The Special Senses
Vision – 3
Photo-transduction

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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
- Know the meaning of nyctalopia
- Contrast the dark and light adaptation

Physiology of Vision

- Stimulus: Light
- Receptor: Retina (Photoreceptors)

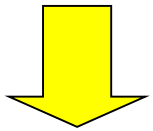
Light

- **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

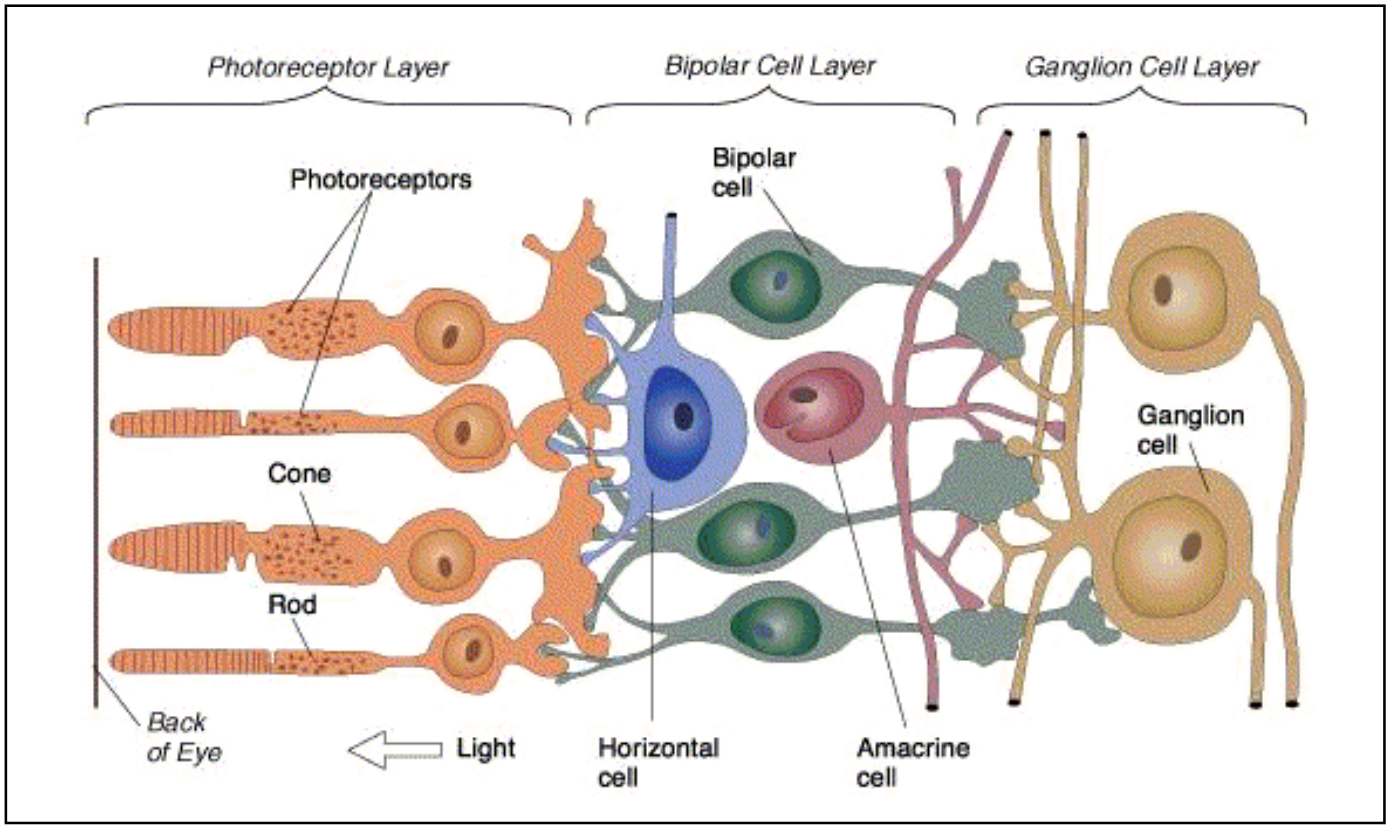
Photoreceptors
Rods & Cones

Morphology & Distribution

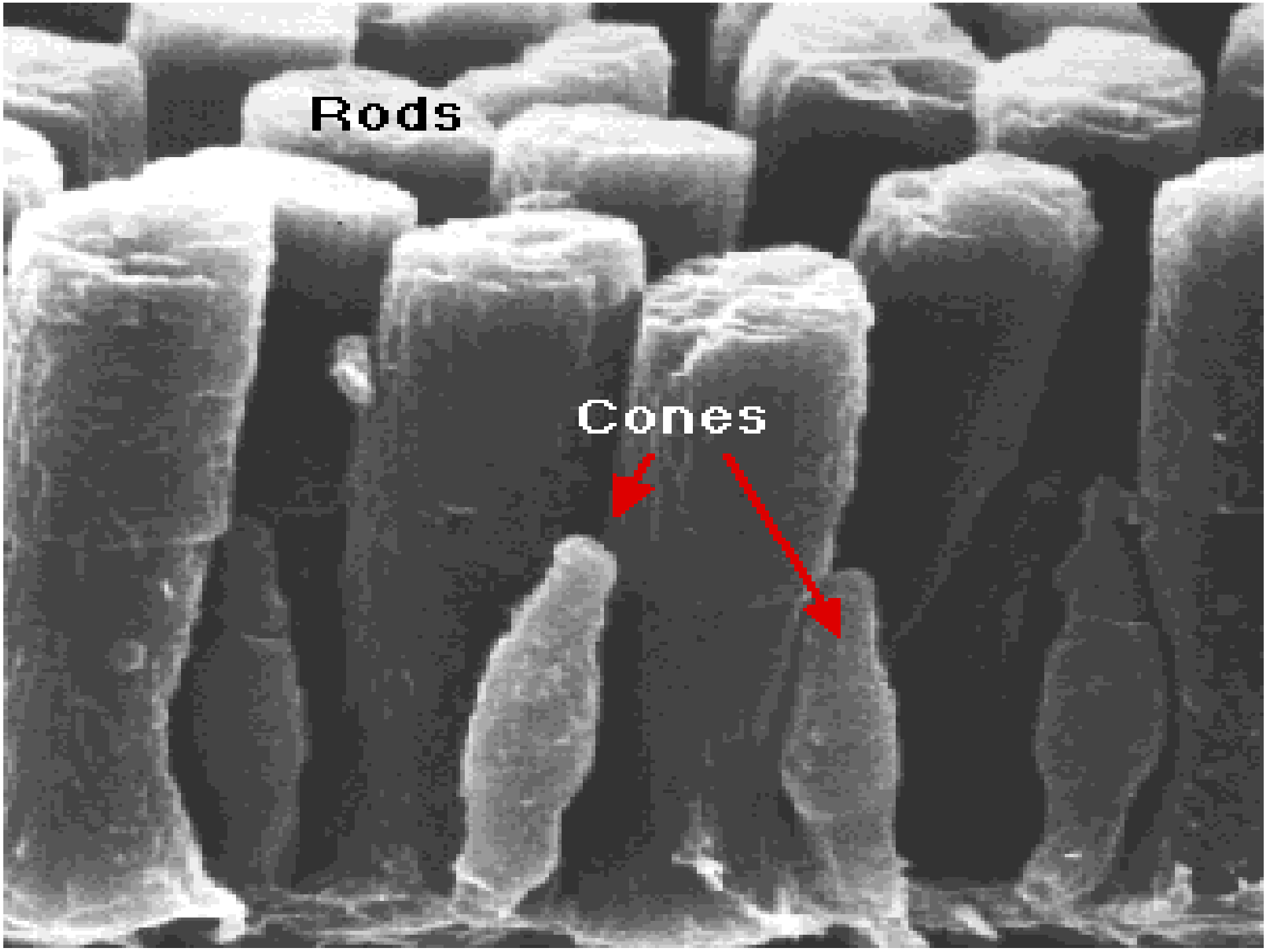
Retina

Back of retina, pigment epithelium

(Choroid)



