ANATOMY OF EYE AND RELATED OCULAR STRUCTURES

HANDWRITTEN NOTES

EXAM READY ANSWERS WITH DIAGRAMS

WITH IMPORTANT PHYSIOLOGY QUESTIONS INCLUDED

DESIGNED FOR OPHTHALMOLOGY RESIDENTS

ANATOMY OF
ORBITAL ANATOMY | EYELID ANATOMY | LACRIMAL GLAND AND EXCRETORY SYSTEM | CORNEA|SCLERA | ANTERIOR CHAMBER | UVEAL TRACT | LENS | RETINA | VITREOUS |

ANATOMY OF EYE EXAM READY NOTES

INDEX

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INDEX

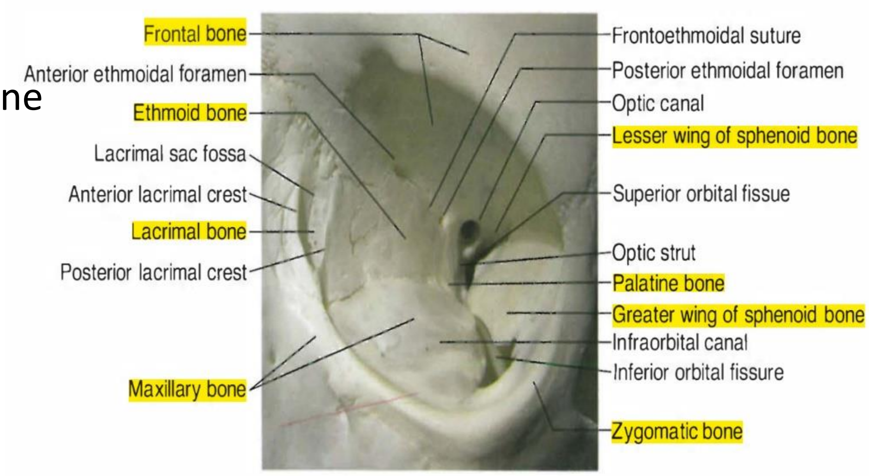
Orbital Anatomy

Orbital Volume:

- ✓ the volume of which, in the adult, is slightly less than 30 cm3.
- ✓ The orbital entrance averages approximately 35 mm in height and 45 mm in width.
- ✓ The maximum width is located approximately 1 cm behind the anterior orbital margin.
- ✓ In adults, the depth of the orbit varies from 40 to 45 mm
- ✓ Both race and sex affect each of these measurements.

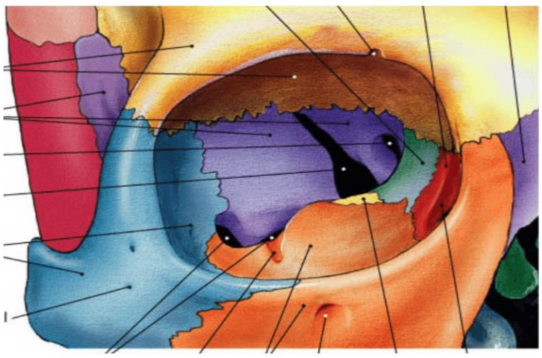
Bony Orbit : Seven bones make up the bony orbit

1. fontal bone
2. ethmoid (or ethmoidal) bone
3. lacrimal bone
4. maxilla (or maxillary bone)
5. zygomatic bone
6. sphenoid bone
7. palatine bone



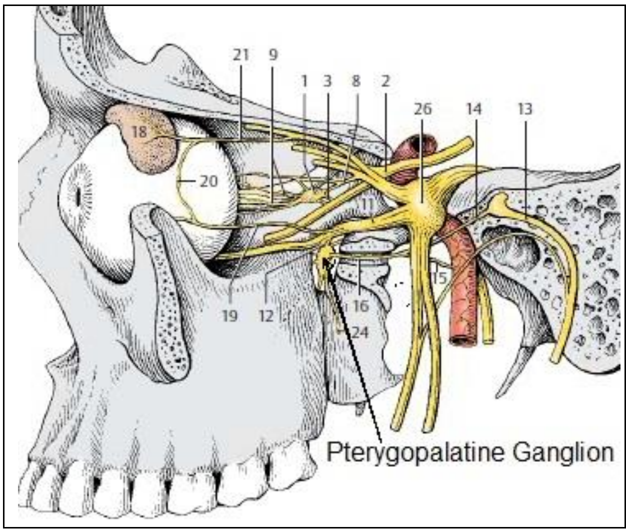
Orbital Margin :

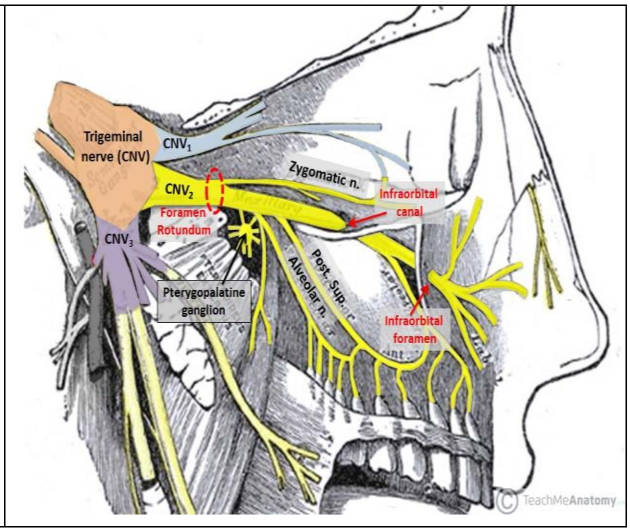
- superior margin is formed by the frontal bone, which is interrupted medially by the supraorbital notch.
- The medial margin is formed above by the fontal bone and below by the posterior lacrimal crest of the lacrimal bone and the anterior lacrimal crest of the maxillary bone.
- The inferior margin derives from the maxillary and zygomatic bones.
- Laterally, the zygomatic and fontal bones complete the rim



☒ It transmits :

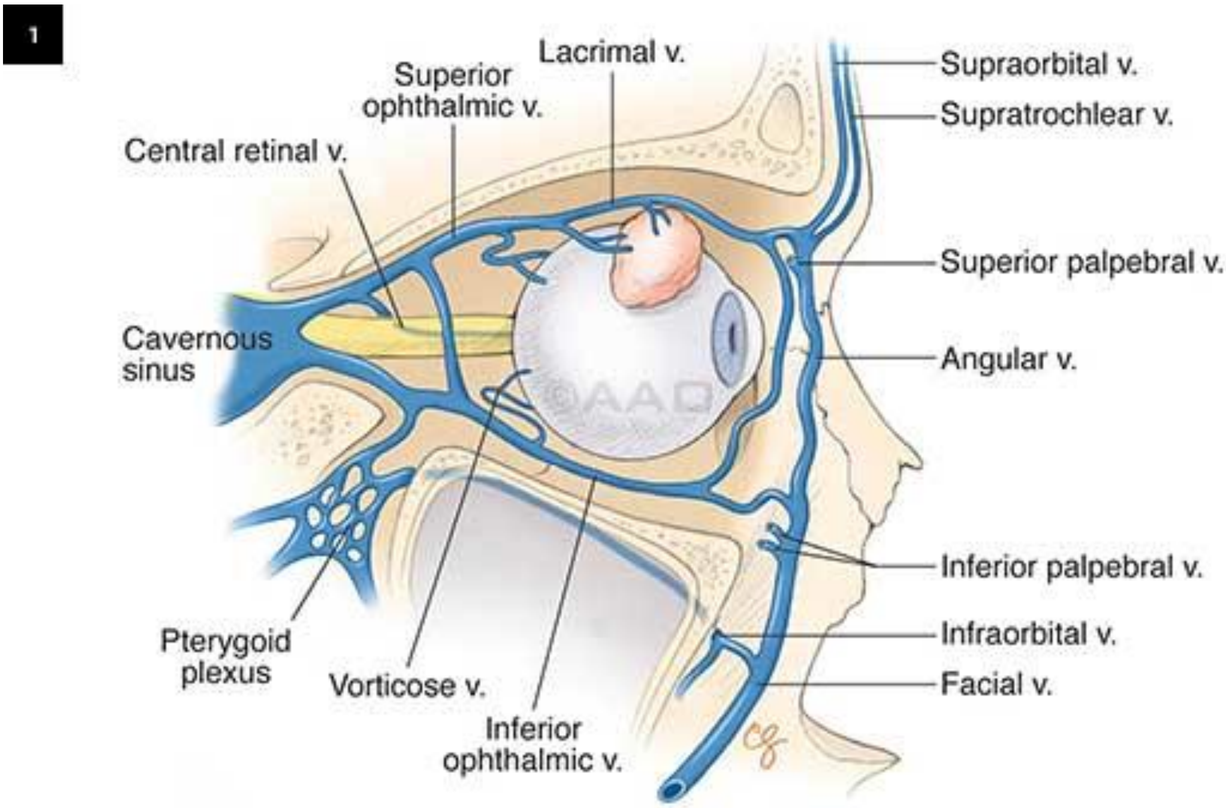
1) the infraorbital and zygomatic branches of CN V2 , an orbital nerve from the pterygopalatine ganglion





2) and the inferior ophthalmic vein.

☒ The inferior ophthalmic vein connects with the pterygoid plexus before draining into the cavernous sinus.



Periorbital Sinuses :

✓ The periorbital sinuses have a close anatomical relationship with the orbits, which are located on either side of the root of the nose.

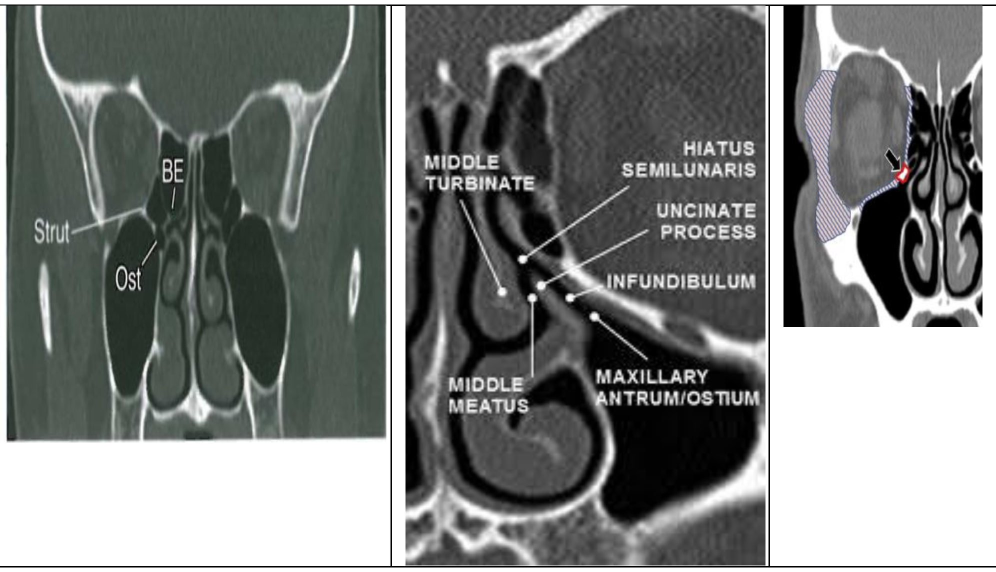
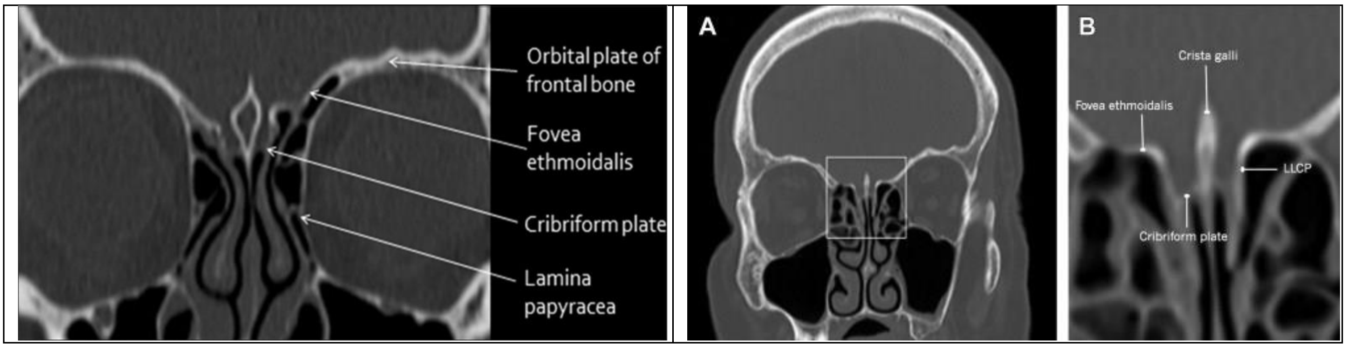


Figure 1-5 Coronal computed tomography scan of the orbits and sinuses showing the relation of the middle inferomedial orbital strut (Strut) to the ostium of the maxillary sinus (Ost). The inferior bulla ethmoidalis (BE) marks the floor of the ethmoidal sinus. This region is referred to as the hiatus semilunaris. The fovea ethmoidalis is the roof of the ethmoidal sinus and is a lateral extension of the cribriform plate. *(Courtesy of William R. Katowitz, MD.)*

- ✓ IOS is significant because of its proximity to the ostium of the maxillary sinus.
- ✓ In addition, the fovea ethmoidalis, which forms the roof of the ethmoidal sinuses, is a lateral extension of the cribriform plate.



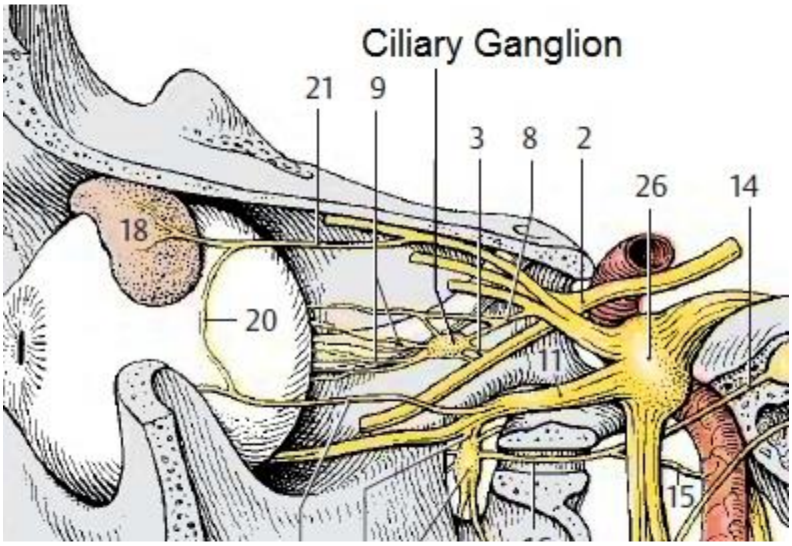
- ✓ It is important to identify the fovea ethmoidalis when planning lacrimal surgery to prevent inadvertent cerebral spinal fluid leakage as well as intracranial injury.

Cranial Nerves :

- Six of the 12 cranial nerves (CN II-VII) directly innervate the eye and periocular tissues.
- Because certain tumors affecting CN I (the olfactory nerve) can give rise to important ophthalmic signs and symptoms, it is important for ophthalmologists to be familiar with the anatomy of this nerve.

