Eye is mainly composed of 3 layers: External layer, which called The Sclera which is a hard connective tissue that gives the eye its round shape. Extension of the sclera into the front is the cornea, which is the translucent in order to allow the light to pass through it, and round in shape which gives the eye its front convex shape that help in focus the light while entering the eys.
Beneath the sclera, there is the choroid layer: which has the blood supply to the eye. Finally in the inside there is retina, which contains the photoreceptors and the neurons needed for the ability to absorb the light and transform it to a neuronal signal. A process which will be described later.

Anteriorly, as we said, we have the cornea. Behind the cornea is the iris, is a pigmented structure that regulate the amount of light entering the eyes by containing the only entrance for the light to the eye in the middle of it which called the pupil. Around the pupil found the connective tissue of the iris, or **stroma**, which contains melanocytes that reflect or absorb light to give the iris its characteristic color. Also embedded in the stroma are the circumferentially organized **sphincter muscle** of the iris and the radially arranged **dilator muscle, these muscles can increase or decrease the size of the pupil and hence controlling the amount of light entering the eye.**

The innervation of the **iris sphincter**, which closes the pupil, is parasympathetic. This pathway begins with preganglionic neurons whose cell bodies lie in the **Edinger-Westphal nucleus in the brain stem** and whose axons terminate in the **ciliary ganglion**. Axons of postganglionic ciliary ganglion neurons, in turn, end as neuromuscular synapses on the sphincter muscle and release acetylcholine. When activated, this pathway results in a reduction in pupil diameter, or **miosis**.

The innervation of the **iris dilator**, which opens the pupil, is sympathetic. The pathway begins with preganglionic neurons whose cell bodies lie in the **intermediolateral cell column** of the
spinal cord at upper thoracic levels and whose axons terminate in the **superior cervical ganglion**. Axons of postganglionic superior cervical ganglion neurons, in turn, end as neuromuscular synapses
on the dilator muscle and release norepinephrine. When activated, this pathway results in an increase in pupil diameter, or **mydriasis**.

The lens, whose function is to help the cornea. Most of the refraction of light occurs here, as well as the accommodation reflex, which we will learn about in upcoming lectures inshallah. The lens is usually elastic, and this helps keep it round. It is attached to a muscle (ciliary muscle, by means of suspensory ligaments) which, when contracted, will result in the thickening of the lens. This parasympathetic reflex is needed for accommodating vision to focus on nearby objects

let's continue talking about the eye,

The eye is divided by the lens into two compartments, one in front of the lens (which has an aqueous fluid), and on behind the lens that's filled with vitreous fluid. And like any other fluid in the body, There is continuous production and filtration of these fluids. If the production increased or the filtration decreased, the amount of fluid will increase, and since the eye is a closed compartment, the pressure inside the eye will also increase; which will affect the neurons in the retina and most importantly will close the blood vessels inside the eye and decrease the blood supply of the retina which will lead to loss of vision sensation. this condition is called glaucoma.

Now,
let's talk about the retina,

The retina is formed by several layer, the first layer the light hit is called the ganglionic cell layer. The ganglionic cells are big and multipolar neurons, but they don't have photoreceptor abilities. Next there are bipolar neurons, which also do not have photoreceptor ability. Then there is the photoreceptor layer that have both the rods and cons which are able to detect light and release the neurotransmitter glutamate to start the neuronal signal that curried by the bipolar neurons to the ganglionic cells, which in part will form the action potential that carried by their axons to the central nervous system. In fact, the optic nerve is formed by the axons of the ganglionic cells.

In addition to these three vertically arranged layers, the retina has two additional types of cells that spread their axons in horizontal manner and help perform processing of light information at the level of the retina. One is called horizontal cells that spread their axons horizontally and control the synapses between the photoreceptors and the bipolar cells, which help in increasing the resolution of the image by performing lateral inhibition. It also help performing color processing.

The second type, is called amacrine cells which found at the synapses between the bipolar cells and the ganglionic cells, in which they help to detect and process the changes of light intensity and movement. In fact in some types of ganglionic cells, they olny take the information from these types of cells and not directly from the bipolar cells, especially in the peripheral part of the retina. We will talk about this when we describe the types of ganglionic cells later on.

Finally, behind the photoreceptor layer is pigmented cell layer. It is composed of epithelial cells which are highly stained with melanin pigment. Its function is to absorb all the extra light to prevent any light from reflecting back on the retina and the photoreceptors and distort the image. In fact, the need for this layer to be directly behind the photoreceptors is the main reason why the retina arranged in this arrangement and the photoreceptor in found deep under other layers.

The inner wall of the eye cavity is covered with retina, and that's why it has the ability to detect light and form vision, never the less, there are some variations in different parts. for a start there is the optic disc, which is the part of the eye that has the entry and exit of blood vessels and axons. Hence it's not covered by retina and one cans see light that fall on that spot, hence its other name which often called blind spot.

