Lecture 23 **د. ستار جابر**

Vision

The eye is often compared to a camera, with **the cornea** acting as the **lens**, the pupillary diameter functioning like the aperture of the camera, and **the retina** serving as **the film**.

The eye is a **roughly spherical organ** enclosed within **a thick layer** of connective tissue (**the sclera**) that is usually **white**.

The sclera is protective and creates **attachment points for three pairs of skeletal (extraocular) muscles** that are used to **adjust the direction of gaze**, stabilize gaze during head movement, and **track moving objects**.

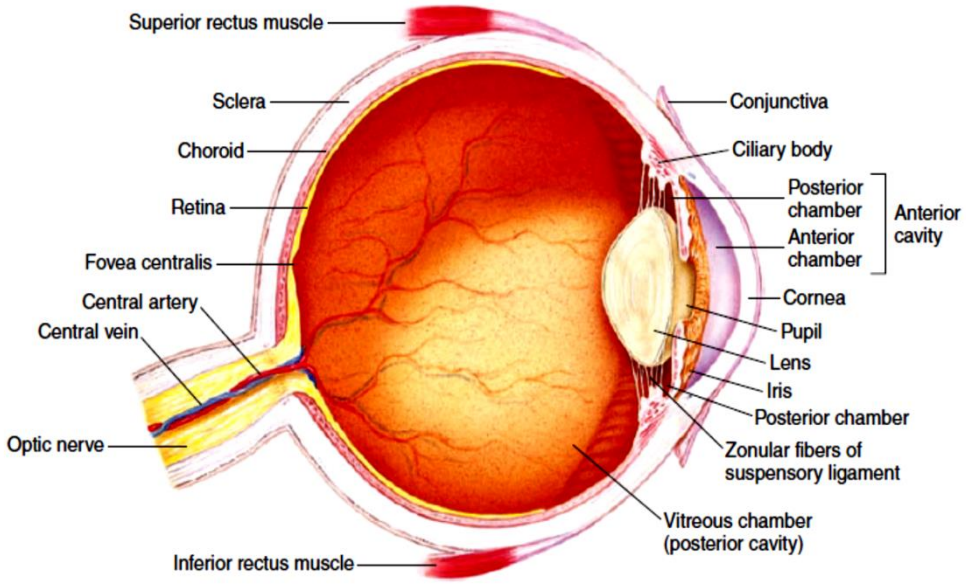


Figure :A schematic of the anatomy of the eye

Because **the photoreceptors** are located at the back of the eye, **photons entering the eye must travel through multiple layers and compartments** before they can be detected.

1. Cornea

Light enters the eye via the cornea, which is **continuous with the sclera**. The cornea comprises **several thin, transparent layers delimited by specialized epithelia**.

The middle layers are composed of collagen fibers along with **supportive keratinocytes** and **an extensive sensory nerve supply**. Blood vessels would interfere with light transmission so **the cornea is avascular**.

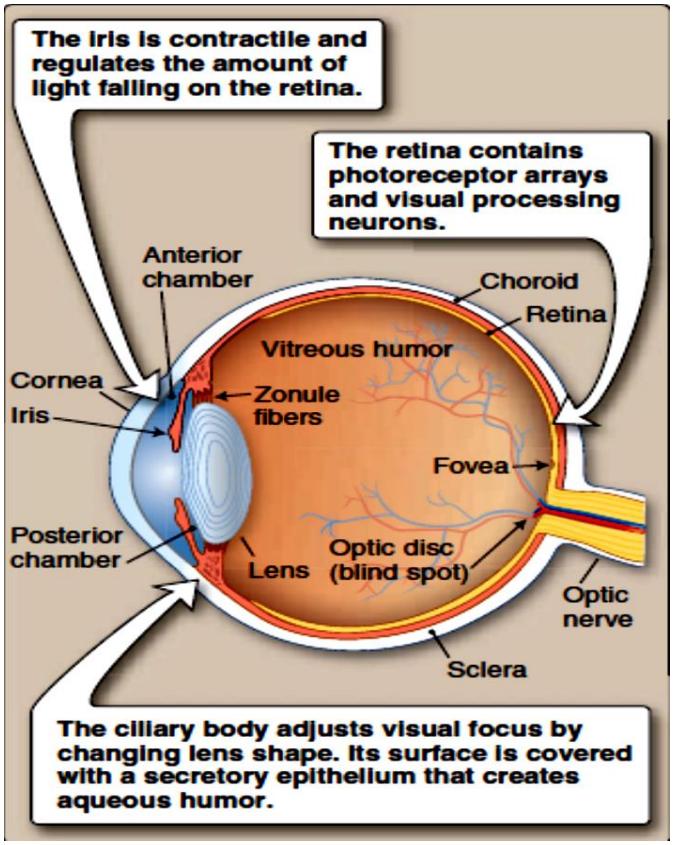


Figure :Eye structure

2. Anterior chamber

The anterior chamber is filled with **aqueous humor**, **a watery plasma derivative**. It is secreted into the **posterior chamber** by a specialized **ciliary epithelium** that covers the **ciliary body**.

