Topic 9. Sense organs (part I)

Control questions

1. Parts of the sensory system. Functions.
2. Types of the receptor cells in sensory organs.
3. General structures of the eye.
4. Embryonic development of the eye.
5. Layers of the eyeball. Their tissues organization and functions.
6. Structure and functions of the lens.
7. Chambers of the eye.
8. Characteristic of the retina's neurons.
9. Layers of the retina.
10. Structure and functions of blind and yellow maculae of the eye.
11. Structure and functions of the rods and cons.
12. Olfactory organ.

Question 1. Parts of the sensory system. Functions.

Information about the external and internal environment is conveyed to the central nervous system by sensory system.

Sensory system consists of three part:

1) the peripheral part is represented by sensory organs that provide the perception of different irritations, such as sound, light waves and so on;

2) the middle part is represented by nerves, providing transmission of irritations to the brain;

3) the central part is represented by brain, containing different centers for the analysis of information.

Question 2. Types of the receptor cells in sensory organs.

Receptor cells are principle cells of the sense organs. There are three types of sensory cells:

1) Primary receptor cells (nerve-sensory) that are nerve cells developing from neural tube. They are present in visual and olfactory organs.

2) Secondary receptor cells (sensoepithelial). They are special epithelial cells developing from ectoderm. They are present in taste, vestibular or equilibrium and acoustic or hearing organs.

3) Neurons developing from neural tube and neural crests and forming sensory nerve endings. They are responsible for touch, pressure, pain, and temperature.

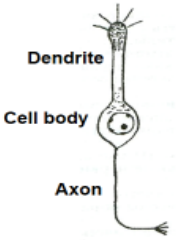

Figure 9.1. Diagram of nerve-sensory cell.

Nerve-sensory cells are bipolar neurons containing one axon and one dendrite, releasing from opposite poles of neuron cell body.

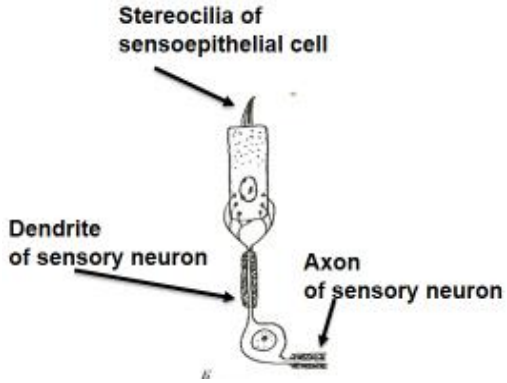

Figure 9.2. Diagram of sensoepithelial cells.

Sensoepithelial cells are columnar shape epithelial receptor cells containing modified microvilli called sensitive stereocilia on their apical domain. Basal domain of sensoepithelial cells contains the nerve endings of sensory neuron dendrites.

Question 3. General structures of the eye.

The eye is the peripheral parts of visual system.

The wall of the eyeball is composed of 3 layers:

1) Sclera and cornea;
2) Vascular layer or uvea;
3) Retina [13].

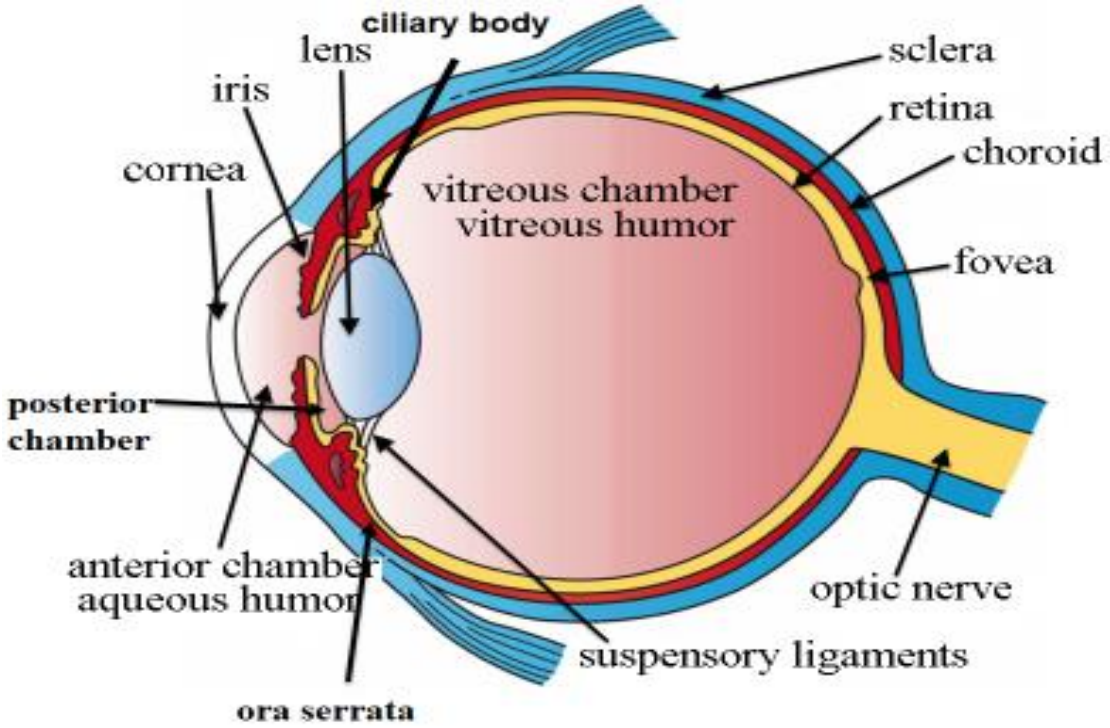

Figure 9.3. Diagram of the eyeball.

