Lesson 1: Human Eye

1.1 Anatomy of the Human Eye

The human eye is a complex sensory organ responsible for vision. It is the window to the brain. This organ is constituted by the eyeball and other accessory structures responsible for vision enclosed with the orbital cavity.

Orbit

The word orbit is derived from “orbis” meaning circle. In the skull, the orbits are two quadrilateral, pyramid-shaped (rather than circular) cavities in which the eyeballs are suspended and supported by the extraocular muscles. The upper and lower walls of the orbital cavity contain perforations known as the superior and inferior orbital fissures through which the nerves and vessels enter or leave the eye. The stalk of the orbit the optic canal through which the optic nerve passes and further connects to the brain.

The Eyeball

The eyeball is a bullbous structure with an antero-posterior (from front to back) diameter of about 24mm and constitutes the cornea and optic nerve from anterior to the posterior pole respectively. **(Figure 1)**

The eyeball is divided in to two segments:

1. **Anterior segment:** It includes all the structures starting from the cornea to the crystalline lens including the iris and the anterior chamber.
2. **Posterior chamber:** It includes all the structures posterior to the lens i.e. the vitreous humor (a gel-like substance filling the space behind the lens), retina, choroid and optic nerve.

Figure 1: Diagram of the longitudinal section of the eyeball

Conjunctiva

The conjunctiva is a transparent, mucosal membrane lining the eyeball and the inner surface of the eyelids. The conjunctiva is a vital structure for secretion of the tear film as well as a defense barrier against infection.

The conjunctiva is divided as:

1. **Palpebral conjunctiva:** starts from the lid margins and lines the eyelids.

2. **Bulbar conjunctiva:** lines the anterior sclera and is continuous with the corneal epithelium at the limbus. It lies loosely over the structures and therefore can be moved easily.
3. **Conjunctival fornix:** is mostly loose and connects the bulbar and the palpebral conjunctiva.

Cornea

Is an avascular (without blood supply), transparent structure forming the anterior one-sixth of the eyeball. It is divided into the 5 layers based on the cells it contains: **(Figure 2)**

1. **Epithelium:** Contains five layers of cells. The surface of the topmost layer of these cells is lined by microvilli (hair-like structures) to facilitate the attachment of the tear film. The basal layer of these cells is vital and indispensable for the maintenance of a healthy corneal epithelium. It also acts as a junction preventing conjunctival tissue from infiltrating the cornea.
2. **Bowman's layer**: This layer does not contain cells (acellular). It shows considerable resistance to infection; although, once destroyed, it cannot regenerate and therefore leaves a scar while healing.
3. **Stroma**: This makes up for 90% of the corneal thickness. It mainly contains collagen fibrils.
4. **Descement's membrane**: is made of a fine network of collagen fibrils. It is highly resistant to trauma and chemical substances. Unlike the Bowman's layer, when injured it can regenerate.
5. **Endothelium**: It contains a single layer of cells that cannot regenerate. It plays a key role in ensuring the cornea is dehydrated. When this layer is damaged, swelling of the cornea occurs (corneal edema) with a loss of transparency.

Figure 2: Microanatomy of the cornea showing the corneal layers

Sclera

The sclera forms the opaque fibrous, protective coat of the eyeball. The anterior portion of the sclera is the visible portion and constitutes the "white" of the eye. When the sclera is thin it appears bluish due to the uvea showing through it. This maybe observed in childhood or due to pathological thinning of the sclera. With age, it may appear yellowish due to the deposition of fat. Anterior to the sclera, is the episclera and it is composed of dense vascular (blood vessels) connective tissue.

Uvea

The uveal tissue is the intermediate vascular coat of the eye that comprises of the iris, ciliary body and the choroid from front to back.

The iris: The iris is the most anterior part of the uveal tract. It is a thin circular disc that acts similar to the diaphragm of the camera with a perforation in its center known as the pupil. The pupil is responsible for regulating the amount of light that enters the eye. For example: it is pinpoint when in bright light and widely dilated in the dark. The colour of the iris is due to the deposition of a pigment in its posterior part and the variation in the colour is due to the amount of pigment deposition.

The ciliary body: The ciliary body continues anteriorly from the choroid at the ora serrata. It appears as a triangle on cut section. This triangle may be divided into two parts: The anterior part with finger-line processes known as the pars plicata, responsible for the for formation of aqueous humor. The posterior part is the smooth surface known as pars plana.

The choroid: It is the most posterior part of the uveal tract. It is responsible for providing nutrition to the outer part of the retina. It extends from the optic nerve to the ora serrata (thin, jagged line where the retina ends). Choroid mainly consists of blood vessels and is enclosed by the sclera and the Bruch's membrane (retinal side). The larger vessels are situated near the sclera and the smaller chorio-capillaries are towards the retina.

Lens

The lens is a crystalline, biconvex, transparent structure between the iris and the vitreous cavity enclosed by a capsule. The capsule is responsible for moulding the lens during accommodation. New lens fibers are constantly being laid under the capsule throughout life resulting in the growth of the lens. One of the main factors in maintaining transparency of the lens is its avascularity (absence of blood vessels). Any opacity of the lens capsule irrespective of time of onset, cause or impact on vision is a cataract.

