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Course: Neurohistology

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QUESTION

1. Write an essay on the histological importance of the eye in relation to their cellular functions.
2. Corona Virus can penetrate the body through the eye and implicate the immune system, briefly discuss the layers of the retina for information penetration.

1. The Eye

The eye is the organ of sight in the human body. It is made up of different parts which carryout various functions that allows the eye to execute the function of sight. The parts of the eye are grouped into external and internal structures.

The external structures are eyelids, eyelash, conjunctiva, muscles, accessory glands. The internal structures are arranged into three layers:

1. **External layer**
    - Cornea
    - Sclera
2. **Middle layer called uveal tract**
    - Iris
    - Ciliary bodies
    - Choroid
3. **Internal layer**
    - Lens
    - Retina

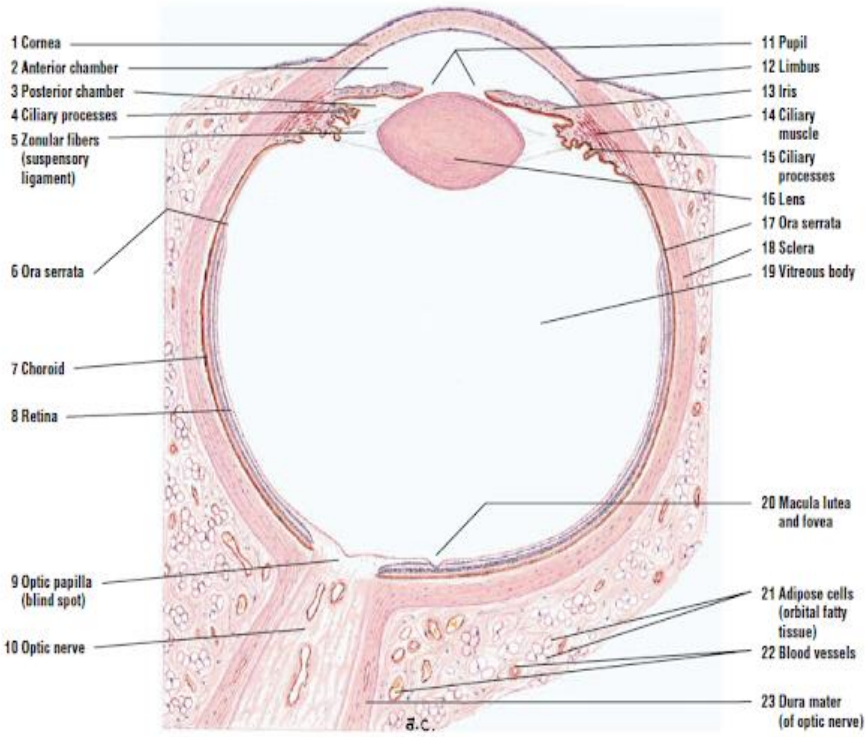
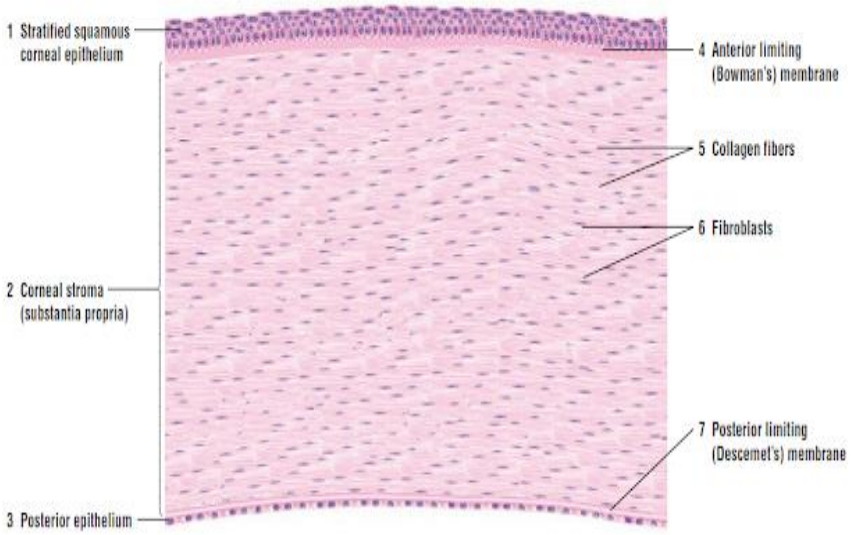


