

The Special Senses

Vision - 3

Photo-transduction

Dr. Salah Elmalik

The Physiology of Vision

Objectives:

At the end of this lecture the student should be able to:

- List and compare functional properties of rods and cones in scotopic and photopic vision
- Know the convergence and its value
- To describe the photosensitive compounds
- Contrast the phototransduction process for rods and cones in light and dark and the ionic basis of these responses

The Physiology of Vision

- Know the process of rhodopsine regeneration
- Know the meaning of nyctalopia
- Contrast the dark and light adaptation
- Know the visual cycle and rhodopsine regeneration

Physiology of Vision

- Stimulus: Light
- Receptor: Retina (Photoreceptors)

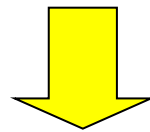
Light

- **Definition:**
'electromagnetic' radiation that is capable of exciting the human eye'
- **Extremely fast**

Visible light & Duplicity Theory of vision

Visible light Spectrum:

- Extends from 397 to 723nm
- Eye functions under two 2 conditions of illumination:
 - Bright light (Photopic) vision
 - Dim light (Scotopic vision) ..Rods



Duplicity theory
of vision

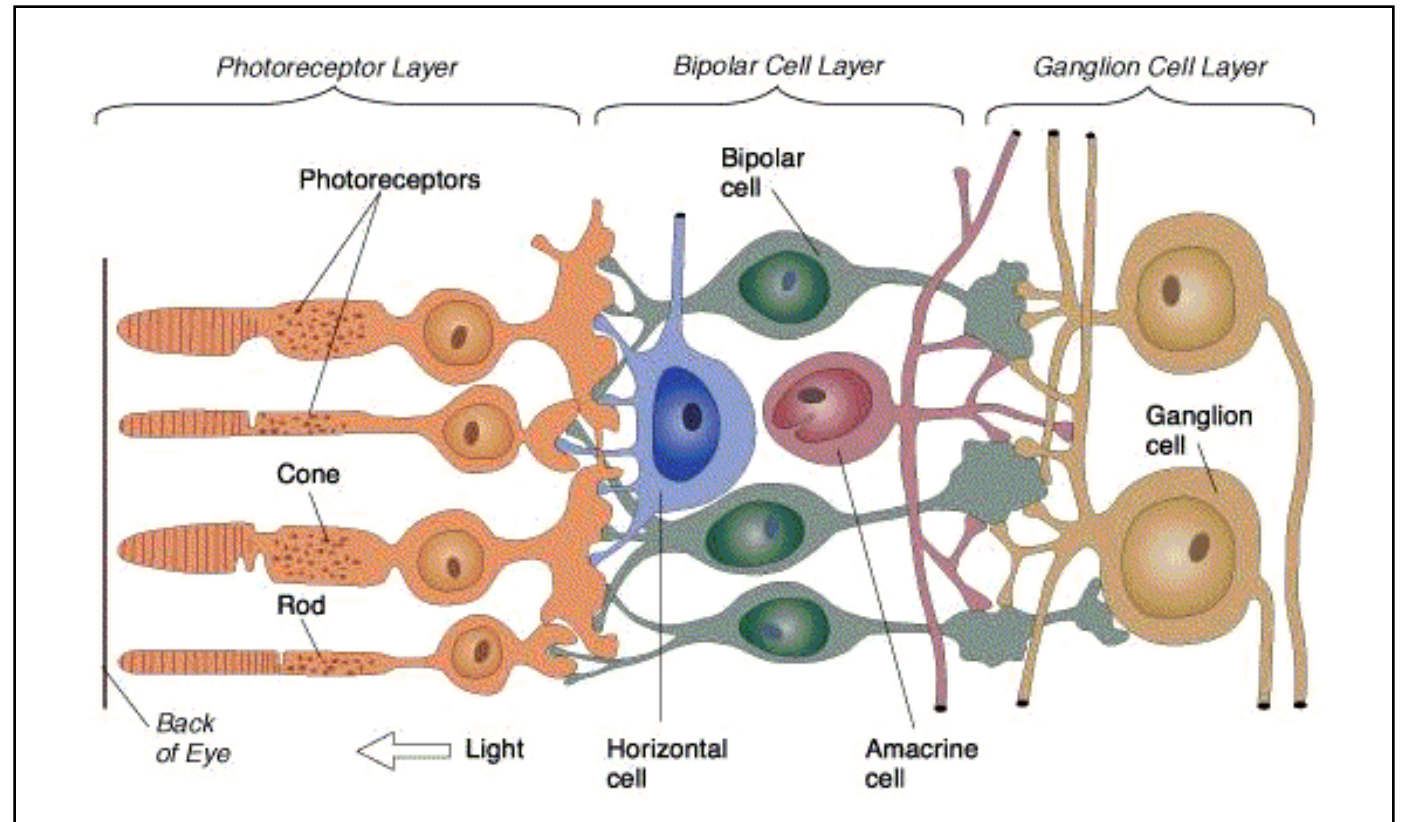


Photoreceptors Rods & Cones

Morphology & Distribution

Retina

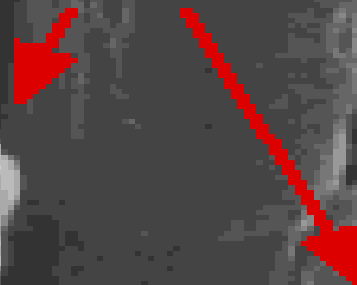
Back of retina,
pigment
epithelium



Light

Rods

Cones



Photoreceptors

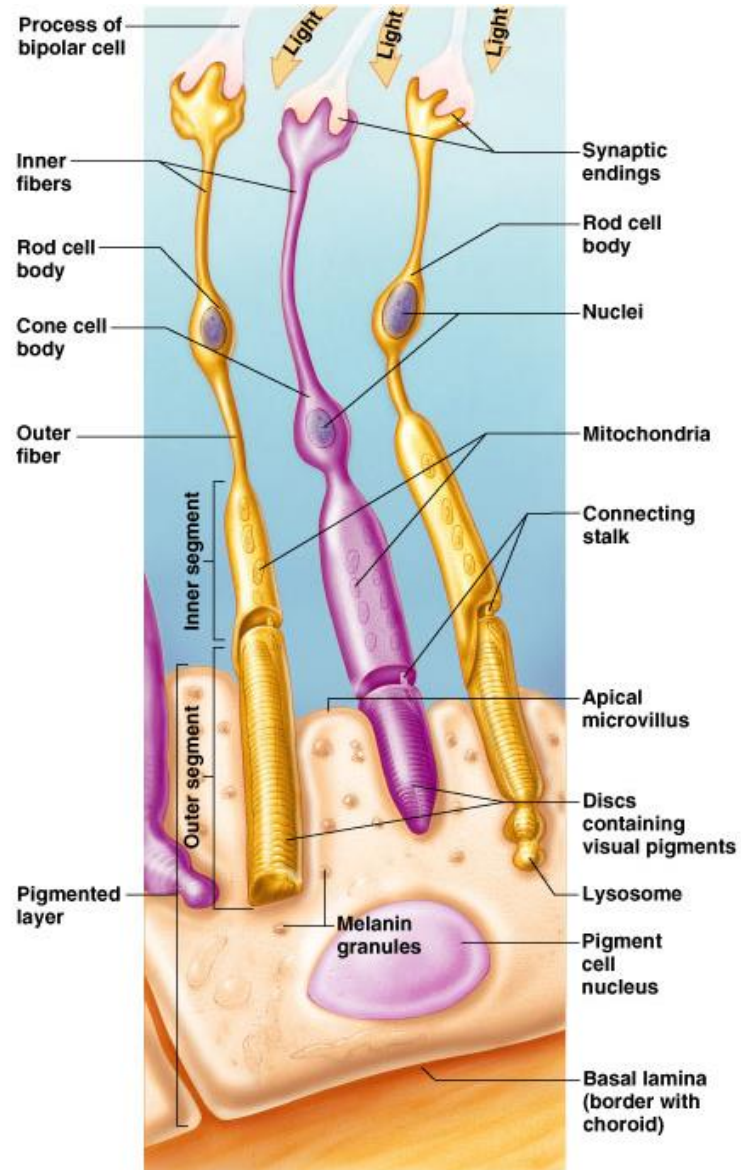


Figure 16.11

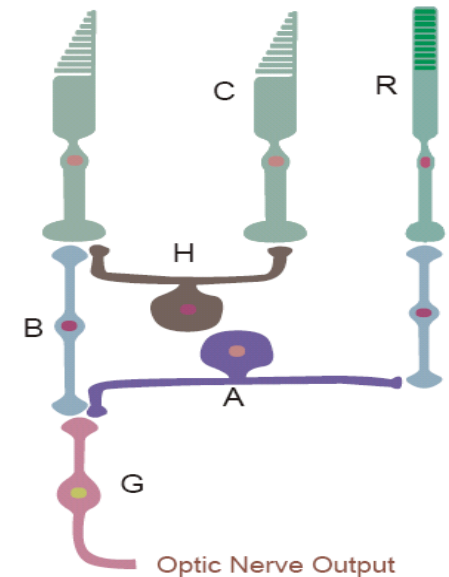
Retina: photoreceptors

- 120,000,000 rods
- 6,000,000 cones

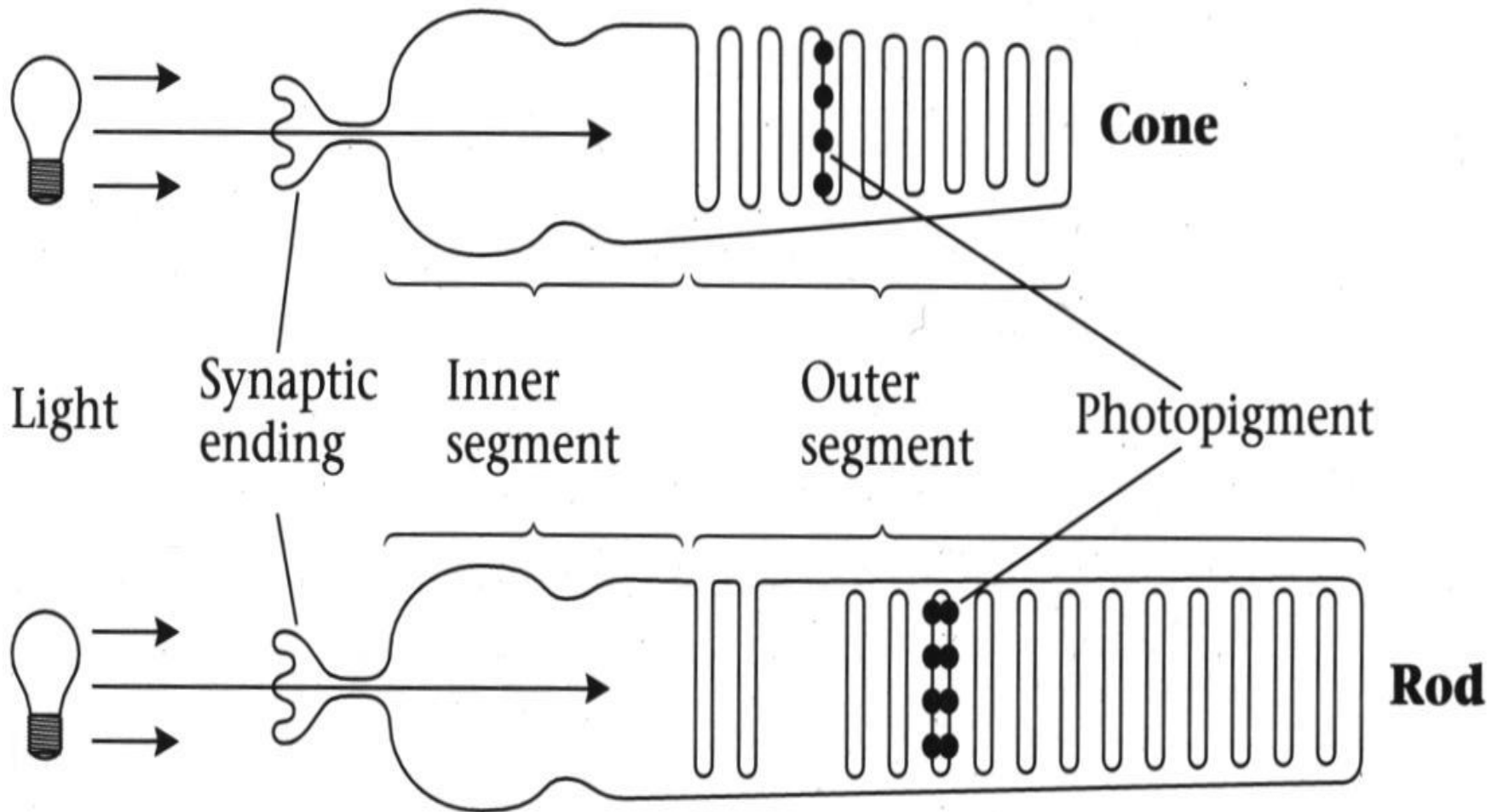
Cones	Rods
Fovea	Periphery
High light levels	Low light levels
Color	Monochromatic
Good acuity	Poor acuity

Shape of rods & cones (receptors of vision)

- Outer segment (modified cilia) has disks full of photosensitive pigment (rhodopsin) react with light to initiate action potential
- In cones is conical, small and contain 3 types of color-sensitive pigments
- In rods it is big, rod like and contain one type of photosensitive pigment
- There are Na channels in the outer segment
- Inner segment full of mitochondria (source of energy for Na-K pump), it is thick in cones
- There is Na-K pump in inner