The outer layer of eyeball is mostly nontransparent sclera. Near anterior pole of eyeball the sclera is continuous with the transparent cornea.

The middle layer of eyeball called uvea is subdivided into:

a) choroid;
b) ciliary body;
c) iris;

The inner layer of eyeball is represented by retina [13].

In eyeball, there are 3 functional apparatuses: refractive; accommodative and photosensitive.

Refractive apparatus of eye includes cornea, anterior chamber, posterior chamber, lens and vitreous chamber (body).

Accommodative apparatus of eye includes ciliary body and iris.

Photosensitive apparatus of eye includes retina.

Question 4. Embryonic development of the eye.

The eye is developed from the different sources - **neuroectoderm, ectoderm and mesenchyme.**

Cranial end of the human embryo neural tube (forebrain) form 2 outpocketings called optic vesicles. They are connected with the brain by optic stalk. Optic stalk is source of optic nerve.

Later the optic vesicles undergo invagination to produce double-layered optic cups. Outer layer of the optic cup is the precursor of the pigment epithelium of the retina and dilator and sphincter pupillary muscles, while inner one is the precursor of the photosensitive part of the retina. Also, the optic cup gives rise to the epithelium of the iris, and ciliary body. Thus, the **neuroectoderm** is source of **retina, dilator and sphincter pupillary muscles, epithelium of the iris and ciliary body, optic nerve** in eyeball [13].

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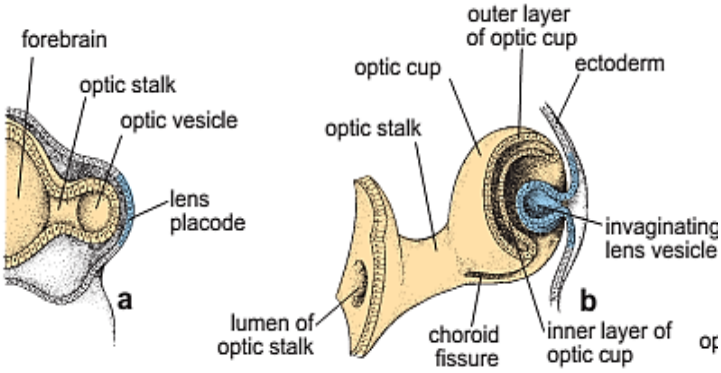

Figure 9.4. Diagram of the development of the eye [13].

Overlying optic vesicle surface ectoderm thickens and forms a lens placode. Invagination of the central region of each lens placode results in the formation of the lens vesicles. After the lens vesicle detaches from the surface ectoderm, this same site again thickens to form the corneal epithelium. Thus, the **ectoderm** is source of **lens and anterior corneal epithelium** in eyeball.

Mesenchyme is source of the **sclera, corneal endothelium, stroma of the cornea, ciliary body, iris, and choroid in eyeball** [13].

Question 5. Layers of the eyeball. Their tissues organization and functions.

Sclera

The sclera is composed of dense fibrous connective tissue that protects the more delicate internal structures of eye and provides attachment for the extrinsic muscles of the eye [13].

Cornea

The cornea covers the anterior one-sixth of the eye. The cornea consists of five layers:

1) Anterior epithelium (corneal epithelium);
2) Bowman's membrane;
3) Corneal stroma (substantia propria);
4) Descemet's membrane;
5) Posterior epithelium (corneal endothelium).

The anterior epithelium is nonkeratinized stratified squamous. It contains numerous free nerve endings and has a high capacity to regeneration.

Bowman's membrane (anterior basement membrane) is a homogeneous-appearing layer on which the corneal epithelium rests. Bowman's membrane consists of collagen fibrils.

The corneal stroma, also called substantia propria, is composed of about 60 thin lamellae and slender, flattened fibroblasts. Each lamella consists of parallel bundles of collagen fibers. But, the collagen fibers in each lamella are arranged at approximately right angles to those in the adjacent lamellae. The transparency of the cornea is due to uniform spacing of collagen fibers and lamellae, and the same refractive index of collagen fibers and ground substance.

Descemet's membrane (posterior basement membrane) is the basal lamina of corneal endothelial cells.

The corneal endothelium is a simple squamous epithelium covering the surface of the cornea that faces the anterior chamber. The corneal endothelium provides for metabolic exchange between the cornea and anterior chamber aqueous humor.

The cornea is avascular structure. It gets nutrition from anterior chamber.

The transitional zone between cornea and sclera is named corneoscleral limbus. The limbus region, specifically, the iridocorneal angle, contains the scleral venous sinus (canal of Schlemm) for the outflow of aqueous humor [13].

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Cornea (slide)

Stain: hematoxylin-eosin

Using this illustration you must perform the exercise 7 of album (topic "Sense organs" (part I))

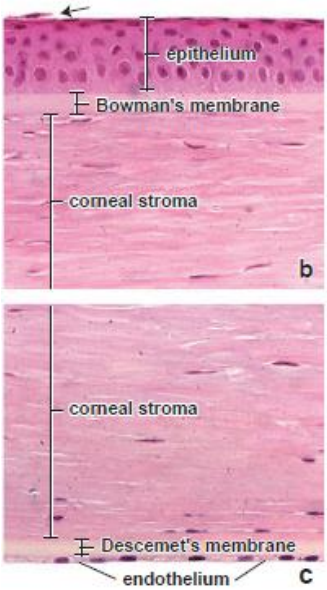

Figure 9.5. Photomicrograph of cornea [13].

