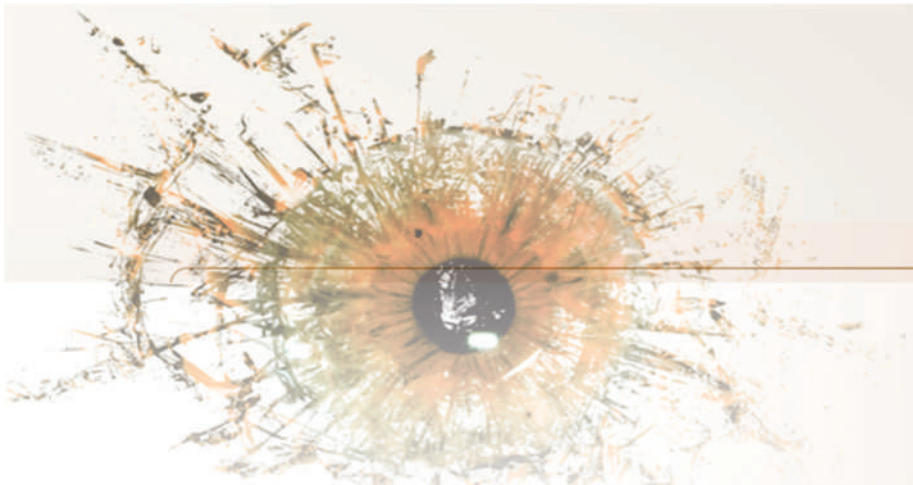

Chapter

1

# Anatomy of Eyeball

**Learning Objectives**

**At the end of this competency, the student should be able to understand the following**

- Basic structure and functions of the eyeball
- Drawing a labelled sagittal section of the eyeball
- Coats and segments of the eyeball
- Blood supply of the eyeball
- Nerve supply of the eyeball

## Competency

**AN41.1:** Describe and demonstrate parts and layers of the eyeball.

The eye is a specialized sensory organ, with its main function being the conversion of visual impulses to electrical impulses (Fig. 1.1). Among the five senses, sight is one of the most frequently used, primarily helping us gather visual information from the surroundings. Visual information constitutes more than 75% of the total sensory information we receive. The sensory unit of the eye comprises three segments: Photoreceptors, the sensory pathway, and the brain centre.

## DIMENSIONS OF THE EYEBALL (Fig. 1.2)

1. **Size**
   - **Vertical diameter:** 23.0 mm
   - **Horizontal diameter:** 23.5 mm
   - **Anteroposterior diameter:** 24 mm

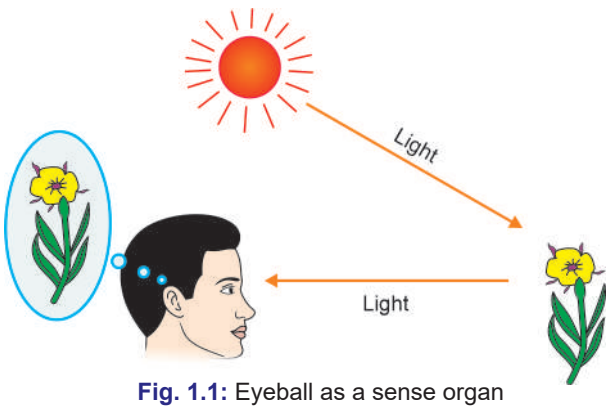


**Fig. 1.1:** Eyeball as a sense organ

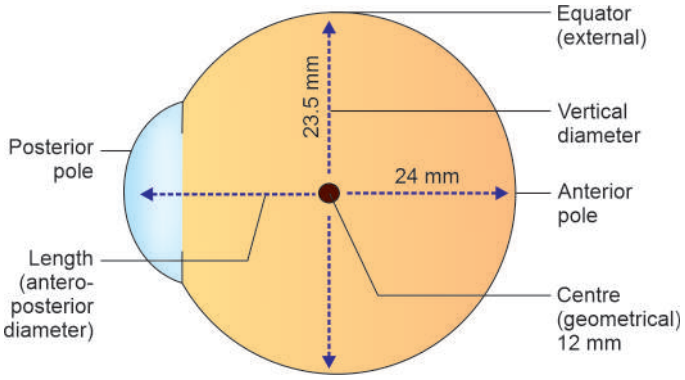


**Fig. 1.2:** Dimensions of eyeball

2. **Volume:** 6.5 cc
3. **Weight:** 7 g
4. **Circumference:** 75 mm
5. **Power:** +60.0 D
6. **Shape:** Oblate spheroid, as the eyeball is not spherical but slightly compressed vertically.

## EXTERNAL ANATOMY

The eyeball is made up of three concentric coats and lies within the bony orbit, covered by two eyelids when closed (Fig. 1.3). It is connected to the occipital cortex of the brain by the second cranial nerve, the optic nerve.

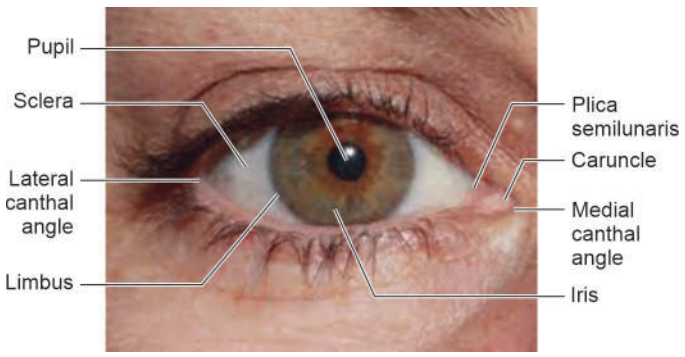


**Fig. 1.3:** External anatomy of eyeball

1. **Orbital cavities:** These are hollow bony sockets in which the eyeballs are located. The walls of the orbit are made up of seven bones that enclose and protect the eyeball.
2. **Eyelids:** These are two skin folds, the upper and lower lids, which cover the ocular surface. They serve a protective function as the two lids close reflexively when an object approaches the eye.
3. **Eyelashes:** Eyelashes are appendages of skin found on the upper and lower lids. The glands at the base of the lashes help lubricate the ocular surface, prevent the lids from sticking together, and protect the eyes by trapping foreign particles.
4. **Eyebrows:** Located in the bony prominence of the frontal bone, eyebrows protect the eyes from foreign particles, direct rays of light, and perspiration.
5. **Lacrimal gland:** The lacrimal gland is responsible for producing tears that lubricate the ocular surface and have a microbicidal action.
6. **Lacrimal apparatus:** The lacrimal apparatus, or tear outflow system, includes the lacrimal punctum, common canaliculi, lacrimal sac, and nasolacrimal duct. Its primary function is to aid in tear circulation and drainage.

## COATS OF THE EYEBALL

The eyeball is made up of three coats (Fig. 1.4):

1. **The outer coat:** Known as the fibrous tunic, it consists of the posterior 5/6 sclera (white part) and the anterior 1/6 transparent cornea, primarily serving a protective function.
2. **The middle coat:** Known as the vascular tunic, it includes the iris, ciliary body, and choroid, from anterior to posterior. Its primary function is nutritive, being responsible for the nourishment of the eyeball.
3. **The inner layer:** Also called the nervous tunic, this comprises the retina, which converts visual impulses into electrical impulses.

