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COURSE: NEUROHISTOLOGY

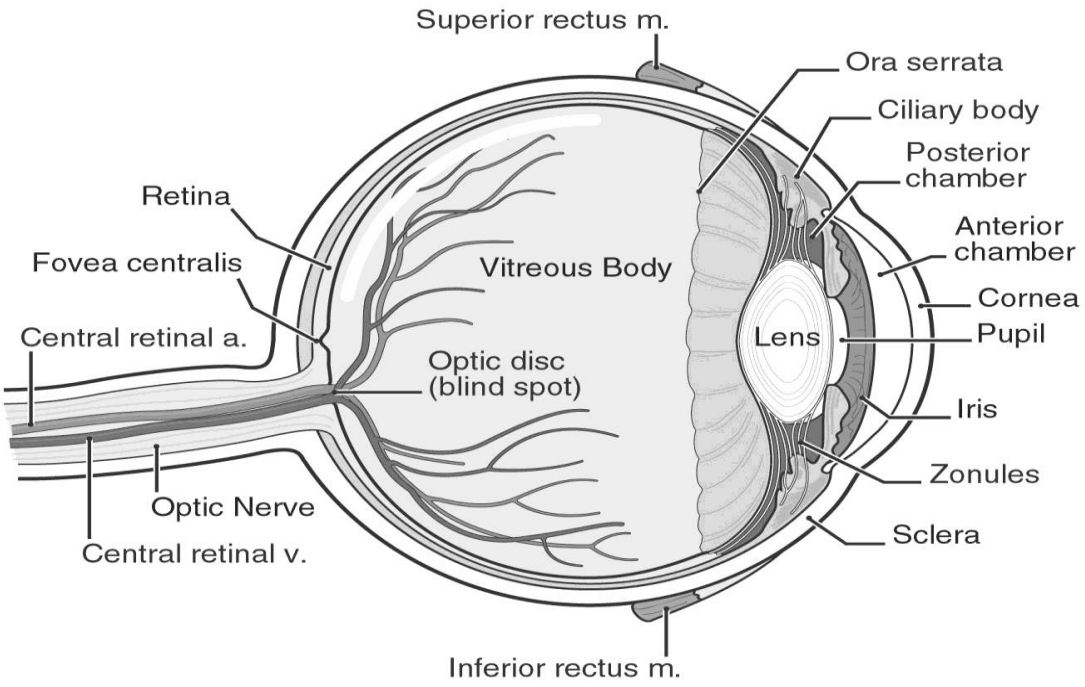
LEVEL: 300

DEPARTMENT: MEDICINE AND SURGERY

Question 1) **Write an essay on the histology importance of eye in relation to the cellular functions.**

Answer

The Diagram of the human eye



The human eye is a specialized sense organ that reacts to light and allows vison. It also is capable of receiving visual images, which are relayed to the brain. The eye has its external and internal structures.

The external structures include the eyelashes, eyelids, Muscles, accessory glands and Conjunctiva.

The internal structures of the eye consist 3 layers of tissue arranged concentrically, they include:

- The sclera and Cornea
- The Uvea which is subdivided into the Iris, Ciliary body and Choroid.
- The Retina.

EXTERNAL STRUCTURES OF THE EYE

1) **Conjunctiva**: The conjunctiva is a thin, transparent mucosa that covers the exposed, anterior potion of the sclera (ocular conjunctiva) andcontinues as the lining on the internal surface of the eyelids. The tarsal plate lie beneath the conjunctiva and contains Meibomian glands, which secrete an oily substance to decrease the evaporation of the tear film.
   Lacrimal fluid keeps the conjunctiva moist.
2) **Accessory Glands**: these include Apocrine glands of Moll, Meibomian glands, Lacrimal glands.
3) **Muscles**: These include the Orbicularis oculi, Levator palpebrae superioris, Superior Tarsal Muscle.
4) **Eyelids**: This is a mobile layer made up of skin and muscular tissue, which covers the eyeball.

INTERNAL STRUCTURES OF THE EYE

1a) **SCLERA**: The sclera is a dense connective tissue made of mainly Type 1 collagen fibers, oriented in different directions and this gives it its white appearance. The sclera provides protection.

