EYE

Our two eyes are positioned in bony sockets in the skull called orbits. Each eye weighs around 7 grams.

Structure of Human Eye

Human eyes work much like a camera, with a single lens concentrating light from all directions onto a layer of light-sensitive cells. The area from which each eye gathers light rays is known as the visual field. We'll delve into the details of the light-sensitive cell layer, called the retina, in the upcoming sections.

The adult human eyeball is approximately spherical in shape. Its wall consists of three layers. The outer layer is called the sclera or fibrous tunic, the middle layer is known as uvea or vascular tunic (which includes the choroid and ciliary body or iris), and the innermost layer is the retina.

Sclera

The sclera is a strong layer made of dense connective tissue, which is why it's tough. It's mostly milky white, giving the eye its "white" appearance, except at the front where it becomes the transparent cornea. The cornea is like a dome and its curved surface helps to bend and focus light. So, the cornea allows light into the eye and shapes it to focus properly. The tear glands keep the cornea's surface moist and free from dust.

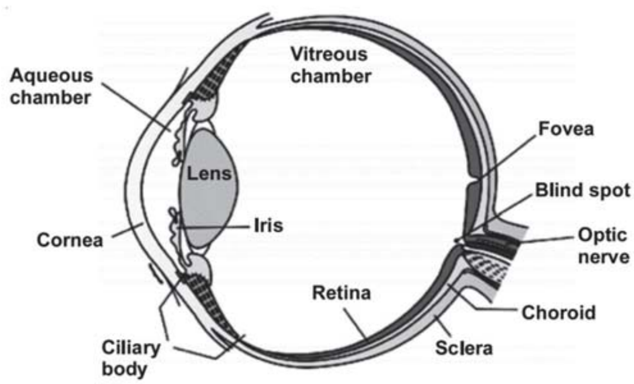

Fig. : Diagram showing parts of an eye

Choroid

The middle layer of the eyeball, called the choroid coat, is rich in melanin pigment and has a good supply of blood vessels. The choroid looks bluish but is hidden behind the tough sclera from the outside. Its main job is to prevent light rays from bouncing around inside the eye, much like the black paint inside a camera.

The choroid layer is thin towards the back two-thirds of the eyeball but thickens in the front to create the ciliary body. This body extends forward to form the iris, a pigmented and opaque structure responsible for the color of the eye, be it black, brown, green, or blue. The iris surrounds an opening called the pupil, and the size of the pupil is controlled by muscle fibers in the iris called iridial muscles. The pupil's diameter adjusts automatically; it widens in dim light to let in more light and narrows in bright light. This not only protects the eye from excessive light but also improves the clarity and depth of vision, much like the diaphragm in a camera adjusts to control the light and focus for a clear image.

Retina

The inner layer of the eyeball is called the retina. It's like the film in a camera because it has the actual light receptors, known as rods and cones. The retina is made up of three layers of cells: ganglion cells, bipolar cells, and photoreceptor cells. These photoreceptor cells include two types, rods and cones, which have light-sensitive proteins called photopigments.

The retina has two parts: the pigment epithelium (nonvisual part) and the neural portion (visual part). The pigment epithelium is a sheet of cells containing melanin between the choroid and the neural part of the retina. Some scientists consider it part of the choroid. Melanin in the choroid and pigment epithelium absorbs extra light, preventing it from bouncing around inside the eye. This ensures that the image formed by the cornea and lens stays sharp and clear. The pigmented layer extends over the choroid, ciliary body, and iris, while the nervous layer stops just before the ciliary body at a point called the ora serrata. Albinos lack melanin pigment throughout their bodies, including their eyes.

Rods

Each eye has about 100 million rods, and these rods are mainly responsible for seeing in low light conditions, which is why they're crucial for twilight (scotopic) vision. For light to be absorbed, there needs to be a light-absorbing substance called a pigment, and in rods, this pigment is called rhodopsin or visual purple. Rhodopsin is a purplish-red protein found in the membranes of rods.

