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SPECIAL SENSES ASSIGNMENT

**Question**

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

**Answers**

1. **Importance of eye**

External structures of the eye include the eyelashes, lids, muscles, accessory glands, and conjunctiva.

The internal structures of the eye consist of three layers of tissue arranged concentrically:

* The sclera and cornea make up the exterior layers.
* The uvea is the vascular layer in the middle, subdivided into the iris, ciliary body, and choroid.
* The retina constitutes the innermost layer and is made up of nervous tissue.

The external structures of the eyes are as follows:

1. *Conjunctiva:* The conjunctiva lines the inner part of the eyelids. The tarsal plate lies beneath the conjunctiva and contains meibomian glands, which secrete an oily substance to decrease the evaporation of the tear film.

2. *Tear film:* The tear film consists of aqueous, mucus, and oily secretions.

3. *Accessory glands:* Apocrine glands of Moll, meibomian glands, lacrimal glands.

4. *Muscles:*Orbicularis oculi, levator palpebrae superioris, superior tarsal muscle.

5. *Eyelid:* The eyelid, likewise known as the cover of the eye, a mobile layer made up of skin and also muscular tissue and also covers the eyeball.

The internal structures of the eyes are organized in the three layers as follows:

**(A)- *"Outermost Layer: Sclera and Cornea":***

1. *The sclera (white of the eye:*

* The sclera is dense connective tissue made of mainly type 1 collagen fibers, oriented in different directions. The lack of parallel orientation of collagen fibers gives the sclera its white appearance, as opposed to the transparent nature of the cornea. However, the collagen of the sclera and cornea are continuous.
* The four layers of the sclera from external to internal are episclera, stroma, lamina fusca, and endothelium.
* The episclera is the external surface of the sclera. It is connected to the Tenon capsule by thin collagen fibers. At the corneoscleral junction, also known as the limbus, the Tenon capsule contacts stroma of the conjunctiva.

2. *Cornea (transparent front layer of the eye):*

* Consists of type I collagen fibers oriented in a uniform parallel direction to maintain transparency
* Consists of five layers: epithelium (non-keratinized, stratified squamous epithelium), Bowman layer, stroma (also called substantia propria), Descemet’s membrane, corneal endothelium.
* Corneal epithelium: fast growing, regenerating multicellular layer which interacts directly with the tear film.
* Bowman layer: This is a layer of subepithelial basement membrane protecting the underlying stroma. It is composed of type 1 collagen, laminin, and several other heparan sulfate proteoglycans.
* Stroma: The largest layer of the cornea, the stroma has collagen fibers arranged in a regular pattern. Keratocytes maintain the integrity of this layer. The function of this layer is to maintain transparency, which occurs by the regular arrangement, and lattice structure of the fibrils, whereby scatter from individual fibrils gets canceled by destructive interference, and the spacing of less than 200 nm allows for transparency.
* Descemet’s membrane: an acellular layer made of type IV collagen that serves as a modified basement membrane of the corneal endothelium
* Corneal endothelium: a one cell thick layer made of either simple squamous or cuboidal cells. Cells in this region do not regenerate and have pumps that maintain fluid balance and prevent swelling of the stroma. When corneal endothelial cells are lost, neighboring cells stretch to attempt to compensate these losses.
* **(B)- "Middle Layer: Uvea (Iris, Ciliary Body, Choroid)":**

*1. Iris:*

* Consists of (1) stromal layer with pigmented, fibrovascular tissue and (2) pigmented epithelial cells beneath the stroma
* The sphincter pupillae and dilator pupillae muscles connect to the stroma
* The pigmented layer of cells blocks rays of light and ensures that light must move through the pupil to reach the retina
* The angle formed by the iris and cornea contains connective tissue with endothelial channels called the trabecular meshwork, which drains aqueous humor in the anterior chamber into the venous canal of Schlemm. From here, fluid drains into episcleral veins.

*2. "Ciliary Body":* The tissue that divides the posterior chamber and vitreous body

* Consists of the ciliary muscle and the ciliary epithelium
* The ciliary muscle, via the lens zonules, controls the structure of the lens, which is vital for accommodation. Zonules are connective tissue fibers that connect the ciliary muscle and lens.
* The ciliary epithelium produces aqueous humor which fills the anterior compartment of the eye.

*3. "Choroid":*

* Consists of a dense network of blood vessels supplying nourishment to structures of the eye, housed in loose connective tissue.
* The choriocapillary layer is located in the innermost part of the choroid and supplies the retina
* The Bruch membrane is an extracellular matrix layer situated between the retina and choroid and has significance in age-related macular degeneration, where an accumulation of lipid deposits prevent diffusion of nutrients to the retina.