Retina

The retina is the innermost part of the eyeball. It is a thin, transparent membrane with a purplish-red hue due to the visual purple of the rods. The retina extends from the optic nerve to the ora serrata. Grossly, it maybe divided into two regions: the posterior pole and the peripheral retina.

Posterior pole: It constitutes two distinct areas, the optic disc and the macula lutea.

The optic disc is seen as a pink, well-defined circular area. It is here that all the retinal layers terminate and the retinal nerve fibers pass through it and further connects to the optic nerve. A depression seen in the optic disc is called the physiological cup.

The macula lutea: This appears as a bland, yellow region when compared to the deeper red, orange surrounding area. A depression in the center part of the of the macula is known as the fovea centralis. **(Figure 3)** It is the most sensitive part of the retina and is responsible for vision. This may be due to the presence of tightly packed cones. Rods are absent in the fovea. The center, shining part of the fovea is the foveola. This region and some surrounding area within the fovea do not contain retinal capillaries (smaller blood vessels) and therefore this area is termed as the foveal avascular zone.

Figure 3: Microscopic structure of the fovea centralis

Peripheral retina: It extends beyond the posterior pole up to the ora serrata.

The retina is the light-sensitive part of the eye that contains:

1. Cones, responsible for colour vision,

2. Rods, which can detect dim light and are responsible for black and white vision and vision in the dark.

When either rods or cones are excited (when light falls on the retina), signals are transmitted through the various layers of the retina into the optic nerve and eventually the brain (cerebral cortex).

Figure 4: Microscopic structure of the Retinal Layers

The retina consists of three types of cells and are arranged in ten layers from outside in:

1. **Pigment epithelium:** The retina begins with the **pigmented epithelium** (layer 1), which is just inside the choroid and firmly adherent to the underlying Bruch's membrane. It is the outermost layer and consists of a single layer of cells containing pigment. The pigment cells have tentacle-like processes that extend into the **photoreceptor layer** (layer 2). These processes are responsible for providing nutrients to the photoreceptors.

2. **Photoreceptor layer (layer of rods and cones):** The photoreceptor layer consists of the rods and cones. This layer contains on the outer segments of the photoreceptors arranged in a fence-like manner. The rods contain a photosensitive substance called the rhodopsin that allow low illumination vision. The cones also contain a photosensitive substance, iodopsin that is primarily responsible form central and colour vision. Light rays that fall onto the photoreceptor array of layer 2 in a point-to-point fashion.

3. **External limiting membrane:** Muller cells, play an important role in maintaining the internal geometry of the retina. Müller cells are oriented radially, parallel to the light path through the retina. The numerous connections made between Müller cells and the inner

segments give the appearance of a continuous layer, the **external limiting membrane** (layer 3 of the retina).

4. **Outer nuclear layer:** This layer 4 of the retina and contains the cell bodies and the nuclei of the rods and cones.

5. **Outer plexiform layer:** It contains connections (synapses) between the photoreceptors and the bipolar and the horizontal cells forming the 5^{th} layer of the retina.

6. **Inner nuclear layer**: The cell bodies of the bipolar and horizontal cells from layer 5 maybe found here in the 6^{th} layer of the retina along with amacrine and Muller cells.

7. **Inner plexiform layer**: The 7^{th}layer of the retina consists of the connections (synapses) between the processes of bipolar cells and amacrine cells from the **inner nuclear layer.**

8. **Ganglion cell layer**: The ganglion cells constitute the 8^{th} layer of the retina. These cells are the output cells of the retina and their axons are responsible for transmitting visual information to the brain.

9. **Nerve fiber layer**: The axons of the ganglion cells form the 9^{th} layer of the retina. These pass along the vitreous surface of the retina while avoiding the fovea, and enter the optic disc, where they leave the eye in the optic nerve. The portions of the ganglion cell axons that are in the optic fiber layer remain unmyelinated (no insulated sheath covering the nerve fibers), but the axons become myelinated (insulated sheath covering the nerve fibers) after they reach the optic disc. The lack of myelin where the axons cross the retina helps light to pass through the inner retina.
10. **Inner limiting membrane**: It is the inner most layer (layer 10) that separates the retina from the vitreous. It is formed by the end-feet of Müller cells.

Optic nerve

The optic nerve is the second of the 12 cranial nerves. It begins at the optic disc and extends up to the optic chiasma (point of contact) where the right and the left optic nerves meet. The optic nerve is the continuation of the retinal nerve fiber layer. The fibers of the optic nerve are very fine structures and count up to about a million in number. The optic nerve is said to be the first part of the eye's connection to the brain.

Suggested Reading

1. Parsons' disease of the eye. Ed Ramanjit Sihota & Radhika Tandon.
2. Comprehensive Ophthalmology. A K Khurana

3. The Anatomy of the Eye and the Orbit. Eugene Wolff