig. 27.6). The scleral surface of this body contains the ciliary muscle. The posterior part of the vitreous surface is smooth and black (pars plana). The anterior part is ridged anteriorly (pars plicata) to form about 70 ciliary processes. The central ends of the processes are free and rounded.

2 Ciliary zonule is thickened vitreous membrane fitted to the posterior surfaces of ciliary processes (Fig. 27.7). The posterior layer lines hyaloid fossa and anterior thick layer form the suspensory ligament of lens (Fig. 27.6).

3 The *ciliary muscle* (Fig. 27.6) is a ring of unstriped muscle which are longitudinal or meridional, radial and circular. The longitudinal or meridional *fibres* arise from a projection of sclera or scleral spur near the limbus. They radiate backwards to the suprachoroidal lamina. The radial fibres are obliquely placed and get continuous with the circular fibres.

The *circular fibres* lie within the anterior part of the ciliary body and are nearest to the lens. The contraction of *all the parts* relaxes the suspensory ligament so that the lens becomes more convex (Fig. 27.6). All parts of the muscle are supplied by parasympathetic nerves. The pathway involves the Edinger-Westphal nucleus, oculomotor nerve and the ciliary ganglion (*see* Flowchart A.4 in Appendix).

IRIS

1 This is the anterior part of the uveal tract. It forms a circular curtain with an opening in the centre, called the *pupil*. By adjusting the size of the pupil, it controls the amount of light entering the eye, and thus behaves like an adjustable diaphragm (Fig. 27.3).

2 It is placed vertically between the cornea and the lens, thus divides the anterior segment of the eye into anterior and posterior chambers, *both containing aqueous humour*. Its *peripheral margin* is attached to the middle of the anterior surface of the ciliary body and is separated from the cornea by the iridocorneal

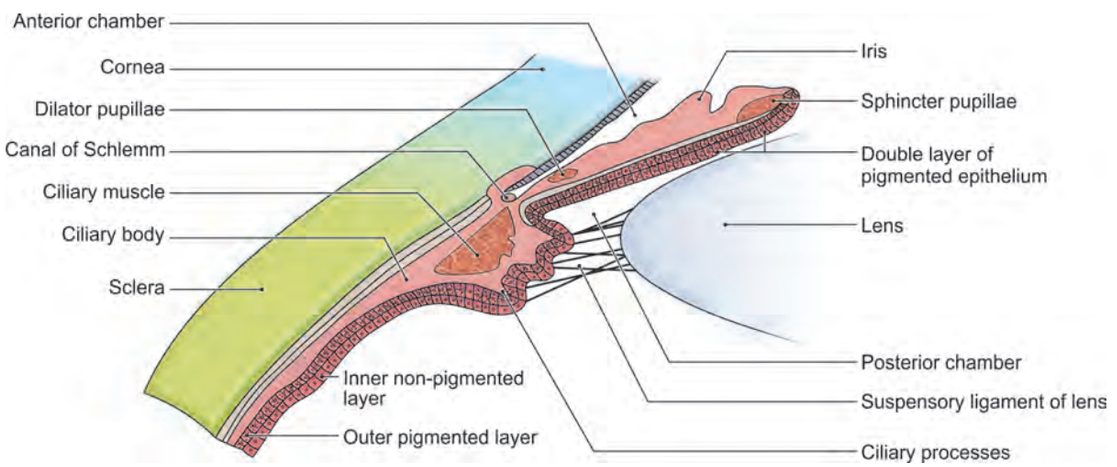


Fig. 27.6: Components of ciliary body and iris (sclerocorneal junction)

