HISTOLOGY 2024-2025

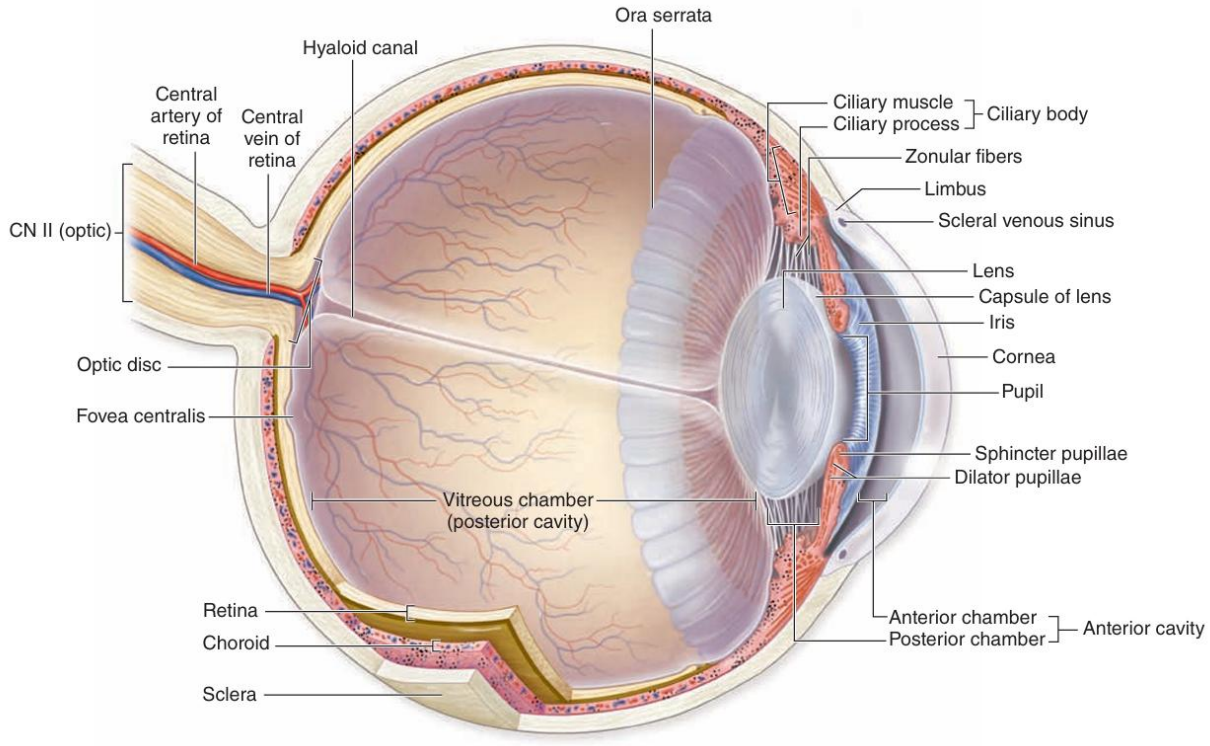
The Eye & Ear: Special Sense Organs

EYES: THE PHOTORECEPTOR SYSTEM

Eye is a highly developed photosensitive organ for reception and analysis the form, intensity and color of light reflected from objects and providing the sense of sight.

Each eye is composed of three concentric tunics or layers:

- A tough external fibrous layer (tunica fibrosa) consisting of the sclera and the transparent cornea;
- A middle vascular layer (tunica vasculosa, uvea) consisting of the choroid, ciliary body, and iris;
- An inner sensory layer, the retina, which communicates with the cerebrum through the posterior optic nerve.



TUNICA FIBROSA

The outermost tunica fibrosa is composed of the **sclera** and the **cornea**. The sclera (the white of the eye) is an opaque, relatively avascular fibrous connective tissue layer that covers the posterior five-sixths of the eyeball. The sclera receives insertions of the extrinsic ocular muscles.

