NEUROHISTOLOGY ASSIGNMENT

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Question 1

Write an essay on the histological importance of the eye in relation to their cellular functions.

Eyes are sense organs of vision/sight. They are highly developed photosensitive organs for analyzing the form, intensity, and color of light reflected from object. They are protected within the orbits of the skull which also contain adipose cushions; each eyeball consists externally of a tough, fibrous globe that maintains its overall shape. Internally the eye contains transparent tissues that refract light to focus the image, a layer of photosensitive cells, and a system of neurons that collect, process, and transmit visual information to the brain.

The eye is composed of three layers:

- **An external fibrous layer**: consisting of the sclera and the transparent cornea.
- **A middle vascular layer**: that includes the choroid, ciliary body & iris.
- **An inner sensory layer**: the retina, which communicates with the cerebrum through the posterior optic nerve.

FIBROUS LAYER

This layer consists of two parts: the posterior sclera and the anterior cornea.

1. **The Sclera:** It is the tough opaque part of the eyeball.

- Its fibrous and tough property gives the eye form and protects the internal structures of the eye and provides the space for the insertion of the extraocular muscles of the eye.
- It is a **dense connective tissue** made up of mainly type 1 collagen fibres which are scattered.
- The lack of parallel orientation of collagen fibres give the sclera its white appearance.
- It is continuous with the transparent substantia propria of the cornea.
- It is covered by thin **non-keratinized stratified squamous epithelium**.
- It is **relatively avascular** (microvasculature is present near the outer surface).
  The sclera is divided into 3 layers:
    a. **The Episclera**: The outermost layer of the sclera composed of loose fibrous,elastic tissue and attaches to the tenon's capsule.
    b. **Sclera stroma proper**: The dense white tissue that gives the area its color.
    c. **Lamina Fusca**: Innermost zone made up of elastic fibers.

2. **The Cornea:** As opposed to the sclera, the cornea is the anterior transparent part of the eye.

- It controls and focuses the entry of light into the eye.
- It bends and refracts the incoming light unto the lens.
- It is completely avascular.

The cornea has five distinct layers:

a. **External epithelium**: **Non-keratinized stratified squamous epithelium** which consists of 5-6 layers of cells. The basal part of the epithelium are numerous mitotic figures responsible for cornea's remarkable regenerative capacity.
   The surface corneal cells shows microvilli protruding into the space filled by the pericorneal tear film. The cornea has one of the richest sensory nerve supplies of any tissue.
b. **Bowman's membrane:** It is the anterior limiting/basement membrane of the external epithelium. It is very thick (the condensation of lamina propria) and contributes to the stability and strength of the cornea, helping to protect against infection of the underlying stroma.
c. Stroma or **substantia propria:** Makes up 90% of corneal tissue. It is formed of many layers of parallel collagen bundles that cross at approximately right angles to each other. The collagen fibres within each lamella are parallel to each other and run the full width of the cornea. In between the collagen lamellae are cytoplasmic extensions of flattened fibroblast-like cells called ***keratocytes.***
d. Descemet's membrane: This is the posterior limiting membrane which supports the internal simple squaous endothelium. It is a thick homogenous structure composed of the fine collagenous filaments organized in a 3 dimensional network.
e. Endothelium: Is an inner single layer of simple squamous epithelium.

The corneal epithelium and endothelium are responsible for maintaining the transparency of the cornea.

VASCULAR LAYER

This layer consists of three parts: choroid, ciliary body and iris. They are collectively known as the **uveal tract.**

1. **Choroid**: It is located in the posterior two-thirds of the eye, the choroid consists of loose, well-vascularized connective tissue and contains numerous melanocytes. These form a characteristic black layer in the choroid and prevent light from entering the eye except through the pupil. Two layers make up the choroid:
   i. ***The inner choroidocapillary lamina***: has a rich microvasculature important for nutrition of the outer retinal layers.
   ii. ***Bruch membrane***: a thin extracellular sheet, is composed of collagen and elastic fibers surrounding the adjacent microvasculature and basal lamina of the retina's pigmented layer.
2. **Ciliary body:** is the anterior expansion of the uvea that encircles the lens, lies posterior to the limbus. Like the choroid, most of the ciliary body rests on the sclera. Important structures associated with the ciliary body include the following:
   - **Ciliary muscle**; composed of smooth muscle. Contraction and relaxation of the ciliary muscles change the tension of the zonular fibres, or suspensory ligaments of the lens. This allows this lens to change shape, a process known as **accommodation.**
   - **Ciliary processes:** are folds of connective tissue that are covered by two layers of epithelium. There is also a complex vasculature that cannot be seen easily. Fluid from these vessels is processed and transported by the epithelial cells to the posterior chamber as **aqueous humor.** The epithelial cells constitute the blood aqueous barrier.