Aqueous humor then flows through the pupil, into the anterior chamber, and drains via the canals of Schlemm to the venous system.

Humor is produced continuously to **deliver nutrients to the cornea** and to create a **positive pressure of 8–22 mm Hg** that stabilizes corneal curvature and its optical properties.

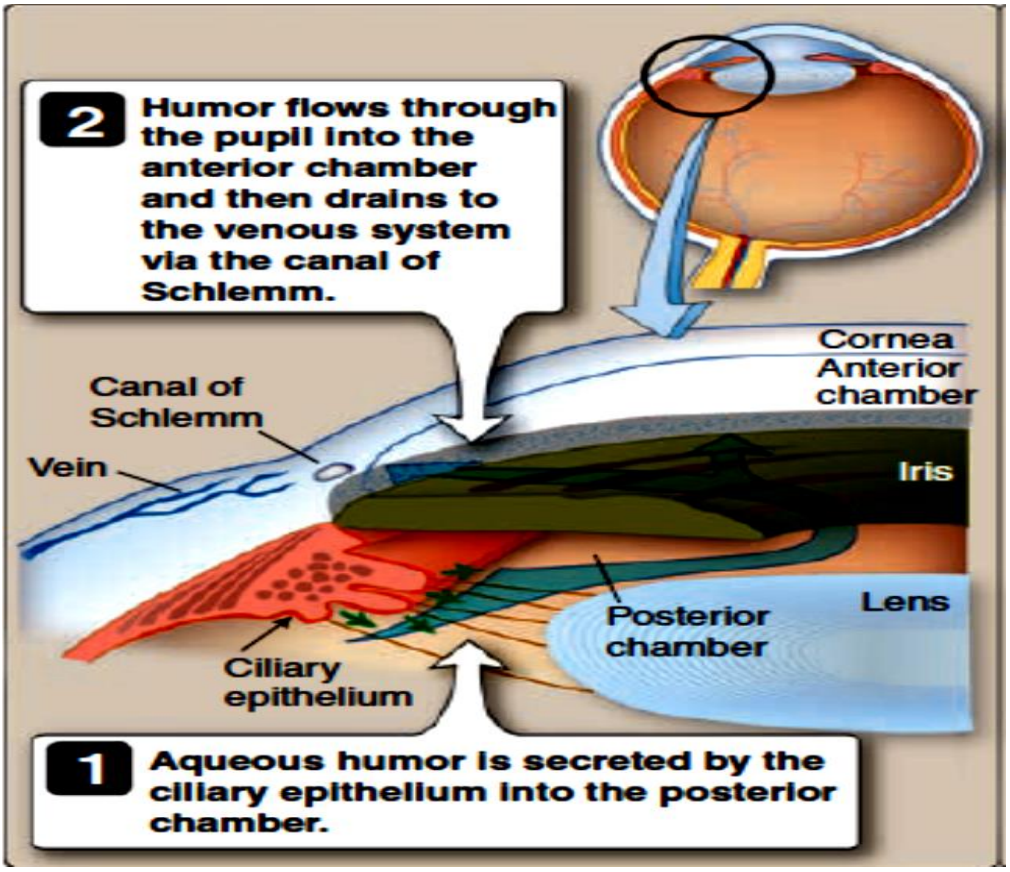


Figure :Aqueous humor secretion & flow

3. Iris

The iris is a pigmented, fibrous sheet with an aperture (the pupil) at its center that regulates how much light enters the eye.

Pupil diameter is determined by two smooth muscle groups that are under autonomic control. **Rings of sphincter muscles** that are controlled by postganglionic **parasympathetic** fibers from **the ciliary ganglion decrease pupil diameter** when they contract (**miosis**) .

A second group of radial muscles controlled by postganglionic sympathetic fibers originating in **the superior cervical ganglion** widen the pupil (**mydriasis**).

Changes in **pupil diameter** are **reflex responses to the amount of light** falling on **specialized photosensitive ganglion cells located in the retina** (the **pupillary light reflex**).

Signals from these cells (photosensitive ganglion cells) travel via the optic nerve to nuclei in the midbrain and then to the Edinger-Westphal nuclei. Here, they trigger a reflex **increase in parasympathetic activity** via the **oculomotor nerve (cranial nerve [CN] III**), and the **pupil constricts**.

Pupillary constriction reduces the amount of light entering the eye and helps prevent photoreceptor saturation. Saturation is **undesirable** in that it functionally **blinds an individual**.