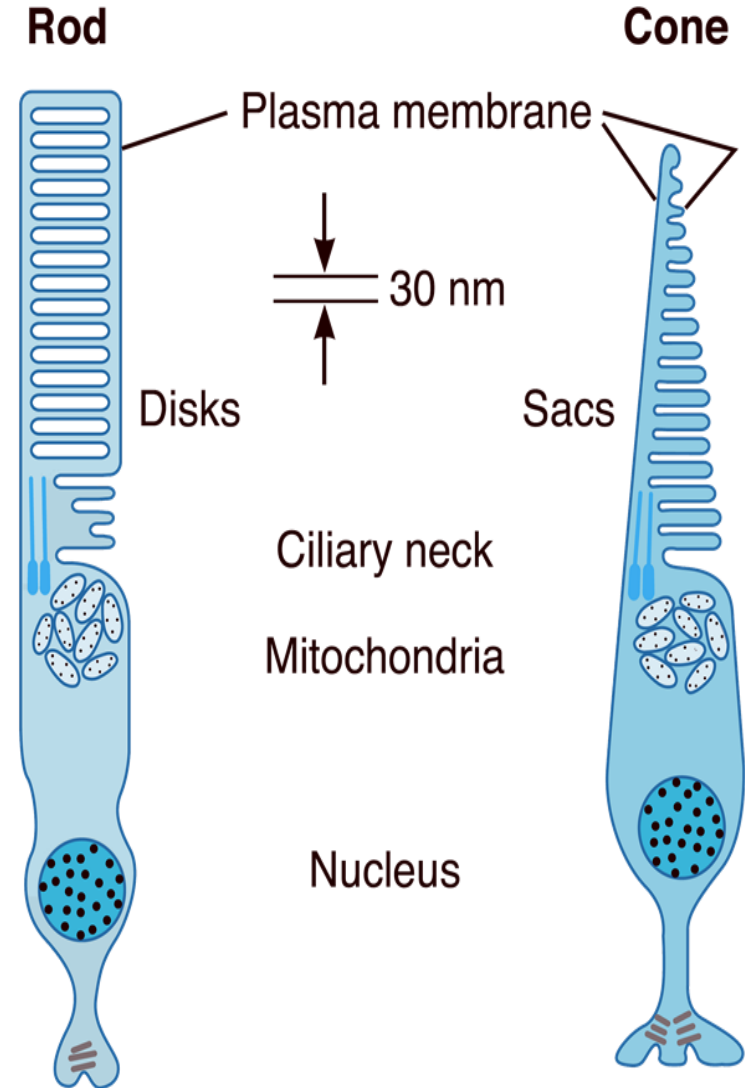


Inside the rod and the cone



Shape of rods & cones cont.

- The inner and outer segments are connected by a ciliary stalk through which the photosensitive compounds travel from the inner segment (where they are manufactured) to the outer segment of the rods and cones (where they are used)



Convergence

❑ Low convergence in cones :

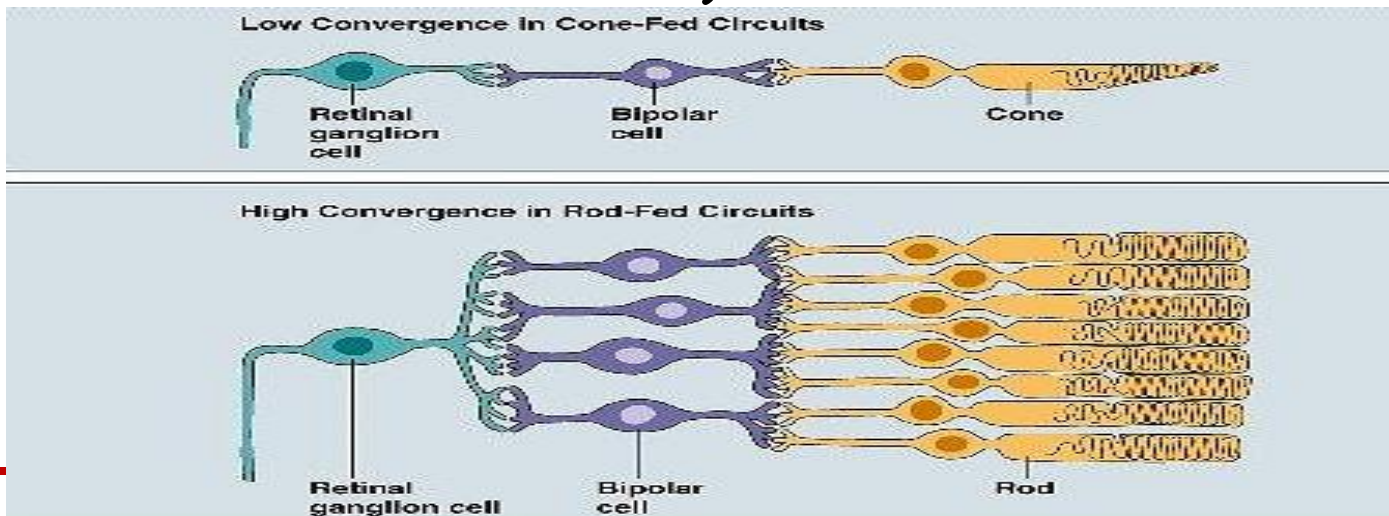
- each foveal cone synapse with →one bipolar cell →one ganglion cell →single optic nerve fiber

❑ Value of low convergence :

- increases visual acuity → integrated information from small area of retina

❑ Disadvantage:

- decreases sensitivity to light i.e need high threshold of illumination to stimulate cones)



Convergence *Cont.*

High convergence of rods:

- several rods about 300 synapse with one bipolar cell & one ganglion cell
- high convergence/ decreases visual acuity = integrated information from large area of retina
- - but increases sensitivity to light i.e so low light threshold stimulate the rods.
- - 120 million rods & 6 million cones converge on 1.2 million optic nerve fibers, (126 million receptors on 1.2 million nerve fibers) so convergence is 105 receptors : 1 fiber.

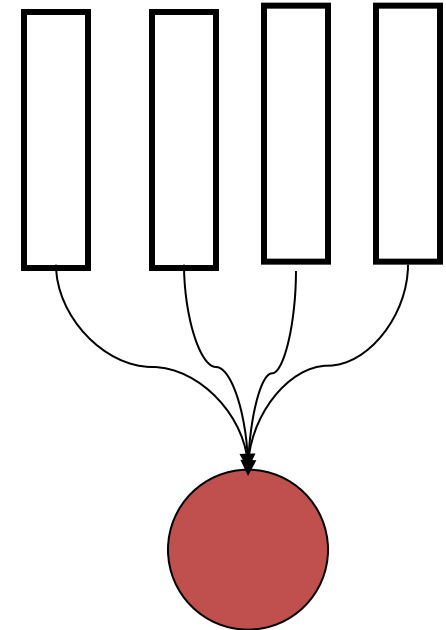
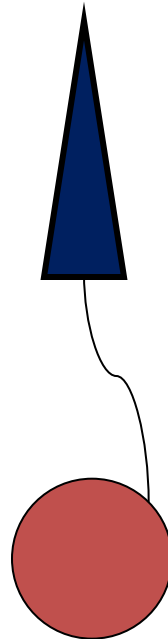
Convergence

Cones

Rods

- **Photoreceptors**

- **Ganglion cells**



Electrophysiology of Vision

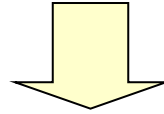
Genesis of electrical responses

Photosensitive compounds

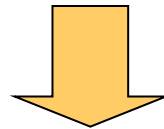
- In Rods its rhodopsin formed of / Scotopsin protein(opsin) + retinal (retinene 1 = aldehyde form of Vit A) = visual purple (Rhodopsin of the rods most strongly absorbs green-blue light and, therefore, appears reddish-purple, which is why it is also called "visual purple)
- -It forms 90% of rods protein ,stored in disks of rods at outer segment
- -At dark rhodopsin is in 11-cisretinal form (inactive) but light sensitive .
- Cones photosensitive pigment (iodopsine) formed of :- Opsin protein (photopsin) + retinal (retinene 1 = aldehyde form of Vit A)
- There are 3 types of photopsine in cones (photopsine I,II,III) each respond to a certain wave length of light for color vision.