Additionally, slightly lateral to the optic disc there is a specialized part of the retina call fovea centralis or macula lutea. This part is the one responsible for precise high acuity vision. It can be detected easily because it appears as a slight depression in the retina. For start it has higher density of receptors compared to other parts of the retina and the receptors are smaller and closer to each other's to give good sensory resolution. Also, the other layers of the retina, like the ganglionic and bipolar cells are shifted laterally to make the photoreceptors directly exposed to light and decrease the amount of light masked by these cells.

Now,
let's talk about Photoreceptors

There are 2 types of photoreceptors; rods and cones. They have small differences in shape, for example cones are thicker and shorter. But they also have many main differences in term of function. for a start, as you know from the biochemistry lecture, there is only one type of rods and its sensitive for almost all visible wave length of the light, and three types of cones which each is sensitive to specific wavelengths and form a specific activity curve, and the activation curves of the three cones overlaps at some wave

lengths. This means that rods detect only one modality of vision and only allow us to see in gray scale. While cones detect 3 modalities and due to the overlap of their activation curves with the help of processing taking place in the retina, they allow our brain to distinguish colors and hence they are the main player for our color vision.

The second difference between rods and cons is their localization in the retina.

Fovea centralis has almost only cones, and in fact cones in this part of retina are very cylinder and very thin to help us get the high resolution vision. And as we move peripherally the percentage of cones decreases and the rods increases.

The third difference is adaptation. Photoreceptors have unique adaptation power in that they have two direction adaptation. Like many other sensory receptors, if they exposed to a continuous big stimulus they will adapt and decrease their receptor potential produced by that stimulus. While in addition, if they are not exposed to a stimulus, or even exposed to a small stimulus, they will increase their sensitivity and increase the receptor potential produced by them. This is due to continues recycling of the photoreceptor molecules you learned in the biochemistry lecture. But the concentration of these molecules is lower in the cones and they have faster cycle compared to rods. Hence cones are less sensitive to light and have narrow adaptation power. That mean they can't detect light if it's too dim, and they get bleached out quickly and can't see if light is too bright. On the other hands, although it takes longer time, rods have wider adaptation range and are more sensitive than cons. Hence, at lower light intensity they are still able to detect light and form vision. And that's why in dark places you can still see things but without colors, because only rods are functioning then.

These differences are accounted for different manifestations of some disorders that affect the retina.

For start, since some of the photoreceptor molecules are formed from vitamin A, vitamin A deficiency will affect the levels of these molecules. And since rods have higher concentration, they will be highly affected and vitamin A deficiency will lead to decrease their sensitivity and make them not able to detect and function at lower levels of light intensity. And then the patient will be not able to see at low light intensity, which called night blindness

There is also a group of genetic and environmental factors that will lead to the degeneration of cones. Since the macula of the eye is only composed from cones, these disorders will lead to macular degeneration and lead to loss of central high acuity vision.

Macular degeneration typically occurs in older people, but in other form of inherited **types it can affect kids at early ages, and this form usually called juvenile macular degeneration** or "Stargardt disease". These patients will have a gradual worsening of vision that may affect one or both eyes. While it does not result in complete

blindness, loss of central vision can affect person life as it can make it hard to read, recognize faces, drive, or perform many of everyday activities

On the other hand, other genetic factors lead and target rods, which lead to rods degeneration and being replaced by dark spots on the retina that why its called Retinitis pigmentosa. Since rods are found in the periphery of the retina, this leads to difficulty in seeing at night, but also to loss of side (peripheral) vision. That why usually it's called tunnel vision.

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As we talked earlier, a lot of processing occurs in the retina, and the retina sends processed information to the central nervous system, via ganglion cells.

But retina has four subtypes of ganglionic cells divided based on their anatomy, distribution in the retina, and the type of information they carry.

The first type is called melanopsin-containing ganglion cells. These cells are usually not connected to bipolar cells and photoreceptors. Instead, melanopsin-containing ganglion are able to detect light on their own. That is due to special light detecting molecules they have which called melanopsin, which is melanin-based in structure (in contrast to the structures in photoreceptors, which are vitamin-A-based).

The second type is called X type cells

These cells are usually small in size, and have narrow distributed dendrites, and each cell is connected to very little number of bipolar cells (no much convergence in the information they get). This means that each of these cells is responsible for a small area of the retina, which makes them have high resolution sensory information. These cells are numerous in the central areas of the retina, and they are responsible for high-resolution detailed vision. In addition, since these usually receive information started in the cones; these cells are also responsible for colored vision.

