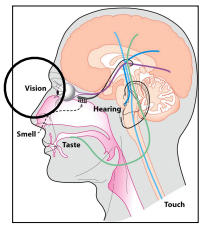
Chem 452 - Lecture 10
Signal Transduction & Sensory Systems
Part 6

Question of the Day: Who has better color vision, a human or a mantis shrimp?

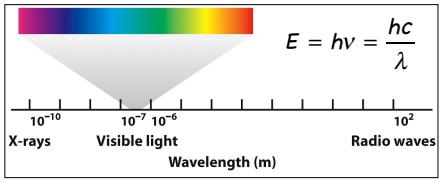
Vision

- Vision involves the transduction of light energy to an nerve signal.
  - We will not discuss the many details on how the vision system recovers after the detection of light.



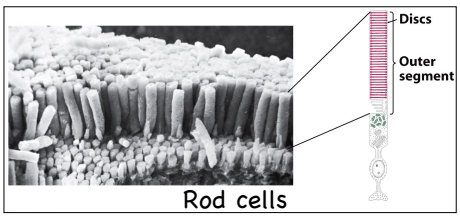
Vision

- Humans are sensitive to electromagnetic radiation (light) with wavelengths between 300 and 850 nm.
  - We are also able to discern the different wavelengths of light within this range.



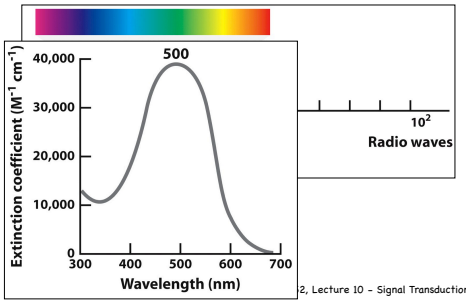
Vision

- There are two types of photoreceptor cells located on the retina of the eye.
  - **Rods cells**, are specialized for sensitivity
  - **Cones cells**, are specialized to determine color



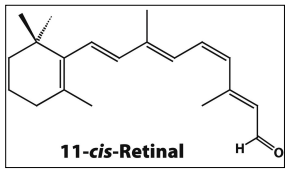
Vision

- Rod cells absorb light most efficiently in the center of the visible spectrum.



Vision

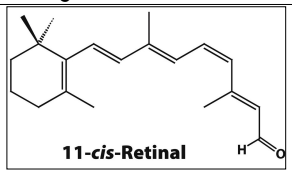
- The light absorbing component of rod cells is the photoreceptor protein **rhodopsin**.
  - The protein component (opsin) of the photoreceptor is a 7TM protein
  - The light absorbing component is the prosthetic group (cofactor) **11-cis-retinal**.



Vision

- The light absorbing component of rod cells is the photoreceptor protein **rhodopsin**.
  - The protein component (opsin) of the photoreceptor is
  - prosthetic

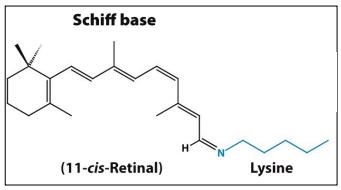
What feature of 11-cis retinal makes it a good absorber of visible light?



This gives rhodopsin a molar absorptivity as high as 40,000 M^{-1} cm^{-1}.

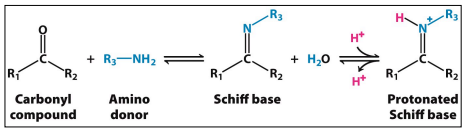
Vision

- At the beginning of the photocycle, the retinal is covalently attached to the opsin using a Schiff base formed with a lysine side chain.



Vision

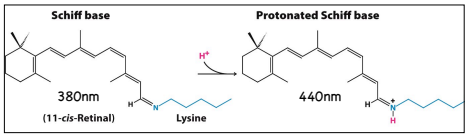
- A Schiff base is formed from a condensation reaction between either a ketone or aldehyde and a primary amine.



  - You will encounter Schiff bases a number of times in Biochemistry II.