The **cornea** is the transparent, highly innervated avascular anterior one-sixth of the tunica fibrosa. It joins the sclera in a region called the limbus. The cornea is composed of five layers:

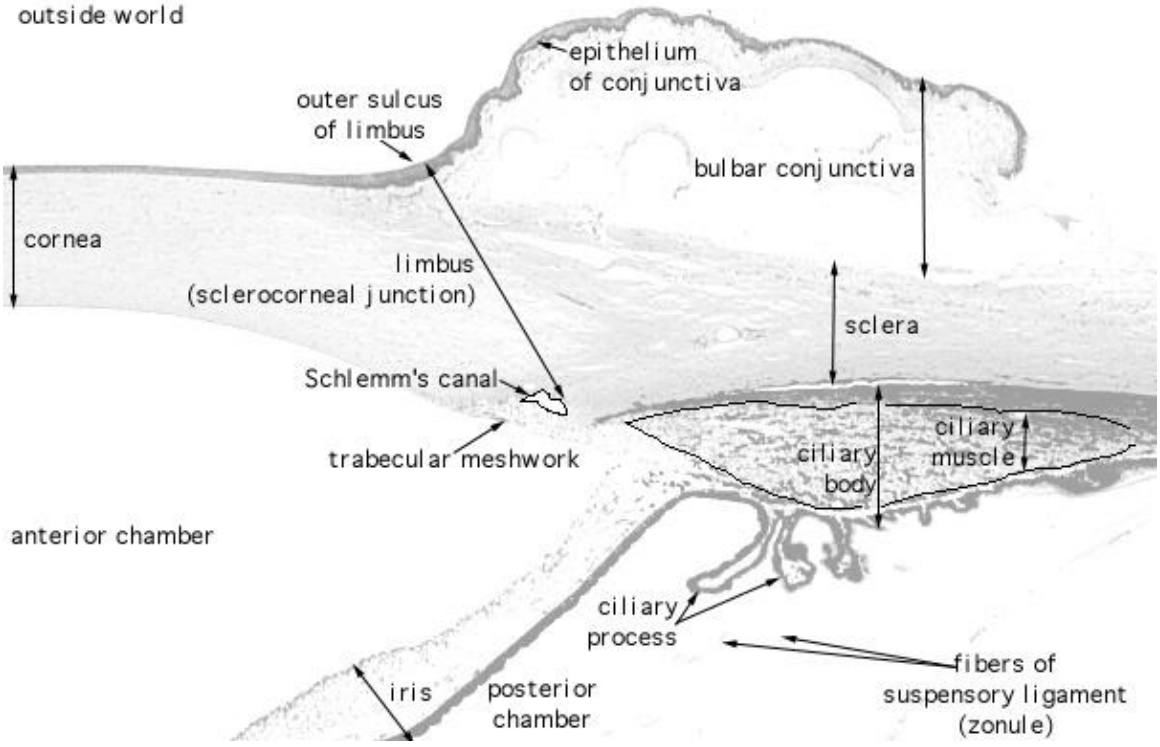
1. The **corneal epithelium** is stratified squamous non keratinized epithelium covers the anterior aspect of the cornea and is continuous with the conjunctiva (a mucous membrane covering the anterior sclera and lines the inner eyelids). It possesses microvilli in its superficial layer that trap moisture, protecting the cornea from dehydration. It is highly innervated with free nerve endings.
2. **Bowman membrane** is a homogeneous noncellular layer that provides form, stability, and strength to the cornea. The basal layer of the corneal epithelium is attached to Bowman membrane via hemidesmosomes.
3. **Corneal stroma** is the thickest corneal layer composing of 5 layers of type I & V collagen fibers which are embedded in ground substance of proteoglycans with chondroitin sulfate and keratan sulfate, a few cells called keratocytes dispersed between the collagen fibers.
4. **Descemet's membrane** (posterior limiting membrane), which is the basement membrane of the endothelium.

