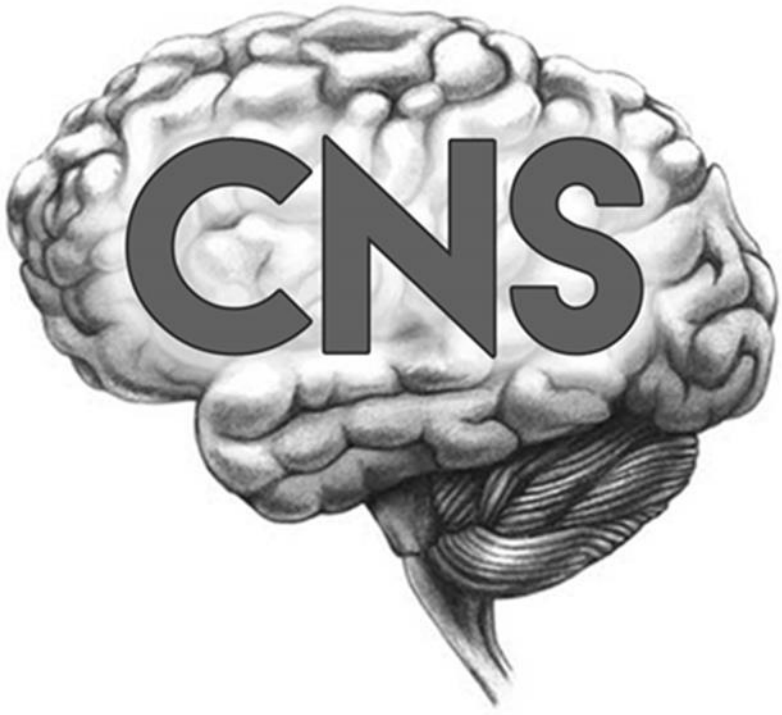

PHYSIOLOGY

● Sheet ○ Slide ○ Handout

Number

15

Subject

The Eye: II. Receptor and Neural Function of the Retina

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♣ Read the following :-

- This sheet was written according to the records of section 3.
- This sheet is composed of two parts;

1) Summary for the last lecture!

2) Photoreceptors; Rods& Cones!

- This sheet is one of the easiest sheets you will encounter because simply, it is repeated –even found in biochem;lecture#1- !
- Vision topic is fun& easy as long you understand it, so make sure of that!

♣ Summary of the last lecture: { You can skip these first three pages }

* Vision is one of the special senses .
* Diopter: a unit of the measurement for the power of the lens.
* The refractive index: is the ratio of the speed of light in air to the speed of light in the substance.
* Accommodation allows us to see near and far objects by adjusting the convexity of our lens.
* Near point: the point nearest to the eye at which an object is accurately focused on the retina as the maximum degree of accommodation is employed/used.
* The Focal length: the distance between the center of a lens and its focal point.
* Structure of the eye: (make sure you can identify each part)
- Sclera
- Cornea (avascular+ the **only** structure that can be transplanted with no fear of immune rejection)
- Choroid (the vascular layer)
- The ciliary muscles& the suspensory ligaments (remember that the ciliary muscles contracts **anteriorly** relaxing the suspensory ligament

and making the lens fatter 'more convex')

- The lens
- Retina
- Canal of Schlemm

* **Cataract** (the opaque lens due to the denaturation of its protein) vs **Glaucoma** (the increased intraocular pressure in the anterior cavity of the eye).

* The eyeball is divided into :

- Anterior cavity (between the lens and the cornea) filled with the fluid of Aqueous humor.

Divided further more to an anterior and a posterior chamber!

- Posterior cavity that is filled with gel-like fluid known as Vitreous humor.

* Convex lens are converging lens while Concave lens are diverging lens!

* What are the requirements of image formation on the Retina?

1. Light refraction. The light passes through 4 medias that are replaced with one lens that has the power of 60 diopter; called **Reduced eye**! 'for teaching purposes only'
2. Accommodation.

Presbyopia: is the loss of the ability to accommodate! (like in aging)

3. Constriction (meiosis) vs **D**ilation (My**d**riasis) of the pupil.
4. Convergence& Divergence of the eyes for binocular vision.

Diplopia: is the case of double-vision.

* Errors of Refraction:

1- Far sightedness (hyperopia); in which ..

- Image is formed **behind** the retina

- The distance between the lens and the retina might be **shorter** than normal genetically!

- Accommodation occurs upon looking at far objects; making them have **longer** than normal near point!