Light


Rods
Cones

Photoreceptors

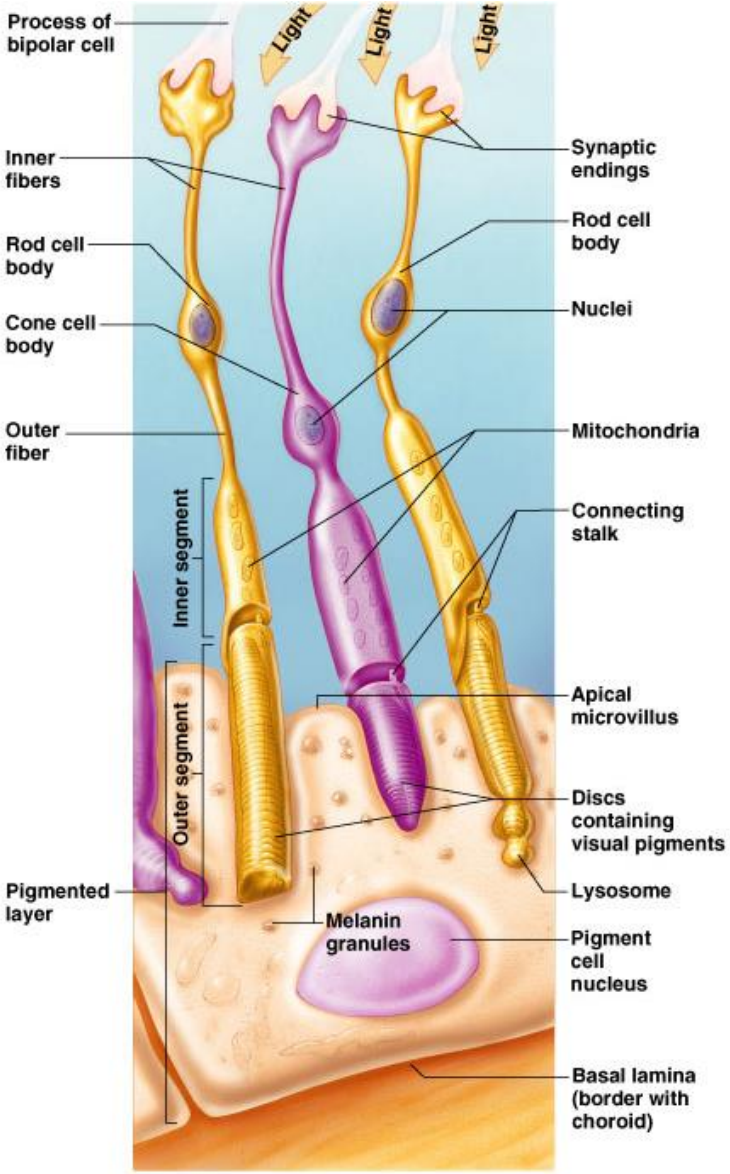


Figure 16.11

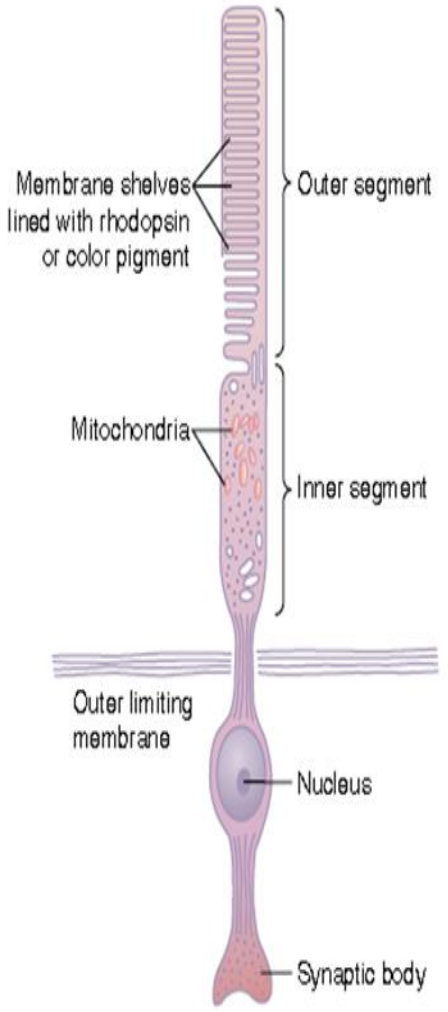
Retina: photoreceptors

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

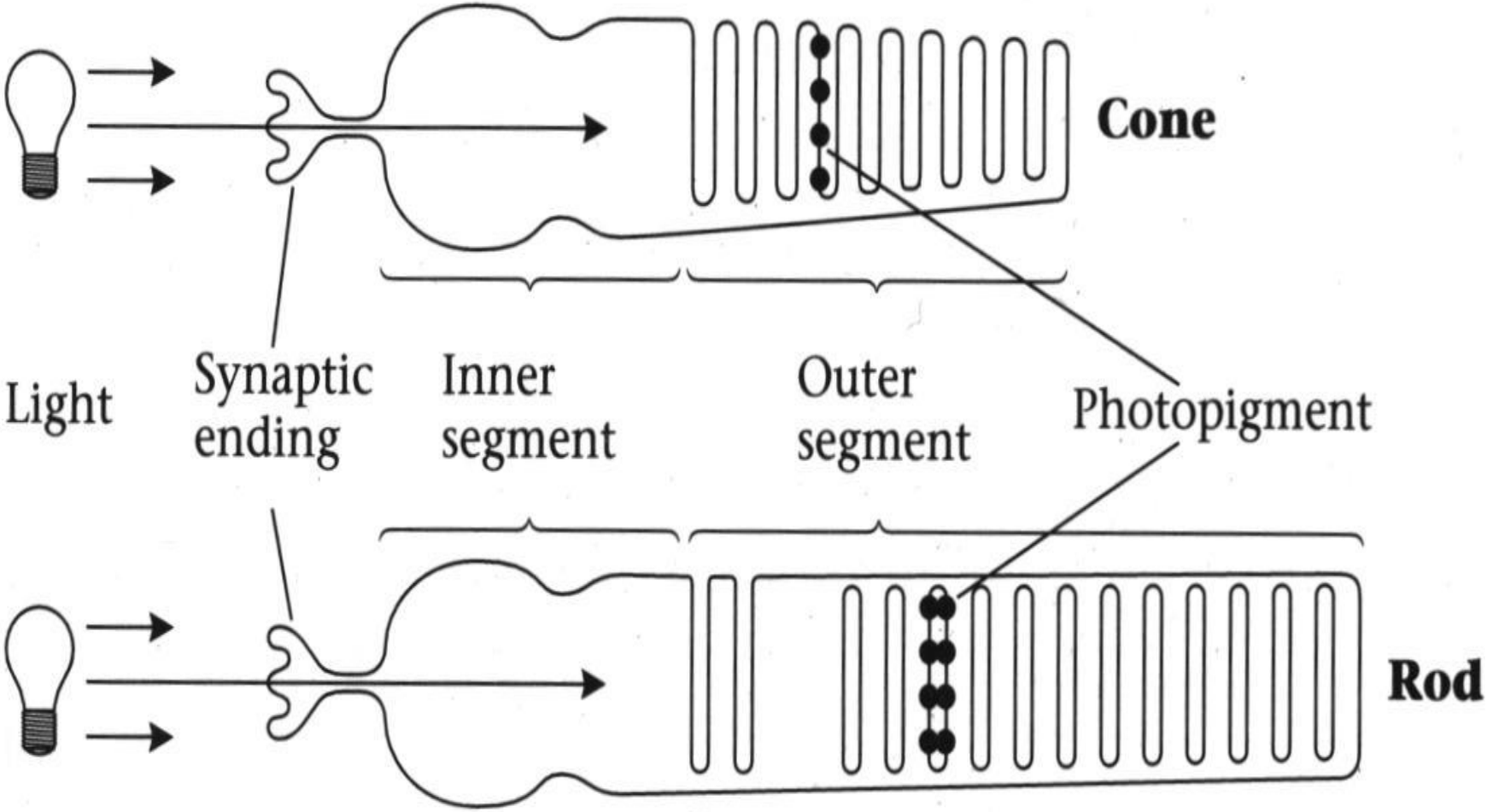
Cones	Rods
Fovea	Periphery
High light levels	Low light levels
Color	Monochromatic
Good acuity	Poor acuity

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 photosensitive pigments
- In rods it is big, rode like and contain one type of rhodopsin
- 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 segment

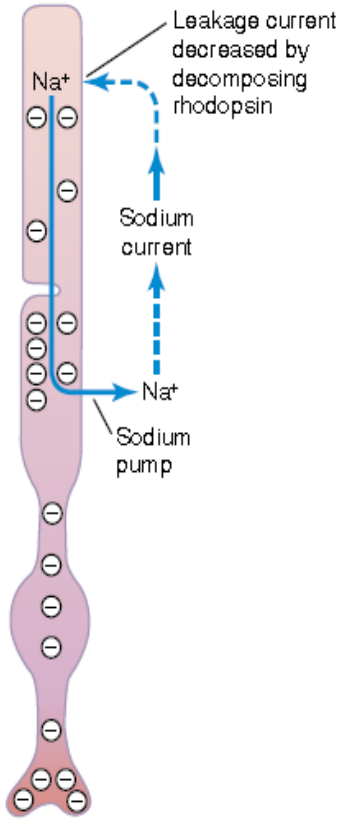


Inside the rod and the cone



Shape of rods & cones cont.

