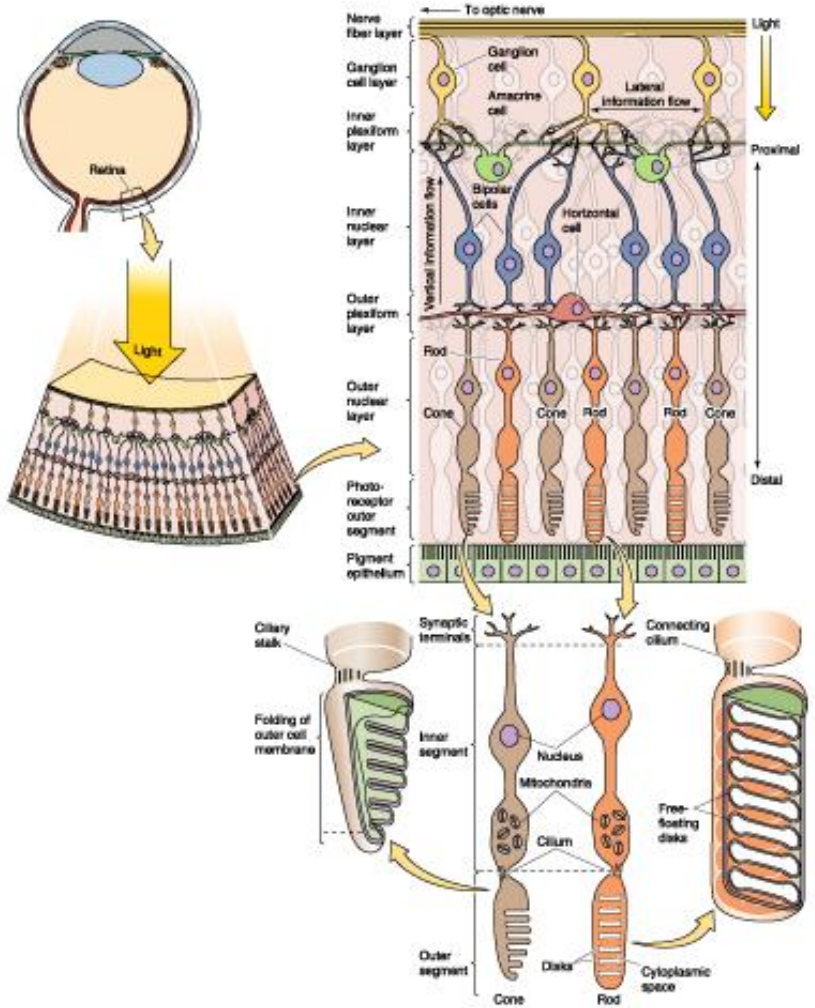
VISION PART 2

Vision---rod/cones



The neural circuits in the retina of a primate

-The incoming light reaches the photoreceptor cells (*rods* and *cones*) only after passing through several thin, transparent layers of other neurons.

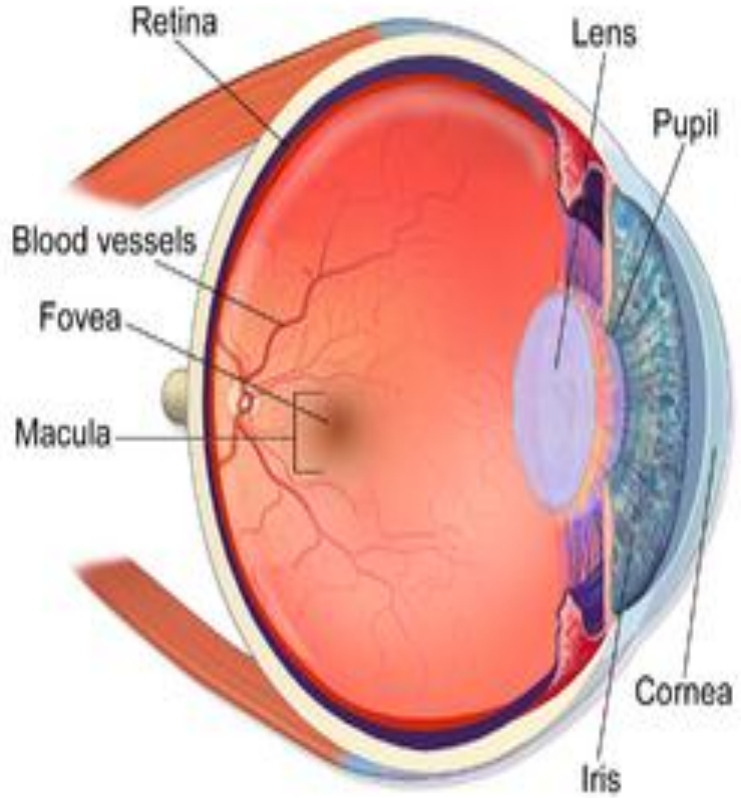
-The pigment epithelium absorbs the light that is not absorbed by the photoreceptor cells and thus minimizes reflections of stray light.

The ganglion cells communicate to the thalamus by sending action potentials down their axons.

However, the photoreceptor cells and other neurons communicate by graded synaptic potentials that are conducted electronically.

The Fovea

- A small area at the center of the retina about 1 sq millimeter
- The center of this area, “the central fovea,” contains only cones
  - these cones have a special structure
  - aid in detecting detailed vision
- In the central fovea the neuronal cells and blood vessels are displaced to each side so that the light can strike the cones directly.
- This is the area of greatest visual acuity