5. **Corneal endothelium** It is a simple squamous epithelium that lines the posterior aspect of cornea, it is the most metabolically active cells of the cornea, responsible for proper hydration state of the corneal stroma to provide maximal transparency and optimal light refraction.

LASIK (Laser-Assisted In-Situ Keratomileusis): The shape or curvature of the cornea can be changed surgically targeting stroma using laser after displacing corneal epithelium as flap to improve certain visual abnormalities involving the ability to focus.

Corneoscleral junction (limbus)
It is transitional area where the transparent cornea merges with the opaque sclera. It encircles the cornea where the following changes from the cornea to sclera occur:

- Bowman's membrane ends and the surface epithelium becomes more stratified as the conjunctiva.
- The stroma becomes vascular and less well-organized at the limbus, as the collagen bundles merge with those of the sclera
- Descemet's membrane and its simple endothelium are replaced with a system of irregular endothelium-lined channels called the trabecular meshwork that allows continuous drainage of aqueous humor from anterior chamber. This fluid moves from these channels into the adjacent larger space of the scleral venous sinus, or **canal of Schlemm**.



Glaucoma *is a condition of abnormally high intraocular pressure. It is caused by obstructions that prevent drainage of aqueous humor from the eye via the canal of Schlemm. Glaucoma is the leading cause of blindness in African Americans in the United States, and worldwide, it is the second leading cause of blindness after cataracts. Since it is an age-related condition, about 1 in 10 persons 80 years of age have glaucoma.*

TUNICA VASCULOSA (UVEAL TRACT)

It is composed of three parts: choroid, ciliary body, and iris.

The **Choroid** is the highly vascular, pigmented layer of the eye on the posterior wall of the eyeball; its

loose connective tissue contains many 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:

- **Choriocapillary layer**: has a rich micro vasculature important for nutrition of the outer retinal layers.
- **Bruch membrane**: a thin extracellular sheet, is com posed of collagen and elastic fibers surrounding the adjacent microvasculature and basal lamina of the retina's pigmented layer.

The **Ciliary body** is the wedge-shaped anterior expansion of the choroid. It is lined on its inner surface by two layers of cells: an **outer pigmented columnar epithelium** rich in melanin and an **inner nonpigmented simple columnar epithelium**. Three structures are associated with the ciliary body:

A. **Ciliary muscle**: makes up most of the ciliary body's stroma and consists of smooth muscle fibers. Contraction of these muscles affects the shape of the lens and is important in visual accommodation. The ciliary muscle is innervated via parasympathetic fibers of the oculomotor nerve.
B. **Ciliary processes** are radially arranged extensions (about 70) of the ciliary body. They have a connective tissue core containing many fenestrated capillaries. They are covered by two epithelial layers. The nonpigmented inner layer transports components from the plasma filtrate in the posterior chamber and thus forms the **aqueous humor**, which flows to the anterior chamber via the pupillary aperture.
C. **Ciliary zonule (zonular fibers)** is a system of many radially oriented fibers composed largely of fibrillin-1 and -2 produced by the nonpigmented epithelial cells on the ciliary processes, they arise from the processes and insert into the capsule of the lens, serving to anchor it in place.

The **Iris** is the most anterior extension of the choroid, separating the anterior and posterior chambers of the eyeball. It incompletely covers the anterior surface of the lens, forming an aperture called the pupil that is continually adjusted by intrinsic pupillary muscles. The iris is covered by an incomplete layer of pigmented cells and fibroblasts on its anterior surface. It has a wall composed of loose vascular connective tissue containing melanocytes and fibroblasts. **Dilator pupillae muscle** is a smooth muscle with fibers that radiate from the periphery of the iris toward the pupil. It contracts upon stimulation by sympathetic nerve fibers, dilating the pupil. **Sphincter pupillae muscle** is smooth muscle arranged in concentric rings around the pupillary orifice. It contracts upon stimulation by parasympathetic nerve fibers of the oculomotor nerve (cranial nerve III), constricting the pupil.