The sclera has 4 layers from external to internal and they include: Episclera, Stroma, Lamina fusca, Endothelium.

b) **CORNEA**: The cornea is the clear, transparent front part of the eye that covers the iris, pupil and anterior chamber. It allows light rays enter the eye and converge the light rays.

The cornea consists of type I collagen fiber oriented in a uniform parallel direction to maintain transparency. The cornea consist of 5 layers:

- **Epithelium**: This is fast growing, regenerating multicellular non-keratinized, stratified squamous layer which interacts directly with the tear film.
- **Bowman's layer**: This is a layer of sub-epithelial basement membrane protecting the underlying stroma. It is composed of Type I collagen, Laminin and several other types heparin sulfate proteoglycans.
- **Stroma**: This is the largest layer of the cornea. The stroma has Collagen fibers arranged in a regular pattern. This layer possess keratocytes, which maintain its integrity.
  The function of this layer is to maintain transparency, which occurs by the regular arrangement and lattice structure of the fibrils.
- **Descement's Membrane**: This is a cellular layer made of type IV collagen that serves as a modified basement membrane of the corneal epithelium.
- **Corneal epithelium**: this is a one cell thick layer made of either simple squamous or cuboidal cells. The cells in this region do not regenerate if damaged.

2a) **IRIS** : The iris is the pigmented tissue lying behind the cornea that gives color of the eye and controls the amount of light entering the eye. The iris consists of stromal layer with pigmented, fibrovascular tissue and Pigmented epithelial cells beneath the stroma.

The pigmented layer of cells blocks rays of light and ensures that light must move through the pupil to reach the retina.

b) **CILIARY BODY**: This is the circumferential tissue inside the eye composed of the ciliary muscle and 70 ciliary processes that produce aqueous fluid.

The ciliary body consists of the ciliary muscles and ciliary epithelium. The ciliary epithelium produces aqueous humor which fills the anterior compartment of the eye.

c) **CHOROID**: this is the vascular (major blood vessel), Central layer of the eye lying between the retina and sclera. Its function is to provide nourishment to the outer layers of the retina through blood vessels. It is part of the Uveal tract.

3a) **LENS**: The lens is a transparent, biconvex intraocular tissue that helps bring rays of light to focus on the retina (It bends light, but not as much as the cornea). It also seperate the aqueous and vitreous chambers. The lens has 3 principal components:

- Lens Capsule
- Lens Epithelium
- Lens Fibers.

The lens is help in place by a radially oriented group fibers, the elastic ciliary zonule, which inserts on both the lens capsule and on the ciliary body.

b) **VITREOUS HUMOR**: This is the transparent, colorless gelatinous mass that fills rear two-thirds of the eyeball, between the lens and the retina. The gelatinous mass is made of type II collagen fibers.

c) **RETINA**: The retina is the light sensitive nerve tissue in the eye that converts images from eye's optical system into electrical impulses that are sent along the optic nerve to the brain, to interpret as vision. There is a blind spot which is caused by absence of light sensitive photoreceptors where the optic nerve enter the eye. The retina has 2 major layers:

i. The inner neural retina which contains the neurons and photoreceptors. This layer's visual region extends anterior only as far as the ora serrata, but it continues as a cuboidal epithelium lining the surface of the ciliary body and posterior iris.

ii. The outer pigmented layer is an epithelium also lines the ciliary body and posterior iris, contributing to the double epithelium described with those structures. The pigmented epithelium consists of low columnar cells with basal

nuclei. The diverse functions of the cells in the retinal pigmented epithelium include the following:

a) Absorb light passing through the retina to prevent its reflection.
b) Removes free radicals.
c) Serves as an important part of the blood-retina barrier.
d) Phagocytose shed components from the adjacent rods and cones.

Finally, 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.

Internal parts of the eye have primarily structural and visual functions. The cornea serves a protective roles and is responsible for 2/3 of the refractive properties of the eye. The remaining 1/3 of refraction is performed by the lens.