Eye Anatomy

Rods, Cones and Ganglion Cells

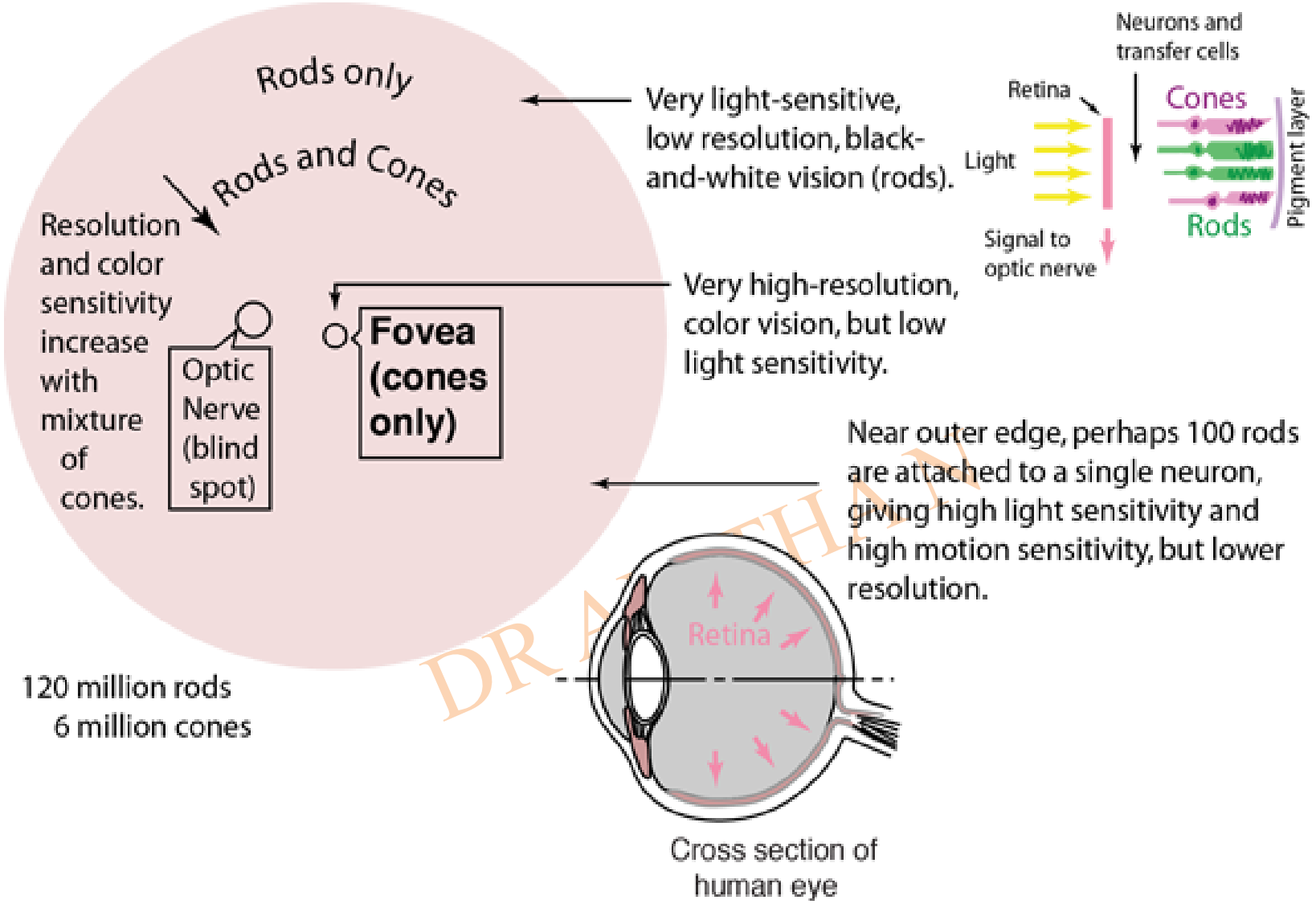
- Each retina has 100 million rods and 3 million cones and 1.6 million ganglion cells.
- 60 rods and 2 cones for each ganglion cell
- At the central fovea there are no rods and the ratio of cones to ganglion cells is 1:1.
- May explain the high degree of visual acuity in the central retina

Rods

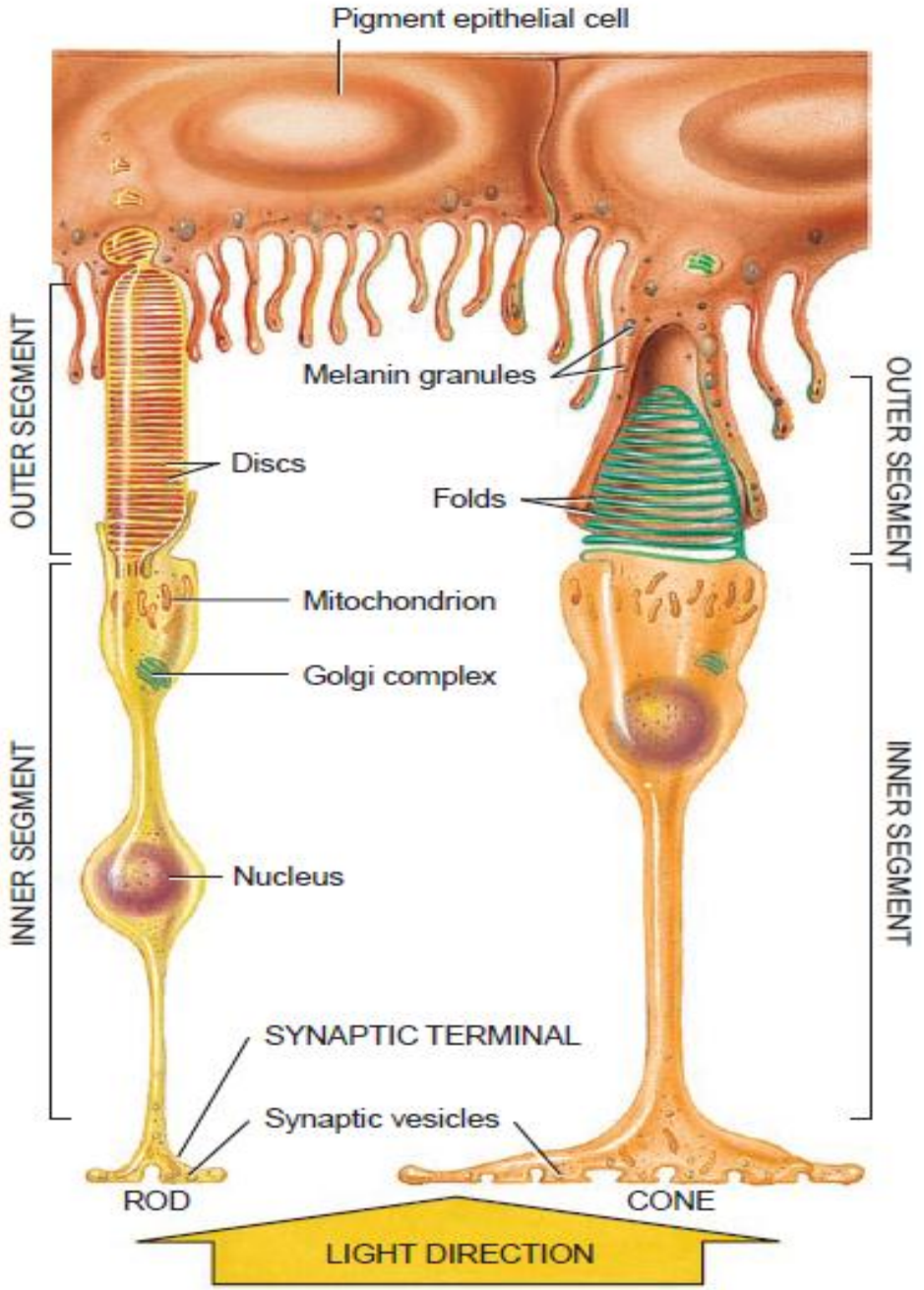
- high sensitivity; specialized for night vision
- more photopigment
- high amplification; single photon detection
- saturate in daylight
- slow response, long integration time
- more sensitive to scattered light
- low acuity; highly convergent retinal pathways, not present in central fovea
- achromatic; one type of rod pigment