Diagram of the eye

Cornea

This is the transparent front layer that covers the iris and pupil. It provides most of the refractive power of the eye i.e. it allows light rays to enter the eye and converge the light ray. Histologically, the cornea consists of five layers. From outer to inner, these layers are:

- Epithelium: The epithelium of the cornea is non-keratinized stratified squamous epithelium. This layer is regenerative and interacts with the tear film. This layer is important because it helps replace cells of the cornea that are lost due to wear and tear.
- Bowman Layer: This is the basement membrane protecting the underlying stroma. It is made up of type 1 collagen fibers, laminin and other heparan sulfate proteoglycans.
- Stroma: This is the largest layer of the cornea and it is made up of type 1 collagen fibers arranged in a uniform parallel direction. The function of this layer is to maintain the transparency of the cornea which is achieved by the regular arrangement of the collagen fibers. This layer is maintained by keratocytes.
- Descemet's membrane: This is the avascular modified basement membrane of the corneal endothelium that is made up of type IV collagen fibers
- Corneal endothelium: This is a one cell thick layer made up of simple squamous or cuboidal cells. These cells do not regenerate and they possess pump which helps maintain fluid balance and prevent swelling of the stroma because of the close proximity of the cornea with the aqueous humor.

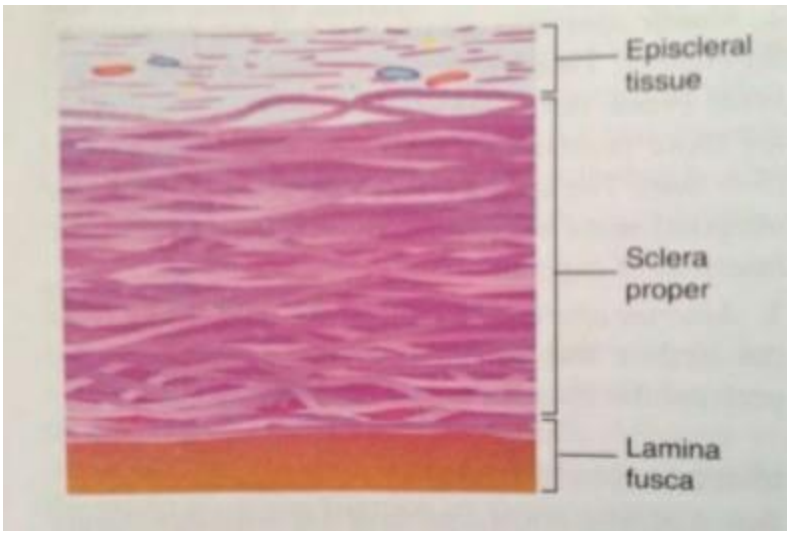


Layers of the Cornea

Sclera

Also known as the white of the eye, it is the opaque, fibrous, tough outer protective layer of the eye which is continuous with the cornea anteriorly and the optic sheath posteriorly. The sclera provides protection and form for the eye. It consists of dense connective tissue made up of type 1 collagen fibers which are oriented in different directions. This irregular arrangement of the collagen fibers is what gives the sclera the white color appearance as opposed to the transparent nature of the cornea. It is made up of 4 layers.

- Episclera: This is the outer most layer of the sclera. It is the thin dense vascularized layer of connective tissue. it is connected to the tenon capsule (deep fascia of the eye) by thin collagen fibers. At the corneoscleral junction (limbus) the tenon capsule contacts the stroma of the conjunctiva.
- Stroma: this is an avascular layer that is made up of collagen fibers. It is opaque due to the scattered arrangement of the collagen fibers. It also contains mucopolysaccharides.
- Lamina fusca: layer is brownish in color due to the presence of pigment cells. It is continuous with the suprachoroidal and supraciliary lamina of uveal tract.
- Endothelium.