When light levels are low, a reflex pupillary dilation increases the amount of light reaching the retina. The pupillary reflexes elicit **identical muscle responses in both eyes**, even though light levels may be changing in **one eye only.**

Pupil diameter always reflects **a balance between tonic sympathetic and parasympathetic nerve activity…….!!!**

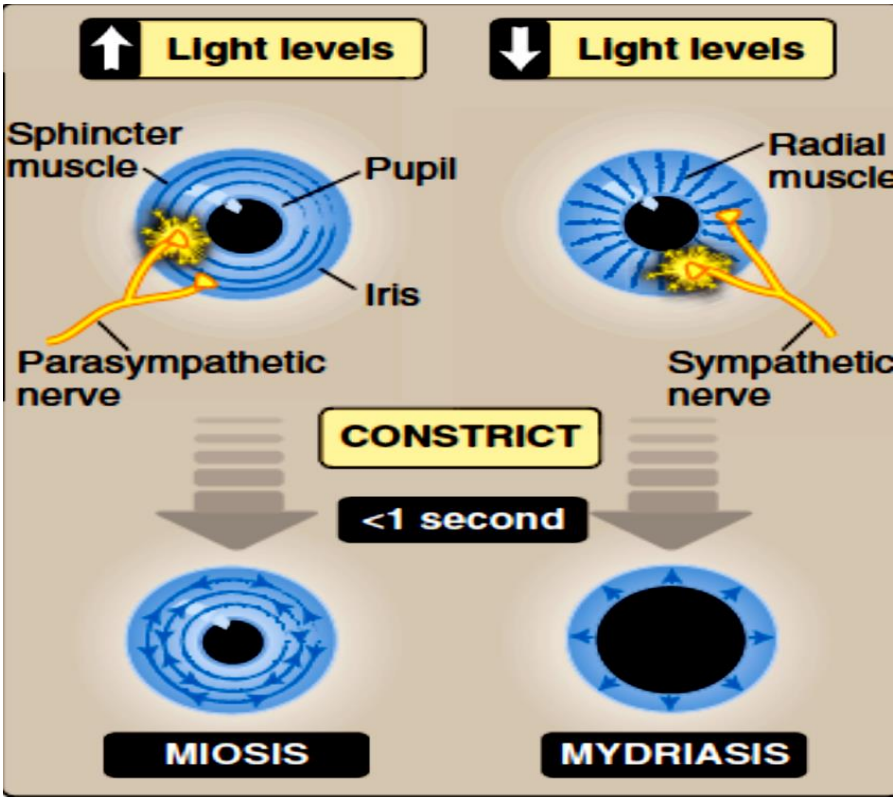


Figure :Regulation of pupil diameter

4. Lens

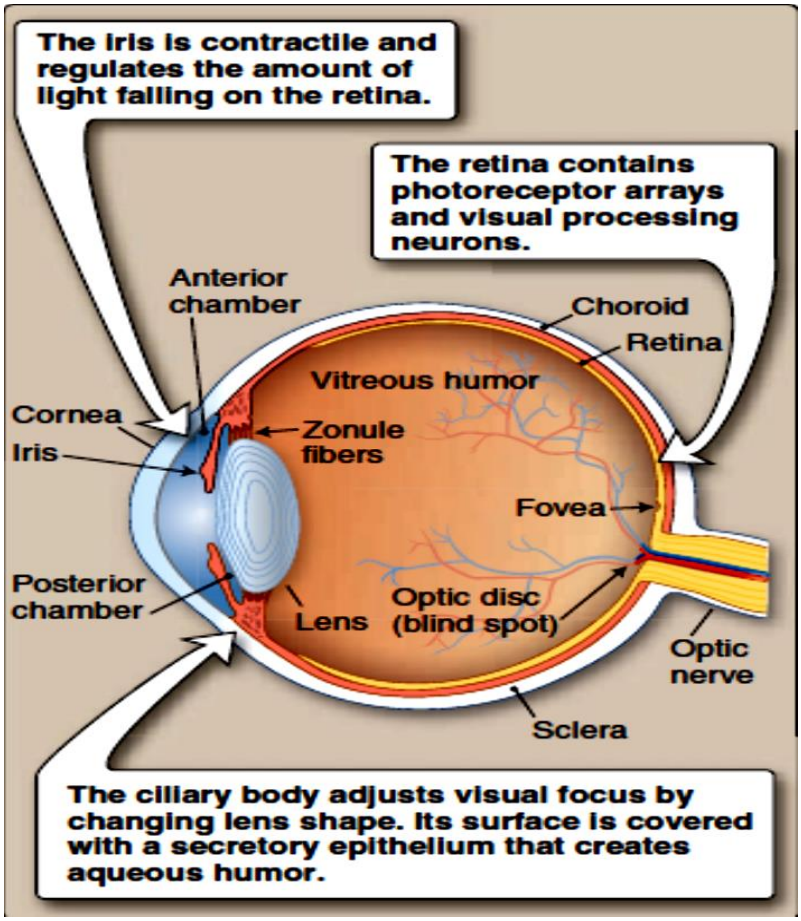
The lens is a transparent, ellipsoid disk suspended in the light path by radial bands of connective tissue fibers (zonule fibers), attached to the ciliary body. The ciliary body is contractile and functions to modify lens shape and adjust its focus .