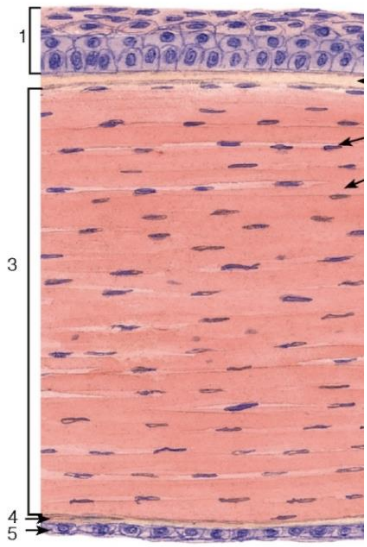

Figure 9.6. Diagram of cornea [18].

Choroid

Choroid is a dark brown vascular middle sheet between sclera and retina. The choroid consists of a lot of vessels and pigment cells melanocytes and collagen fibers that are loosely attached to the overlying sclera. The inner vessels of this layer provide nutrients to the cells of the retina. Towards the ora serrata the choroid is continues into the ciliary body and iris. The ora serrate is a junction between the ciliary body and the retina [13].

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Ciliary body

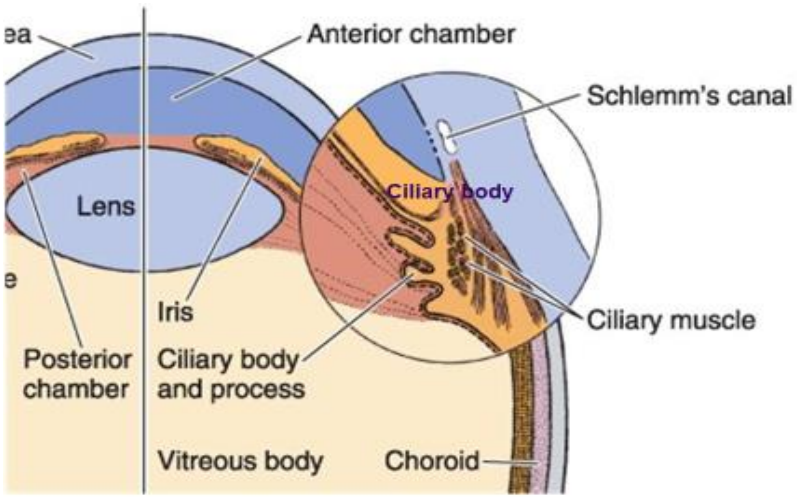

Figure 9.7. Diagram of the eyeball's anterior part.

The ciliary body is the thickened anterior portion of the vascular coat, lying between the iris and choroid.

Ciliary body consists of 2 parts:

1) outer is a siliary muscle (smooth muscle tissue) lying longitudinal, radial and circular. The muscle component provides the accommodation of lens to distant and near vision;

2) inner is a vascular part (vascularized loose connective tissue) which extends into the ciliary processes.

Ciliary processes are covered by a double layer of columnar epithelium called ciliary epithelium. Main function of this epithelium is secretion of aqueous humor filling the chambers of eyeball and secretion and anchoring of the zonular fibers that form the suspensory ligament of the lens [13].

Iris

The iris is the most anterior part of the vascular coat forming a contractile diaphragm in front of the lens to regulate the amount of light that enters the eye.

The iris arises from the anterior part of the ciliary body and separates the anterior and posterior chambers of eyeball. The pupil is the central aperture of iris.

The anterior surface of iris consists of a layer of fibroblasts and melanocytes. Beneath it there a thick layer of loose connective tissue or iris stroma. The iris stroma contains fibers, fibroblasts and melanocytes and blood vessels.

In stroma of the iris there is concentrically oriented smooth muscle called the constricter pupillae muscle (sphincter muscle). It is responsible for reducing pupillary size in response to bright light.

The dilator pupillae muscle is a thin sheet of radially oriented contractile processes of pigmented myoepithelial cells constituting the anterior pigment epithelium of the iris. This muscle is responsible for increasing pupillary size in response to dim light.

The posterior surface of the iris is covered by the bilayer pigment epithelium including anterior pigment epithelium and posterior pigment epithelium [3].

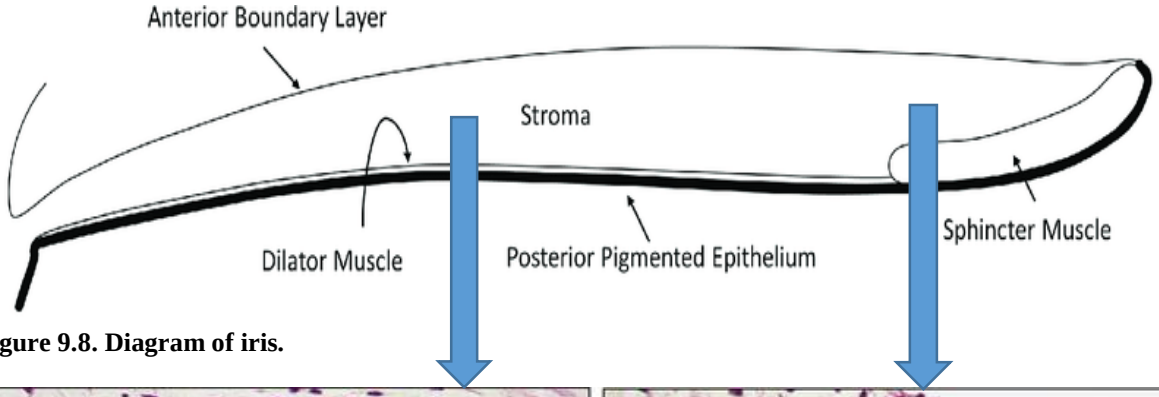

Figure 9.8. Diagram of iris.