Rhodopsin is made up of a protein called opsin, which is attached to a molecule called retinal, a form of vitamin A. While retinal itself is light orange, it turns into the deep purplish-red color of rhodopsin when connected to opsin. When light is absorbed by rhodopsin, retinal separates from the protein, causing the rod to become partially bleached and generating a nerve impulse. The more light that hits the rods, the more rhodopsin gets bleached. Fortunately, this process is reversible, as some rhodopsin can be made again from its breakdown products, retinal and opsin. There's also evidence that the eye continually produces fresh retinal by oxidizing vitamin A. The body's vitamin A reserves thus act as a large source for making retinal. It's not surprising then that a deficiency in vitamin A is often linked to night blindness, which is the inability to see in the dark.

Cones

Unlike rods, cones work best in bright light and are responsible for our ability to see colors. Therefore, daylight (photopic) vision and color vision are the tasks of cones. In the human eye, there are three types of cones, each with its own special pigments that respond to red, green, and blue lights. These pigments are called cone pigments, and retinal is the important part of each.

Cones come in three types: short wavelength-sensitive (blue) cones, medium wavelength-sensitive (green) cones, and long wavelength-sensitive (red) cones. Each type of cone is sensitive to a primary color, and theoretically, our brain can mix these color sensations to create over 17,000 different hues that our eyes can distinguish.

For color vision, the visual pigments are erythropsin (sensitive to red), chloropsin (sensitive to green), and cyanopsin (sensitive to blue). In moonlight, we can't see colors because only rods are active due to the low light level, and cones don't work.

Different color sensations are produced by various combinations of these cones and their pigments. When all three types of cones are stimulated equally, we perceive a sensation of white light.

Bipolar Cells

Beside the layer of cells that sense light, there is another layer called the intermediate layer of short-sensory bipolar cells.

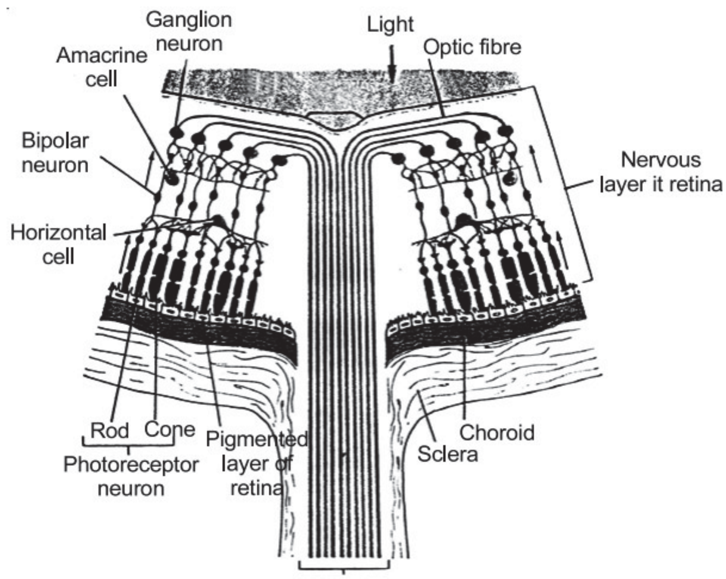

Fig: Schematic diagram to show the layer of the retina and main structures therein.

Bipolar cells are essentially bipolar neurons, as we mentioned earlier when talking about the retina of the eye. These neurons have a cell body with one axon and one dendrite.

Ganglion Cells

Following the layer of bipolar cells is the layer of retinal ganglion cells, with bipolar cells connecting with these ganglion cells. The axons of the retinal ganglion cells come together to form the optic nerve.

The optic nerves exit the eye, and at a spot toward the inner side of the back of the eyeball, retinal blood vessels enter. This particular point where the optic nerve leaves is known as the blind spot. The blind spot lacks photoreceptor cells, like rods and cones, so no image forms there, hence the name "blind spot."

At the back of the eye, beside the blind spot, there's a yellowish pigmented area called the macula lutea, also known as the yellow spot. Within the macula lutea is a central pit called the fovea. The fovea is a thinned-out part of the retina where only cones are densely packed. This makes the fovea the spot with the highest visual acuity and sharpest vision.