Vision

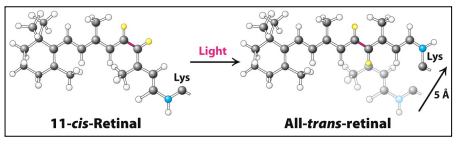
- The shift in the absorbance maximum of the retinal to up around 500 nm, when bound to the opsin, suggests that the Schiff base is in its protonated form.



  - It is believed that a nearby glutamate residue helps to stabilize the positively charge Schiff base.

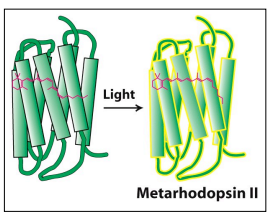
Vision

- The absorption of a photon of light brings about a chemical change in the 11-cis-retinal.
  - The cis-double bond is isomerized to a tran-double bond.



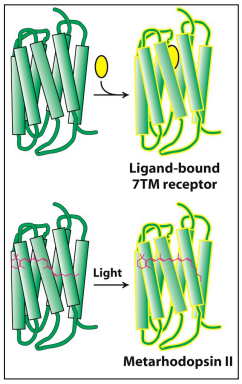
Vision

- This results in a conformational change in the opsin.
  - The activated rhodopsin is called **metarhodopsin II.**



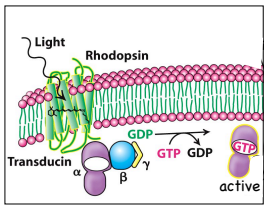
Vision

- This is analogous to the change that occurs in other 7TM receptors upon ligand binding.



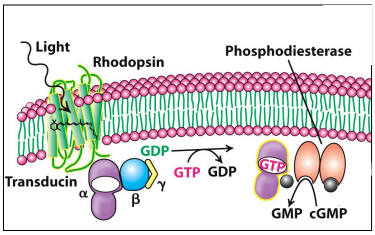
Vision

- And, as with other G-protein receptors, this leads to the activation of a G-protein called **transducin**.



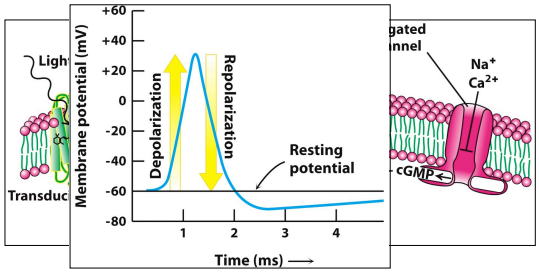
Vision

- The active transducin G-protein binds to an inhibitor of a cGMP phosphodiesterase.
  - The active phosphodiesters leads to the breakdown of the secondary messenger, cGMP.



Vision

- And lowering the cGMP concentration leads to the closure of a cGMP-gated Na^+/Ca^{2+} channel, and hyperpolarization of the membrane potential.



Vision

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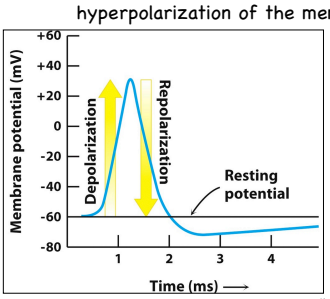
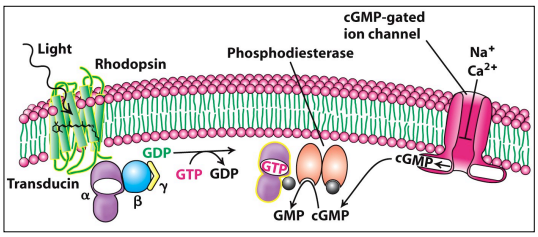


- This behavior is noticeably different than what we have encountered before with the olfactory receptors, but it too leads to a triggering of and action potential in neighboring neurons.

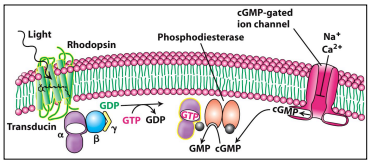
Vision

- The concomitant lowering of the intracellular Ca^{2+} levels leads to the activation of a guanylate cyclase (not shown) and recovery of the cGMP levels.



