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Nervous system and Special senses organs

Week 11

CENTRAL NERVOUS SYSTEM

The major structures comprising the CNS are the **cerebrum, cerebellum, and spinal cord.**

Cerebrum

Grey matter consists of **nerve cells, nerve fibers, glia cell and capillaries.**

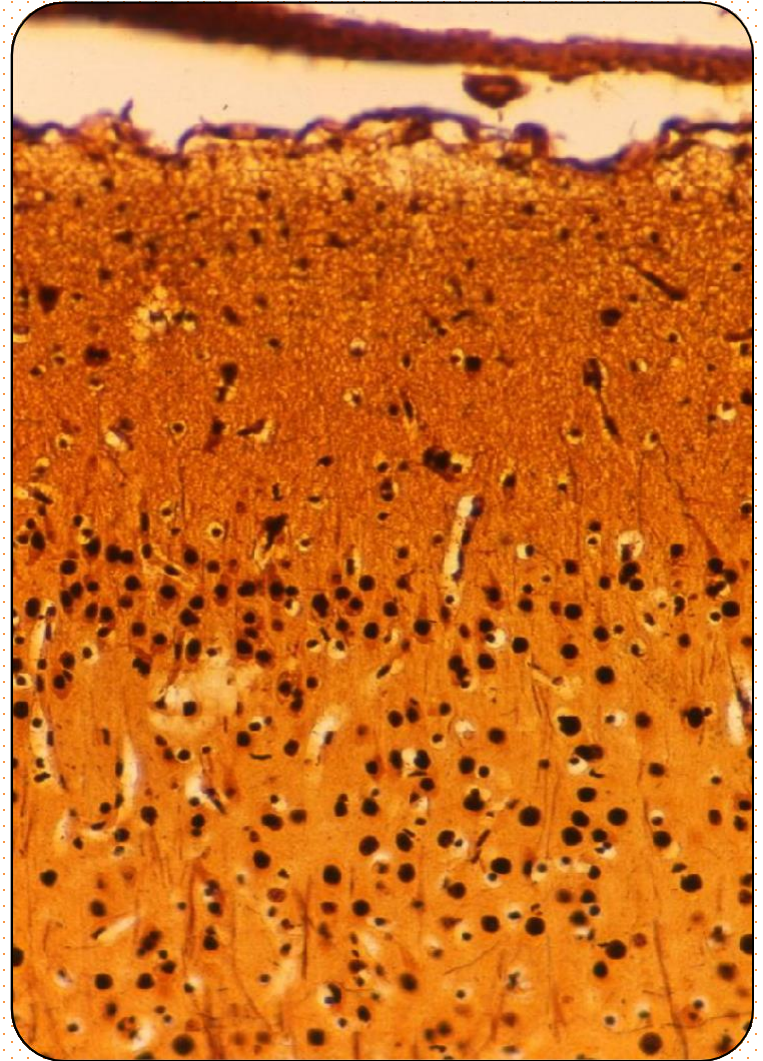
- Neurons in the cortex differ in the shape and size of the perikaryon and in the length, number and orientation of dendrites and axons.

White matter is located under the cortex.

- It consists of **myelinated nerve fibers, glial cells and capillary.**

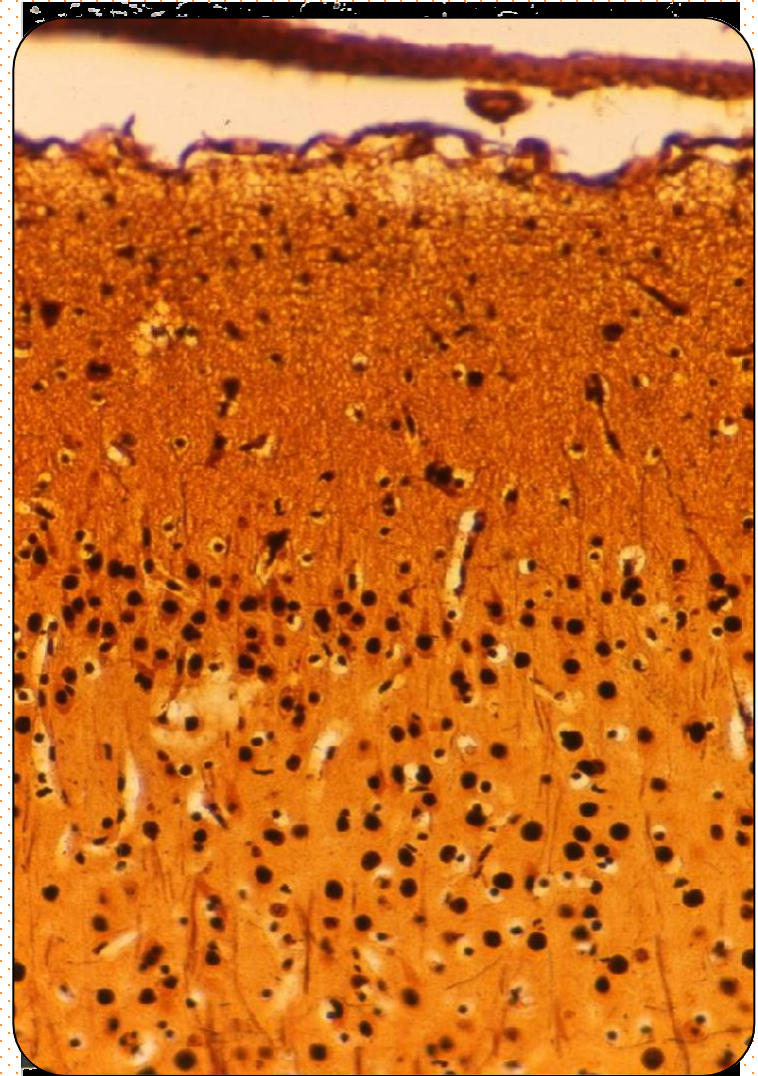
Gray matter neurons

- **Pyramidal cells** - pyramid shape, top towards the surface of the crust; size varies, the largest are the Betz cells in the fifth layer of the cortex (motor zone).
- **Granular) cells** – interneurons, modulatory role, all extensions end in the cortex.
- **Spindle cells** – long dendrites and an axon towards the surface of the brain that gives off horizontal collaterals.
- **Martinotti cells** - polygonal cells with short dendrites and a long axon towards the surface of the brain (they are absent only in the superficial layer of the brain)
- **Horizontal (Cajal) cells** - similar to spindle cells, are found only in the surface layer - synapses with cell extensions from deeper layers.



Cerebral cortex

1. **Lamina molecularis** (plexiformis)
 - Dendrites and axons of neurons from deeper layers and cells of Cajal.
2. **Lamina granularis externa**
 - Stellate (granular) and small pyramidal cells - synapses with axons and dendrites of cells from deeper layers.
3. **Lamina pyramidalis externa**
 - Medium-sized pyramidal cells, with a smaller number of stellate, spindle and Martinotti cells.
4. **Lamina granularis interna**
 - Main receptor layer, stellate cells.
5. **Lamina pyramidalis interna**
 - Large pyramidal cells, in smaller numbers stellate, spindle and Martinotti cells.
6. **Lamina multiformis (polymorphis)**
 - Pyramidal, stellate, spindle and Martinotti cells.

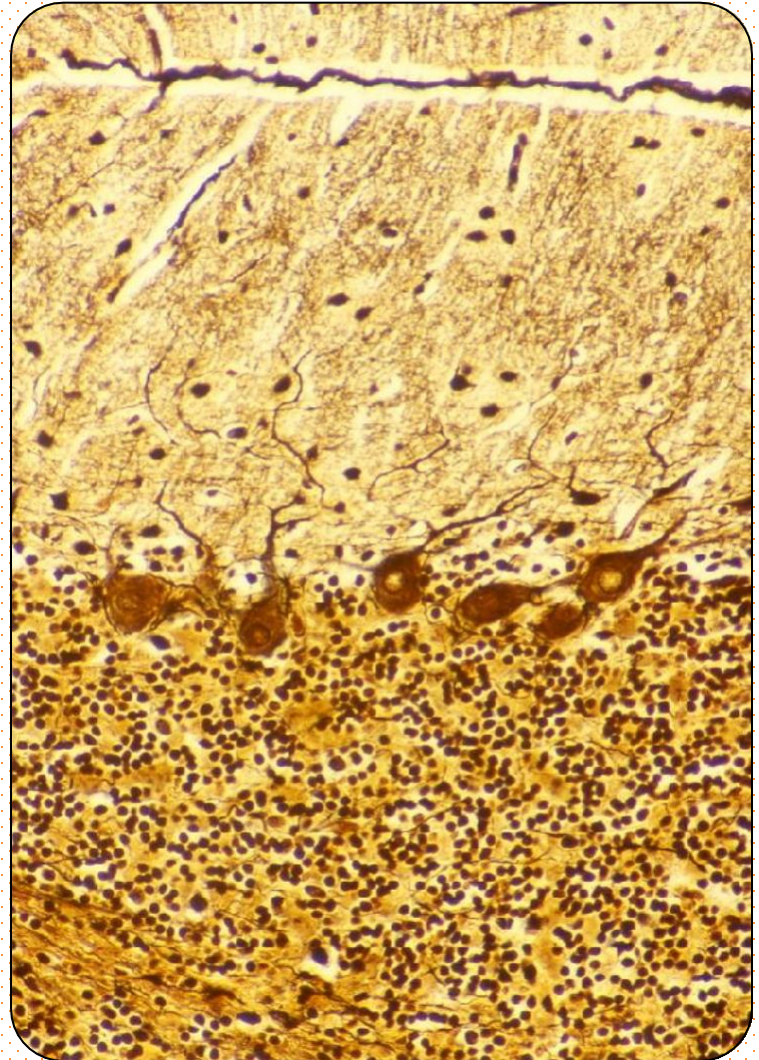


Cerebellum

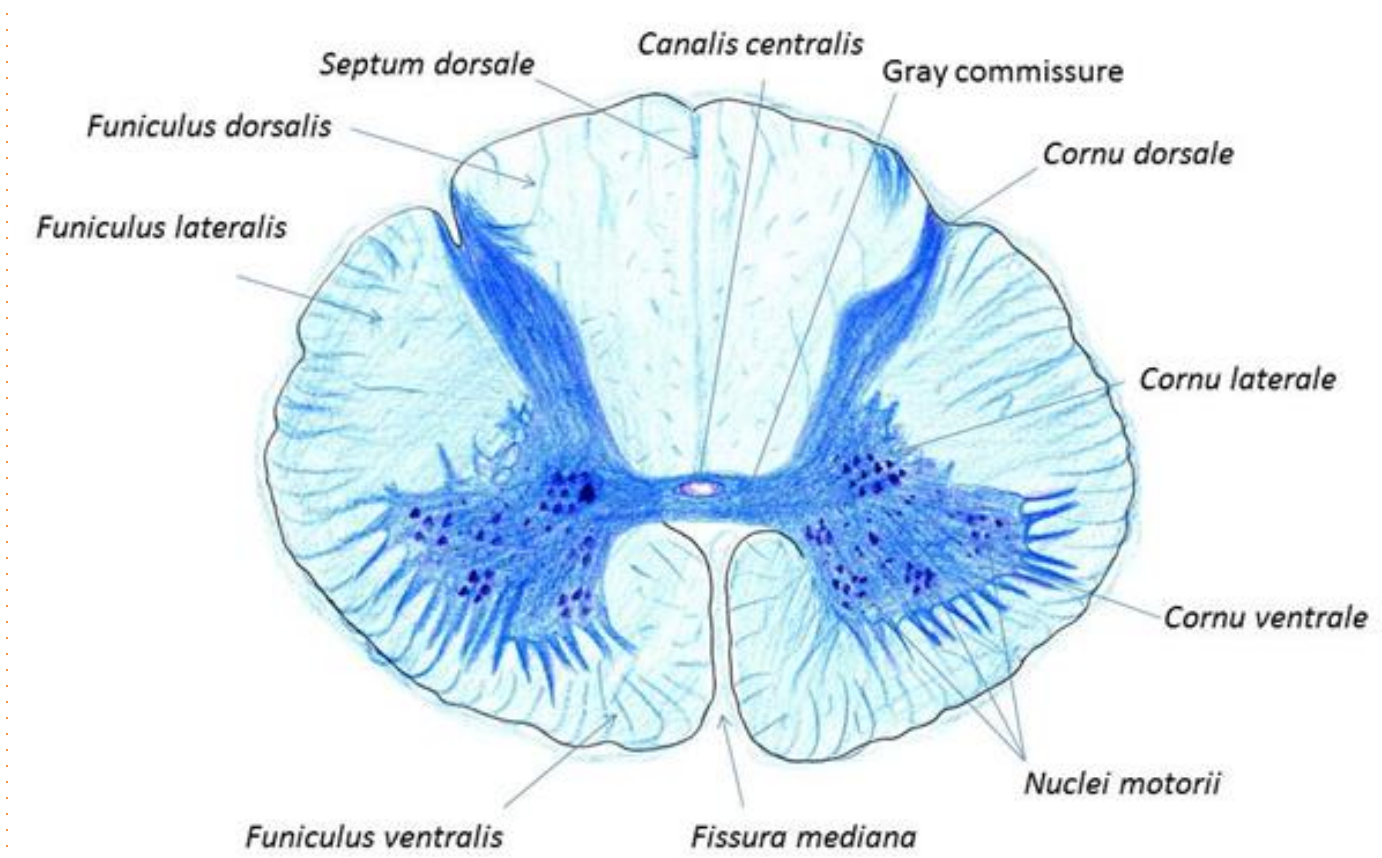


Cerebellar cortex

1. **Molecular layer** - the thickest layer;
 - star-shaped and columnar neurons
2. **Purkinje's neurons** layer;
3. **Stratum granulosum** inner layer;
 - small granule neurons (the smallest cells in the body) and large granule neurons (Golgi type II)

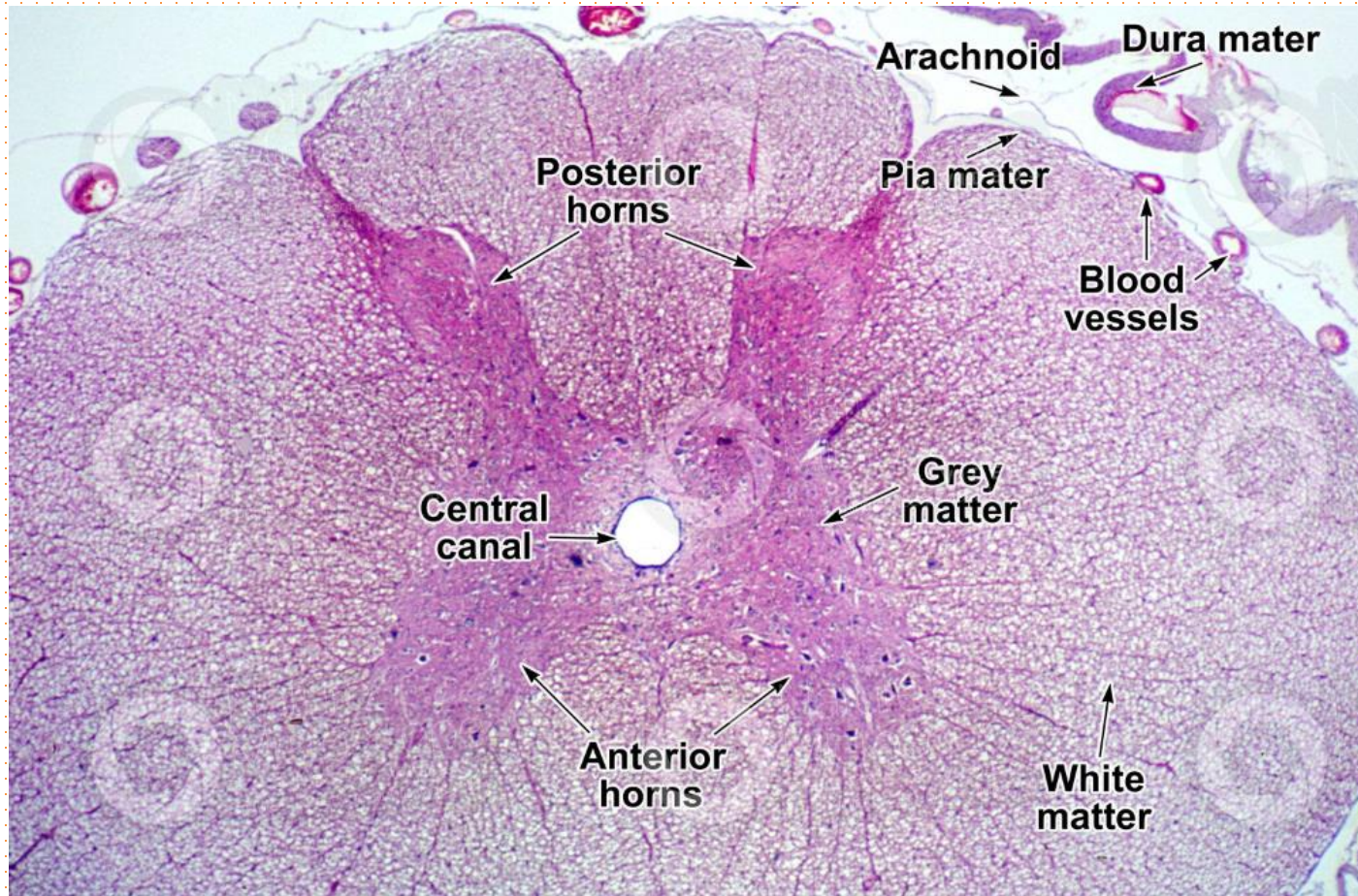


Spinal cord



- **Gray matter** - anterior and posterior horns.
- Anterior horns - multipolar cells - spinal cord motor neurons - axons form the ventral roots of spinal nerves (skeletal musculature)

Medulla spinalis



- Posterior horns - smaller neurons - transmit impulses from the periphery to the CNS.
- Branches of sensitive pseudounipolar neurons of spinal ganglions enter the posterior horns.

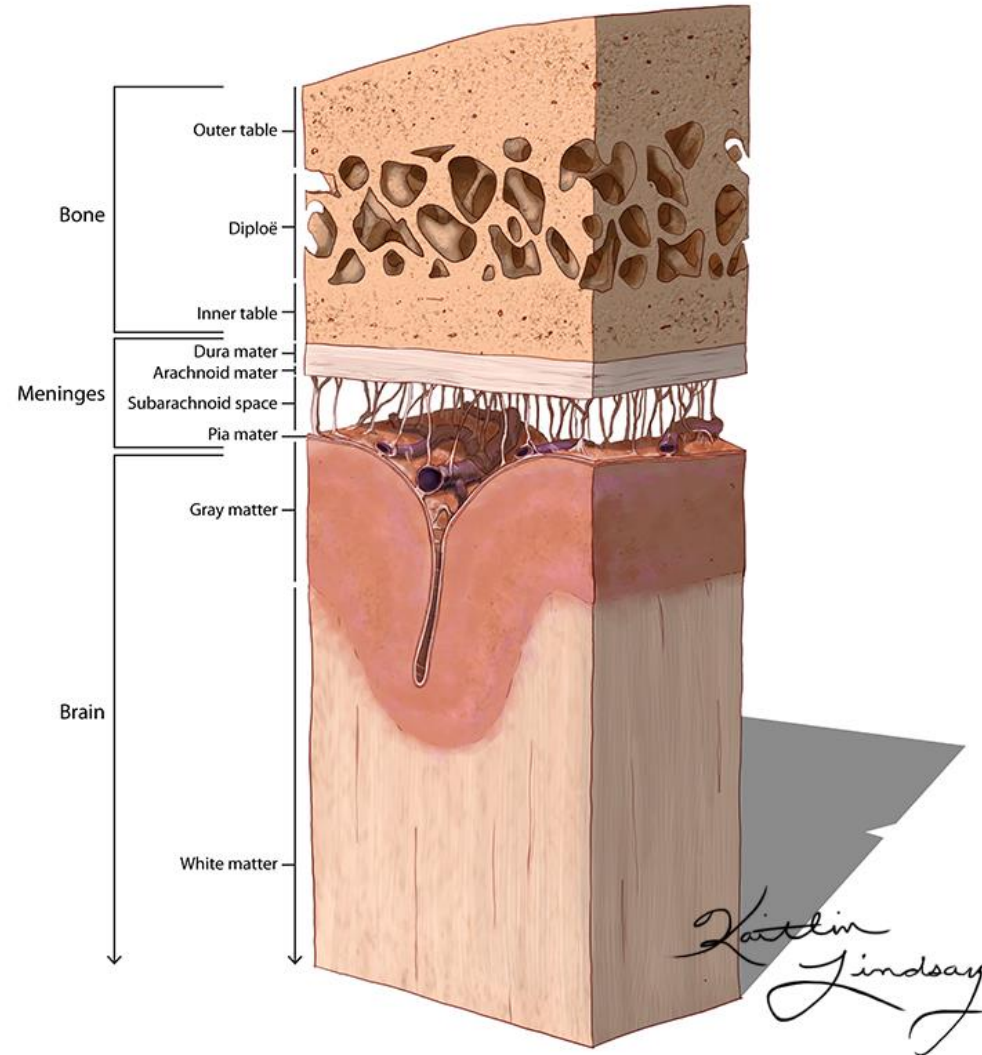
Spinal cord



- **White matter** is made up of ascending and descending tracts and fascicles.
- Ascending and descending pathways and bundles are built of myelinated axons and glial cells.

Meninges

- The skull and the vertebral column protect the CNS, but between the bone and nervous tissue are membranes of connective tissue called the meninges. Three meningeal layers are distinguished: **the dura, arachnoid, and pia mater.**



Dura

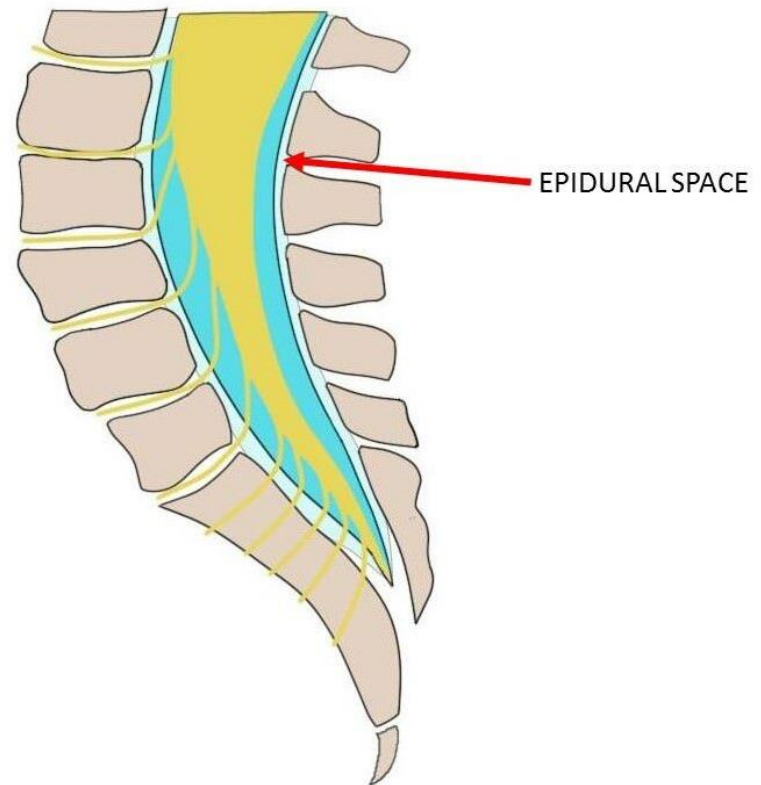
- The dura continues on the epineurium of the peripheral nerves.
- The thickest and toughest covering of the CNS.
- In the cranium, it adheres to the periosteum of the skull, in the spinal canal to the periosteum of the vertebrae.
- It is composed of irregularly distributed **bundles of collagen fibers, fibroblasts, blood vessels and nerve bundles**.
- In the spinal canal, the dura **is single-layered**, in the skull, it is **two-layered**.
- **The two layers are separated only in the area of the venous sinuses of the dura.**
- On the inside, the dura is covered with an incomplete layer of mesothelial cells - the **meningothelium** (they cover both the arachnoid and the pial).

Between the dura and the arachnoid is the subdural space.



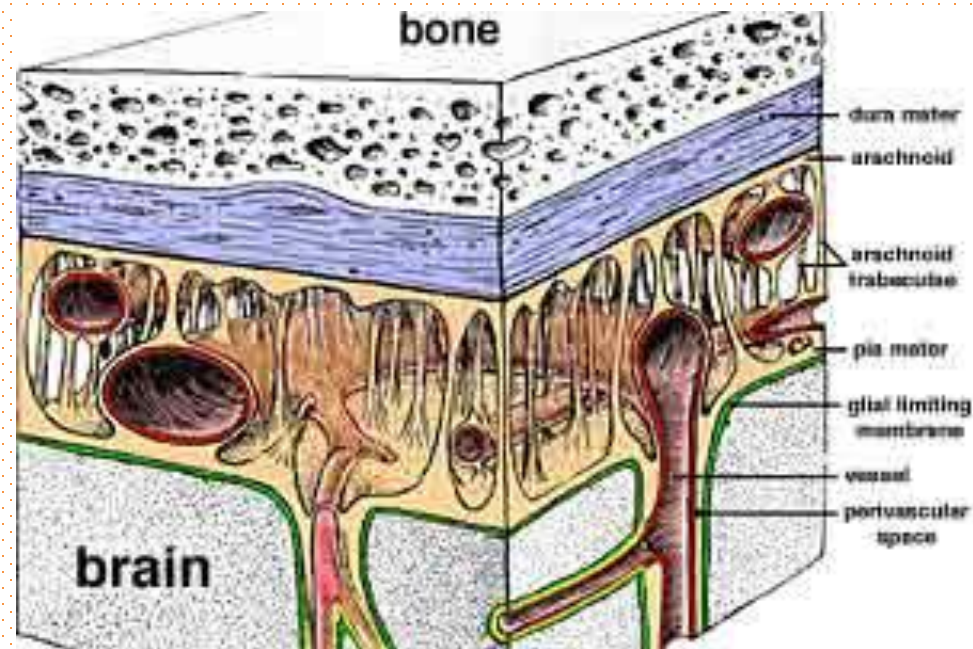
Dura mater

- The **spinal dura** has **one layer** (it corresponds to the inner layer of the cerebral dura, it has more elastic fibers)
- Between the spinal dura and the periosteum of the SPINE exists narrowly **epidural space**.
- The epidural space is filled with loose connective tissue, anastomosing thin veins and fat cells.
- To the arachnoid - subdural space.



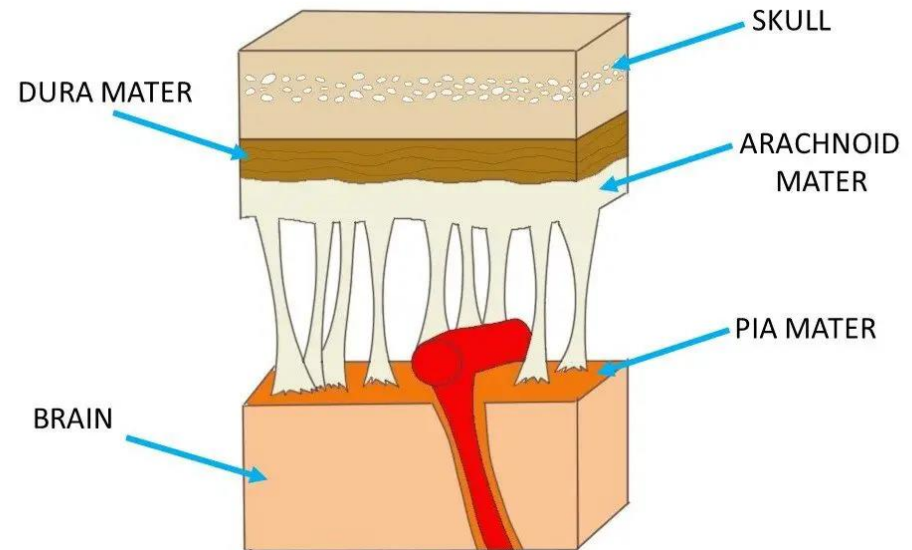
Arachnoid

- The middle meninge often associated with pia in the complex **pia-arachnoidea or leptomeninx.**
 - Arachnoidea is located under the dura, from which it is separated by the **subdural space.**
 - Both sides of the subdural space are lined by **meningothelium.**
- Has two components:
- sheet of connective tissue in contact with the dura mater
 - a system of loosely arranged trabeculae composed of collagen and fibroblasts



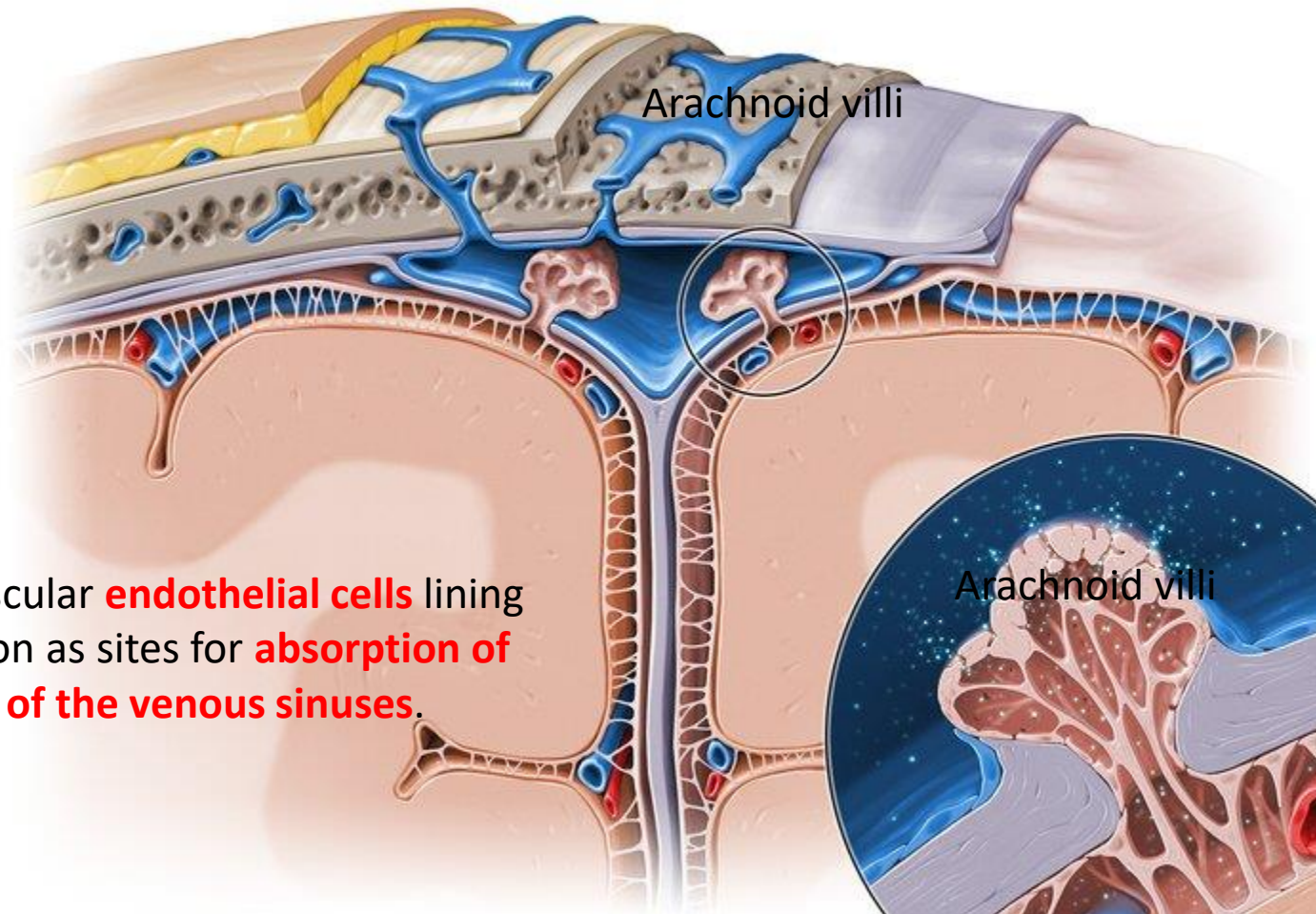
Arachnoid

- **Arachnoid membrane** is thin plate (roof) – 5-6 layers of dense fibroblasts (they prevent spillage of CSF in subdural space).
- **Trabeculae** - from the arachnoid membrane a network of trabeculae that attach to the upper surface of the pia mater.
- The space between the arachnoid membrane and the upper surface of the pia mater is called the **subarachnoid space**.
- Trabeculae – collagen fibers covered with meningotheilium.