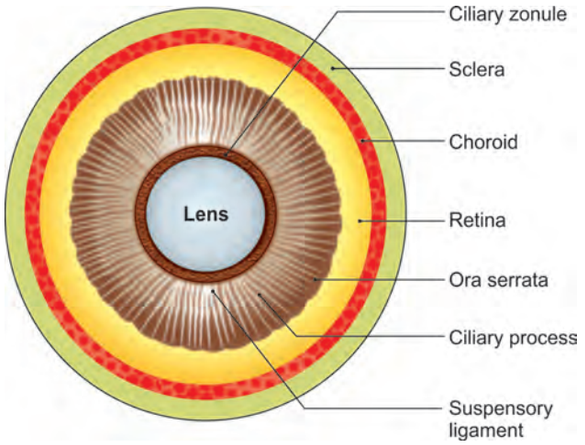


Fig. 27.7: Anterior part of the inner aspect of the eyeball seen after vitreous has been removed

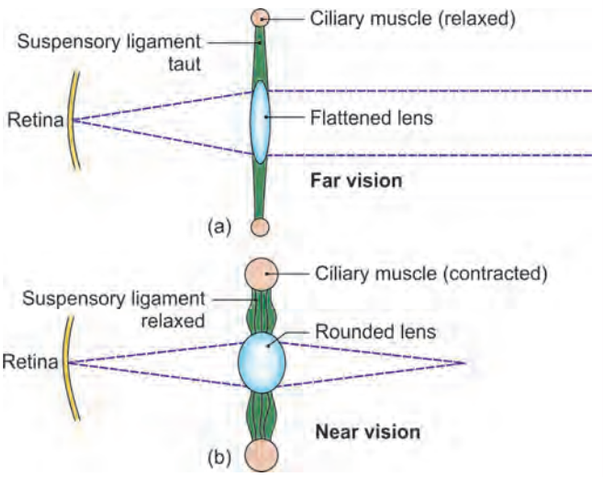
angle or angle of the anterior chamber. The *central free margin* forming the boundary of the pupil rests against the lens (Fig. 27.1).

3 The anterior surface of the iris is covered by a single layer of mesothelium, and the posterior surface by a double layer of deeply pigmented cells which are continuous with those of the ciliary body (Fig. 27.6). The main bulk of the iris is formed by stroma made up of blood vessels and loose connective tissue in which there are pigment cells. The long posterior and the anterior ciliary arteries join to form the *major arterial circle* at the periphery of the iris. From this circle, vessels converge towards the free margin of the iris and join together to form the *minor arterial circle* of the iris (*see* Fig. 21.10).
The colour of the iris is determined by the number of pigment cells in its connective tissue. If the pigment cells are absent, the iris is blue in colour due to the diffusion of light in front of the black posterior surface.

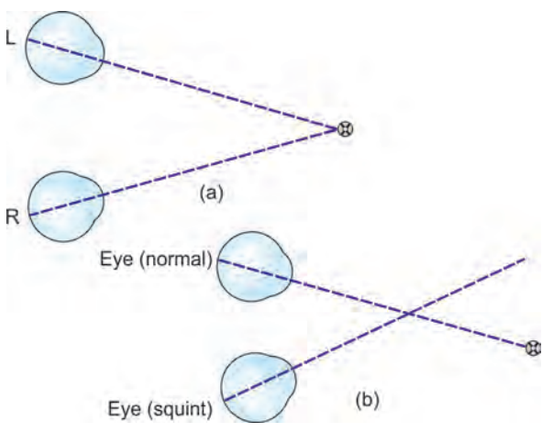
4 The iris contains a well-developed ring of muscle called the *sphincter pupillae* which lies near the margin of the pupil. Its nerve supply (parasympathetic) is similar to that of the ciliary muscle. The *dilator pupillae* is an ill-defined sheet of radial muscle fibres placed near the posterior surface of the iris. It is supplied by sympathetic nerves (Fig. 27.6).

CLINICAL ANATOMY

- While looking at infinite far, the light rays run parallel; ciliary muscle is relaxed, suspensory ligament is tense and lens is flat (Fig. 27.8a).
- While reading a book, the ciliary muscles contract and suspensory ligament is relaxed making the lens more convex (Fig. 27.8b).