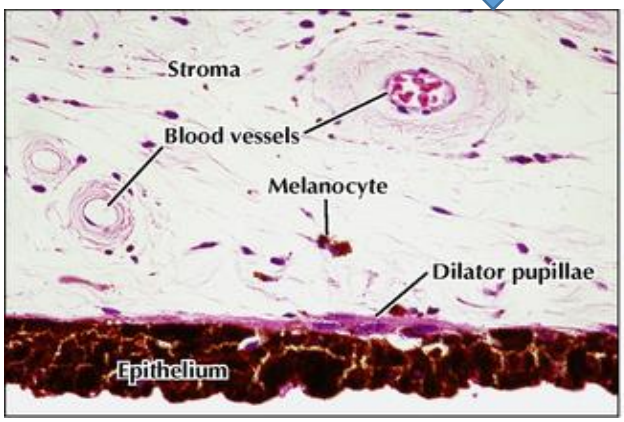

Figure 9.9. Photomicrograph of iris.

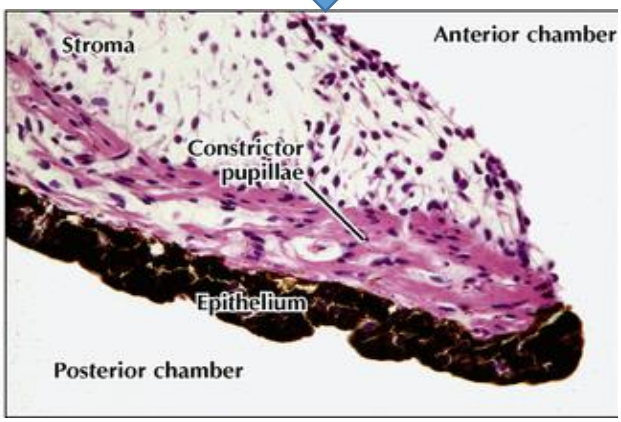

Figure 9.10. Photomicrograph of iris.

Question 6. Structure and functions of the lens.

The lens is a transparent, avascular, biconvex structure suspending between the edges of the ciliary body by the zonular fibers. These fibers form a connection between the ciliary body and the equatorial (lateral) region of the lens.

The function of the lens is to focus light on the retina.

The lens has three principal components:

1) The lens capsule;
2) The subcapsular epithelium;
3) The lens fibers.

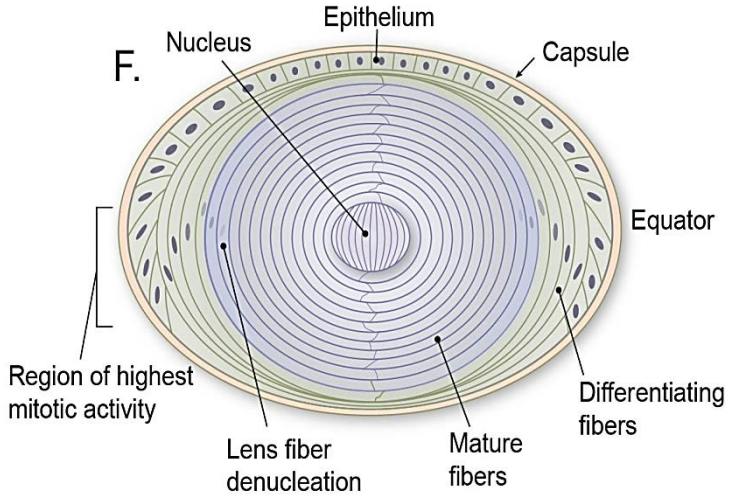

Figure 9.11. Diagram of lens.

The lens capsule surrounds the lens outside. One end of each zonular fiber is embedded in the capsule of lens. The lens capsule is a secretory product of the anterior lens cells. They are cuboidal epithelial cells presenting only on the anterior surface of the lens to produce here a subcapsular epithelium.

Subcapsular epithelial cells located near the equator of lens have capacity to mitosis and differentiation into lens fibers. Towards the central part of the lens, the lens fibers, become highly elongated and appear as thin, flattened structures. They lose their nuclei and other organelles as they become filled with proteins called crystallins. Near the center of the lens, the fibers are compressed and condensed to produce a nucleus [3].

Question 7. Chambers of the eye.

In eye there are 3 chambers:

1) Anterior chamber;
2) Posterior chamber;
3) Vitreous body [R].

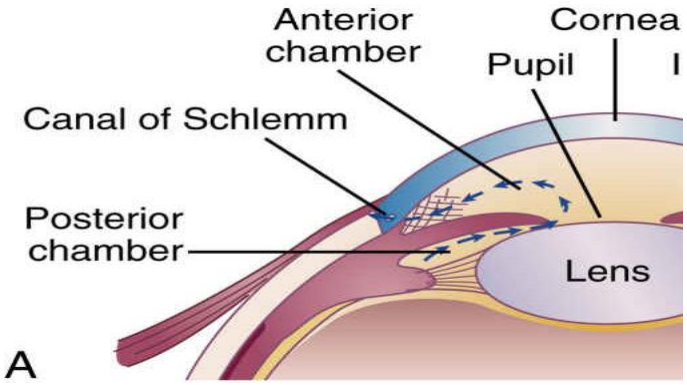

Figure 9.12. Diagram of production and removal of aqueous humor.