3. **Iris:** It is the most anterior extension of the middle uveal layer which covers part of the lens, leaving a round central pupil. It contains pigment in dark eyes. It has two parts: anterior and posterior. Involuntary muscles control the size of the pupil.
   --The anterior part is mesothelium formed of flattened cells on hyaline basement membrane, continuous with mesothelial lining of the cornea. Deeper in the iris, the stroma consists of loose connective tissue with melanocytes and sparse microvasculature. Stroma is not pigmented in blue and albino eyes.
   --The posterior part has a two-layered epithelium continuous with that covering the ciliary processes, but very heavily filled with melanin. The highly pigmented posterior epithelium of the iris blocks all light from entering the eye except that passing through the pupil.
   Melanocytes of the iris stroma provide the color of one's eyes.

SENSORY LAYER

1. **The Retina:** It is the innermost layer of the eye responsible for the visual processing that turns light energy from photons into 3-dimensional images; it has two layers: an outer pigmented layer and an inner retinal layer.

- **The Retinal pigmented epithelial layer**: consists of cuboidal or low columnar cells with basal nuclei and surrounds the neural layer of the retina. The cells have well-developed junctional complexes, gap junctions, and numerous invaginations of the basal membranes associated with mitochondria. The apical ends of the cells extend processes and sheath-like projections that surround the tips of the photoreceptors.
  Some functions of these layer include:
  ■ It absorbs scattered light that passes through the neural layer, supplementing the choroid in this regard.
  ■ With many tight junctions, cells of the pigmented epithelium form an important part of the protective blood-retina barrier and helps regulate ion transport between these compartments.
  ■ The cells play key roles in the visual cycle of retinal regeneration.
  ■ Phagocytosis of shed components from the adjacent photoreceptors and degradation of this material occurs in these epithelial cells.
- **Neural Retina:** This is the inner layer of the retina which functions as an outpost of the central nervous system with glia and other neuronal subtypes in 9 well arranged layers.

2. **The Optic Disc:** It is called the blindspot; it occurs at the posterior of the retina where the axons in the retina's nerve fiber layer (NFL) converge at the ***optic nerve entrance*** which is composed of unmyelinated nerve fibres containing glial supporting tissues and capillaries. At lamina cribosa, the fibers are interspersed by fibrous network from sclera; after piercing the lamina cribosa, fibres get their myelin sheath and the nerve is surrounded by three meninges. Thus, the fibers leave the eye as the **Optic Nerve.**

Other important structures in the eye include:

- **Lens:** The lens is a transparent biconvex structure suspended immediately behind the iris, which focuses light on the retina. It is a unique avascular tissue and is highly elastic, a property that normally decreases with age. The lens has three principal components:
  - A thick, homogeneous ***lens capsule*** that surrounds the lens and provides the place of attachment for the fibers of the ciliary zonule.
  - A subcapsular ***lens epithelium*** consists of a single layer of cuboidal cells present only on the anterior surface of the lens. The epithelial cells attach basally to the surrounding lens capsule and their apical surfaces bind to the internal lens fibers.
  - ***Lens fibers*** are highly elongated, terminally differentiated cells that appear as thin, flattened structure. Lens fibers are packed tightly together and form a perfectly transparent tissue highly specialized for light refraction. Together with the ciliary muscles, this structure allows the process of **visual accommodation**.

- **Vitreous Body:** It occupies the large vitreous chamber behind the lens. It consists of transparent, gellike connective tissue that is 99% water ***(vitreous humor***), with collagen fibrils and hyaluronate, contained within an external lamina called the ***vitreous membrane***. The only cells in the vitreous body are called *hyalocytes,* which synthesize the hyaluronate and collagen, and a few macrophages.

Question 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.

The retina is the innermost part of the eye that is responsible for the visual processing of light energy. It is a layered structure with 10 distinct layers of neurons interconnected by synapses. Within these layers are cells that help in the transmission and image formation- visual processing. The layers from anterior to posterior includes:

1) **The Inner Limiting Membrane Layer (ILM)**: It is the boundary between the retina and the vitreous body, formed by astrocytes and the end feet of muller cells. It is separated from the vitreous humor by a basal lamina.

2) **Nerve Fiber Layer (NFL)**: Also called the ***stratum opticum;*** consists of ganglion cell axons and runs parallel to the retinal surface. The fibres proceed to the optic disc, turn at a right angle and exit the eye through the Lamina Cribosa as the optic nerve. The fibres generally are unmyelinated and have no Schwann sheath. It is thickest near the optic disc, gradually diminishing toward the ora serrata.

3) **Ganglion Cell Layer (GCL)** : Made up of large ganglionic cells and neuroglia. Ganglion cells are arranged in a single row but in macula lutea, there are several rows. The cells in these layer, together with other cells, help transmit image forming and non-image forming information from the retina in the form of action potential to several regions in the brain.