**(C)- "Innermost layer: Lens, Vitreous, And Retina":**

1. Lens: separates the aqueous and vitreous chambers

* Consists of an outer capsule, a middle layer called cortex, and an inner layer called the nucleus.
* The capsule is the basement membrane of the lens epithelium which lies below
* New lens cells differentiate from the lens epithelium and are incorporated peripherally, pushing older lens cells towards the middle.

2. Vitreous: a jelly-like space made of type II collagen separating the retina and the lens.

3. Retina: nervous tissue of the eye where photons of light convert to neurochemical energy via action potentials.

Moreover, the retina itself is divided into various layers as follows:

Retinal pigment epithelium: made of cuboidal cells containing melanin which absorbs light. These cells also establish a blood-retina barrier through tight junctions.

 "Rod and cone cells": the layer of cells with photoreceptors and glial cells. Rods are located peripherally and are more sensitive to light and motion than cones. Cones have higher visual acuity and specificity for color vision.

* *"Outer limiting membrane"*: a layer of Muller cells and rod/cone junctions which serves to separate the photosensitive regions of the retina from the areas that transmit the electrical signals.
* *"Outer nuclear layer"*: This layer consists of nuclei of rod and cone cells.
* *"Outer plexiform layer"*: This layer contains synaptic processes of rod and cone cells.
* *"Inner nuclear layer':* This layer contains the cell body of glial, amacrine, bipolar, and horizontal cells
* *"Inner plexiform layer"*: This layer relays information from cells of the inner nuclear layer. Thus, this layer has axons of amacrine, bipolar, and glial cells and dendrites of retinal ganglion cells.
* *"Ganglion cell layer"*: This layer contains nuclei of retinal ganglion cells.
* *"Nerve fiber layer"*: This layer contains axons of retinal ganglion cells and the astroglia which support them. Collectively, these axons constitute the optic nerve.
* *"Internal limiting membrane"*: A thin layer of Muller glial cells and basement membrane which demarcates the vitreous anteriorly from the retina posteriorly.

The layers of the eye perform distinct functions which coalesce to create a unified, perceptual experience. The essential role of the external eye structures is to protect the delicate tissue of the internal eye. The eyelid prevents foreign bodies from entering the inner eye and helps refresh and distribute the tear film by blinking. Eyelashes are finely sensitive to touch and warn the eye of possible debris and particles that may cause injury.

Internal parts of the eye have primarily structural and visual functions. The cornea serves a protective role and is responsible for two-thirds of the refractive properties of the eye. The remaining one-third of refraction is performed by the lens, which is functionally adjustable through the action of the zonular fibers and ciliary muscles. At the end of the visual process, as rays of light bend through the cornea and lens, photon energy is converted to neurochemical action potentials by cells of the retina, which then send these impulses to the brain, via the optic nerve.

The uvea of the eye is a crucial mediator of nutrition and gas exchange, as blood vessels course through the ciliary body and iris, while the choriocapillaris in the posterior eye help support the retina. This abundant blood supply is implicated in uveitis, as inflammatory mediators enter the eye through this vascular network

2. **Layers of the Retina**

The retina is a layered structure with ten distinct layers of neurons interconnected by synapses. The cells subdivide into three basic cell types: photoreceptor cells, neuronal cells, and glial cells. Beginning with the innermost layer (closest to the vitreous) and proceeding outwards towards the choroid and sclera, the layers are as follows:

1. Inner limiting membrane
2. Nerve fiber layer (NFL)
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. The layer of rods and cones
10. Retinal pigment epithelium

Within these layers of the retina, there are multiple different types of cells with specific functions that help transmit incoming photons into action potentials that the brain's cortices process into three-dimensional vision. The six different cell types in the retina include:

1. Rods
2. Cones
3. Retinal Ganglion cells
4. Bipolar cells
5. Horizontal cells
6. Amacrine cells

**Photoreceptor cells** consist principally of cones and rods but also have a much rarer intrinsically photosensitive retinal ganglion cells, which are stimulated by light even when all rods and cones are blocked.

Cones function best under illuminated conditions and provide color vision. Rods function primarily in dim light and provide black-and-white vision. Each human retina contains approximately 120 million rods and 6 million cone photoreceptors. The central retina is cone dominated and the peripheral retina is rod dominated. The highest density of cones is at the center of the fovea. There are no rods in the center of the fovea.

The photosensitive ganglion cells contain the pigment melanopsin. Alteration in this pigment by light is involved in non- image forming responses to light, such as synchronization of circadian rhythms to the light-dark cycle, contributing to regulation of pupil size and influencing release of melatonin from the pineal gland.