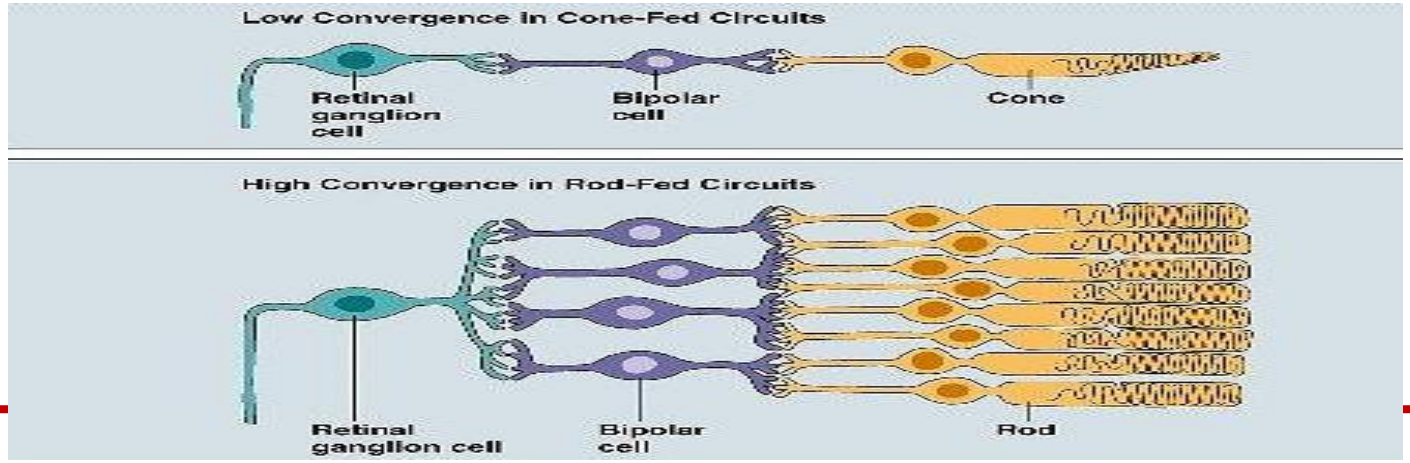
- The inner and outer segments are connected by a ciliary stalk through which the photosensitive compounds travel from the inner segment (where they are manufactured) to the outer segment of the rods and cones (where they are used)



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.

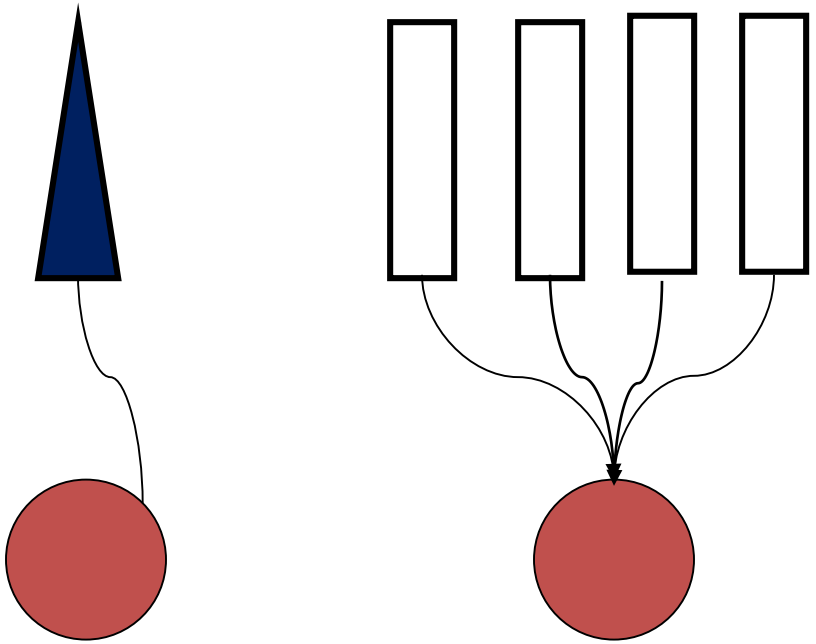
High convergence of rods:

- several rodes 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 rode& 6 million cone converge on 1.2 million optic nerve fibers , (126 million receptors on 1.2 million nerve fiber)so convergence is 105 receptor : 1 fiber.