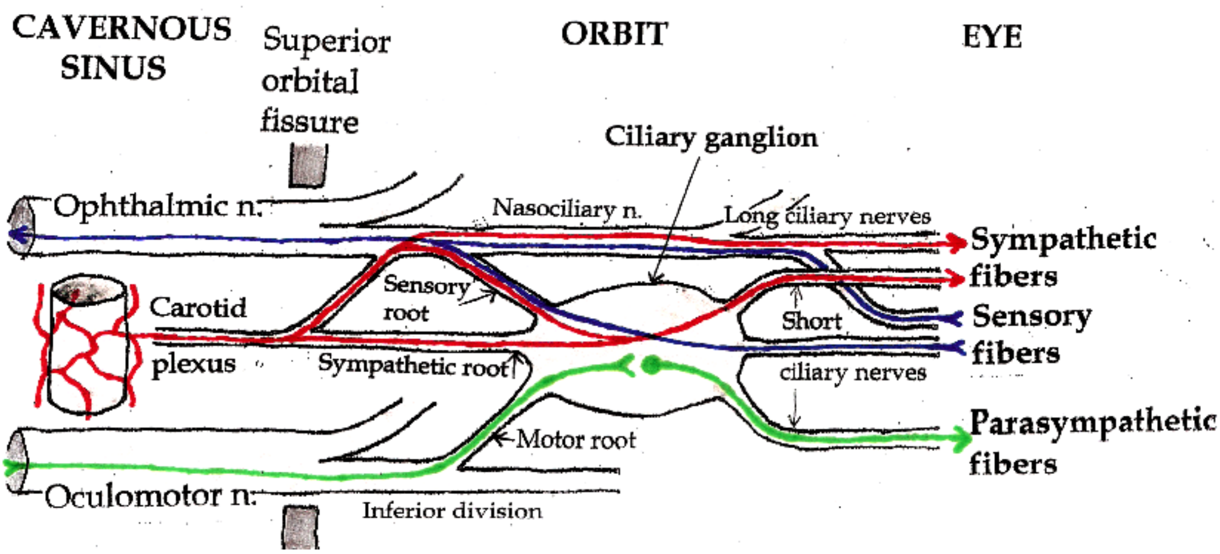
Ciliary Ganglion :

- ❖ It is located approximately 1 cm in front of the annulus of Zinn
- ❖ On the lateral side of the ophthalmic artery
- ❖ Between the optic nerve and the lateral rectus muscle



❖ It receives three roots :

1. A long sensory root (long ciliary nerve) :
   - It arises from the nasociliary branch of CN V1.
   - It is 10-12 mm long
   - It contains sensory fibers from the cornea, the iris, and the ciliary body.
2. A short motor root :
   - It arises from the inferior division of CN III, which also supplies the inferior oblique muscle.
   - The fibers of the motor root synapse in the ganglion, and the postganglionic fibers carry parasympathetic axons to supply the iris sphincter.
3. A sympathetic root :
   - It comes from the plexus around the internal carotid artery.
   - It enters the orbit through the superior orbital fissure within the tendinous ring
   - It passes through the ciliary ganglion without synapse
   - It innervates ocular blood vessels and the dilator muscles of the pupil.

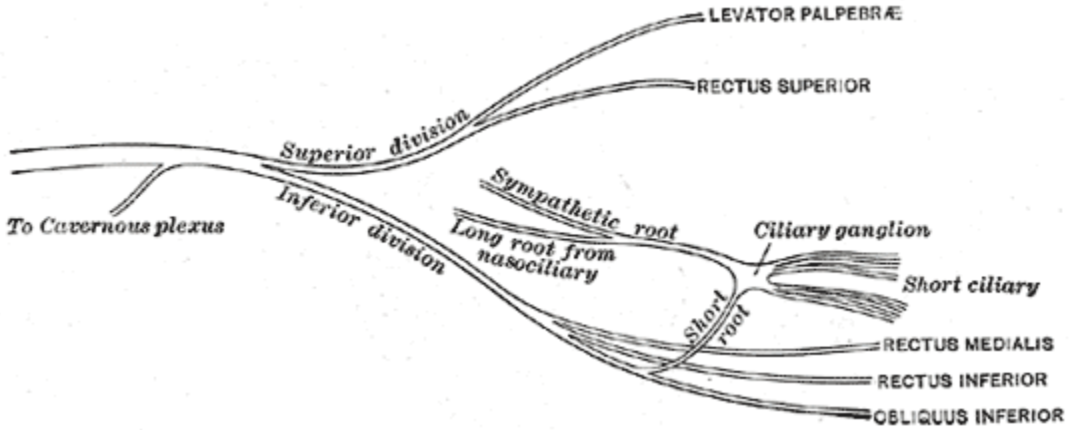


❖ Branches of the Ciliary Ganglion :

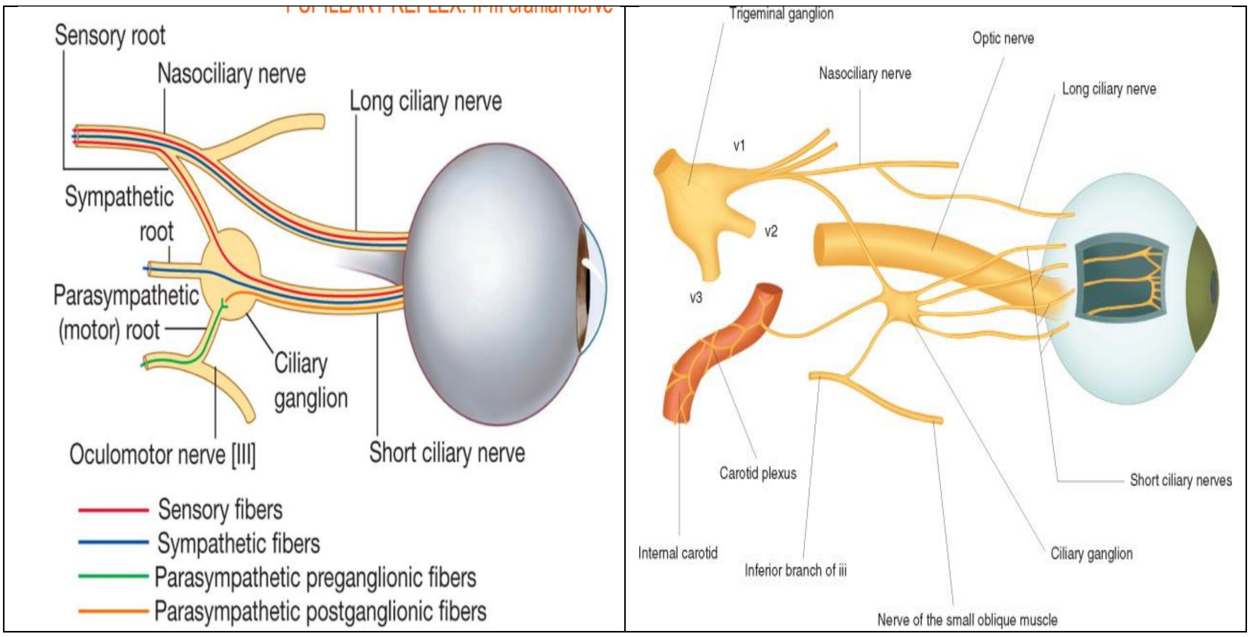
- Only the parasympathetic fibers synapse in the ciliary ganglion.
- The sympathetic fibers are postganglionic from the superior cervical ganglion and pass through it without synapse.
- Sensory fibers from cell bodies in the trigeminal ganglion carry sensation from the eye, orbit, and face.
- Together, the sensory fibers; the nonsynapsing sympathetic fibers; and the myelinated, fast-conducting postganglionic parasympathetic fibers form the short ciliary nerves.

❖ Short Ciliary Nerves:

- Two groups of short ciliary nerves, totaling 6- 10
- arise from the ciliary ganglion



- They travel on both sides of the optic nerve
- Together with the long ciliary nerves, pierce the sclera around the optic nerve.



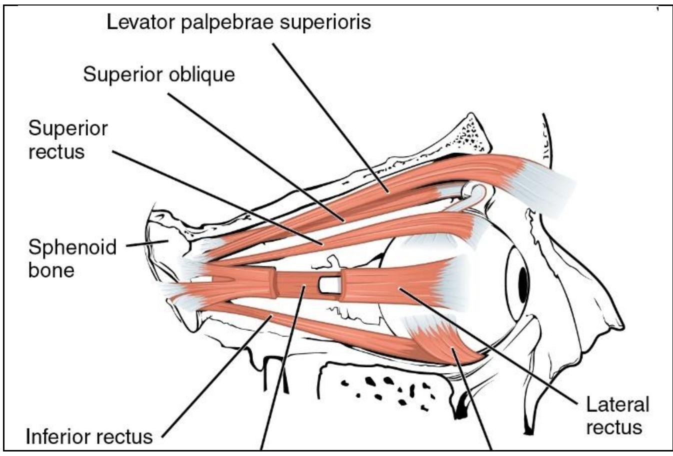
- They pass anteriorly between the choroid and the sclera into the ciliary muscle, where they form a plexus that supplies the cornea, the ciliary body, and the iris.

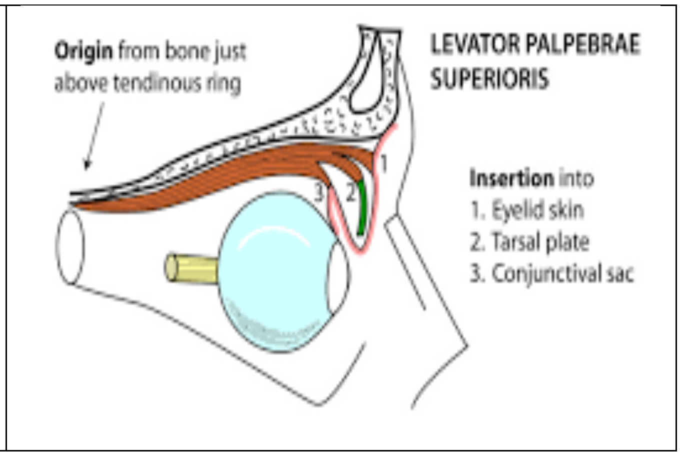
Extraocular Muscles : There are 7 extraocular muscles :

1) medial rectus
2) lateral rectus
3) superior rectus
4) inferior rectus
5) superior oblique
6) inferior oblique
7) levator palpebrae superioris

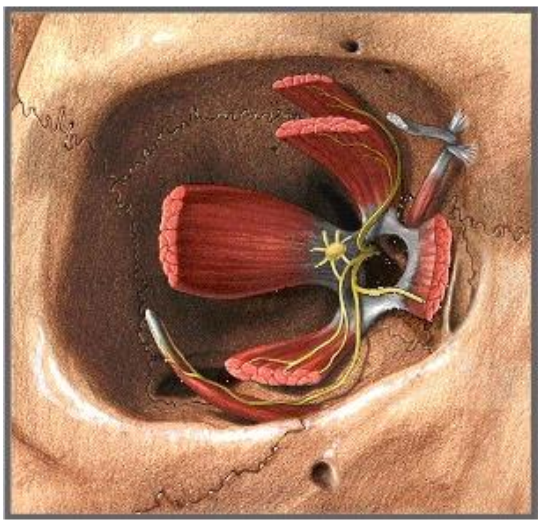
Extraocular Muscle Origins :

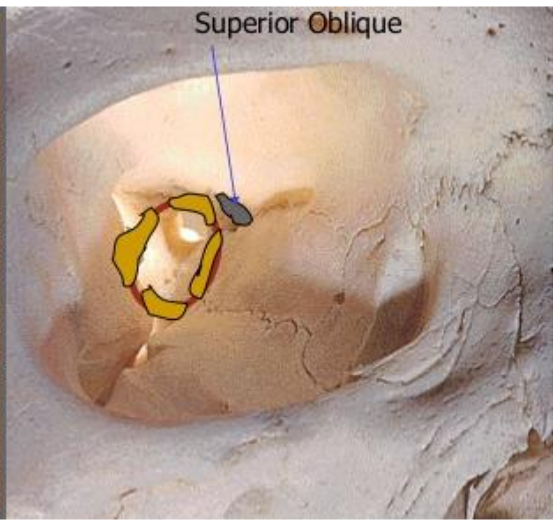
- The annulus of Zinn consists of superior and inferior orbital tendons and is the origin of the 4 rectus muscles.
- The upper tendon gives rise to the entire superior rectus muscle, as well as portions of the lateral and medial rectus muscles.
- The inferior tendon gives rise to the entire inferior rectus muscle and portions of the medial and lateral rectus muscles.
- The levator palpebrae superioris muscle arises from the lesser wing of the sphenoid bone, at the apex of the orbit, just superior to the annulus of Zinn.



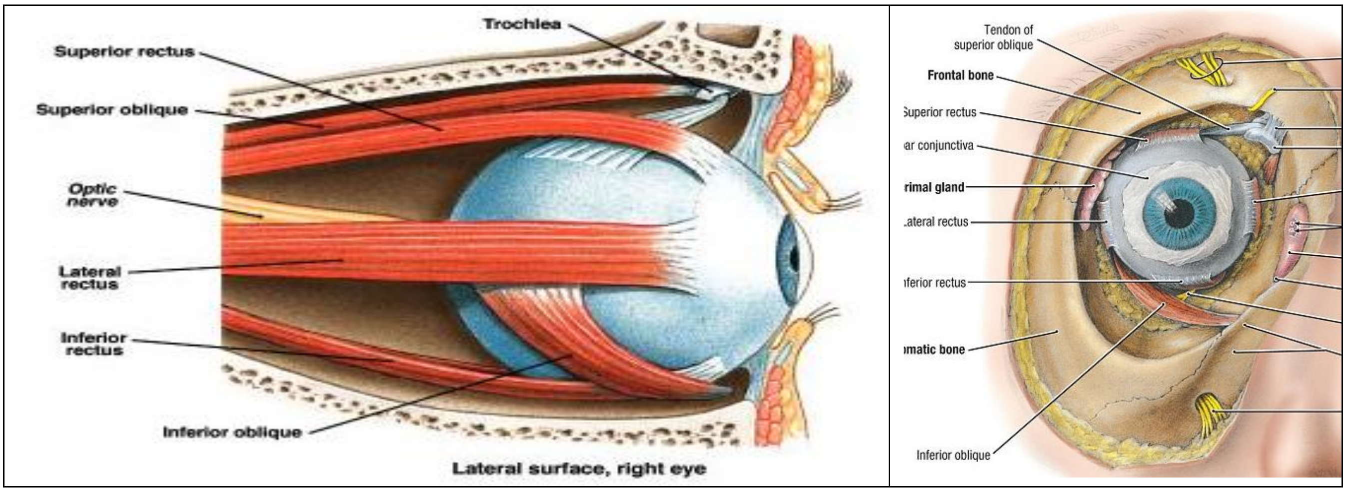


- The superior oblique muscle originates from the periosteum of the body of the sphenoid bone, above and medial to the optic foramen.





▪ The inferior oblique muscle originates anteriorly, from a shallow depression in the orbital plate of the maxillary bone, at the anteromedial corner of the orbital floor, near the lacrimal fossa. From its origin, the inferior oblique muscle then extends posteriorly, laterally, and superiorly to insert into the globe.



Extraocular Muscle Insertions :

- ✓ The 4 rectus muscles insert anteriorly on the globe.
- ✓ The muscle insertions lie progressively farther from the limbus, starting at the medial rectus muscle and then proceeding to the inferior rectus, lateral rectus, and superior rectus muscles
- ✓ An imaginary curve drawn through these insertions creates a spiral, which is called the spiral of Tillaux.