Arachnoid

- Subarachnoid space it is filled with cerebrospinal fluid.
- Nerves and the main arteries and veins of the brain, lined with meningotheilium, pass through it.
- Arachnoidea does not extend into the sulci of the brain - in those places is the subarachnoid space expanded - subarachnoid cisterns.
- **Arachnoid villi** grow from the outer surface of the arachnoid - penetrates the dura mater and protrudes into blood-filled dura venous sinuses located there.



Covered by the vascular **endothelial cells** lining the sinuses, function as sites for **absorption of CSF into the blood of the venous sinuses**.

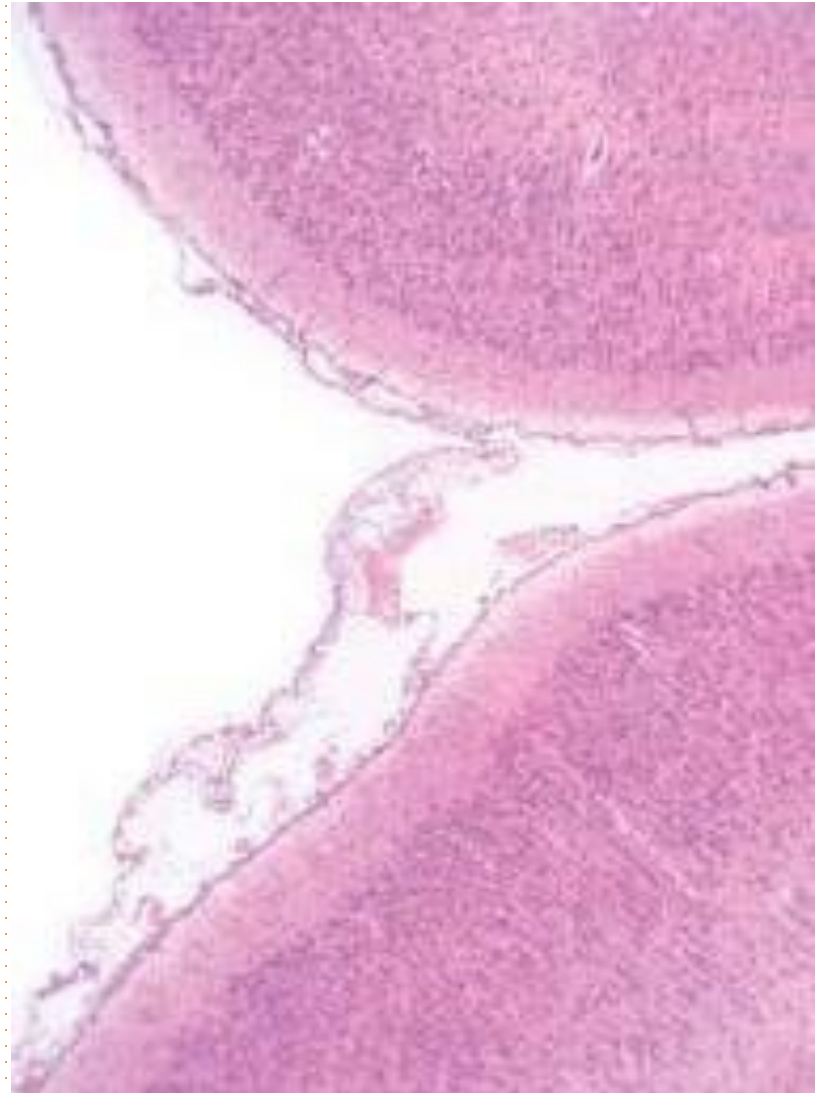
Pia mater

Tender mother

- Directly rests on the brain following its contours.
- It is separated from the nerve cells and fibers of the brain by the basal lamina and the **glial limiting membrane**, (foot-like extensions of astrocytes).

The pia mater is composed of **two layers**.

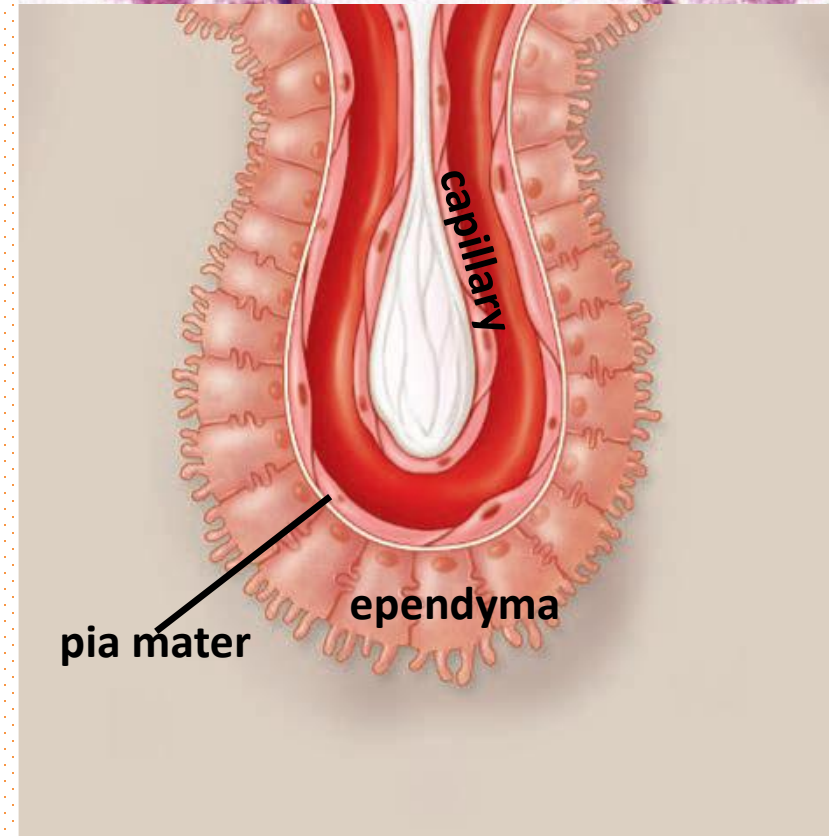
- **Epipial layer** is more superficial and contiguous with the arachnoid trabeculae
- **Inner layer**, the **intima pia**, is adherent to the adjacent neural tissue



Choroid plexus

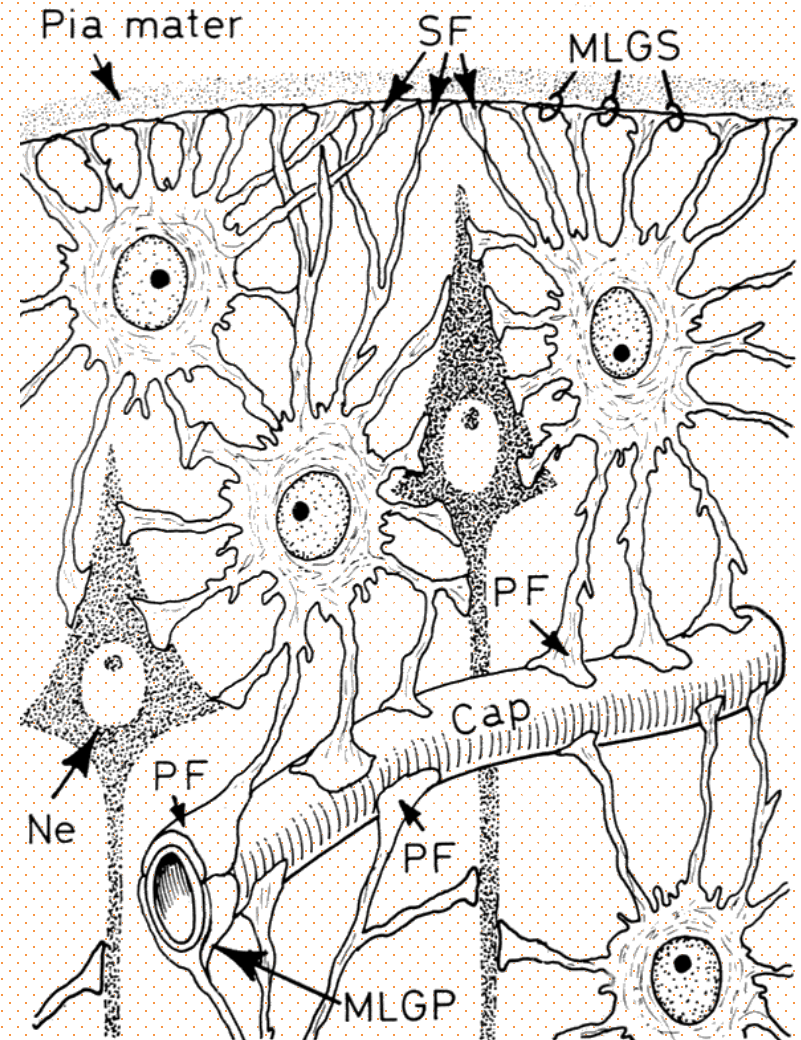
- It secretes **cerebrospinal fluid**.
- Extensions protrude into the ventricular cavities from the roof of the III and IV chambers, as well as from parts of the walls of the lateral chambers.
- Well-vascularized connective tissue covered with a single-layered epithelium - modified ependyma.
- The epithelium consists of a single row of cuboidal or low-cylindrical cells with a rounded top that are connected by occlusive and adherent zonules.
- Apical surface - microvilli; basal - basal labyrinth.
- Above the epithelium are macrophages.

Cerebrospinal fluid is produced by selective ultrafiltration of capillary filtrate through the epithelium of the choroid plexus.



Blood-brain barrier

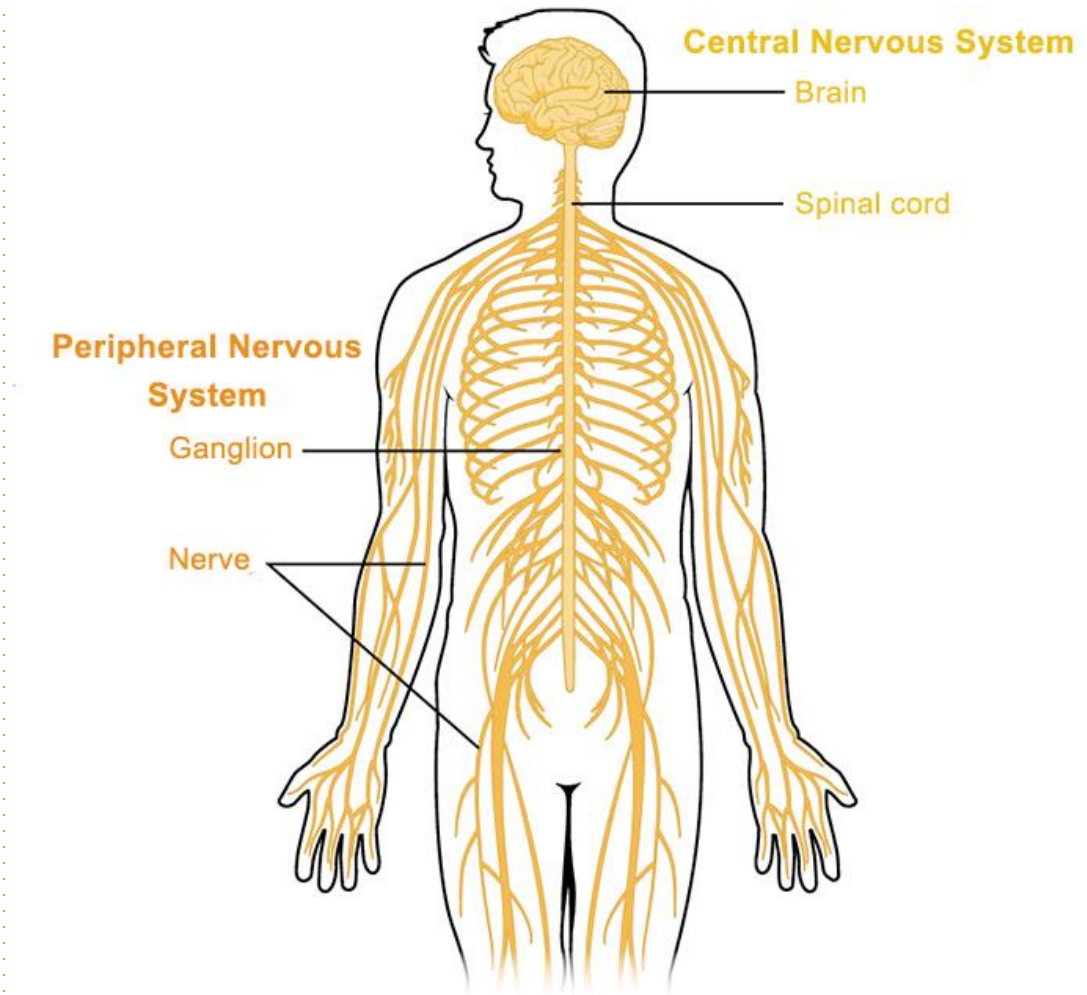
- **Blood-brain barrier** is a functional barrier that allows much tighter control than that in most tissues over the passage of substances moving from blood into the CNS.
- Граде је три компоненте:
 - **Capillary endothelium**
 - **Basal lamina**
 - **Perivascular limiting layer of astrocytic feet**



Peripheral nervous system

Peripheral nervous system

- It is located outside the glial limiting membrane.
- It includes
 - **nerves,**
 - **ganglia**
 - **nerve endings**
- It is in continuity with the central nervous system



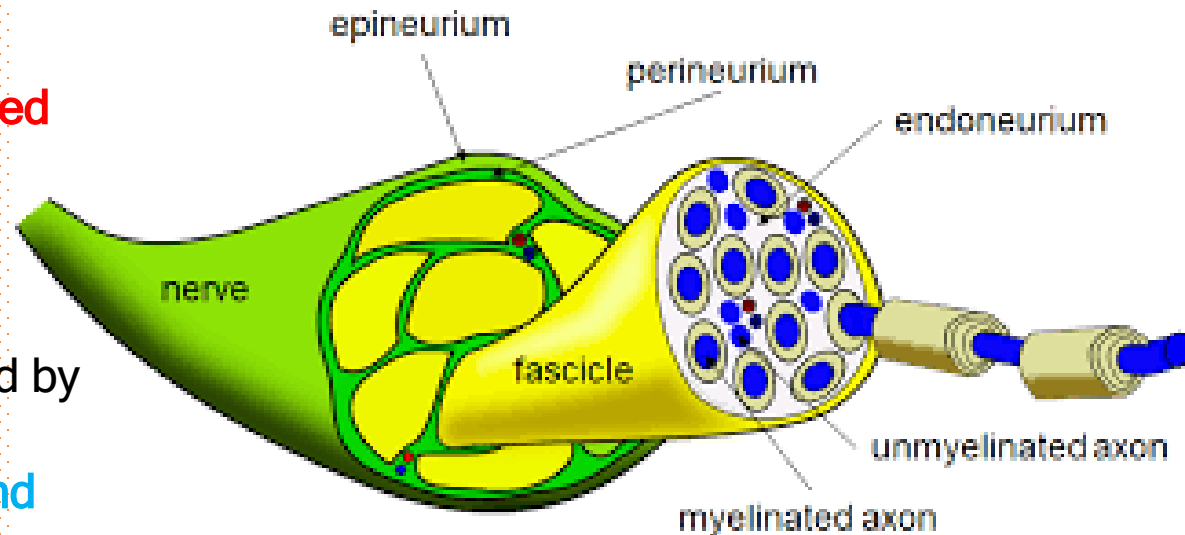
Nerves

- They are built by axon bundles (fascicles).

Nerve fibers can be:

- **Myelinated and unmyelinated**
- **Afferent and efferent**
- **Motor and sensory**

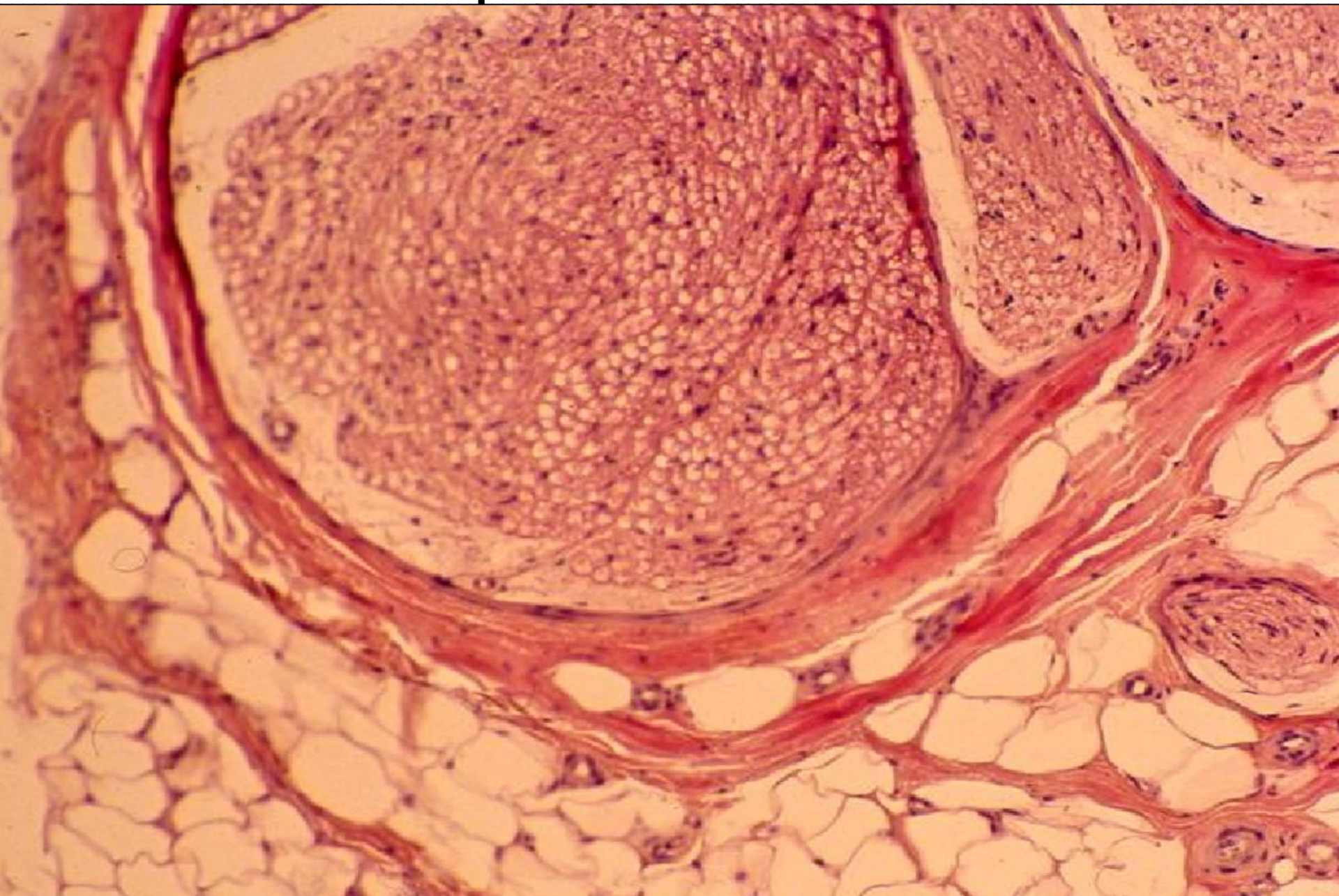
- Nerve fibers are surrounded by three connective sheaths: **epineurium, perineurium and endoneurium**.



Epineurium

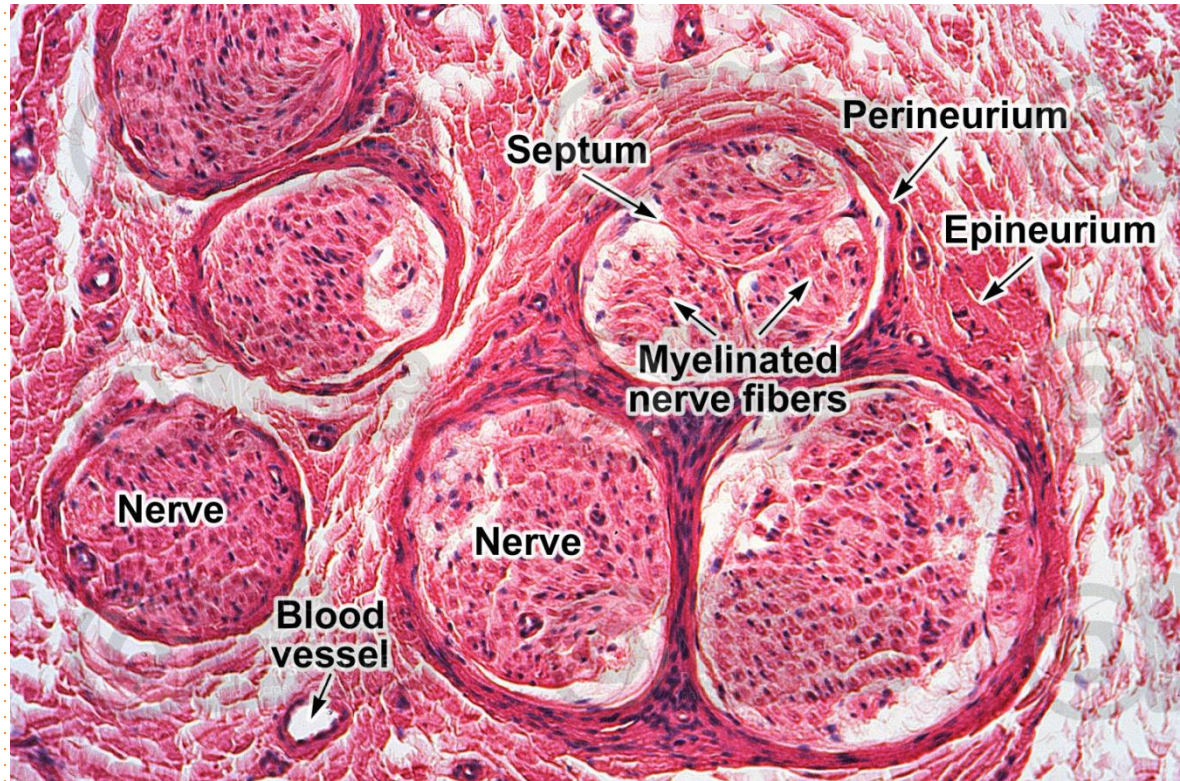
- Dense, irregular fibrous coat called the **epineurium**, which extends deeply to fill the space between fascicles.
- It unites nerve bundles into one.
- It contains wavy collagen fibers, blood and lymph vessels and fat cells.





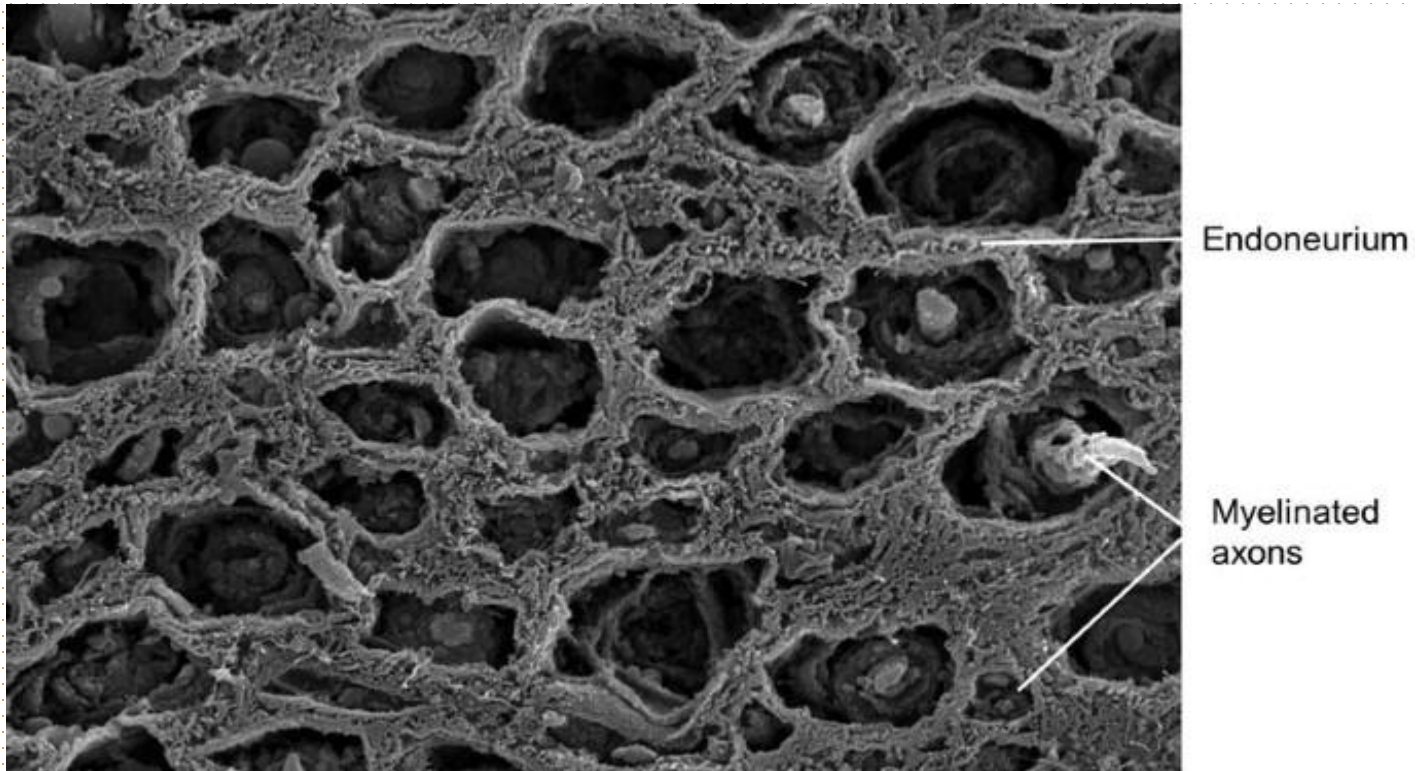
Perineurium

- Each fasciculus within the peripheral nerve has its own sheath - **perineurium**.
- Contains **flat fibrocytes** sealed together by tight junctions. Several layers of these unique connective tissue cells with capillary wall makes **blood-nerve barrier**.
- Cells contain microfilaments and dense bodies.
- Connective tissue consists of collagen fibers without fibrocytes.



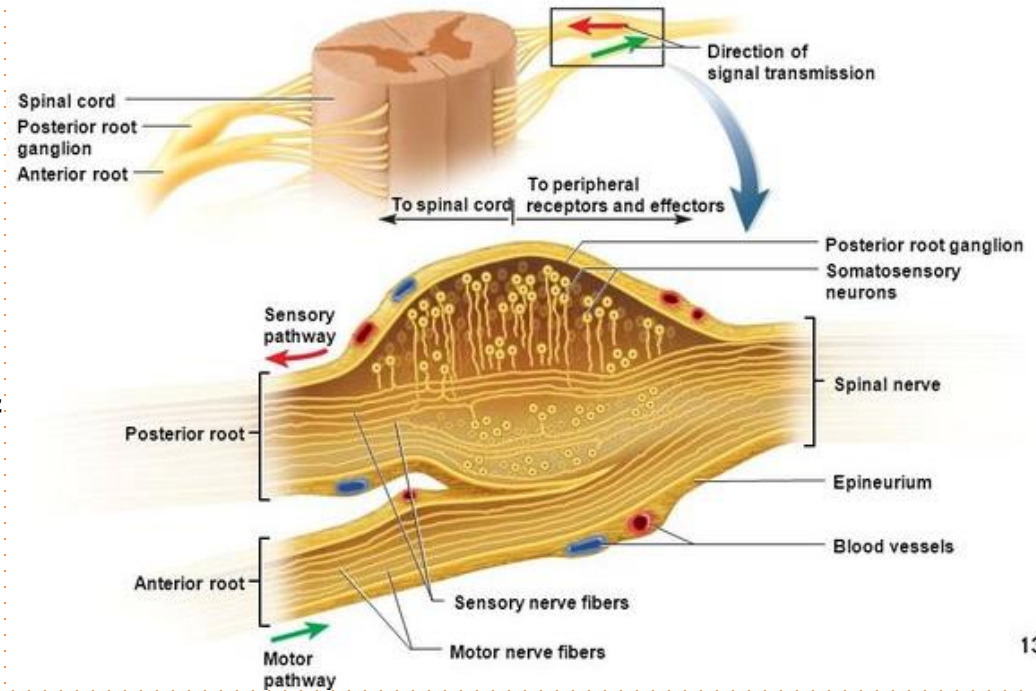
Endoneurium

- Immediately around the external lamina of the Schwann cells is a thin layer called the **endoneurium**
- Reticular fibers, scattered fibroblasts, and capillaries.
- The endoneurium is weakly vascularized, so metabolism is based on exchange via perineurium.



