

Name: Ibediro obiora

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Anatomy Of The Eye

QUESTION 1

The Fibrous Tunic: Cornea and Sclera

Cornea

The cornea forms the anterior surface of the eye in an area largely corresponding to the pigmented iris, which is visible behind the cornea. The diameter of the cornea is ~11 mm; the thickness ranges from ~0.5 mm centrally to ~1mm along the margins of the cornea. The cornea is formed by three cellular layers, which are separated from each other by two thin, acellular layers. Blood vessels are not normally found in the cornea, and the cells are not pigmented.

The anterior surface of the cornea is lined by a stratified squamous epithelium. The basement membrane of this anterior corneal epithelium rests on the first acellular layer, the anterior limiting lamina or Bowman's membrane. It separates the epithelium from the corneal stroma and consists of densely packed collagen fibrils embedded in ground substance.

The corneal stroma consists of 200 - 250 layers of regularly organized collagen fibrils (mainly tropocollagen type I, but also types III, V and VI). Collagen fibres within each layer will run parallel to each other but at large angles to collagen fibres in the next layer. Flattened fibrocytes, referred to as keratocytes, are located between the layers of collagen fibres. The regular arrangement of the collagen fibres and their small diameter (20 - 60 nm) account for the transparency of the cornea.

The posterior surface of the cornea is lined by an endothelium, the posterior endothelium. The posterior endothelium and the corneal stroma are separated from each other by the posterior limiting lamina or Descemet's membrane, which corresponds to the basement membrane of the posterior endothelium.

The lateral margins of the cornea are continuous with the conjunctiva (anterior corneal epithelium) and sclera (corneal stroma).

Sclera

The sclera is a tough layer of dense connective tissue consisting of collagenous fibres and networks of elastic fibres. Melanocytes are present in deep parts of the sclera in addition to the usual complement of connective tissue cells. Distended by the intraocular pressure, the sclera maintains the shape of the eyeball. It is also the site of attachment of the ocular muscles.

Anteriorly, the sclera forms a slight protrusion into the eyeball before it merges with the cornea - the scleral spur, which provides a point of insertion for part of the ciliary muscle. The sclerocorneal junction houses the canal of Schlemm, through which the aqueous humor is drained into ciliary veins.

The Vascular Tunic: Choroid, Ciliary Body and Iris

Choroid

The choroid consists of loose connective tissue, which houses a dense network of blood vessels. Connective tissue cells and melanocytes are numerous. The latter give the choroid its dark colour. Small blood vessels are especially frequent in the innermost part of the choroid, which is called the choriocapillary layer. This layer supplies the retina with nutrients. Bruch's membrane is located between the choroid and the retina. It consists of two layers of collagen fibres and a network of elastic fibres between them.

Ciliary body

The ciliary body is an inward extension of the choroidal at the level of the lens. Ciliary processes are short extensions of the ciliary body towards the lens. A small amount of loose connective tissue similar to that of the choroid is located between smooth muscle cells which form the bulk of the ciliary body. They form three bundles, the ciliary muscle.

The inner surface of the ciliary body and its processes are lined by two layers of columnar cells which belong to the retina - the ciliary epithelium formed by the pars ciliaris of the retina. The outer cell layer is pigmented, whereas the inner cell layer, i.e. the layer that faces the posterior chamber of the eye, is nonpigmented.

The ciliary processes contain a dense network of capillaries. The cells of the inner layer of the ciliary epithelium generate the aqueous humor of the eye, i.e. they transport the plasma filtrate generated by the capillaries in the ciliary processes into the posterior chamber of the eye. Tight junctions between the cells form the blood - aqueous humor barrier.

Fibers, which consist of fibrillin, extend from the ciliary processes towards the lens and form the suspensory ligament of the lens. These fibres are also called zonule fibres. Two of the bundles of the ciliary muscles attach to the sclera and stretch the ciliary body when they contract, thereby regulating the tension of the zonule fibres. The reduced tension will result in a thickening of the lens which focusses the lens on close objects - a process called accommodation.