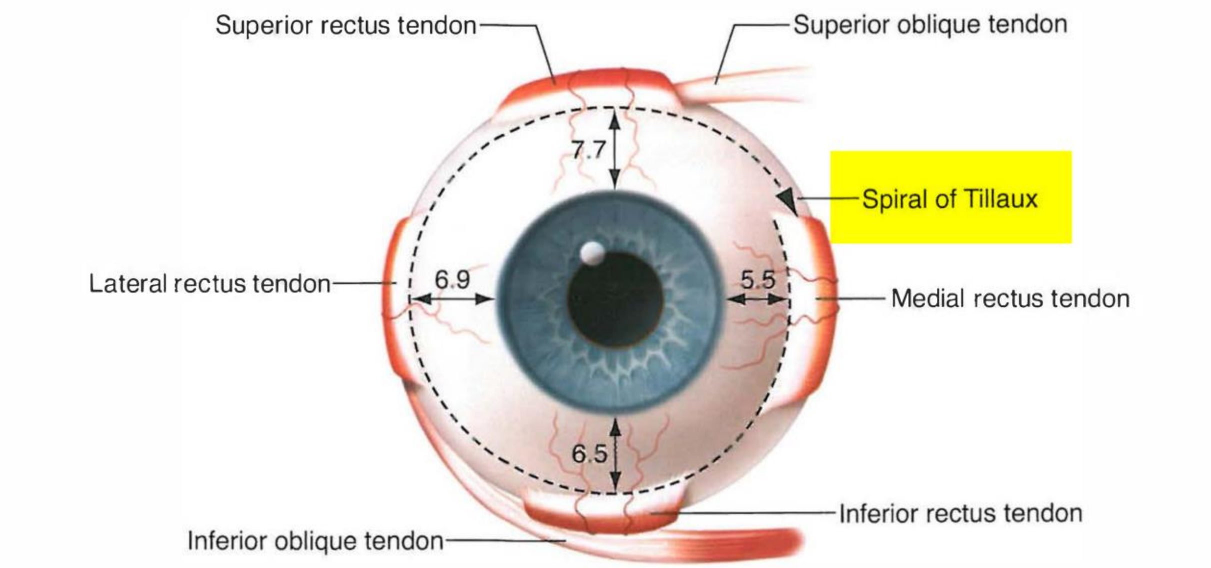
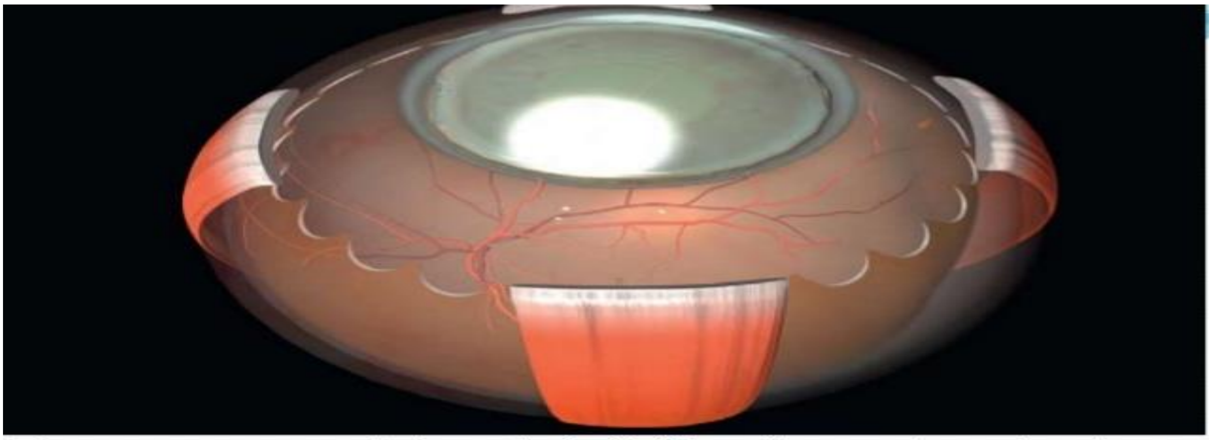


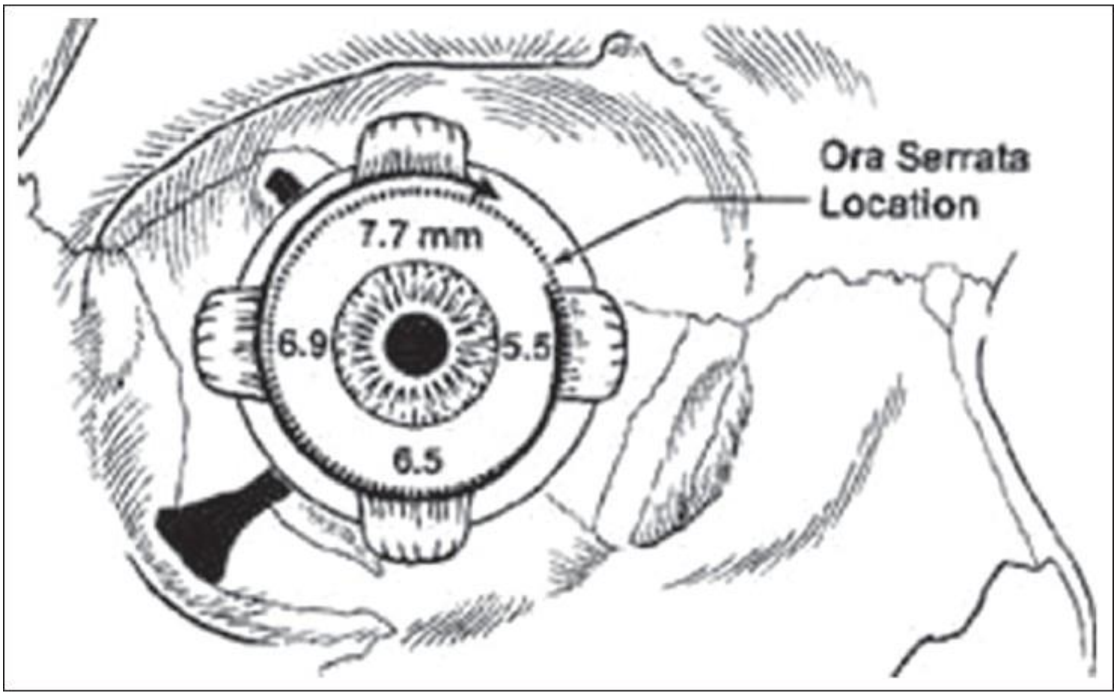
Figure 1-12 The medial rectus tendon is closest to the limbus, and the superior rectus tendon is farthest from it. By connecting the insertions of the tendons beginning with the medial rectus, then the inferior rectus, then the lateral rectus, and finally the superior rectus, a spiral (known as the *spiral of Tillaux*) is obtained. Measurements are in millimeters. *(Illustration by Christine Gralapp.)*

- ✓ The relationship between the muscle insertions and the ora serrata is clinically important.

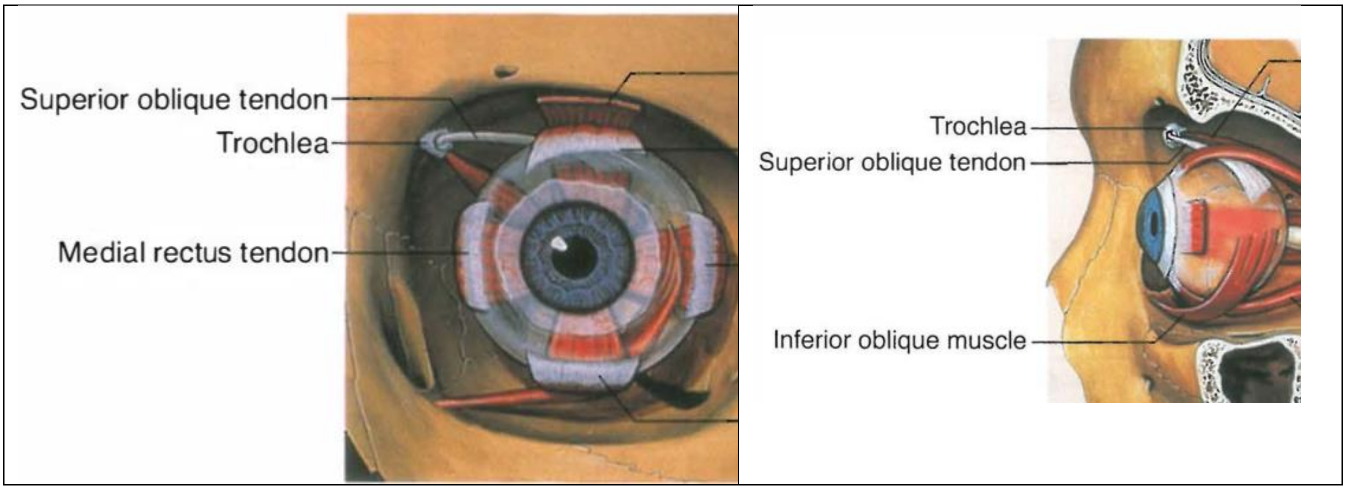


The ora serrata and the spiral of Tillaux (rectus insertions).

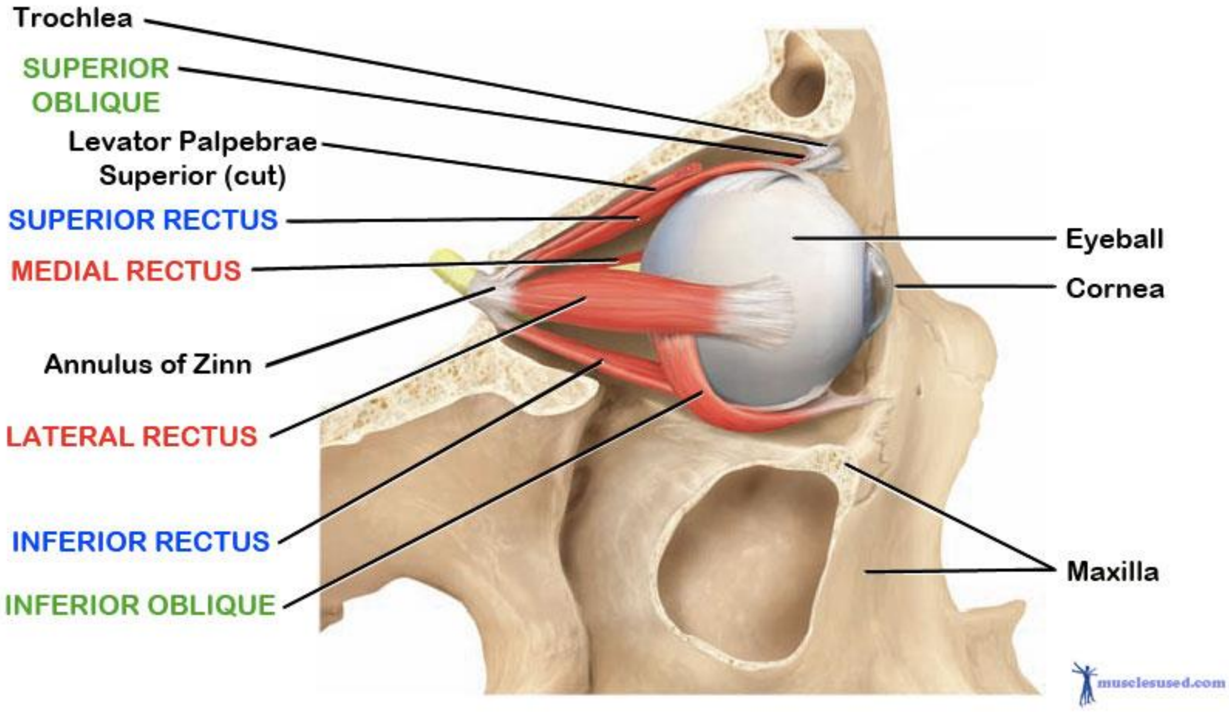
- ✓ A misdirected suture passed through the insertion of the superior rectus muscle could perforate the retina.



- ✓ The superior oblique muscle, after passing through the trochlea in the superior nasal orbital rim, inserts onto the sclera superiorly, under the insertion of the superior rectus.

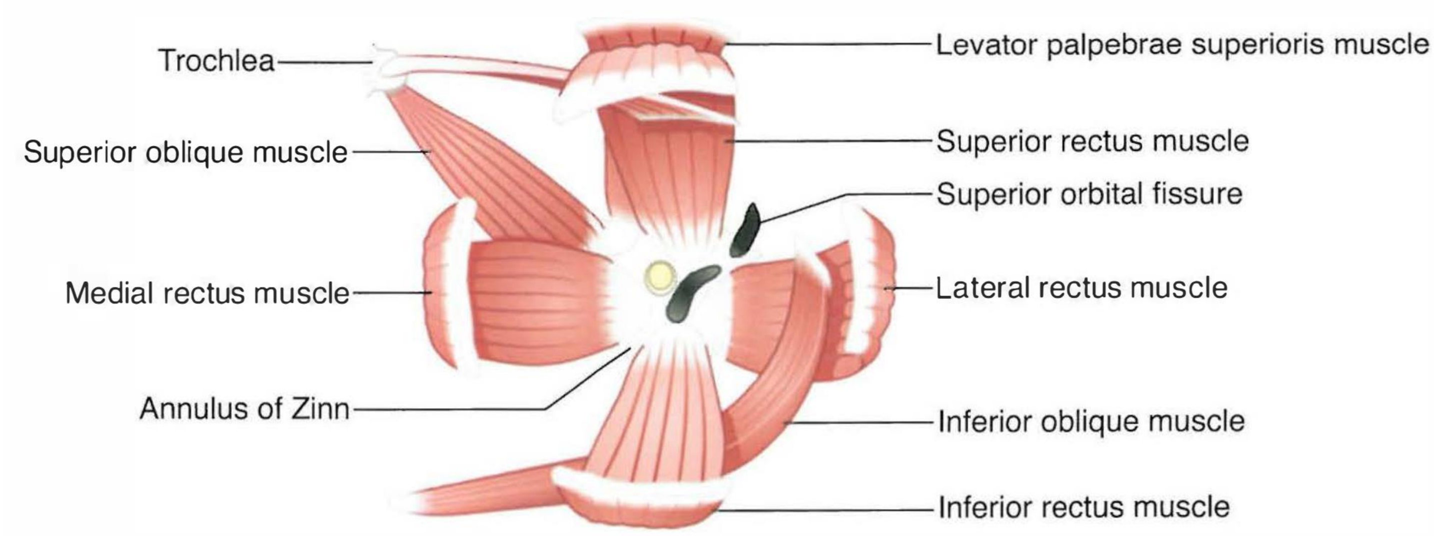


✓ The inferior oblique muscle inserts onto the sclera in the posterior inferior temporal quadrant.



Extraocular Muscle Distribution in the Orbit :

Note the relationship between the oblique muscles and the rectus muscles.