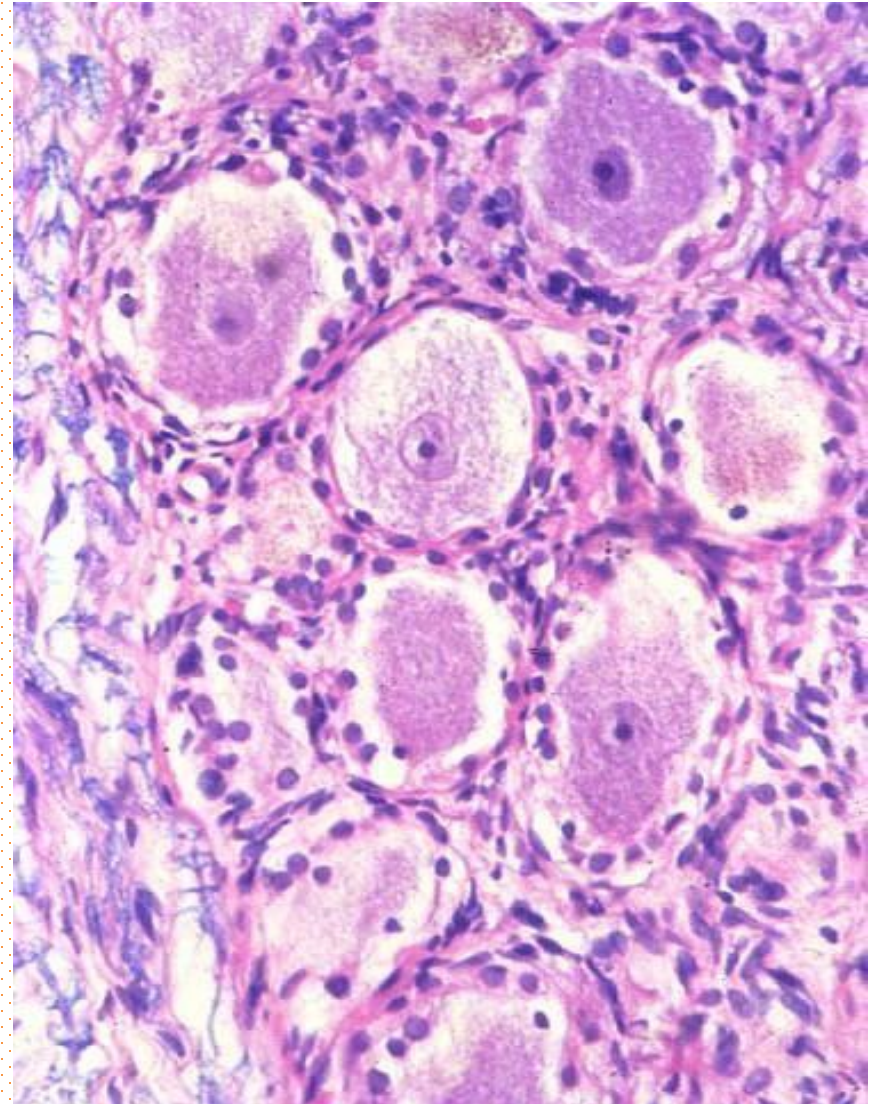
Ganglia

- Nerve cell bodies outside the CNS can group together to form **ganglia**.
- Ganglia stand in the way of peripheral nerves.
- According to histological organization, they are divided into **sensory and autonomic** (vegetative) ganglia.
- **Sensory ganglia** include ganglia of **spinal nerves** (spinal ganglia) and ganglia of **brain nerves** (cerebral ganglia).
- **Autonomic ganglia** belong to the ANS and include **sympathetic** and **parasympathetic** ganglia (no significant histological differences)



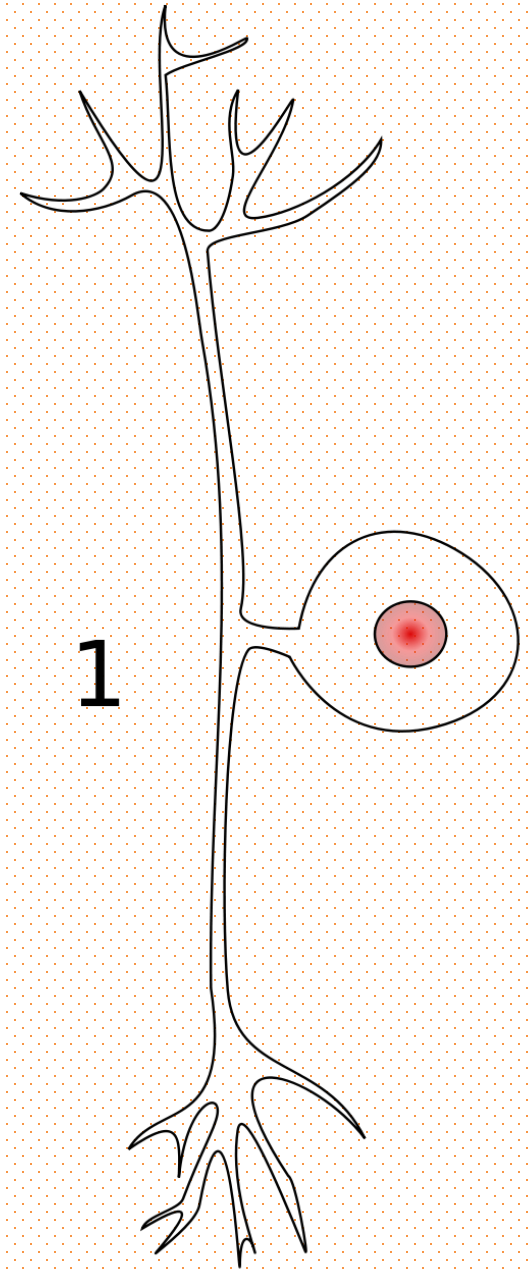
Spinal ganglia

- They are embedded in the back root of the spinal nerves.
- Large **neuron bodies** are associated with **glial satellite cells**.
- Capsule is built from **dense connective tissue** in continuity with the dura mater and the epineurium and **several layers of flattened epithelial cells** and loose connective tissue that continues on the arachnoid and perineurium.
- **Pseudounipolar neurons** arranged in irregular groups separated by connective tissue and bundles of nerve fibers.



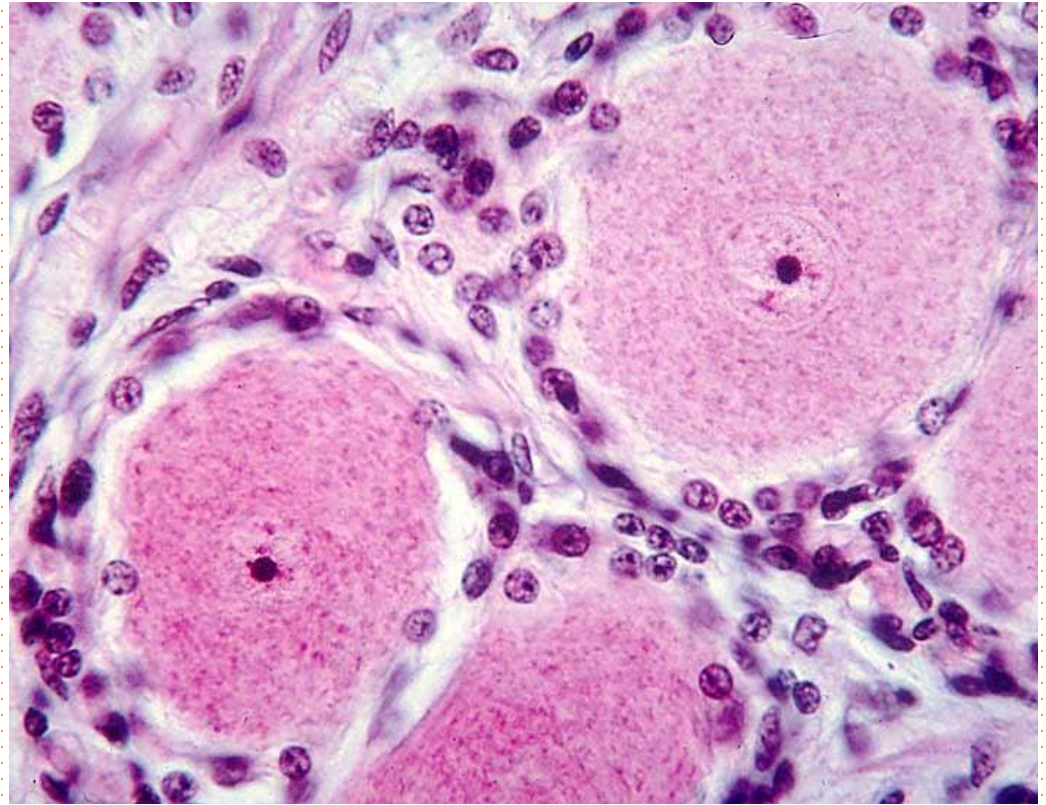
Spinal ganglia

- There are **pseudounipolar neurons** with centrally set nucleus, pronounced nucleolus and organelles of the synthetic pathway.
- One branch brings an impulse from the periphery - it corresponds to a dendrite.
- The second branch as an axon takes the impulse through the back spinal nerve root to the spinal gray matter.



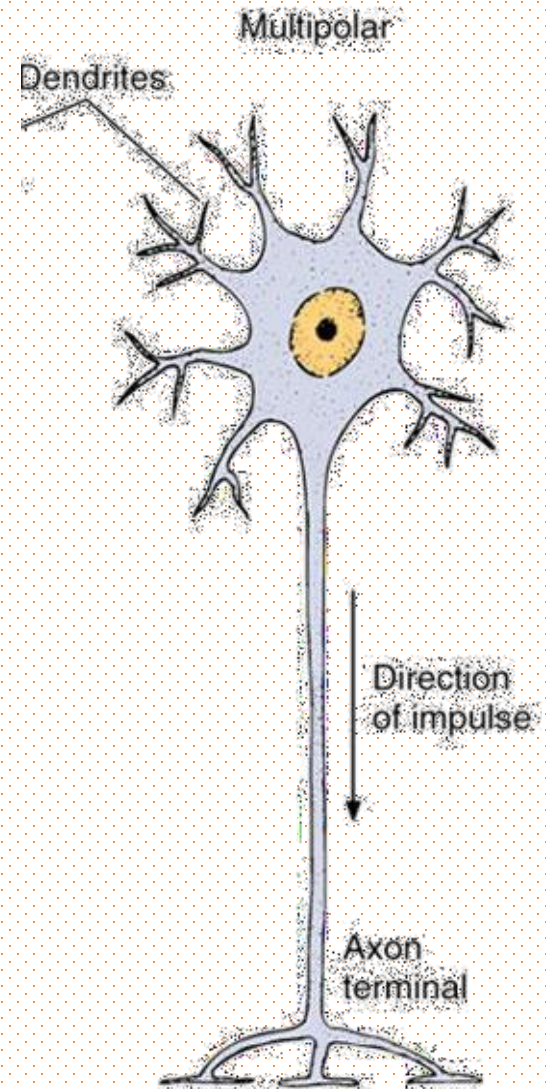
Cerebral ganglia

- They are associated with certain cranial nerves (V, VII, VIII, IX, X).
- According to their histological structure, they are **similar to spinal ganglia**.



Autonomic ganglia

- They belong to ANS.
- They include **sympathetic and parasympathetic ganglia**.
- Both have **similar histological structure**.
- Unlike spinal ganglia, they contain **multipolar ganglion cells** - significantly smaller than the pseudounipolar cells of spinal ganglia.
- Nucleus is round and eccentrically placed, one or two nucleoli are expressed and synthetic organelles are developed.
- Also, **satellite cells**



ANS

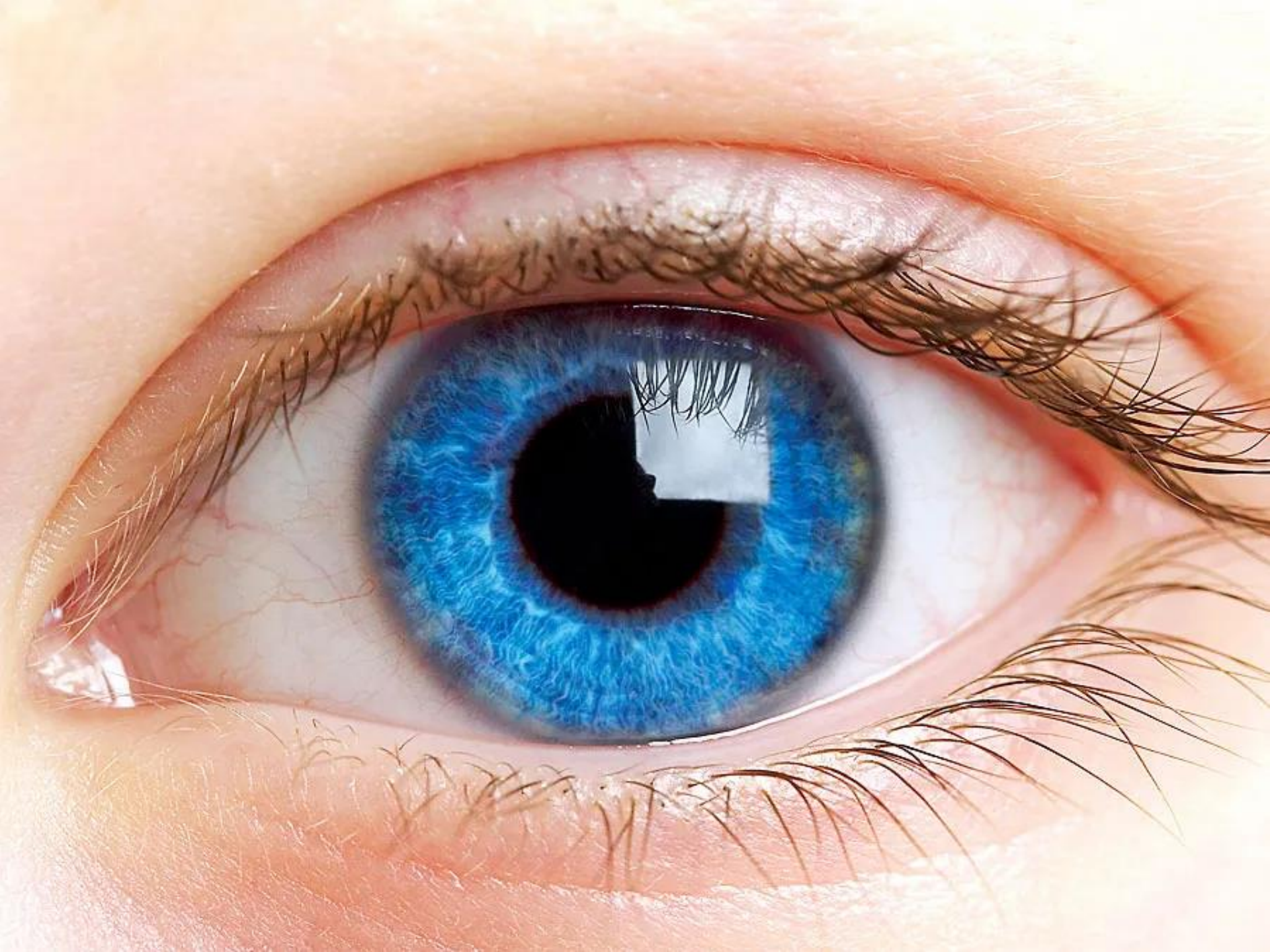
Neuronal cell bodies of preganglionic **sympathetic nerves** are located in the **thoracic and lumbar segments** of the spinal cord and those of the **parasympathetic division** are in the **medulla and midbrain and in the sacral portion** of the spinal cord.

Sympathetic second neurons are located in small ganglia **along the vertebral column**, while second neurons of the **parasympathetic** series are found in very small **ganglia** **always located near or within the effector organs**.

Special sense organs

Receptors

- **Peripheral endings of sensitive neurons** that receive and transform usually one type of stimulus.
- The receptor detects the stimulus and translates it into an action potential.
- The action potential is transmitted to the CNS by afferent neurons.
- In the CNS, the action potential is translated into information.
- The information is processed and the person becomes aware of the given stimulus.
 - **Mechanoreceptors**
 - **Chemoreceptors**
 - **Thermoreceptors**
 - **Baroreceptors**
 - **Photoreceptors**



Eye

The organ of vision consists of:

- eye
- auxiliary structures of the eye

The eye consists of:

- eyeballs
- optic nerve

Auxiliary structures of the eye include:

- muscles of the eye socket
- eye lids
- conjunctiva
- lacrimal glands

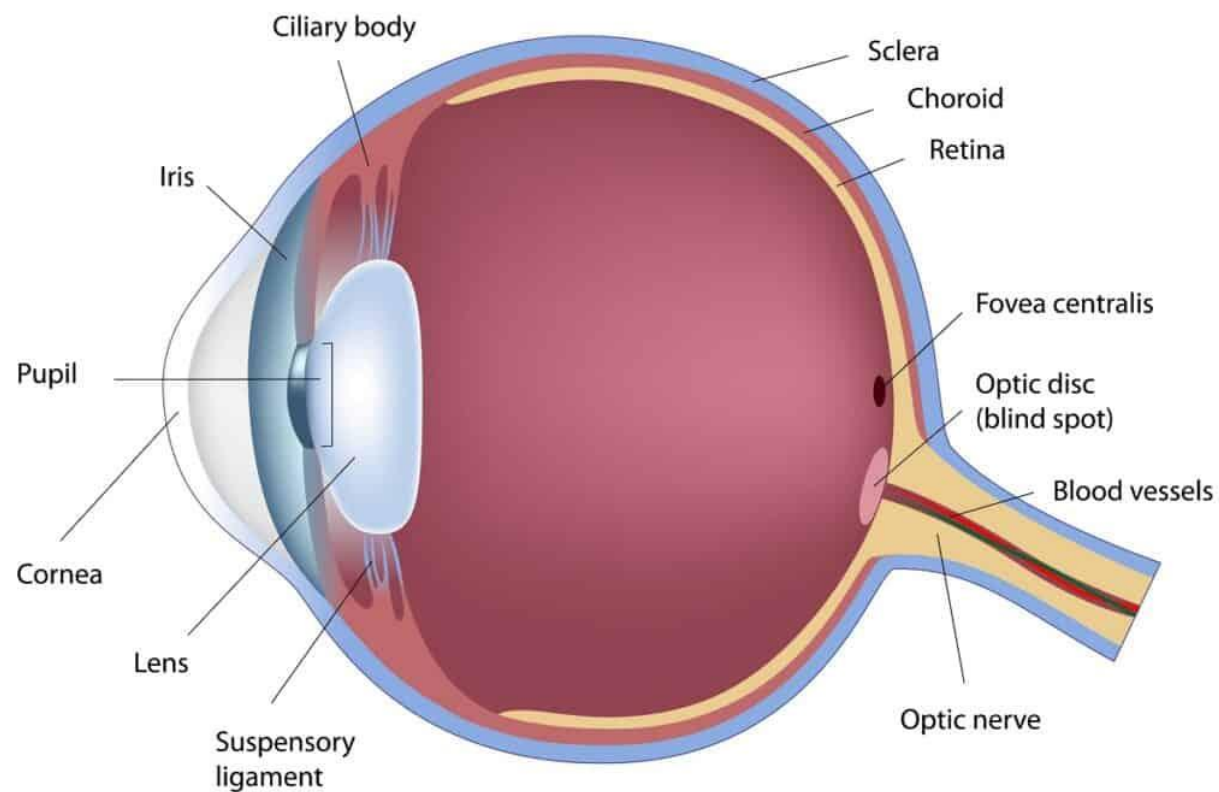
Eye

- The eye consists of the **eyeball** and the **optic nerve**.

Eye ball it is composed of:

- wall
- internal content

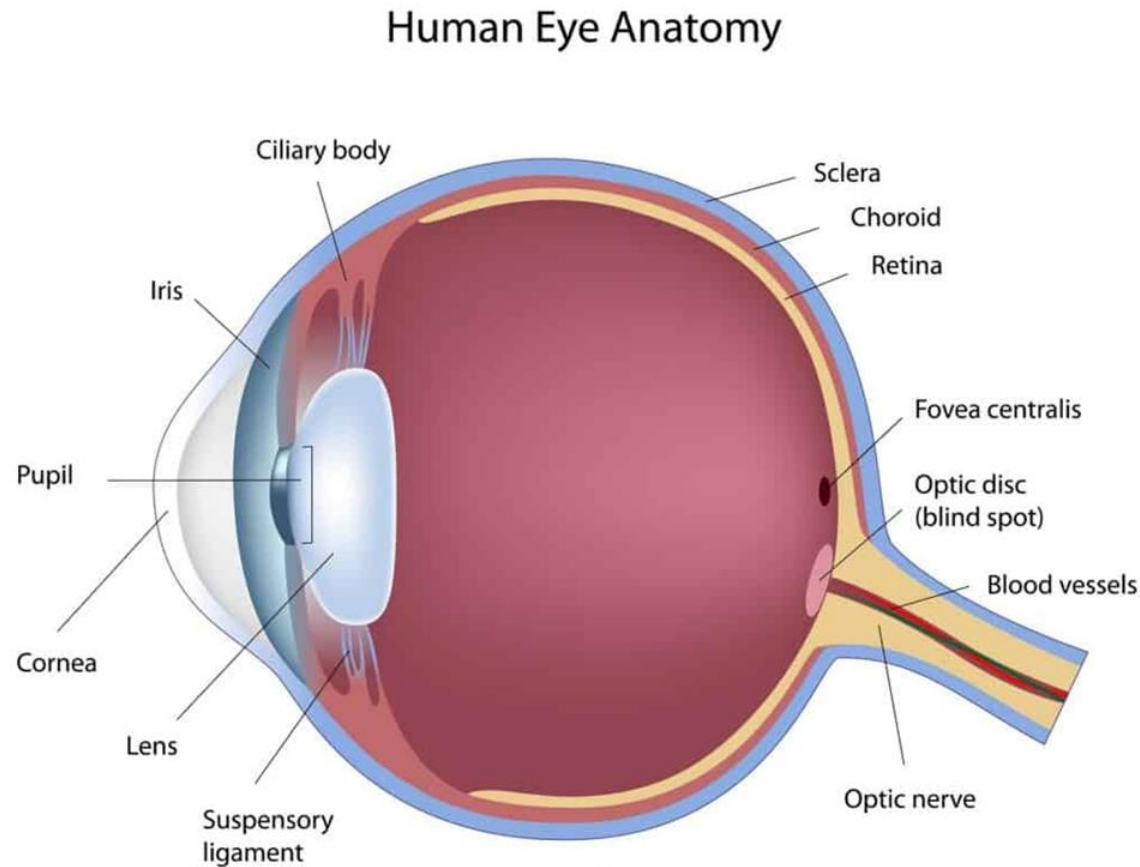
Human Eye Anatomy



Eyeball

Eyeball is composed of three concentric tunics or layers

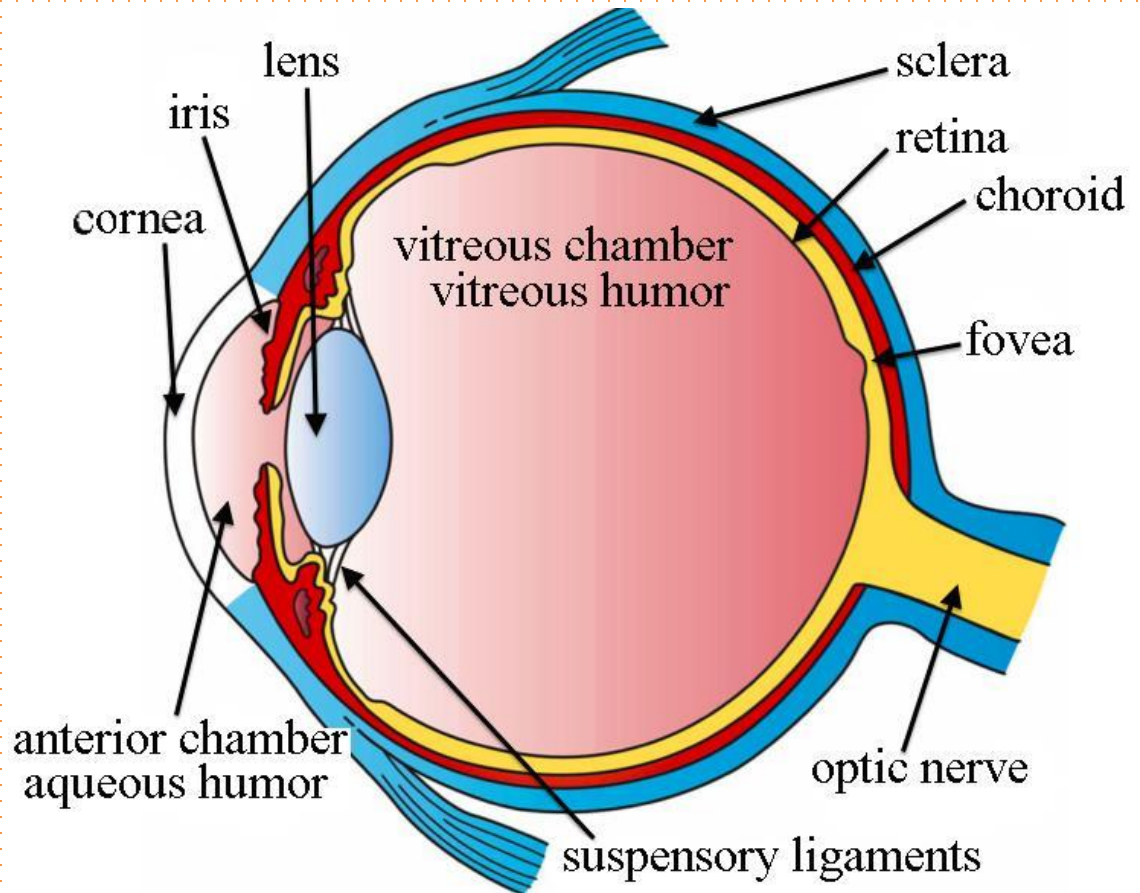
- External fibrous layer consisting of the **sclera** and the transparent **cornea**;
- Middle vascular layer consisting of the **choroid**, **ciliary body**, and **iris**
- Inner sensory layer, the **retina**, which communicates with the cerebrum through the posterior optic nerve



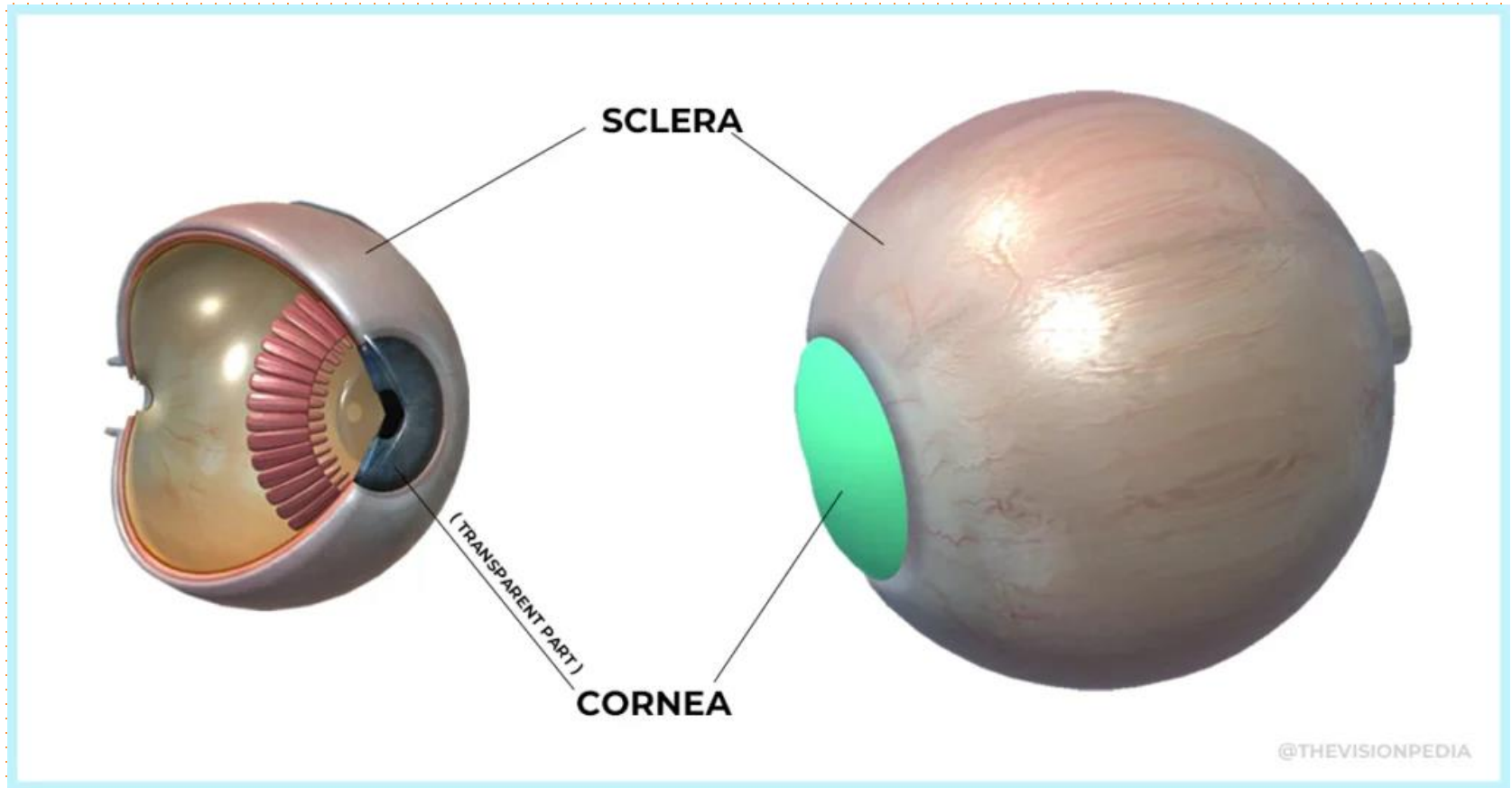
Eye content

The content of the eyeball consists of:

- Aqueous humor
- Lens
- Vitreous body



Fibrous layer

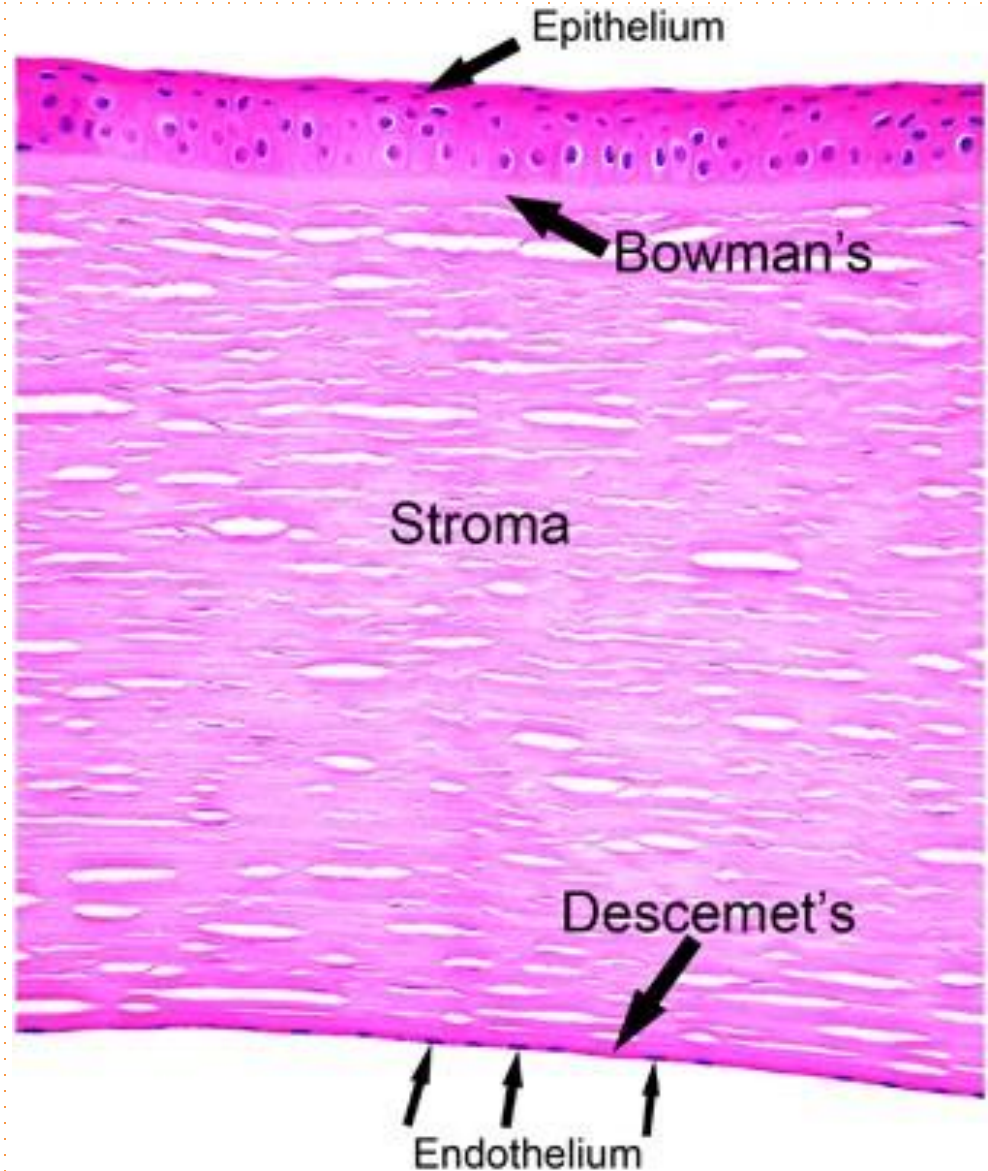


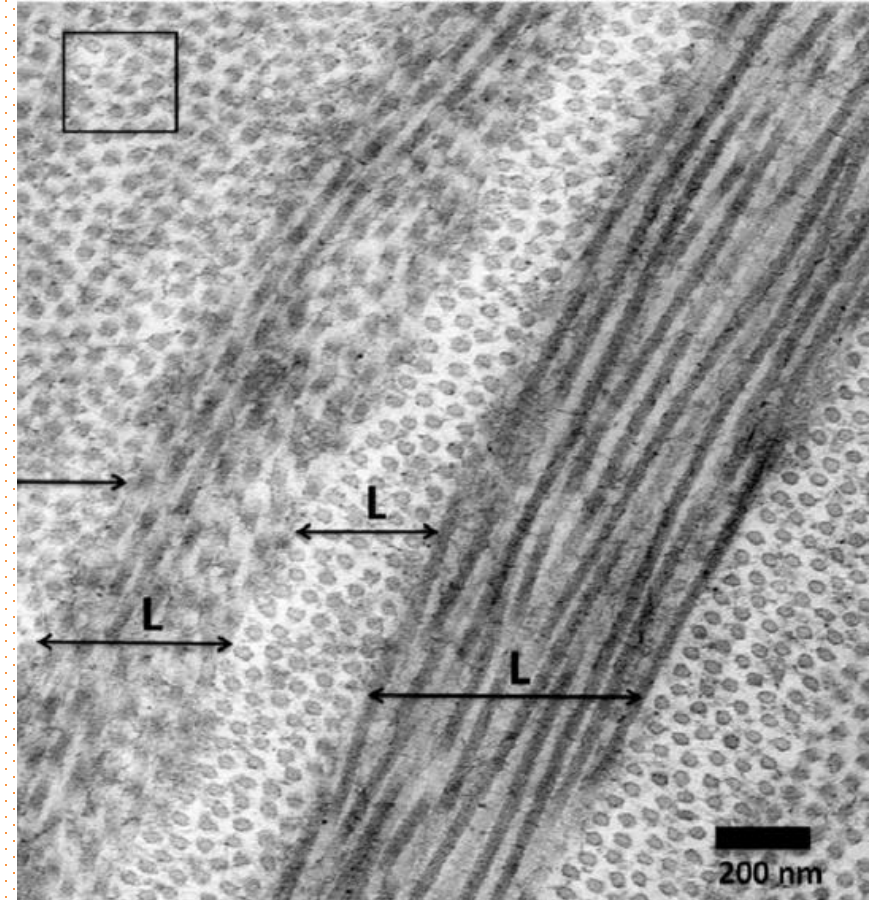
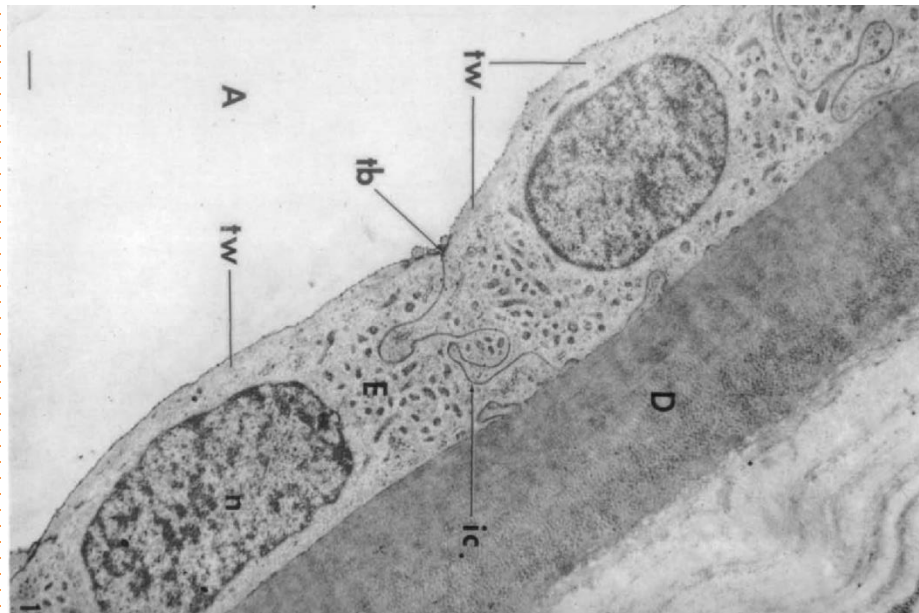
- The outer or fibrous covering of the eye consists of the **cornea and sclera**.
- The cornea covers the **front sixth**, and the sclera covers the rest of the fibrous sheath.

Cornea

Built from five layers:

1. **Epithelium** non-keratinized stratified epithelium
2. **Bowman's membrane** – basement membrane of the epithelium
3. **Stroma** - parallel collagen fibers in lamellae, between which are cells - keratocytes.
4. **Descemet membrane** – basement membrane of the endothelium
5. **Endothelium** – Single row squamous epithelium





Corneal epithelium is nonkeratinized, five or six cells thick, and densely supplied with **free nerve endings** that trigger the blinking reflex.

Stroma comprises approximately 90% of the cornea's thickness, consisting of some 60 layers of long **type I collagen fibers** arranged in a precise orthogonal array and alternating with flattened cells called **keratocytes**. Completely avascular, and nutrients reach the keratocytes and epithelial cells by diffusion from the surrounding limbus and aqueous humor behind the cornea.

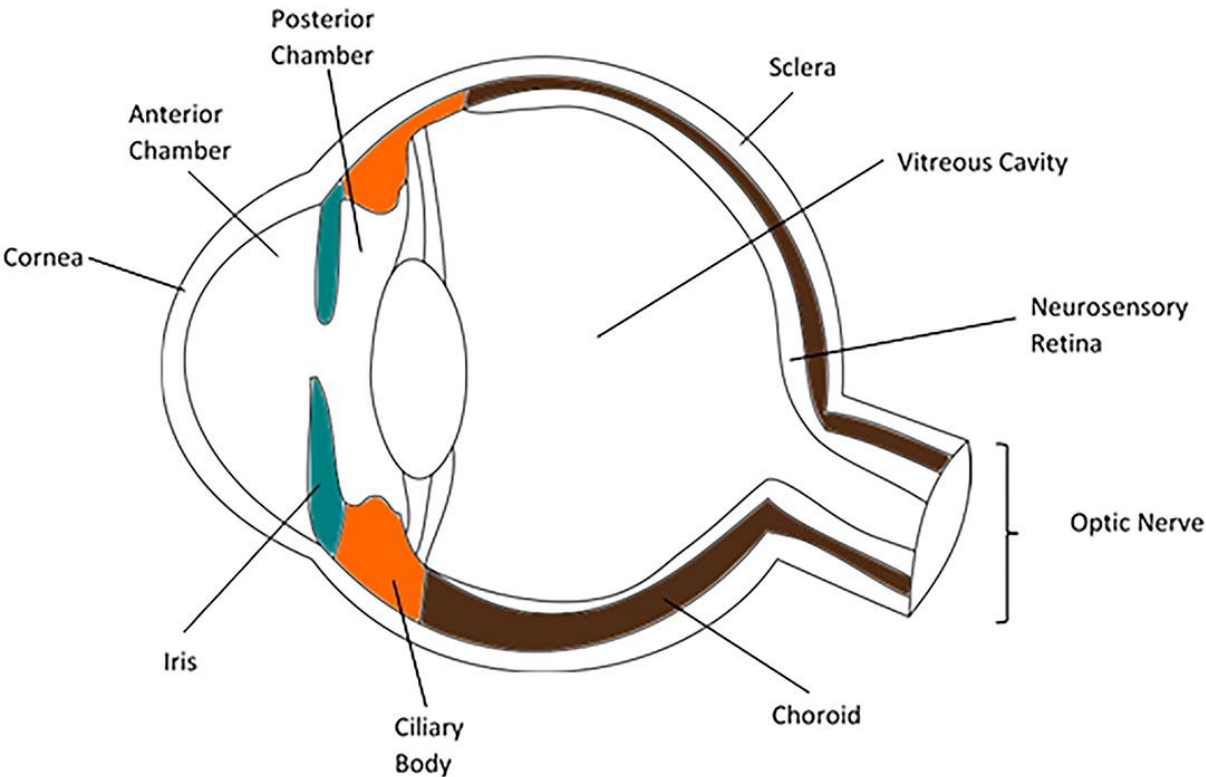
Sclera

- The opaque part of the fibrous covering of the eye.
- It is made of dense CT - the fibers are of unequal thickness and irregular orientation.

It consists of 3 layers:

1. **Episclera** space filled with loose connective tissue.
2. **Stroma**
3. **Lamina fusca - Pigment layer of the sclera** - deepest layer of the sclera has a dark color that contains loose connective tissue with many pigment cells (melanocytes).

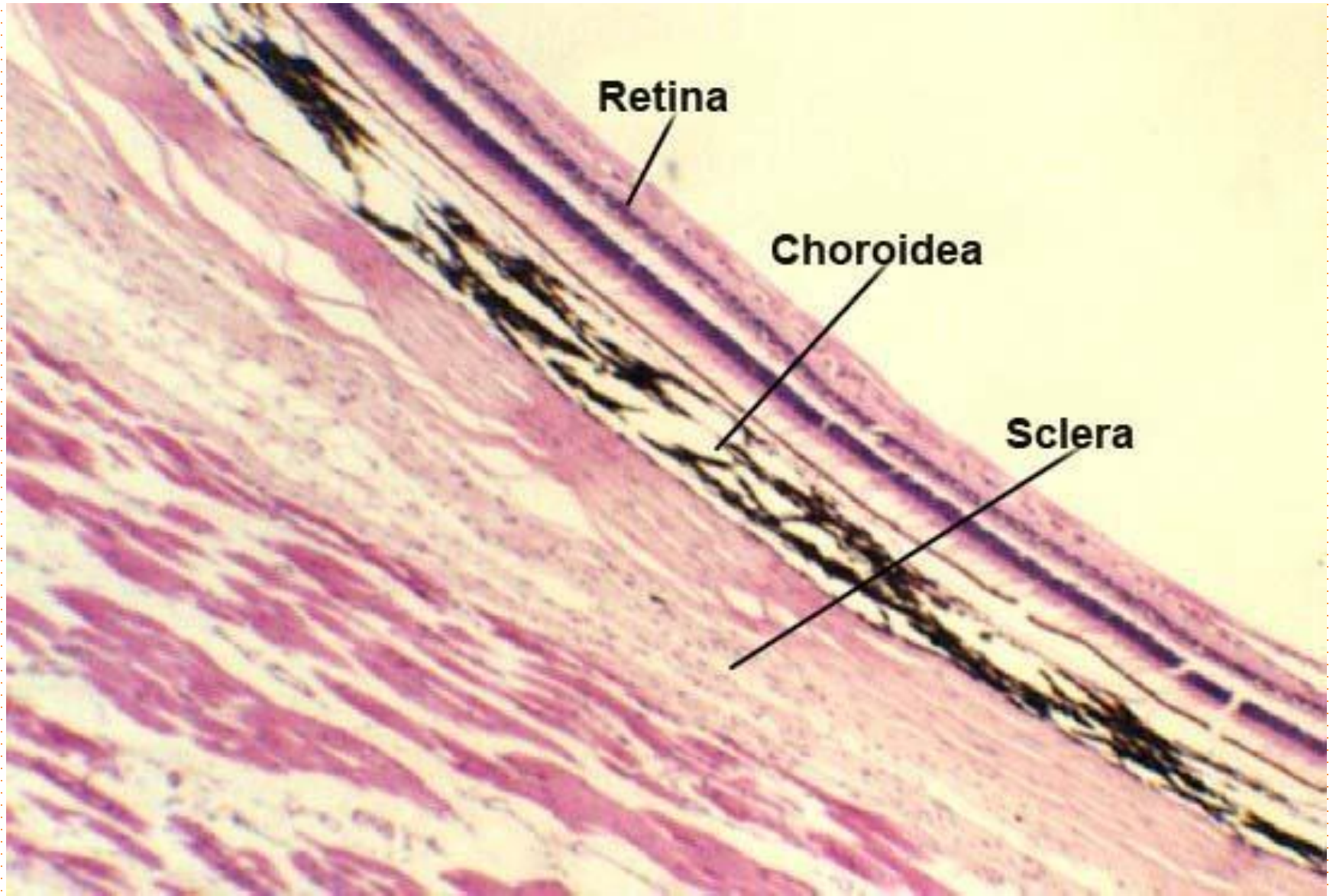
Vascular layer (uvea)



- The middle (vascular) layer of the eye is **rich in blood vessels** of different caliber.
- It is located between the sclera and the retina.
- It is divided into three segments:

Choroid
Ciliary body
Iris

Choroid



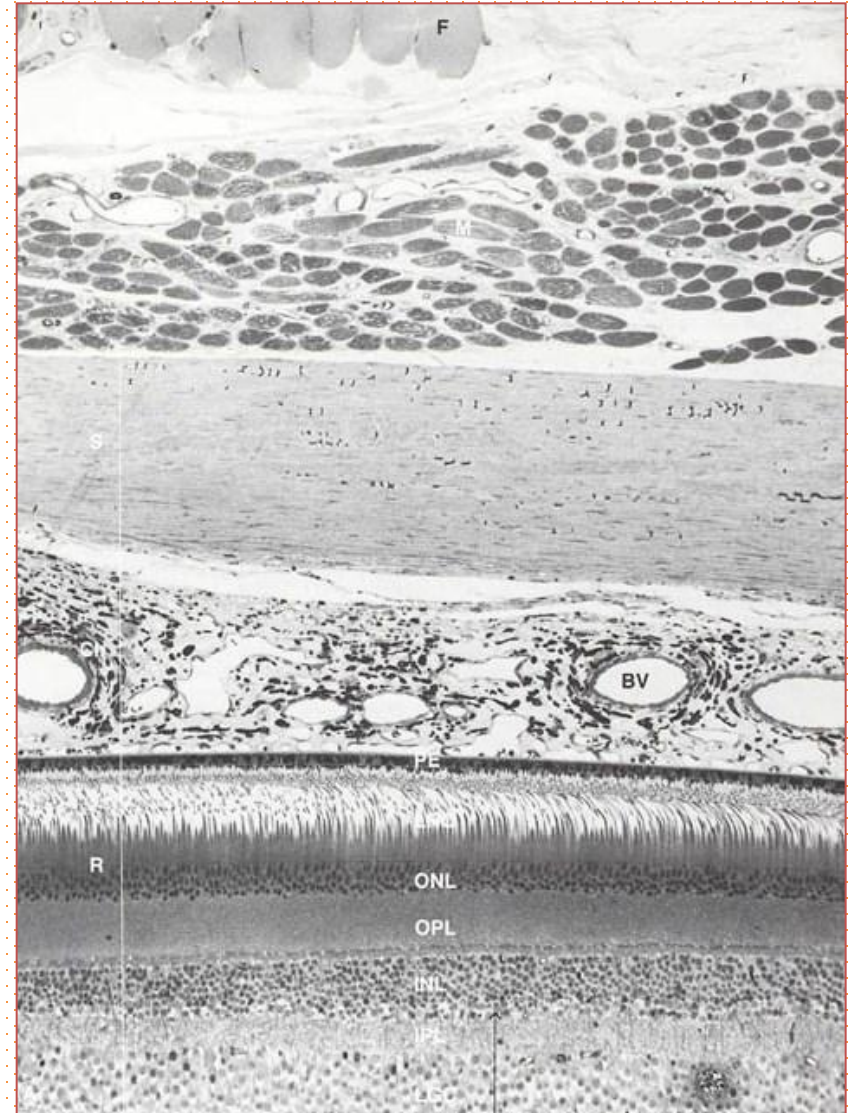
Choroid

- It represents 2/3 of the retinal membrane of the eye.
- It extends from the optic nerve to the **ora serrata**, which separates it from the ciliary body.
- It is made of **melanocyte-rich loose connective tissue** through which blood vessels pass.
- Extremely well vascularized.
- The diameter of the blood vessels decreases from the sclera to the retina.

Choroid

The following layers are separated from the sclera to the retina:

- **Lamina suprachoroidea** – loose connective tissue with melanocytes; a large blood vessels.
- **Lamina vasculosa** – arteries and veins of larger and medium caliber whose branches penetrate the choriocapillary layer.
- **Choriocapillary layer** - dense network fenestrated capillaries.
- **Bruch's membrane** - separates the choroid from the retinal pigment layer.

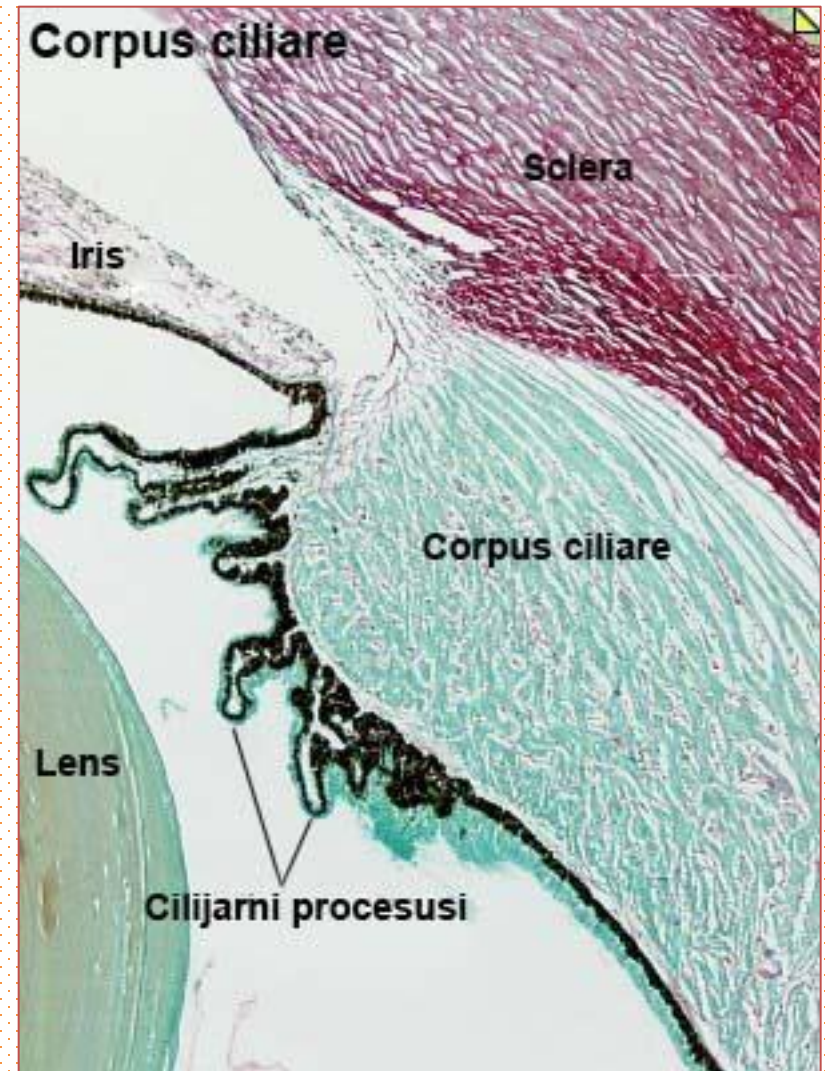


Ciliary body

- Most of the ciliary body rests on the sclera.
- On the longitudinal section of the eye, the ciliary body has the shape of a triangle.

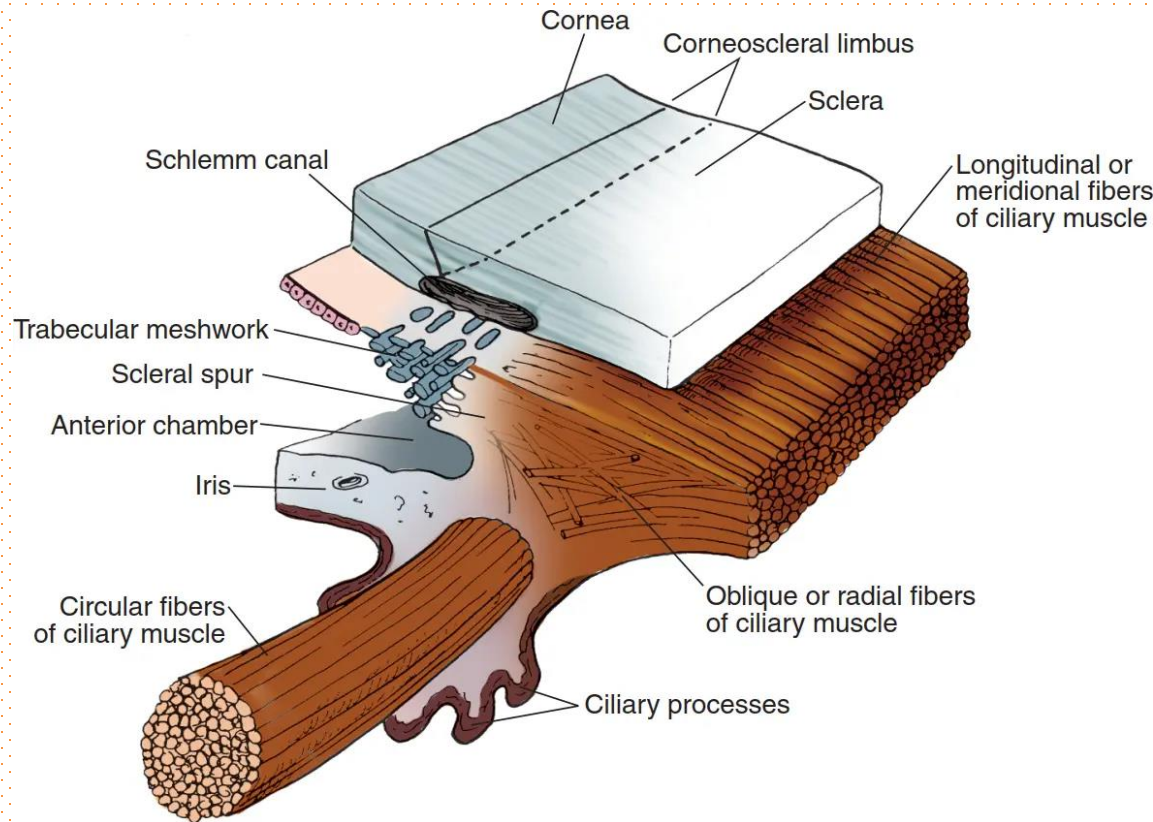
Main components

- Ciliary muscle
- Ciliary processes
- Ciliary zonule



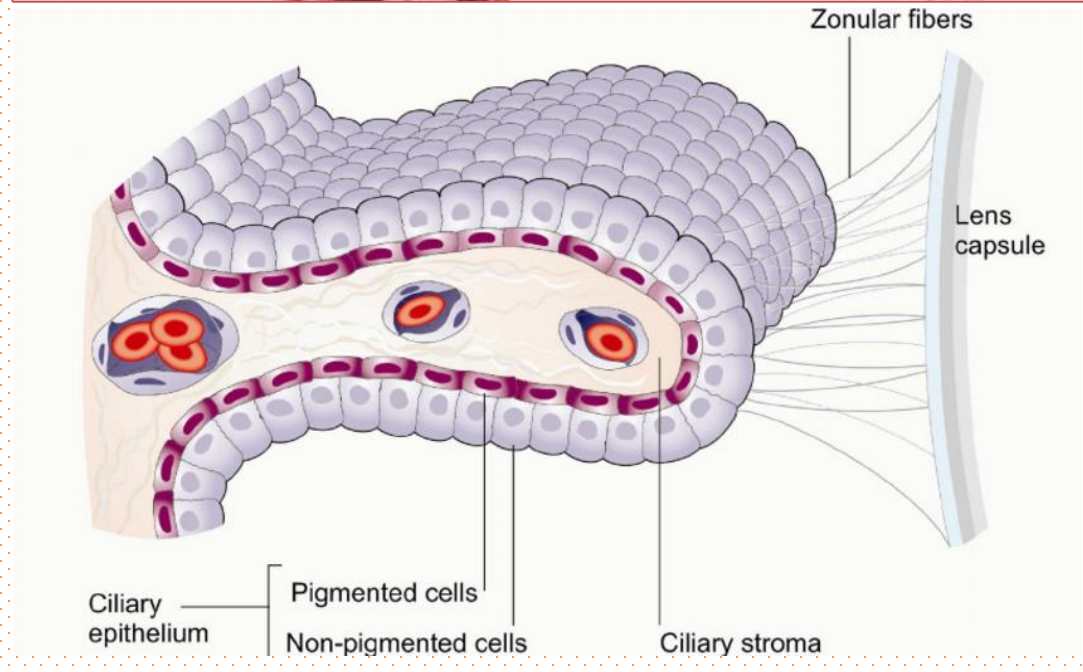
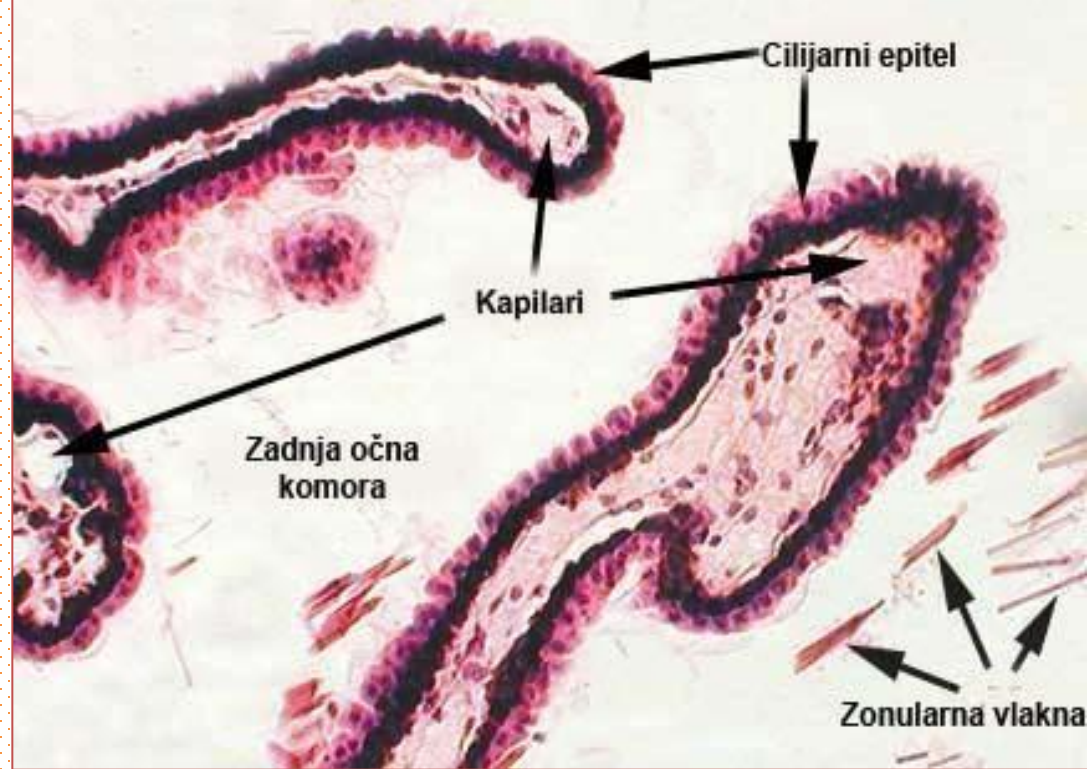
Ciliary muscle

- The **ciliary muscle** is made up of two bundles of smooth muscle cells.
- One bundle of cells has a **radial orientation** - it regulates the outflow of aqueous humor from the eye anterior chamber via Schlemm's canal.
- The other has an **circular orientation** - by changing the tone, it tightens or loosens the zonular fibers (enables eye accommodation).

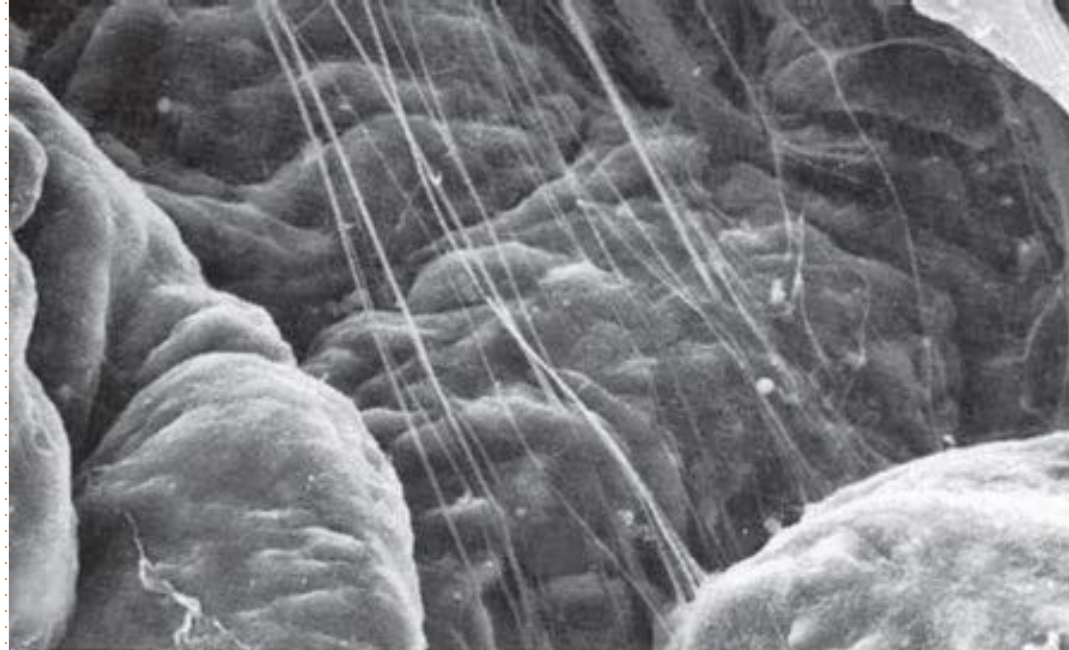
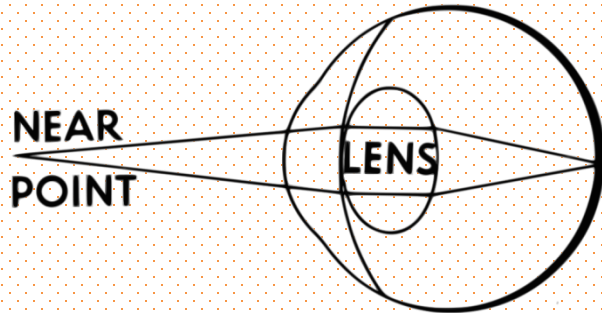
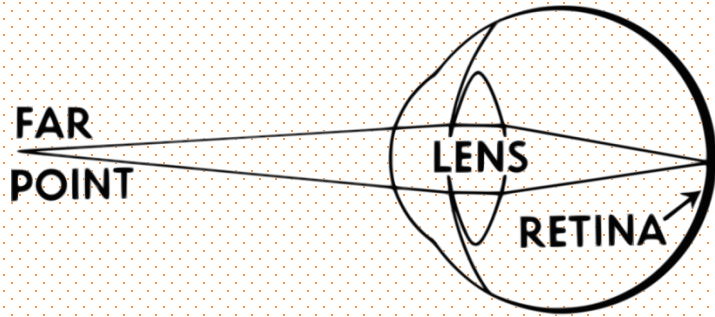


Ciliary processes

- 70-80 ciliary extensions from which **zonular fibers** extend towards the eye lens, which participate in the accommodation of the eye.
- Zonular fibers start from the ciliary processes and sink into the equatorial plane of the lens.
- These provide a large surface area covered by a double layer of low columnar epithelial cells, the **ciliary epithelium**.
- Zonular fibers are made **of fibrillin 1 and 2**



Accommodation of the eye

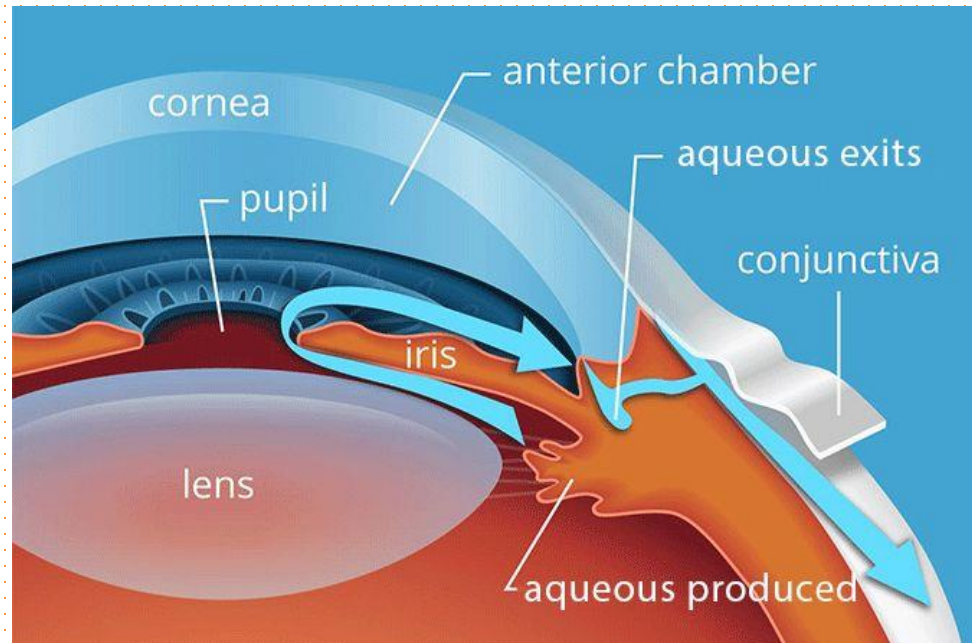


Accommodation of the eye refers to the eye's ability to adjust its focus to see objects clearly at different distances. This is achieved by changing the shape and curvature of the eye's natural lens to bring images into sharp focus on the retina.