Figs 27.8a and b: (a) Relaxed ciliary muscles with flattened lens; (b) Contracted ciliary muscles with round lens



Figs 27.9a and b: (a) Normal eyes; (b) In squinting eyes

- Human vision is coloured, binocular and three-dimensional. Normally, right and left eyes are focused on one object (Fig. 27.9a). In squinting, fixing eye (F) focuses on the object, but the squinting eye (S) is 'turned inwards' resulting in a convergent squint (Fig. 27.9b).

INNER COAT/RETINA

1 This is the thin, delicate inner layer of the eyeball. It is continuous posteriorly with the optic nerve. The outer surface of the retina (formed by pigment cells) is attached to the choroid, while the inner surface is in contact with the hyaloid membrane (of the vitreous). Opposite the entrance of the optic nerve (infero-medial to the posterior pole), there is a circular area known as the *optic disc*. It is 1.5 mm in diameter.

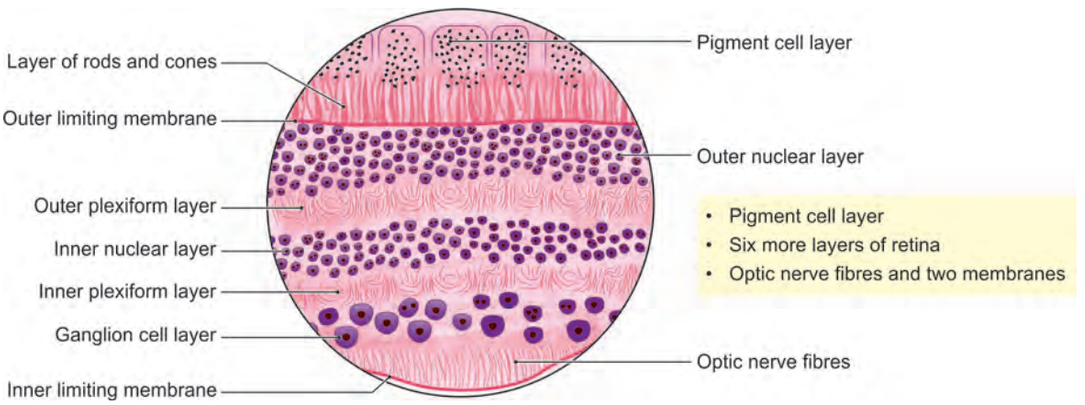


Fig. 27.10: Histological layers of the retina

2 The retina diminishes in thickness from behind forwards and is divided into optic, ciliary and iridial parts. The *optic part of the retina* contains nervous tissue and is sensitive to light. It extends from the optic disc to the posterior end of the ciliary body. The anterior margin of the optic part of the retina forms a wavy line called the ora serrata (Fig. 27.1).

Beyond the ora serrata, the retina is continued forwards as a thin, non-nervous insensitive layer that covers the ciliary body and iris, forming the *ciliary and iridial parts of the retina.* These parts are made up of two layers of epithelial cells (Fig. 27.6).

3 The depressed area of the optic disc is called the *physiological cup* (Fig. 27.3). It contains no rods or cones and is, therefore, insensitive to light, i.e. it is the *physiological blind spot*. At the posterior pole of the eye 3 mm lateral to the optic disc, there is another depression of similar size, called the *macula lutea.* It is avascular and yellow in colour. The centre of the macula is further depressed to form the *fovea centralis.* This is the thinnest part of the retina. It contains cones only, and is the site of maximum acuity of vision (Fig. 27.3).

4 The rods and cones are the light receptors of the eye. The *rods* contain a pigment called *visual purple.* They can respond to dim light (*scotopic vision*). The periphery of the retina contains only rods, but the fovea has none at all. The *cones* respond only to bright light (*photopic vision*) and are sensitive to colour. The fovea centralis has only cones. Their number diminishes towards the periphery of the retina.