## BASIC STRUCTURE OF THE HUMAN EYEBALL

The human eye consists of the conjunctiva, cornea, sclera, iris, ciliary body, choroid, pupil, lens, anterior chamber, posterior chamber, aqueous humour, vitreous humour, retina, and optic nerve (Fig. 1.5):

1. **Conjunctiva:** The conjunctiva is a thin, translucent membrane that partly covers the anterior surface of the eyeball and the inner surface of the eyelids. It terminates at the limbus on the ocular surface. The term "conjunctiva" means "to join," as it connects the eyeball to the eyelids.
2. **Cornea:** The cornea is the transparent, converging structure that forms the anterior 1/6th part of the outer coat and forms the anterior boundary of the anterior chamber.
3. **Sclera:** The sclera is an opaque and tough layer forming the posterior 5/6th part of the outer coat. It protects and gives shape to the entire eyeball.
4. **Iris:** The iris is the anterior part of the middle coat (uveal tract). It is a muscular diaphragm located behind the cornea and forms the posterior boundary of the anterior chamber. The iris regulates the amount of light entering the eye by adjusting the size of the pupil.
5. **Pupil:** The pupil is a circular opening in the centre of the iris that regulates the amount of light entering the eye.
6. **Ciliary body:** The ciliary body is the middle part of the uveal tract. It secretes aqueous humour and plays a role in accommodation.
7. **Choroid:** The choroid is the posterior part of the uveal tract, formed primarily of blood vessels, which nourish the adjacent structures, including the retina.

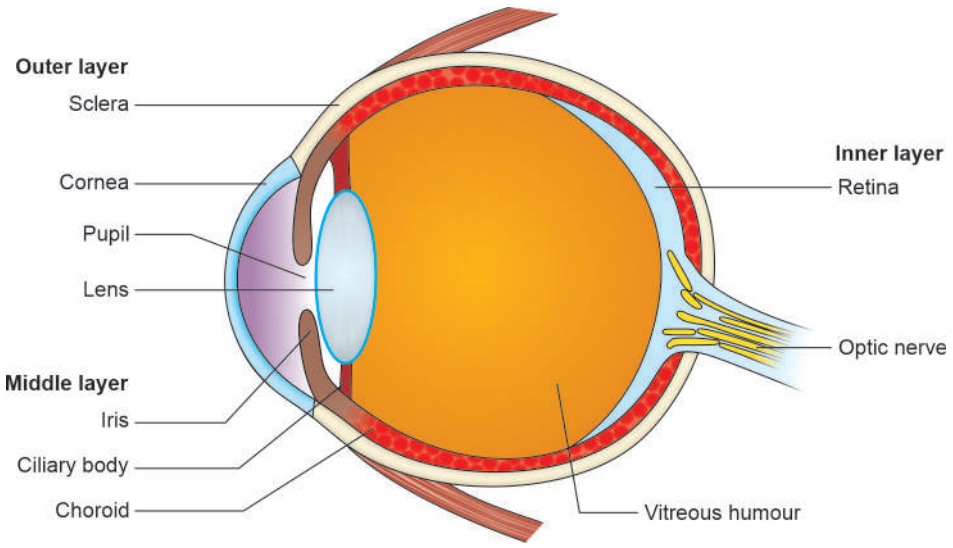


**Fig. 1.4:** Coats of eyeball

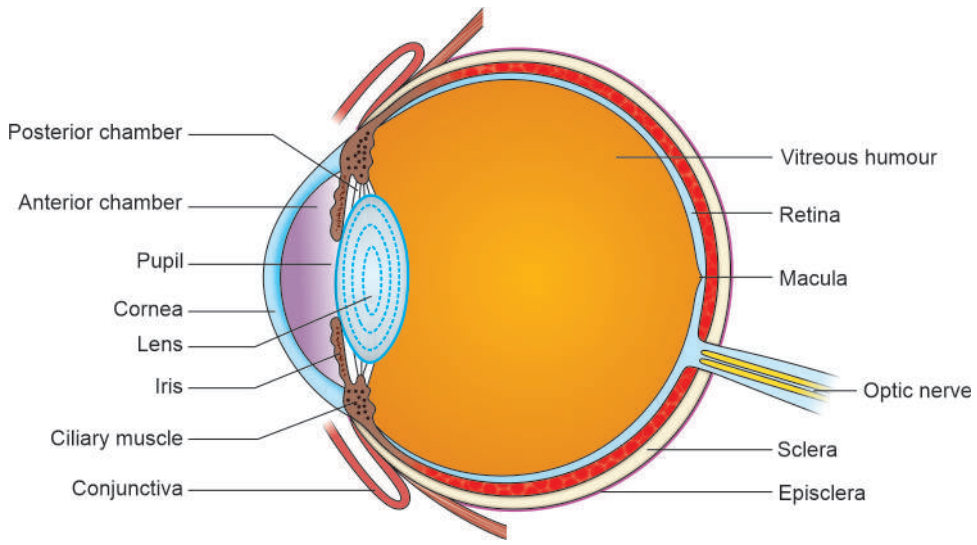


**Fig. 1.5:** Basic structure of eyeball

8. **Lens:** The lens is a biconvex transparent structure suspended by zonules behind the iris. It helps further converge light rays and focus them on the retina.
9. **Retina:** The retina is a transparent, light-sensitive tissue at the back of the eye, consisting of ten layers.
10. **Macula:** The macula is the visually sensitive area of the posterior retina that produces sharp and clear images.
11. **Fovea:** The fovea is a depression in the centre of the macula (light spot) that provides the sharpest visual acuity due to the maximum density of cones.
12. **Optic nerve:** The optic nerve, or second cranial nerve, is a bundle of sensory nerve fibres at the back of the eyeball. It carries visual information from the retina to the brain via the visual pathway.

## SEGMENTS AND CHAMBERS

The eyeball is divided into two segments by the lens: the anterior segment and the posterior segment (Fig. 1.6).

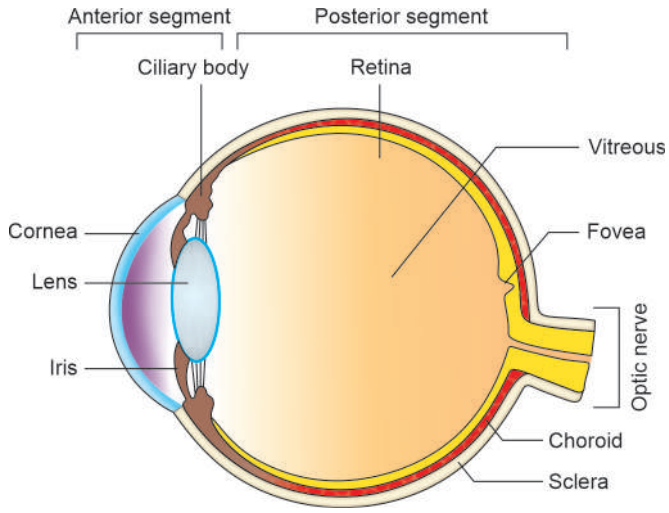


**Fig. 1.6:** Segments of eyeball

1. **Anterior segment:** The anterior segment consists of the lens and the part of the eyeball cavity in front of the lens. It is filled with a watery, clear fluid called aqueous humour and is divided into two chambers by the iris:
   - **Anterior chamber:** The space bounded by the cornea anteriorly and the iris posteriorly.
   - **Posterior chamber:** The narrow space bounded anteriorly by the posterior surface of the iris and posteriorly by the anterior surface of the lens, zonules, and ciliary processes.
2. **Posterior segment:** The posterior segment is the space between the lens and the retina. It is filled with a gel-like substance called vitreous humour.