Retinal photoreceptors mechanism

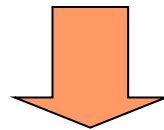
Light



Absorption by photosensitive substances



Structural change in photosensitive substances



Phototransduction



Action potential in the optic nerve

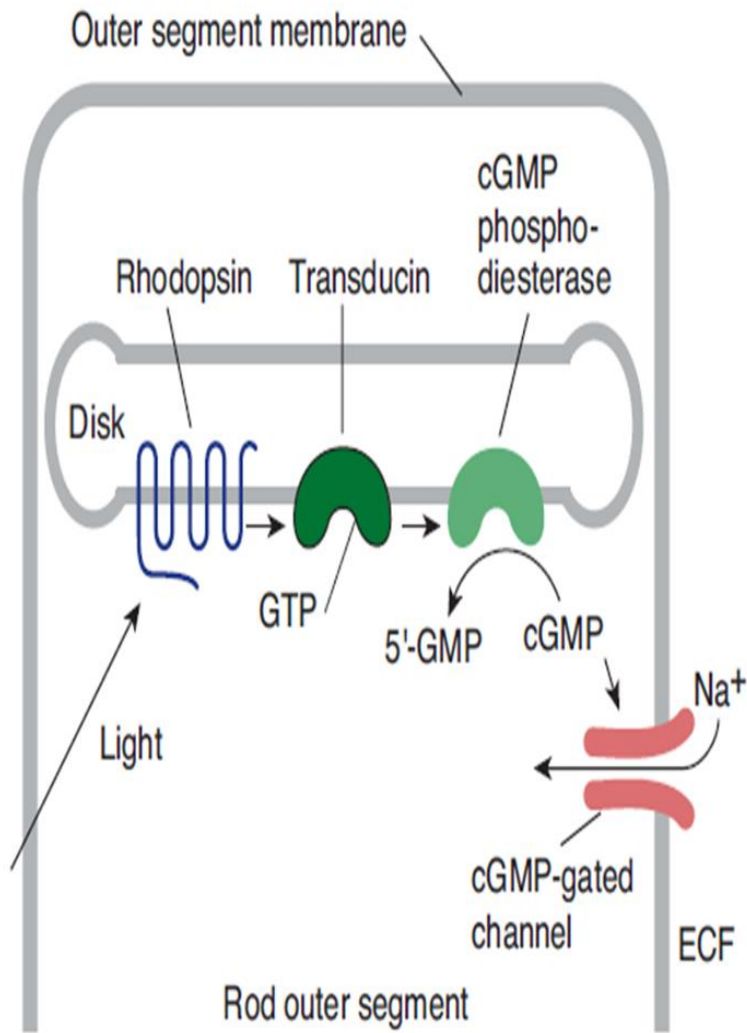
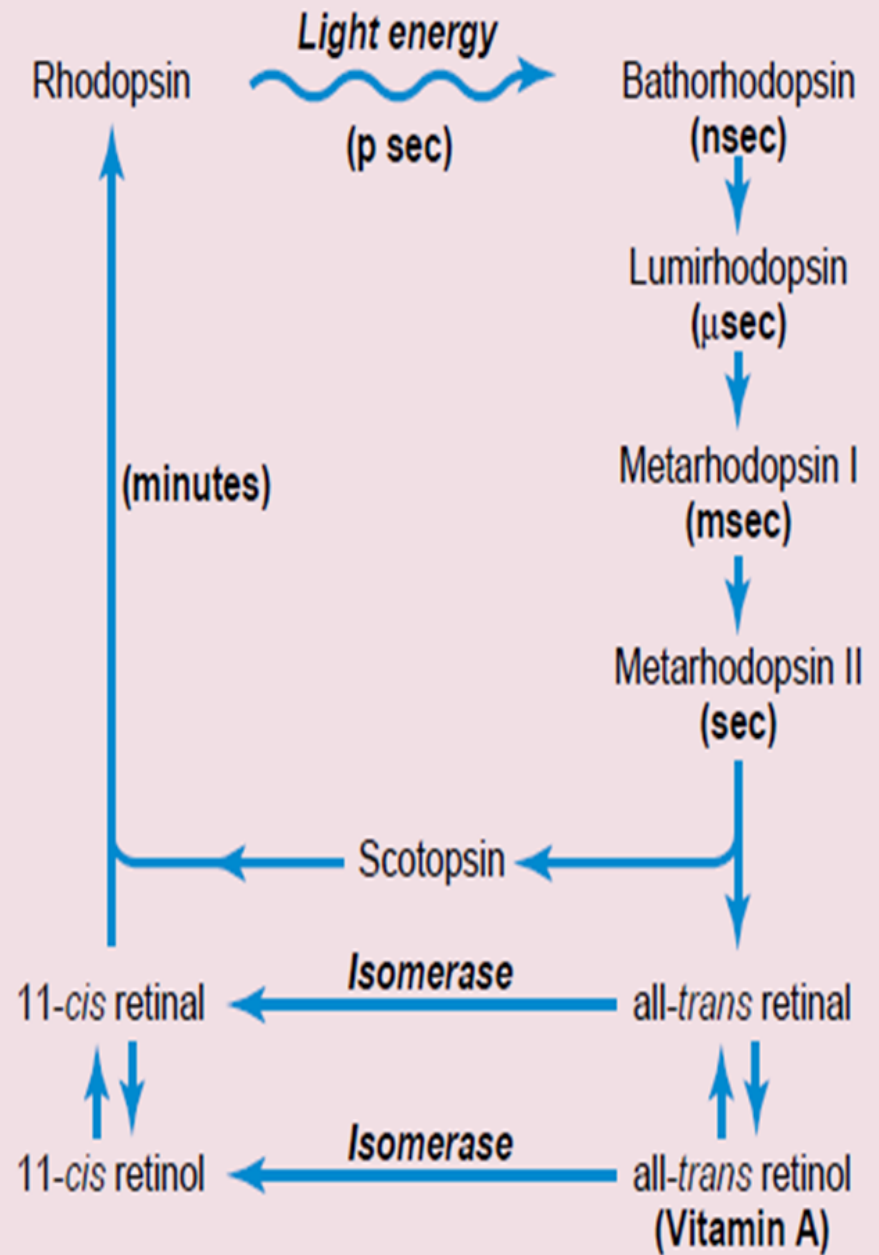


FIGURE 12-14 Initial steps in phototransduction in rods. Light activates rhodopsin, which activates transducin to bind GTP. This activates phosphodiesterase, which catalyzes the conversion of cGMP to 5'-GMP. The resulting decrease in the cytoplasmic cGMP concentration causes cGMP-gated ion channels to close.