The **lens** is a biconvex transparent flexible structure composed of the lens capsule, subcapsular epithelium, and lens fibers. The lens capsule is a thick basal lamina that envelops the entire lens epithelium. The subcapsular epithelium (on the anterior and lateral lens surfaces only) is composed of a single layer of cuboidal cells that communicate with each other via gap junctions and interdigitate with lens fibers. Lens fibers represent highly differentiated, elongated cells that when mature lack both nuclei and organelles. Lens fibers are filled with a group of proteins called **crystallins**.

Presbyopia *is the inability of the eye to focus on close objects (accommodation). This is usually associated with aging, since it is related to decreasing elasticity of the lens, which prevents it from assuming a spherical shape. This condition can usually be corrected with eyeglasses.*

A ***Cataract*** *is an opacity of the lens resulting from the accumulation of pigment or other substances in the lens fibers that scatter the light entering the lens, thus preventing sharp focusing of the light on the retina. This condition is often associated with aging. If untreated, it leads to a gradual loss of vision. When the opacity becomes severe, an ophthalmologist may remove and replace the affected lens with a man-made lens restoring clear vision.*

The **Vitreous body** occupies the large vitreous chamber behind the lens. It consists of transparent, gel like 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 a small mesenchymal population near the membrane called **hyalocytes**, which synthesize the hyaluronate and collagen, and a few macrophages.

THE RETINA

The retina is the innermost of the three tunicae of the eye and is responsible for photoreception. It is interposed between the choroid and the vitreous humor. It is composed of two layers-a photosensitive layer containing rods and cones and several interneurons, and a non-sensitive pigmented layer housing melanin producing cells. The **photosensitive (visual) portion** of the retina ends at the ora serrata, whereas the **non-sensitive (pigmented) portion** continues anteriorly to cover the ciliary body and the posterior surface of the iris.

Retina Pigmented Epithelium

The 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 contain pigment vesicles extend processes and sheath-like projections surrounding the tips of the photoreceptors. also contains numerous phagocytic vacuoles and secondary lysosomes, peroxisomes, and abundant smooth ER (SER) specialized for retinal (vitamin A) isomerization.

The diverse functions of the retinal pigmented epithelium include the following:

1. Absorbs scattered light.
2. Forms part of the blood-retina barrier & regulates ion transport.
3. Retinal regeneration (esterification of vitamin A essential for formation of visual pigments by rods & cones).
4. Phagocytosis of shed components from the adjacent photoreceptors.
5. Removal of free radicals.