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
- 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


Rods only
Very light-sensitive, low resolution, black-and-white vision (rods).
Rods and Cones
Resolution and color sensitivity increase with mixture of cones.
Optic Nerve (blind spot)
Fovea (cones only)
Very high-resolution, color vision, but low light sensitivity.
Near outer edge, perhaps 100 rods are attached to a single neuron, giving high light sensitivity and high motion sensitivity, but lower resolution.
120 million rods
6 million cones
Retina
Cross section of human eye
Neurons and transfer cells
Retina
Cones
Light
Rods
Pigment layer
Signal to optic nerve

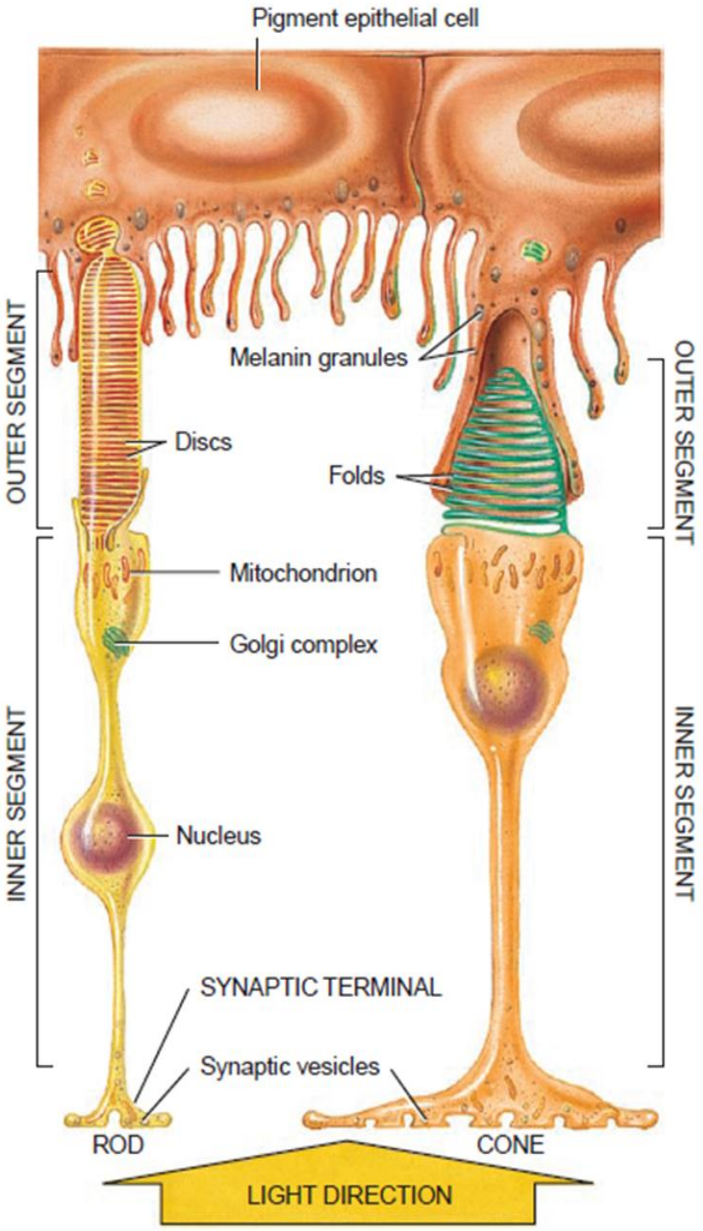
PHOTORECEPTORS
&
PHOTOPIGMENTS



Structure of Receptors

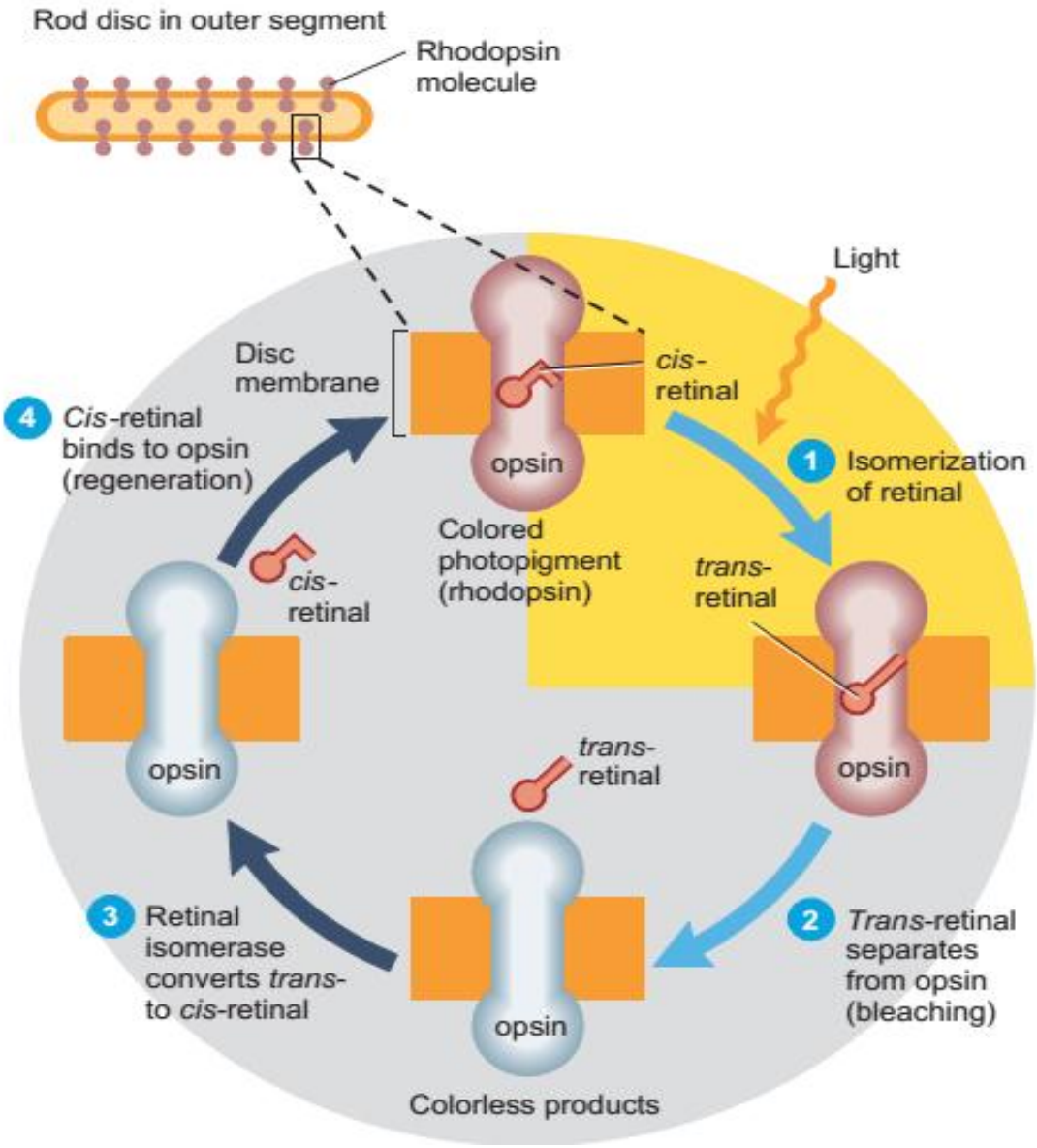
- Photo-receptors convert light energy into action potential
- Rods are slender elongated structures
  - Diameter =1 µm
  - Length = 40 µm
- Outer segment of rods is specialized for photo-reception
- Contains stacks of about 1000 discs
  - Closed and flattened sacks (160 angstroms)
- Densely packed with photo-sensitive pigment
- Discs are formed by inner segment
  - Migrate to outer segment