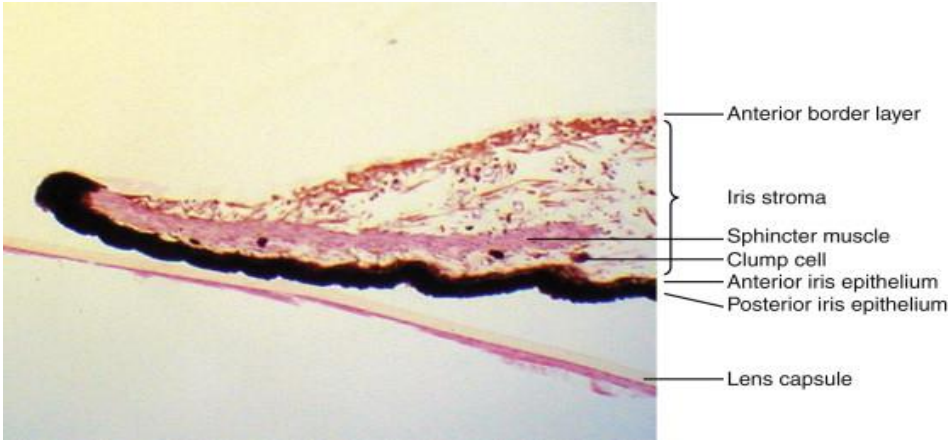


Layers of Sclera

Iris

The iris is the pigmented tissue lying behind the cornea that gives color to the eye. It controls the amount of light entering the eye by varying the size of the papillary opening(pupil). The iris has two layers

- Stromal layer: This is the pigmented fibrovascular layer which is connected to the sphincter pupillae which contracts the pupil in a circular motion and dilator pupillae which pulls the iris radially to enlarge the pupil.
- Pigmented epithelial cells: this layer lies beneath the stroma layer. These pigmented cells prevent light from entering through the iris so that light passes through the pupil only. It is two cells thick. The outer edge of the iris (known as root) attaches to the sclera and the anterior ciliary body. The angle formed by the iris and the cornea contains connective tissue with endothelial channels called trabecular meshwork which drains aqueous humor in the anterior chamber into the venous canal of Schlemm (circular vessel that surrounds the cornea). From here, it drains into the episcleral veins.

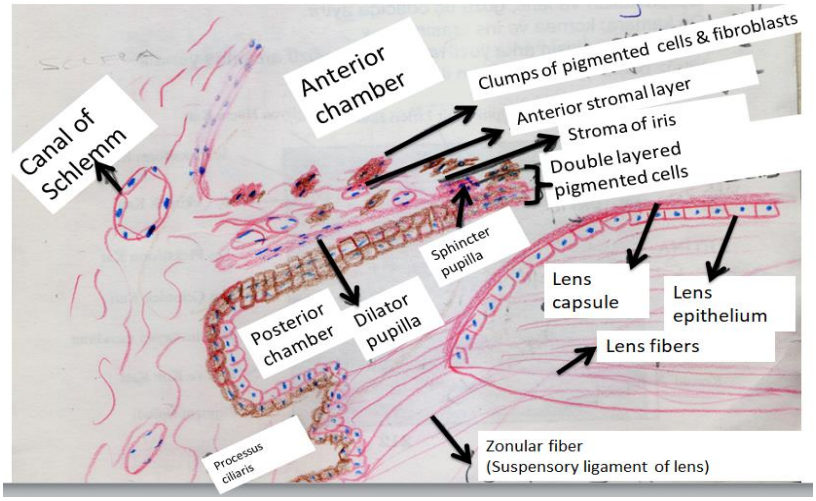


Layers of Iris

Ciliary Bodies

This is a ring-shaped tissue that separates the posterior chamber from the vitreous body. It is made up of

- Ciliary muscles: The ciliary muscle is smooth muscle that consist of three muscle fibers; longitudinal, circular and oblique muscle fibers. These muscles attach to the lens via lens zonules (suspensory ligaments) and hence they can control the shape of the lens and allow it to focus light on the retina appropriately.
- The ciliary epithelium: This layer produces aqueous humor which fills the anterior compartment of the eye.