## FLUIDS OF THE EYEBALL

1. **Aqueous humour:** A transparent fluid present in the anterior segment of the eye, secreted by the ciliary epithelium. It is watery in consistency, similar to plasma, but with a lower protein concentration (Fig. 1.7).

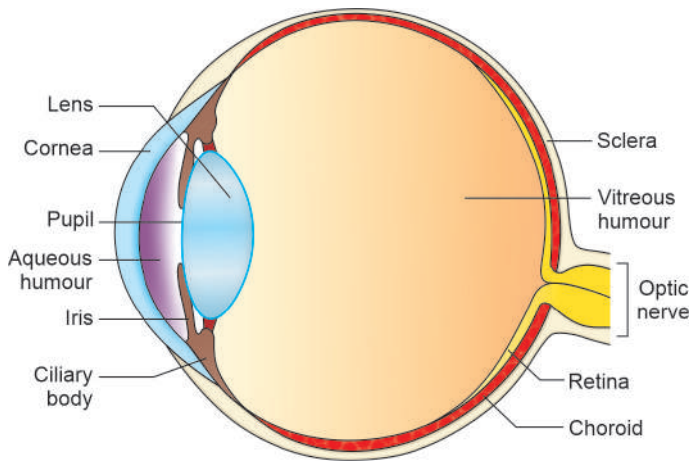


**Fig. 1.7:** Fluids of eyeball

2. **Vitreous humour:** Vitreous humour is a jelly-like transparent substance that fills the posterior segment of the eyeball.

## MUSCLES OF THE EYE

There are seven extrinsic and three intrinsic muscles acting around and within the eyeball to serve specific functions (Fig. 1.8):

I. **Extrinsic muscles:** The extraocular or extrinsic muscles are located outside the eyeball and control eye movements in different directions—horizontally, vertically, or obliquely. The extrinsic muscles are seven in number, namely:
   1. Superior rectus
   2. Inferior rectus
   3. Lateral rectus
   4. Medial rectus
   5. Superior oblique
   6. Inferior oblique
   7. Levator palpebrae superioris

II. **Intrinsic muscles:** Intrinsic muscles are located within the eyeball and assist in modifying the lens curvature and altering pupillary size. The intraocular muscles are three in number, namely (Fig. 1.9):
   1. Sphincter pupillae
   2. Dilator pupillae
   3. Ciliary muscle

### Orbit

The orbit is a pyramidal-shaped bony cavity containing the eyeball and extraocular contents. It has four walls, bounded anteriorly by the base of the orbit and merging posteriorly to form the orbital apex (Fig. 1.10). The seven bones forming the orbit are:

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

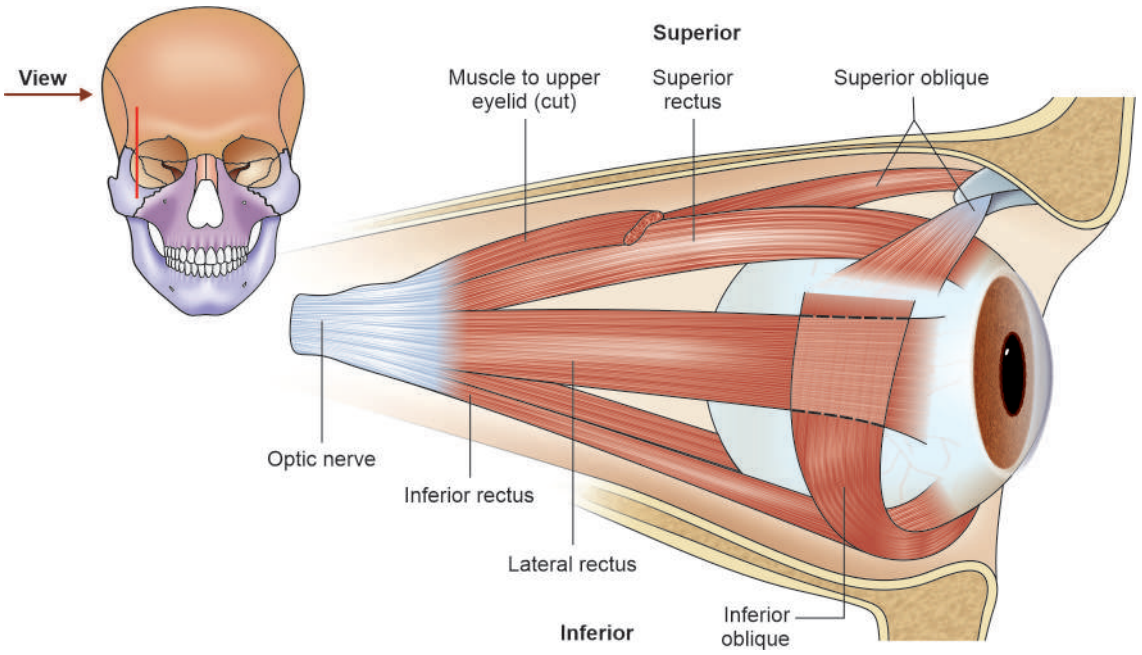


**Fig. 1.8:** Extrinsic muscles of eyeball

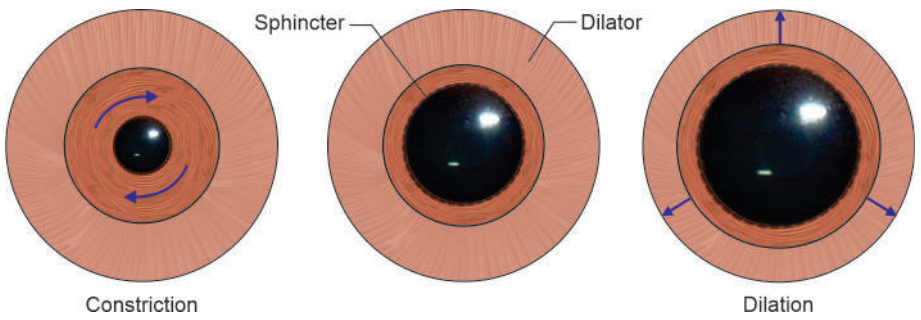


**Fig. 1.9:** Intrinsic muscles of eyeball

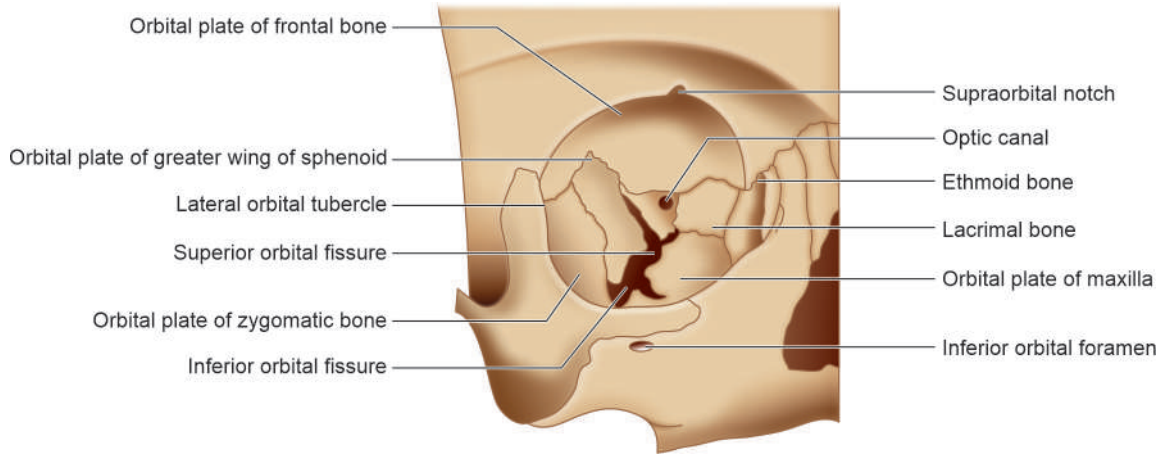


**Fig. 1.10:** Structure of orbit

## Human Eye and Vision

Light rays entering the eye are converged through the transparent cornea and aqueous humour. The iris plays a pivotal role in controlling the amount of light entering the eye by adjusting the size of the pupil. The light rays are further converged by the lens and vitreous humour to finally focus on the retina. The photoreceptors (rods and cones) in the retina convert light impulses into electrical impulses, which travel via the optic nerve to the brain through the visual pathway.