- Fixed by **convex** lenses

2_ Near sightedness (myopia); in which ..

- Image formed **in-front** of the retina

- The distance between the lens and the retina might be **longer** than normal genetically!

- Maximum accommodation is at a distance shorter than the near point! (**Shorter** than normal near point)

- Fixed by **concave** lenses

* Another common error of vision is the Astigmatism; which occurs when one of the planes of the cylindrical lenses of the cornea is different; which fails all the focal lines to meet at one point. It is fixed by **cylindrical** lenses!

• **END OF THE SUMMARY !**

♣ We start the new lecture for this sheet by finishing the last part of the previous sheet which is concerned with Visual test acuity ..

* Remember we said that Errors of refraction (such as Far& Near sightedness ..) are different from visual acuity abnormalities!

* Visual acuity abnormality is what is described when someone tells you that his/her vision is 6/9. Keep in mind that these number differs according to the unit used (meter, feet, ..)

* Recall that the distance between the lens and the Retina is 17mm.

* As mentioned later during this sheet; Fovea Centralis is the best area in the retina for sharp image as it only contains cones! (Cones is one type of the photoreceptors found in the Retina, the other is the Rods)

* The diameter of the cones in the fovea is ~ 1.5 μm; consider it 2 μm

 # The following points needs a clear mind; try to stay focus while you go through them ..

* Now, In order to see two points as separate ones; these two points must hit 2 different receptors!

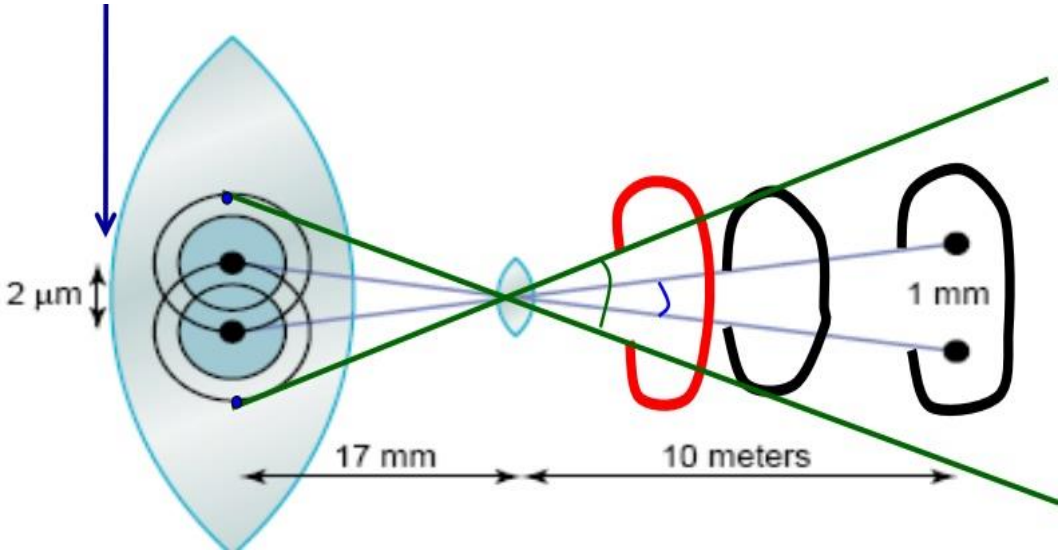
* For a healthy individual to be able to see these two points as separate; they must form an angle of **1 minute** on the lens! WAIT .. What is 1 minute ?

- Recall that a circle is 360 degrees; each degree corresponds to 60 minutes; each 1 minute corresponds to 60 seconds .. !

- For this 1 minute angle to be perfect at telling two points apart; the density of the cones should be sufficient in the area where these two points had hit the retina. Any degeneration in the cones would require more than 1 minute angle to discriminate these two points as separate!

- We can say that the 1 minute angle; is the minimal angle needed to be formed by two separate points on the lens in order to hit two different receptors thus being discriminated as two by the brain!

-Go ahead and read the last two points again and please make sure you get the idea.



* Q1: For a healthy individual; what happens if the two points had an angle of more/ larger than1 minute? – try to answer before reading the answer-

A1: Since the angle is larger than 1 minute; then this means that the two points successfully had hit two different receptors and the brain can therefore; discriminate them as two separate ones

Q2: For a healthy individual; what happens if the two points had an angle of less/ smaller than 1 minute? – try to answer before reading the answer; YOU HAVE TO !-

A2: Since the angle is smaller than 1 minute; then these two points had hit the same receptor (had hit only one receptor) and the brain can NOT therefore; discriminate these two points apart and will be seen as one !