By contraction of the inner bundle of the ciliary muscle, the zonular fibers loosen - spherical lens shape (near). By relaxing, they tighten, reduce the convexity of the lens and accommodate for distance. With aging, the contractile ability of the ciliary muscle decreases.

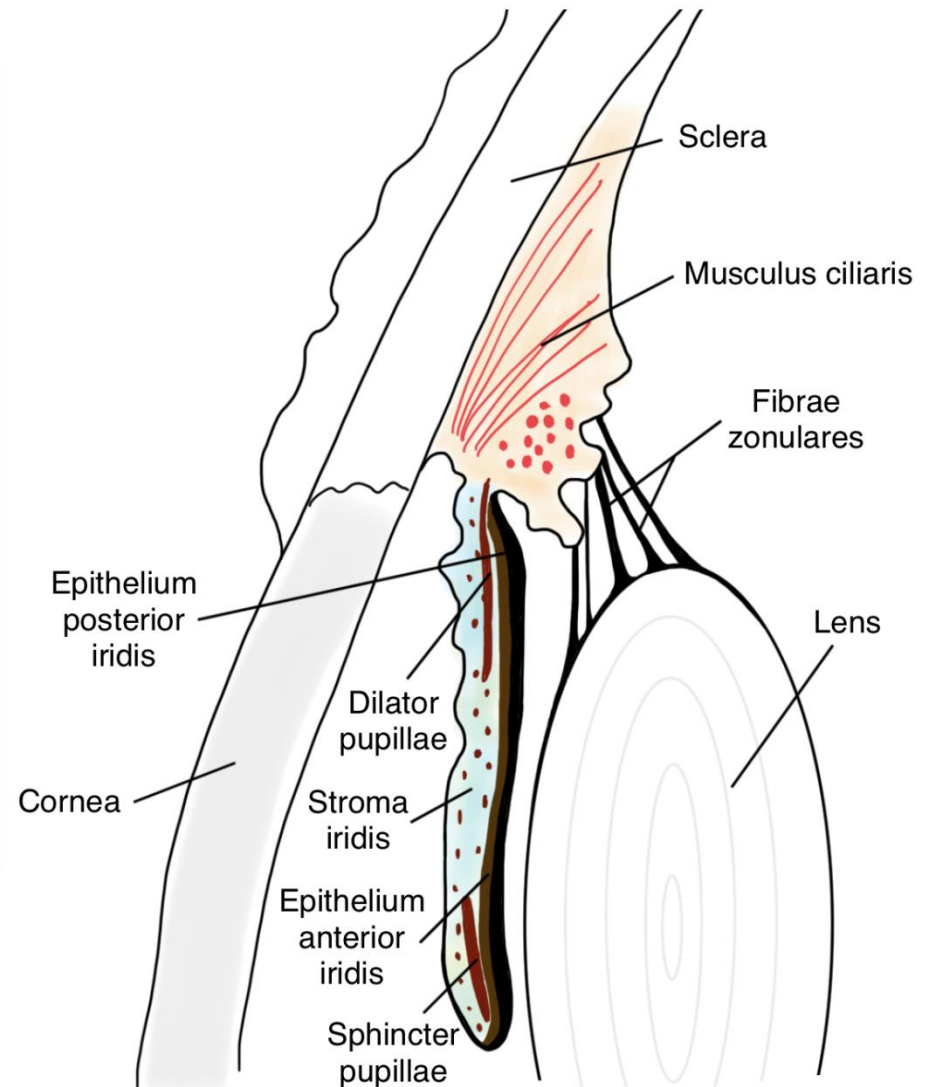
Aqueous humor

- Cells of this dual epithelium have extensive basolateral folds with Na^+/K^+ -ATPase activity and are specialized for secretion of aqueous humor.
- Fluid from the stromal microvasculature moves across this epithelium as aqueous humor.
- Aqueous humor is secreted by ciliary processes into the **posterior chamber**, flows **through the pupil** into the **anterior chamber**, and drains at the **angle formed by the cornea and the iris** into the channels of the trabecular meshwork and the scleral venous sinus, from which it enters venules of the sclera.



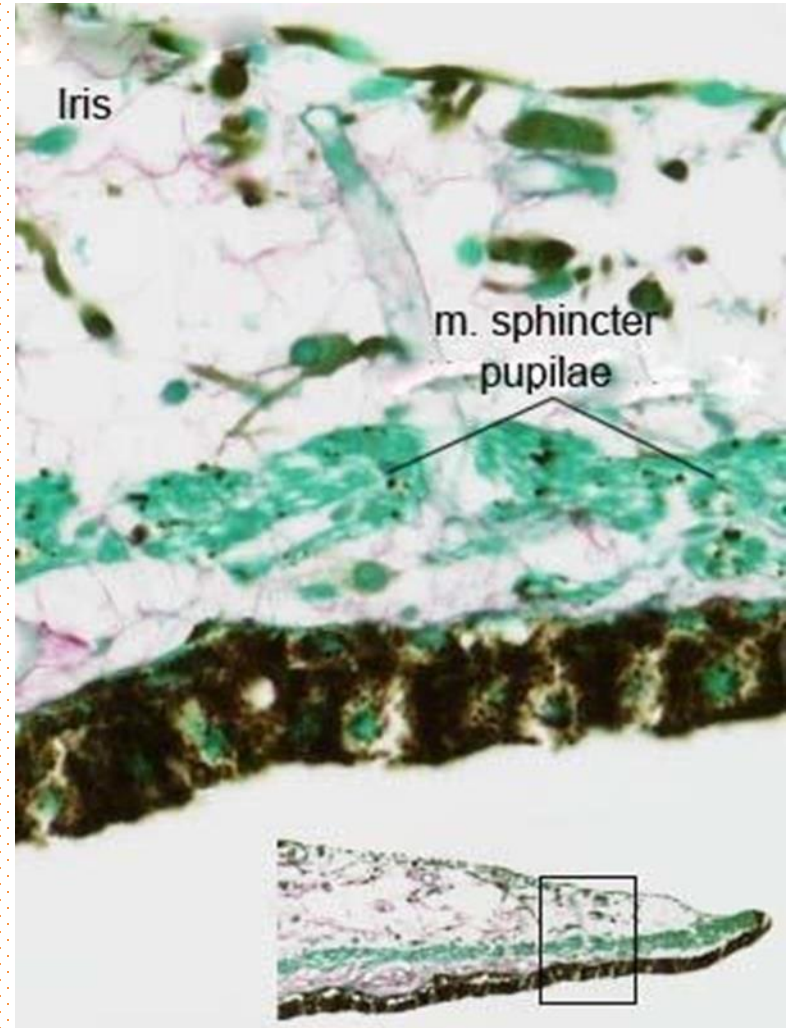
Iris

- It builds the front, free part of the vascular layer of the eyeball.
- It has a round shape tiles with central opening that fits **pupil**.
- It separates the anterior from the posterior chamber of the eye.
- It forms a contractile diaphragm in front of the lens.



Iris

- **Anterior surface** has no epithelium and consists only of a matted layer of interdigitating fibroblasts and melanocytes.
- **Posterior surface** of the iris has a two-layered epithelium continuous with that covering the ciliary processes, but very heavily filled with melanin.
- Myoepithelial cells form a partially pigmented epithelial layer and extend contractile processes radially as the very **thin dilator pupillae muscle**.
- Smooth muscle fibers form a circular bundle near the pupil as the **sphincter pupillae muscle**



Retina



Retina pigmented epithelium the part that covers the iris and the ciliary body not capable of receiving light sensations

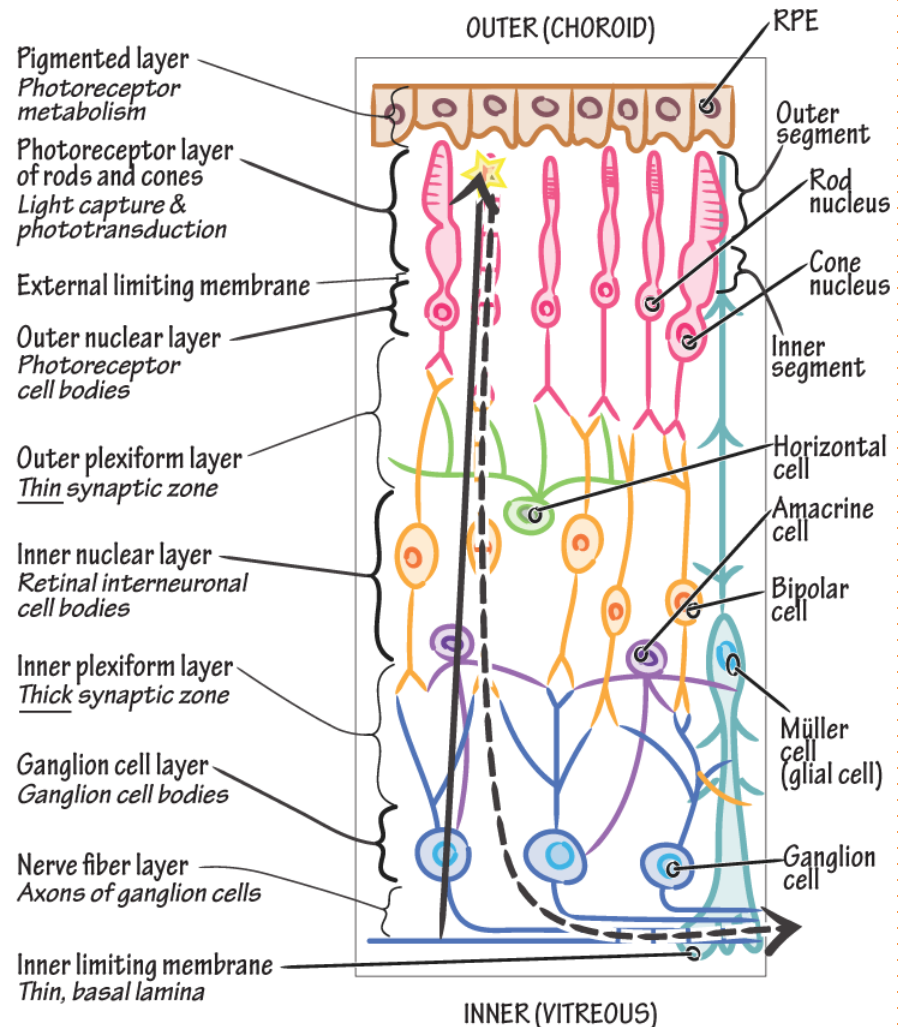
Neural retina the back part that is photosensitive

The division line of the blind and optic part - **ora serrata**.

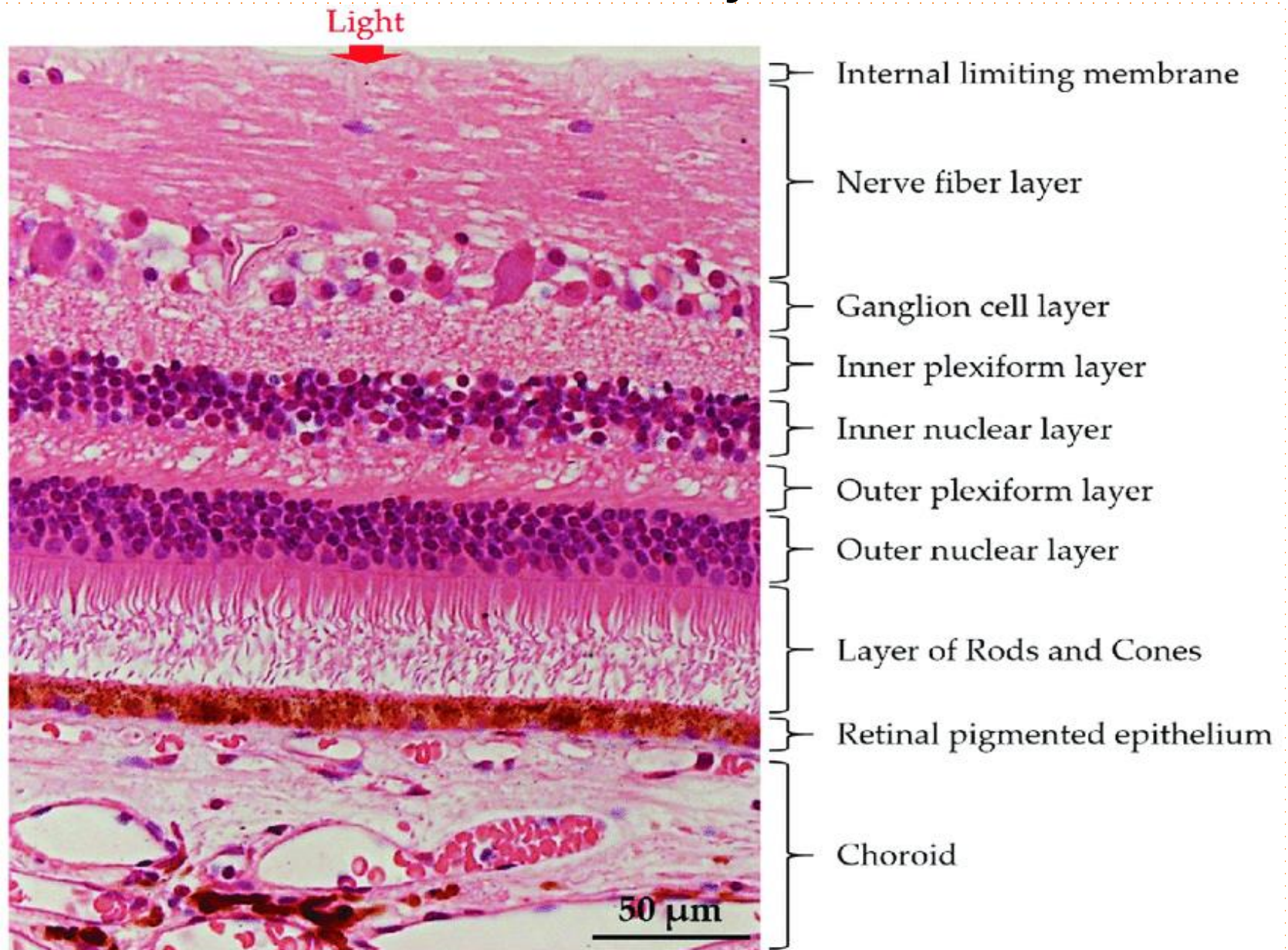
Neural retina

Neural retina contains neurons in three layers:

- external (**rods and cones**) in **outer nuclear layer**
- intermediate (**bipolar, horizontal and amacrine cells**) in **inner nuclear layer**
- intrinsic (**ganglion cells**) in **ganglionic layer**



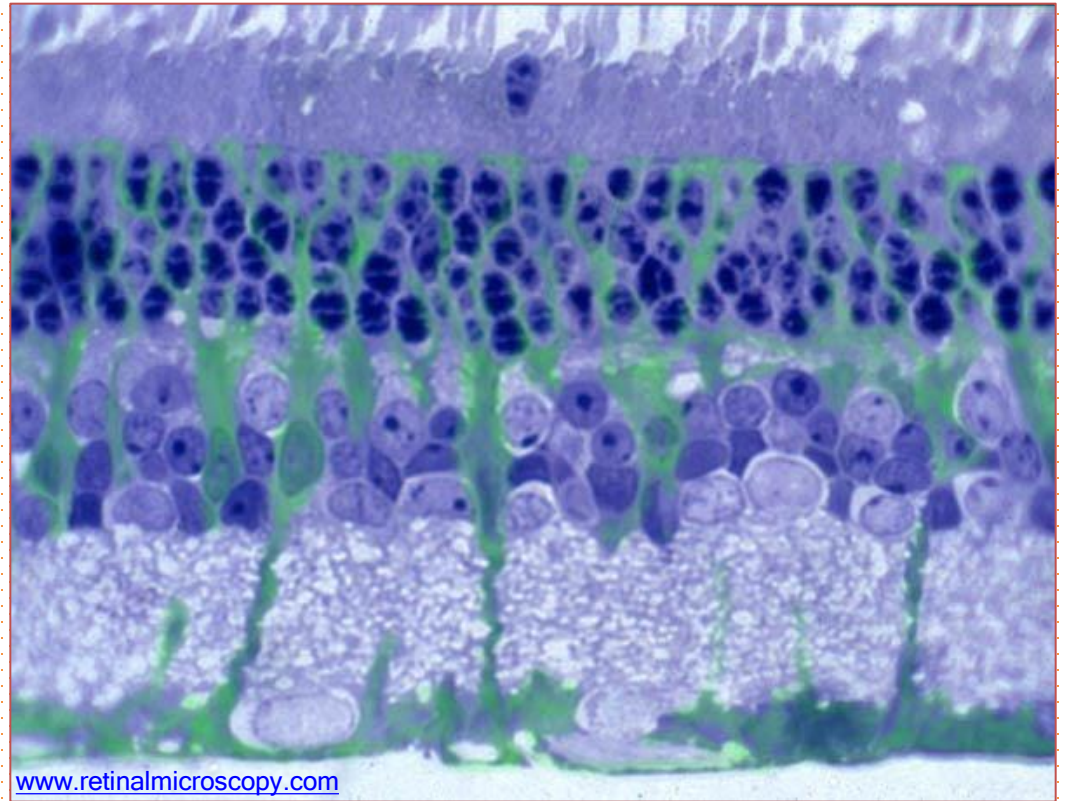
Neural retina layers



1. **inner limiting membrane** (ILM), a basement membrane covered by expanded processes of Müller cells, which are not distinguishable in routine preparations.
2. **nerve fiber layer** (NFL), containing the ganglionic cell axons, which converge at the optic disc and form the optic nerve.
3. **ganglionic layer** (GL), containing cell bodies of the ganglion cells and thicker near the retina's center than its periphery.
4. **inner plexiform layer** (IPL), containing fibers and synapses of the ganglion cells and the bipolar neurons of the next layer.
5. **inner nuclear layer** (INL), with the cell bodies of several types of bipolar neurons, which begin to integrate signals from the rod and cone cells.
6. **outer plexiform layer** (OPL), containing fibers and synapses of the bipolar neurons and rod and cone cells.
7. **outer nuclear layer** (ONL), with the cell bodies and nuclei of the photosensitive rod and cone cells.
8. **outer limiting layer** (OLL), a line formed by junctional complexes holding the rod and cone cells to the intervening Müller cells.
9. **rod and cone layer** (RCL), which contains the outer segments of these cells where the photoreceptors are located.
10. non-neural **pigmented layer** (PL), which has several supportive functions important for the function and maintenance of the neural retina.

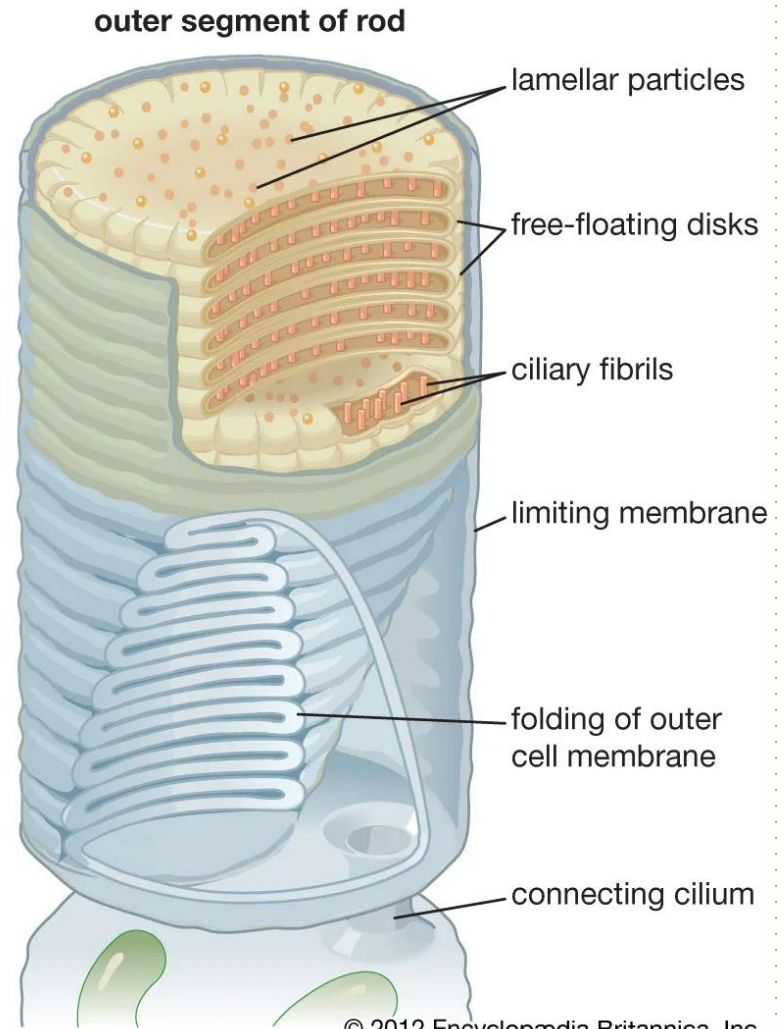
Müller cells

- The major role of the Müller cells is to maintain the structural and functional stability of retinal cells.
- Muller cells are the principal glial cell of the retina. They form architectural support structures stretching radially across the thickness of the retina and are the limits of the retina at the outer and inner limiting membrane, respectively

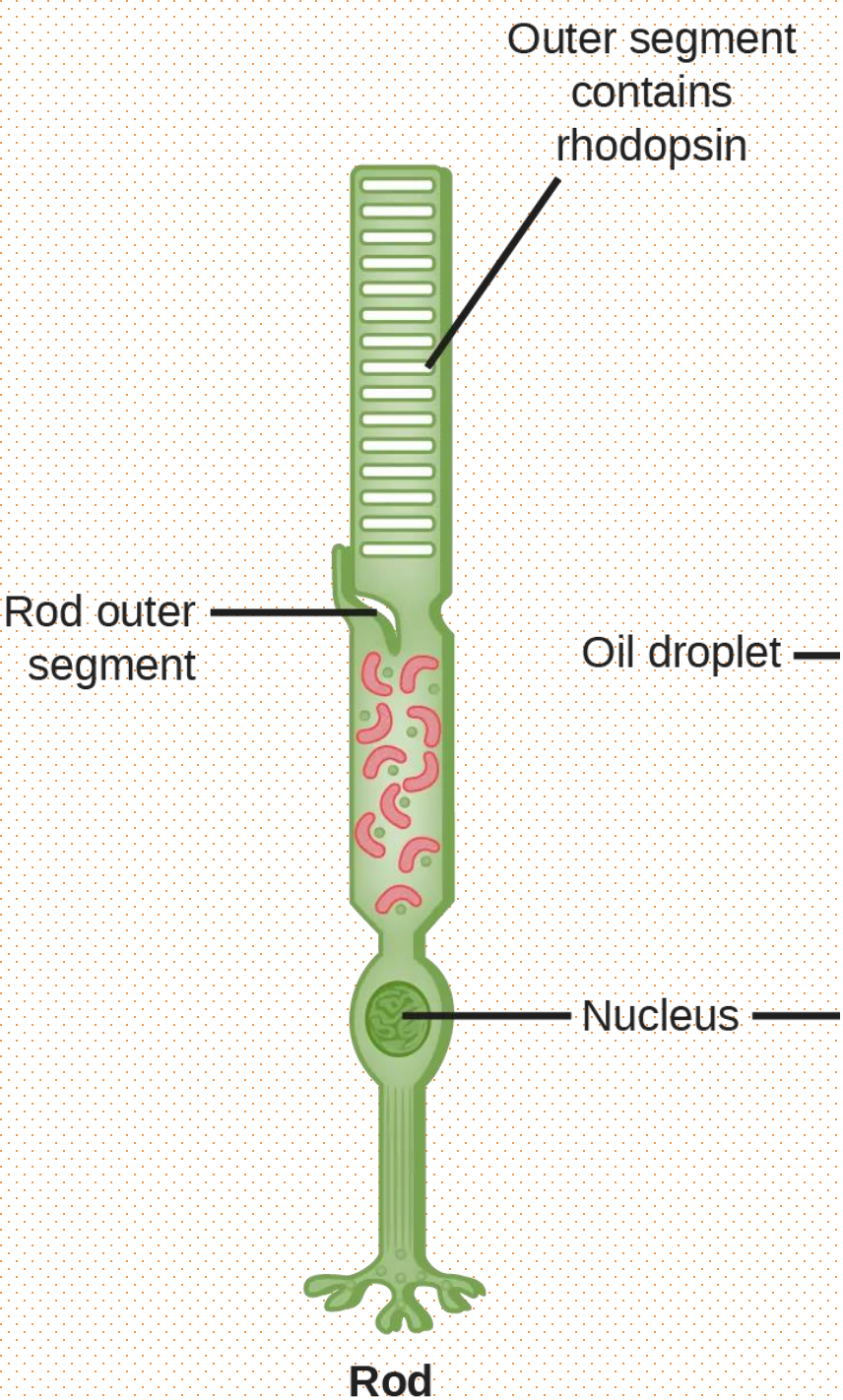


Rods

- 90 million rod cells sensitive to light
- The outer segment of the rod consists of 600-1000 flattened membrane disks.
- They are formed by bending of the plasmalemma and move towards the tip of the rod.
- 90-100 membrane discs are formed daily and the same number are phagocytosed by pigment cells from the apical pole of the rod.
- The membrane disc travels 9-13 days from the site of origin to the site of phagocytosis.
- The pigment **rhodopsin** is incorporated into the outer surface of the lipid bilayer.