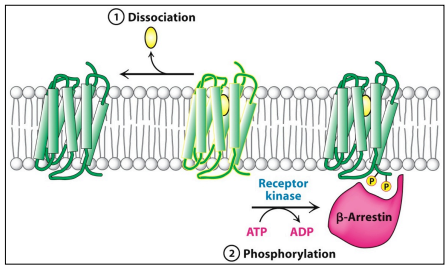
Vision

- The signal is also turned off by
  - The auto hydrolysis of the GTP that is bound to the transducin
  - And by the phosphorylation of the photoreceptor by a rhodopsin kinase. This leads to to binding of the protein **arrestin** and blocks further activation of transducin.



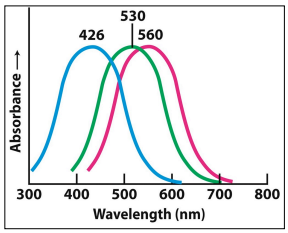
Vision

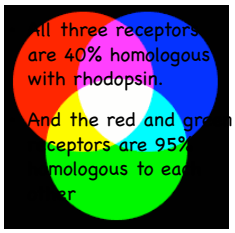
- We saw a similar strategy used to turn off the β-adrenergic signal transduction pathway.



Vision

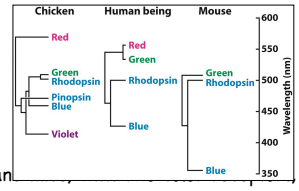
- Color vision in the cone cells is mediated by three different 7TM photoreceptors which are tuned to different wavelengths of light.





Vision

- Evolutionarily, the red receptor appears to have evolved most recently.



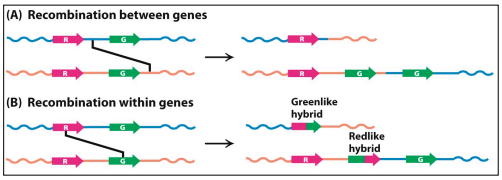
- Dogs an see fewer colors that we do.
- But birds, with 5 color receptors, see more colors

Vision

- And butterflies have 6 color receptors,
- While the mantis shrimp has 12 to 16 color receptors !!!

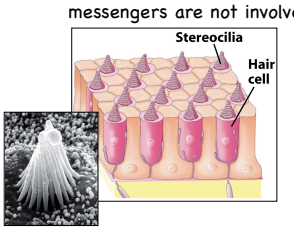
Vision

- Because the red and green color receptors are so homologous and reside next to one another on the X chromosome,
  - Homogous recombination can lead to red-green color blindness.



Hearing

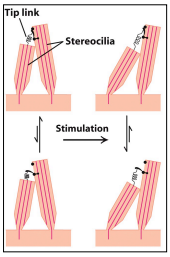
- Hearing requires fast detection of mechanical stimuli.
  - Humans can distinguish temporal delays in sound as short as 0.02 ms.
  - This suggests that the production of second messengers are not involved.

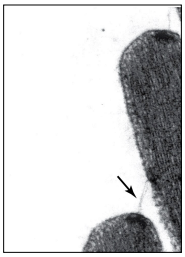


- Sound waves are detected by hair cells located in cochlea of the inner ear.

Hearing

- Displacement of the hair bundle towards the highest point leads to and increased membrane potent.



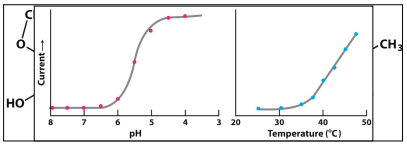


Touch

- Like taste, touch is a combination of sensory systems that are expressed in a single organ, which is the skin.
  - Though not as well understood as other systems, pressure is believed to lead to the opening of Na^+ channels.
  - Touch is also connected to our ability to sense pain.

Touch

- Pain receptors are called **nociceptors**.
  - These are the receptors that respond to spicy foods.
  - For example, **capsaicin**, which is found in chili peppers, binds to and stimulates the opening of a ligand-gated Na^+ channel, called the VR1 receptor.
  - This same receptor also responds to temperature and acid



Next up

- Lecture 11 - Molecular Motors
  - Chapter 35