* By now you should understand that; in comparison to a healthy individual (who has a good density of receptors), if the density of the cones -mainly- had been reduced (degenerated); you need to get the two points closer to the person; thus forming a larger angle (bigger than 1 minute) by which hitting two separate receptors in order to see them apart !

Back to the test itself .. you only need to get the concept ! Don't memorize ..

* There are different boards to do this test.

* For simplicity we will discuss the one with E letters; known as the 'Tumbling E chart'.

- Each line in the chart has different directions for the letter E as you can see ..

- Each line is represented with a small number above it ..

* How is the test done? And what does these numbers mean?

- The patient is asked to stand 6 meters away from the chart ..

- Testing each eye at a time; the doctor asks the patient to tell the direction of the letter E ..

- Each line represents what a healthy individual can see from a distance that corresponds to that little number found above it as we said .. For example; first line was 60meters, the second was 36meters, the third was 24meters, the fourth was 12meters, the fifth was 6meters and the sixth was 3meters … Now a healthy individual should see clearly till the line that corresponds to the distance of 6meters which is the fifth line in our example; so he we can say he is 6/6 !

- Now for more interpretation; what would 6/60 means? It means that a distance of 6meters, the patient can only see what a healthy one can from a distance of 60meters!

- What does it mean if he stopped at the level of line number 3? His result is 6/24 .. which means? Yes, at a distance of 6 meters; he can only see what a healthy individual would see at a distance of 24meters!

- Try the fourth line by yourself just like above ;)

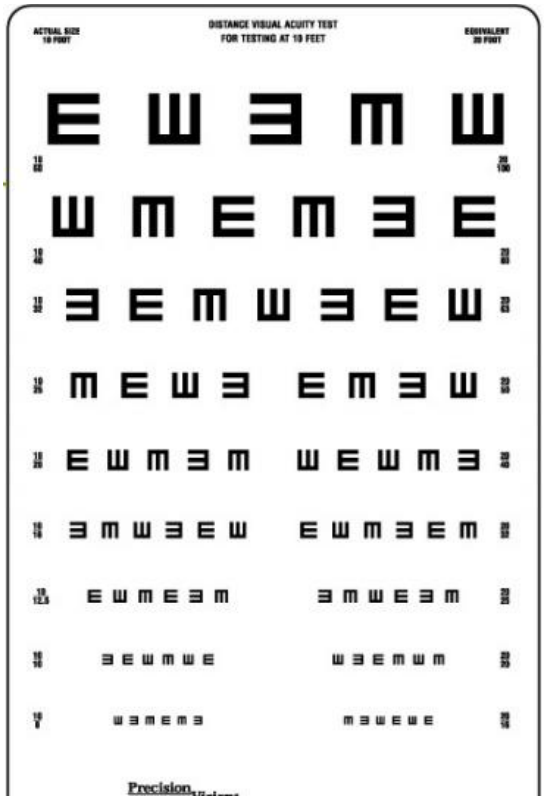
- ** NOT Required, what if you were able to see till the sixth line clearly ? well this means that your vision is really outstanding and sharp ! You can see from a distance of 6meters what a normal person can see from a 3 meters away!

* FEW NOTES YOU MUST KEEP IN MIND:

- The previous two points were just an example, don't memorize anything ..
- Think of the 6meters as the corresponding length needed to form our 1 minute angle, which is actually the basis for this test ..
- Different unites and different techniques are used in this test; like the 20 feet corresponds to the 6 meters !

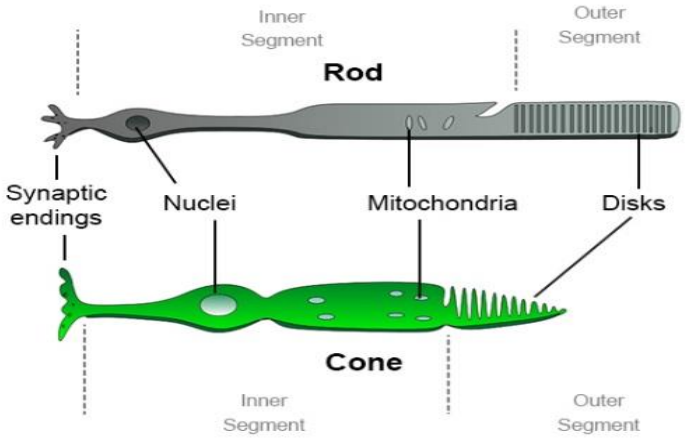
Simple point that was mentioned by the Docotr:

- If you fail to see the two points apart; you would be un-able to see the edges of the letter **C** (Sometimes the letter **C** is used instead of the letter **E**); so instead of seeing the letter **C** you would see the letter **O**!