- Cones have thick inner segment and conical outer segment
- The saccules formed in outer segment
  - By in-folding of the cell membrane

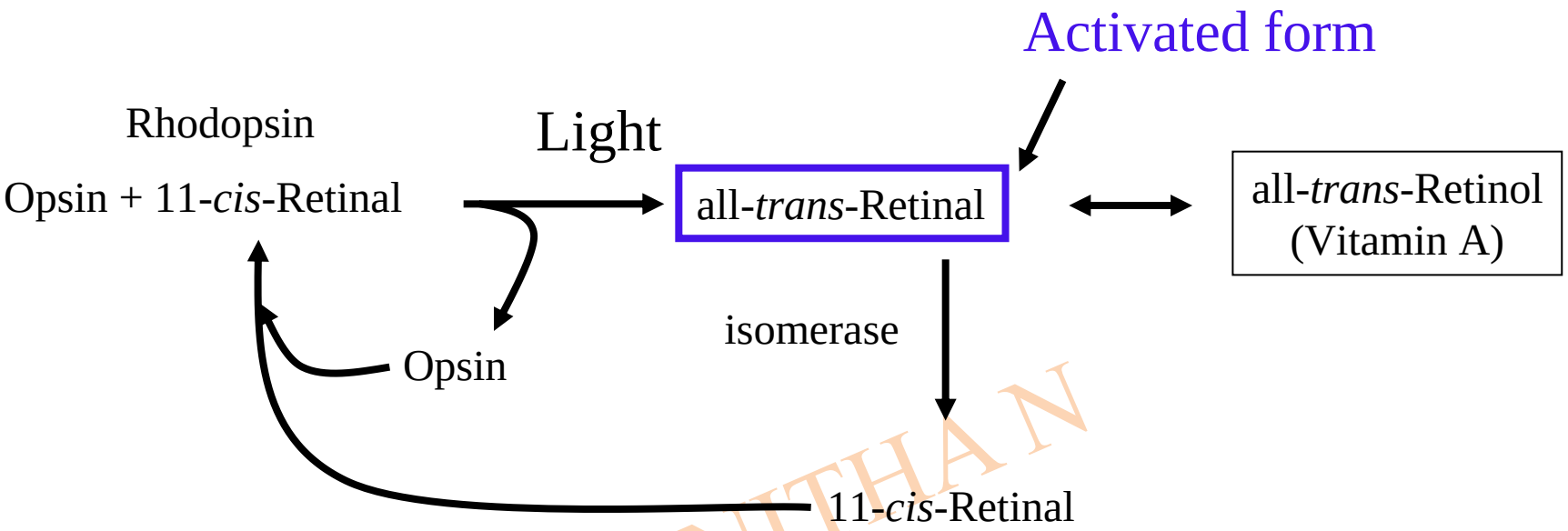


PhotoPigments

- Consist of
  - **Opsin** - a Glycoprotein
  - **Retnene (retinal)**
    - Carotenoid pigment, derivative of Vitamin A & Responsible for capture of light
- **Rods** have rhodopsin
  - Scotopsin + retinal
- **Cones** have iodopsin
  - Photopsin + retinal