The location of the extraocular muscles within the orbit and their relationship to surrounding nerves and bone :

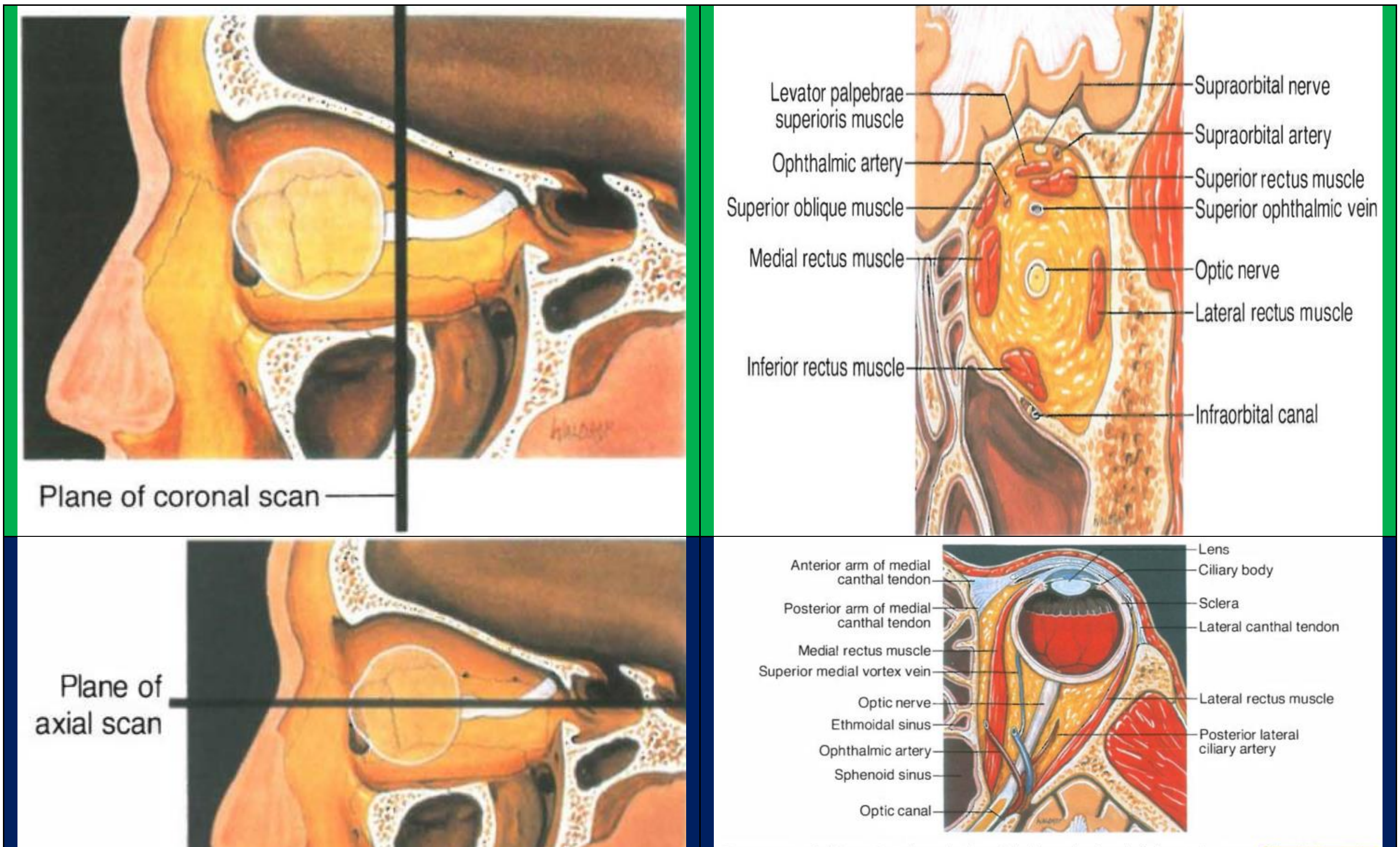
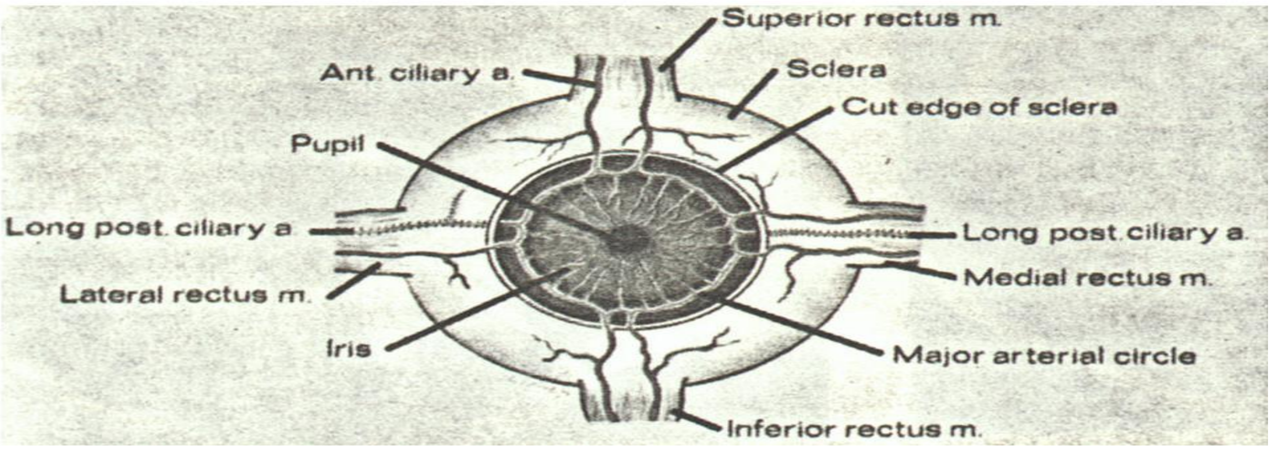


Figure 1-16 Axial section through the midorbit at the level of the optic nerve. The third portion of the ophthalmic artery crosses the nerve in the posterior orbit. *(Reproduced with permission from*

Blood Supply to the Extraocular Muscles :

- Generally, the extraocular muscles are supplied by :
  1) The inferior and superior muscular branches of the ophthalmic artery
  2) lacrimal artery
  3) infraorbital artery.
- The lateral rectus muscle is supplied by a single vessel derived from the lacrimal artery; the other rectus muscles receive 2 anterior ciliary arteries that communicate with the major arterial circle of the ciliary body via perforating scleral vessels.



Innervation of the Extraocular Muscles :

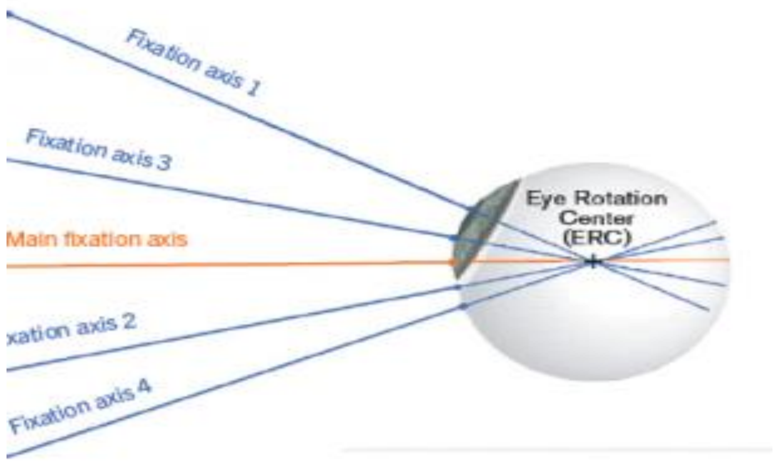
✸ CN III (the oculomotor nerve) has superior and inferior divisions:

- The upper division innervates :
  1. the levator palpebrae superioris
  2. superior rectus muscle
- The lower division innervates :
  1. medial rectus
  2. inferior rectus
  3. inferior oblique

✸ CN IV (the trochlear nerve) innervates the superior oblique muscle.

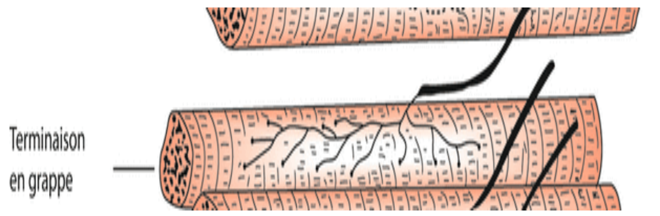
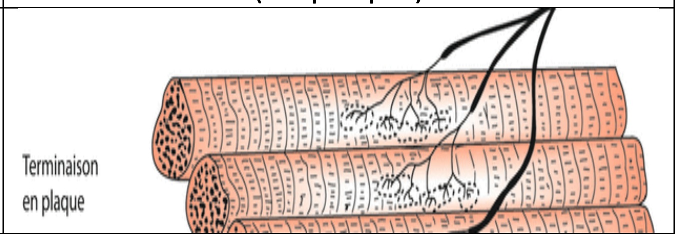
✸ CN VI (the abducens nerve) innervates the lateral rectus muscle.

Muscle	Origin	Insertion	Blood Supply	Size
MR	Annulus of Zinn	. Medially . In horizontal meridian . 5.5 mm from limbus	Inf.musc.branch of oph.ar	. Long = 40.8 mm . Tendon = 3.7 mm . Wide = 10.3 mm
IR	. Annulus of Zinn . At orbital apex	. Laterally . In vertical meridian . 6.5 mm from limbus	. Inf.musc.branch of oph.ar . infraorbital artery	. Long = 40 mm . Tendon = 5.5 mm . Wide = 9.8 mm
LR	. Annulus of Zinn . Spanning the SOF (SOF : superior orbital fissure)	. Medially . In horizontal meridian . 6.9 mm from limbus	Lacrimal artery	. Long = 40.6 mm . Tendon = 8 mm . Wide = 9.2 mm
SR	. Annulus of Zinn . At orbital apex	. Laterally . In vertical meridian . 7.7 mm from limbus	sup.musc.branch of oph.ar	. Long = 41.8 mm . Tendon = 5.8 mm . Wide = 10.6 mm
SO	. the periosteum of the body of the sphenoid bone, above and medial to the optic foramen . Between annulus of Zinn and periorbita	. To trochlea . Through pulley at orbital rim . Then hooking back under SR . inserting posterior to center of rotation	sup.musc.branch of oph.ar	. Long = 40 mm . Tendon = 20 mm . Wide = 10.8 mm
IO	From a depression on orbital floor near to orbital rim (maxilla)	. In the posterior inferior temporal quadrant. . At level of macule . posterior to center of rotation	. Inf.musc.branch of oph.ar . infraorbital artery	. Long = 37 mm . Tendon = 0 mm (no tendon) . Wide = 9.6 mm



Fine Structure of the Extraocular Muscles :

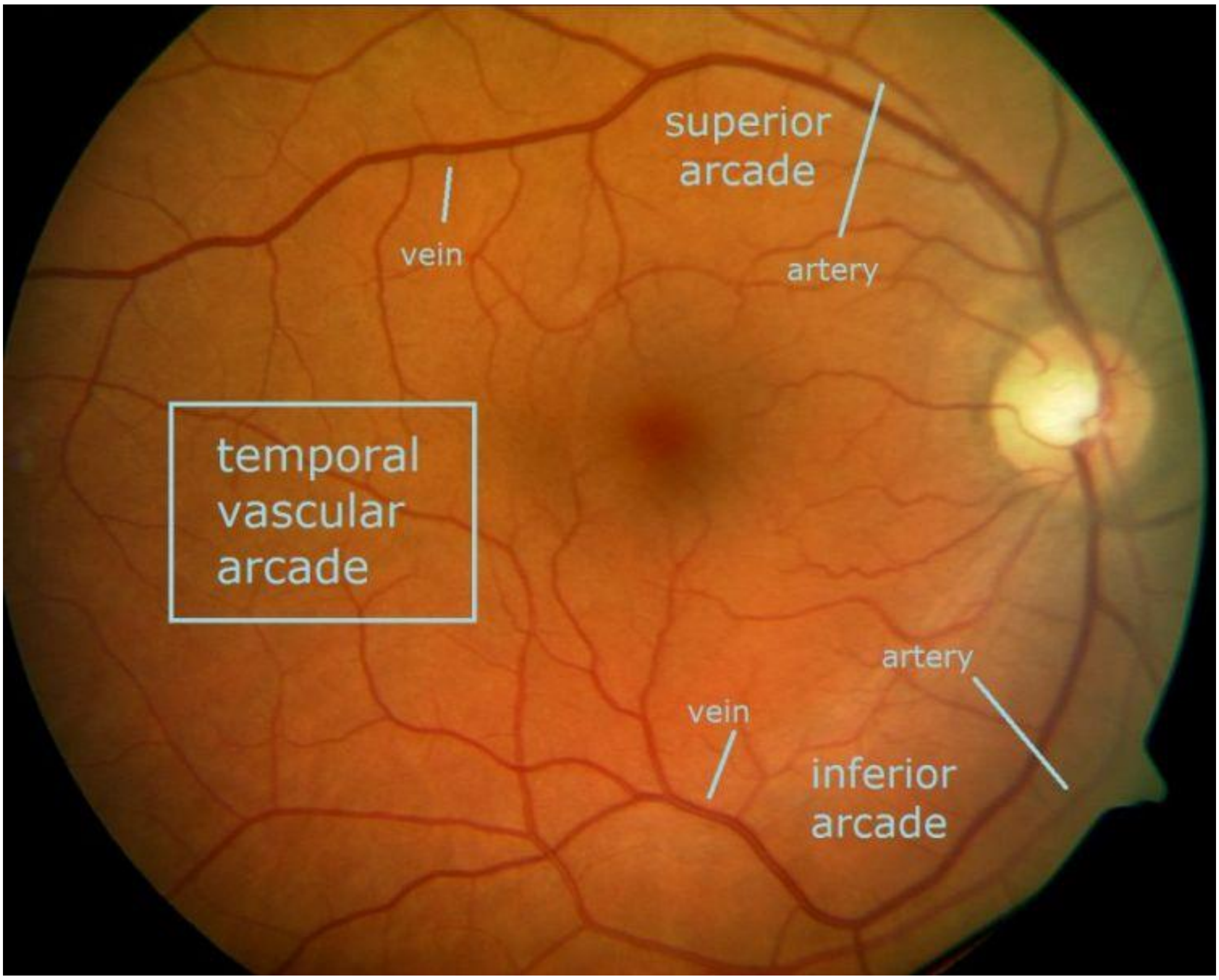
- ✓ In the extraocular muscles, the ratio of nerve fibers to muscle fibers is very high (1: 3-1 :5) compared with the ratio of nerve axons to muscle fibers in skeletal muscle (1 :50- 1 : 125).
- ✓ This high ratio enables precise control of ocular movements.
- ✓ The fibers of the extraocular muscles can be classified to :

slow, tonic-type fibers	**fast, twitch-type fibers**
unique to extraocular muscles	more similar to skeletal muscle fibers
Smaller than twitch-type fibers	Larger than tonic-type fibers
they contract slowly and smoothly	they contract rapidly
tend to be located more superficially in the muscle, nearer the orbital wall	located deeper in the muscle
They are innervated by multiple grapelike nerve endings (en grappe)	They have platelike nerve endings (en plaque)
	
useful for smooth pursuit movements.	aid in rapid saccadic movements of the eye.

- ✓ The fibers of the extraocular muscles can be further classified by contractile properties, histochemical profile, and myosin content.