The iris separates anterior and posterior chambers from each other. The anterior chamber situates between the cornea and the iris. The posterior chamber is enclosed by the iris, zonular fibes and lens.

Both anterior and posterior chambers are filled by a fluid, called the aqueous humor. Aqueous humor is produced in the posterior chamber by the epithelium lining ciliary processes.

The aqueous humor is similar to blood plasma. It passes from the ciliary body toward the lens, and then between iris and lens to reaches the anterior chamber of the eye. In the anterior chamber, the aqueous humor passes laterally to the iridocorneal angle and finally reaches the canal of Schlemm, which communicates with the veins of the sclera.

Vitreous body is a transparent gelatinous substance that fills the eye between the posterior surface of the lens and the retina. The vitreous body is almost 99% water with soluble proteins, hyaluronan, glycoproteins, widely dispersed collagen fibrils. The fluid component of the vitreous body is called the vitreous humor [13].

Question 8. Characteristic of the retina's neurons.

Retina is a multilayered sheet of neural tissue covering the inner aspect of the posterior two thirds of the eyeball.

It consists of two basic layers:

1) The retinal pigment epithelium;
2) The neural retina [13].

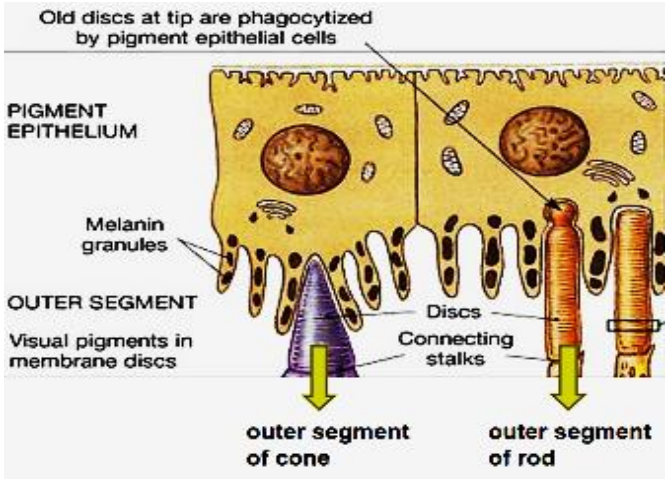

Figure 9.13. Diagram of pigment epithelium.

The retinal pigment epithelium is the outer layer of retina that rests on the choroid. It is represented by a single layer of cuboidal pigment cells, containing numerous melanin granules. Apical parts of pigment cells contain a complex of cytoplasmic processes that project, between the photoreceptor cells.

Pigment cells are important in absorbing excess light and they have capacity to phagocytose and dispose of membranous discs from the rods and cones of the retinal photoreceptor cells [13].

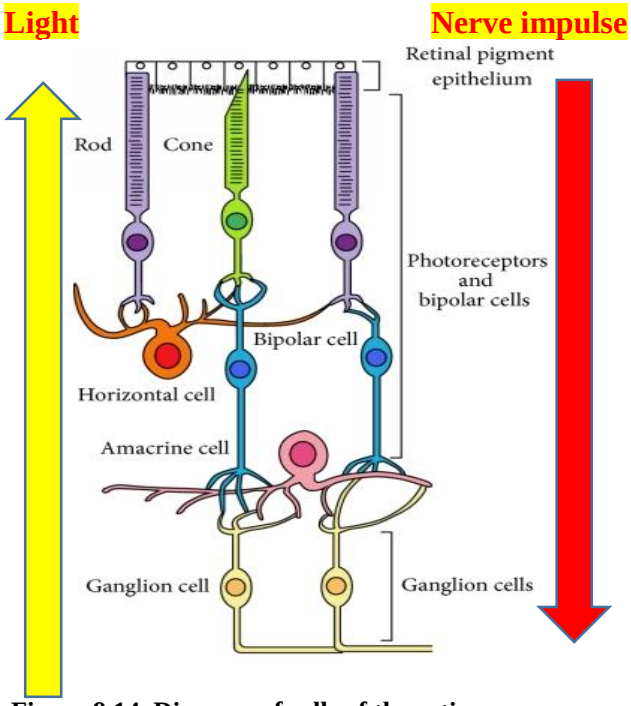

Figure 9.14. Diagram of cells of the retina.

The neural retina is represented by neurons and glial cells that can be classified into four groups of cells:

1) Photoreceptor cells - rods and cones;
2) Conducting neurons - bipolar neurons and ganglion cells;
3) Association neurons - horizontal and amacrine neurons;
4) Supporting cells - neuroglial Müller's cells [13].

Photoreceptor cells and conducting neurons of retina belong to typical bipolar neurons, because all they contain dendrite and axon releasing from opposite poles of the neurons. Dendrites of photoreceptor cells and conducting neurons toward the retinal pigment epithelium, but their axons toward the vitreous body.

Photoreceptor cells are sensitive to light. Light passes through all retinal layers to activate the photoreceptor cells. The photoreceptor cells transduce the light into electrochemical signals, which pass to bipolar neurons and then ganglion cells. The ganglion cells collect all visual information and send it along their axons, producing the optic nerve.

Horizontal and amacrine neurons are association neurons having long dendrites. The dendrites of horizontal neurons synapse with axons of the rods and cones cells and dendrites of bipolar neurons in the outer plexiform layer. They regulate synaptic transmission between rods and cones and bipolar neurons.