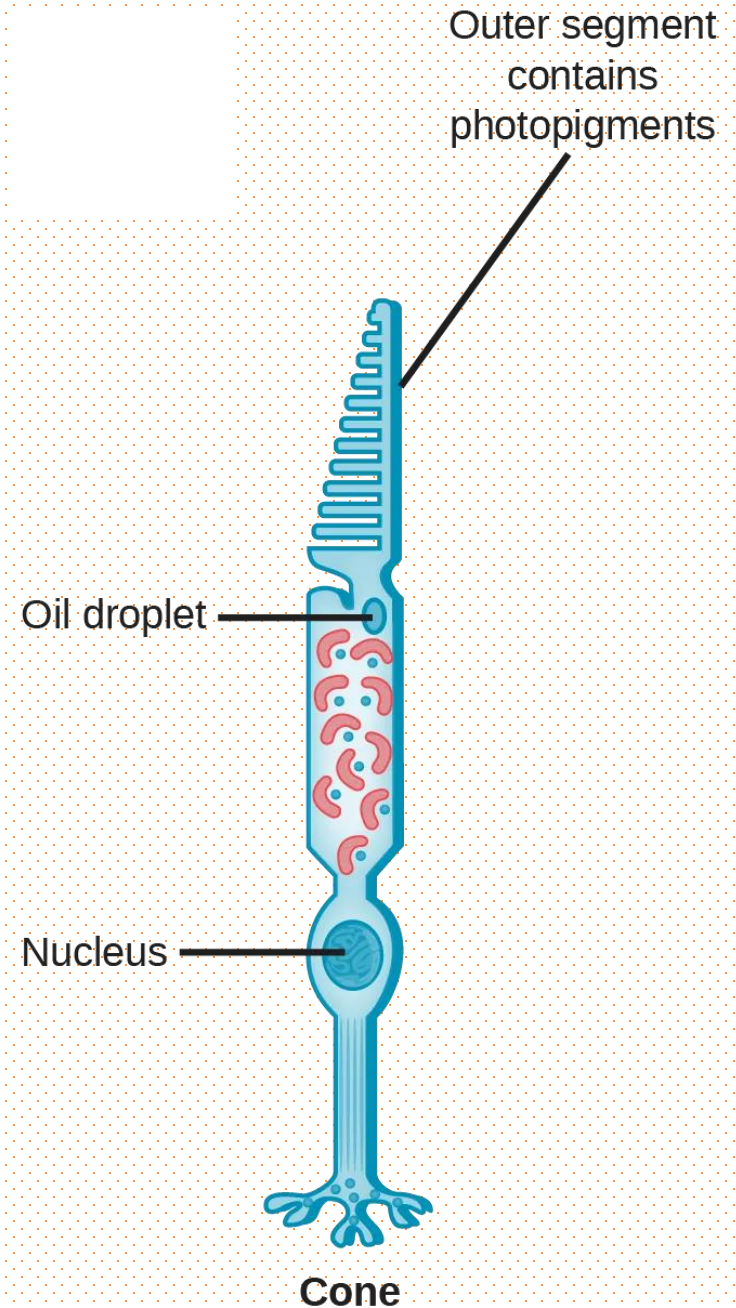


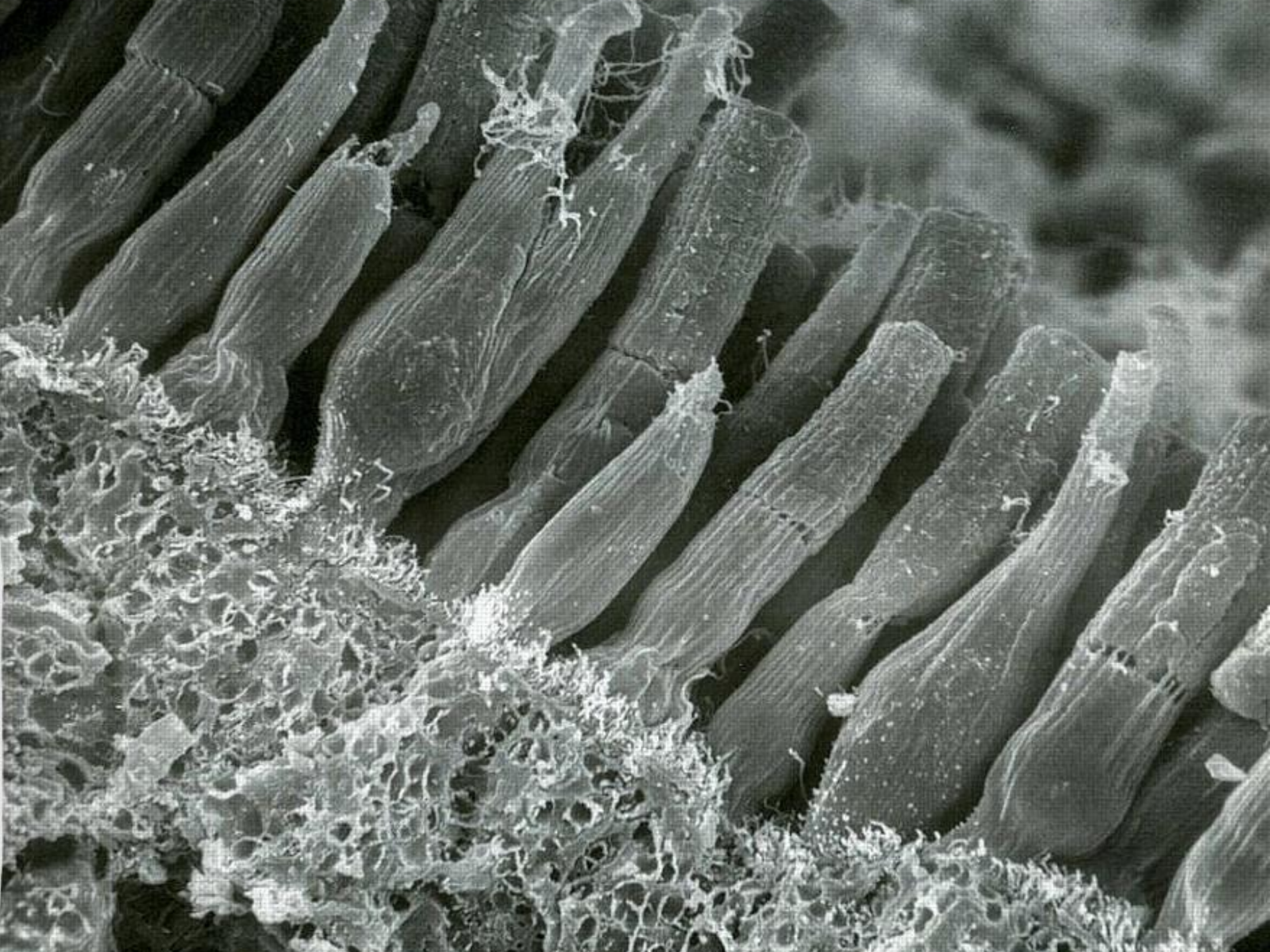
Rods



Cones

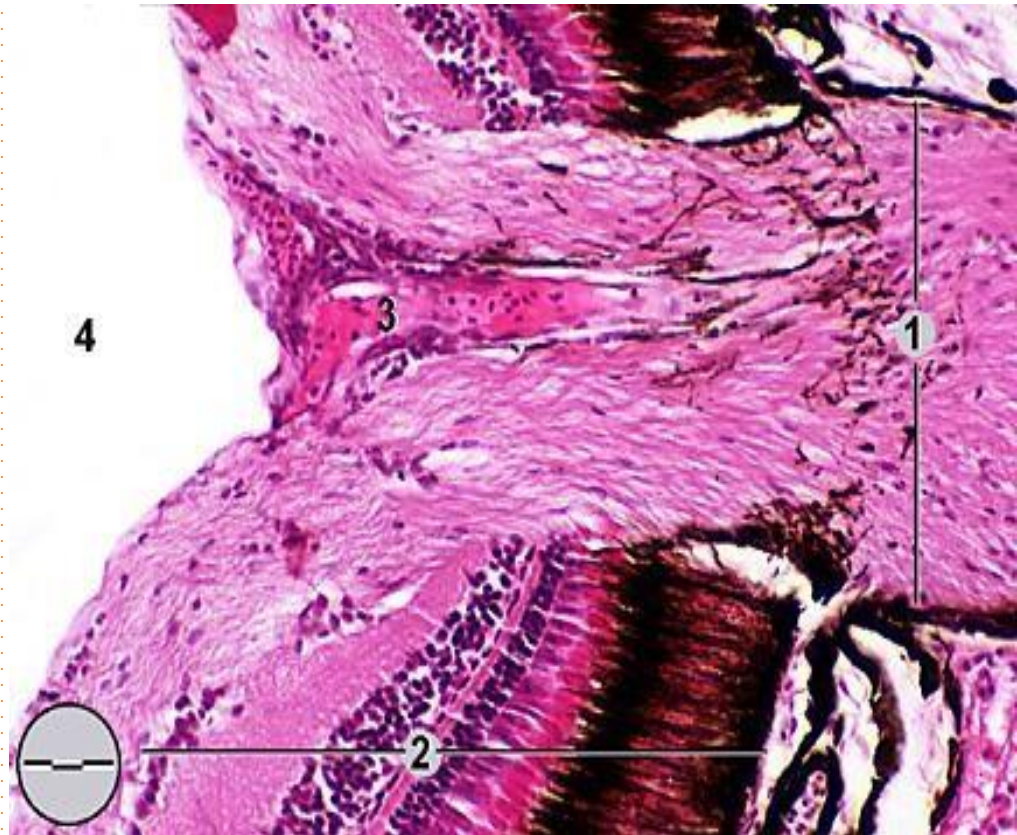
- 4.6 million cone cells
- Membrane discs are not separated from the cell membrane.
- They are formed by bending the plasmalemma and maintain continuity with it.
- It is embedded in membrane discs the visual pigment **iodopsin**.
- Iodopsin occurs in three forms sensitive to **red**, **green** and **blue** (RGB) colors - three functional types suppositories.





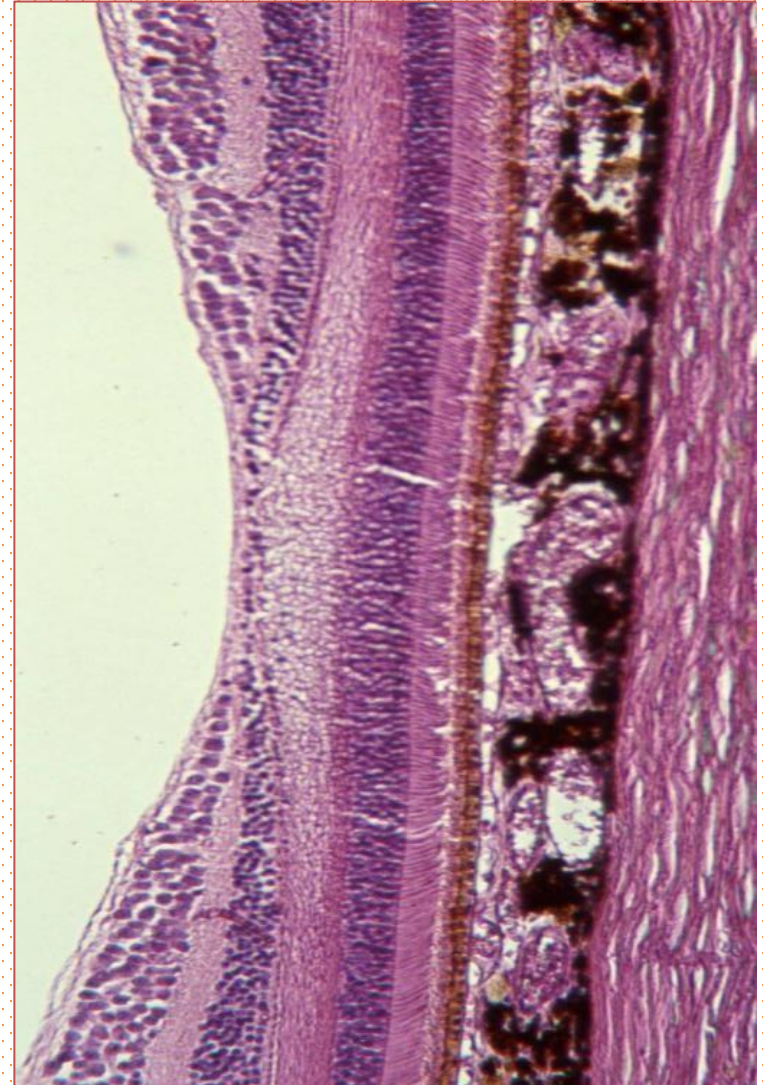
Specialized Areas of the Retina

- In the optic part of the retina there are two specialized fields - the **blind spot** and the **macula lutea** of the retina.
- The retinal **blind spot** is a round field about 1.5 mm in diameter.
- In the blind spot, the axons of the ganglion cells leave the retina to form the eyeball nerve.
- This part of the retina contains no neurons and is not sensitive to light.



Macula lutea

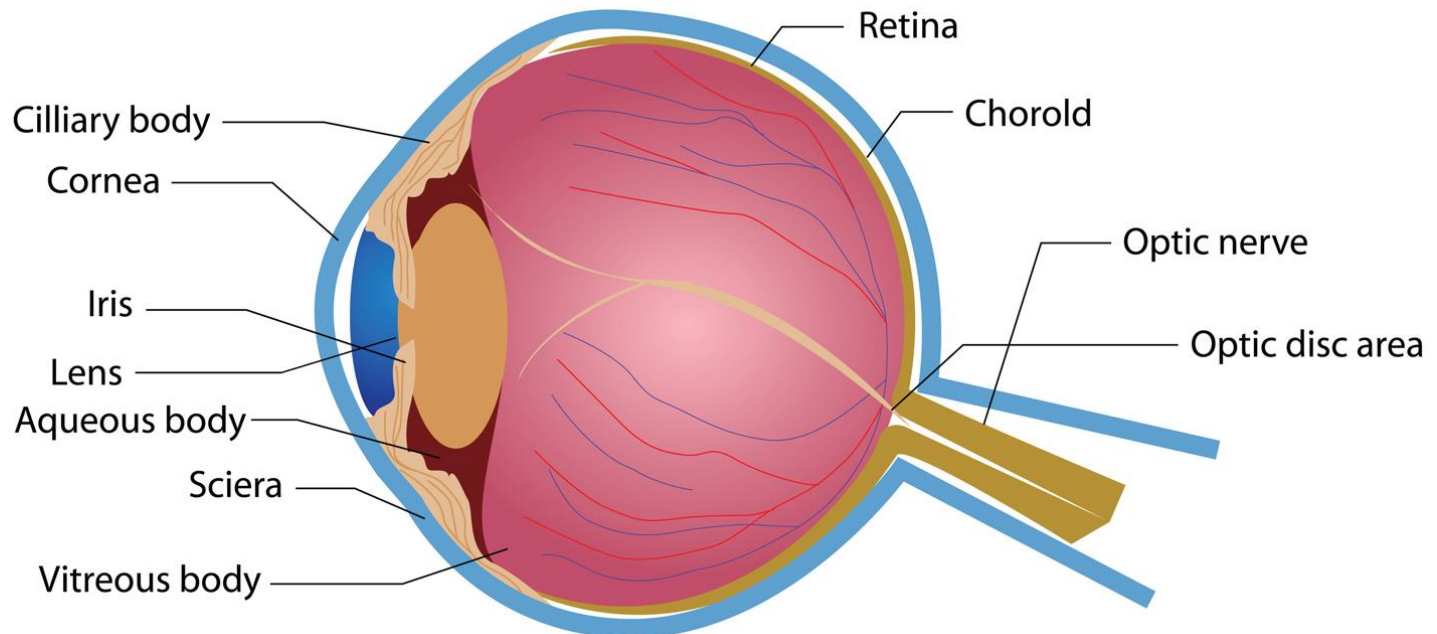
- Outside and below the blind spot is a yellowish field of the same size called the **macula lutea**.
- The yellow pigment xanthophyll is deposited in nerve cells.
- The center of the yellow spot is hollowed out like a funnel - **fovea centralis**.
- It contains **only cones**.
- All layers of photoreceptors are moved aside - the light directly hits the photosensitive cells.
- It represents the point with the highest visual acuity.
- No blood vessels - nutrition from of the choriocapillary layer of the choroid.



Eyeball content

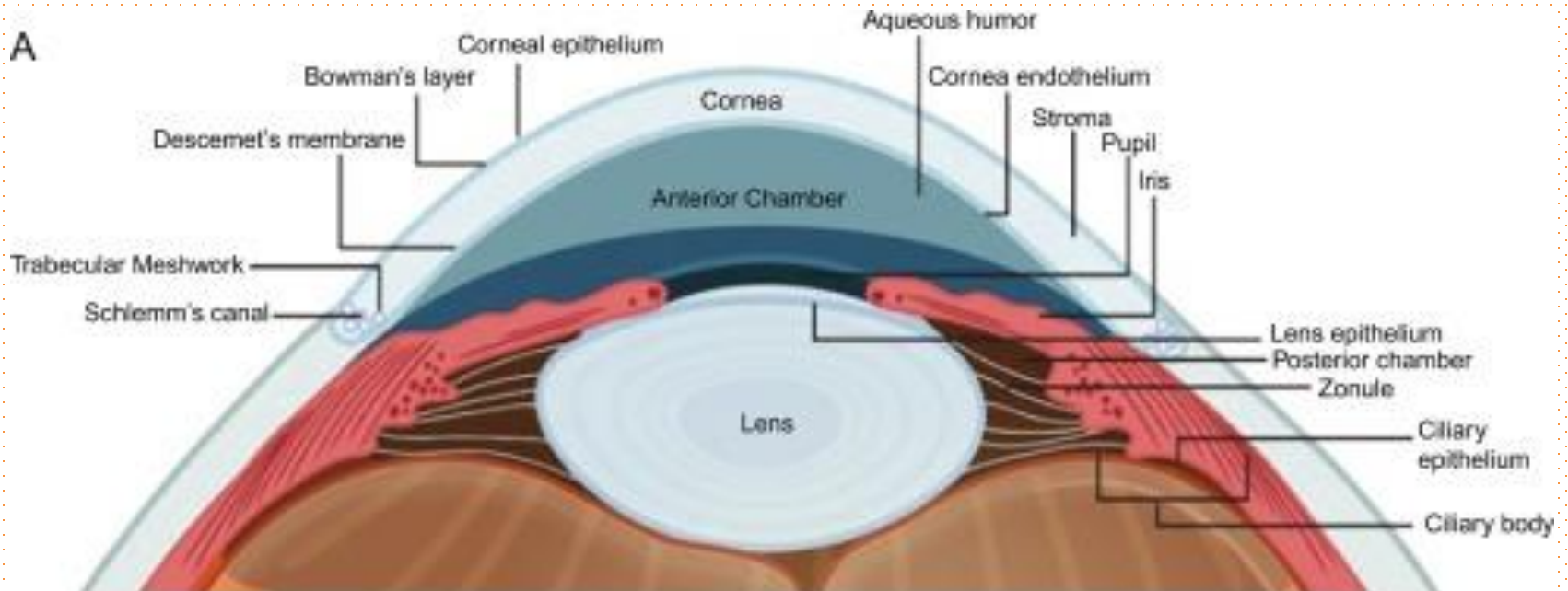
Content of the eyeball:

- Aqueous humor
- Lens
- Vitreous body



(humor aquosus)

- A clear liquid that fills the **anterior and posterior eye chamber**.
- It is secreted through **ciliary epithelium** in the posterior chamber of the eye.
- It is drained from the anterior chamber of the eye into the bloodstream via **Schlemm's canal**.
- Through the aqueous humor the cornea and lens are nourished.

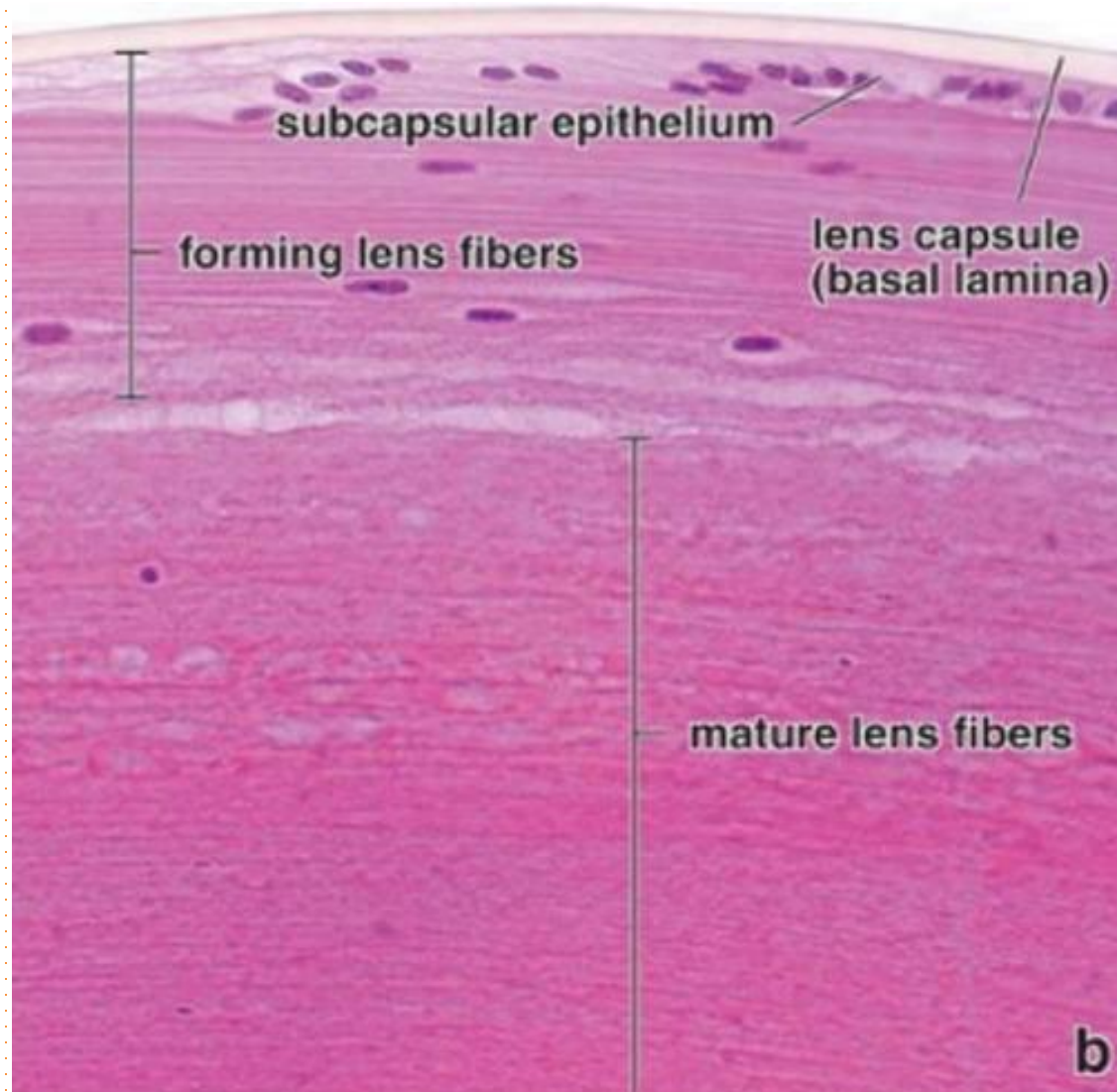


Lens

- Lens is a transparent biconvex structure suspended immediately behind the iris, which focuses light on the retina.

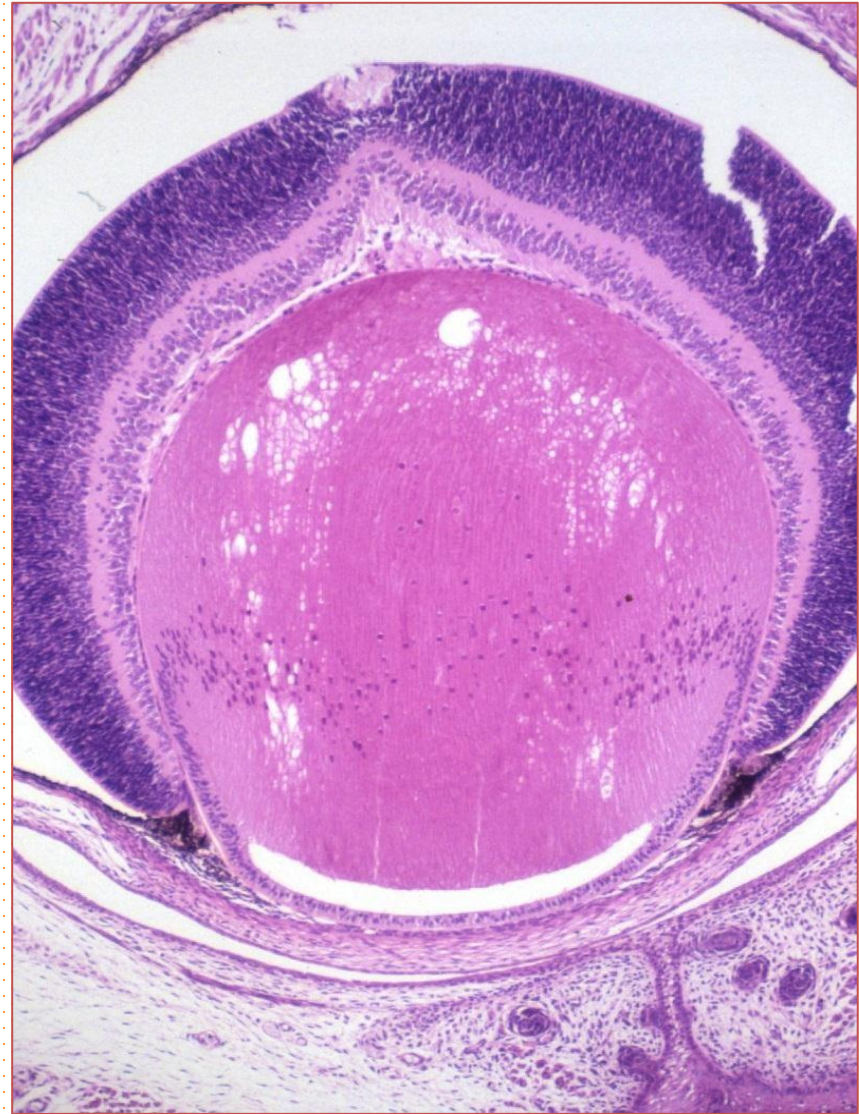
Has three principal components

- **Lens capsule** (proteoglycans and type IV collagen)
- **Lens epithelium** (single layer of cuboidal cells present only on the anterior surface)
- **Lens fibers** (cell cytoplasm filled with a proteins called crystallins,)



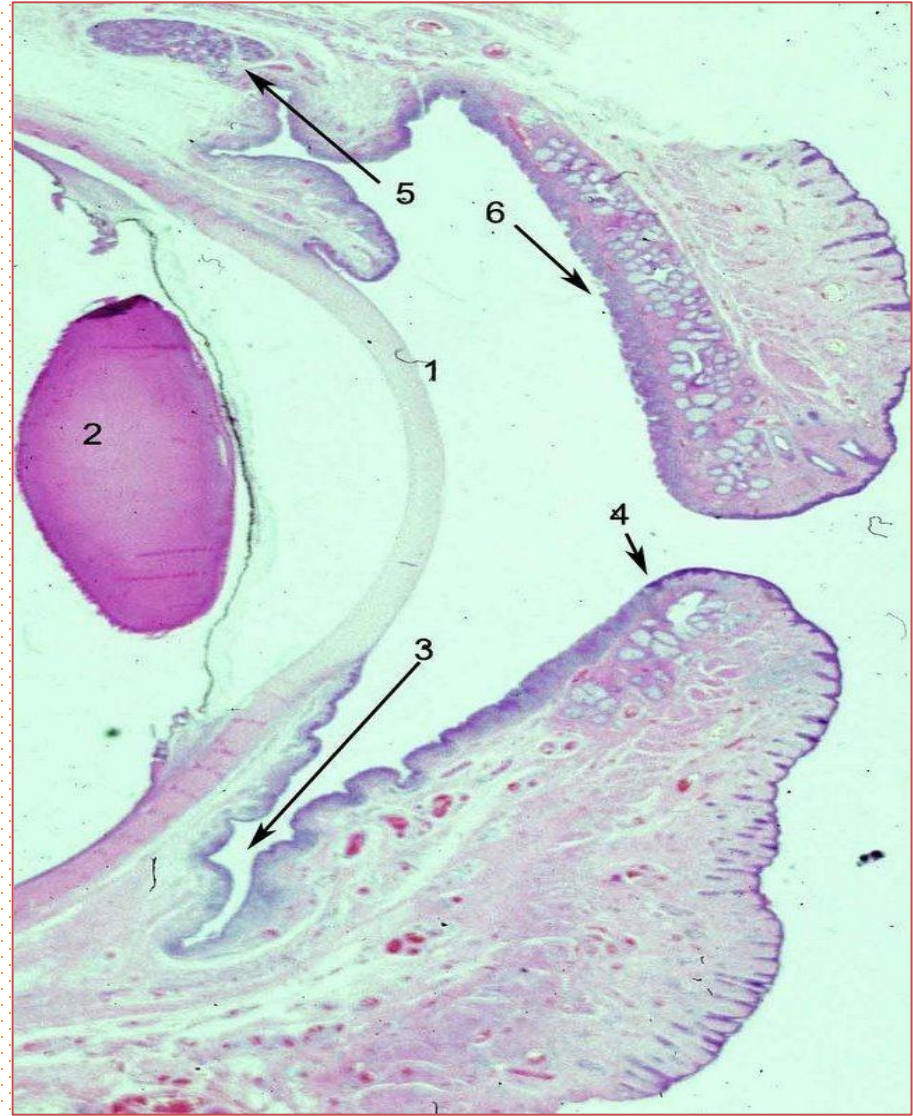
Vitreous body

- Airy gelatinous substance.
- It fills part of the eyeball
- Most of the vitreous body is made up of **water in which hyaluronic acid is dissolved.**
- A smaller part of the contents on the periphery of the vitreous body consists of **hyalocytes** - fibroblast-like cells that synthesize collagen fibers.
- The vitreous body maintains the shape of the eyeball and presses the sensory retina against the pigment epithelium, preventing retinal detachment.



Accessory Structures of the Eye

- Eyelids
- Conjunctiva
- Lacrimal apparatus

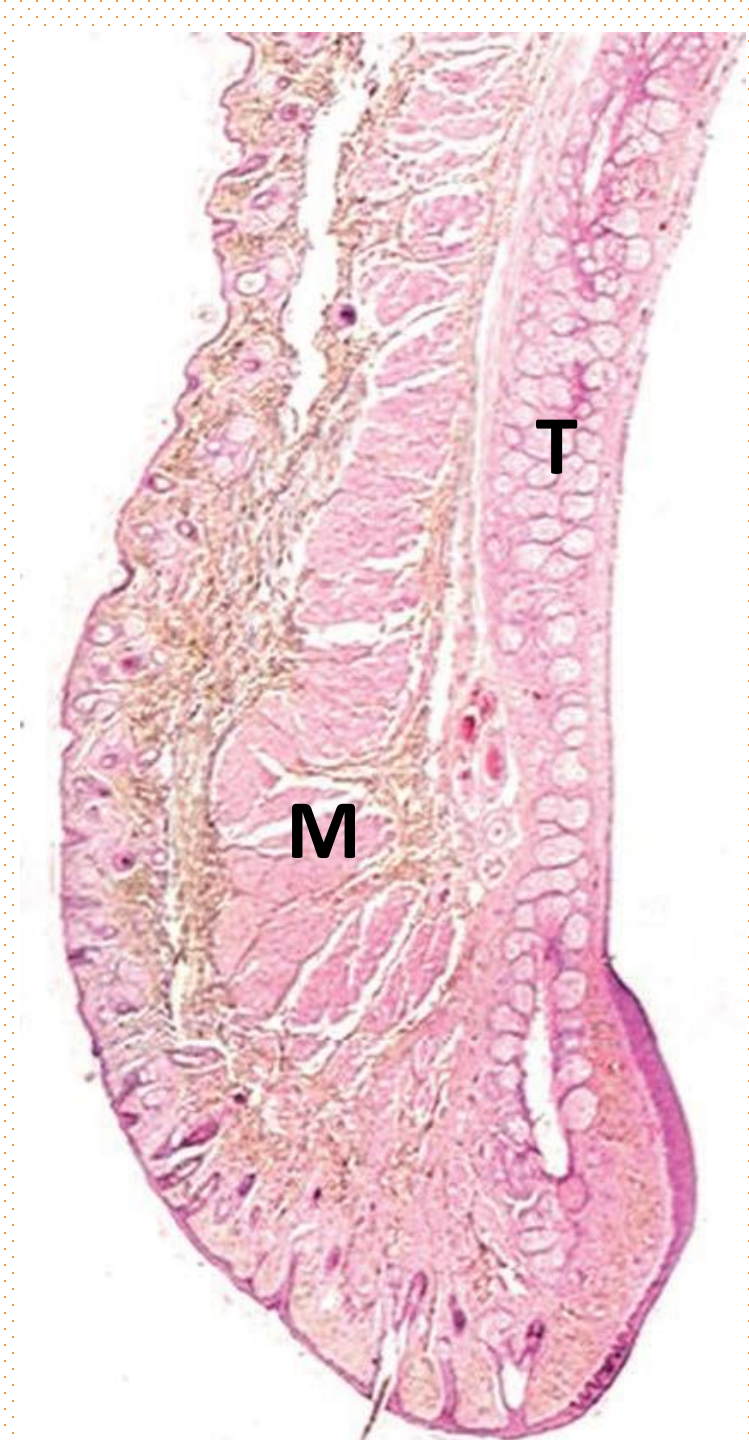


Eyelids

- Skin folds which cover the eyeball from the front.