Now, moving on to the main topic of this lecture ..

♣ THE EYE: II. RECEPTOR AND NEURAL FUNCTION OF THE RETINA



* Retina is the light sensitive part of the eye and it contains two types of photoreceptors:
- Rods are for night vision
- Cones are for day and color vision

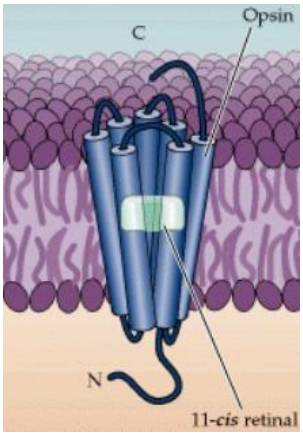
* Retina is arranged into neural architecture and the light must pass through these elements to strike the photoreceptors.

* Photoreceptors are composed of an outer segment, inner segment& synaptic ending!

* The outer segment is composed of disks-like membrane, that is formed from phospholipids& proteins. Proteins constitute about 40% of the membrane in both rods& cones. The major protein is known as Opsin; in Rods, there is only one type of opsin while in Cones, there is 3 types of opsin; each corresponds to one color (out of the three; Red, Green& Blue).

Reminder from Biochem for clarification:

- Rhodopsin is the vision-receptor found on the cones& rods. Look at the adjacent figure.
- Rhodopsin is composed of the protein Opsin + Chromophore.
- Chromophore is the 11-cis-Retinal, in which Vitamin A is needed. This clarifies why Vitamin A is linked to vision.



* Rods are known to be Achromatic; meaning they only have one type of color pigment(Opsin) which gives it the ability to only give us a grayscale of vision; from Black to White. The opsin found in rods is referred to by the name 'Scotopsin' (Scotopia + Opsin .. Scotopia= Greek word for dark-adapted vision)

* Due to having only 3 types of opsin which represents the main three colors(Red, Green& Blue) in Cones, any other color that we see is just a mixture of stimulation of these different opsins.

* Any genetic deficiency in one of three opsins in Cones could cause Color Blindness ;

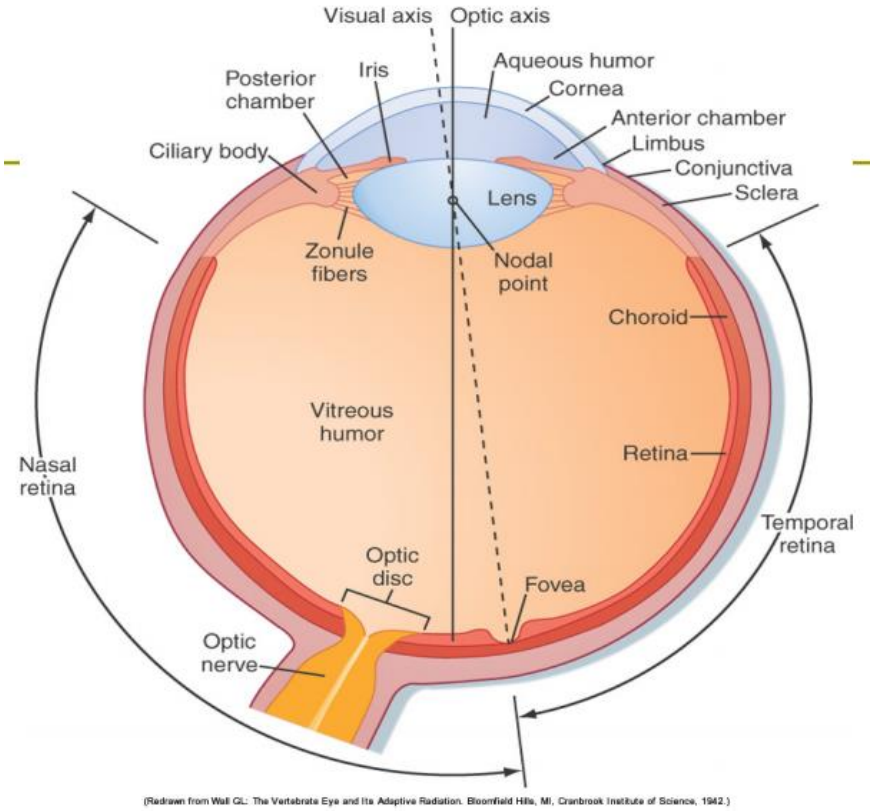
- Red& Green are X-linked; therefore men are more common affected. (An estimation of 8% of males are color blinded)
- Blue is autosomal recessive.