## Blood Supply of the Eye

The ocular circulation is crucial for the nourishment and normal functioning of the eyeball.

## Arterial Supply

The eyeball receives its arterial supply from several branches of the ophthalmic artery, which is a branch of the internal carotid artery. The arteries supply different ocular structures and the visual pathway through the ophthalmic artery, circle of Willis, cerebral arteries, and external carotid artery (Fig. 1.11).

## Ophthalmic Artery

The ophthalmic artery is the major source of blood supply to ocular and orbital structures. It is the first intracranial branch of the internal carotid artery, arising as it exits the cavernous sinus (Fig. 1.12). The numerous branches of the ophthalmic artery are:

1. Lacrimal artery
2. Lateral palpebral artery
3. Recurrent meningeal artery
4. Long and short posterior ciliary arteries
5. Muscular branches of ophthalmic artery
6. Anterior ciliary arteries
7. Episcleral and conjunctival arteries
8. Central retinal artery
9. Supraorbital and supratrochlear artery

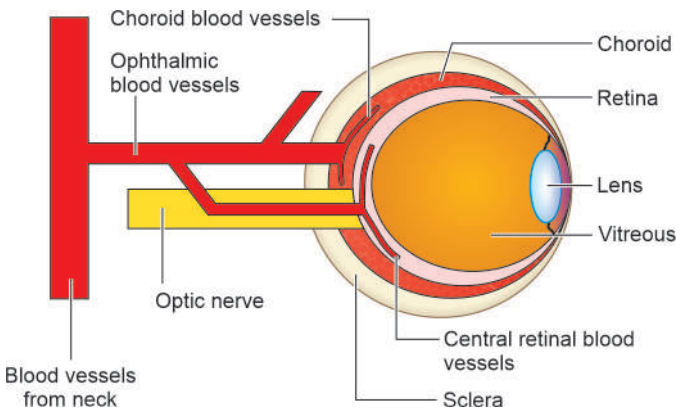


**Fig. 1.11:** Ocular blood supply

1. **Lacrimal artery:** This is a branch of the ophthalmic artery. The lacrimal artery lies along the upper border of the lateral rectus muscle, running with the lacrimal nerve to supply the lacrimal gland.
2. **Lateral palpebral artery:** The lateral palpebral artery is a branch of the lacrimal artery. It forms the inferior and superior palpebral arcades by anastomosing with the medial palpebral arteries, supplying the lid and conjunctiva.
3. **Recurrent meningeal artery:** This artery arises from the ophthalmic artery in the posterior part of the orbit and passes backwards through the superior orbital fissure. It anastomoses with the middle meningeal artery, a branch of the external carotid artery, forming a site of anastomosis between the internal and external carotid arteries.
4. **Long and short posterior ciliary arteries:** The long posterior ciliary arteries, two in number, arise from the ophthalmic artery and run just below the optic nerve. They pierce the sclera on the medial and lateral sides of the optic nerve and run forward between the sclera and choroid, supplying the ciliary body (Fig. 1.13). Long posterior ciliary arteries anastomose near the iris root with the anterior ciliary arteries to form the circulus arteriosus iridis major. The short posterior ciliary arteries, 10–20 in number, arise from the ophthalmic artery and pierce the sclera to supply

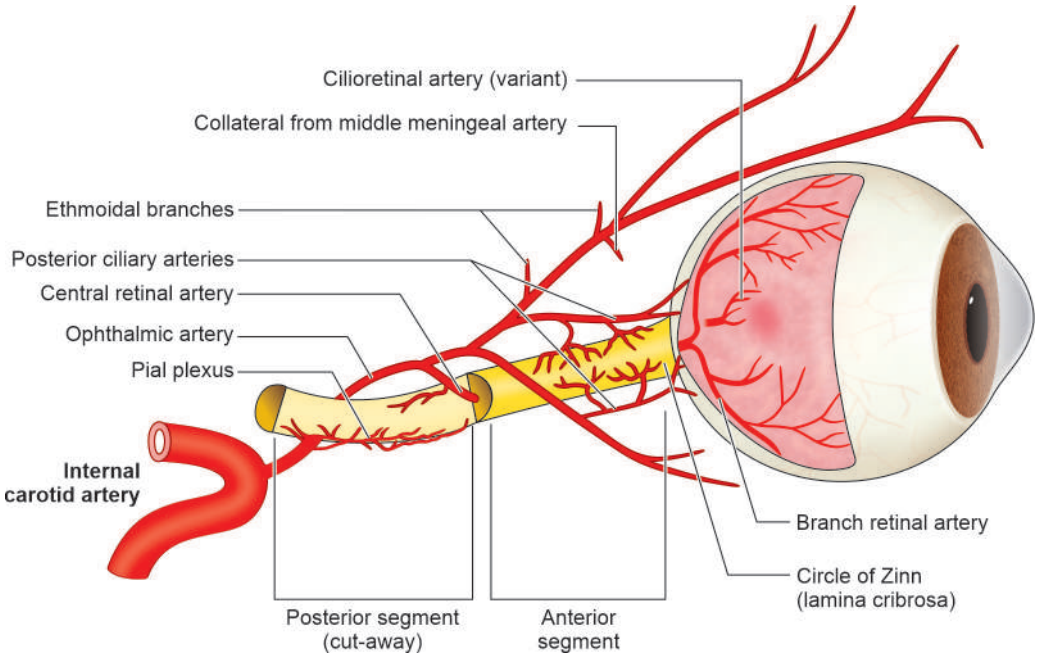


**Fig. 1.12:** Blood supply to the eyeball

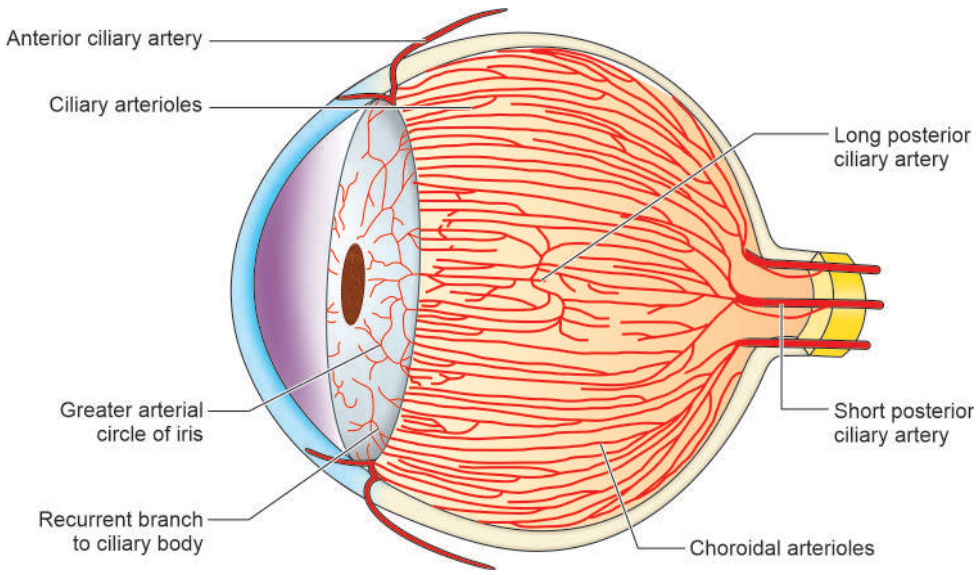


**Fig. 1.13:** Long and short posterior ciliary arteries

the choroid directly. The circle of Zinn is a circular anastomosis between the lateral and medial short ciliary arteries, lying close to the optic nerve to supply the choroid.