The third type is called Y cells

In contrast to X cells, Y ganglion cells are large in size with large axons and widely distributed dendrites. These cells are more prominent on the periphery part of the retina, and they are connected to rods. Usually, each y cell is connected to many bipolar cells (a lot of convergence) which lead to low sensory resolution and less visual acuity. But due wide

spread dendrites and large axons, they help in detecting moving objects and can carry that information quickly to the central nervous system.

The fourth type is called W cells.

This type of ganglionic cells has various anatomy but most of them are similar to Y cells in anatomy, that's large cells with widely distributed dendrites. And usually found in the peripheral part of the retina. But they are usually connected to amacrine cells not to bipolar cells, which make them very sensitive and able to not only detect movement, but some of them will only fire action potential if an object moved in only one certain direction but not the other .

Now, once the information reaches the various types of ganglionic cells, it will be carried to the central nervous system, were it will have many destination and targets of the central nervous system.

Like all sensations, the main target will be the cortex to get conscious part of the visual sensation. Both the X and Y types of ganglionic cells travel in this pathway. And like other sensations, this pathway will stop first in the thalamus in a nucleus called lateral geniculate nucleus of the thalamus, later it will projects to the area of the cortex responsible of receiving visual information which called primary visual cortex. We will describe this pathway in details in the lecture room.

In addition to the cortex, the visual information will be sent to three subcortical destinations, and will be associated with involuntarily and unconscious processes related to vision.

The first destination will be the hypothalamus,

This is carried by a pathway called retino-**hypothalamic pathway**. This pathway is formed by the melanopsin-containing ganglion cells, and in this target, it help regulate the body circadian and seasonal rhythms, by sending the changes of light information to the hypothalamus, and help it forming the body internal clock. All circadian rhythms or seasonal changes of body functions such as changes and cycles of hormones secretions you have learned earlier in the endocrine course are due to this center and pathway. Anther more obvious process that is under the regulation of this pathway is sleep as we will see when we will talk about sleep in later lecture.

Since this pathway relay on the melanopsin-containing ganglion cells, it will not be affected by disorders that target photoreceptors such as Macular degeneration or retinitis pigmentosa. While, On the other hand, lesions that cause general cell damage to the retina

such as vascular lesions in the retina or glaucoma, will affect this pathway and have an impact on circadian rhythms of the body.

The second destination is an area in the midbrain called pretectum.

This pathway is the one responsible about what called pupillary light reflex. In that the pupil of the eyes constrict when the eye is exposed to light, and the amount of constriction increase as the intensity of light increase. This pathway form the afferent fibers of the papillary light reflex; it carries the stimulation of the retina and the information regard the intensity of light that falls on the retina to area in brain stem, specifically in the midbrain part of the brain stem called olivary pretectal nucleus.

The neurons in the olivary pretectal nucleus travel and target the Edinger-Westphal nucleus at both sides. This is a parasympathetic nucleus that as described earlier, sends fibers through the oculomotor nerves of both sides to synapse in the two ciliary ganglia, which have Postsynaptic fibers that innervate the constrictor muscles of the eyes. Hence, the more intense light fall on the retina, this pathway have higher firing rates, which lead to more constricted pupil.

Here is a section show the Edinger-Westphal nucleus and the level of the neucleus in the mid-brain

The third destination is another area that also part of the midbrain called Superior Colliculus

The superior colliculus is a multilayer nucleus that has several functions that can be summarized and simplified as 1) helps and control eyes movements and mediates some visual reflexes, 2) Mediate motor reflexes that controlling orientation of the head, eyes, and body to visual or auditory stimuli, 3) help in give us orientation and direct our behaviors toward specific points in space or specific object

Since this pathway is all about movements and direction, its formed mainly by the axons of the W type of ganglionic cells and some of the Y types also.

Like many subcortical parts of the brain that must send the information to the cortex. The superior colliculus will projects eventually to the **cortex,** but it will not project to the primary visual cortex, instead, the information from superior colliculus will project to cortical areas that are responsible for the perception of movement and directions found such as the insular cortex or posterior parietal cortices like area 5 and 7. Also, in their pathway to the cortex they still will synapses in the thalamus like any fibers go to the cortex, the nucleus that these fiber synapses at is called the pulvinar nucleus, which is the same nucleus also of the vestibular pathway).

This pathway is responsible phenomena called "blind-sight".

Blindsight is the ability of people who are blind due to damage of the primary visual respond and detect visual stimuli even though they do not consciously see. These patients can still guide hand movements towards an object even though they cannot see what they are reaching for. And has the ability to kind of "see" visual features, such as edges and moving objects, but cannot gain a holistic visual percept.

If you like to see more about this phenomenon there are plenty of articles and videos you can find online, but a good suggestion is a video on the link in the description part of this video

https://www.youtube.com/watch?v=GwGmWqX0MnM

and

https://www.youtube.com/watch?v=4Xan6UqNCQ8