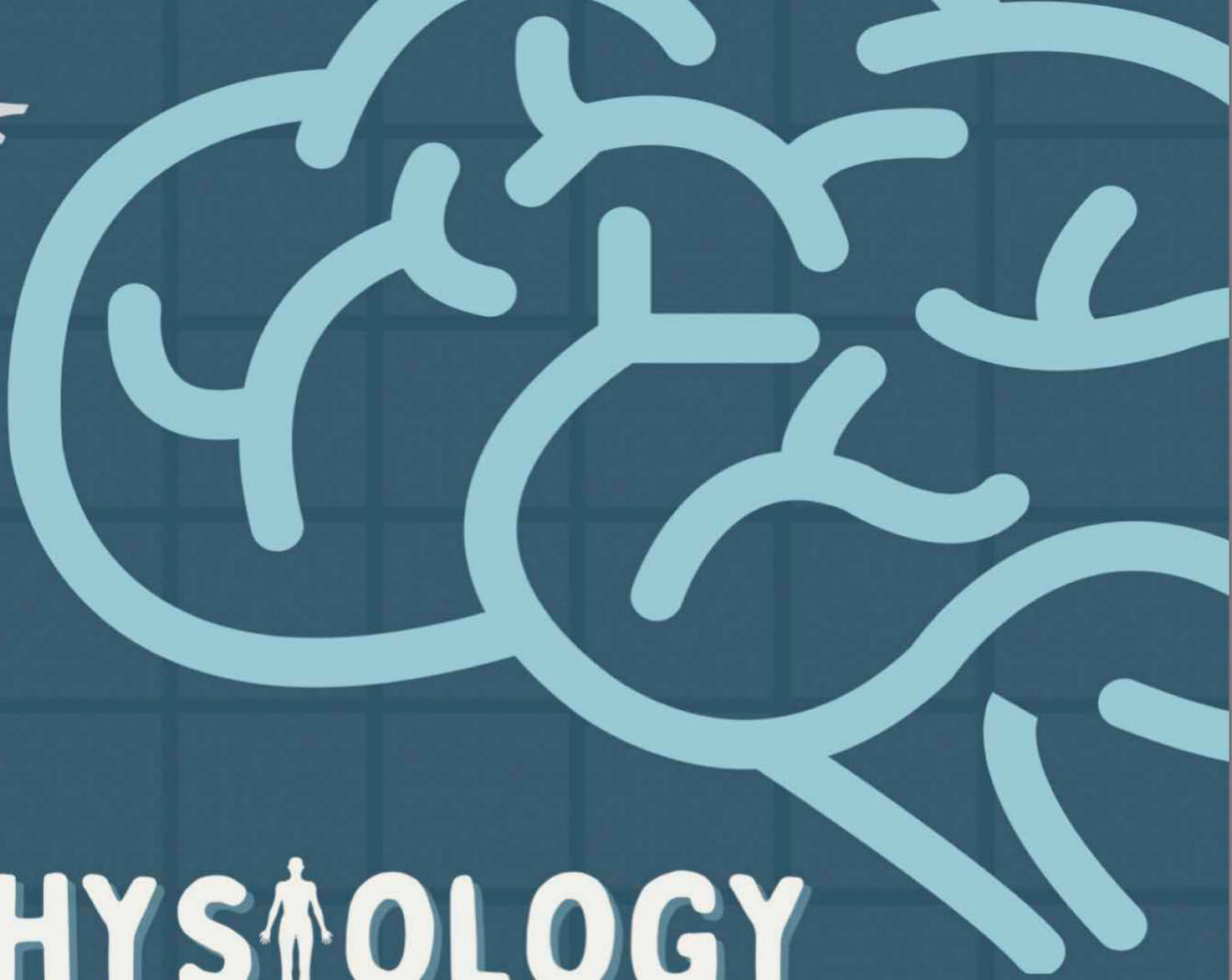


PHYSIOLOGY

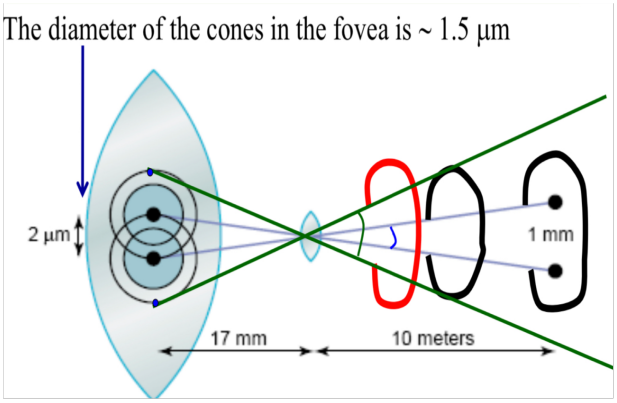
SHEET NO. 7

WRITER : 018 sheets

CORRECTOR : Sawsan Alqeam

DOCTOR : Faisal Mohammad

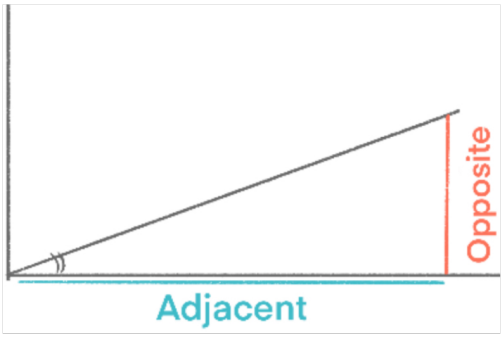
Visual Acuity Test:



- It's used to test the ability of the eye to discriminate details or for simplicity 'to distinguish 'two points'', and it's expressed by degrees of angles (you need to know that each degree is divided into 60 minutes, and each minute is further divided into 60 seconds, which means that the degree = 3600 seconds.)
- **As we know: To sense two points, they must hit two different receptors**
- **These two light points form an angle when they reach the lens, normally this angle is—1 min or less, abnormal cases have an angle of more than 1 min**

Elaboration:

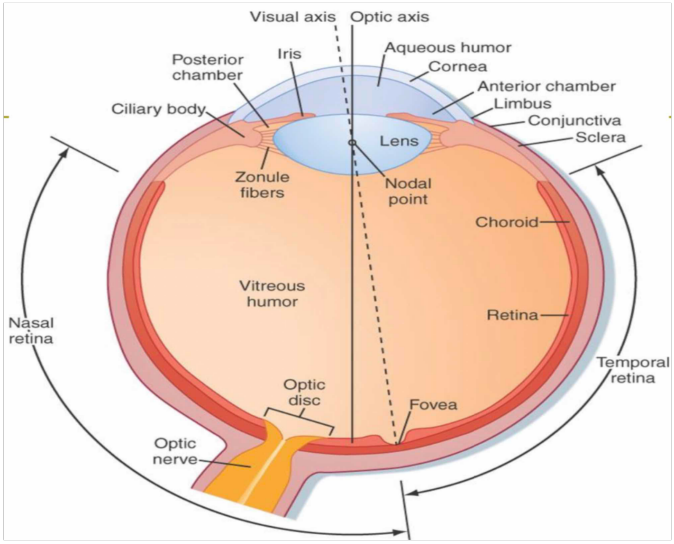
- A person can normally distinguish 2 separate points if they lie **at least 2* micrometers apart on the retina**, the normal visual acuity of the human eye for discriminating between two point sources of light is about 25 seconds of arc (25/3600 of a degree). * Why 2 micrometers? To ensure that it is larger than the foveal cone receptor diameter which is 1.5 micrometers.
- That is, when light rays from two separate points strike the eye with an angle of at least 25 seconds between them, they can usually be recognized as two points instead of one.
- Meaning that a person with **normal visual acuity** looking at two bright points of light **10 meters away** can barely distinguish the spots as separate entities when **they are 1.5 to 2 millimeters apart.**



- **Now, from where these numbers came from?**
  - the tangent equation of an angle, it equals the opposite side over the adjacent side. Now if we know that the opposite is 1.2-2 mm (distance between the 2 points) and the adjacent is 10000 mm (10 m) (distance between the eye and 2 points) we can tell that the angle is tan inverse of this ratio which is 25 seconds here. From these distances we can find the angle and know whether it's normal or not