5. **Muscular branches of ophthalmic artery:** Muscular arteries have two main branches:
   - **Medial branch:** Supplies the inferior rectus, medial rectus, and inferior oblique.
   - **Lateral branch:** Supplies the superior rectus, lateral rectus, superior oblique, and levator palpebrae superioris.
6. **Anterior ciliary artery:** Anterior ciliary arteries are branches of the muscular artery. Seven in number, two each supply the superior, medial, and inferior rectus muscles, while one supplies the lateral rectus. These branches pierce the sclera about 4 mm from the limbus and enter the eyeball to anastomose with the long posterior ciliary artery to form the circulus arteriosus major near the root of the iris. Several branches from this plexus supply the ciliary processes and run radially through the iris towards the pupillary margin, where they anastomose with each other to form the circulus arteriosus minor (Fig. 1.14).
7. **Episcleral and conjunctival arteries:** Small vessels are derived from larger branches of the ophthalmic artery and supply the episclera and conjunctiva. The bulbar conjunctiva is supplied by the ophthalmic artery, a branch of the internal carotid artery, while the palpebral conjunctiva is supplied by the external carotid artery. The blood circulation of the bulbar

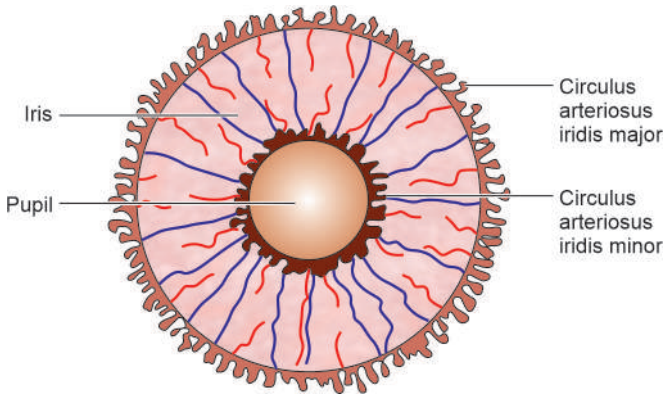


**Fig. 1.14:** Circulus arteriosus major and minor

and palpebral conjunctiva forms a connective link between the internal carotid artery and external carotid artery.

8. **Central retinal artery (CRA):** The central retinal artery is a branch of the ophthalmic artery arising near the optic foramen. It runs a wavy course forward below the optic nerve, and 10–15 mm behind the eyeball, the artery pierces the dura and arachnoid of the optic nerve, from which it receives its coverings (Fig. 1.15). In the subarachnoid space, the central retinal artery runs a short course and invaginates the pia to reach the centre of the optic nerve surrounded by a sympathetic nerve plexus. At the optic disc, the central retinal artery emerges and divides into superior and inferior branches, which further subdivide into temporal and nasal branches. There are four terminal branches of the central retinal artery:
   - Superior temporal
   - Superior nasal
   - Inferior temporal
   - Inferior nasal
9. **Supraorbital and supratrochlear artery:** These branches dichotomously branch as they move towards the *ora serrata* and terminate without anastomosis, as end arteries.

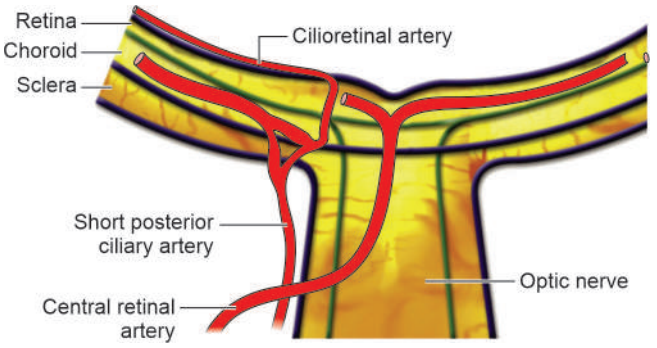


**Fig. 1.15:** Central retinal artery and its branches

## Blood Supply of the Retina

The retina has a dual blood supply from both the central retinal artery and the choriocapillaris. The outer four layers of the retina are supplied by the choriocapillaris, and the inner five layers are supplied by the central retinal artery (Fig. 1.16). The fifth layer, or outer plexiform layer, is the watershed region, as it receives blood supply from both sources.

There are two retinal capillary networks:

1. **Superficial:** The superficial capillary network is located at the nerve fibre layer level.
2. **Deep:** The deep capillary network is located between the inner nuclear layer and the outer plexiform layer.

## Blood Supply of the Visual Pathway (Fig. 1.17)

1. **Intraocular optic nerve:** It is supplied by short posterior ciliary arteries, forming the circle of Zinn.
2. **Intraorbital optic nerve:** It is supplied by the pial plexus of vessels. The central retinal artery pierces the dural sheath of the intraorbital part of the optic nerve but does not supply it.