Layers of ciliary body and lens

Choroid

This is the vascular layer that lies in between the sclera and retina. Its function is to provide nourishment to the structures of the eye. It is housed in loose connective tissue. Along with the iris and ciliary body the choroid forms the uveal tract. Structures in the choroid is generally divided into four layers.

- Haller's layer: outermost layer consisting of larger diameter blood vessels.
- Sattler's layer: layer of medium diameter blood capillaries.
- Choriocapillaris: layer of capillaries that supply the retina
- Bruch membrane: this is the extracellular matrix layer between the choroid and the retina that allows diffusion of substances to the retina from the choroid.

Figure 29.7C

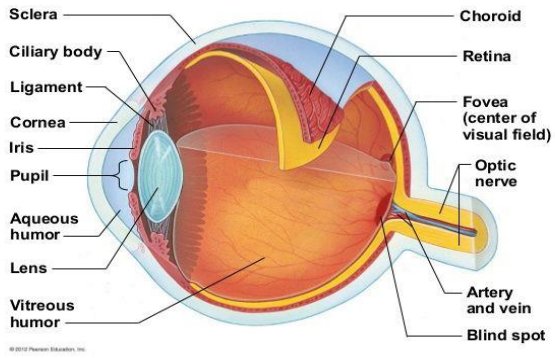


Diagram of the eye showing the choroid

Lens

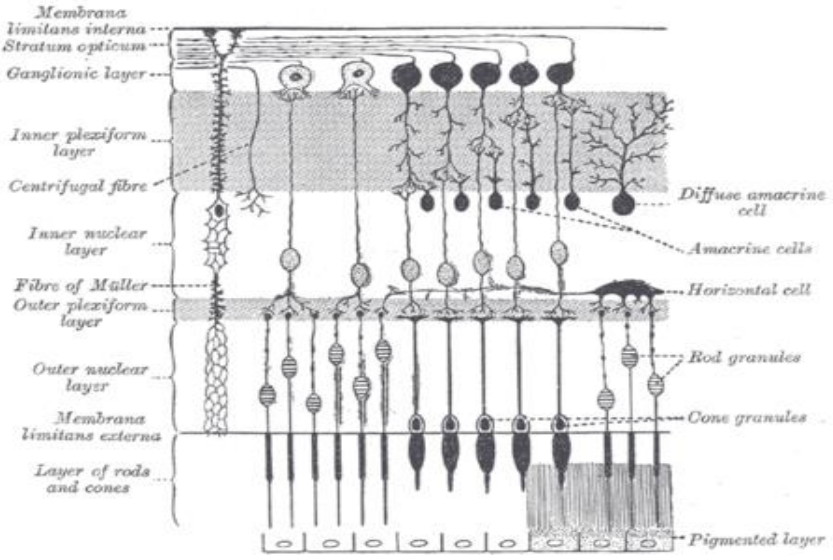
This is a transparent biconvex structure in the eye that together with the cornea focuses light rays on the retina. The cornea contributes most of the eyes focusing power (2/3), however, its focus is fixed. Accommodation, which is the refocusing of light to better view near objects, is achieved by the lens. It consists of three layers

- Lens capsule: This is a smooth, transparent basement membrane that completely surrounds the lens. It is elastic and composed of collagen type IV and glycosaminoglycans. It is synthesized by the lens epithelium. The elasticity of the lens allows the lens to change shape when the ciliary muscles contract and relax.
- Lens epithelium: This is simple cuboidal epithelium and it is located beneath the lens capsule in the anterior portion of the lens. It maintains the homeostatic function of the lens through Na^+/K^+ -pumps. They also produce lens fibers.
- Lens fibers: They are long, thin, transparent cells firmly packed within the core of the lens. They are held together by gap junctions. New cells produced by the lens epithelium are added to the periphery pushing old cells to the middle.