4) **Inner Plexiform Layer (IPL)**: Formed by synapses between axons of bipolar cells and dendrites of ganglionic cells, which forms a dense reticulum of fibrils. Within this reticulum, a

few branched spongioblasts are sometimes embedded. Bipolar cells transmits impulse to the retinal ganglion cells.

5) **Inner Nuclear Layer (INL)**: Consists of nuclei of bipolar cells and nuclei of muller cells. These cells have more cytoplasm around the nucleus than that of bipolar cells. Muller cells lie in the outer part of this layer; amacrine cells are the association cells. The horizontal cells establish contact between different photoreceptors. ***The retinal vasculature of the deep capillary network is located in this layer.***

6) **Outer Plexiform Layer (OPL)**: Contains spherules of ***rods*** and foot plates of cones and dendrites of bipolar cells. It consists of a dense network of synapses between dendrites of horizontal cells from the inner nuclear layer and photoreceptor cell inner segment from the outer nuclear layer. It is much thinner than the outer plexiform layer.

7) **Outer Nuclear Layer (ONL)**: Formed by closely packed nuclei of photoreceptor cells; contains the rod and cones cell bodies (the cone cell body and nucleus are larger than that of the rod). Cone outer fibers are very short and therefore the cone nuclei lie in a single layer close to the external limiting membrane.

8) **External Limiting Membrane (ELM)**: is a sieve-like membrane composed of inward extension of muller fibers. It is not a true basement membrane but is formed by tight junctions between apical processes of muller cells and photoreceptor cells. It is situated at the bases of rods and cones; it mainatains the retinal structure.

9) **Photoreceptor Layer (PL)**: Formed by the dendrites of photoreceptor cells – Rods and Cones (they are cells that respond to light); these cells extend into the pigmented layer.
    - Rods are more numerous than cones, except at macula lutea.
    - Rods are cylindrical and are arranged perpendicular to the surface.
    - Cones do not constrict.

    The distinguishing feature of photoreceptors is the presence of large amounts of tightly packed membrane that contains the photopigment, rhodopsin, or a related molecule.

10) **Retina Pigmented Epithelium (RPE)**: Also called ***non-nervous layer.*** It is a single layer of cells that provide nutrition and waste removal for the photoreceptor cells. The cells are flattened or cuboidal; apical parts project between rods and cones. The dark pigment has the function of absorbing light after the photoreceptors have been stimulated; creates a dark chamber effect in the eye. This layer gives mechanical support to the eye and prevents reflection of light.

The cells within these layers that perform particular roles and form functional circuits that specialize in detecting specific variations and movement of light, which is responsible for the visual processing in the retina, includes:

a) **Photoreceptors (Rods and Cones):** Form the outer nuclear layer; the detection of light begins here, which is the deepest cell layer.
    - Synapse with bipolar cells at the outer plexiform layer with the use of neurotransmitter-glutamate.

- **Rods**: responsible for dim light vision; very sensitive to light.
- **Cones**: not very light sensitive but are specific for a particular wavelength of light. They are responsible for high acuity color vision.

b) **Bipolar cells:** Make up Inner Nuclear Layer.
   - Synapse with amacrine cells and ganglion cells at the inner plexiform layer.
   - At the inner plexiform layer, bipolar cells are responsible for transmitting an impulse to retinal ganglion cells.

c) **Amacrine cells:** They are inhibitory cells which interact with bipolar cells and retinal ganglion cells.
   - They modulate the excitation of the retinal ganglion cells through contact with ganglion cell dendrites or bipolar cell axon terminal bulbs using the neurotransmitters GABA and glycerine.

d) **Retinal ganglion cells:** Form the ganglion cell layer.
   - They vary significantly in terms of their size, connections and responses to visual stimulation but they all share the defining property of having a long axon that extend to the brain.
   - These cells are the final receivers and transmitters of the initial stimulus.
   - They send the information they receive down their axons, which eventually forms the optic nerve and project to higher brain centres.

e) **Horizontal cells:**
   - Assist in operations such as contrast enhancement and preservation of spatial information.
   - They modulate the communication between photoreceptors and bipolar cells.

f) **Muller cells:**
   - They are glial cells which support metabolism and homeostasis of the retina.
   - They contact almost every cell type in the retina, spanning the entire width from the photoreceptors to the inner retina.

How Light Is Transmitted.

Light striking the retina initiates a cascade of chemical and electrical events that ultimately trigger nerve impulses that are sent to various visual centres of the brain through the fibers of the optic nerve. Neural signals from the rods and cones undergo processing by other neurons, whose output takes the form of action potentials in the retinal ganglion cells whose axons form the optic nerve. Several important features of visual perception can be traced to the retinal encoding and processing of light.