5 The retina is composed of ten layers (Fig. 27.10):
   a. The outer pigmented layer
   b. Layer of rods and cones
   c. External limiting membrane
   d. Outer nuclear layer
   e. Outer plexiform layer
   f. Inner nuclear layer (bipolar cells)
   g. Inner plexiform layer
   h. Ganglion cell layer
   i. Nerve fibre layer
   j. The internal limiting membrane.

6 The retina is supplied by the *central artery*. This is an end artery. In the optic disc, it divides into an upper and a lower branch, each giving off nasal and temporal branches. The artery supplies the deeper layers of the retina up to the bipolar cells. The rods and cones are supplied by diffusion from the capillaries of the choroid. The retinal veins run with the arteries (Fig. 27.11).

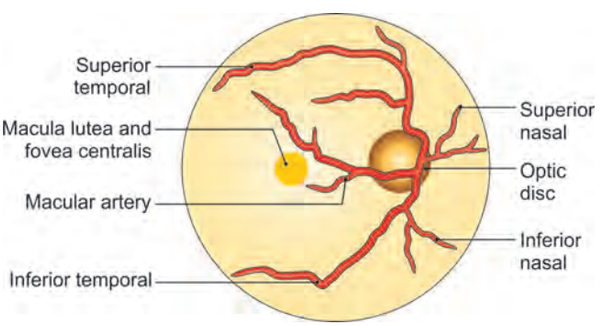
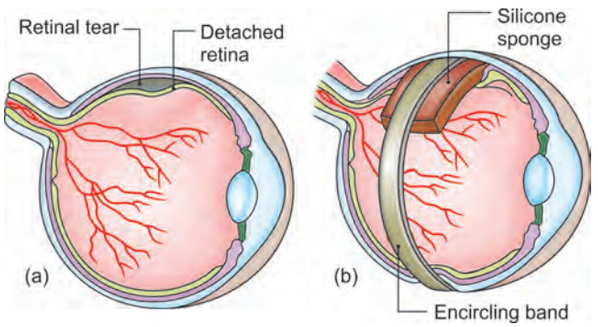


Fig. 27.11: Distribution of central artery of the retina

CLINICAL ANATOMY

Retinal detachment occurs between outer single pigmented layer and inner nine nervous layers. Actually, it is an inter-retinal detachment. Silicone sponge is put over the detached retina, which is kept in position by a 'band' (Figs 27.12a and b).



Figs 27.12a and b: (a) Detached retina; (b) Banding of the retina

AQUEOUS HUMOUR

This is a clear fluid which fills the space between the cornea in front and the lens behind the anterior segment. This space is divided by the iris into anterior and posterior chambers which freely communicate with each other through the pupil.

The aqueous humour is secreted into the posterior chamber from the capillaries in the ciliary processes. It passes into the anterior chamber through the pupil. From the anterior chamber, it is drained into the anterior ciliary veins through the spaces of the iridocorneal angle or angle of anterior chamber (located between the fibres of the ligamentum pectinatum) and the canal of Schlemm (Figs 27.3 and 27.6).

Interference with the drainage of the aqueous humour into the canal of Schlemm results in an increase of intraocular pressure (glaucoma). This produces cupping of the optic disc and pressure atrophy of the retina causing blindness.

The intraocular pressure is due chiefly to the aqueous humour which maintains the constancy of the optical dimensions of the eyeball. The aqueous is rich in ascorbic acid, glucose and amino acids, and nourishes the avascular tissues of the cornea and lens.

CLINICAL ANATOMY

Over production of aqueous humour or lack of its drainage or combination of both raise the intraocular pressure. The condition is called glaucoma. It must be treated urgently.

LENS

Features

The lens is a transparent biconvex structure which is placed between the anterior and posterior segments of the eye. It is circular in outline and has a diameter of 1 cm. The central points of the anterior and posterior surfaces are called the anterior and posterior *poles* (Fig. 27.13). The line connecting the poles constitutes the *axis* of the lens, while the marginal circumference is termed the *equator*. The chief advantage of the lens is that it can vary its dioptric power. It contributes about 15 dioptres to the total of 58 dioptric power of the eye. A dioptre is the inverse of the focal length in meters. A lens having a focal length of half meter has a power of two dioptres.