Retina

The retina is the light sensitive nerve tissue in the eye that converts images from the eye optical system to electrical impulses that are carried through the optic nerve to the brain for interpretation as vision. It lines 2/3 of the inner part of the eye. The images in the form of photons of light are converted to electrical impulses through action potentials. On the retina is a central pit called fovea. It is surrounded by a yellow spot called macula. It produces the sharpest vision and it contains high concentration of cones within the macula with no retinal blood vessels. **Cones** are the light sensitive retinal receptor cells that provides detail vision and color discrimination. They function under bright light. Rods are the light sensitive specialized retinal receptors that work at low light levels (night vision). **Rods** function with movement and provides light/dark contrast. It makes up peripheral vision. The retina has ten layers. From closest to farthest from the vitreous body, they include;

- Inner limiting membrane: A thin layer of muller glial cells (retinal glial cells) and basement membrane which separates the vitreous from the retina.
- Nerve fiber layer: This layer contains axons of retinal ganglion cells and the astrocytes which support them. Collectively, these axons constitute the optic nerve. In the region where this nerve is found, there are no photoreceptors hence this region is referred to as the blind spot.
- Ganglion cell layer: contains nuclei of retinal ganglion cells.
- Inner plexiform layer: This layer contains the axons of amacrine, bipolar, glial and the dendrites of retinal ganglion cells. Amacrine cells are cells that connect bipolar cells with ganglion cells. The axons relay information to the cell bodies in the inner nuclear layer.
- Inner nuclear layer: This layer contains the cell body of glial, amacrine, bipolar and horizontal cells. Horizontal cells are cells that connect bipolar cells to each other. Their axon is also found in this layer.
- Outer plexiform layer: This layer contains the synaptic processes of rods and cones cells.
- Outer nuclear layer: This layer contains the cell bodies of rods and cones.
- Outer limiting membrane: Rods and cones consists of synaptic terminal, cell body, inner segment and outer segment. The outer limiting membrane is a layer of muller glial cells that separates the cell bodies from the inner segment of the rods and cones.
- Photoreceptive (Bacillary) layer: This layer contains the inner and outer segments of the rods and cones. The inner and outer segments are connected to each other by cilium. The inner segment contains the abundant mitochondria while the outer segment contains the light absorbing materials.
- Retinal pigmented epithelium: This is the most external layer of the retina. It is made up of a layer of simple cuboidal epithelial cells. This layer is closest to the choroid plexus and it provides nourishment and supportive functions to the neural retina. The melanin pigment in this layer prevents the reflection of light and this is very important for clear vision.

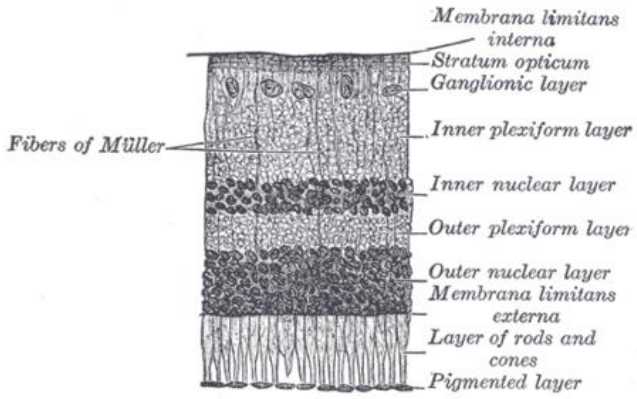


Layers of the Retina

2. The Retina

The mucus membrane of the eye happens to be one of the mediums through which the SARS coV2 enters the body to cause COVID-19, the ongoing pandemic, which causes mild to severe respiratory complications. Hence, basic understanding of the workings of the eye is important. The eye is made up of many parts, however, the retina is the part of the eye involved in creating visual images. As mentioned earlier, the retina is the light sensitive nerve tissue in the eye that converts images from the eye optical system to electrical impulses that are carried through the optic nerve to the brain for interpretation as vision. The retina has ten layers. From closest to farthest from the vitreous body, they include;