The lens is composed of **long, thin cells** that are arranged in **tightly packed**, concentric layers, **much like the layers of an onion**.

The cells are dense with crystallins, proteins that give the lens its transparency and determine its optical properties. The lens is enclosed within **a capsule composed of connective tissue** and an epithelial layer.

5. Vitreous humor

Vitreous humor is **a gelatinous substance composed largely of water and proteins.** It is maintained under **slight positive pressure** to hold the retina against the sclera.



6. Retina

The retina lines the inside surface of the eye, covering roughly 75% (11 cm2) of its total surface area.

When light reaches the retina, it still has to penetrate **multiple layers of neurons and their supporting structures before it can be detected by photoreceptors.** The neuronal layers are **transparent**, so light loss during passage is minimal.

The retina contains two specialized regions. The **optic disc** is a small area where **the photoreceptor array is interrupted to allow blood vessels and axons** from the retinal neurons to exit the eye, creating a **blind spot** .

Nearby, in **the center of the field of vision**, is a circular area called the **macula lutea**.

At its center is a small (1-mm diameter) pit called the fovea. **The neuronal layers separate here to allow light to fall directly on photoreceptors**, creating an area of **maximal visual acuity**.

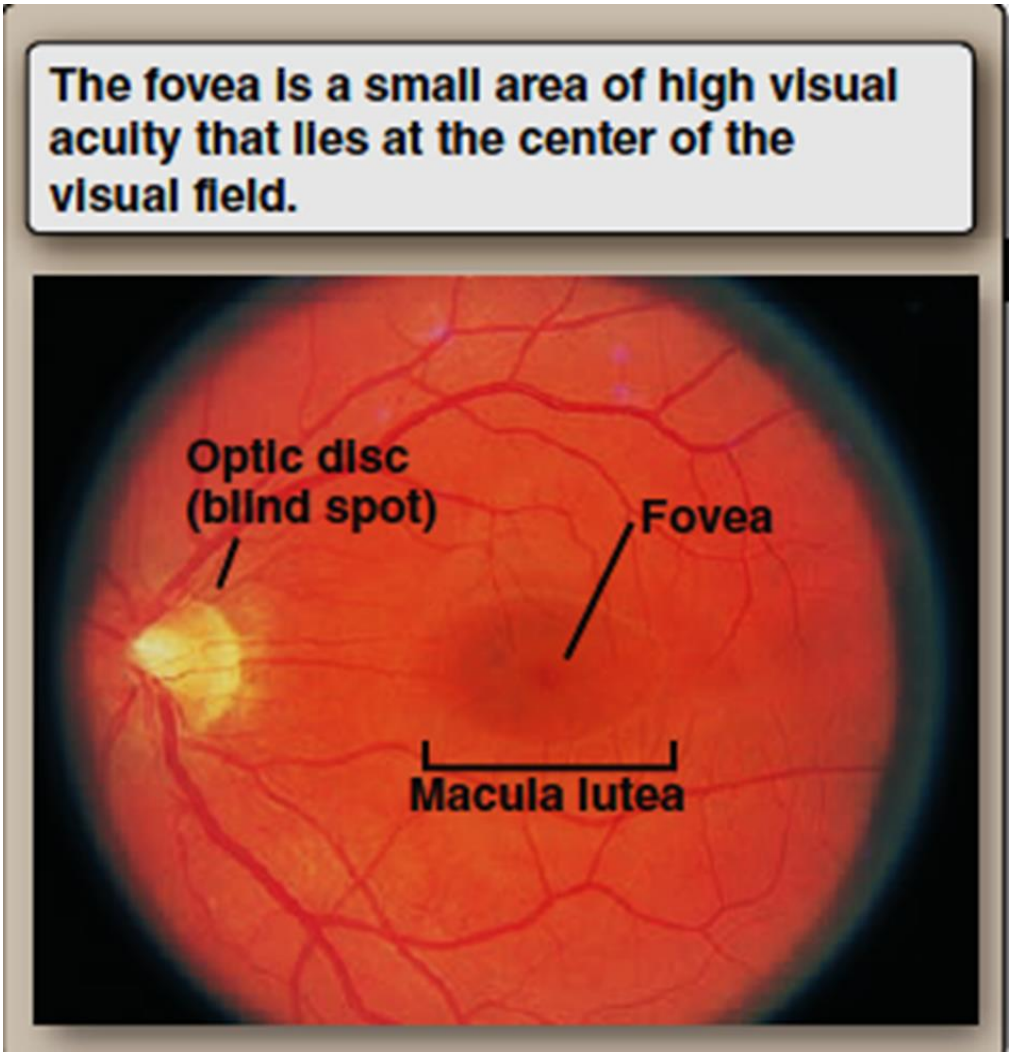


Figure :Retinal landmarks

The Retina is a highly organized structure comprising **layers of cells that generate photosensory data** (**the photoreceptors**), process visual signals (**bipolar cells**, **horizontal cells**, **ganglion cells**, and **amacrine cells**), or support neuronal activity (**the pigment epithelium and neuroglia**).

1. Pigment epithelium: The innermost retinal layer is a black, pigmented epithelium that absorbs stray photons that might otherwise interfere with imaging and decrease visual acuity. The color is imparted by numerous **melanin** pigment granules.

The pigment epithelium also supplies photoreceptors with nutrients, is involved with **retinal recycling**, and assists with photoreceptor turnover.

Photoreceptor membranes are subject to constant damage by photons and, hence, are turned over continually.

The entire rod stack is replaced once every 10 days.

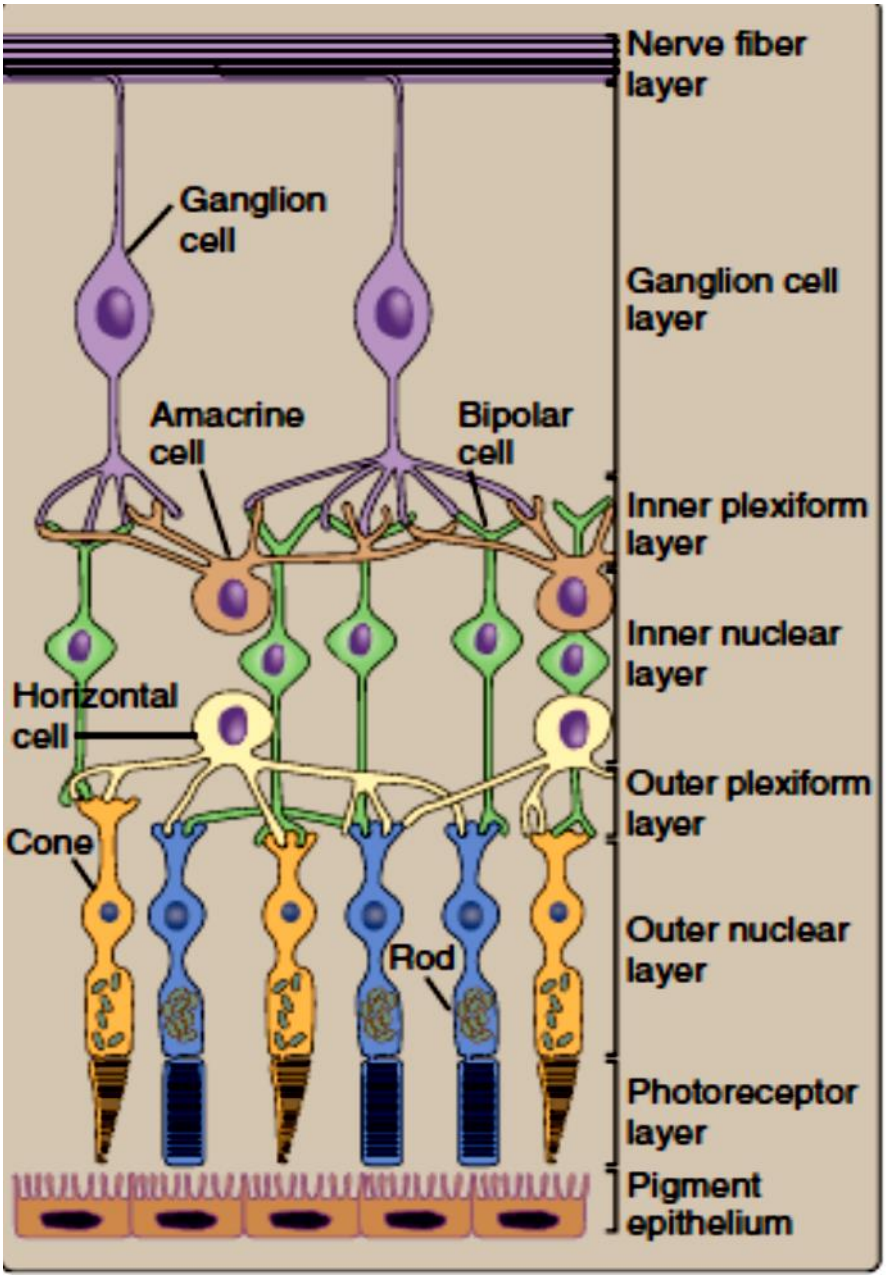


Figure :Principal retinal cell layers and interconnections

2. Neuroglia: Because **the retina is an extension of the brain**, the photoreceptors and all associated excitable cells receive support from

glia.