Aqueous and Vitreous Chamber

The inside of the eyeball is split into two main sections by the iris and lens. The front one, between the cornea and the lens, is called the aqueous chamber. So, the aqueous chamber is the area between the cornea and the lens, and it's filled with a thin watery fluid known as aqueous humor. This fluid eventually drains into the bloodstream.

The back chamber, between the lens and the retina, is called the vitreous chamber. Thus, the vitreous chamber is the space between the lens and the retina. It's filled with a clear, semi-solid, gel-like substance called vitreous humor. Unlike aqueous humor, vitreous humor doesn't drain out of the eye; its job is to provide support for the eyeball.

Note:

- In the fovea, the relationship between photoreceptor cells, bipolar cells, and ganglion cells is 1: 1: 1. However, outside the fovea, multiple photoreceptor cells in the outer part of the retina often connect with a single bipolar cell in the middle part of the retina, and several bipolar cells link up with a single ganglion cell in the inner part of the retina. This leads to the merging or convergence of information.

- The actual absorption of light doesn't happen with opsin but with 11-cis retinal, which transforms into 11-trans retinal isomer. This change in shape causes retinal and opsin to separate, a process known as bleaching.

Mechanism of Vision

The light coming from different objects is captured by our eyes and directed inwards. When entering the eyes, the light rays can be either parallel or spreading apart. Light from distant objects (> 6 meters) is parallel when it reaches the eye, while light from close objects (< 6 meters) is spreading apart when it gets to the eye. In both cases, the light rays need to be bent or refracted to focus on the retina. The curved cornea, the refracting eye lens, and the fluids in the eye all play a part in this process. The visible light is focused on the retina through the cornea and lens, creating impulses in the rods and cones on the retina.

As mentioned before, the photopigments in the rods consist of opsin (a protein) and retinal (a form of vitamin A). Similarly, cone pigments in human eyes consist of retinal and three different types of proteins (opsins) to which retinals are attached. When light hits the rods and cones, it causes retinal to detach from opsin, resulting in changes in the structure of opsin. This change in opsin structure leads to alterations in membrane permeability, creating potential differences in the photoreceptor cells, namely rods and cones. As these cells connect with bipolar cells in the next layer, a signal is produced, generating action potentials in the bipolar cells. Since bipolar cells connect with ganglion cells, action potentials are transmitted to the ganglion cells through the bipolar cells. These action potentials then travel through the axons of the retinal ganglion cells, which bundle together to form the optic nerve. Ultimately, the impulses generated in the ganglion cells are transmitted through the optic nerve to the visual cortex area of the brain.

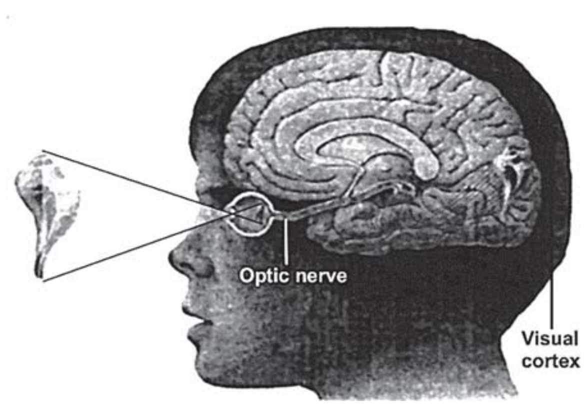

Fig.: Human eye and image formation

The visual cortex area is situated in the back part of the cerebrum's occipital lobes. Once the neural impulses reach this area, which is specialized for understanding visual signals, they are analyzed, and the image formed on the retina is recognized. This recognition relies on memories and experiences stored in the brain.

It's important to note in the diagram that the image created by the eye's lens on the retina appears upside down and reversed. However, our brain interprets these images in a way that makes objects appear the right way up to us.

Light rays in visible wavelength focussed on the retina

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Activation of photopigment of rods and cones

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Light induces dissociation of the retinal form opsin resulting in the changes in the structure of the opsin.

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Membrane permeability of rods and cones changes.

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Potential difference generated in the photoreceptor cell.

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It generates action potential in the ganglionic cells through the bipolar cells.

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Action potentials are transmitted by the optic nerve to the visual cortex of brain.

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Image formed on the retina is recognised based on earlier memory and experience.