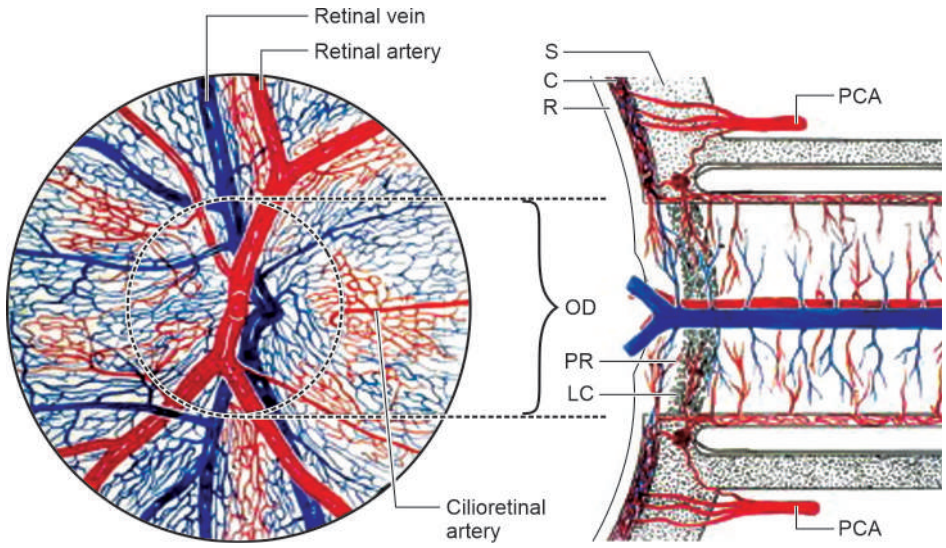


**Fig. 1.16:** Retinal blood circulation

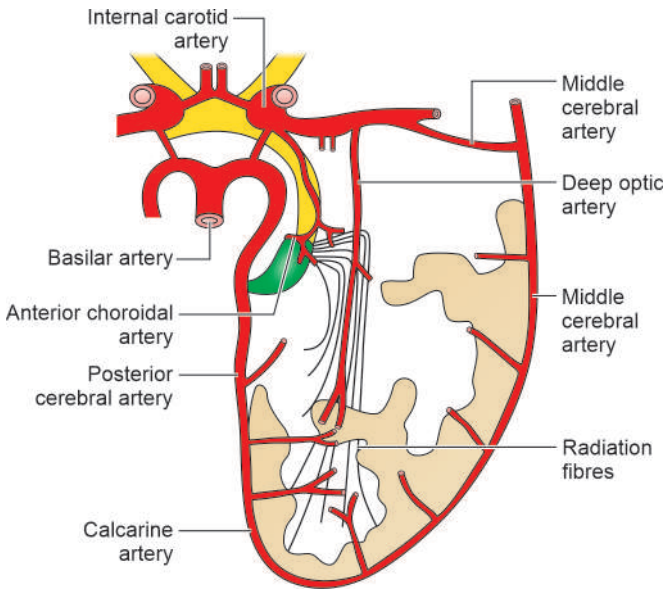


**Fig. 1.17:** Blood supply to visual pathway

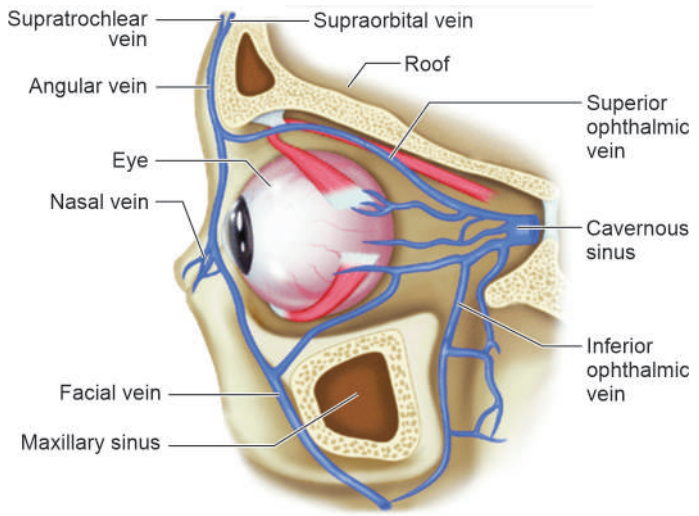


**Fig. 1.18:** Venous drainage to eyeball

3. **Intracranial optic nerve:** It is supplied by the superior hypophyseal and ophthalmic arteries.
4. **Optic tract:** It is supplied by pial vessels from the anterior choroidal and posterior communicating arteries.
5. **Lateral geniculate body and posterior aspect of optic radiation:** These areas are supplied by the middle and posterior cerebral arteries.
6. **Visual cortex:** The visual cortex is supplied by the posterior cerebral artery.
7. **Occipital pole (macular area):** The middle cerebral artery supplies the visual cortex area located in the occipital lobe of the brain. This leads to macular sparing in lesions of the occipital lobe.

## Applied Anatomy

1. Ophthalmic artery occlusion may cause ocular ischemic syndrome.
2. Amaurosis fugax, characterized by transient loss of vision, occurs due to temporary occlusion of the ophthalmic artery.
3. Central retinal artery occlusion may be associated with the preservation of central vision in a few individuals due to the cilioretinal artery perfusing the macula (Box 1.1).

**Box 1.1:** Cilioretinal artery—applied aspect

The capillary network is well developed in the parafoveal zone, however there exists a capillary free zone in the central fovea, known as the foveal avascular zone (FAZ). In 20% of population cilioretinal artery, a branch of ophthalmic artery supplies the macula in addition to the central retinal artery.

## Venous Drainage

The venous drainage from various orbital structures is through (Fig. 1.18):

1. Vortex veins
2. Central retinal vein
3. Superior ophthalmic vein
4. Inferior ophthalmic vein
5. Angular vein
6. Cavernous sinus

1. **Vortex veins:** The vortex veins are the main source of venous drainage from the choroid. There are four vortex veins that exit the eyeball posterior to the equator. These are the superotemporal, superonasal, inferonasal, and inferotemporal trunks, located at 11, 1, 5, and 7 o'clock, respectively (Fig. 1.19). Vortex veins pierce the sclera behind the equator and drain into the superior and inferior ophthalmic veins, which ultimately drain into the cavernous sinus.
2. **Central retinal vein:** Retinal veins follow the retinal arteries during their course in the retina and join to form the main venous trunk, the central retinal vein. The central retinal vein travels through the optic nerve and exits it 10 mm behind the eyeball. It drains blood from the eyeball either into the superior ophthalmic vein or directly into the cavernous sinus.
3. **Superior ophthalmic vein:** The superior ophthalmic vein is formed by the joining of the superior and inferior ophthalmic branches in the superomedial part of the anterior orbit (Fig. 1.20). It lies above the optic nerve.
4. **Inferior ophthalmic vein:** The inferior ophthalmic vein receives branches from the lower eyelid, inferior and lateral extraocular muscles, lacrimal sac, conjunctiva, and the inferior vortex veins. The inferior ophthalmic vein communicates with:
   i. Superior ophthalmic vein
   ii. Pterygoid plexus of veins
   iii. Anterior facial vein
5. **Angular vein:** The angular vein is formed by the union of the supratrochlear and supraorbital veins.