Müller cells, which are a **retina-specific glial subtype**, occupy the spaces between neurons and form a barrier (the **inner delimiting membrane**) that separates **the retina from vitreous humor**.

End

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2019

Medical Physiology I

Lecture 24 **د. ستار جابر**

The eyes convert **energy in the visible spectrum** into **action potentials** in the optic nerve. **The wavelength of visible light ranges from approximately 397 to 723 nm.**

The images of objects in the environment are **focused on the retina**. The light rays **striking the retina generate potentials in the rods and cones**.

Impulses initiated in the retina are **conducted to the cerebral cortex**, where they produce **the sensation of vision**.

Ganglion cell axons gather to form **the optic nerves (CN II**), **one per eye**, which **convey visual signals from the retina to the brain**.

The optic nerves meet and merge immediately **in front of the pituitary gland** at a structure called the **optic chiasm** .

Here, **nasal retinal fibers cross the midline and join temporal fibers from the contralateral eye to form optic tracts** that converge on the **lateral geniculate nucleus** of the thalamus.

In practice, this crossing over (decussation) ensures that **sensory data from the right visual fields of both eyes is transmitted to the left side of the brain, and *vice versa*.**

The data streams are then transmitted from the thalamus via optic radiations to the primary visual cortex in the occipital lobe for analysis and interpretation.

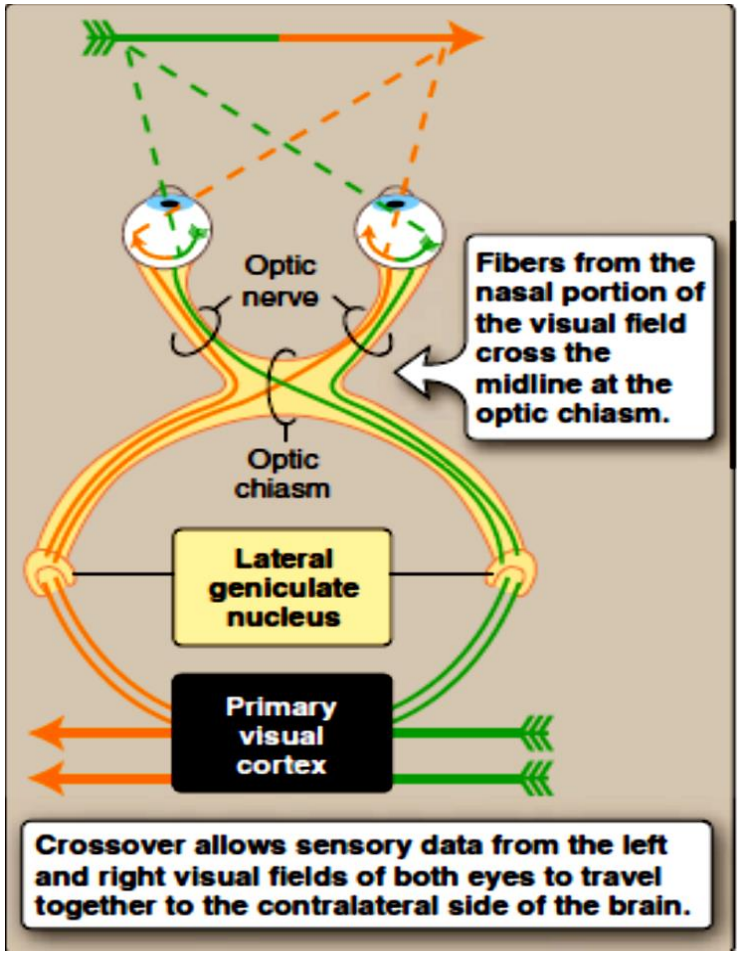

Figure :Pathways for visual information flow to the brain.

Photoreceptors

Retinal photoreceptors are arranged in highly regular arrays so that spatial information can be extracted from the photoreceptor excitation patterns.

The retina contains two types of photoreceptors that share a similar cellular structure.

1.Rods are specialized to detect single photons of light. They **cannot differentiate color** but they **can generate an image under low-light** conditions and thereby facilitate **scotopic vision** (derived from the Greek word for darkness, *skotos*).