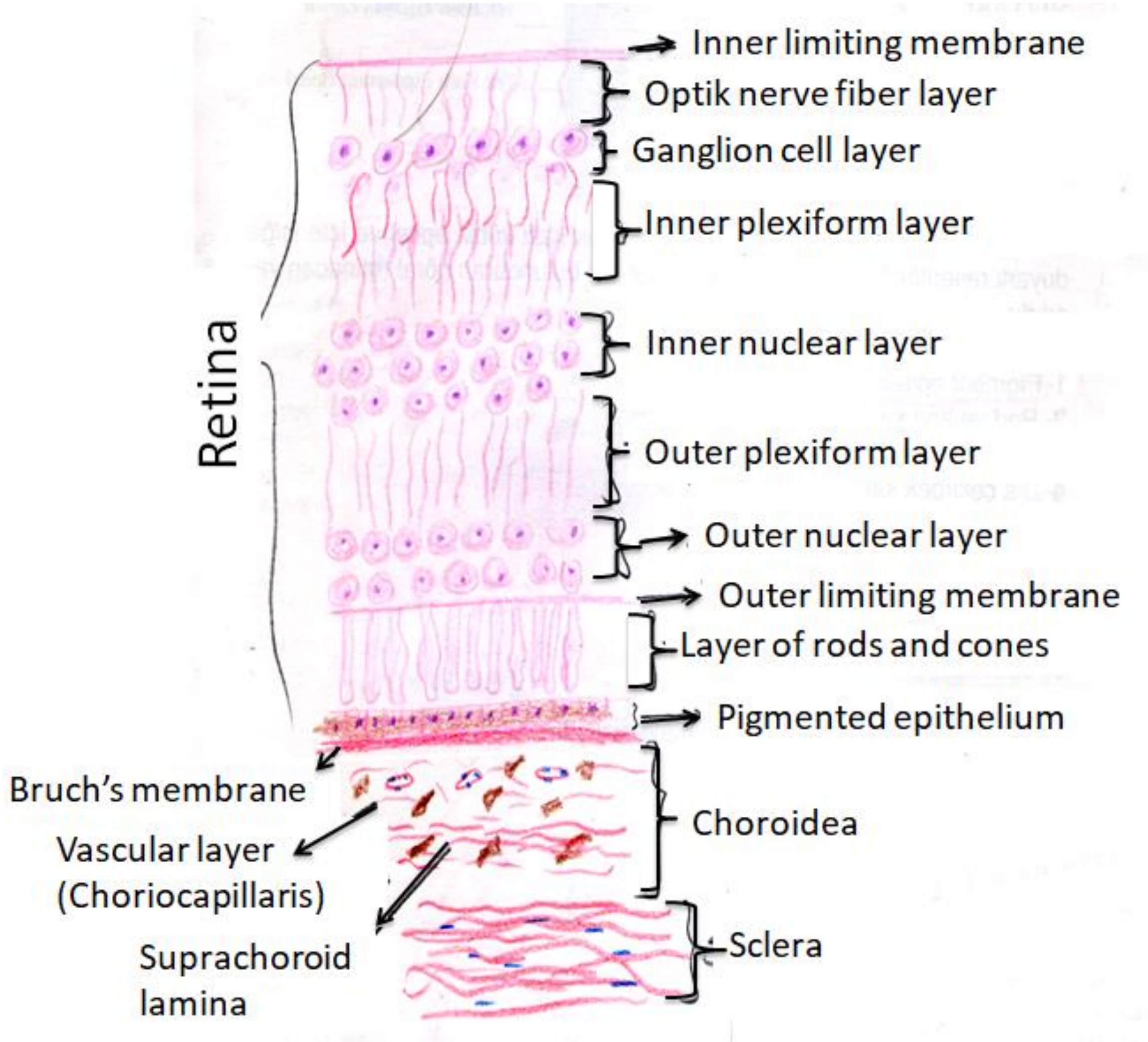
Retina

- ✓ The fundus oculi is the part of the eye that is visible with ophthalmoscopy; it includes the retina, its vessels, and the optic nerve head, or optic disc.
- ✓ The macula, 5-6 mm in diameter, lies between the temporal vascular arcades.



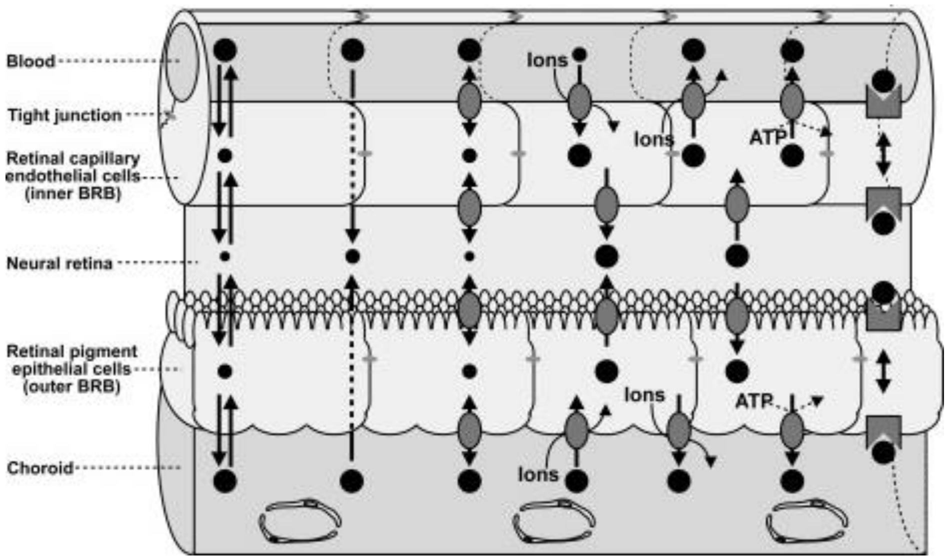
- ✓ At the macula's center lies the fovea, which is rich in cones and responsible for color vision and the highest visual acuity.
- ✓ In the far periphery, the ora serrata (the junction between the retina and the pars plana) can be observed with gonioscopy or indirect ophthalmoscopy.
- ✓ The reddish color of the fundus is due to the transmission of light reflected from the posterior sclera through the capillary bed of the choroid.
- ✓ The retina is a thin, transparent structure that develops from the inner and outer layers of the optic cup.
- ✓ In cross section, from inner to outer retina, the 10 layers of the neurosensory retina are :
    1) internal limiting membrane
    2) nerve fiber layer
    3) ganglion cell layer
    4) inner plexiform layer

5) inner nuclear layer
6) middle limiting membrane
7) outer plexiform layer
8) outer nuclear layer
9) external limiting membrane
10) rod and cone inner and outer segments



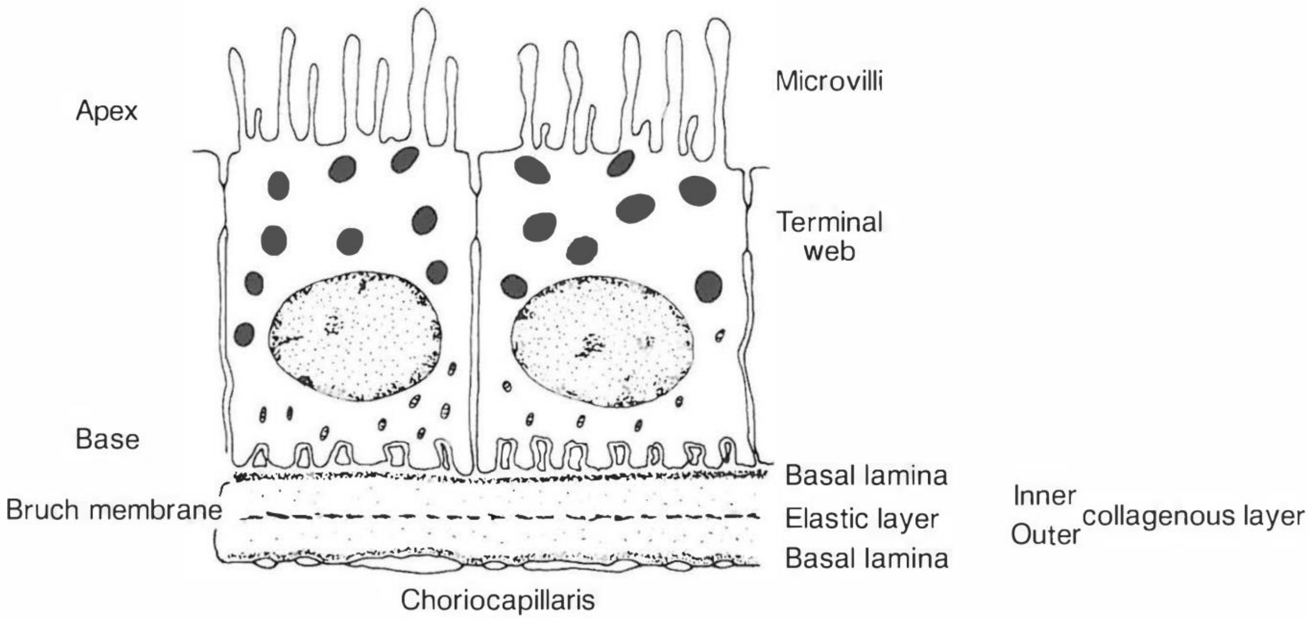
Retinal Pigment Epithelium :

- ✓ The structure of the outer pigmented epithelial layer is relatively simple compared with that of the overlying inner, or neurosensory, retina.
- ✓ The RPE consists of a monolayer of hexagonal cells that extends anteriorly from the optic disc to the ora serrata, where it merges with the pigmented epithelium of the ciliary body.
- ✓ Its structure is deceptively simple considering its many functions :
  - vitamin A metabolism
  - maintenance of the outer blood-retina barrier

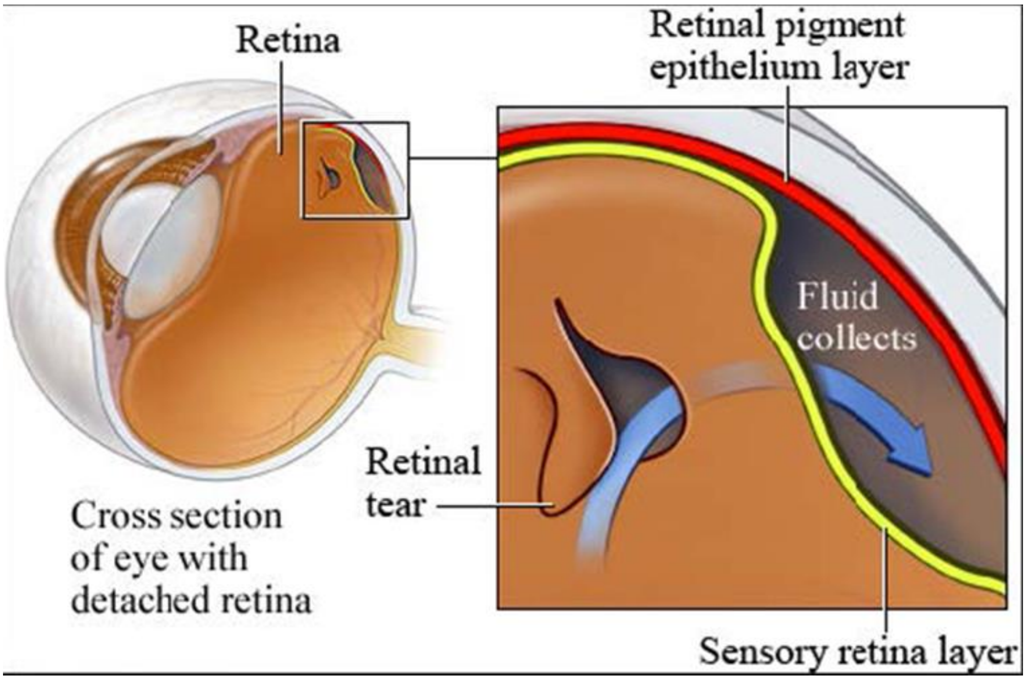


- phagocytosis of the photoreceptor outer segments
- absorption of light (reduction of scatter)
- heat exchange
- formation of the basal lamina of the Bruch membrane
- production of the mucopolysaccharide matrix surrounding the outer segments
- active transport of materials into and out of the RPE

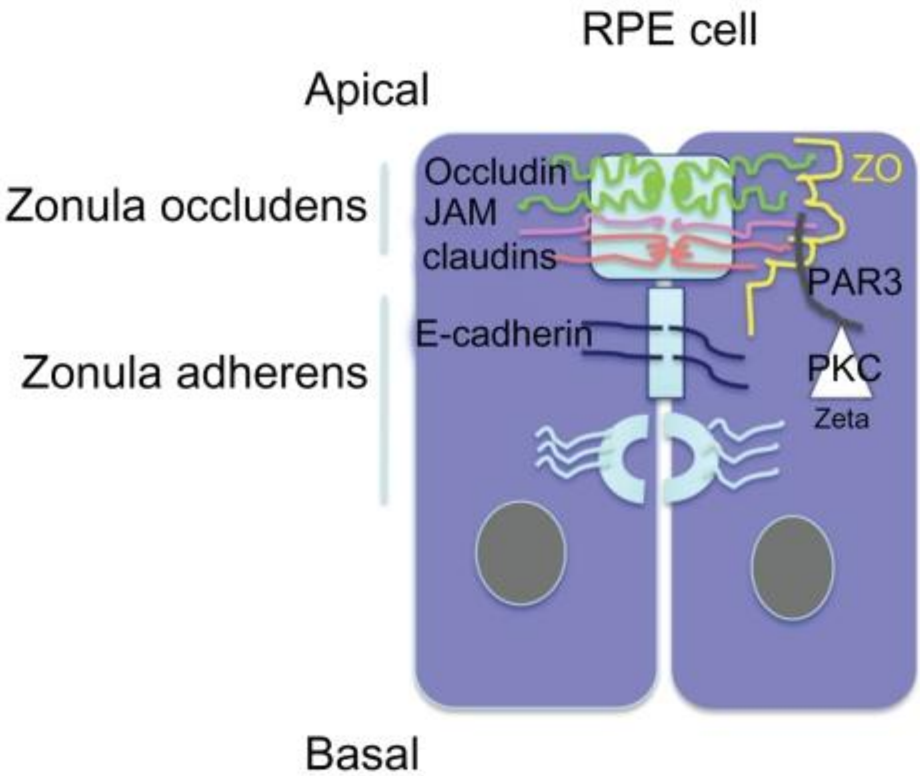
✓ Like other epithelial and endothelial cells, the RPE cells are polarized.
✓ The basal aspect is intricately folded and provides a large surface of attachment to the thin basal lamina that forms the inner layer of the Bruch membrane.



✓ The apices have multiple villous processes that engage with the photoreceptor outer segments.
✓ Separation of the RPE from the neurosensory retina is called retinal detachment

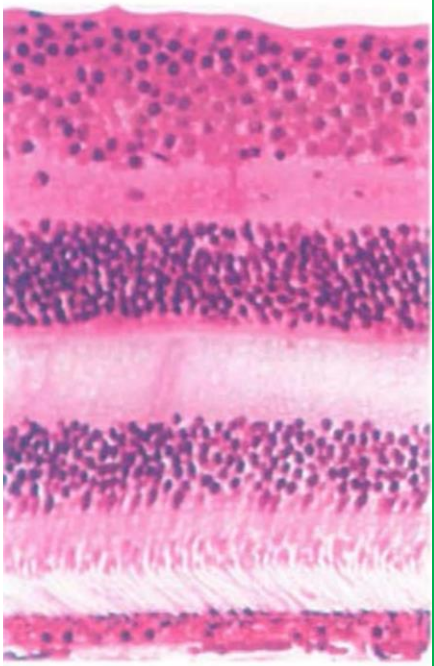
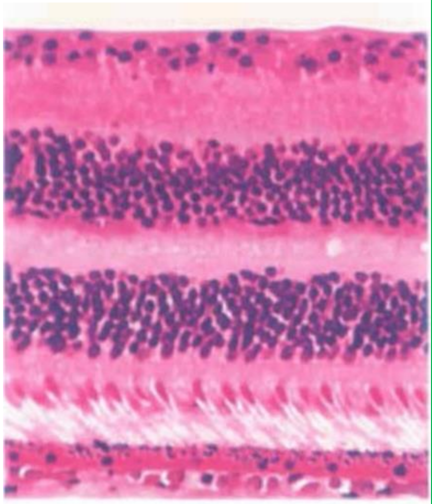
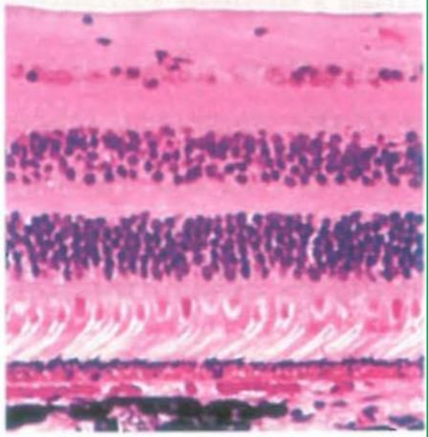


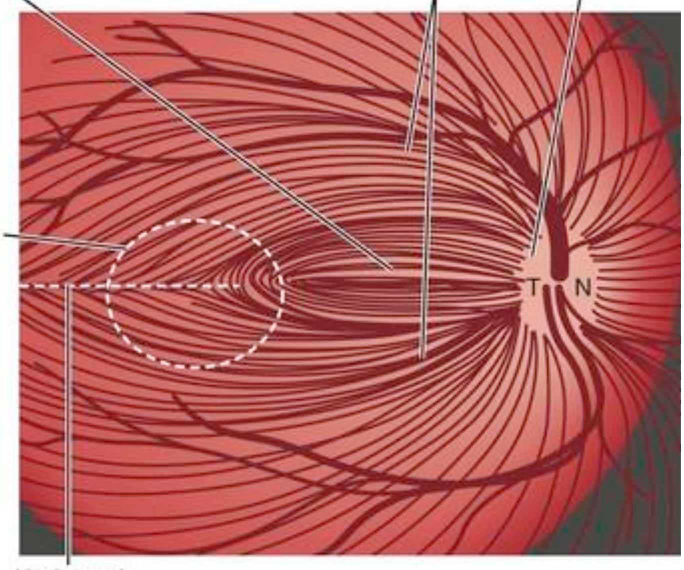
- ✓ Contiguous RPE cells are firmly attached by a series of lateral, intercellular junctional complexes.
- ✓ The zonulae occludentes and zonulae adherentes not only provide structural stability but also play an important role in maintaining the outer blood-retina barrier.