- Clinically, what we do is use a chart (Snellen's)
  - This chart has letters with details, we set a person 6 meters away from it, then we go down through it until the person can't see clearly anymore, (most people can see all of the chart levels)
  - If they stopped seeing clearly at let's say the level of 6/12 this means, this person can only at 6 meters see what normal eyes see at 12 meters, meaning, in order to this person to see an object of a certain size that's 12 meters away, it has to be brought 6 meters closer and we say his sight is 6/12.
- Interpretations:
  - 6/6 → ability to see letters of a given size at 6 meters, when they can't be seen on a distance more than 6 meters in a normal eye anyway.
  - 6/12 → what a normal person can see at 12 meters, this person must be at 6 meters to see.
  - 6/60 → what a normal person can see at 60 meters, this person must be at 6 meters to see.
- Defects here are different from refraction errors, but can be dealt with by the same fixing methods, because, what a person with a lowered acuity need, is for the points to be further away from each other, and what does separation better than diverging lenses?
- **Fixing: Biconcave diverging lens (negative lens)**

Let's revise the layers of the eye:



1. Outer layer: sclera that continues as cornea in front.
2. Middle layer: choroid [vascular layer] that continues as ciliary body and iris (the colored part of the eye) in front.
3. Inner layer: retina [neural layer] what does it contain?
   - Macula lutea: a small area at the center of the retina about 1 sq mm. the center of this area is **the central fovea or fovea centralis** which, as we will study later, contains cones only and that's what

makes it responsible for sharp and discriminative vision. [for a picture to be seen clear and colorful it must come into fovea]

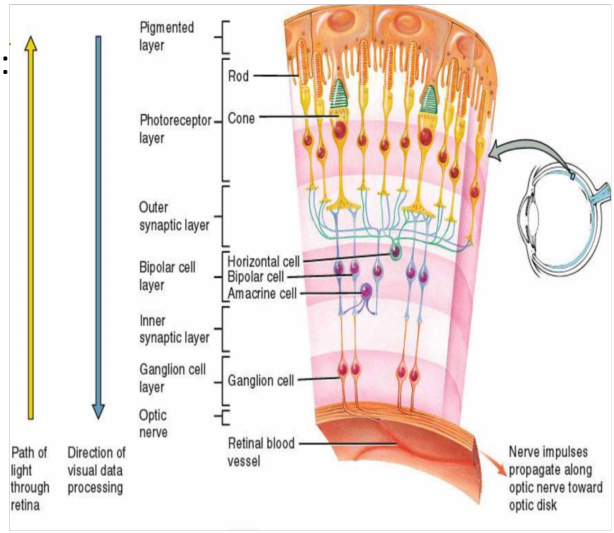
- Optic disc: it is the area where optic nerve exits, and central retinal vessels enter or leave. This area lacks visual receptor; therefore, it is called **blind spot.**
- Ophthalmologists examine the optic disc area looking at the central retinal artery because it is the most superficial artery in the body to diagnose atherosclerosis or bleeding especially in hypertensive patients

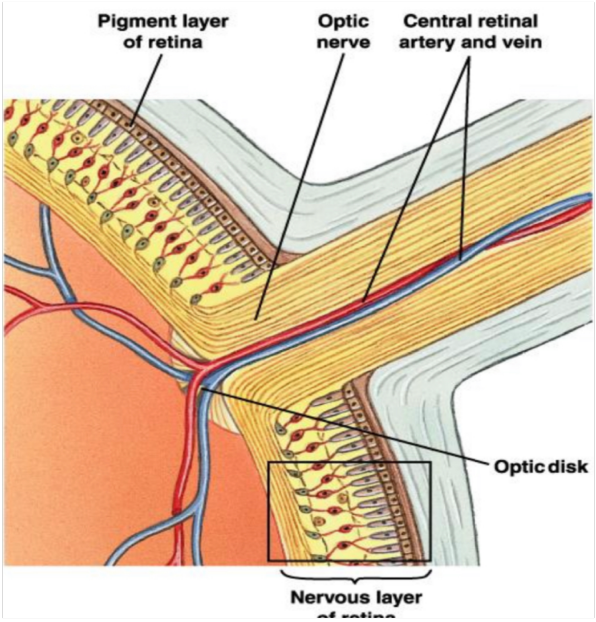
Structure of the retina:

Please notice that the layers are arranged from outside to inside that is from the outer region of the retina to the vitreous body inside the posterior cavity