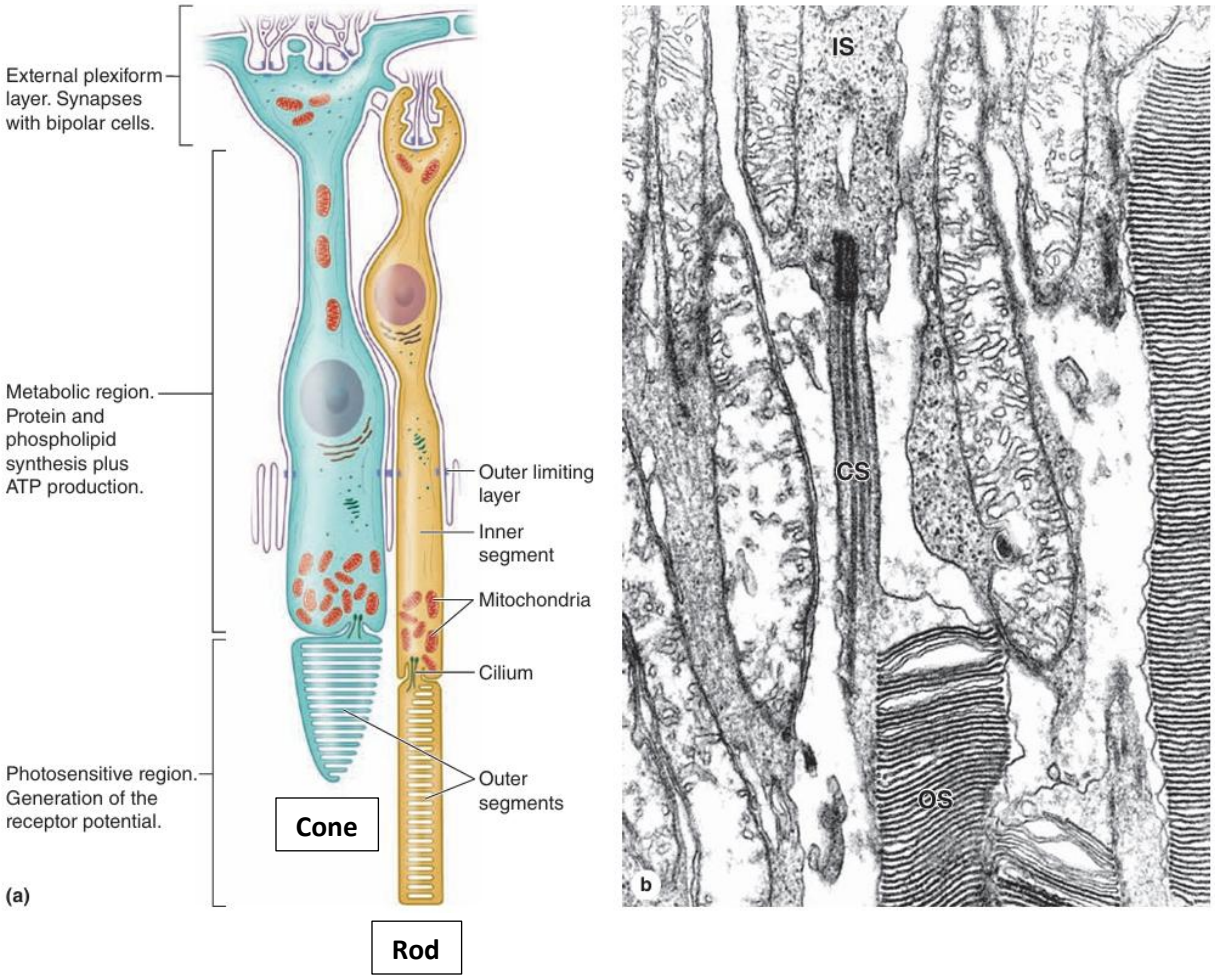
Neural Retina

It consists 9 layers of photoreceptive (including rods and cones) and neural cells. All neurons of the retina are supported metabolically by elongated, regularly arranged glial cells called **Müller cells**, they extend processes that span the entire thickness of the neural retina. Muller cells are critical for retinal function as they:

1. Provide neurotrophic substances
2. Remove waste products
3. Regulate ions & water homeostasis
4. Regulate blood flow
5. Maintain blood-retina barrier
6. Forming outer limiting layer & inner limiting membrane

Rod cells (Rods)

These are modified elongated neurons having outer and inner segments, the inner segment possesses mitochondria, glycogen, polyribosomes, and proteins, which migrate to the outer segments to be incorporated into the membranous disks. While the outer segment contains flattened membranous disks contain visual purple pigment called **rhodopsin**, these disks are shed and phagocytized by pigment epithelium. Rods are more abundant and **sensitive to low-intensity light**.



Cones

These are less numerous than rods but produce greater visual acuity than rods. The have same structure as rods but differ in:

- The membranous disks in the outer segments of cones are invaginations of the plasma membrane, whereas in rods they are not.
- Cones possess **iodopsin** in their disks. The amount of this photopigment varies in different cones, making them differentially sensitive to red, green, or blue light.
- They are sensitive to high-intensity light.