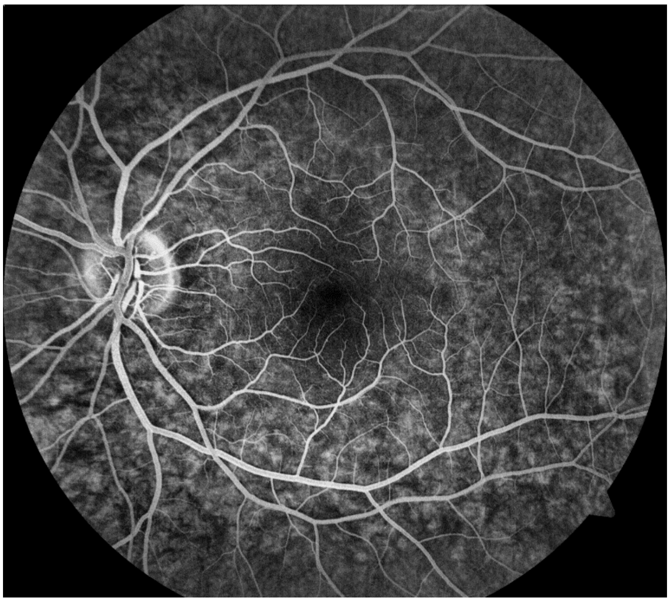
- ✓ Zonulae occludentes consist of fused plasma membranes forming a circular band or belt between adjacent cells.
- ✓ A small intercellular space is present between zonulae adherents

✓ The retina and RPE show important regional differences.

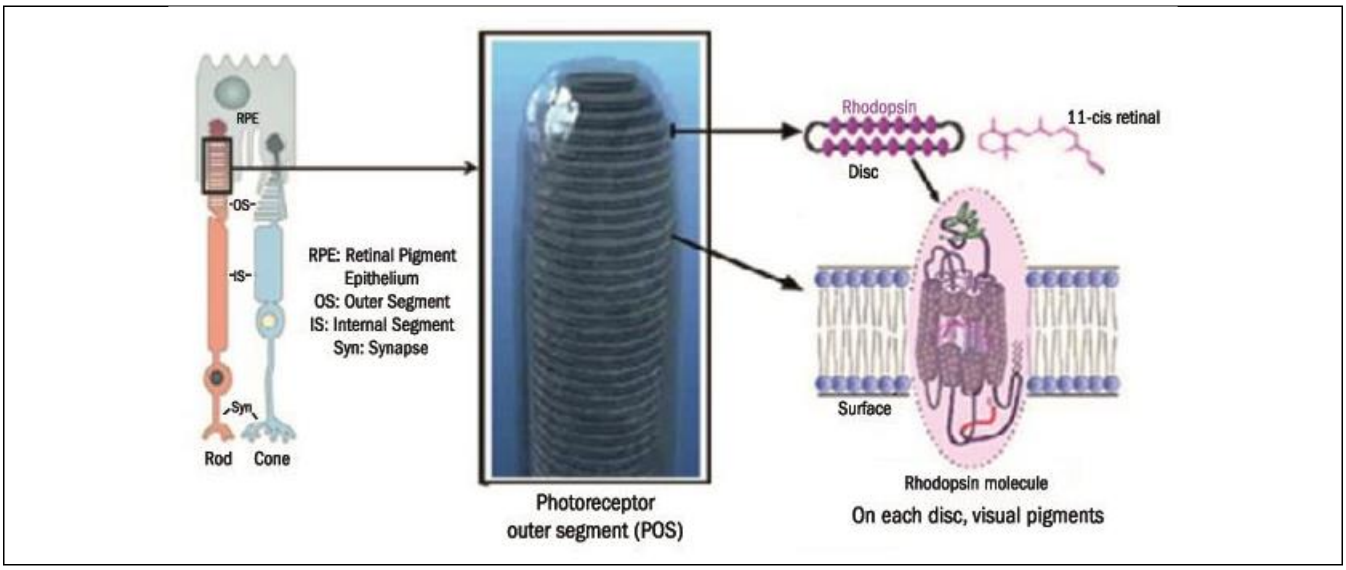
Regional differences in the retina		
Papillomacular bundle	Macula	Peripheral retina
		

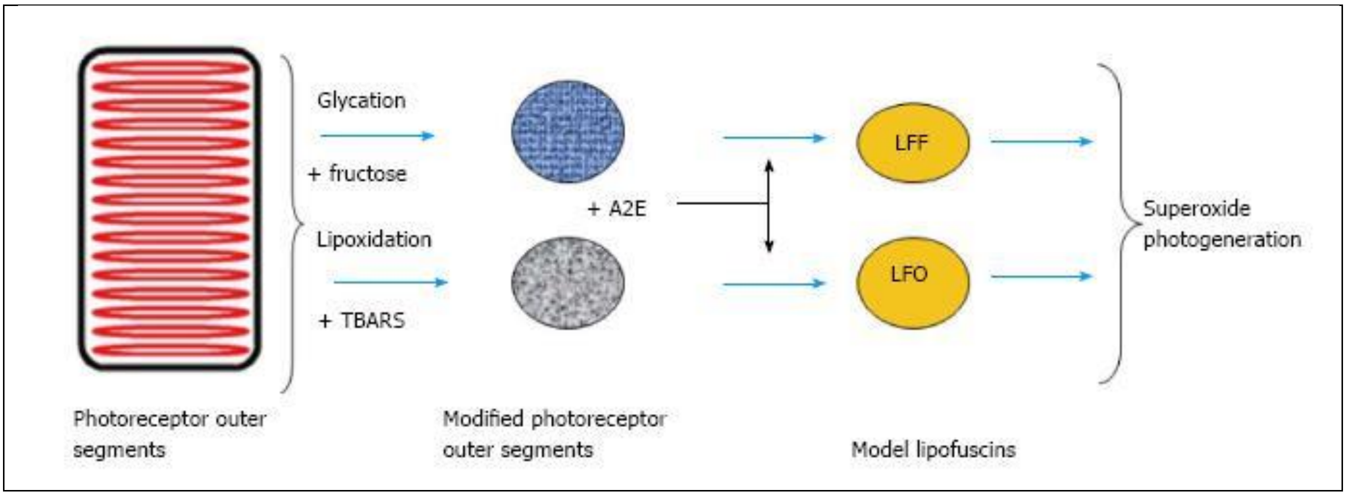


✓ The retina is thickest in the papillomacular bundle near the optic nerve (0.23mm) and thinnest in the foveola (0. 10 mm) and ora serrata (0. 11 mm).
✓ RPE cells vary from 10 to 60 µm in diameter.
✓ Compared with RPE cells in the periphery, RPE cells in the fovea are taller and thinner, contain more melanosomes, and have larger melanosomes. These characteristics account in part for the decreased transmission of choroidal fluorescence observed during fundus fluorescein angiography.



- ✓ Cells in the periphery are shorter, broader, and less pigmented.
- ✓ The eye of a fetus or infant contains between 4 and 6 million RPE cells.
- ✓ Although the surface area of the eye increases appreciably with age, the increase in the number of RPE cells is relatively small.
- ✓ No mitotic figures are apparent within the RPE of the normal adult eye.
- ✓ The cytoplasm of the RPE cells contains multiple round and ovoid pigment granules (melanosomes).
- ✓ These organelles (melanosomes) develop in situ during formation of the optic cup and first appear as nonmelanized premelanosomes.
- ✓ These organelles' development contrasts sharply with that of the pigment granules in uveal melanocytes, which are derived from the neural crest and later migrate into the uvea.
- ✓ Lipofuscin granules probably arise from the discs of photoreceptor outer segments and represent residual bodies arising from phagosomal activity.





- ✓ This so-called wear-and tear pigment is less electron dense than the melanosomes, and its concentration increases gradually with age.
- ✓ Clinically, these lipofuscin granules are responsible for the signal observed with fundus autofluorescence.
- ✓ Phagosomes are membrane-enclosed packets of disc outer segments that have been engulfed by the RPE.

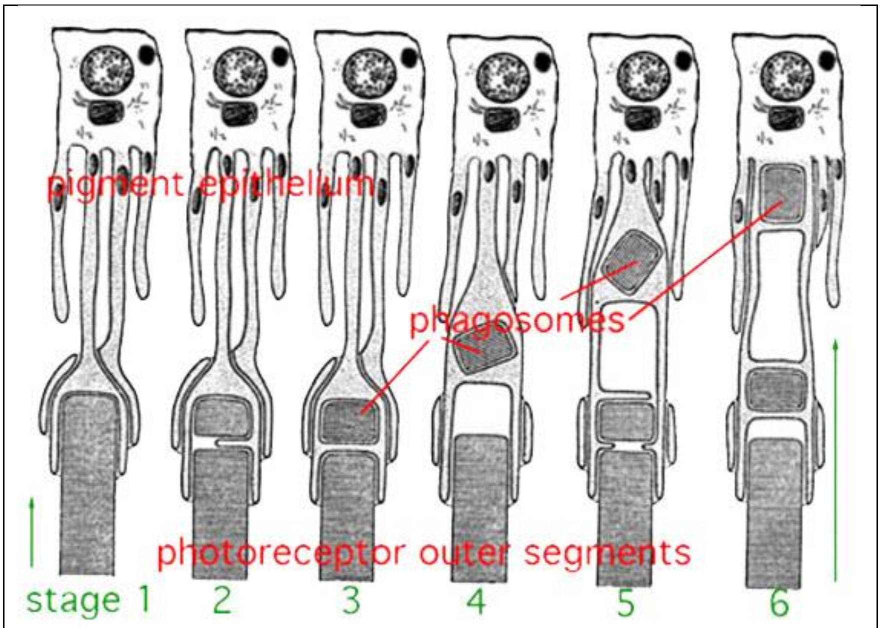
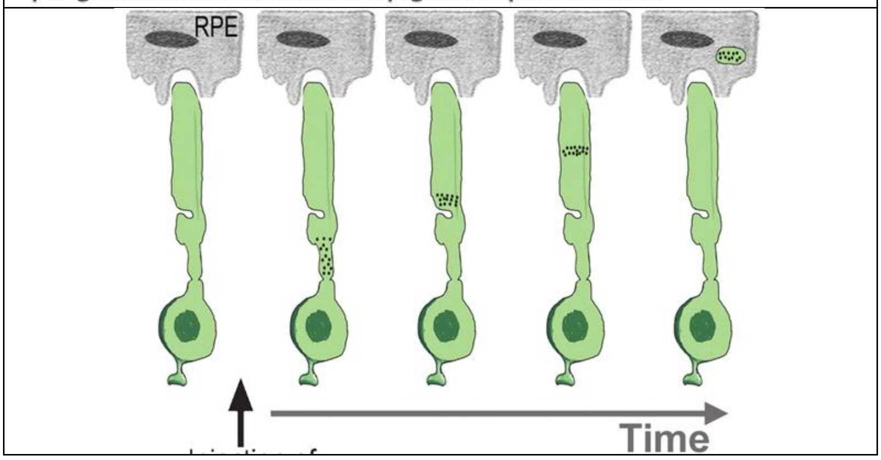
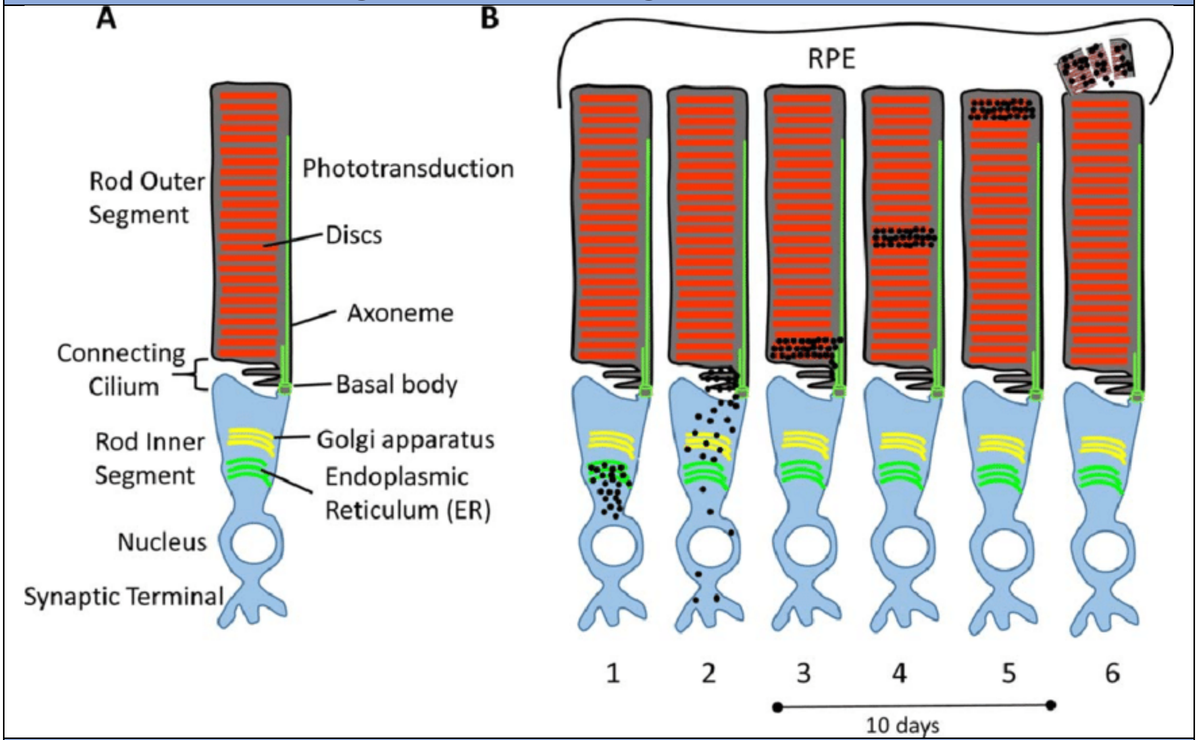


Fig. 12. Diagrammatic representation of disc shedding and phagosome retrieval into the pigment epithelial cell.