Retinal ganglion cells send axonal projections that converge in the optic disc and pass through the lamina cribrosa unmyelinated, to not interfere with incoming light. Retinal ganglion cells’ axons target the suprachiasmatic nucleus, olivary pretectal nucleus, intergeniculate leaflet, ventral division of the lateral geniculate nucleus, and preoptic area.

**Neural cells (nerve cells)** include bipolar cells, ganglion cells, horizontal cells, and amacrine cells. Bipolar cells are contained entirely within the retina, connecting the photoreceptors to the ganglion cells. These are vertically oriented (perpendicular to the retinal surface). There are nine types of bipolar cells. Bipolar cells are postsynaptic to rods and cones.

Ganglion cells have dendrites that synapse with bipolar cells. The axons of ganglion cells become the nerve fiber layer within the retina and then become optic nerve fibers terminating within the brain.

Horizontal cells connect bipolar cells with each other. Horizontal cells are the laterally interconnecting neurons in the outer plexiform layer of the retina. Horizontal cells are responsible for allowing eyes to adjust to see well under both bright-light and dim-light conditions. These are horizontally oriented (parallel to the retinal surface).

Amacrine cells connect bipolar and ganglion cells with each other. Amacrine cells function within the inner plexiform layer, the second synaptic retinal layer where bipolar cells and retinal ganglion cells form synapses. There are about 40 different types of amacrine cells, most lacking axons. Like horizontal cells, amacrine cells are horizontally oriented and work laterally, affecting the output from bipolar cells. Each type of amacrine cell connects with a particular type of bipolar cell, and generally has a particular type of neurotransmitter.

**Glial cells** are interspersed between and among the axons of the ganglion cells within the retina and optic nerve. These supporting cells of the retina include Muller cells, astrocytes, and microglial cells.

Muller cells, the principal glial cells of the retina, form a supporting matrix radially across the thickness of the retina and also form the inner and outer limiting membranes of the retina. Muller cell bodies sit in the inner nuclear layer and project irregularly thick and thin processes in either direction to the outer limiting membrane and to the inner limiting membrane. Muller cell processes insinuate themselves between cell bodies of the neurons in the nuclear layers and envelope groups of neural processes in the plexiform layers. Retinal neural processes are only allowed direct contact at their synapses.

Astrocyte cell bodies and processes are almost entirely restricted to the nerve fiber layer of the retina.

Microglial cells are of mesodermal origin. Unlike the Muller cells and astrocytes, they are not neuroglial.

Focused (or unfocused) light passes through the inner layers of the retina to reach the photoreceptors (rods and cones). Because the photoreceptive cells lie outermost within the retina, light must first pass through and around the ganglion cells and through the thickness of the retina before reaching the rods and cones. The light does not pass through the pigment epithelium or the choroid, which are opaque.

The outer segments of the rods and cones contain photo pigment, which captures individual photons of light and initiates neural signaling. The photoreceptor inner segments contain the axon terminal, where neurotransmitter is released to the bipolar cells. The inner segments also function efficiently to funnel light to the outer segments.

The outer segments of the rods and cones transduce the light and send the signal through the cell bodies of the outer nuclear layer and out to their axons. In the outer plexiform layer, photoreceptor axons contact the dendrites of both bipolar cells and horizontal cells. Horizontal cells are horizontally oriented (parallel to the retinal surface) interneurons, which aid in signal processing. Bipolar cells are vertically oriented (perpendicular to the retinal surface).

Cones synapse with eight different types of bipolar cells. Five of these are called diffuse bipolar cells and make synaptic contact with up to 20 cones. The other three types contact only single cones and are called midget bipolar cells. Because there are 150 million photoreceptors and only 1 million optic nerve fibers, there must be convergence of signals and individual cone signals mix with others. In addition, the horizontal action of the horizontal and amacrine cells can allow one area of the retina to influence another.

The bipolar cells in the inner nuclear layer process input from photoreceptors and horizontal cells. They transmit the signal to their axons. In the inner plexiform layer, bipolar axons contact ganglion cell dendrites and amacrine cells, another class of interneurons, through synapses. Ganglion cells are vertically oriented while amacrine cells are horizontally oriented.

The ganglion cells of the ganglion cell layer send their axons through the nerve fiber layer and converge at a point nasal to the center of the retina, forming the optic nerve. The ganglion cell axons all leave the eye at the optic disk. Theses axons travel all the travel all the way to the lateral geniculate nucleus in the brain stem. At the optic disc, no retinal photoreceptors, bipolar cells, ganglion cells, or accessory cells are present. Each human optic nerve has 1,000,000 axons.