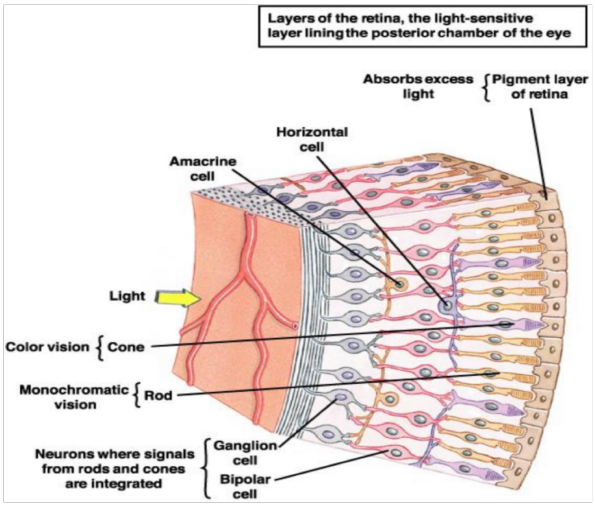
a. Pigmented layer
   - Pigment layer of the retina is very important.
   - Layer of cells that produce the black pigment (melanin)
   - absorbs extra light = prevents light reflection in the globe of the eye
   - Without the pigment there would be diffuse scattering of light rather than the normal contrast between dark and light = if this layer is absent, light will reflect, and the picture will be hazy because this extra light will stimulate many receptors.
   - Vitamin A derivatives are stored in alcoholic form [cis- / trans- retinol] inside this layer and in the rods and cones also.
   - This what happens in albinos (genetic absence/ deficiency in melanocyte activity = melanocytes are normal in structure and number, but they don't produce melanin). They have poor visual acuity because of scattering of light and when they try to read, they get the book close to them to control the amount of light coming to their eye.

b. Neural retina:
   - Photoreceptor layer (the rods and cones layer): contains the outer segment of these cells (photoreceptors). Notice that the receptors are in a very deep layer except in the fovea centralis receptors are superficial
   - Outer nuclear layer: contains cell bodies of photoreceptors
   - Outer plexiform layer (outer synaptic layer): contains synapses between axons of the rods and cones and the dendrites of the bipolar cells.





- Inner nuclear layer (bipolar cell layer): contains nuclei of the bipolar cells, amacrine cells and horizontal cells.
  **horizontal cells: are inhibitory interneurons (lateral inhibition)
- Inner plexiform layer (inner synaptic layer): contains synapses between axons of bipolar cells and dendrites of ganglion cells
- The ganglionic layer: contains ganglion cells with long axons
- Nerve fiber layer (optic nerve): ganglionic axons that converge at the optic disc and form the optic nerve [these axons converge and go back to exit out from the retina as optic nerve]
- NOTES:
  - path of light through retina is from layer 7 back to the pigmented layer, while the direction of visual data processing is the opposite.
  - In the central fovea the neuronal cells and blood vessels are displaced to each side so that the light can strike the cones directly and that's the cause of the depression or groove seen in this area and the cause of the very sharp vision [because light doesn't pass through all the layers so it doesn't refract, and the picture will not be hazy]



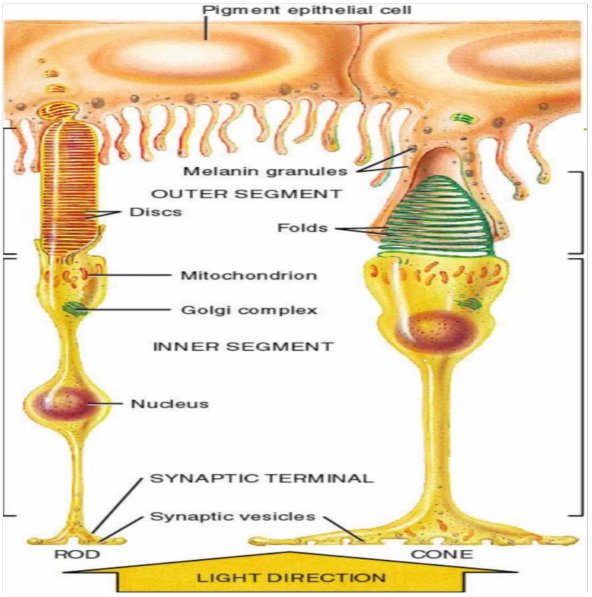
Comparison between rods and cones:

Notes:

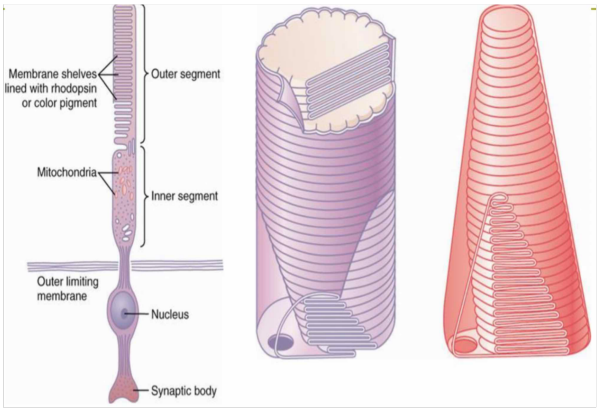
- The number of ganglionic cells is 1.6 million for each retina
- Visual acuity (two-point discrimination) is greatest in cones. These cones have a special conical structure with a diameter of 1µm. for the image to go into fovea centralis (cones only) and hit two cones, the distance between the two points must be 2µm. and as we know the distance between the retina and the center of the lens is 17mm so the angle will be 1 minute

	Rods + very dim light	Cones + bright light
Vision	Night vision (no color discrimination)	Day Color vision Sharp (aid in detecting details)
Number	100 million for each retina	3 million for each retina
Sites	Periphery (laterally)	Center (fovea centralis contains cones only)
Types/ pigments	One type (produce white or black color only) – achromatic	Three types each with a different pigment that is sensitive to a different part of the visible spectrum (red, blue, green) – trichromatic Any other color is a mixture of stimulation of the three types
Convergence	Every 60 rods converge into one ganglion cell (leads to loss of sharpness)	Every 2 cones converge into one ganglion cell (at the central fovea there are no rods and the ratio of cones to ganglion cells is 1:1 / sharp)
Light sensitivity	High sensitivity (small amount of light can stimulate it producing receptor potential that is going to summate because of the high number of convergences) More sensitive to scattered light	Lower sensitivity More sensitive to direct axial rays
Amplification	High – can detect single point	Low – less convergence (1:1 is more)
Photopigment	More	Less
Visual acuity	Low (highly convergent retinal pathways)	High (less convergent retinal pathways)
Response and integration time	Slow response, long integration time	Fast response, short integration time
Saturate in	In day light	With intense light

Structures of rods and cones

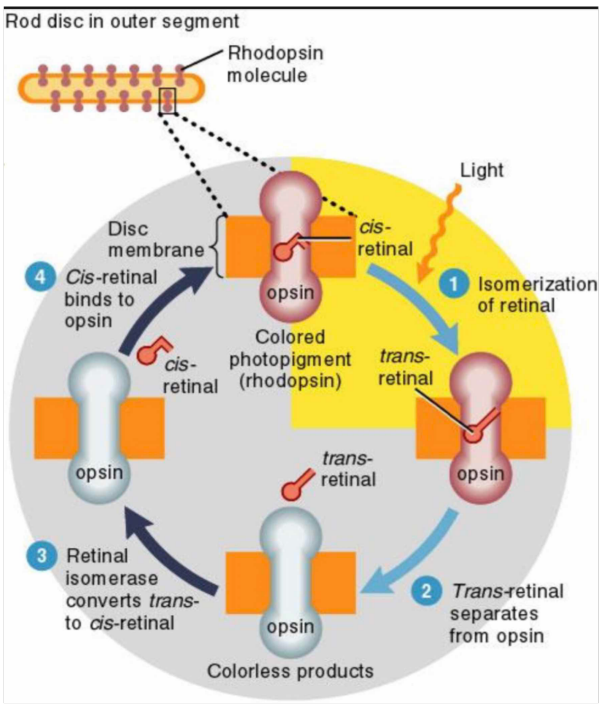


1. outer segment
   - Membranes of cells stacked together. 40% of the membrane constitutes of the opsin protein and 11-cis retinal (vitamin A derivative, aldehyde form) forming rhodopsin which is the color pigment.
   - There are 1 type of opsin in rods and 3 types of opsin in cones.
   - Vitamin A derivatives are formed in the pigmented layer and in the rods and cones.
   - this segment is embedded in the pigmented layer.
2. Inner segment: contains mitochondria (for energy).
3. Nucleus.
4. Synaptic body: like axon terminal containing the neurotransmitter glutamate.