1. Inner limiting membrane
2. Nerve cell layer
3. Ganglion cell layer
4. Inner plexiform layer
5. Inner nuclear layer
6. Outer plexiform layer
7. Outer nuclear layer
8. Outer limiting membrane
9. Photoreceptive layer
10. Retinal pigmented epithelium



Layers of the Retina

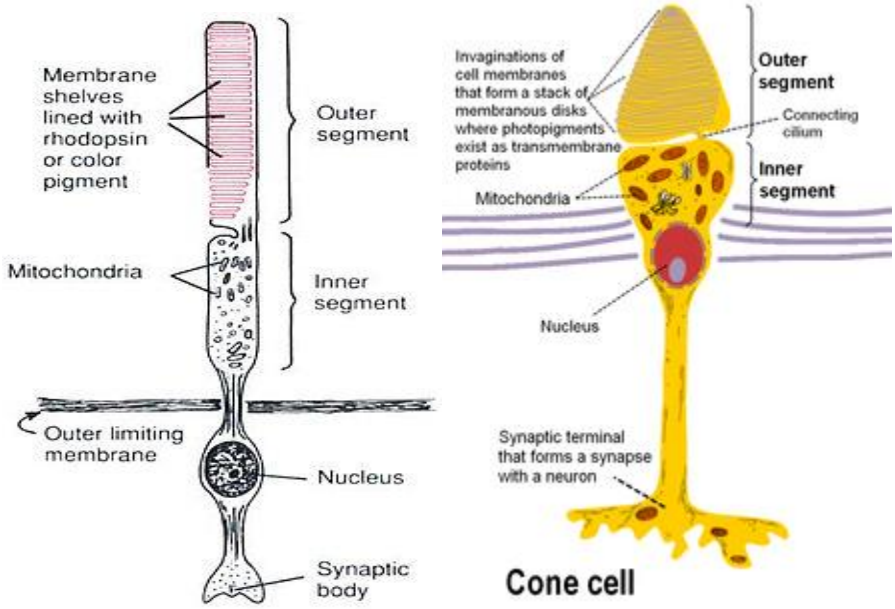
These layers can be grouped into four main processing stages.

- Photoreception
- Transmission to bipolar cells
- Transmission to ganglion cells
- Transmission along optic nerve

The retina in humans is inverted in the sense that light sensing cells are in the back of the retina. The light has to pass through layers of neurons and capillaries before it reaches the rods and cones.

Photoreception

Photoreception is the mechanism of light detection by the eye through photoreceptive cells- rods and cones, that lead to vision. The photoreceptive cells span through ***the outer plexiform, outer nuclear and photoreceptive layers***. The part of the photoreceptive cells that detect light is the outer segment. The light rays in the form of light stimuli passes through the layers of the retina to reach the outer segment of the rods and cones in the photoreceptive layer. These cells convert the light stimulus into electrical nerve impulse (action potential). They send the impulses to their synaptic ends in the outer plexiform layer.



Rod Cell Cone Cell

Phototransduction

Rods and cones consist of synaptic terminal, cell body, inner segment and outer segment. The inner segment contains abundant mitochondria while the outer segment contains the light absorbing materials. The outer segments are modified cilia that contain disks filled with opsin (protein molecules that absorb photons). In rods the opsins are called rhodopsin (opsin + retinal) while in cones they are called photopsin (different types of opsin + retinal). **Phototransduction** is the cascade of changes in the rods and cones triggered when light hits and activates chromophore (retinal). This process is similar in both rods and cones.