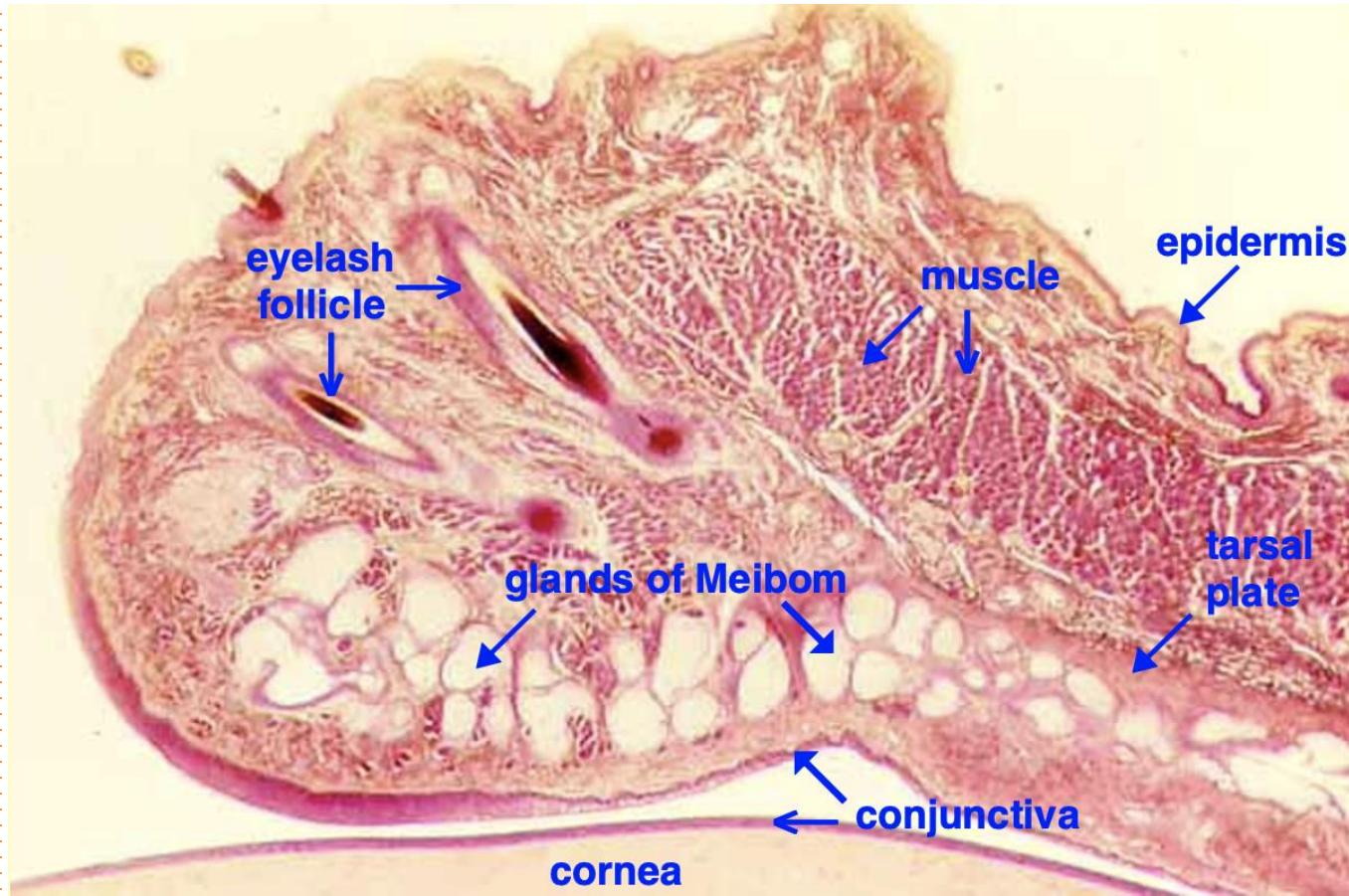
From the outside

- Skin (thin and elastic)
- Orbicularis oculi muscle
- Tarsal plate with modified sebaceous, Meibomian glands, glands
- Palpebral conjunctiva



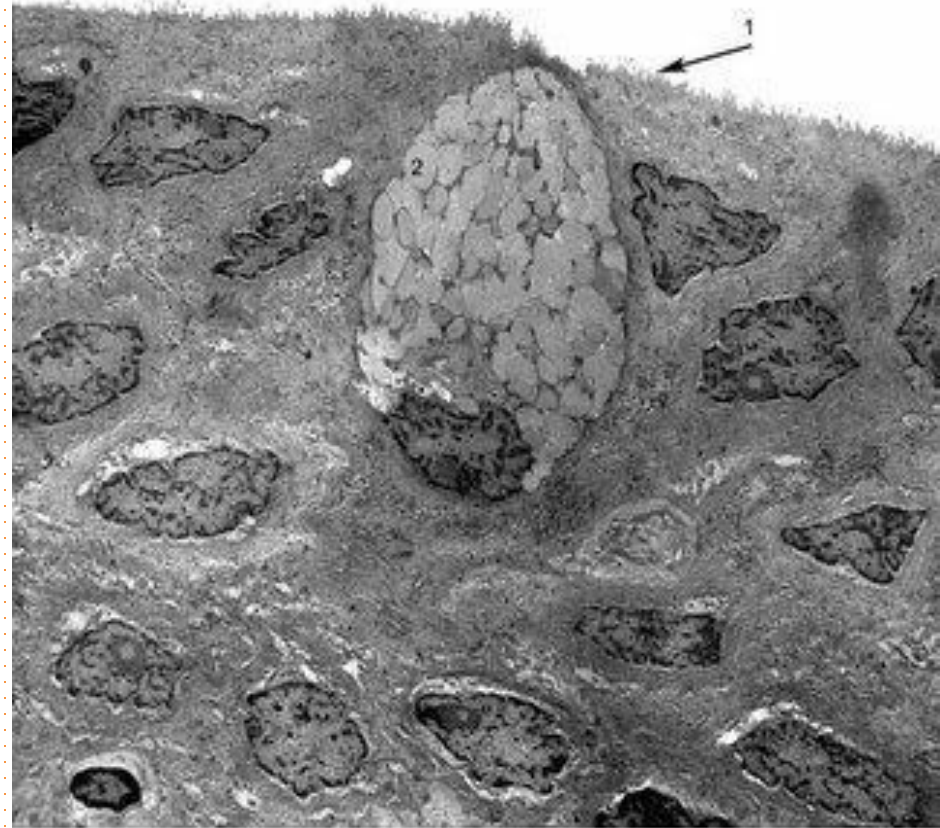
Eyelids

- **Eyelashes** do not have an erector muscle.
- **Zeiss' modified sebaceous glands and Moll's modified apocrine sweat glands** open into their follicles.
- The secretion has a similar composition and role to that of Meibom's glands.



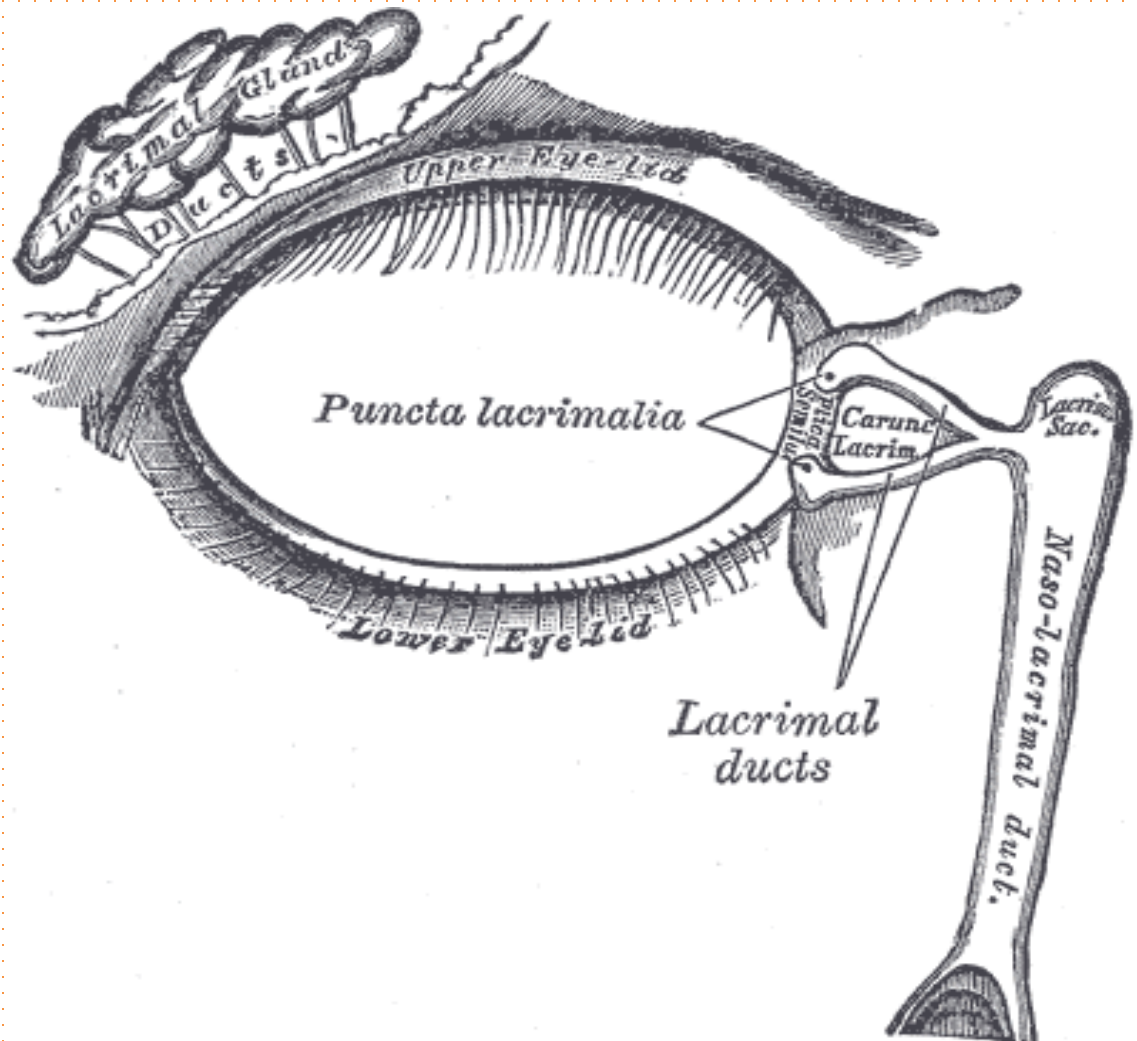
Conjunctiva

- **Conjunctiva** is a thin, transparent mucosa that covers the exposed, anterior portion of the sclera and continues as the lining on the inner surface of the eyelids.
- It consists of a **stratified columnar epithelium**, with numerous small goblet cells, supported by a **thin lamina propria** of loose vascular connective tissue

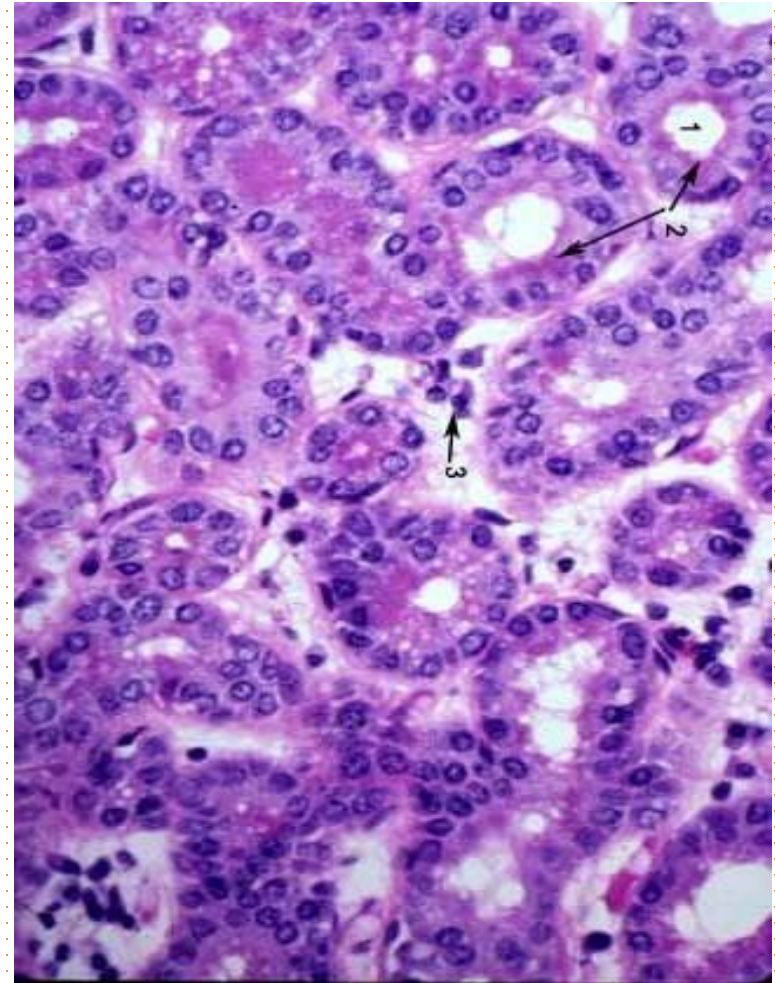


Lacrimal apparatus

- lacrimal gland
- lacrimal ducts
- lacrimal sac
- nasolacrimal duct



- Lacrimal gland of similar histology structur like a **serous salivary gland**.
- It has lower cells - lacrymocytes and a wider lumen of the acinus.
- The lacrimal gland has **6-12 main draining ducts** that open into the superior vault of the atrium.
- About **0.5 ml of tears** are produced daily in the lacrimal glands



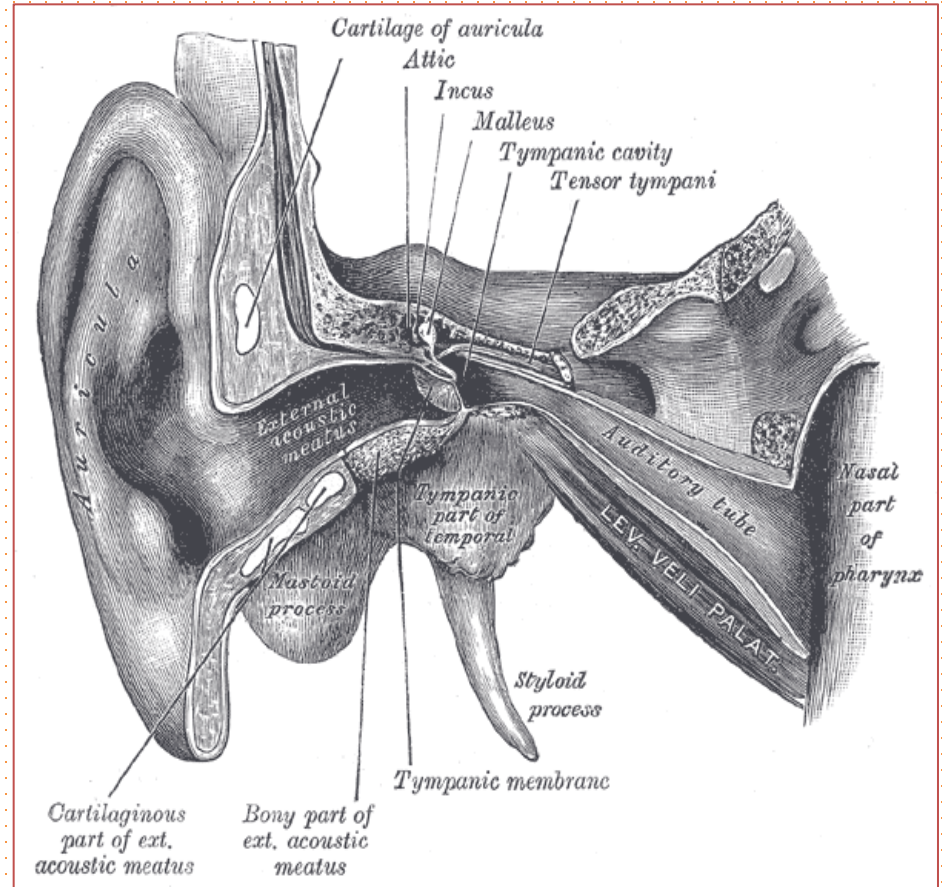
VESTIBULOAUDITORY SYSTEM

VESTIBULOAUDITORY SYSTEM

External ear, which receives sound waves;

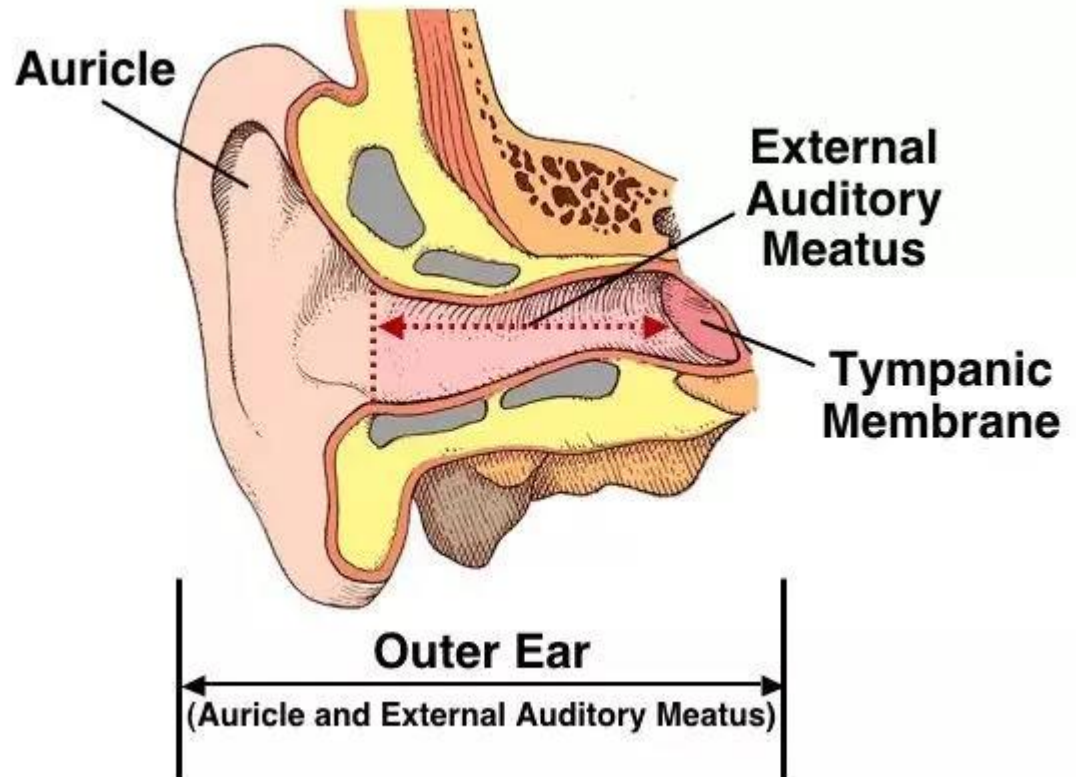
Middle ear, in which sound waves are transmitted from air to fluids of the internal ear via a set of small bones;

Internal ear, in which these fluid movements are transduced to nerve impulses passing via the acoustic nerve to the CNS. In addition to the auditory organ, the internal ear also contains the **vestibular organ** that allows the body to maintain equilibrium



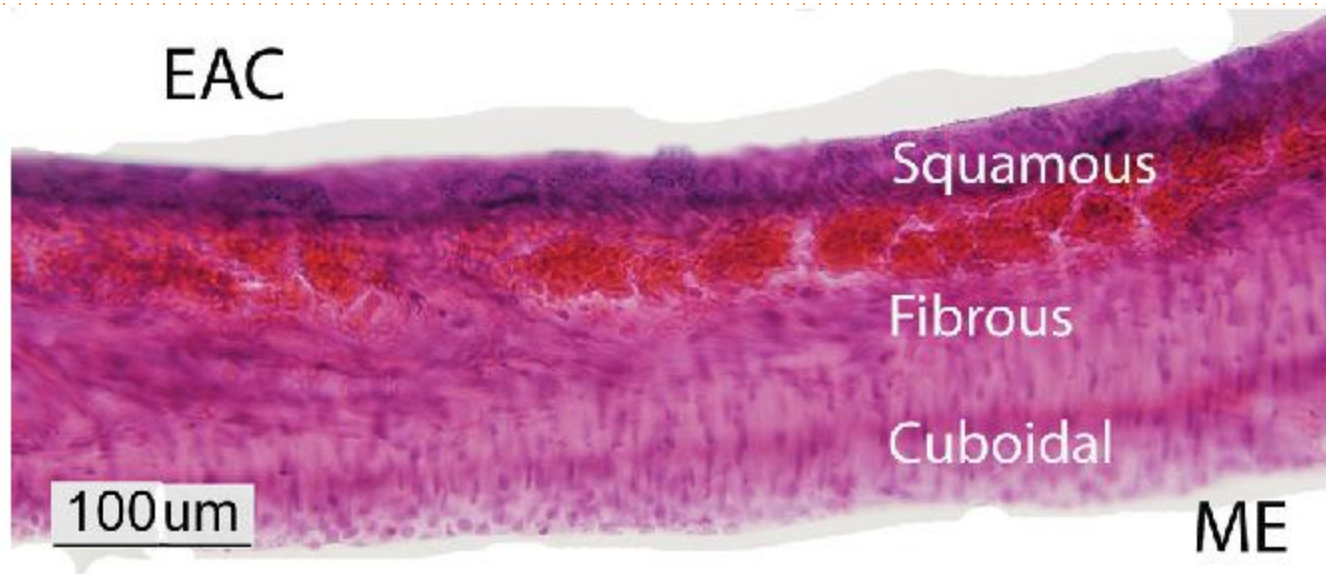
External ear

- The outer ear consists of the **auricle** (pina) and the **external ear canal**
- It extends from the **auricle to eardrum**.
- A thin skin covers the canal wall. In the dermis there are hair follicles, sebaceous glands and modified **apocrine sweat glands** (gll. ceruminosae).
- The secretion of apocrine glands, with sebum and desquamated cells of the epidermis, forms **earwax** (cerumen).



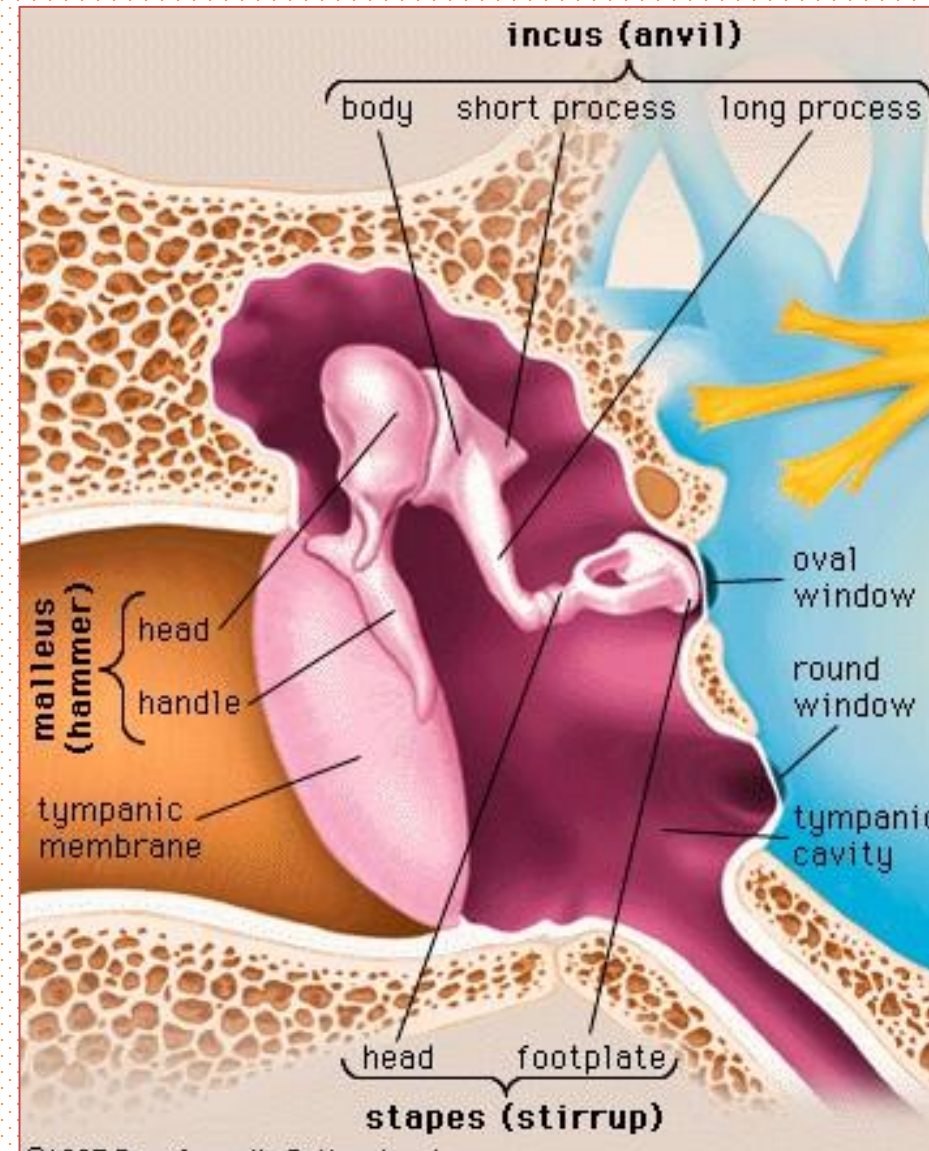
membrana tympani

- Thin, **three-layer membrane**.
- The **outer side** of the tympanic membrane is lined with **skin**, and the **inner side** with **mucous membrane**.
- In the **middle** there is **a fibrous layer** (collagen fibers with elastin network).
- The skin is thin, without hair, epidermal folds, sweat and sebaceous glands.



Middle ear

- Tympanic cavity
- Eustachian tube
- Auditory ossicles
- Air-filled mastoid cavities of the temporal bone.



Ossicles....

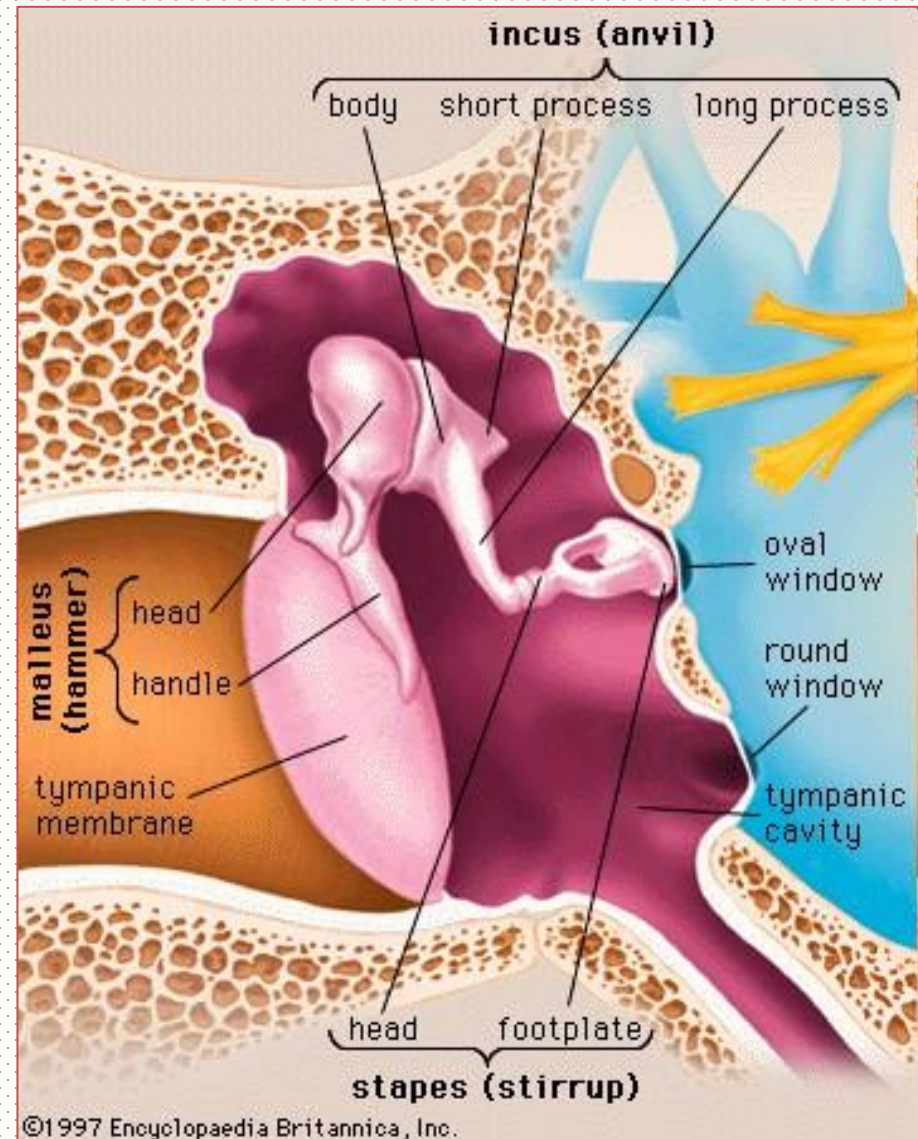
Three ossicles in the tympanic that articulate with each other:

- **Maleus**
- **Incus and**
- **Stapes**

- Through this chain of auditory bones, vibrations are transmitted from the eardrum to the perilymph of the inner ear.

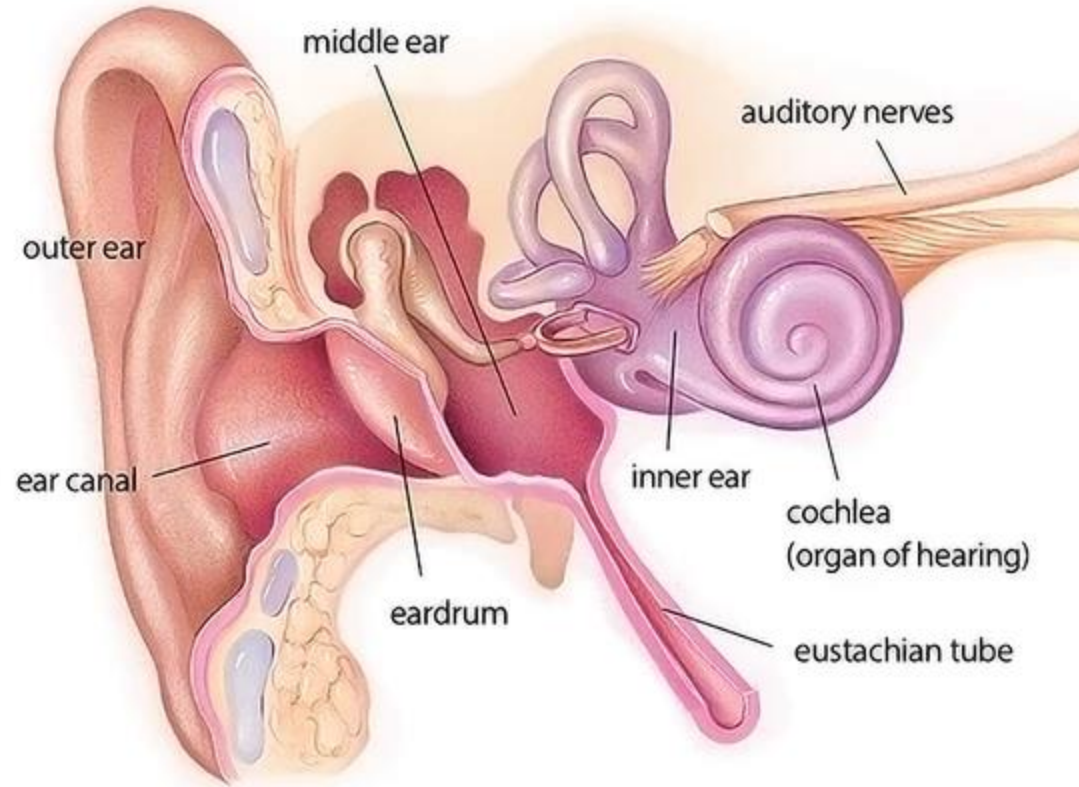
...Also two striated muscles:

- **M. tensor tympani** attaches to maleus (tightens the eardrum).
- **M. stapedius** (the smallest skeletal muscle) attaches to the stirrup.