2. Cones function optimally in daylight and mediate **photopic**, or color, vision.

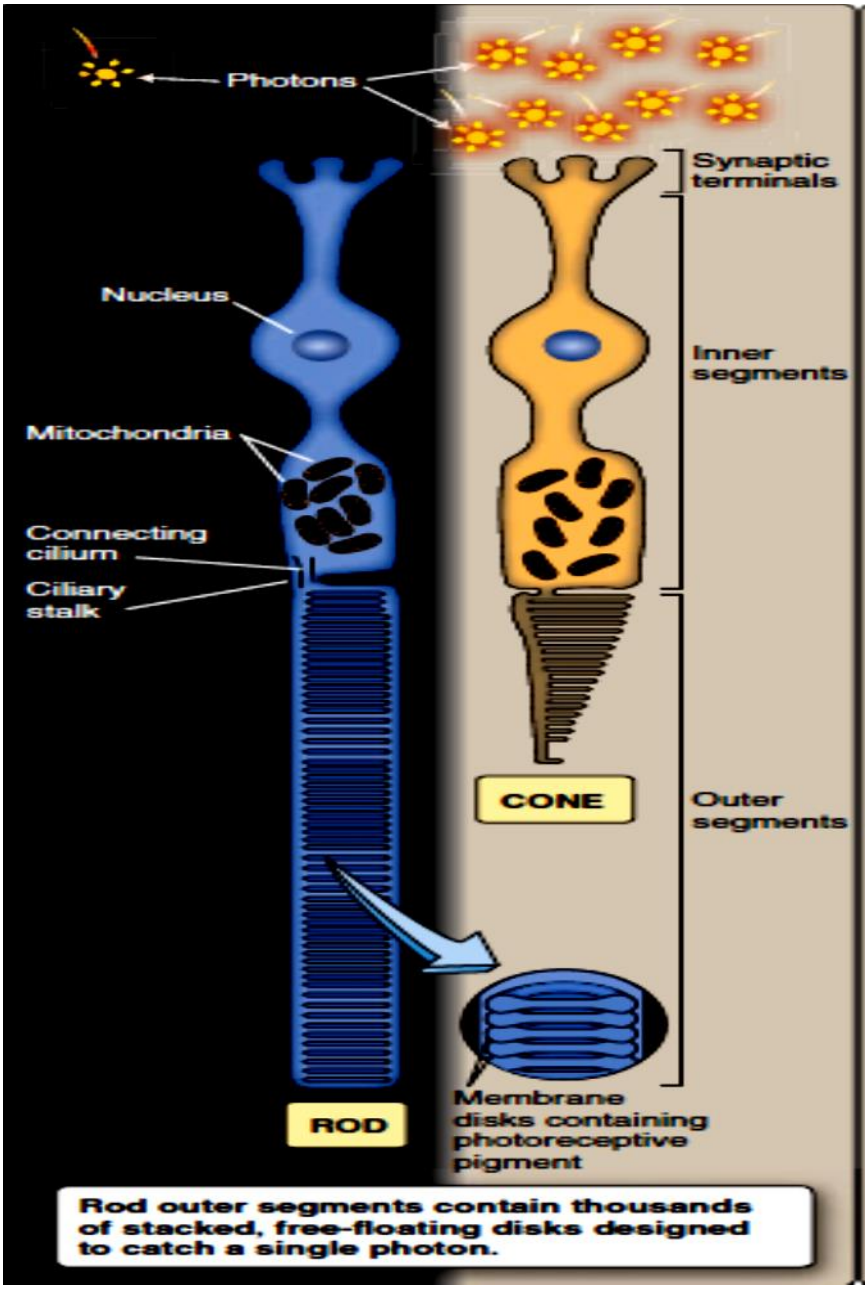

Figure :Photoreceptor structure

Photoreceptors are long, thin, excitable cells .At the center is a cell body that encloses the nucleus. The cell body extends in one direction to form a short axon that branches into several presynaptic structures.

The opposite end of the cell is long and cylindrical and divided into two segments.

The inner segment contains all the other organelles required for normal cell function, including numerous mitochondria. The inner segment gives rise to a cilium (**connecting cilium**) that is grossly modified to house the phototransduction machinery.

This compartment, which is known as the **outer segment**, is connected to the inner segment by a short **ciliary stalk**.

Disk membranes

The bloated sensory cilium that comprises the rod outer segment is packed with 1,000 discrete, flattened, membranous disks that are stacked like dinner plates **alongside the ciliary axoneme**.

Cones contain similar but less numerous stacks that are infoldings of the surface membrane.

The rod stacks are designed to capture a single photon as it traverses the eye's photosensitive layer. To make this a reality, the disk membrane is so densely packed with photosensory pigment molecules that there is little room left over for lipid!