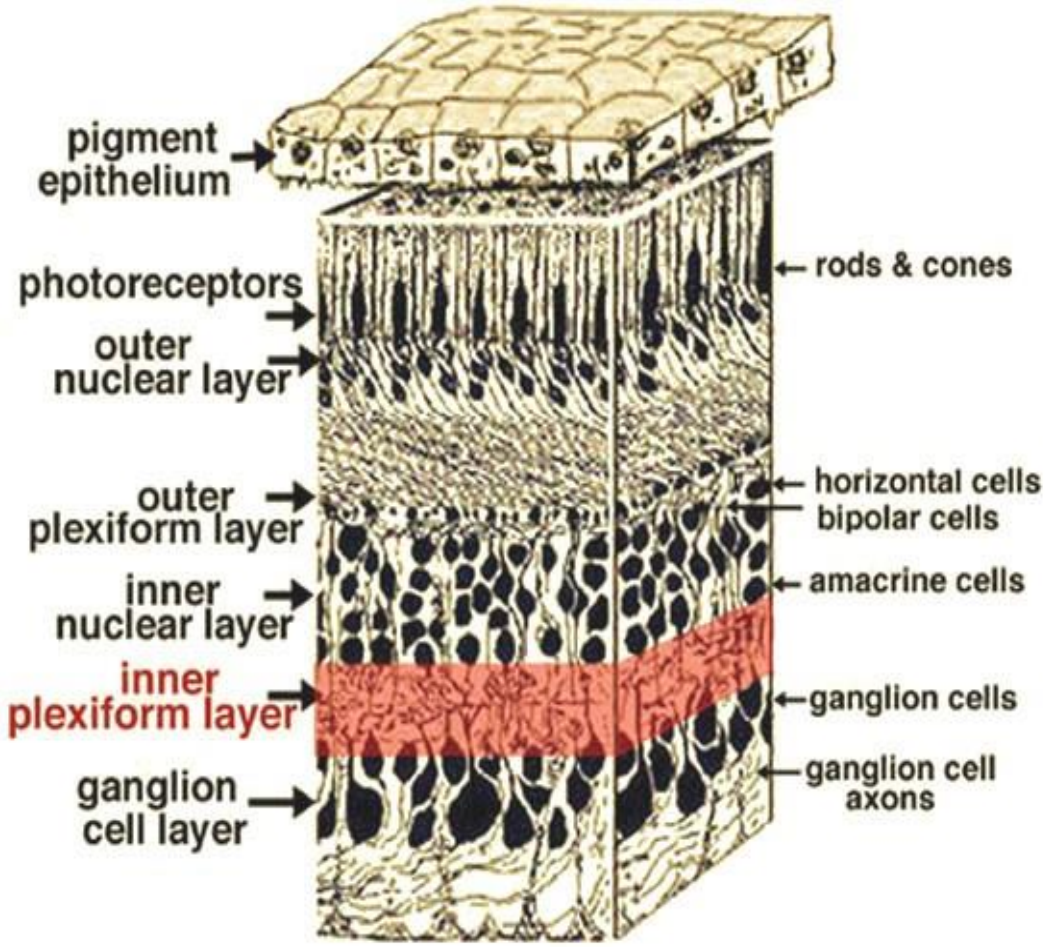
The Uvea of the eye is a crucial mediator of nutrition and gas exchange as blood vessels course through the ciliary body and iris, while the choriocapillaris in the posterior eye help support the retina.

Question 2) **Coronavirus can penetrate the body through the eye and implicate the immune system. Briefly discuss the layers of the retina for information penetration.**

The retina is a nervous tissues of the eye where photons of light convert to neurochemical energy via; action potential. That is, It is the innermost layer of the eye that is responsible for visual processing that turns light energy from photos into 3-dimensional images. The cells are subdivided into 3 basic cell types:

I. Photoreceptor cells- Rod cells and cone cells
II. Neuronal cells- Bipolar Neurons, Ganglion cells, Amacrine cells, Horizontal cells.
III. Glial cells- cells of Muller.