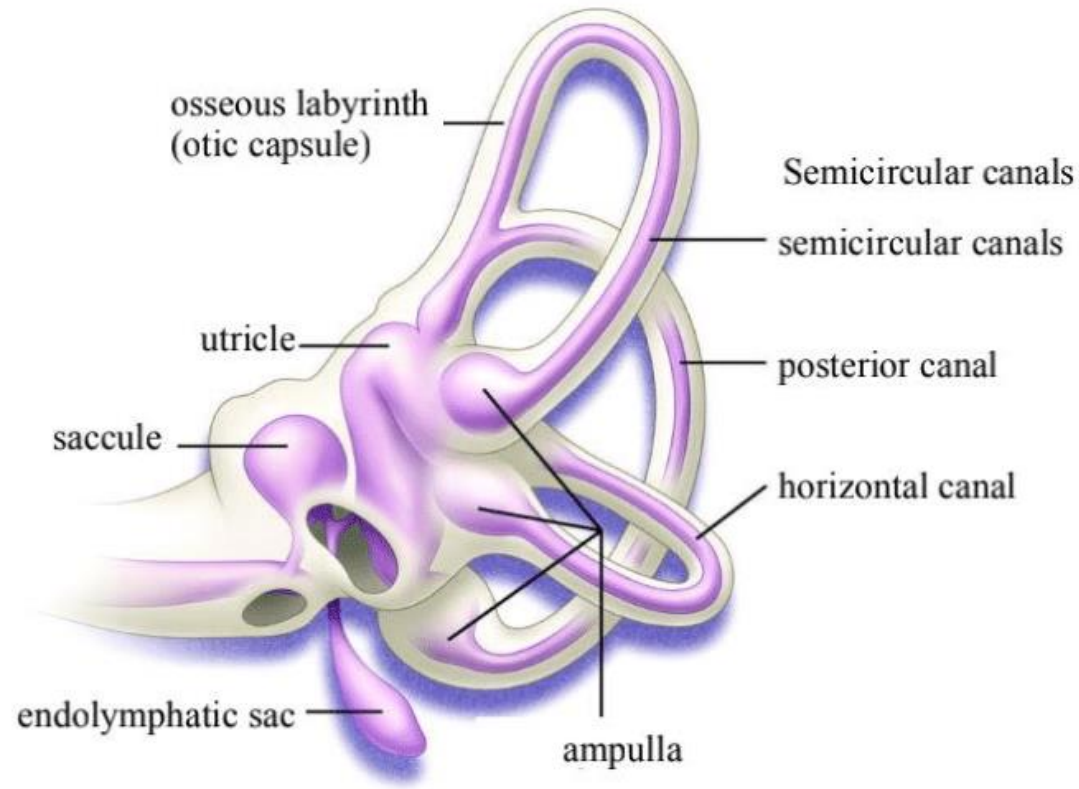
Inner ear

- The inner ear consists of two components - the **bony and membranous labyrinth**.
- In certain parts, the two labyrinths have merged.
- In the largest part of the ear, they are separated by a narrow space filled with a clear liquid - **perilymph**.



Membranous labyrinth

- Membranous labyrinth floats in the perilymph of the bony labyrinth.
- It fits in shape to a great extent.
- It is made by a system of closed, **interconnected membranes filled with endolymph**.
- Around the membranous labyrinth circulates the **perilymph**
- As part of the membranous labyrinth, **utricle, saccule, three semicircular ducts and the cochlear duct** are distinguished.

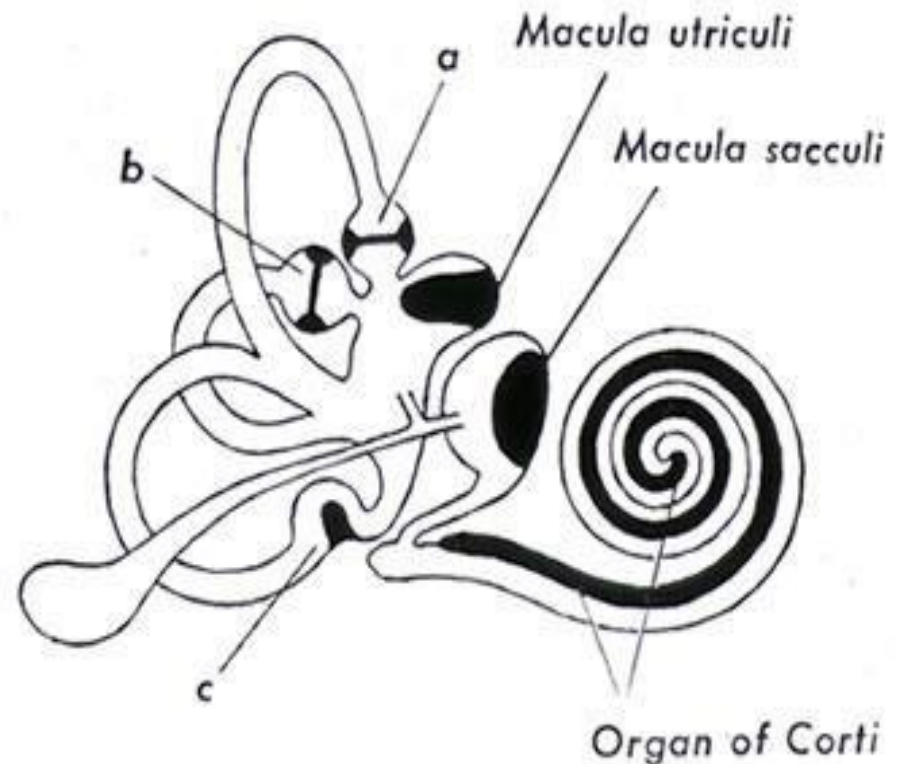


From the structural and functional aspect the membranous labyrinth contains two parts.

- One houses the organ of balance and orientation (**equilibrium**), and the other houses the auditory organ (**hearing**).
- Organ of balance and orientation is located in **utricle, saccule and semicircular ducts**.
- Auditory organ is housed in **cochlear duct**.

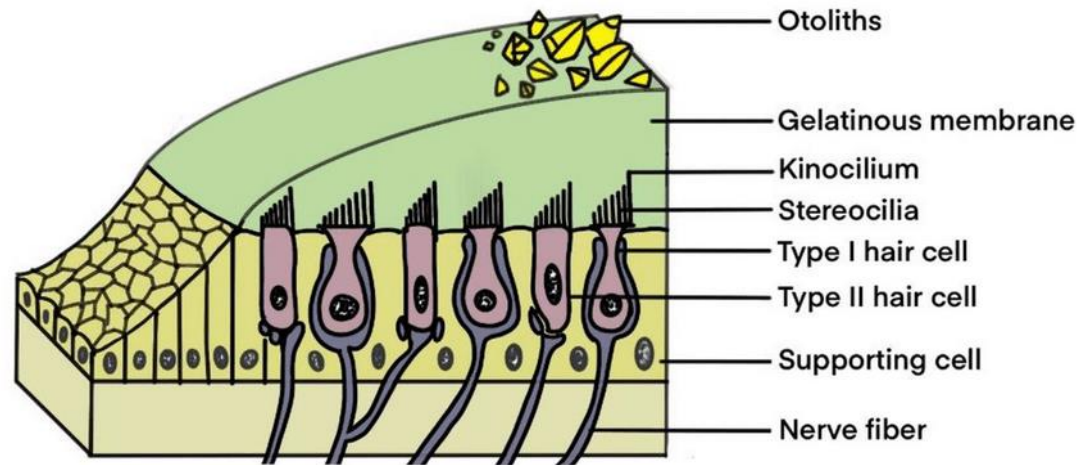
Equilibrium.....

- Mediating the functions of the inner ear, structures containing epithelial lining areas with columnar **mechanoreceptor cells**, called **hair cells**, in **5 specialized sensory regions**:
- **Two maculae** of the utricle and saccule,
- **Three cristae ampullares** in the enlarged ampullary regions of each semicircular duct,



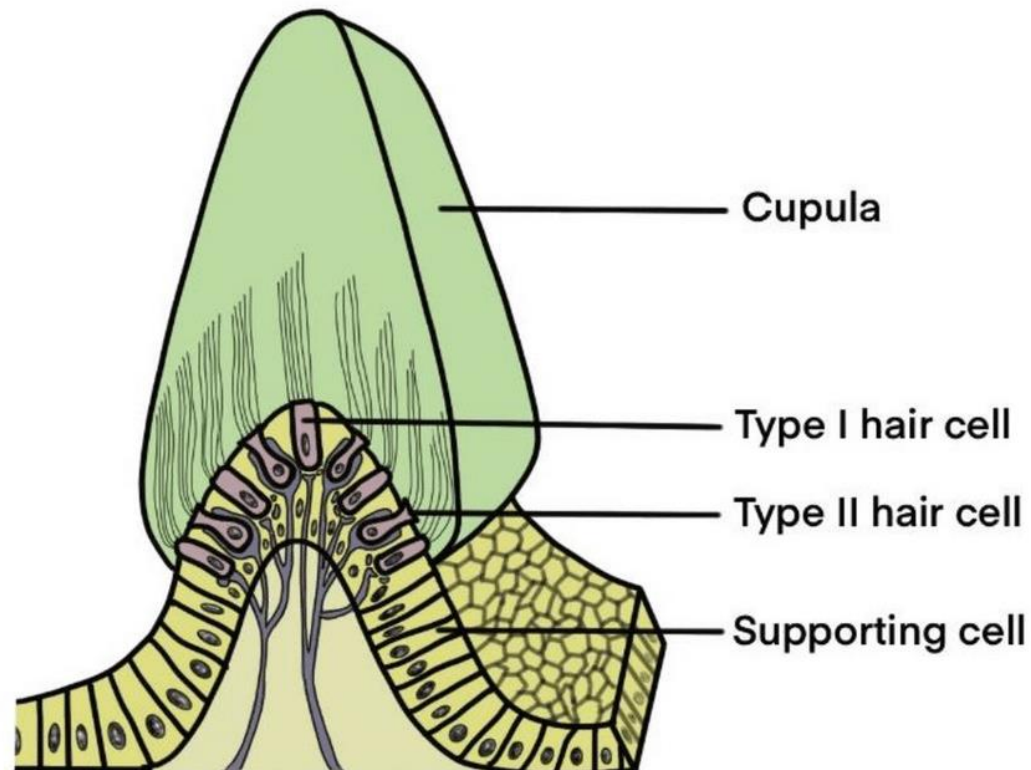
Maculae of utricle and saccule

- Contains **neuroepithelial and supporting cells**.
- There are 30-50 stereocilia and one kinocilia on the apical surface of the hair cells. The tips of the stereocilia and kinocilium are embedded in a thick, gelatinous layer of proteoglycans called the **otolithic membrane** that contains crystals of CaCO_3 and protein called **otoliths**.
- **Type I hair cells** have rounded basal ends completely surrounded by an afferent nerve terminal.
- **Type II hair cells** are cylindrical, with bouton endings from afferent nerves.
- Supporting cells form a glycoprotein-rich otolith membrane that covers the macular epithelium.



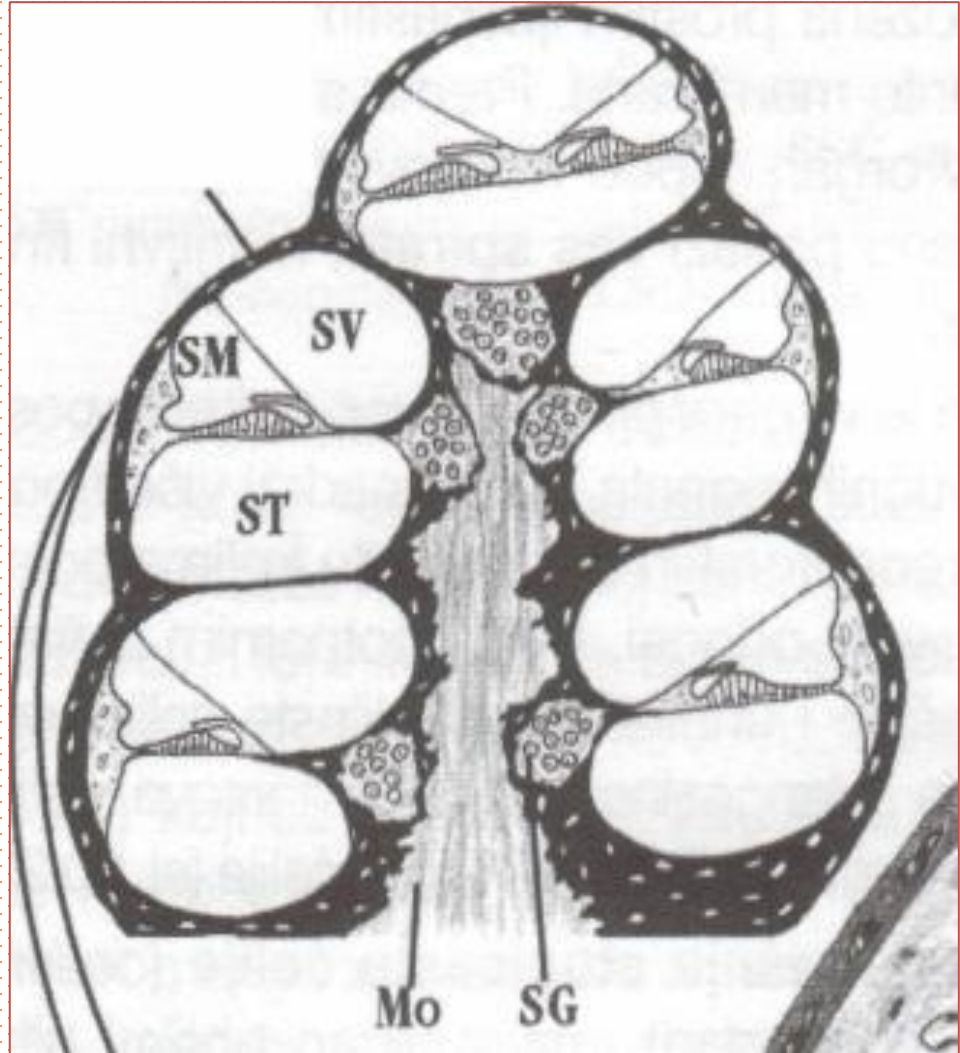
Cristae ampullares

- They are built by neuroepithelium and well-perfused thickened loose connective tissue.
- Epithelium is identical to epithelium of macula - **two types neuroepithelial cells and supporting cells.**
- The otolith membrane is thicker and reaches the opposite wall of the ampula - the dome (**cupula**).

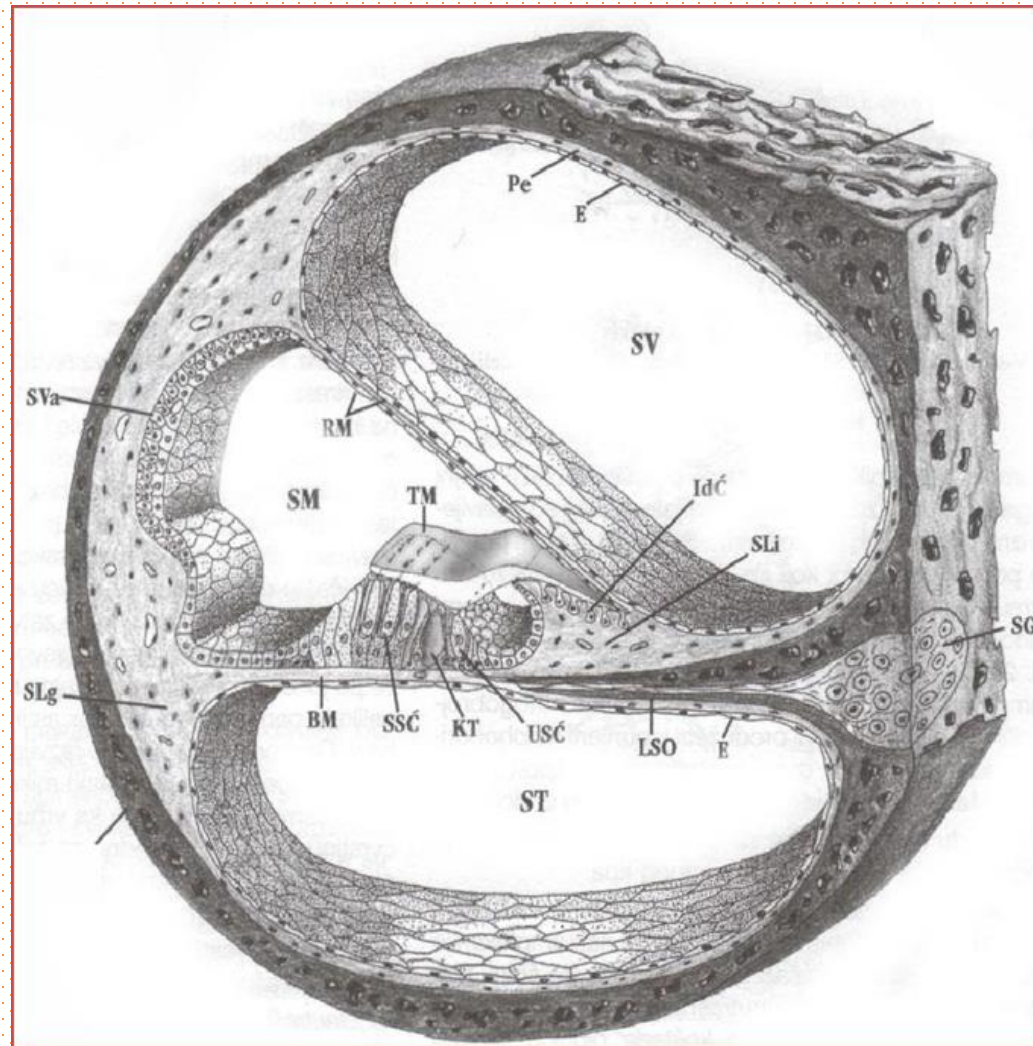


Hearing.....

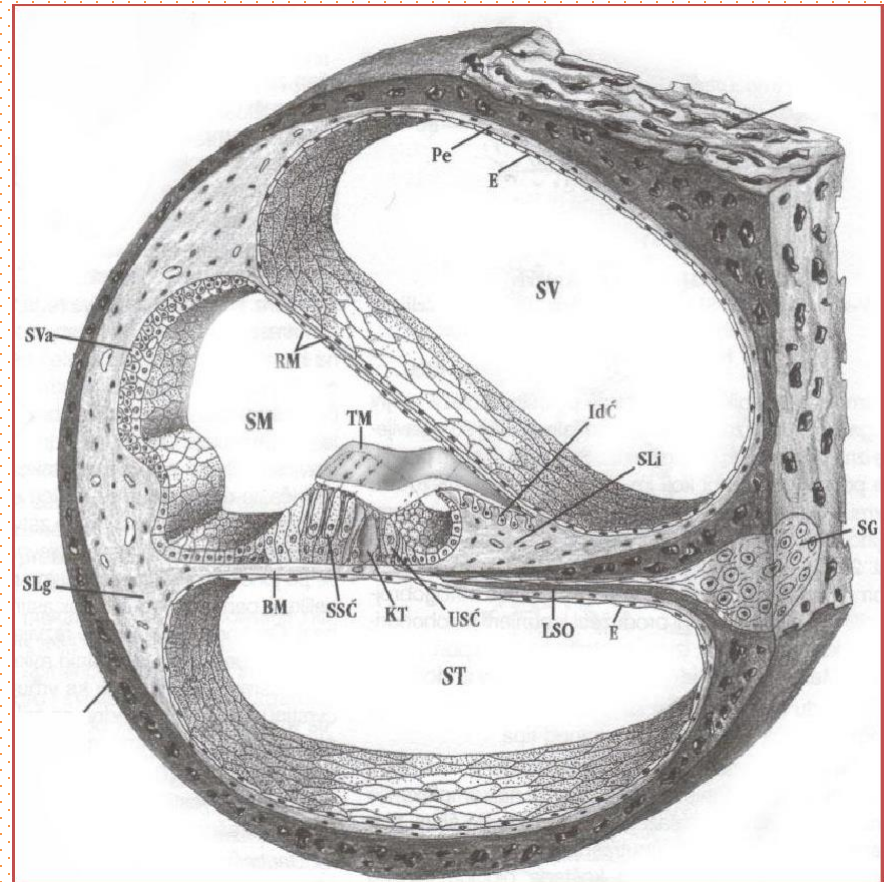
- **Cochlear duct**, a part of the membranous labyrinth shaped as a spiral tube, contains the hair cells and other structures that allow auditory function.
- Within the bony cochlea, this duct is one of three parallel compartments, or **scalae** which coil $2\frac{3}{4}$ turns within the cochlea.
 - **Scala tympani**
 - **Scala media**
 - **Scala vestibuli**



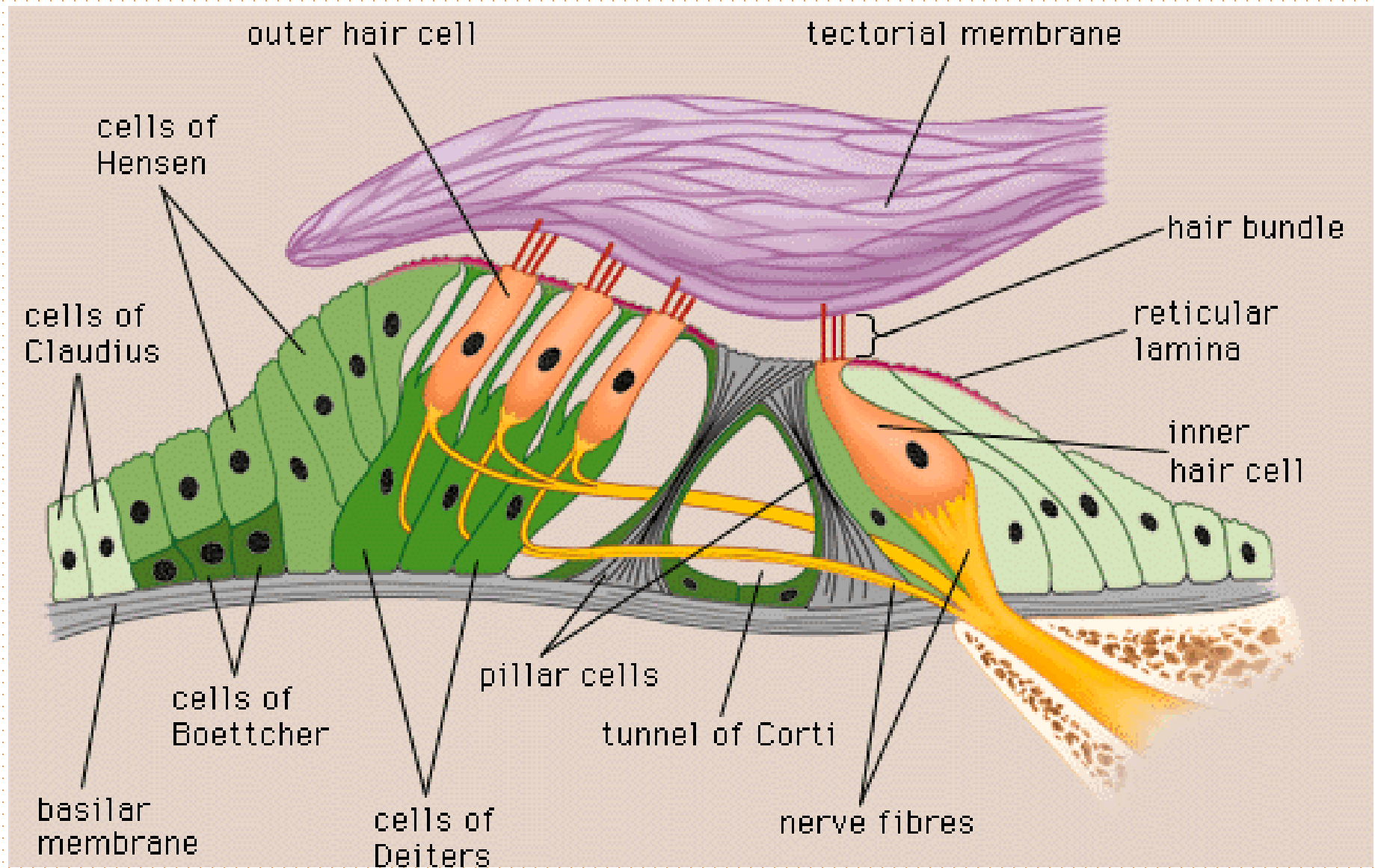
- Scala media is the cochlear duct that ends blindly at the top of the cochlea.
- The scala media is filled with **endolymph**.
- Upper floor (scala vestibuli) and the lower floor (scala tympani) are **filled with perilymph**.
- SV is separated from the SM by the very thin **Reissner membrane** lined on each side by simple squamous epithelium
- ST is separated from the scala media by the **fibroelastic basilar membrane**.



- The scala tympani and vestibuli communicate with each other at the apex of the cochlea via a small opening called the **helicotrema**. Thus these two spaces with perilymph are actually one long tube.
- **Stria vascularis**, located in the lateral wall of the cochlear duct (scala media) produces the endolymph.



Organ of Corti

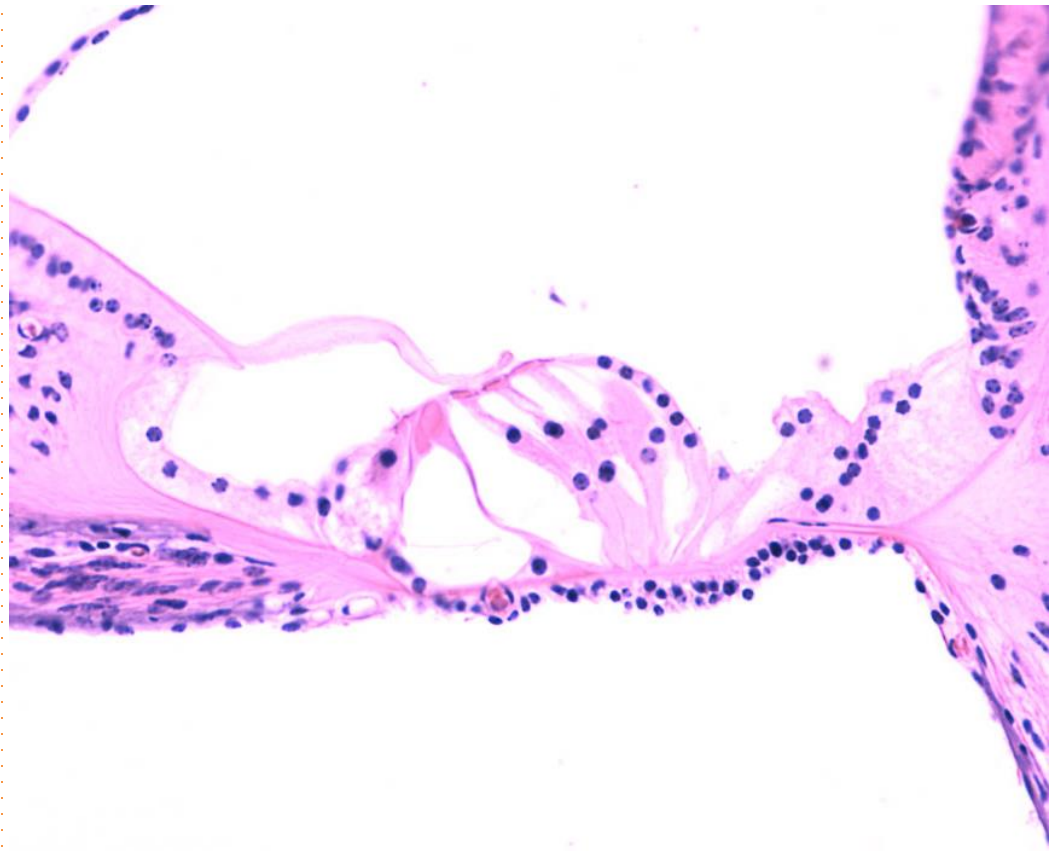


Organ of Corti

- A highly **specialized epithelium** capable of receiving sound signals.
- Contains multiple types of **supporting** and **receptor** cells.

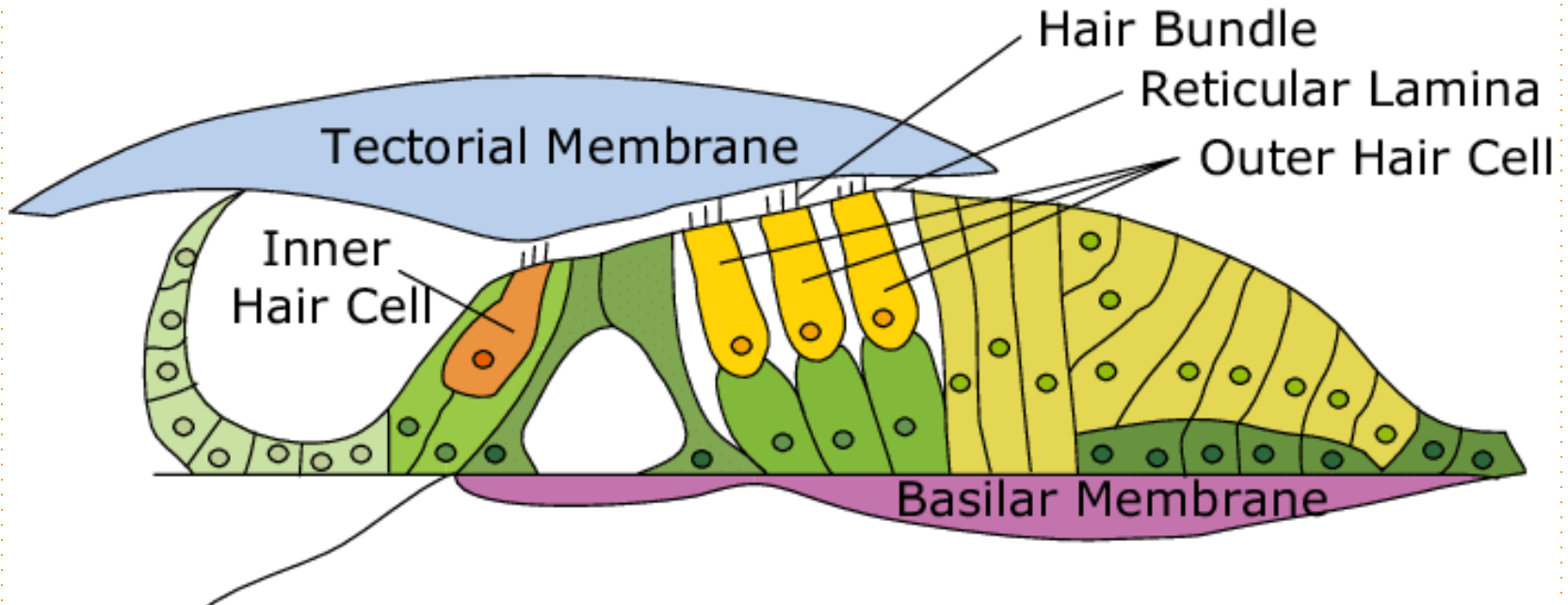
Among the supporting cells

- **Outer and inner pillar cells**
- **Outer and inner phalangeal (Deiters') cells.**
- **Hansen's, Becher's, Claudius' and marginal cells.**



Hair cells

- **Inner and outer hair cells** are distinguished.
- They have no contact with basilar membrane
- They "sit" on the phalangeal cells.
- On the free surface, they bear "hairs" in several rows embedded in **tectorial membrane**.
- The "hairs" are extremely long microvilli and usually denote as **stereocilia**.



- **Inner hair cells** - pear-shaped mechanoreceptors (3500 cells with 60 stereocilia).
- Arranged in **one row** (from the base to the tip of the cochlear duct).
- **Outer hair cells** - cylindrical shape (15000 cells with 100-200 stereocilia each).
- They form 3 rows at the base of the cochlear duct, and 5 rows at the top of the cochlea.