The posterior surface of the lens is more convex than the anterior. The anterior surface is kept flattened by the tension of the suspensory ligament. When the ligament is relaxed by contraction of the ciliary muscle, the anterior surface becomes more convex due to elasticity of the lens substance.

The lens is enclosed in a transparent, structureless elastic *capsule* which is thickest anteriorly near the circumference. Deep to capsule, the anterior surface of the lens is covered by a *capsular epithelium*. At the centre of the anterior surface, the epithelium is made up of a single layer of cubical cells, but at the periphery, the cells elongate to produce the *fibres* of the lens. The fibres are concentrically arranged to form the lens substance. The centre (nucleus) of the lens is firm (and consists of the oldest fibres), whereas the periphery (cortex) is soft

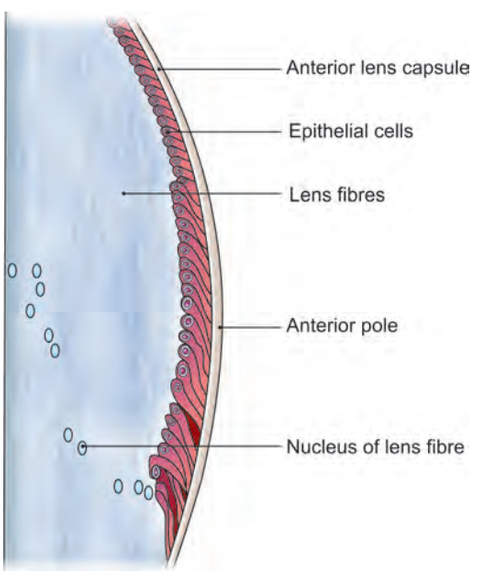


Fig. 27.13: The lens

and is made up of more recently formed fibres (Fig. 27.13).

The *suspensory ligament of the lens* (or the zonule of Zinn) retains the lens in position and its tension keeps the anterior surface of the lens flattened. The ligament is made up of a series of fibres which are attached peripherally to the ciliary processes, to the furrows between the ciliary processes, and to the ora serrata. Centrally, the fibres are attached to the lens, mostly in front, and a few behind the equator (Fig. 27.5).

DISSECTION

Give an incision in the anterior surface of lens and with a little pressure of fingers and thumb press the body of lens outside from the capsule.

CLINICAL ANATOMY

- Lens becomes opaque with increasing age (cataract). Since the opacities cause difficulty in vision, lens has to be replaced.
- The central artery of retina is an end-artery. Blockage of the artery leads to sudden blindness.
- Left third nerve paralysis causes partial ptosis and dilated pupil. The cornea is turned downwards and outwards (Fig. 27.14).
- Horner's syndrome results in partial ptosis and miosis (Fig. 27.15).
- In brainstem death, both the pupils are dilated and fixed (Fig. 27.16).
- Eye sees everyone. One can see the interior of the eye by ophthalmoscope. Through the ophthalmoscope, one can see the small vessels in the retina and judge the changes in diabetes and hypertension (Figs 27.17a and b). In addition, one can also examine the optic disc for evidence of papilloedema, caused by raised intracranial pressure.

VITREOUS BODY

It is a colourless, jelly-like transparent mass which fills the posterior segment (posterior four-fifths) of the eyeball. It is enclosed in a delicate homogeneous *hyaloid membrane*. Behind, it is attached to the optic disc, and in front to the ora serrata; in between it is free and lies in contact with the retina. The anterior surface of the