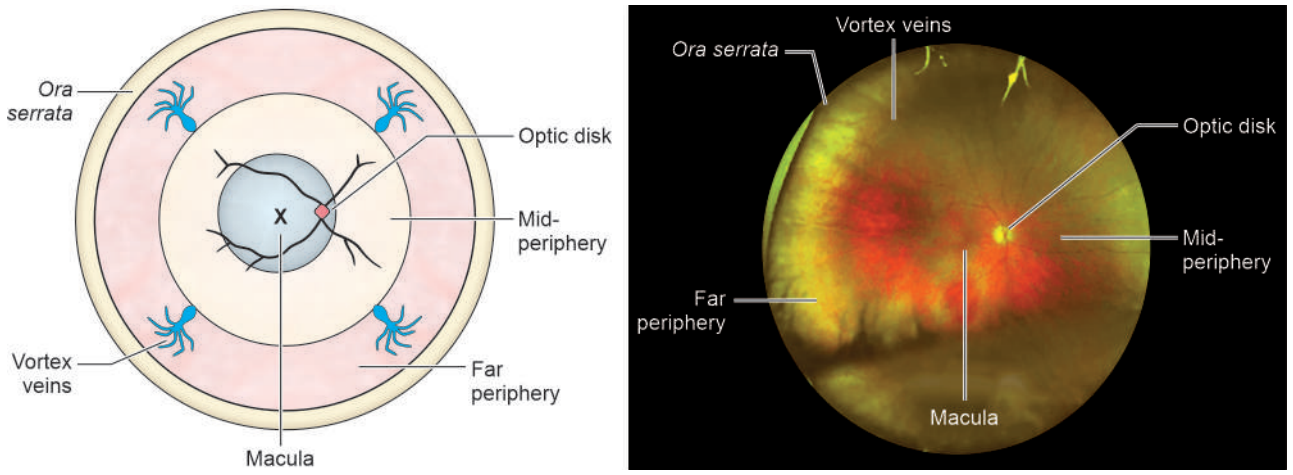


**Fig. 1.19:** Vortex veins

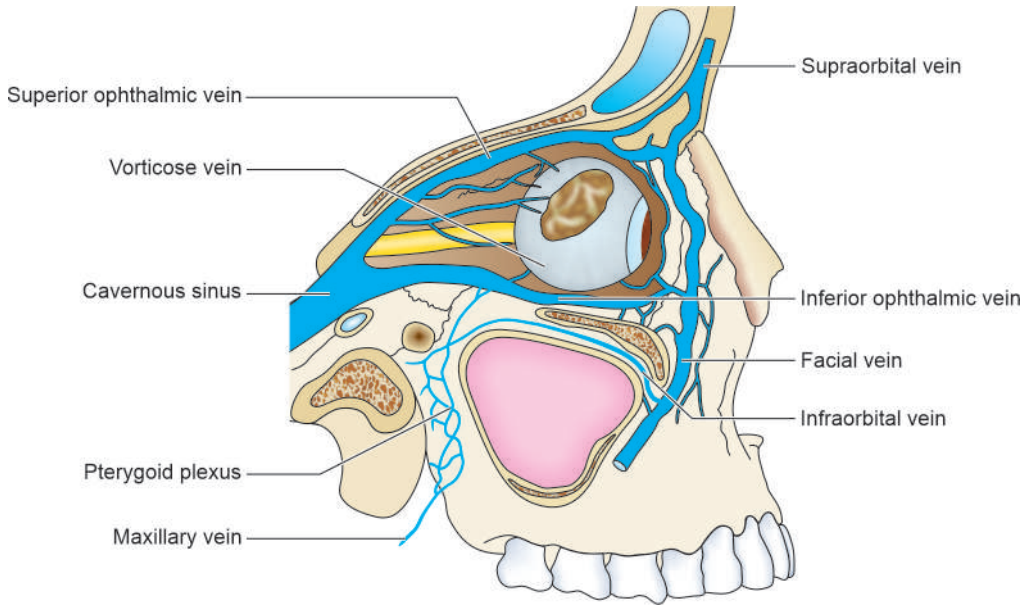


**Fig. 1.20:** Superior and inferior ophthalmic veins

It runs about 8 mm from the medial canthus, down along the side of the nose, and across the medial edge of the palpebral ligament (Fig. 1.21). It lies lateral to the angular arteries.

The angular vein is an important landmark in lacrimal sac surgery and continues inferiorly to the facial vein.

6. **Cavernous sinus:** The cavernous sinus derives its name from the word "cavern," meaning open space. It is a large venous space situated in the middle cranial fossa, one on each side of the body of the sphenoid bone. The lateral wall, roof, and medial wall are formed by the meningeal dura mater, while the floor is formed by the endosteal dura mater. Anteriorly, the sinus extends up to the medial end of the superior orbital fissure and posteriorly up to the apex of the petrous temporal bone (Fig. 1.22). The cavernous sinus tributaries are as follows:
   i. **From the orbit:** Central retinal vein, medial ophthalmic vein, superior ophthalmic vein, and branches of the inferior ophthalmic vein.

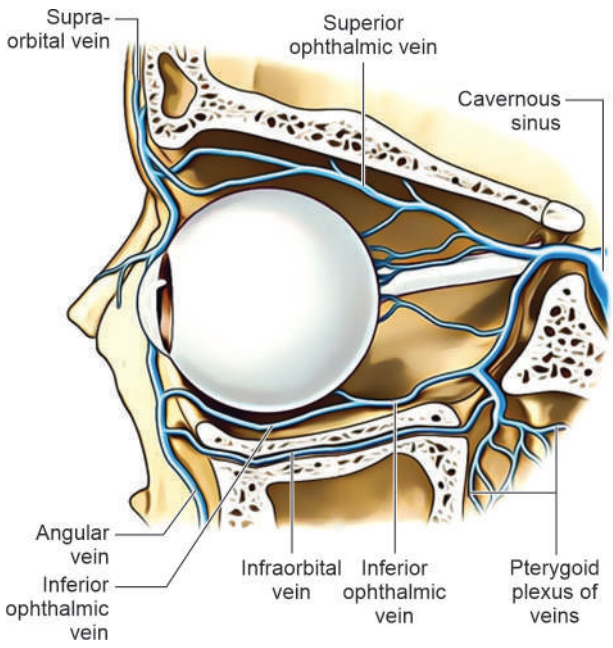


**Fig. 1.21:** Angular vein

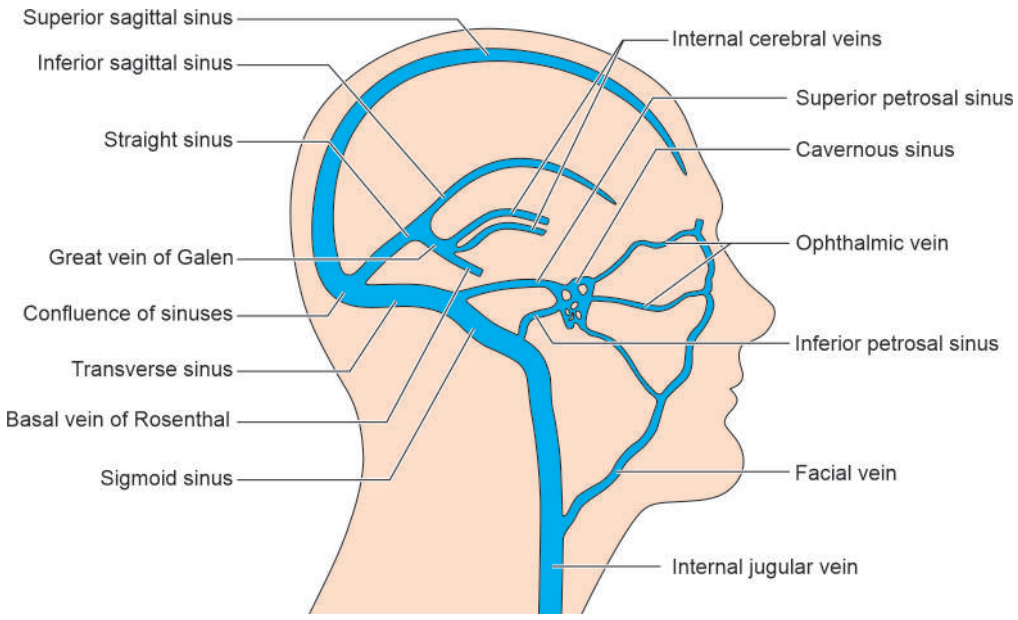


**Fig. 1.22:** Cavernous sinus

ii. **From the brain:** Superficial middle cerebral vein and inferior cerebral vein from the temporal lobe.
iii. **From the meninges:** Sphenoparietal sinus

The right and left cavernous sinuses communicate with each other through the intercavernous sinuses anteriorly and posteriorly.

## Applied Anatomy

The two cavernous sinuses are connected with each other, so any infection from the affected side may be transmitted to the opposite side. Thus, sometimes unilateral orbital cellulitis may lead to bilateral proptosis in the late stages of cavernous sinus thrombosis.

## Lymphatic Drainage

There are no lymph channels in the eyeball except for the lid and conjunctiva. The drainage is as follows:

1. Lateral two-thirds of the upper and lower lids are drained by preauricular lymph nodes.
2. Medial one-third is drained by the submandibular lymph nodes.