* Moving to the inner segment of the photoreceptors where we can find the cell organelles like the nuclei& mitochondria.

* The area of the optic disc has no photoreceptors, so it doesn't participate in vision; therefore known as the Blind Spot. Through the ophthalmoscope we can see the retinal arteries in the blind spot (This is the most superficial area for viewing the arteries) even for testing for atherosclerosis.

* Found in the temporal part of the retina is the Macula; in its center what is known as Fovea Centralis. For sharp with good coloring image; light must hit this part of the retina as it's full of cones (it has NO Rods) that faces immediately the light.

* Look at the optic axis and the visual axis(crossing directly into the Fovea).



*The following figure is really important !

• Layers of retina; going from deep layers to most superficial:

- Pigmented layer: Melanocytes with Melanin pigment. Why do we need this layer?

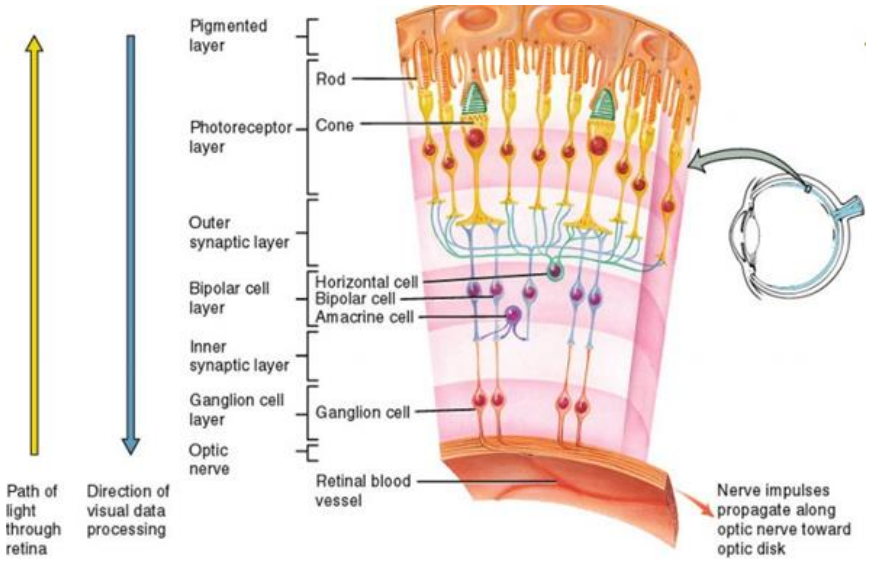
Simply for absorption of extra light coming to the receptors in order to get a sharper image!

○ Medical importance!

Albinos; people who have genetic deficiency in synthesizing the melanin pigment THOUGH they have normal cell count of melanocytes.(Activity is deficient). They lack the ability to sharpen the image by absorbing the extra light; so they try to get an object very close to their eyes ,when trying to read for example, limiting by that the amount of light going in! Otherwise their vision will be blurred due to the excessive light !

- Next layer is the Receptors; Rods& Cones.(Look at their nuclei)
- Next is the Outer synaptic layer 'Outer plexiform layer' in which the cones& rods synapse with the 2nd order neuron; Bipolar cells!
- Next is the Bipolar cell layer. You can find some-other interneurons which aid in the lateral inhibition for sharpening the signal(image) !
- Next comes the Inner synaptic layer 'Inner plexiform layer' in which the Bipolar cells synapse with the Ganglion neurons.

- Ganglion cells form the next layer; from which their axons extend to form the **Optic Nerve**!



* Now in term of numbers :

- 100 million Rods per one Retina, which are distributed peripherally (more found when we go to the periphery of the retina)
- 3 million cones per one Retina, which are distributed centrally (remember when we said that the Fovea has the highest amount of cones)
- 1.6 million of ganglion cells

Which brings us to how is this possible ? (too many Rods or Cones and only few of Ganglion)

The answer is **Convergence**!

- Many Rods converge to one Ganglion cell giving the Rods its ability to be very sensitive to light !(Night vision)
- Only one or two of Cones synapse to one Ganglion neuron giving them the ability to produce a sharp, Good colored image !