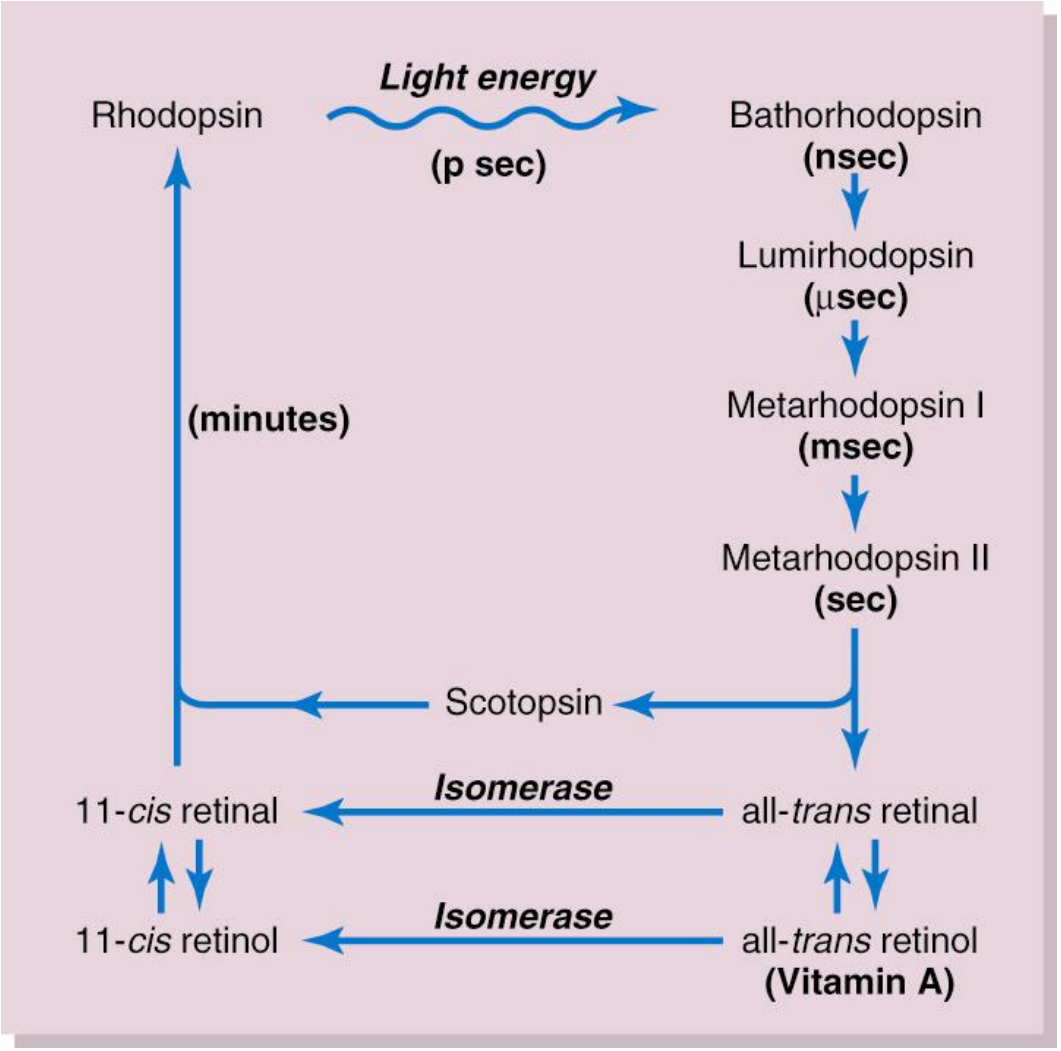

Rod disc in outer segment
Rhodopsin molecule
Light
Disc membrane
cis-retinal
opsin
1 Isomerization of retinal
Colored photopigment (rhodopsin)
trans-retinal
opsin
2 Trans-retinal separates from opsin (bleaching)
trans-retinal
opsin
Colorless products
3 Retinal isomerase converts trans- to cis-retinal
cis-retinal
opsin
4 Cis-retinal binds to opsin (regeneration)

Photochemistry of Pigment molecules



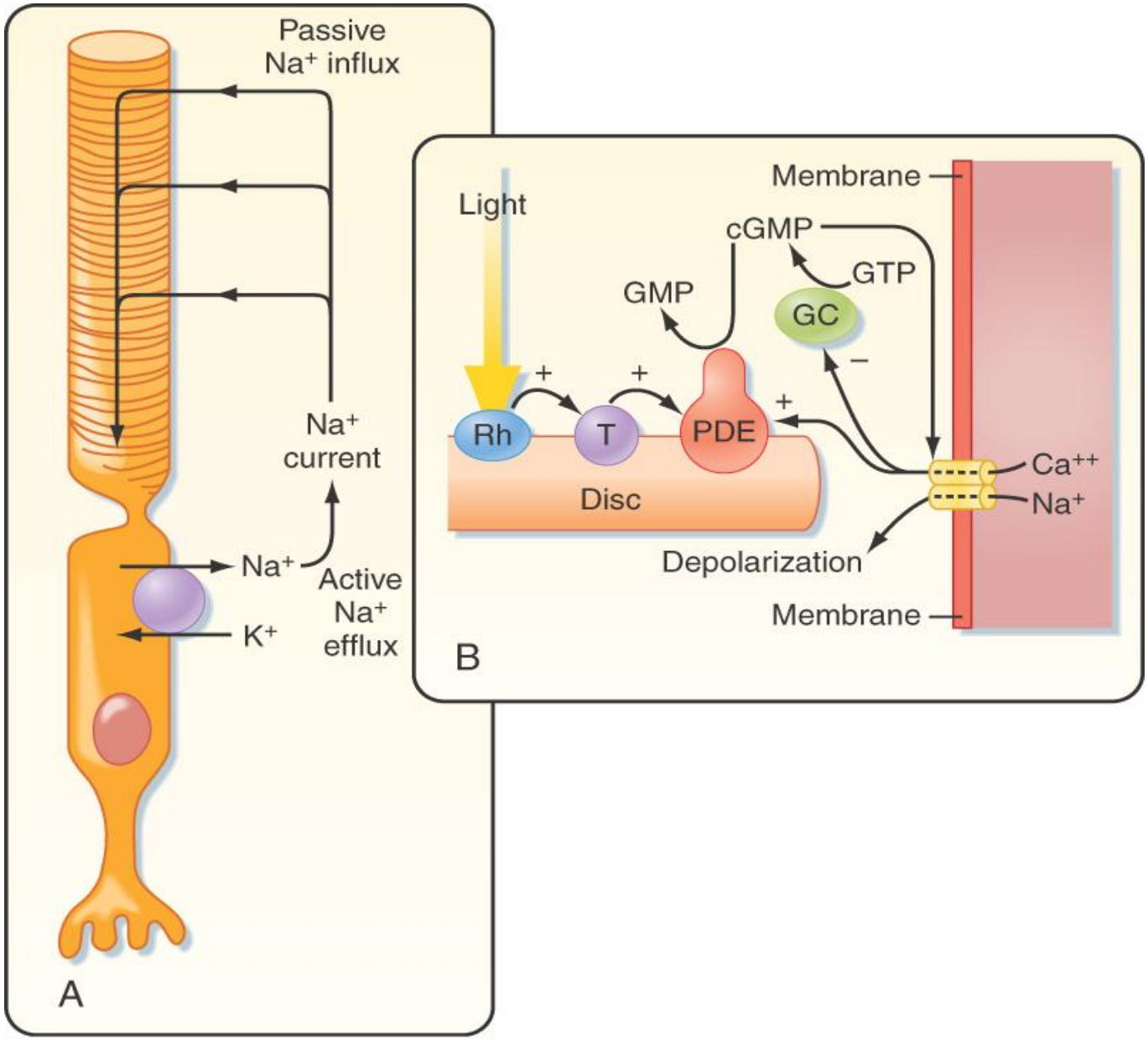
Light converts 11-*cis*-Retinal to all-*trans*-Retinal