## Nerve Supply of Eyeball

The ocular nerve supply is provided by sensory, motor, sympathetic, and parasympathetic innervation. The sensory and motor supply of the eyeball originates from six pairs of cranial nerves. These nerves work synchronously for eye movements, reflexes, and vision.

### *A. Sensory Nerve Supply*

The sensory supply of the eyeball is via the ophthalmic division of the trigeminal (Vth) cranial nerve. The ophthalmic nerve supplies the ocular structures through various branches:

1. **Lacrimal nerve:** Supplies the conjunctiva, lacrimal gland, and lateral part of the upper lid.
2. **Frontal nerve:** The two branches of the frontal nerve are:
   i. **Supratrochlear nerve:** Supplies the conjunctiva, the medial part of the upper lid, and the skin of the forehead above the root of the nose.
   ii. **Supraorbital nerve:** Supplies the conjunctiva, the central part of the upper eyelid, and part of the forehead skin and scalp.
3. **Nasociliary nerve:** The branches are:
   i. **Long ciliary nerves:** Supply the cornea, iris, and ciliary body.
   ii. **Short ciliary nerves:** Supply the cornea, iris, and ciliary body.
   iii. **Anterior ethmoidal nerve:** Supplies the ethmoidal and sphenoidal air sinuses.
   iv. **Posterior ethmoidal nerve:** Supplies the ethmoidal and sphenoidal air sinuses.
   v. **Infratrochlear nerve:** Supplies the conjunctiva, lacrimal sac, and medial part of the eyelids.
4. **Optic nerve:** The optic nerve, or the second cranial sensory nerve, is located at the back of the eye and carries sensory visual impulses from the retina to the brain in the form of electrical impulses.

### *B. Motor Nerve Supply*

The motor nerve supply of the eyeball is as follows (Fig. 1.23):

1. **3rd, 4th, and 6th cranial nerves:** These supply the extraocular muscles and are responsible for various ocular movements.
   The third cranial nerve (oculomotor nerve) has two branches:

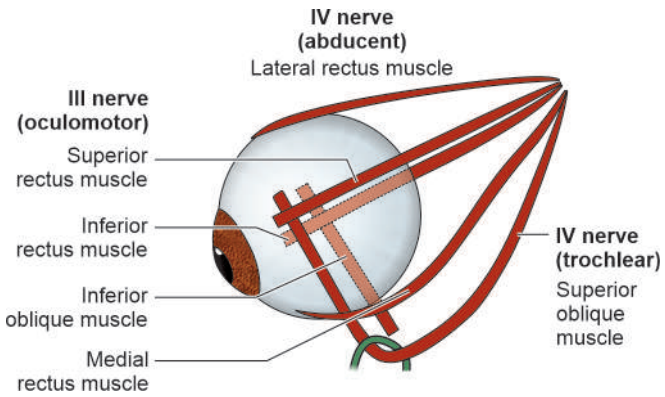


**Fig. 1.23:** Motor nerve supply to eyeball

- **Superior branch:** Supplies the LPS and superior rectus muscle.
- **Inferior branch:** Supplies the inferior rectus, medial rectus, and inferior oblique muscles. It also carries presynaptic parasympathetic fibres to the ciliary ganglion.

The fourth cranial nerve (trochlear nerve) supplies the superior oblique muscle.

The sixth cranial nerve (abducent nerve) supplies the lateral rectus muscle. **Mnemonic: SO4; LR 6**

2. **7th (facial) cranial nerve:** Supplies the orbicularis oculi muscle, which helps in eyelid closure.

### *C. Autonomic Supply*

The autonomic innervation to the eyeball is as follows (Fig. 1.24):

1. **Sympathetic nerve supply:** Sympathetic fibres supplying the eyeball separate from the carotid plexus within the cavernous sinus. The fibres run forward through the superior orbital fissure and merge with the long and short ciliary nerves to supply the dilator pupillae muscle of the iris.
2. **Parasympathetic nerve supply:** Parasympathetic innervation originates in the midbrain and pons to supply the sphincter pupillae, ciliary muscle, lacrimal gland, and blood vessels via the oculomotor nerve (Box 1.2).

**Box 1.2:** Ocular blood supply physiology

Blood flow through the ocular tissues is regulated by local and systemic regulatory mechanisms:

- Chemical control of ocular blood flow
- Nervous control of ocular blood flow

### Ciliary Ganglion

It is a parasympathetic ganglion situated in the posterior part of the orbit just behind the eyeball. It is 1–2 mm in diameter and is formed of three rami:

1. **Long sensory root:** The sensory root arises from the nasociliary nerve and contains sensory fibres from the cornea, iris, and ciliary body.
2. **Short parasympathetic root:** The parasympathetic root arises from the inferior division of the third cranial nerve (oculomotor nerve) and carries preganglionic parasympathetic fibres from the Edinger-Westphal nucleus of the third nerve to the ciliary ganglion. It innervates the sphincter pupillae and ciliary muscle.
3. **Sympathetic root:** The sympathetic root is derived from the sympathetic plexus of the internal carotid artery and carries dilator fibres to the dilator pupillae muscle of the iris and constrictor fibres to the blood vessels.

**Branches:** The short ciliary nerves, 6–10 in number, arise from the anterior aspect of the ciliary ganglion. These contain sensory, postganglionic sympathetic, and postganglionic parasympathetic fibres for the eyeball.

**SUMMARY**

- The eyeball has three concentric coats: The outer fibrous coat, the middle vascular coat, and the inner nervous coat. It occupies the anterior one-fifth of the bony orbit and is protected by eyelids.
- The second sensory cranial nerve (optic nerve) connects the eyeball to the visual cortex, carrying visual impulses to the brain. The arterial supply to the eyeball is via the ophthalmic artery, a branch of the internal carotid artery. The venous drainage from the eyeball is into vortex veins, angular veins, and superior and inferior ophthalmic veins.
- The nerve supply of the eyeball is via sensory, motor, sympathetic, and parasympathetic fibres, which help to maintain normal eyeball functions.

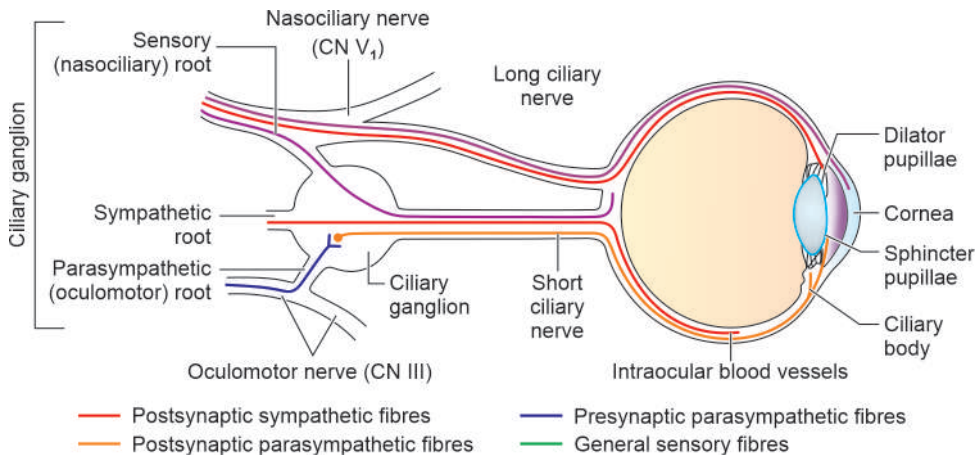


**Fig. 1.24:** Autonomic nerve supply to eyeball