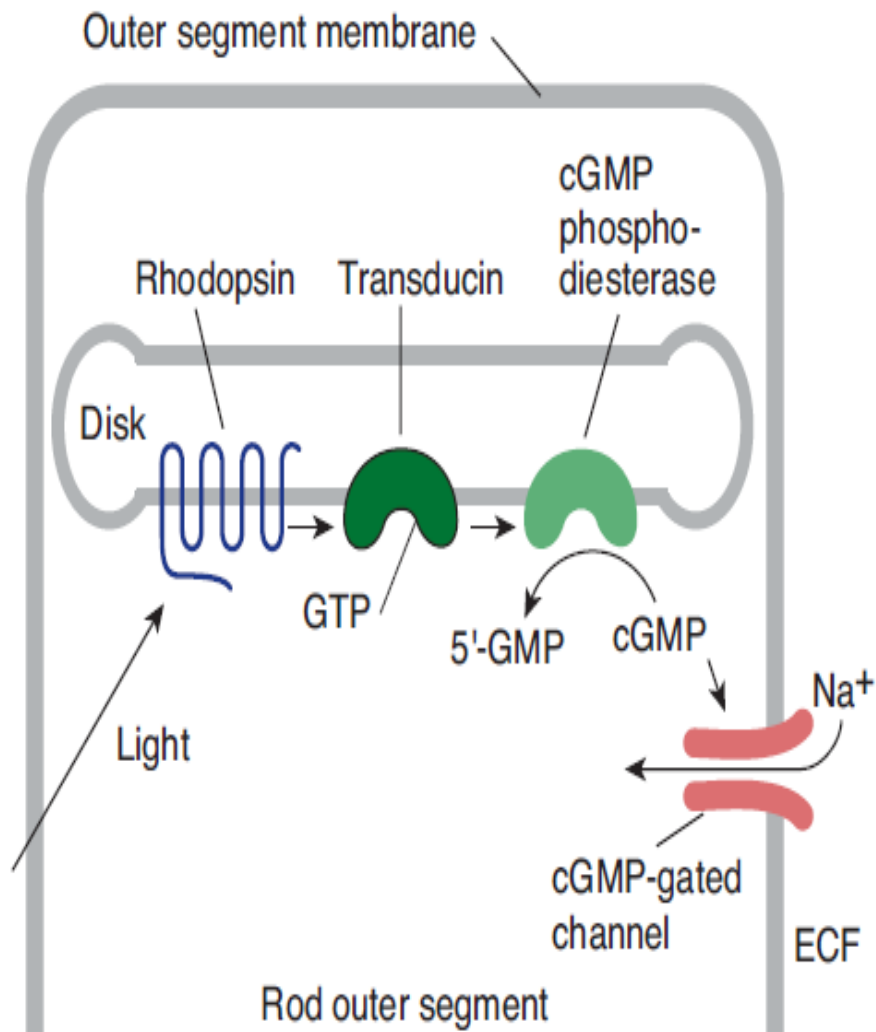


FIGURE 12-14 Initial steps in phototransduction in rods.