Rhodopsin Cycle

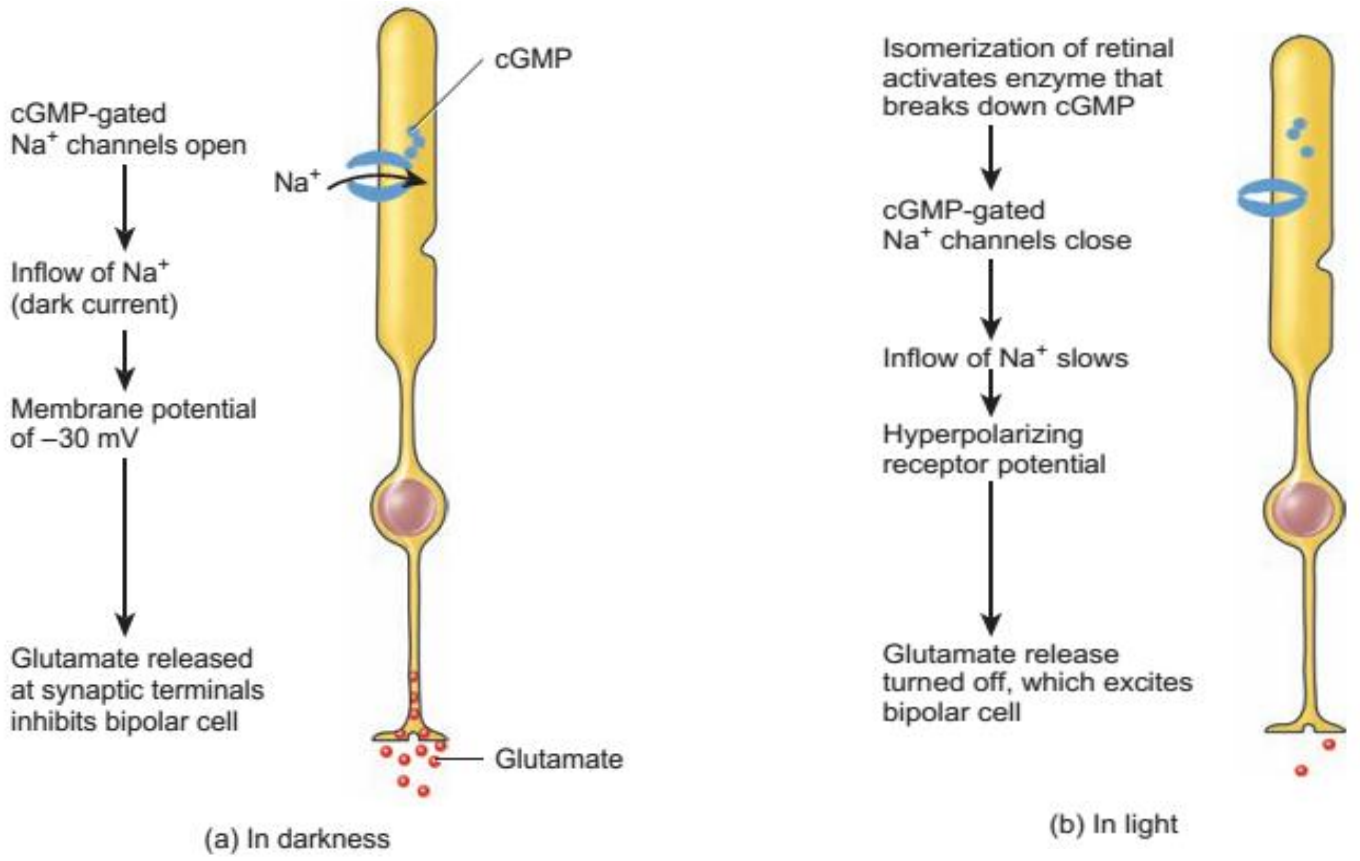


Mechanism for Light to Decrease Sodium Conductance

- cGMP is responsible for keeping Na^+ channel in the outer segment of the rods open.
- Light activated rhodopsin (metarhodopsin II) activates a G-protein, *transducin*.
- Transducin activates cGMP *phosphodiesterase* which destroys cGMP.
- *Rhodopsin kinase* deactivates the activated rhodopsin (which began the cascade) and cGMP is regenerated re-opening the Na^+ channels.

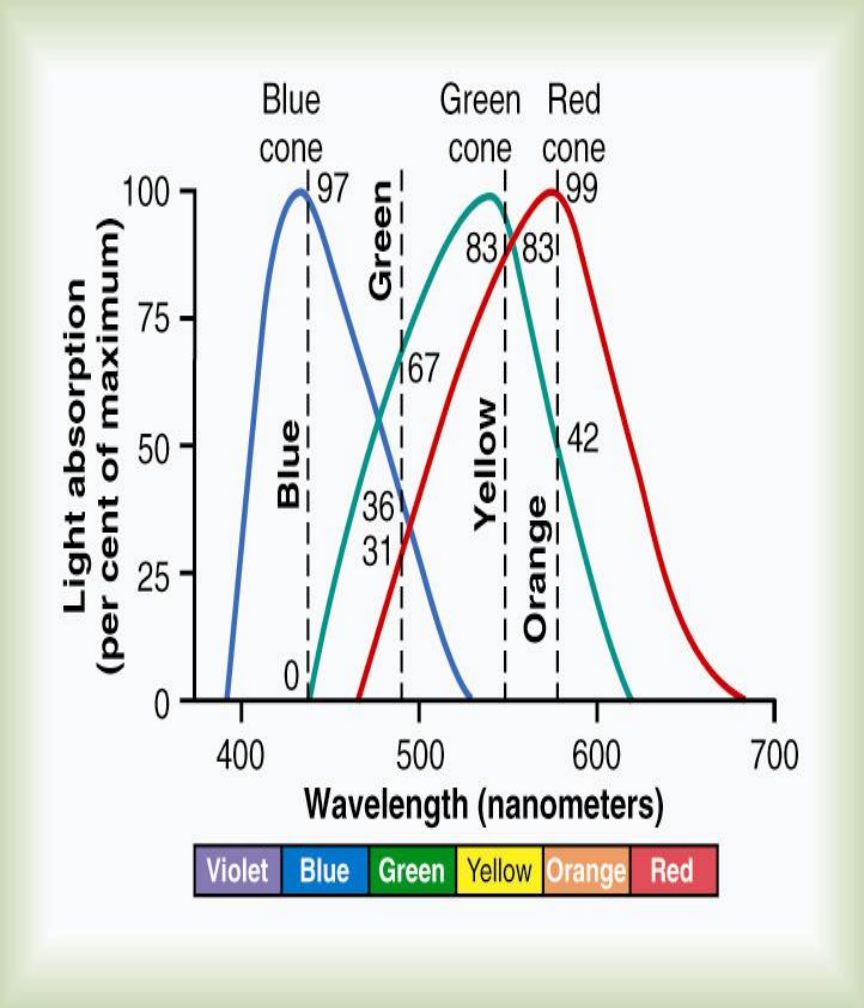


Operation of rod photoreceptors



Color Vision

- Color vision is the result of activation of cones.
- 3 types of cones:
  - blue cone
  - green cone
  - red cone
- The pigment portion of the photosensitive molecule is the same as in the rods, the protein portion is different for the pigment molecule in each of the cones.
- Makes each cone receptive to a particular wavelength of light