Photochemistry of vision:

a. As we know, in the rods or cons discs present in the outer segments there are rhodopsin molecules [visual purple in rods called scotopsin scoto =dark, opsin = responsible for the sensitivity in dark) and photopsin in cones]. Rhodopsin is composed of a protein called opsin and a pigment retinal. Retinal has two forms:
   1. Cis-retinal: which is bound to opsin forming the colored photopigment rhodopsin. → opsin is inactivated
   2. Trans-retinal: which is separated from opsin. → opsin is activated



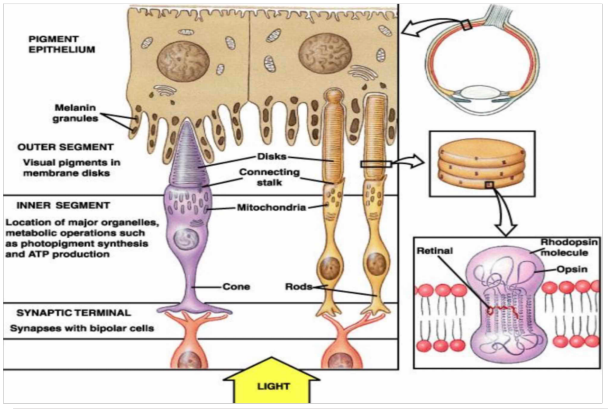
Notes:

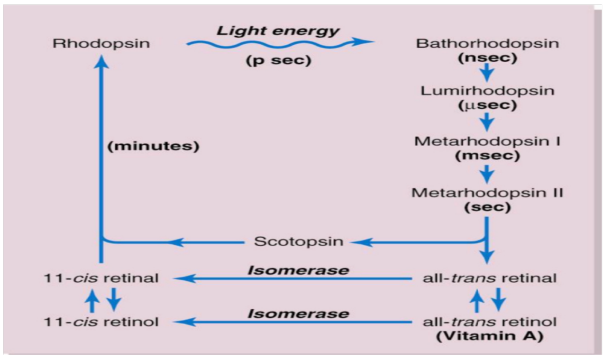
- Light converts retinal from the cis form to the **trans** form [isomerization of retinal] leading to decomposition of rhodopsin and activation of opsin.

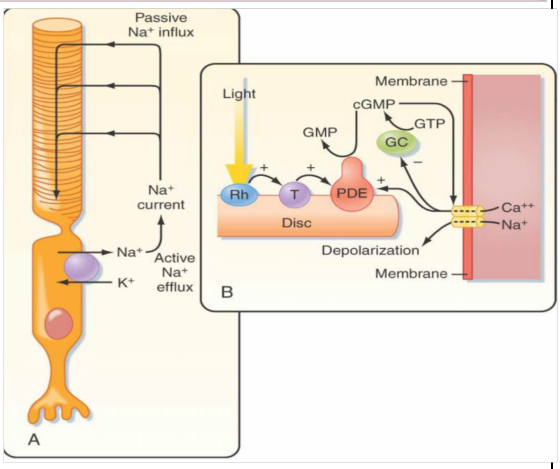
- Retinal isomerase converts trans- to cis retinal leading to deactivation of opsin (dark)
- Trans retinal has the same chemical structure but is a straight molecule rather than an angulated molecule.
- Trans configuration doesn't fit with the binding site on the scotopsin and the retinal begins to split away (decomposition).
- In the process of splitting away a number of intermediary compounds are formed.

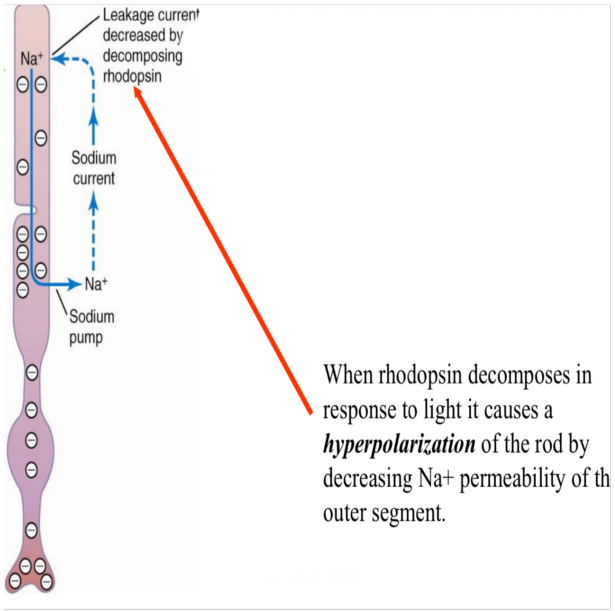
b. Light activates opsin -> opsin activates membrane protein called transducin (G-protein) -> transducin activates cGMP phosphodiesterase -> cGMP phosphodiesterase will break down cGMP into GMP.