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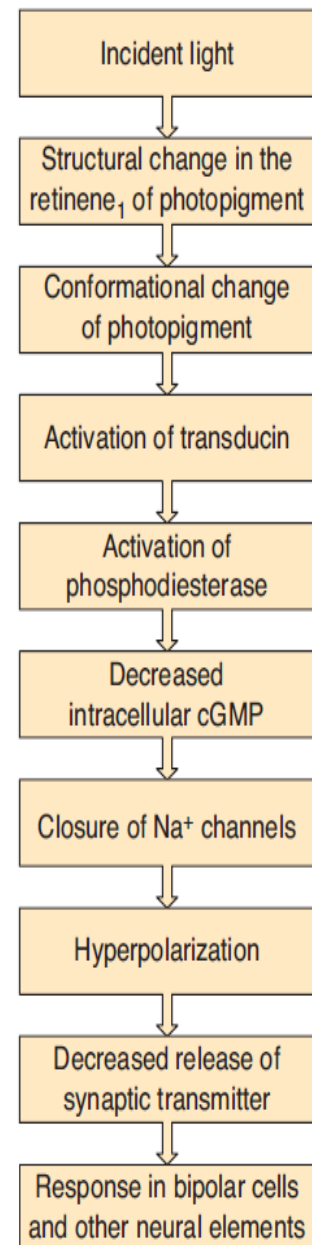
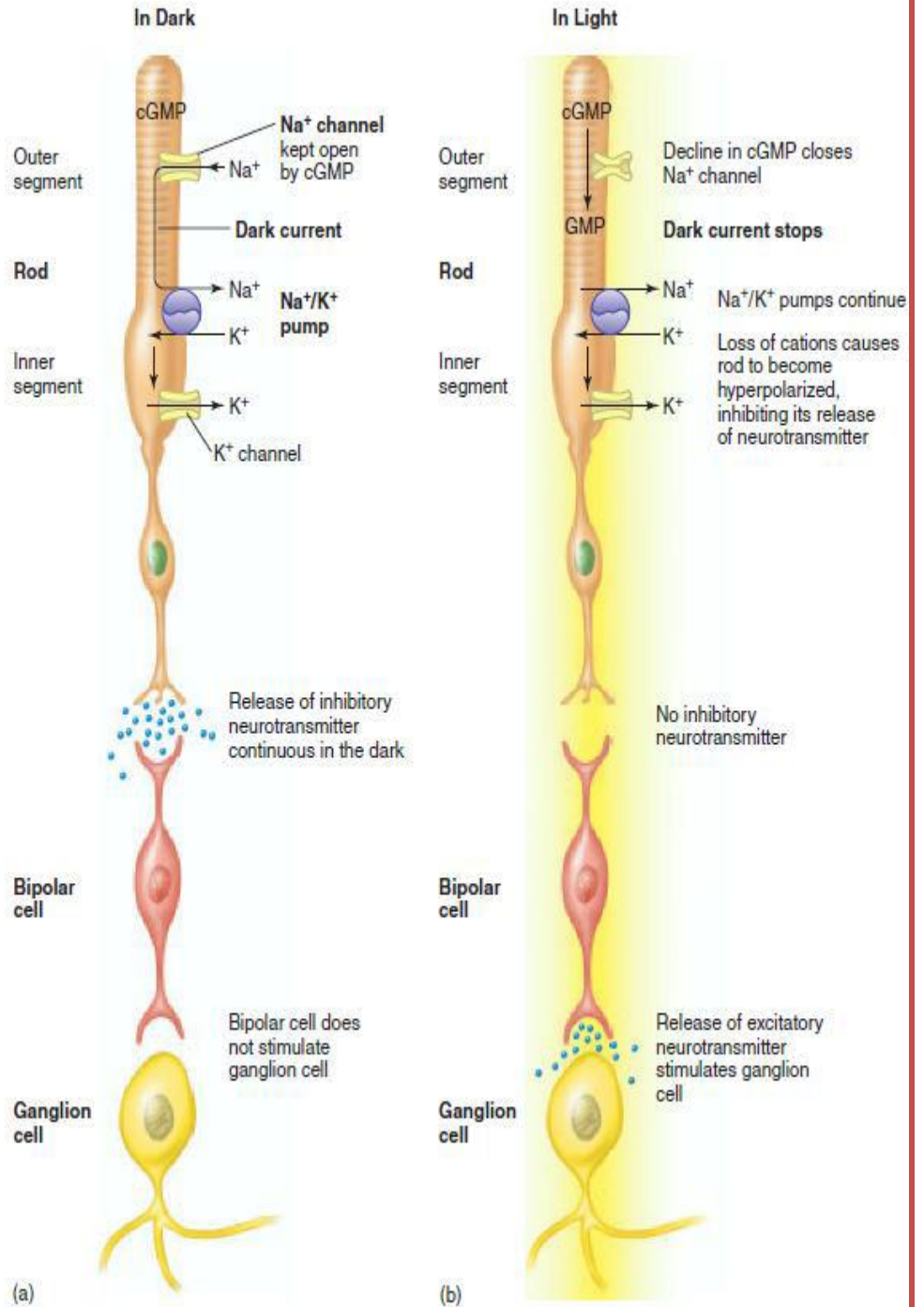
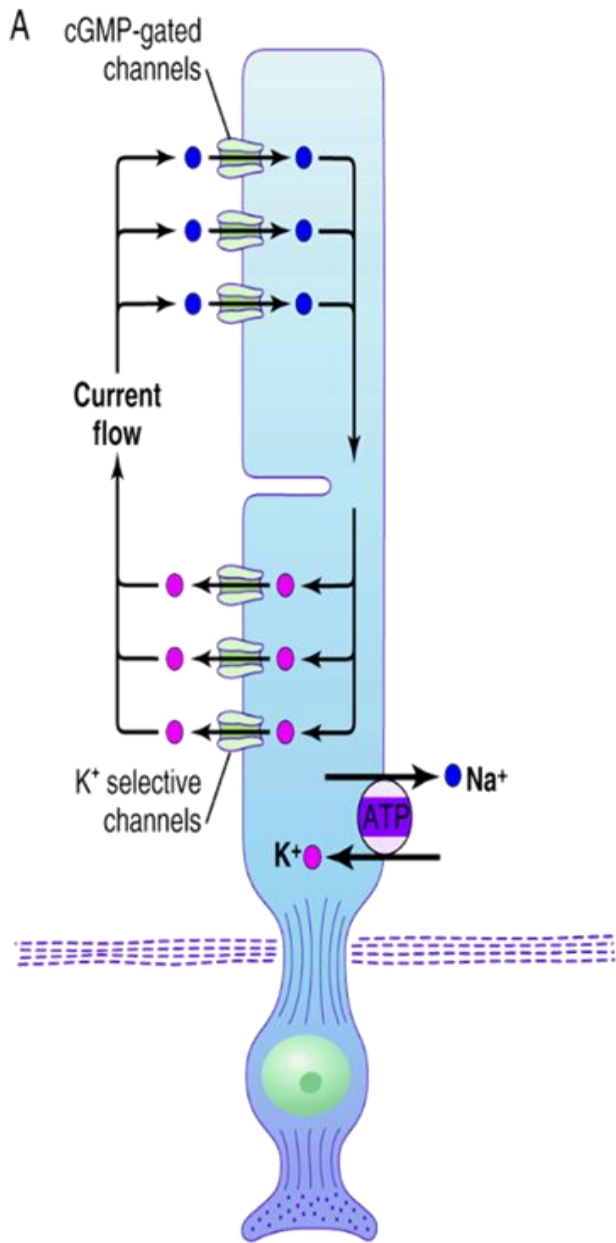
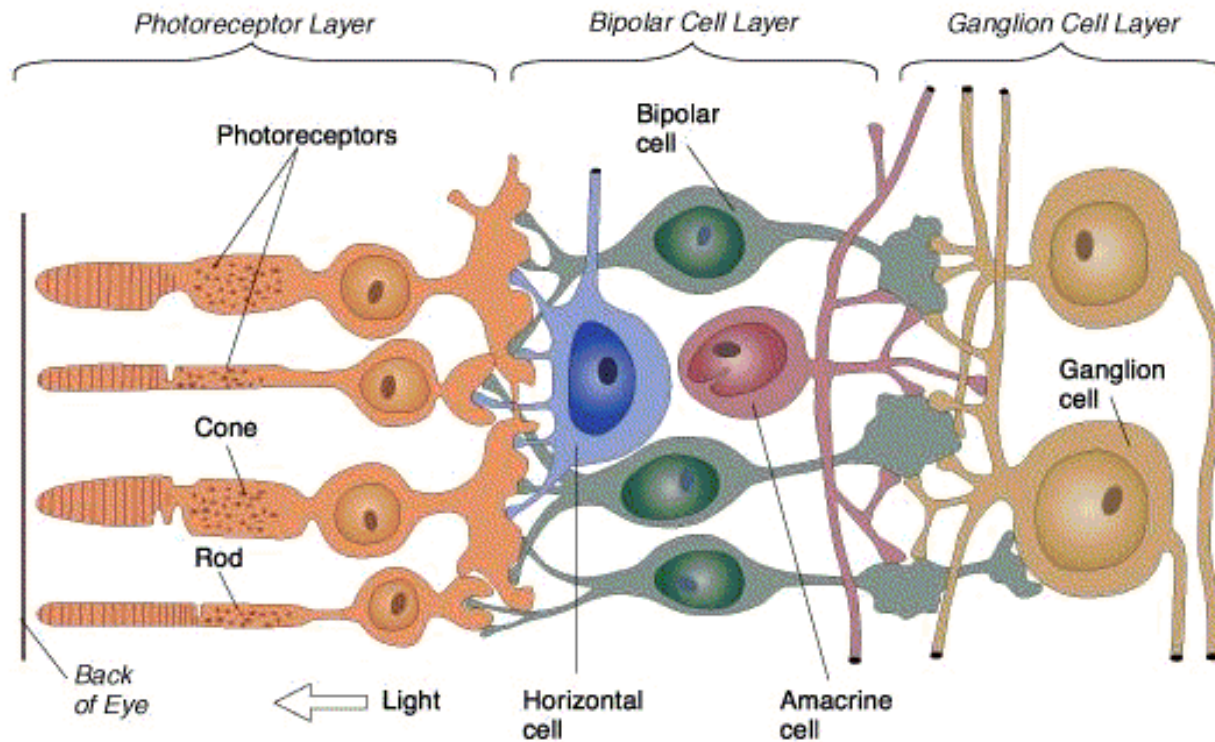


FIGURE 12-15 Sequence of events involved in phototransduction in rods and cones.