✓ Several stages of disintegration are evident at any given time.

Diagram of outer segment renewal



1) Radioactively tagged amino acids are injected into the retina, chased, and labeled proteins accumulate.
2) Autoradiography reveals radioactively tagged proteins moving toward the connecting cilium and incorporated into discs.

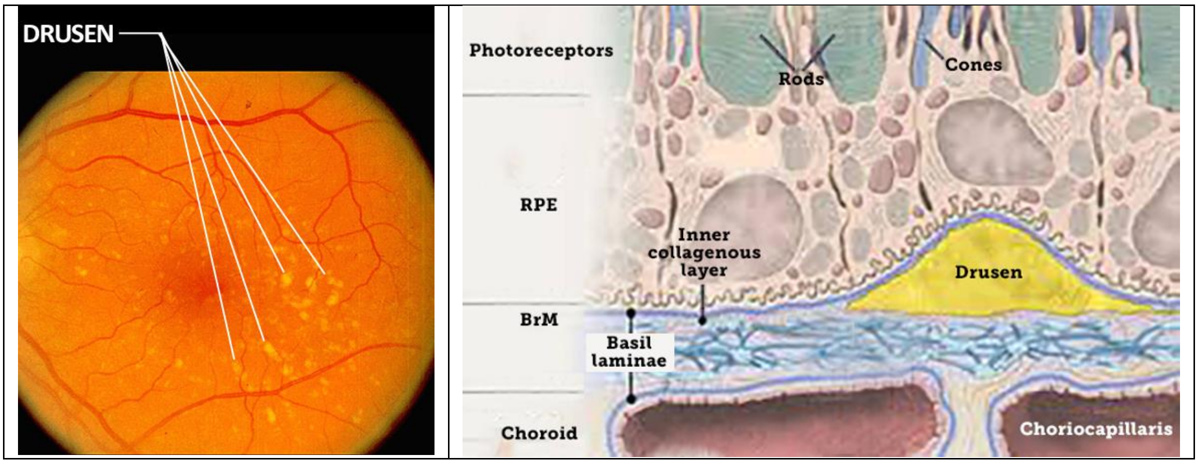
3-5) Bands of labeled discs are displaced distally to the OS tip within 10 days.

6) Labeled discs undergo phagocytosis by the RPE.

✓ In some species, shedding and degradation of the membranes of rod and cone outer segments follow a diurnal rhythm synchronized with daily fluctuations of environmental light.

✓ The cytoplasm of the RPE also contains :
- numerous mitochondria (which are involved in aerobic metabolism)
- rough-surfaced endoplasmic reticulum
- a Golgi apparatus
- and a large round nucleus.

✓ Throughout life, incompletely digested residual bodies, lipofuscin pigment, phagosomes, and other material are excreted beneath the basal lamina of the RPE. These contribute to the formation of drusen, which are accumulations of this extracellular material.

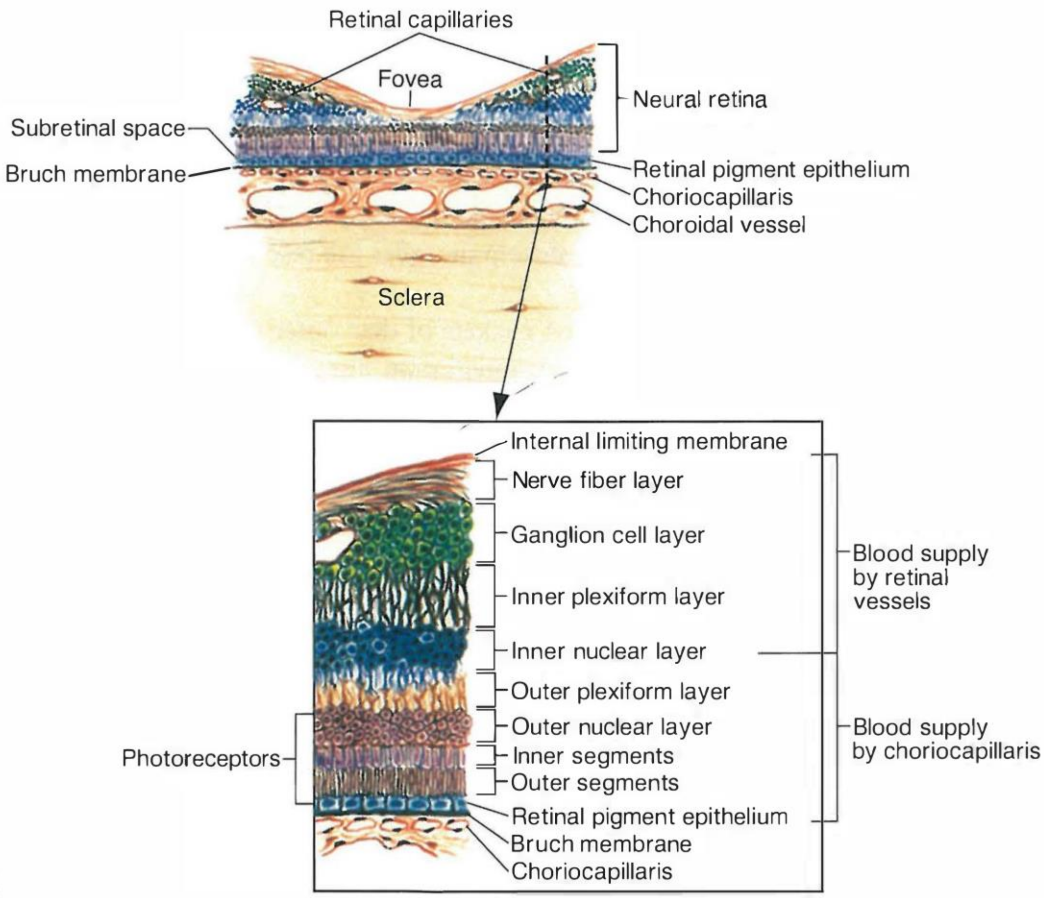


- ✓ Drusen can vary in size and are commonly classified by their funduscopic appearance as either hard or soft.
- ✓ Drusen are typically located between the basement membrane of the RPE cells and the inner collagenous zone of the Bruch membrane.

Neurosensory Retina :

The neurosensory retina is composed of :

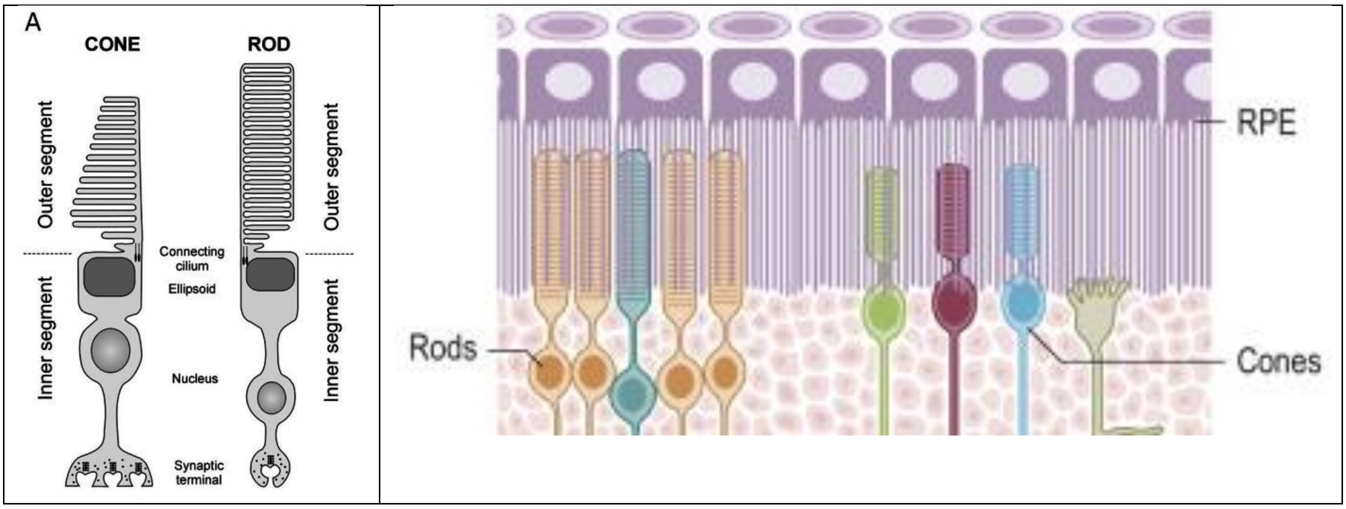
1. Neuronal elements
2. Glial elements
3. and vascular elements



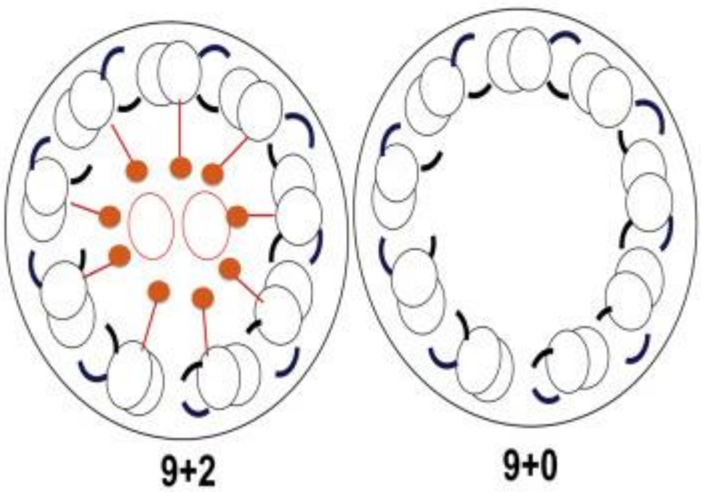
A

i. Neuronal elements :

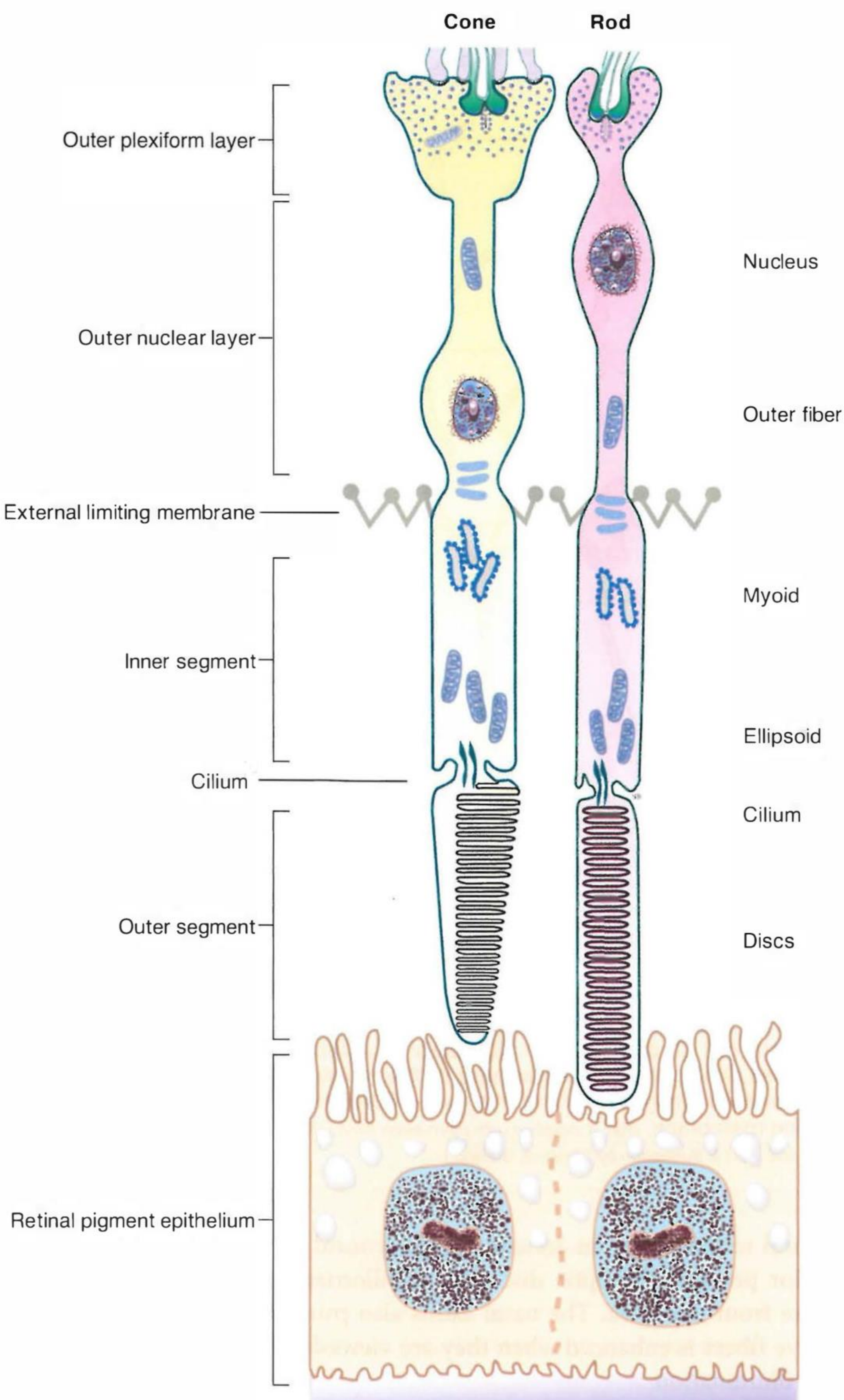
- The photoreceptor layer of the neurosensory retina consists of highly specialized neuroepithelial cells called rods and cones.
- Each photoreceptor cell consists of an outer segment and an inner segment.
- The outer segments, surrounded by a mucopolysaccharide matrix, make contact with the apical processes of the RPE.



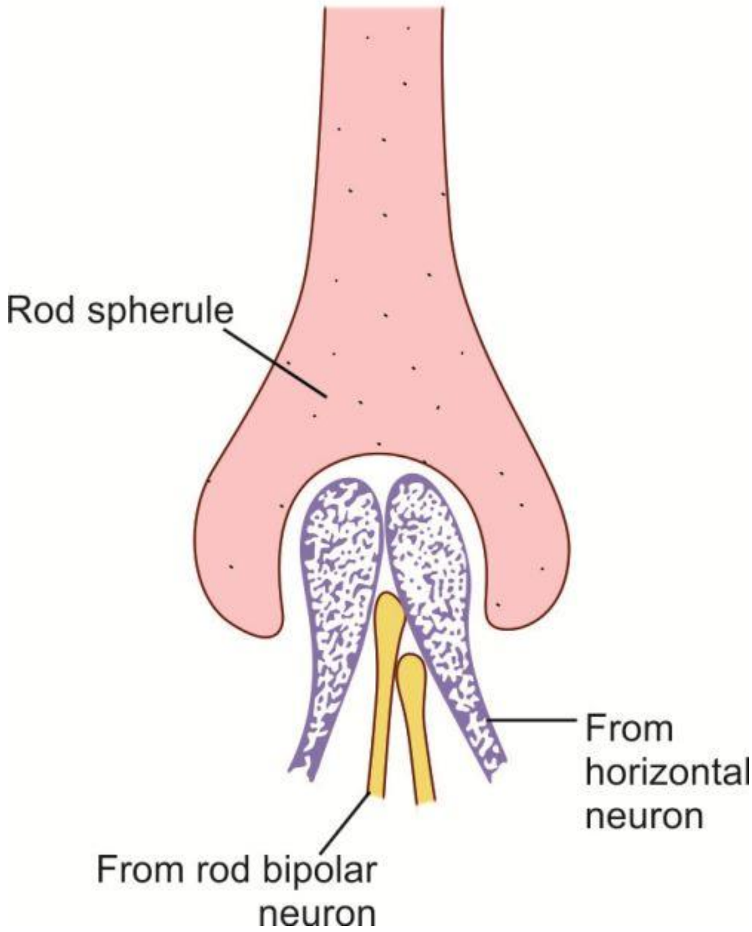
- Tight junctions or other intercellular connections do not exist between the photoreceptor cell outer segments and the RPE.
- The factors responsible for keeping these layers in apposition are poorly understood but probably involve active transport.
- The rod photoreceptor consists of an outer segment that contains multiple laminated discs resembling a stack of coins and a central connecting cilium.
- The microtubules of the cilium have a 9-plus-O cross-sectional configuration rather than the 9-plus-2 configuration found in motile cilia.