Iris

The posterior surface of the iris is covered by the retina. The inner layer of the retina, i.e. the layer facing the posterior chamber, is called the posterior epithelium of the iris. Both layers of the retina are pigmented, but pigmentation is heavier in the inner layer. In the region of the central opening of the iris, the pupil, the retina extends for a very short distance onto the anterior surface of the iris. The iridial stroma consists of a vascularized loose connective tissue rich in melanocytes in addition to macrophages and fibrocytes, which are all surrounded by a loose meshwork of fine collagen fibers. The anterior surface of the iris is not covered by an epithelium - instead of we find a condensation of fibrocytes and melanocytes, the anterior border layer of the iris.

The iris forms the aperture of the eye. Myoepithelial cells in the outer (or anterior) layer of the retina, i.e. the layer adjacent to the stroma of the iris, have radially oriented muscular extensions. These extensions form a flat sheet immediately beneath the anterior layer of the retina, the dilator pupillae muscle. Embedded in the central portion of the iridial stroma are smooth muscle cells which form the

annular sphincter pupillae muscle. In humans, this muscle surrounds the pupil as a less than 1 mm wide and only 0.2 mm thick band. The two muscles regulate the size of the pupil.

Pupillary constriction, which is mediated by the sphincter pupillae muscle, is clinically referred to as miosis - dilation, mediated by the dilator pupillae muscle, as mydriasis.

The pigmentation of cells in the stroma and anterior border layer of the iris determines the color of the eyes. If cells are heavily pigmented the eyes appear brown. If pigmentation is low the eyes appear blue. Intermediate levels create shades of green and grey.

Lens

The lens consists of a lens capsule, the subcapsular epithelium and lens fibres. It does not contain blood vessels or nerves.

The lens capsule is generated by the cells of the subcapsular epithelium and corresponds to a thick, elastic basal lamina. The zonule fibres insert into the lens capsule.

Cells of the subcapsular epithelium (or anterior lens cells) are mitotically active. In adult individuals they only cover the anterior "hemisphere" of the lens. As they divide, cells gradually move towards the equator of the lens where they transform into lens fibres. The apical part of the gradually elongating cell extends between the subcapsular epithelium and adjacent lens fibres towards the anterior pole of the lens. The basal part extends towards the posterior pole. The nucleus remains close to the equatorial plane of the lens.

The mature lens fibres, i.e. very long (up to 12 mm), hexagonal cells, form the body of the lens. They are located immediately deep to the cells of the subcapsular epithelium. Lens fibres are nucleated in the soft, outer cortex of the lens. As new lens fibres are added to the periphery of the cortex, lens fibres located deeper in the cortex lose their nuclei and become part of the somewhat harder nucleus of the lens. In the intact lens, lens fibres are tightly connected to each other. Few organelles are scattered in a cytoplasm filled with crystallin proteins. These proteins are responsible for the transparency and refractive properties of the lens and account for up to 60% of the mass of lens fibres.

The optical properties of the lens change from periphery to central parts because of differences in the amounts of crystallins contained in lens fibres. These differences correct for distortions of colours and shapes (called spherical and chromatic aberrations) which commonly occur at the margins of glass lenses. These aberrations are easy to observe when you look through a loupe - or even in not-so-good microscopes at the margins of the field of view, where they are easy to detect when the slide is moved.

The Neural Tunic: Retina

Similar to the retinal lining of the iris and ciliary body, the outer layer of the light sensitive retina forms a single layer of cuboidal cells - the pigment epithelium. The inner layer of the retina contains the

photoreceptors, the first neurones which process the sensory information, and the neurones which convey the pre-processed sensory information to the central nervous system. Receptors, neurones, supporting cells and their processes are segregated into nine layers:

1. The layer of rods and cones contains the outer, rod- or cone-shaped light sensitive segments of the photoreceptive cells. The light sensitive part and the perikaryon of the rods and cones are connected by a narrowed bridge of cytoplasm. At the level of this connection the rods and cones are surrounded by the processes of a specialised type of glial cells, Müller cells, which form the
2. outer limiting membrane.
3. The outer nuclear layer contains the nuclei and perikarya of the rods and cones. Their processes form part of the
4. outer plexiform layer, where they form synapses with the processes of neurones whose cell bodies are located in the
5. inner nuclear layer. The cells of the inner nuclear layer are concerned with the initial processing of the sensory input. The three major neurone types are horizontal, bipolar and amacrine cells. The inner nuclear layer also houses the perikarya of the Müller cells.
6. The inner plexiform layer contains the processes of the inner nuclear layer neurones which convey the sensory input to the
7. ganglion cell layer. Ganglion cells are not evenly distributed. There are few of them towards the periphery of the retina. Close to the fovea, ganglion cells form a densely packed layer. Both ganglion cells and the cell bodies located in the inner nuclear layer which contact the rods and cones of the fovea are displaced towards the margins of the fovea.
8. Layer of optic nerve fibres. The axons of the ganglion cells travel in this layer towards the optic disc. Towards the optic disc, the thickness of this layer increases as more and more axons are added to it.
9. The inner limiting membrane corresponds to a basal lamina formed by the Müller cells.

Optic Nerves

Because of the origin of the retinae and optic nerves from the developing forebrain, the optic nerves (cranial nerves II) corresponds to fibre tracts connecting parts of the CNS - in this case the ganglion cells of the retina with neurones in the lateral geniculate nucleus of the thalamus and neurones in the superior colliculus and pretectum of the midbrain.

Ganglion cell axons run towards the optic disc where they turn towards the sclera. Numerous bundles (or fascicles) of axons pass through the choroid and openings in the sclera, the lamina cribosa. The axons become myelinated in this region. Collectively, the bundles form the optic nerve. Like other parts of the CNS, the optic nerve is surrounded by the three meninges - the outer dura mater, the middle arachnoid and the inner pia mater, which are separated from each other by subdural and subarachnoid spaces. At the eyeball, the dura fuses with the sclera while the arachnoid and pia mater merge with the choroid.

Connective tissue septa, which arise from the pia mater, separate the fibre bundles in the optic nerve. The axons in the optic nerve are supported by astrocytes and oligodendrocytes. Microglia is also present.

Eyelid

The posterior (facing the eyeball) and anterior (facing the world) surfaces of the eyelid are also called conjunctival and cutaneous parts. The cutaneous part is covered by skin and contains sweat glands, sebaceous glands and, along the margins of the lid, 3-4 rows of hairs - the eyelashes. Modified apocrine sweat glands, the glands of Moll, empty into the follicles of the eyelashes. The eyelashes lack arrector pili muscles.

The inner, conjunctival part of the lids is lined by conjunctiva. Beneath the conjunctiva, large sebaceous glands are embedded in a plate of dense connective tissue containing many elastic fibres. The plate and the sebaceous glands within it are called the tarsal plate the tarsal glands (also Meibomian glands). Extensive skeletal muscle bundles between the tarsal plate and the skin belong to the orbicularis oculi muscle.

Conjunctiva

The margins of the cornea merge with the conjunctiva. The conjunctiva extends over the the 'white of the eye', which corresponds to the anterior part of the sclera, folds back and continues over the posterior part of the eyelid. At the opening formed by the eyelids, the conjunctive merges with the skin which covers the anterior surface of the eyelids.

The epithelium of the conjunctiva varies from stratified squamous (most of it) to stratified columnar (at the reflection from the sclera to the eyelid). It contains goblet cells. The conjunctival epithelium rest on the loose connective tissue of its lamina propria.

QUESTION 2

The eye is formed by three layers, or tunics. Each of these three layers contributes with parts that have structural / nutritive functions and parts that form the optic and photoreceptive apparatus of the eye. From the outside to the inside of the eyeball the three tunics are the

1. fibrous tunic, which forms a capsule enclosing and protecting the other components of the eye. It is subdivided into the sclera, with primarily structural functions, and the cornea, which is part of the optic apparatus.
2. vascular tunic, which forms the choroid, ciliary body and iris. This tunic is also called the uveal tract. The choroid has primarily nutritive functions. The ciliary body generates the aqueous humor of the eye, but the ciliary muscle also functions in the optic apparatus. The iris is part of the optic apparatus in which it functions a contractile diaphragm, i.e. the aperture of the eye.

3. neural tunic consists of the retina. The retina proper forms the photoreceptive layer of the eye. As a double-layered epithelium, the retina also covers the ciliary process and the posterior surface of the iris, where it has both nutritive and structural functions. ^L_{SEP} The ciliary and iridial parts of the retina are described together with the ciliary process and iris.