Diagram of the layers of Retina



The layer of the retina, beginning from the external surface are as follows:

1. Retinal pigment epithelium: This is a single layer of cuboidal epithelial cells containing pigment. This layer is closest to the choroid and provides nourishment and supportive functions to the neural retina. The pigment prevents light reflection throughout the globe of the eyeball.

2. Layer of rods and cones: The rods are processes of rod cells, and cones are processes of cone cells. The tips of the rods and cones are surrounded by processes of pigment cells.

3. External limiting layer: This layer separates the inner segment portions of the photoreceptors from their nuclei.

4. Outer nuclear layer: The outer nuclear layer contains the cell bodies and nuclei of rod cells and of cone cells.

5. Outer plexiform layer: This layer consists projections of rods and cones ending in the rod spherule and cone pedicle respectively. These make synapses with dendrites of bipolar cells and horizontal cells.

6. Inner nuclear layer: This layer contains nuclei and surrounding cell bodies of the amacrine cells, bipolar cells and horizontal cells.

7. Inner plexiform layer: This layer contains the synapse between the bipolar cell axons and the dendrites of the ganglion and amacrine cells.

8. Ganglion cell layer: This layer contains nuclei of ganglion cells, the axons of which become the optic nerve fibers and some displaced amacrine cells.

9. Nerve fiber layer: This layer consists of the ganglion cell bodies. The fibers converge on the optic disc where they pass through foramina of the lamina cribrosa to enter the optic nerve. There is a thin layer of Muller cell footplates existing between this layer and the inner limiting membrane.

10. Inner limiting membrane: This is the basement membrane elaborated by Muller cells.

CELLS AND NEURONS FOUND IN THE RETINA

ROD CELLS

The human retina has approximately 120 million rod cells. They are extremely sensitive to light, responding to a single photon, and allow some vision even with light low levels, such as at dusk or night time. Rod cells are thin, elongated cells (50 m x 3 m), composed of two distinct segments. The outer segment is photosensitive; the inner segment contains the metabolic machinery for the cell's biosynthetic and energy-producing processes. The outer rod-shaped segment consists mainly of 600–1000 flattened membranous discs stacked like coins and surrounded by the plasma membrane. Between this outer segment and the cell's inner segment is a constriction, the connecting stalk, which is a modified cilium arising from a basal body. The inner segment is rich in glycogen and mitochondria

near the base of this cilium. Abundant polyribosomes located inside the mitochondrial region produce proteins that are transported to the outer segment, where they are incorporated into the membranous discs. These proteins include the visual pigment rhodopsin (visual purple) which is bleached by light and initiates the visual stimulus.

CONE CELLS

The human retina has 6 or 7 million cone cells, which are less sensitive to low light than rod cells and are specialized for colour vision in bright light. Three functional types of cone cells, not distinguishable morphologically, contain variations of the visual pigment iodopsin with maximal sensitivities in the red, blue, or green regions of the visible spectrum, which enables these cells to detect those colours in reflected light.

Cone cells are also elongated, with outer and inner segments, a modified cilium connecting stalk, and an accumulation of mitochondria and polyribosomes. The outer segments of cones differ from those of rods in their shorter, more conical form and in the structure of their stacked membranous disks, which in cones remain as continuous invaginations of the plasma membrane along one side. Also, newly synthesized membrane proteins are distributed uniformly throughout the outer segment of cones and although iodopsin turns over, the discs are shed much less frequently than in rods.

BIPOLAR NEURONS

Bipolar neurons are second-order long-projection neurons that receive visual input from photoreceptors and projects their axons onto retinal ganglion cells. Thirteen different types of bipolar cells divide into rod bipolar cells and cone bipolar cells, depending on the cell from which cell they receive inputs. Each cone bipolar cell and rod bipolar cell is further subdivided depending on whether it depolarizes in response to light (ON-bipolar cells) or those that hyperpolarize (OFF-bipolar cells). Cone bipolar cells are either ON or OFF type whereas rod bipolar cells are only the ON type.

Rods specialize in scotopic vision and thus only need to determine whether or not photons are striking the retina quantitatively, thus ON bipolar cells are adequate for this binary function.