Retina



Electrophysiology of Vision

Electric recording in Retinal cells:

- Rods & Cones: Hyperpolarization
- Bipolar cells: Hyper- & Depolarization
- Horizontal cells: Hyperpolarization
- Amacrine cells: Depolarizing potential
- Ganglion cells: Depolarizing potential

Photoreceptor pigments

Photoreceptor pigments

- **Composition:**

- **Retinene1 (Aldehyde of vitamin A)**

- Same in all pigments

- **Opsin (protein)**

- Different amino acid sequence in different pigments

Rhodopsin (Rod pigment):

Retinene + scotopsin

Photoreceptor compounds_{-cont}

Rhodopsin (visual purple, scotopsin):

Activation of rhodopsin:

- In the dark:

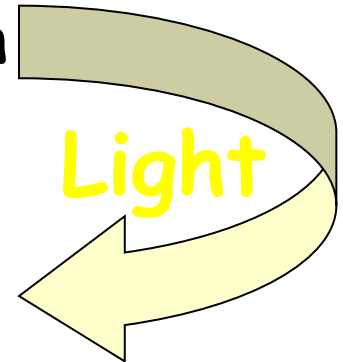
retinene1 in the 11-*cis* configuration

All-*trans* isomer



Metarhodopsin II

Closure of Na channels





Change in photopigment



Metarhodopsin II



Activation of transducin



Activation of phosphodiesterase



Decrease IC cyclic GMP



Closure of Na channels



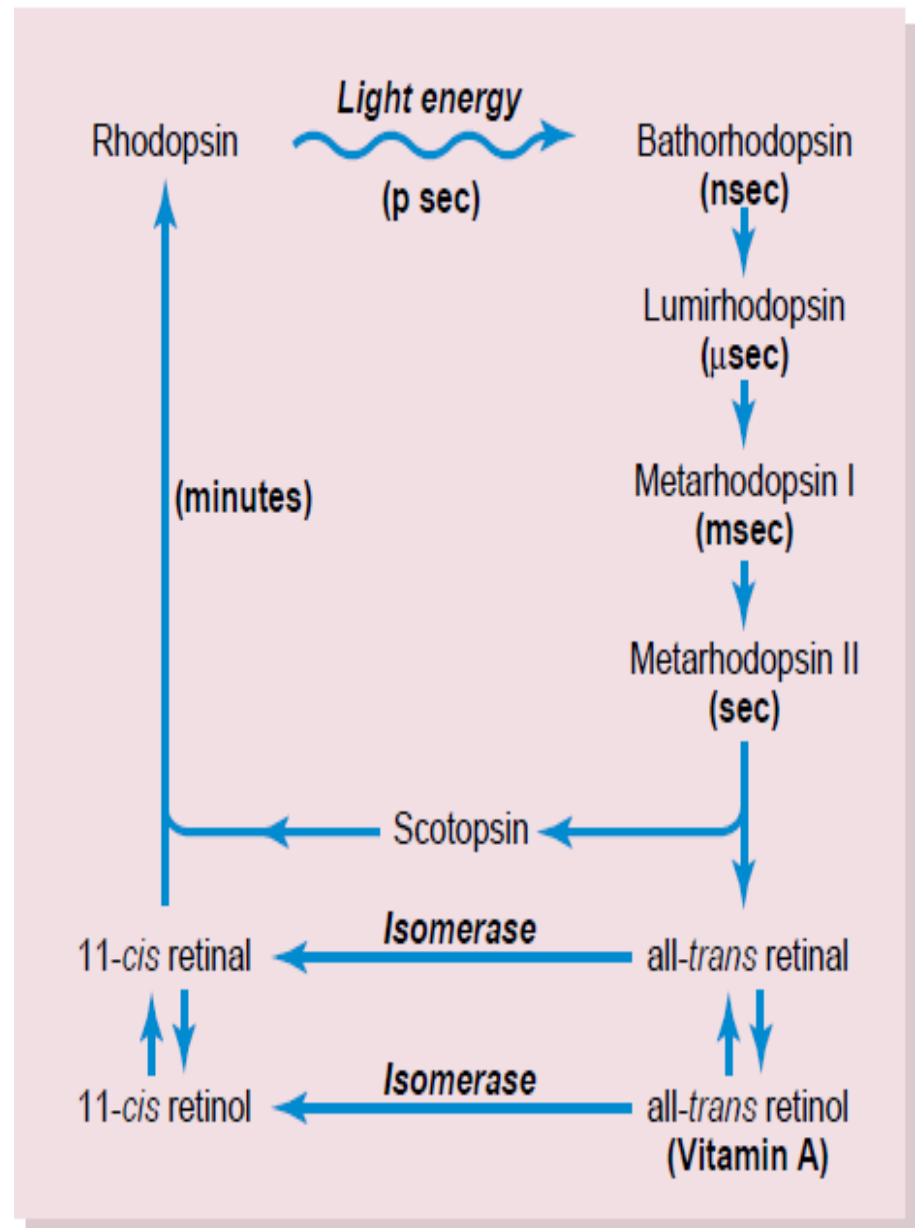
Hyperpolarization of receptor
Decrease release of synaptic transmitter
Action potential in optic nerve fibres

Visual Cycle

- Retinal is produced in the retina from Vitamin A, from dietary beta-carotene.
- light induces Isomerization of 11-cis-retinal into metarhodopsin I
- then into metarhodopsin II ,then into all-trans-retinal by a conformational change (bleaching) and all trans-retinal separate from opsin by light and opsin remains alone.
- In dark:
 - Trans-retinal is enzymatically re-converted to the 11-cis-retinal form via an retinal isomerase enzyme.
 - Since the scotopsin is present alone (having been removed from the rhodopsin) it immediately will combine with 11-cis-retinal to regenerate new rhodopsin
- *-*At dark : 11cis-Retinal in rods + scotopcin → → rhodopsin regeneration*