The dendrites of amacrine cells synapse with axons of bipolar neurons and dendrites of ganglion cells in the inner plexiform layer. They regulate synaptic transmission between bipolar neurons and ganglion cells.

Müller's cells are large supporting neuroglial cells that extend from the inner and outer limiting membranes, to produce them [3].

Question 9. Layers of the retina.

The specific arrangement and associations of the nuclei and processes of retina cells result in the retina being organized in ten layers. The ten layers of the retina, from outside inward, are:

1) **Retinal pigment epithelium** is the outer layer of the retina presenting by a single layer of pigment cells;

2) **Layer of rods and cones (photoreceptor layer)** presenting by dendrites of rods and cones (outer and inner segments of photoreceptor cells);

3) **Outer limiting membrane** presenting by the apical boundary of Müller's cells;

4) **Outer nuclear (granular) layer** presenting by the cell bodies (nuclei) of retinal rods and cones;

5) **Outer plexiform layer** presenting by the axodendritic synapses between the axons of the photoreceptor cells and dendrites of bipolar cells;

6) **Inner nuclear (granular) layer** presenting by the cell bodies (nuclei) of bipolar neurons and also the cell bodies of horizontal, amacrine and Müller's cells;

7) **Inner plexiform layer** presenting by the axodendritic synapses between the axons of the bipolar cells and dendrites of ganglion cells;

8) **Ganglion cell layer** presenting by the cell bodies (nuclei) of ganglion cells;

9) **Layer of optic nerve fibers** presenting by the axons of ganglion cells that lead from the retina to produce the optic nerve following to the brain;

10) **Inner limiting membrane** presenting by the basal boundary of Müller's cells [3].

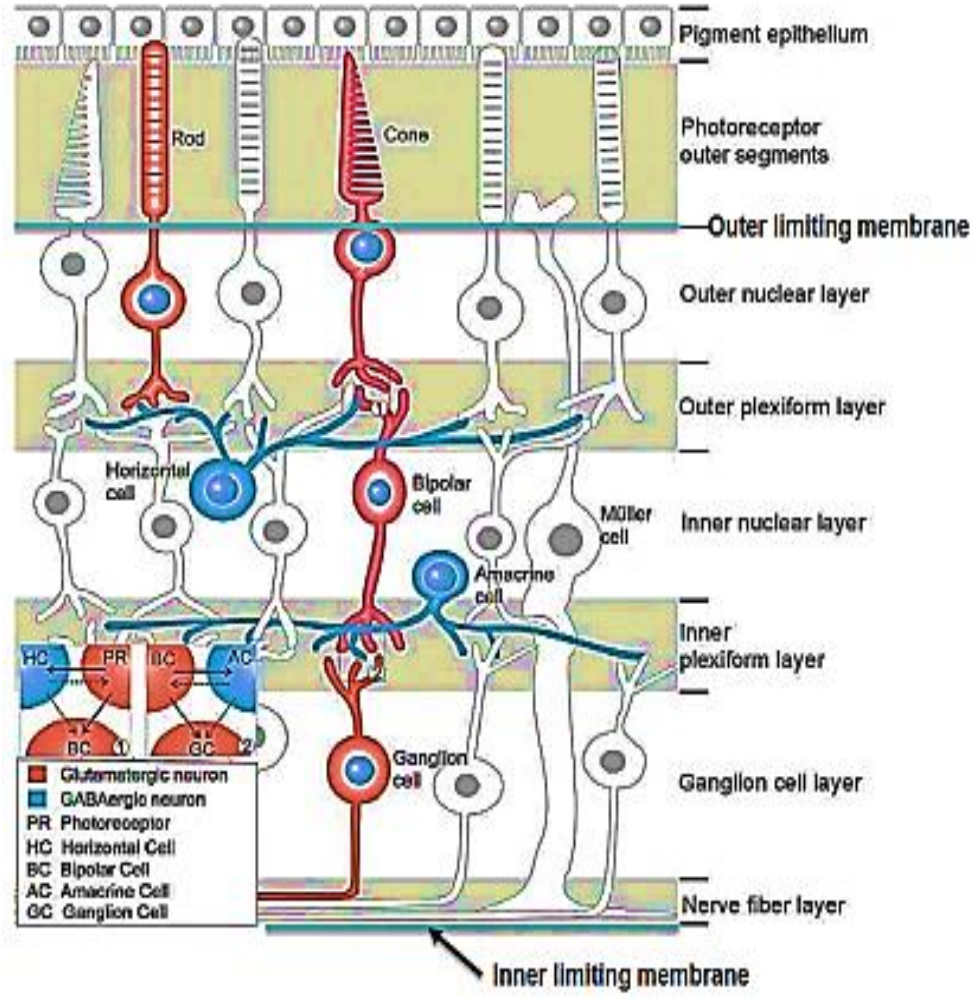

Figure 9.15. Diagram of the layers in retina.