- In the outer segment of rods and cones there are cGMP gated Na-channels (which open whenever there is cGMP). Those channels are ligand-gated channels and not voltage-gated channels, so they don't cause action potential.
- In the previous sequence cGMP is broken down by cGMP phosphodiesterase, meaning that cGMP is becoming less, and those cGMP dependent Na-channels are closing.
- Thus, Na isn't getting into the outer segment of the rods and cones, no more Na influx, causing hyperpolarization of these receptors.
- Hyperpolarization stops the secretion of neurotransmitters.
- Photoreceptor potential (when exposed to the stimulus/light) is hyperpolarizing potential
- Rhodopsin kinase deactivates the activated rhodopsin (which began the cascade) and cGMP is regenerated re-opening the Na+ channels.



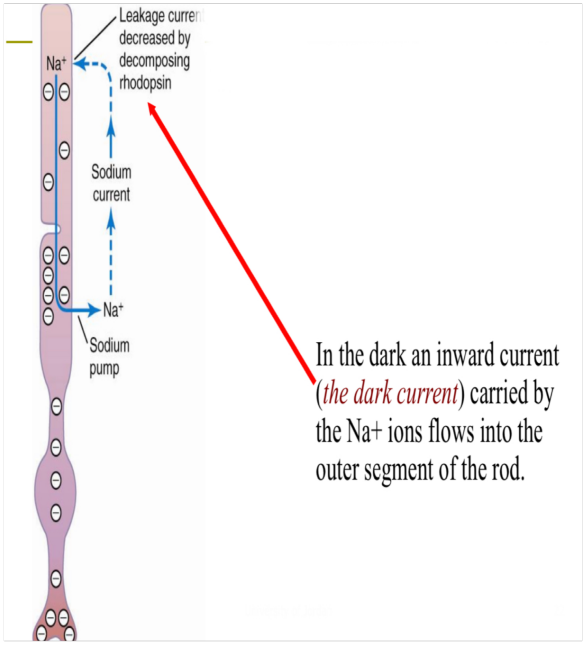






c. The opposite occurs during night (in the Dark), retinal isn't converted from cis to trans form, thus, it stays attached to opsin deactivating it. This leads to the deactivation of cGMP phosphodiesterase, cGMP won't be broken down, we have a lot of cGMP opening the cGMP dependent Na-channels, Na will influx into the outer segment of the rods and cones causing Depolarization.