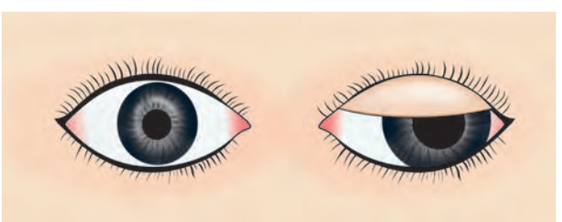


Fig. 27.14: Left third nerve paralysis

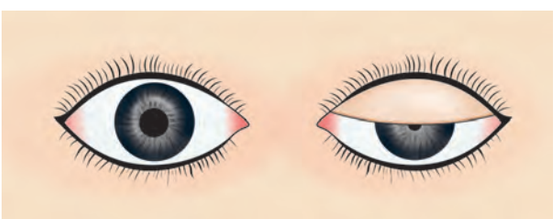


Fig. 27.15: Horner's syndrome in left eye

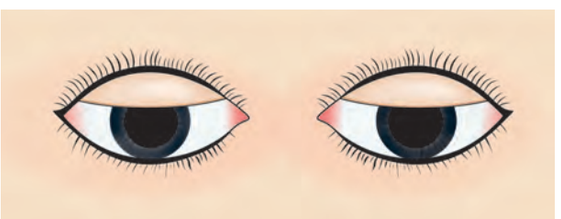
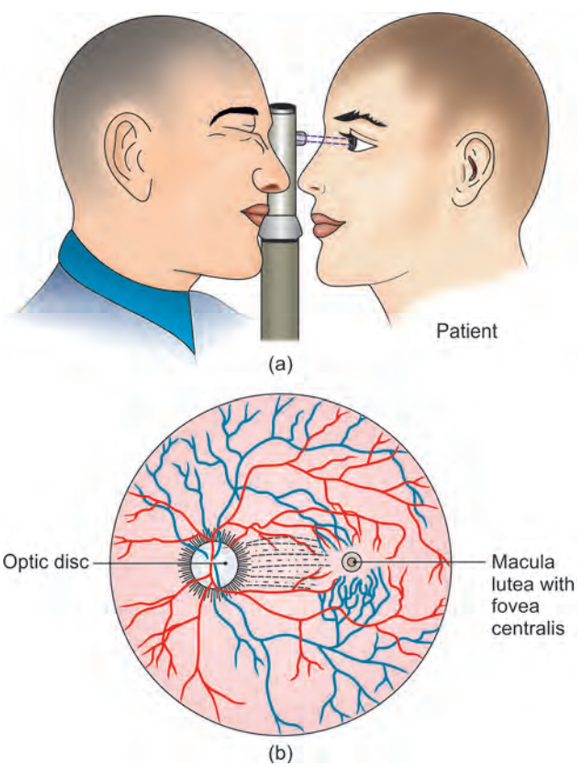


Fig. 27.16: Brainstem death



Figs 27.17a and b: (a) Procedure for ophthalmoscopy; (b) Retina as seen by ophthalmoscope

vitreous body is indented by the lens and ciliary processes (Fig. 27.1).

DEVELOPMENT

Optic vesicle forms optic cup. It is an outpouching from the *forebrain* vesicle.

Lens from *lens placode (ectodermal)*

Retina—pigment layer from the *outer layer of optic cup;* nervous layers from the *inner layer of optic cup.*

Choroid, sclera—*mesoderm*

Cornea—*surface ectoderm forms the epithelium, other layers develop from mesoderm.*

Molecular Regulation

The proteins WNT, BMP, TGF-β and FGF (fibroblast growth factor) are responsible for optic vesicle and PAX6 for lens vesicle differentiation.

Inhibition of sonic hedgehog (SHH) and expansion of PAX2 expression causes failure of separation of eyes resulting in cyclops. Overexpression of SHH causes loss of eye structures.

Vitamin A deficiency during embryonic development can result in anterior segment defects (of cornea and eyelid).