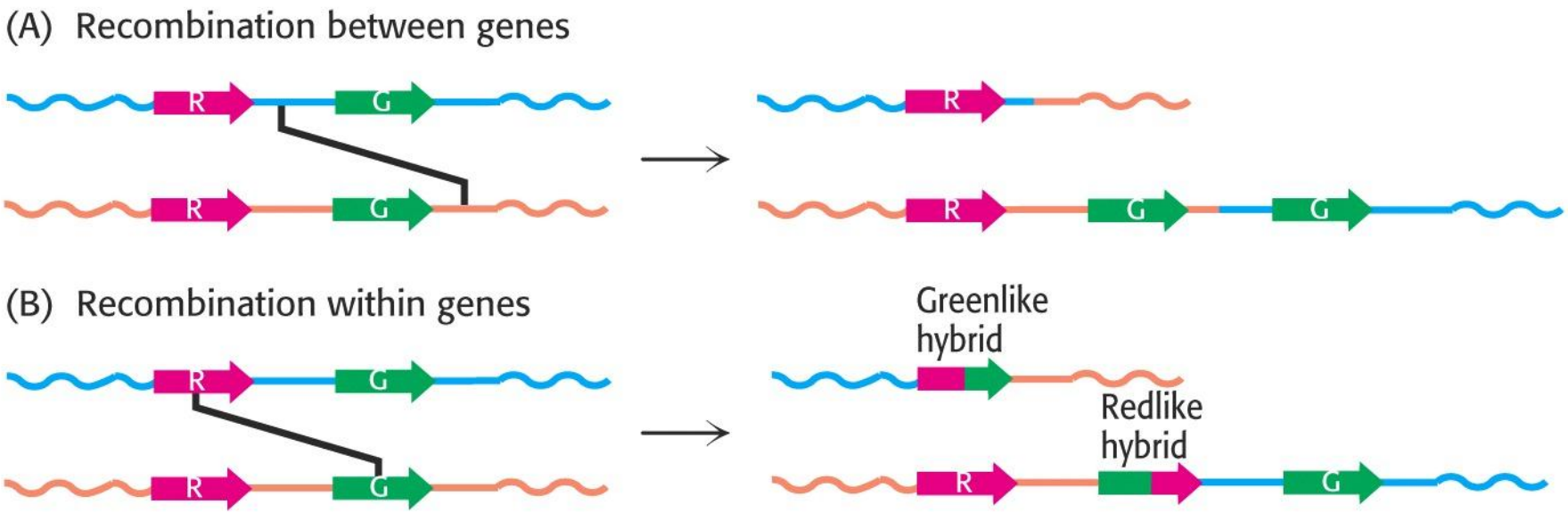


Color Blindness

- lack of a particular type of cone
- genetic disorder passed along on the X chromosome
- occurs almost exclusively in males (blue color blindness is usually autosomal recessive gene but it is rare)
- about 8% of women are color blindness carriers
- most color blindness results from lack of the red or green cones
  - lack of a red cone, *protanope.*
  - lack of a green cone, *deuteranope.*

Recombination pathways leading to color blindness

Rearrangements in the course of DNA replication
A) Loss of visual pigment B) The formation of hybrid pigemnt genes that encode photoreceptors with anomalous abs. spectra



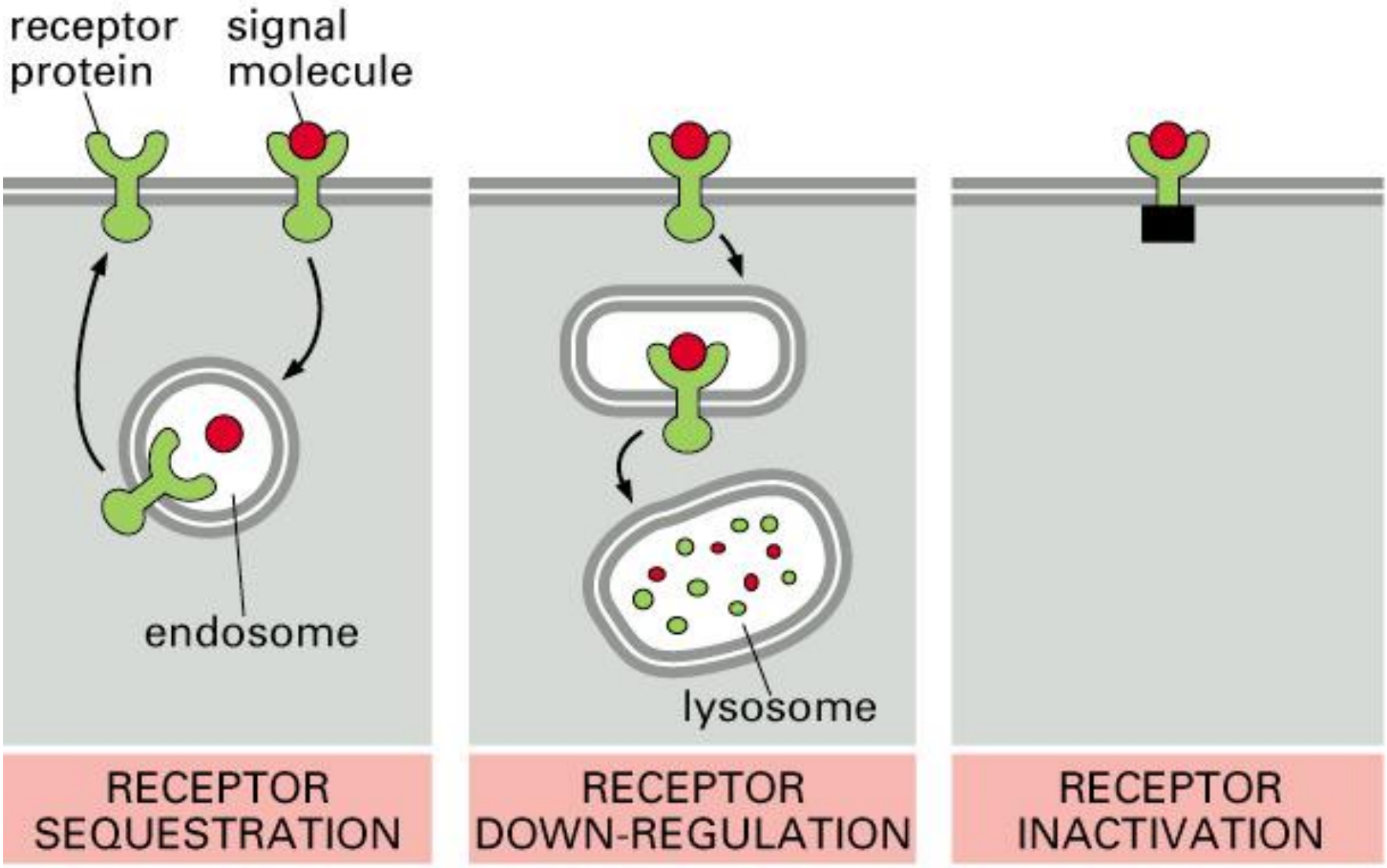
A homologous recombination: the exchange of DNA segment at equivalent positions between chromosomes with substantial similarity