Posterior wall of the eye (slide)

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Using this illustration you must perform the exercise 9 of album (topic "Sense organs" (part I))

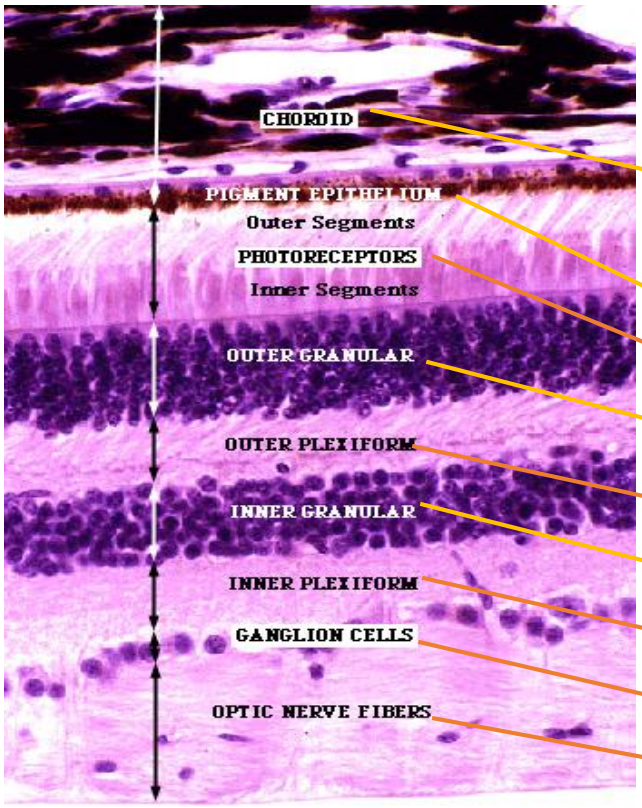

Figure 9.16. Photomicrograph of posterior wall of the eye.

Sclera

Figure 9.17. Diagram of posterior wall of the eye [18].

Question 10. Structure and functions of blind and yellow maculae of the eye.

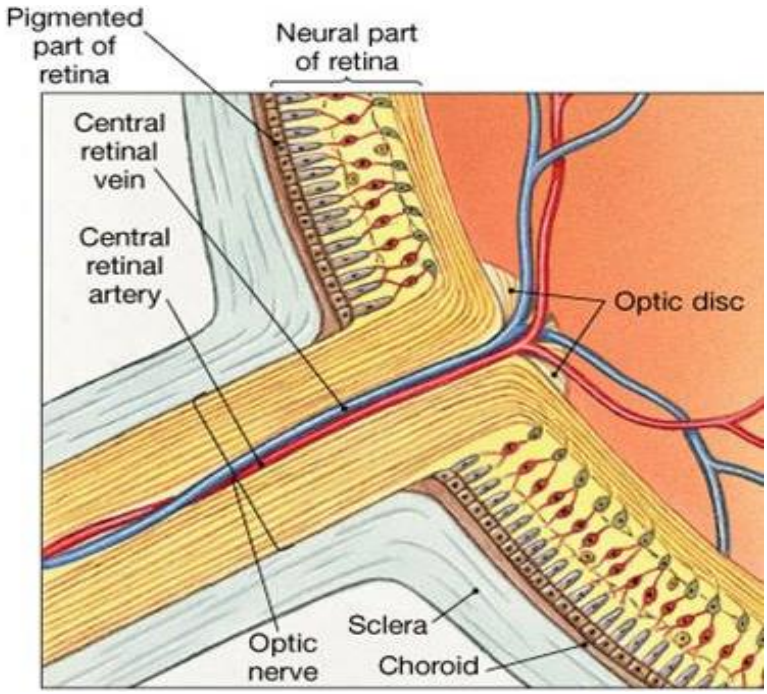

Figure 9.18. Diagram of the optic disc.

The **blind macula** also known as **optic disc (optic nerve papilla)**. It is the site at the posterior wall of the eye where the axons of the retina ganglion cells converge to form the optic nerve. Because the optic disc is devoid of photoreceptor cells, it is a blind spot in the visual field [13].

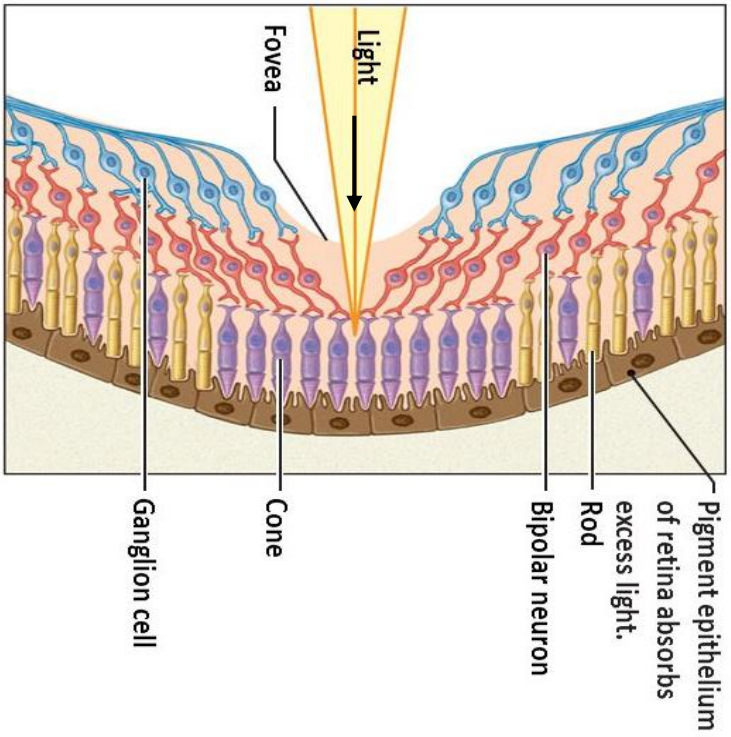

Figure 9.19. Diagram of the fovea.