* ***Note:*** In the next page, you can find a comparison between Rods& Cones! Try to understand them before just memorizing them; because they are required for the final exam in all three; Anatomy+ Physio+ Biochem!

Rods

- high sensitivity; specialized for night vision
- more photopigment
- high amplification; single photon detection
- saturate in daylight
- slow response, long integration time
- more sensitive to scattered light

Cones

- lower sensitivity; specialized for day vision
- less photopigment
- less amplification (less divergence 1:1 is more)
- saturate with intense light
- fast response, short integration time
- more sensitive to direct axial rays

Rods

- low acuity; highly convergent retinal pathways, not present in central fovea
- achromatic; one type of rod pigment

Cones

- high acuity; less convergent retinal pathways, concentrated in central fovea
- trichromatic; three types of cones, each with a different pigment that is sensitive to a different part of the visible spectrum, **Red**, **Green** and **Blue**

♣ PHOTO-CHEMISTRY OF VISION:

*Check the figure ..

* Let us put this as points ;

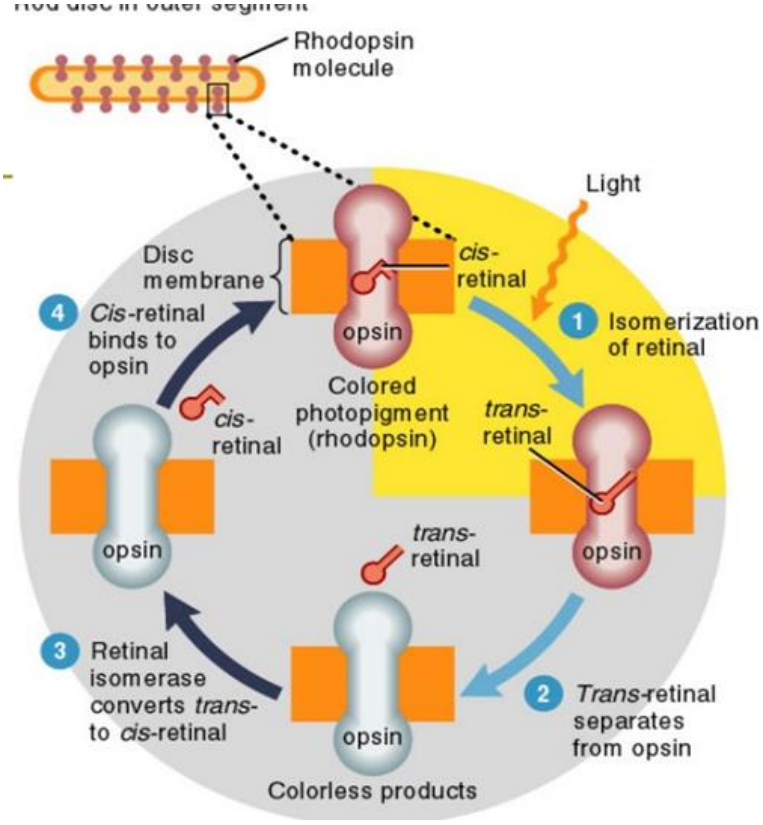
- Normally the receptor on Rods or Cones is the opsin (part of the Rhodopsin)

- Bounded to the Opsin is 11-cis-retianl

- Once light hits this 11-cis-retinal, it converts into 11-trans-retinal and breaks from the opsin!

- Opsin gets activated and it activates a near-by enzyme known as Transducin!

- Transducin activates cGMP-phosphodiesterase (converting the cyclic form to a non-cyclic form) which coverts cGMP to GMP ! (Drop in the level of cGMP)



- Now normally; during the dark; we have high levels of cGMP; needed for special gated Na channels found in the outer segment 'cGMP-gated-channels'. Once are open, the membrane depolarizes ..
So during the *d*ark our photoreceptors are *d*epolarizing. When light hits them; they get hyperpolarized! Which is our **receptor potential** (The Hyperpolarization) for the visual pathway!
- Another thing you should be careful about is that Glutamate in the visual pathway is an **inhibitory** neurotransmitter released upon depolarization (dark). Once the photoreceptors gets stimulated its secretion decreases! (Remember; inhibition of the inhibition is stimulation !) So the Bipolar cells gets stimulated and the visual transduction proceeds so that the vision process is done ;)

Simple Note that needs to be said from the previous sheet; Normal vision is referred to as **Emmetopia** !

* Sorry for any mistake! :')

THE END