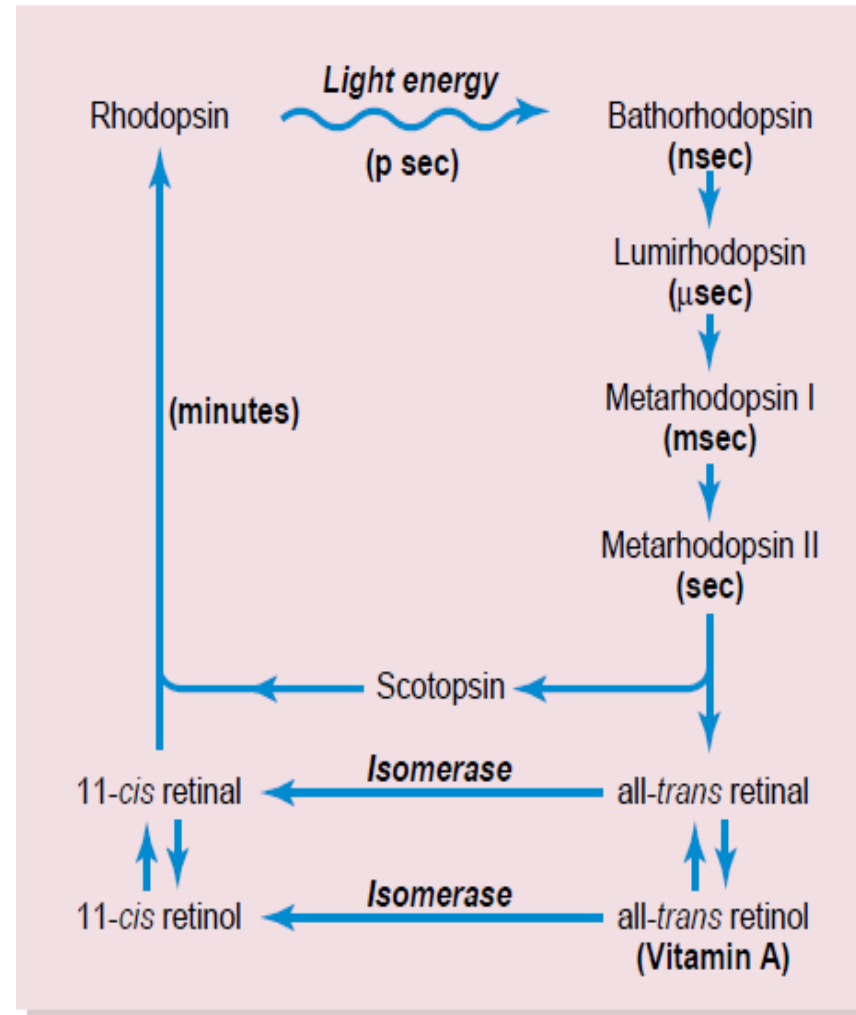
Scotopsin Retinal Visual Cycle

- The amount of rhodopsin in the receptors therefore varies inversely with the incident light level.
- When there is excess retinal in the retina, it is converted back into vitamin A, thus reducing the amount of light-sensitive pigment in the retina.



Photochemistry of Color Vision by the Cones

- Photopsins Retinal Visual Cycle
- The cones are about 30 to 300 times less sensitive than rods to light



Dark adaptation

Dark adaptation:

- Increased sensitivity of the photoreceptors when vision shifts from bright to dim light

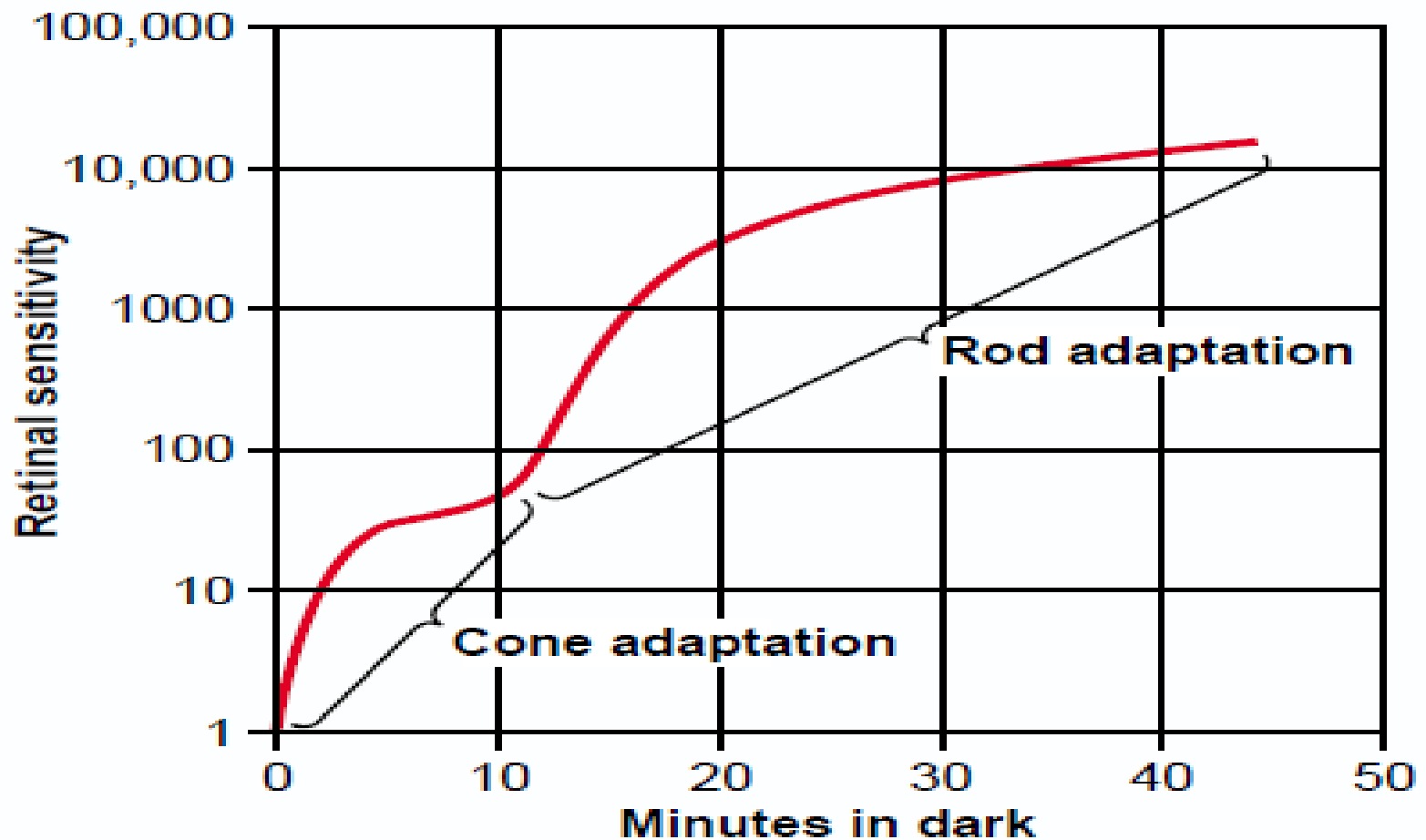
Dark adaptation

- Reaches max in 20 minutes
- First 5 minutes threshold of cones ↓
- 5 to 20 mins ↑ Sensitivity of rods

Mechanism of dark adaptation:

↑ Regeneration of rhodopsin

Adaptation Curve



NYCTALOPIA:- (night blindness)

- Vitamine A (main source of retinal of rhodopsin) deficiency cause rods , cones & retinal degeneration & loss of rods
- -- R / Intravenous vit A if receptors are well.

Light adaptation:-

■ When light switched on again, the rods are knocked out of action (they stop sending AP at high levels of light) & cones start to function to adjust & adapt to the level of brightness in 5 min this is called Light adaptation



THANK YOU

SHUKRAN GAZEELAN