FACTS TO REMEMBER

- Cornea is used for grafting or transplantation.
- Sclera is pierced by number of structures including the optic nerve.
- Choroid contains big capillaries. These nourish the layer of rods and cones of retina by diffusion.
- Ciliary body contains ciliary muscles supplied by short ciliary nerves. These contract to relax the suspensory ligament of lens, so that the anterior surface of lens can become more convex for accommodation.
- Iris contains a weak dilator pupillae at the periphery, supplied by sympathetic fibres. It also contains a strong constrictor or sphincter pupillae near the pupillary margin. This is supplied by parasympathetic fibres relayed through ciliary ganglion.
- Central artery of retina is an 'end artery'
- Through dilated pupil, one can see the state of blood vessels of the retina.

CLINICOANATOMICAL PROBLEM

A patient was diagnosed as a case of 'retinal detachment'.

- Is retinal detachment, detachment of retina from the choroid?
- Name the layers of retina with its blood supply.

Ans: The retinal detachment is actually an inter-retinal detachment. The outer pigmented layer stays with choroid, while the inner nine layers get detached and cause the problem. The outer layer is developed from the outer layer of optic cup whereas the inner layers arise from the inner layer of optic cup. The blood supply of the outer five layers is from choroidal arteries whereas those of the inner nervous layers is by the 'central artery of retina', which is an absolute end-artery. The layers of retina (Fig. 27.10) are:

1. Outer pigmented layer
2. Layer of rods and cones
3. External limiting membrane
4. Outer nuclear layer
5. Outer plexiform layer
6. Bipolar cell layer
7. Inner plexiform layer
8. Ganglionic cell layer
9. Layer of optic nerve fibres
10. Inner limiting membrane

FURTHER READING

- O'Rahilly R. The timing and sequence of events in the development of the human eye and ear during the embryonic period proper. Anat Embryol Berl 1983;168:87–99.

  This paper presents the stages of human ear development.
- Kolb H, Linberg KA, Fisher SK. Neurons of the human retina—a Golgi study. J Comp Neurol 1992;318:147–87.

  The most comprehensive description of the morphology of neural cell types in the human retina.
- Tabinda Hasan, Satyam Khare, Shilpi Jain, Puneet Gupta, Sanjay Sharma. Retinal Vasculature—an imaging based morphological study. Journal of the Anatomical Society of India, 2013;62:146–56.

Frequently Asked Questions

1. Write short notes/enumerate:
- a. Cornea
- b. Choroid
- c. Structures piercing the sclera
- d. Layers of retina
- e. Ciliary muscles
- f. Lens
- g. Aqueous humour

Multiple Choice Questions

1. Which of the following muscles does not develop from mesoderm?
- a. Muscles of heart
- b. Muscles of iris
- c. Deltoid
- d. Superior rectus

2. Which of the following nerves supplies the cornea?
- a. Supraorbital
- b. Nasociliary
- c. Lacrimal
- d. Infraorbital

3. Parasympathetic fibres supply all the following muscles, *except:*
- a. Constrictor pupillae
- b. Dilator pupillae
- c. Radial fibres of ciliaris muscle
- d. Circular fibres of ciliaris muscle

4. Retina consists which of the following number of layers?
- a. Eight
- b. Ten
- c. Nine
- d. Eleven

5. One of the following symptoms is not seen in Horner's syndrome:
- a. Partial ptosis
- b. Miosis
- c. Anhydrosis
- d. Exophthalmos

Answers

1. b **2.** b **3.** b **4.** b **5.** d

VIVA VOCE

- Name the layers of the eyeball.
- Enumerate the structures piercing the sclera.
- Name the histological layers of the cornea.
- What is myopia? How is it corrected?
- Name the muscles present in the ciliary body.
- What is the action and nerve supply of ciliary muscles?
- Name the muscles present in the iris. Which nerves supply these muscles?
- What are the layers of retina?
- Why is optic disc called the 'blind spot'?
- Trace the secretion, circulation and absorption of aqueous humour.
- What are the results of Horner's syndrome?
- How does lens develop?
- How does retina develop?
- How does cornea develop?
- Where does retinal detachment occur?
- Why do cataract and glaucoma develop?