Photoreceptors are densely packed within the sheet, with rods outnumbering cones 20-fold (130 million rods *versus* 7 million cones). Although both rods and cones are found throughout the retina, **their distribution is unequal.**

1. Rods dominate **the peripheral retina**, which optimizes these areas for night vision.

2. Cones are **concentrated in the central retina**, which imparts this area with a **high degree of visual acuity**. At its center is **the fovea, which contains cones alone**. The fovea's lack of rods means that it cannot participate in night vision.

The potential changes that initiate action potentials in the retina are generated by **the action of light on photosensitive compounds in the rods and cones.** When light is absorbed by these substances, their structure changes, and this **triggers a sequence of events** that initiates neural activity.

The eye is unique in that **the receptor potentials of the photoreceptors and the electrical responses of most of the other neural elements in the retina are local, graded potentials,**

and it is only in the ganglion cells that **all-or-none action potentials** transmitted over appreciable distances are generated.

The responses of the rods, cones, and horizontal cells are hyperpolarizing, and the responses of the bipolar cells are either hyperpolarizing or depolarizing, whereas **amacrine cells** produce depolarizing potentials and spikes that may act as generator potentials for the propagated spikes produced in the ganglion cells.

The cone receptor potential has a sharp onset and offset, whereas the rod receptor potential has a sharp onset and slow offset.

The curves relating the amplitude of receptor potentials to stimulus intensity have similar shapes in rods and cones, but **the rods are much more sensitive**. Therefore, rod responses are proportional to stimulus intensity at levels of illumination that are below the threshold for cones.

On the other hand, cone responses are proportional to stimulus intensity at high levels of illumination when the rod responses are maximal and cannot change. This is why cones generate good responses to changes in light intensity above background but do not represent absolute illumination well, whereas rods detect absolute illumination.

Ionic Bases of Photoreceptors Potentials

Na+ channels in the outer segments of the rods and cones are **open in the dark**, so current flows from the inner to the outer segment .Current also flows to **the synaptic ending of the photoreceptor**.

The Na+, K+ ATPase in the inner segment maintains **ionic equilibrium**. Release of synaptic transmitter (**glutamate**) is steady in the dark.

When light strikes the outer segment, the reactions that are initiated close some of the Na+ channels, and the result is a hyperpolarizing receptor potential.

The hyperpolarization reduces the release of glutamate, and this generates a signal in the bipolar cells that ultimately leads to action potentials in ganglion cells. **The action potentials are transmitted to the brain.**

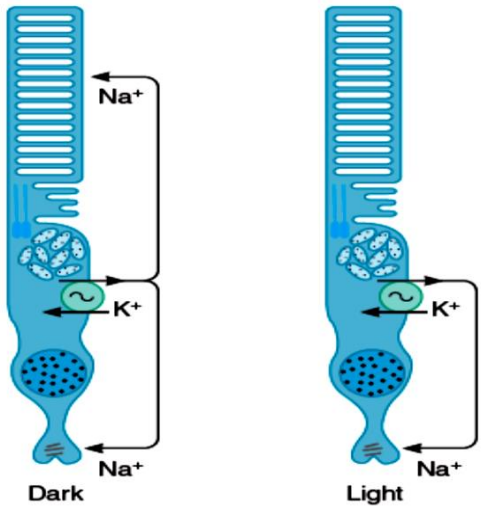

Figure :Effect of light on current flow in visual receptors. In the dark, **Na^+ channels** in the outer segment are held open by cGMP. **Light leads to increased conversion of cGMP to 5′-GMP**, and some of the channels close. This produces hyperpolarization of the synaptic terminal of the photoreceptor.

Rhodopsin

The photosensitive pigment in the rods is called **rhodopsin (visual purple). Rhodopsin is composed of retinal, an aldehyde of vitamin A**, and a protein called **opsin.**

Because of the importance of **vitamin A** in the synthesis of **retinal**, it is not surprising that a deficiency in this vitamin produces visual abnormalities.

Opsin is part of the large family of G-protein-coupled receptors (GPCR).

Night vision is monochromatic because rods contain only one visual pigment. They are designed to register small amounts of light, **not provide information about its quality**.

Distinguishing colors requires two or more pigments that signal maximally at different wavelengths. Color vision employs three cone-cell types, each containing a different visual pigment.

All use **11-cis retinal** as a chromophore, and **the phototransduction mechanism** is the same .However, the opsins differ in their primary sequence, which shifts pigment sensitivity to different wavelengths on the visible spectrum.

S cones respond maximally to short wavelengths (violet-blue: 420 nm**), M cones** to medium wavelengths (green-yellow: 530 nm), and **L cones** to long
wavelengths (yellow-red: 560 nm).

Overlap in pigment absorption spectra means that all three cone types respond to most visible light frequencies, but the intensity of their responses differs according to how close the stimulus is to the cone's optimal range. The brain then extrapolates colors from the data streams emerging from the retina.

End

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