Termination of the signal

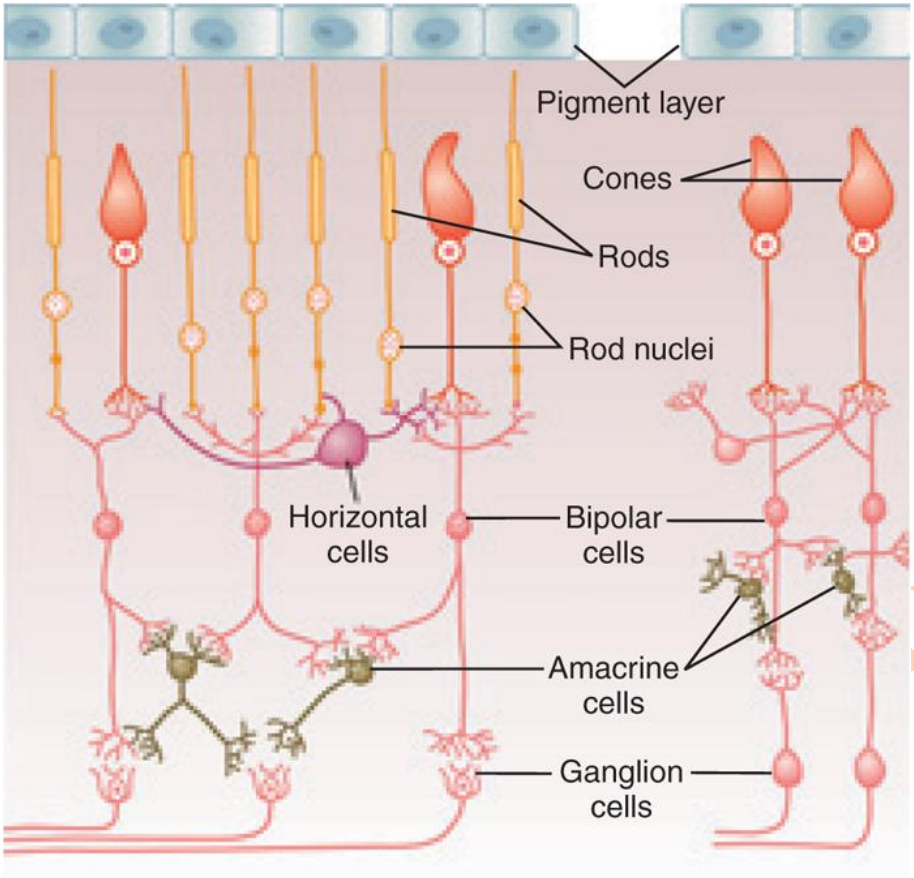
- One of the most important part of the signaling machinery is termination of the signal even in the presence of the stimulus.
- This phenomenon is referred to as **“desensitization”**

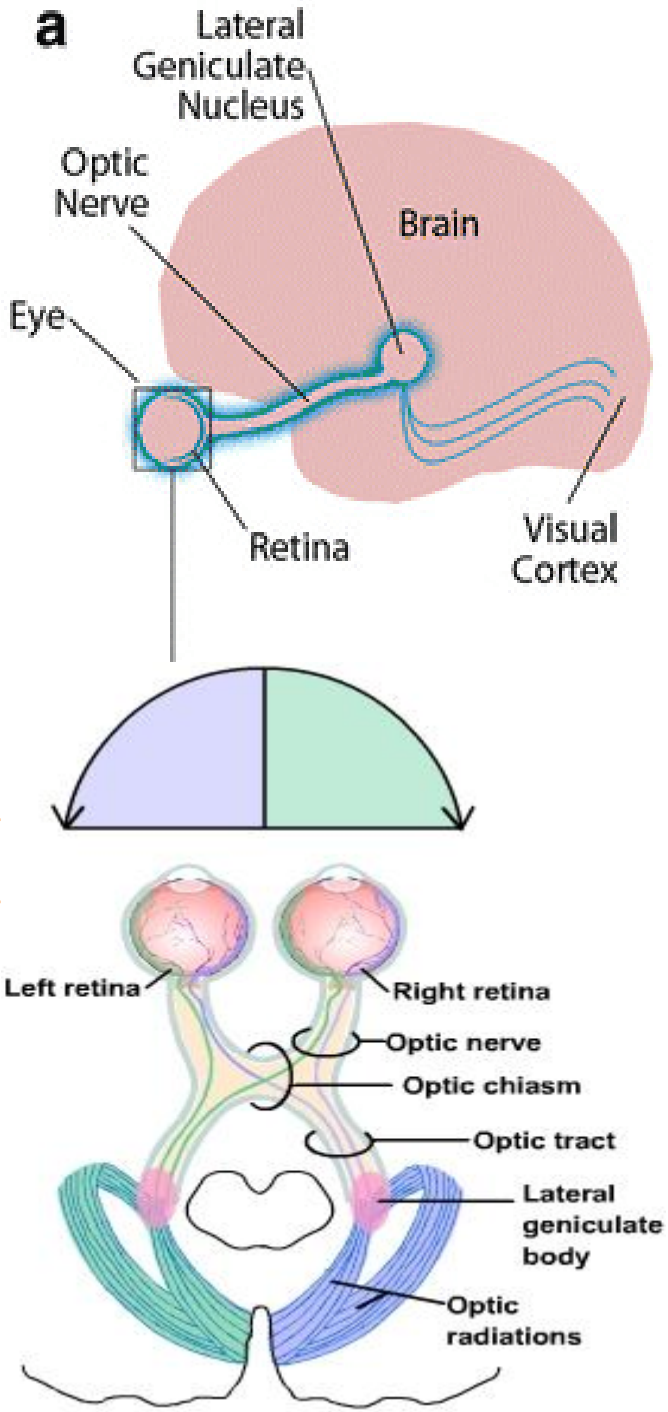
- Such mechanisms operate at both the level of the receptor as well as down stream at the level of G-protein

- Rapid termination of the receptor signal is controlled by **receptor phosphorylation** which is mediated by second messenger-kinases **PKA** and **PKC** or by a distinct Receptor-kinsases (**GRKs**) together with **arrestins**


receptor protein
signal molecule
endosome
lysosome
RECEPTOR SEQUESTRATION
RECEPTOR DOWN-REGULATION
RECEPTOR INACTIVATION

Neural Function of the Retina





Neural Function of the Retina

Neural Circuitry of the Retina

- Photoreceptors transmit signals to the outer plexiform layer where they synapse with bipolar cells and horizaontal cells
- Horizontal cells which transmit signals horizontally in the outer plexiform layer from the rods and cones to bipolar cells
- Bipolar cells which transmit signals vertically to the inner plexiform layer, where they synapse with ganglion cells and amacrine cells
- Amacrine cells transmit signals either directly from bipolar cells to ganglion cells or horizontally from axons of the bipolar cells to dendrites of the ganglion cells or other amacrine cells
- Ganglion cells which transmit output signals from the retina through the optic nerve into the brain