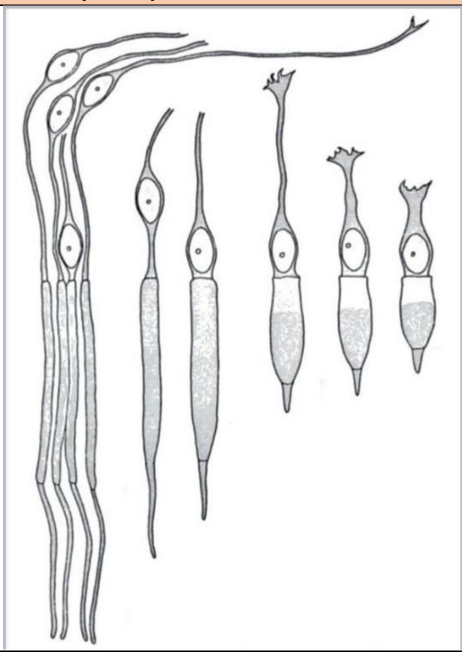
- The rod inner segment is subdivided into two additional elements :
    1) an outer ellipsoid element containing numerous mitochondria
    2) an inner myoid element containing a large amount of glycogen
- the myoid is continuous with the main cell body, where the nucleus is located



- The inner portion of the cell contains the synaptic body, or spherule, of the rod, which is formed by a single invagination that accommodates two horizontal cell processes and one or more central bipolar dendrites.

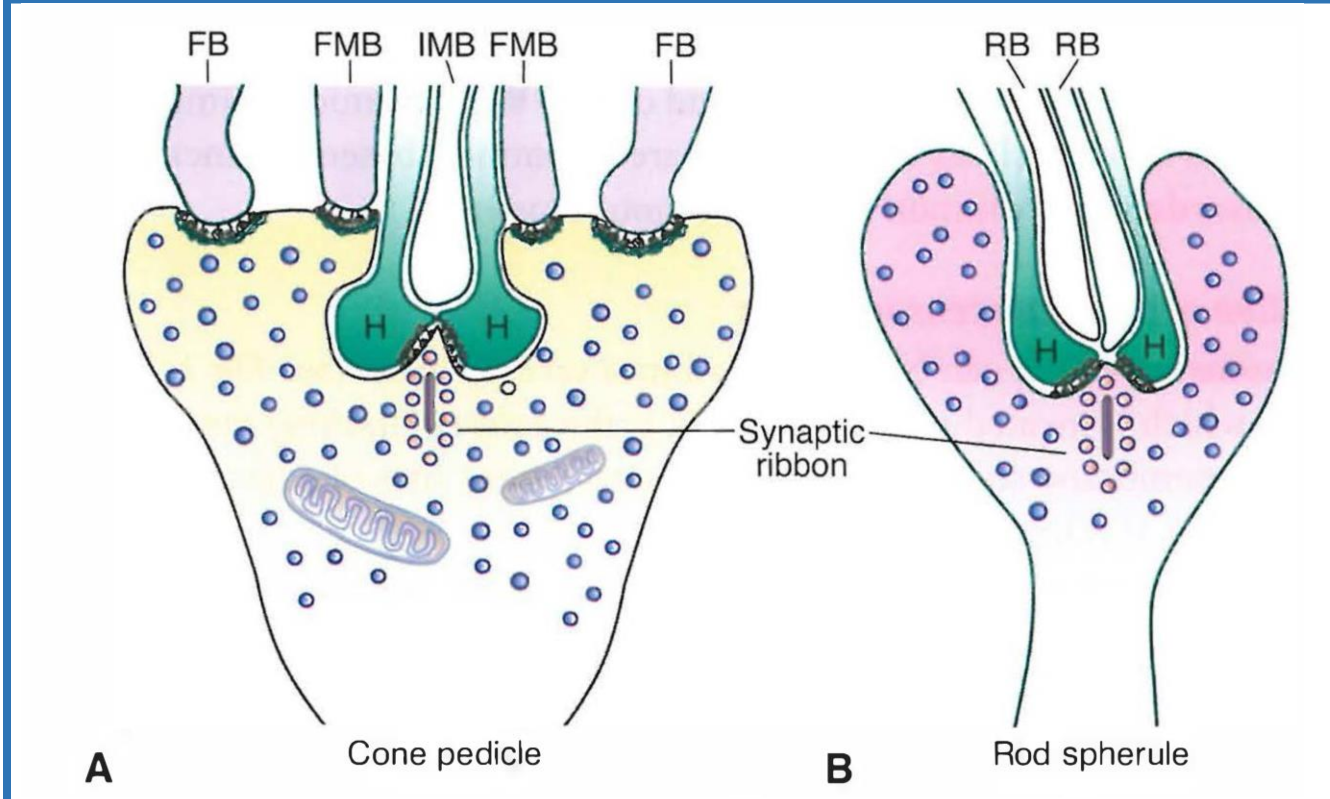


- The outer segments of the cones have a different morphology depending on their location in the retina.

Cone shapes across the retina. Central (Foveal) cones on the left, more peripheral cones towards the right.


- The extrafoveal cone photoreceptors of the retina have conical ellipsoids and myoids, and their nuclei tend to be closer to the external limiting membrane than are the nuclei of the rods.
- Although the structure of the outer segments of the rods and cones is similar, at least one important difference exists.
- Rod discs are not attached to the cell membrane; they are discrete structures.
- Cone discs are attached to the cell membrane and are thought to be renewed by membranous replacement.
- The cone synaptic body, or pedicle, is more complex than the rod spherule.

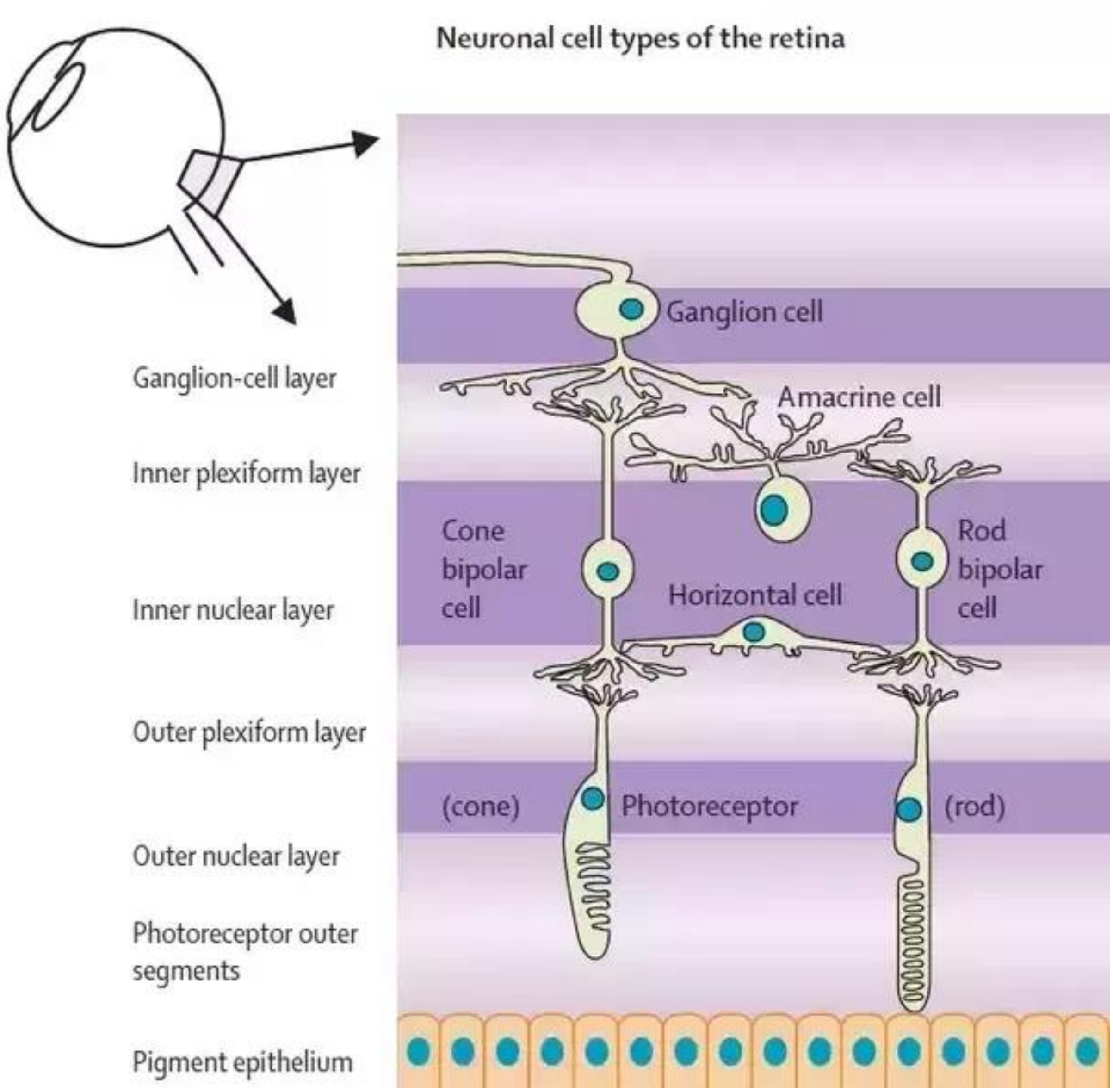
Synaptic bodies of photoreceptors



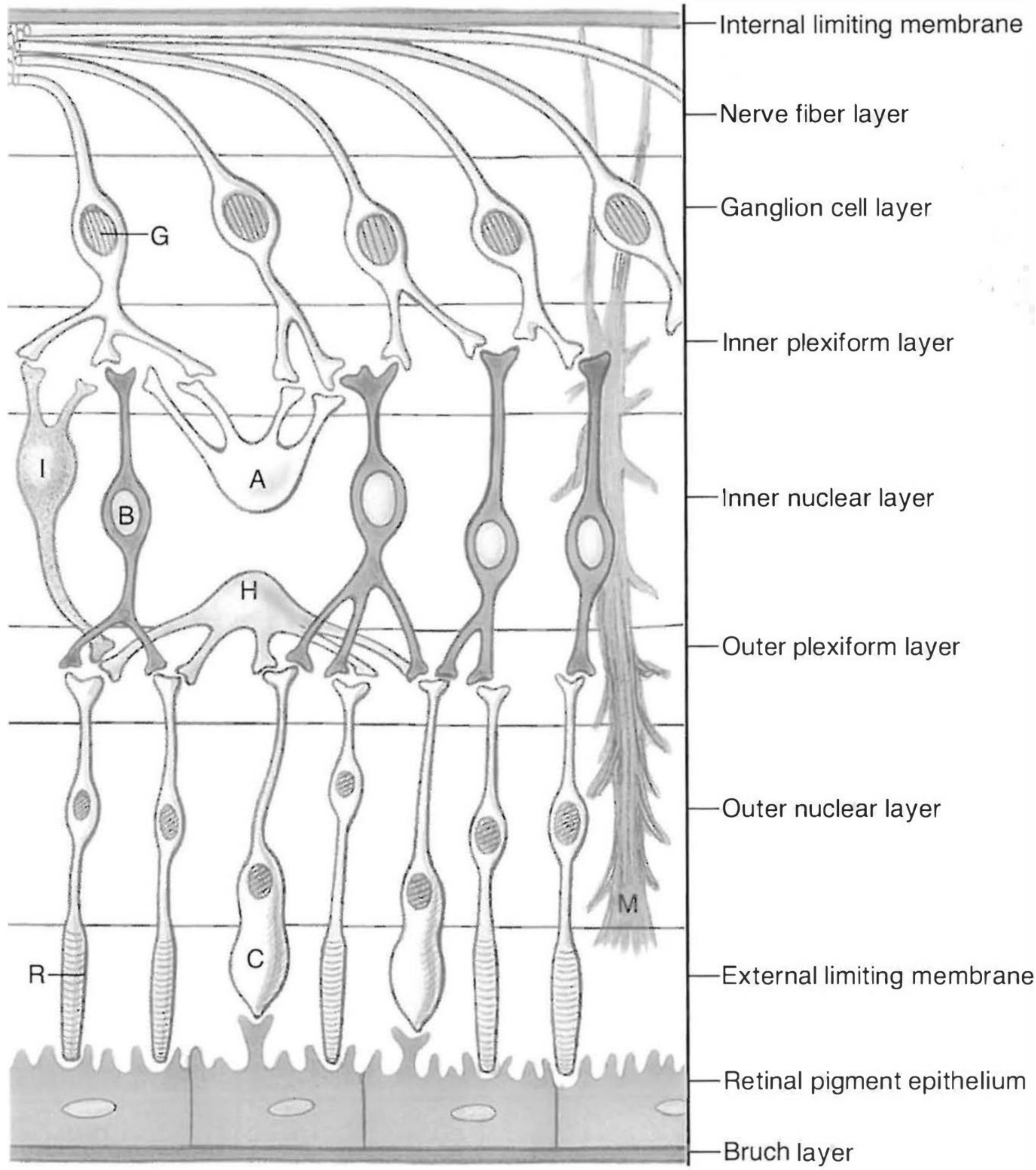
A = Cone pedicle with synapses to several types of bipolar cells.
B = Rod spherule with synapses to bipolar cells.
FB = flat bipolar
FMB = flat midget bipolar
H = horizontal cell processes
IMB = invaginating midget bipolar
RB = rod bipolar.

- Cone pedicles synapse with other rods and cones as well as with horizontal and bipolar cell processes.

- Foveal cones have cylindrical inner segments similar to rods but otherwise are cytologically identical to extrafoveal cones.
- Horizontal cells make synaptic connections with many rod spherules and cone pedicles; they also extend cell processes horizontally throughout the outer plexiform layer.



- Bipolar cells are oriented vertically; their dendrites synapse with either rod or cone synaptic bodies, and their axons make synaptic contact with ganglion cells and amacrine cells in the inner plexiform layer.
- The axons of the ganglion cells bend to become parallel to the inner surface of the retina, where they form the nerve fiber layer and later the axons of the optic nerve.



R	C	B	H	A	I	G
rod	cone	bipolar	horizontal	amacrine	inner plexiform cell	ganglion

Note that the Muller cell (M) extends across almost the whole thickness of the retina; the apical processes of Muller cells form the external limiting membrane; the foot processes of Muller cells partially form the internal limiting membrane

- Each optic nerve has more than 1 million optic nerve fibers.
- The nerve fibers from the temporal retina follow an arcuate course around the macula to enter the superior and inferior poles of the optic disc.
- The papillomacular fibers travel straight to the optic nerve from the fovea.