Using rods for example, in the dark, rhodopsin is not active and cation channels are open by cyclic guanosine monophosphate (cGMP) allowing influx of cations which keeps the cell depolarized and leads to the release of the neurotransmitter; glutamate. When light is present, rhodopsin absorbs a photon of light. Retinal changes from 11-cis-retinal (original form) to all-trans retinal. This causes a conformational change in opsin, which in turn activates transducin. Transducin activates cGMP phosphodiesterase which breaks down cGMP. Reduction in the number of cGMP results in closure of the cation channels which in turn leads to hyperpolarization of the rods and reduction in the release of glutamate. Less glutamate in the synaptic cleft excites a set of bipolar neurons and the action potential stimulated in these bipolar neurons, is transmitted to the brain for interpretation. After activating transducin, all-trans-retinal

dissociate from opsin and are transported to the pigmented epithelium where they are converted to 11-cis-retinal and transported back to the rods (this mechanism is known as **bleaching**). When the light is removed, Arrestin binds to rhodopsin and preventing it from activating transducin. This stops the cascade and soon cGMP level rises and opens up the cation channel thus returning the rods back to their depolarized state.

Transmission to Bipolar Cells

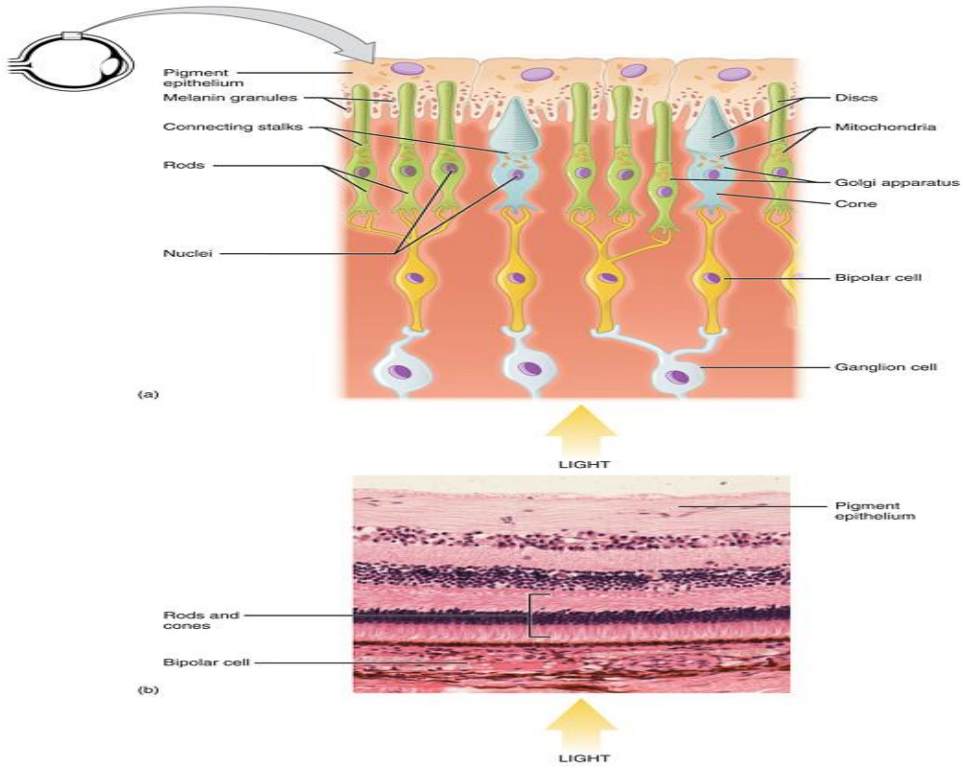
This process involves ***the inner nuclear layer and the inner plexiform layer***. The bipolar neurons found in these layers form synapses with the synaptic processes of the rods and cones in the outer plexiform layer. The electrical impulses generated are transferred through these synapses to the bipolar neurons. The impulses travel to the axons of the bipolar neurons and are transmitted to the ganglion cells.

Transmission to the Ganglion Cells

This process involves ***the ganglion cell and nerve fiber layers*** of the retina. The retinal ganglion cells are found in these layers and they form synapses with the bipolar neurons. Impulses from the bipolar neurons are transmitted to them.

Transmission along the Optic Nerve

The axonal fibers of the ganglion cells form the optic nerve which transmits the nerve impulse to the brain for interpretation. There are no photoreceptors present in the region of the retina where ganglion axon fibers feed into the optic nerve.



Layers of the Retina