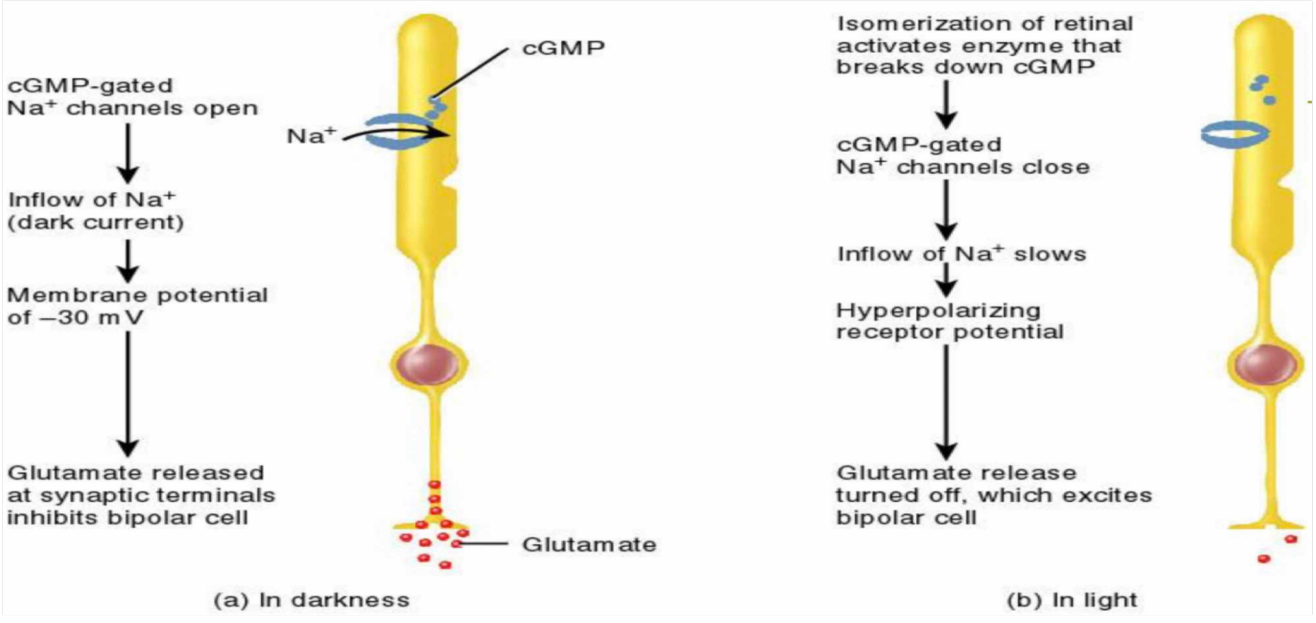
- To summarize: Dark leads to Depolarization of photoreceptors.
- Depolarization leads to secretion of neurotransmitters.



➔ The question here is that light which is the stimulus of photoreceptors leads to hyperpolarization decreasing the neurotransmitters release, while dark leads to depolarization increasing the neurotransmitters release and that's opposing what we always thought about the stimulus and the depolarization and hyperpolarization states, so how can we explain that?

➔ The answer is that the neurotransmitter here is glutamate which is considered inhibitory in the visual receptors. Meaning that when light leads to hyperpolarization and decrease of glutamate, in fact light excites the rest of cells (bipolar cells and ganglionic cells). On the other hand, dark leads to depolarization and increase of glutamate release, in fact dark inhibits the rest of cells (bipolar cells and ganglionic cells).

➔ Extra notes: 1- there is Na+ pump in the inner segment that keeps pumping Na+ out of the cell. 2- The greater the amount of light the greater the decomposition of the pigment and the greater the electronegativity (hyperpolarization).



d. Receptor cells and bipolar cells respond by local potentials (receptor potential) either EPSP or IPSP not action potential. The only type of cells that respond by action potential in the eye is the ganglionic cells. (And some amacrine cells)
for revision: The rod receptor potential: Normally about -40 mV. Normally the outer segment of the rod is very permeable to Na+ ions. In the dark an inward current (the dark current) carried by Na+ ions flow into the outer segment of the rod. The current flows out of the cell, through the efflux of K+ ions in the inner segment of the rod.

Duration and sensitivity of the receptor potential:

- A single pulse of light causes activation of the rod receptor potential for more than on second. [slow response, long integration time]
- In the cones these changes occur 4 times faster. [fast response, short integration time]
- Synaptic after potential: when you look at light and close your eyes, you will see spotlights. That's because receptor potential continues more than the time for action potential/ receptor potential continues to activate ganglionic cells for more time than the time for a single pulse light.
- Receptor potential is proportional to the logarithm of the light intensity, and this is very important for discrimination of the light intensity. When we are using the logarithmic scale, we will have bigger numbers and therefore bigger differences between the degrees of light intensity (1, 10, 100, 1000, …) increasing the sensitivity of the retina.

Role of vitamin A:

- It is the precursor of all-trans-retinal, the pigment portion of rhodopsin.
- it is stored in the pigmented layer, rods, and cones.
- Vitamin A is lipid soluble. It is stored in fat and liver. Therefore, vitamin A deficiency (lack of vitamin A) occurs if there is no intake of vitamin A for more than 6 months. (Nutritional disease)
- Lack of vitamin A causes a decrease in retinal. This result in a decreased production of rhodopsin and a lower sensitivity of the retina to light or what's called night blindness. Explanation: rods will be affected more because of their huge number, and they are responsible of vision during night so there will be an abnormality in seeing things during night. But during the day, there is too much intense light that can easily stimulate cones and rods even with the lack of vitamin A.

sensitivity is directly proportional to amount of pigment