Cones cells provide information for the photopic vision that can differentiate fine details, movements and colours, and this require both ON and OFF bipolar cells to qualitatively differentiate incoming photons.

Bipolar cells link the inner and outer layers of the retina by forming a synaptic connection with the rods and cones in the inner plexiform layer.

RETINAL GANGLION CELLS

Retinal ganglion cells (RGCs) are the retina's main output neuron, but also a third class of photoreceptors that are also photosensitive and help transmit both image-forming and non-image forming information that functions in the physiological processes of the circadian rhythm, modulation of melatonin release, and regulation of pupil size. RGCs receive both excitatory and inhibitory inputs from two types of intermediate neurons: amacrine cells and bipolar cells. Ganglion cells are of two main types. Those that synapse with only one bipolar neuron are mono-synaptic, while those that synapse with many bipolar neurons are polysynaptic.

Monosynaptic ganglion cells are also called midget ganglion cells. Each of them synapses with one midget bipolar neuron. We have seen that midget bipolars in turn receive impulses from a single cone. This arrangement is usual in the central region of the retina, and allows high resolution of vision to be attained.

Polysynaptic ganglion cells are of various types. Some of them synapse only with rod bipolars (rod ganglion cells). Others have very wide dendritic ramifications that may synapse with several hundred bipolar neurons (diffuse ganglion cells). This arrangement allows for summation of stimuli received through very large numbers of photoreceptors facilitating vision in poor light.

HORIZONTAL NEURONS

Horizontal cells are involved in modulating information transfer between bipolar cells and photoreceptors and are involved with helping eyes adjust to both bright light and low light conditions. They have wide and diffuse horizontal projections and couple to their neighbours via gap junctions. Horizontal neurons are of two types, rod horizontals and cone horizontals, depending on whether they synapse predominantly with rods or cones. Each horizontal cell gives off one long process, and a number of short processes (7 in case of rod horizontal cells, and 10 in case

of cone horizontal cells). The short processes are specific for the type of cell: those of rod horizontals synapse with a number of rod spherules, and those of cone horizontals synapse with cone pedicles. The long processes synapse with both rods and cones (which are situated some distance away from the cell body of the horizontal neuron). The long and short processes of horizontal cells cannot be distinguished as dendrites or axons, and each process probably conducts in both directions.

AMACRINE NEURONS

The term amacrine is applied to neurons that have no true axon. Like the processes of horizontal cells those of amacrine neurons also conduct impulses in both directions. Each cell gives off one or two thick processes that divide further into a number of branches. Different types of amacrine neurons are recognised depending upon the pattern of branching. We have seen that the processes of amacrine neurons enter the internal plexiform layer where they may synapse with axons of several bipolar cells, and with the dendrites of several ganglion cells. They also synapse with other amacrine cells. At many places an amacrine process synapsing with a ganglion cell is accompanied by a bipolar cell axon. The two are referred to as a dyad. The amacrine cells are believed to play a very important role in the interaction between adjacent areas of the retina resulting in production of sharp images. They are also involved in the analysis of motion in the field of vision.

CELLS OF MULLER

These cells, also known as retinal gliocytes, give off numerous protoplasmic processes that extend through almost the whole thickness of the retina. Externally, they extend to the junction of the layer of rods and cones with the external nuclear layer. Here the processes of adjoining gliocytes meet to form a thin external limiting membrane. Internally, the gliocytes extend to the internal surface of the retina where they form an internal limiting membrane. This membrane separates the retina from the vitreous. The retinal gliocytes are neuroglial in nature. They support the neurons of the retina and may ensheath them. They probably have a nutritive function as well. Some astrocytes are also present in relation to retinal neurons.

CLINICAL ANATOMY

Cone-rod dystrophy: This is a rare genetic isolated inherited retinal disorder characterized by primary cone degeneration with significant secondary rod involvement. Typical presentation includes reduced visual acuity, central scotoma, photophobia, colour vision alteration followed by night blindness and loss of peripheral visual field.

Glaucoma: This refers to a group of eye diseases which result in damage of the optic nerve and cause vision loss. Ocular hypertension is the most important risk factor in most glaucomas.