The yellow macula (macula lutea) is the area surrounding the **fovea (fovea centralis)**. The fovea is a small depression located at the posterior pole of the optical axis of the eye.

Except for the photoreceptor layer, most of the retina layers are reduced or absent in this region. Here the photoreceptor is composed entirely of cones. In this area, the retina is specialized for discrimination of details and color vision [13].

Question 11. Structure and functions of the rods and cons.

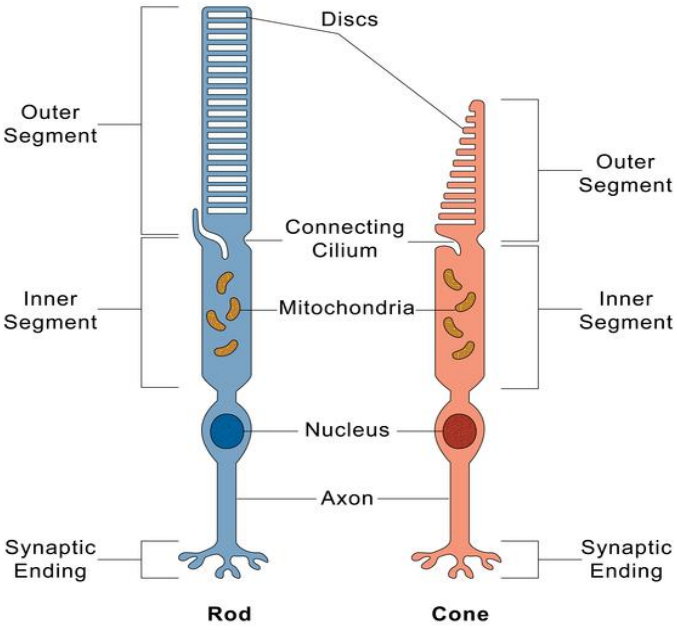

Figure 9.20. Diagram of rods and cons.

The ultrastructure of rod and con cells is similar. Both they consist of the cell bodies, containing the nucleus and external and internal processes releasing from opposite poles of their cell bodies. Their external process is modified dendrite consisting of two segments: outer and inner. The structure called connecting cilium binds the outer and inner segments with each other.

The outer segment of rod cell has rod shape and is composed of enclosed membrane flattened disks that are oriented transverse to the axis of the rod cell.

The outer segment of con cells is a conical more short structure presenting by disks membranes that are continuous with the con cell membrane. The inner segment of rod and con cells contains a great number of mito-chondria concentrating in area called ellipsoid [13].

The internal processes of rod and con cells are axons.

The retina contains approximately 120 million rods and 7 million cones. Rod cells contain the visual pigment rhodopsin, cone cells contain the visual pigment iodopsin. Both rhodopsin and iodopsin are present on the outer surface of the membranous discs.

Rod cells are specialized for motion detection and vision in dim light. Cone cells are specialized for fine acuity and color vision. Each cone cell is specialized to respond maximally to one of three colors: red, green, or blue [3].

Question 12. Olfactory organ.

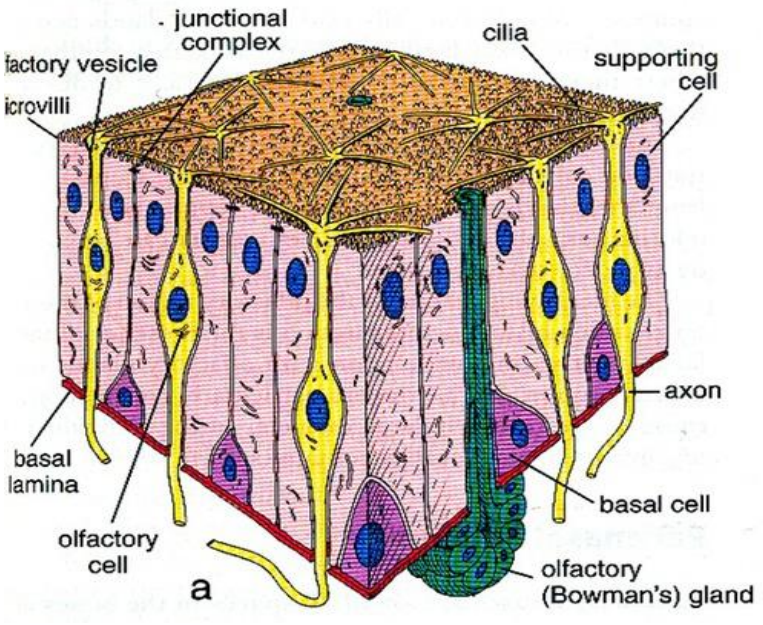

Figure 9.20. Diagram of olfactory mucousae [13].

Olfactory organ is represented by olfactory mucousae of the nasal cavity and provides the sense of smell. The olfactory mucousae are covered by olfactory epithelium.

The olfactory epithelium is a tall pseudostratified epithelium. It consists of three types of cells:

1) Supporting cells that are tall columnar cells with microvilli on the apical surface.

2) Basal cells that are small cells laying between the bases of the supporting cells and providing the regeneration in olfactory epithelium.

3) Olfactory cells that are bipolar neurons. The apical their process is a modified dendrite containing a bulbous head with six or eight olfactory cilia. Cilia are exited by a contact with odorous substances. The basal process of olfactory cell is axon. The olfactory nerve is formed by axons of the olfactory cells, passes through the ethmoid bone to the brain into the olfactory center.

The lamina propria in the olfactory area contains the olfactory (Bowman's) glands. Their secret keeps the surface of the olfactory epithelium moist [13].