Color blindness: Partial color blindness is normally an inherited disorder due to recessive mutations in genes for one or more iodopsins or other genes required for cone function. The most common form, red-green color blindness, affects the cones responsible for detecting light at these two wavelengths and occurs much more frequently in men than women because many key genes for the color sensitivity of cones are on the X chromosome. With two X chromosomes, women do not show the disability but can be carriers of the mutation.

EARS: THE AUDIORECEPTOR SYSTEM

The ear consists of three parts: the external ear, which receives sound waves; the middle ear, through which sound waves are transmitted; and the internal ear, where sound waves are transduced into nerve impulses. The vestibular organ, responsible for equilibrium, is also located in the inner ear.

Internal ear (a bony labyrinth within the temporal bone)

The bony labyrinth, composed of the semicircular canals, vestibule, and cochlea, is filled with perilymph, and houses the membranous labyrinth, which is filled with endolymph.

Semicircular canals house the semicircular ducts of the membranous labyrinth.

The **vestibule** houses the saccule and utricle.

The **cochlea** winds two and a half times around a bony core (the modiolus), which contains blood vessels and the spiral ganglion. It is subdivided into three spaces: the scala vestibuli and scala tympani, which are both filled with perilymph, and the scala media, or cochlear duct, which is filled with endolymph.

Structure and function of internal ear components

Bony Labyrinth Component (Containing Perilymph and the Membranous Labyrinth)	Membranous Labyrinth Component (Within Bony Labyrinth and Containing Endolymph)	Structures With Sensory Receptors	Major Function
Vestibule	Utricle, saccule	Maculae	Detect linear movements and static position of the head
Semicircular canals	Semicircular ducts	Cristae ampullares	Detect rotational movements of the head
Cochlea	Cochlear duct	Spiral organ	Detect sounds

Utricle and saccule (within the vestibule)

(a) The saccule and utricle are saclike bodies composed of a thin sheath of connective tissue lined by simple squamous epithelium.
(b) Each gives rise to a duct; the two ducts join, forming the endolymphatic sac.
(c) They possess small, specialized regions, called **maculae**, which contain type I and type II neuroepithelial hair cells, supporting cells, and a gelatinous layer (**otolithic membrane**, The outer region of this layer contains barrel-shaped crystals called **otoliths** typically 5-10 µm in diameter).

Vestibular hair cells

(a) These neuroepithelial cells contain many mitochondria and a well-developed Golgi complex.
(b) They have elongated, rigid **stereocilia** (sensory microvilli) arranged in rows and a single cilium (**kinocilium**). These cilia extend from the apical surface of the hair cells into the otolithic membrane. They function in the detection of linear acceleration.

Cristae ampullares (of semicircular canals ampullae)

(a) are specialized sensory regions within the ampullae of the semicircular ducts.
(b) are similar to maculae but have a thicker, conical glycoprotein layer (**cupula**), which does not contain otoliths.
(c) They function to detect rotational movements of the head as they deflected by movement of endolymph movement in the canal.

Cochlear duct

It is part of membranous labyrinth contains the **spiral organ of Corti (audioreceptive organ)**. It is bordered above by the scala vestibuli and below by the scala tympani of the bony cochlea. These scalae, which contain perilymph, communicate with each other at the **helicotrema** at the apex of the cochlea.

Vestibular membrane consists of two layers of squamous epithelium, one derived from the scala media and the other from the lining of the scala vestibulae. It helps maintain the high ionic gradients between the perilymph in the scala vestibuli and the endolymph in the cochlear duct.

Basilar membrane is a thick layer of amorphous material containing keratin-like fibers on which hair cells of the organ of Corti rest on. Two types of hair cells and supporting cells can distinguished. The processes

of hair cells (stereocilia) are embedded in Tectorial membrane.
Stria vascularis is a vascular pseudostratified epithelium on the lateral aspect of cochlear duct, its function is to secret endolymph.