Convergence

Cones Rods

- Photoreceptors
- Ganglion cells



Electrophysiology of Vision

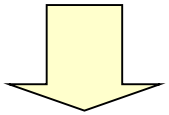
Genesis of electrical responses

Photosensitive Compounds

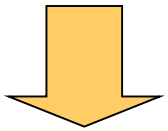
- 1. photosensitive pigment of cones (iodopsine) formed of :- Opsin protein(photopsin) + retinal (retinene 1 = aldhyde form of Vit A)
- 2-There are 3 types of iodopsin in cones (photopsine I,II,III) each respond to a certain wave length of light for color vision.
- 3-In Rods its rhodopsin formed of / Scotopsin protein+ retinal (retinene 1 = aldhyde form of Vit A)
- 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 form which increase sensitivity of rods to light

Retinal photoreceptors mechanism

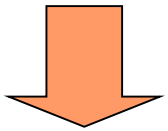
Light



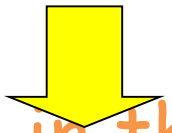
Absorption by photosensitive substances



Structural change in photosensitive substances



Phototransduction



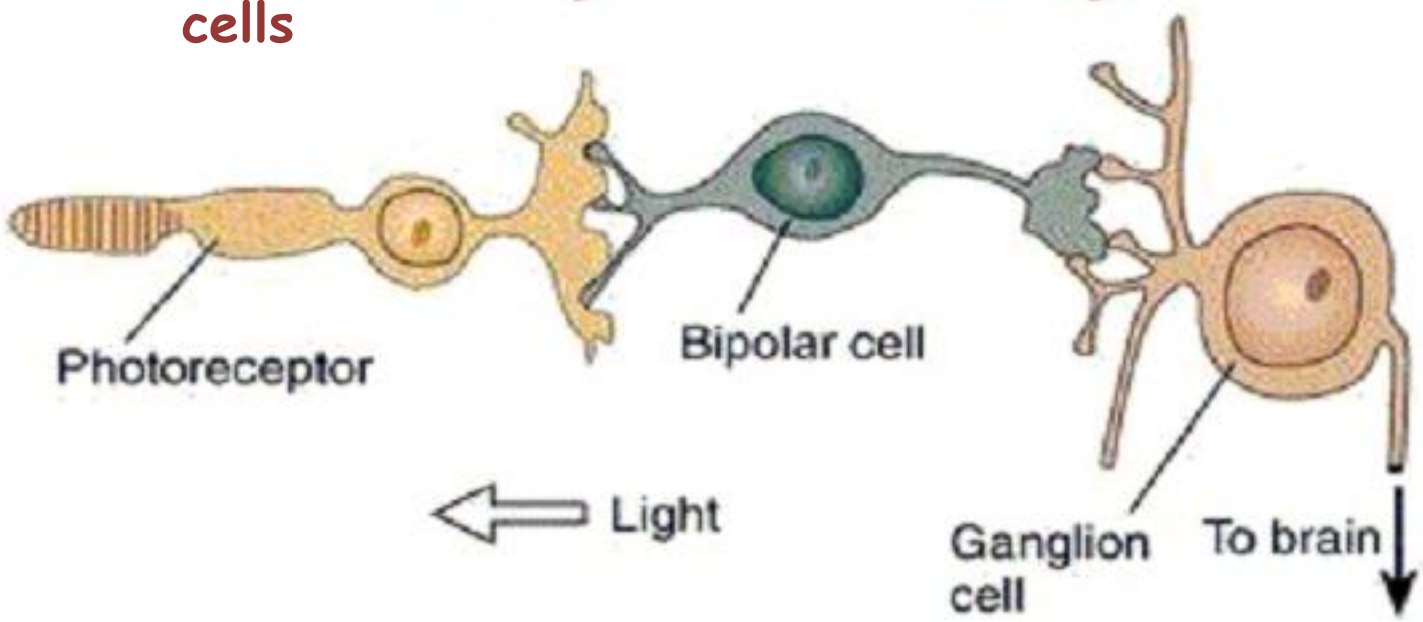
Action potential in the optic nerve

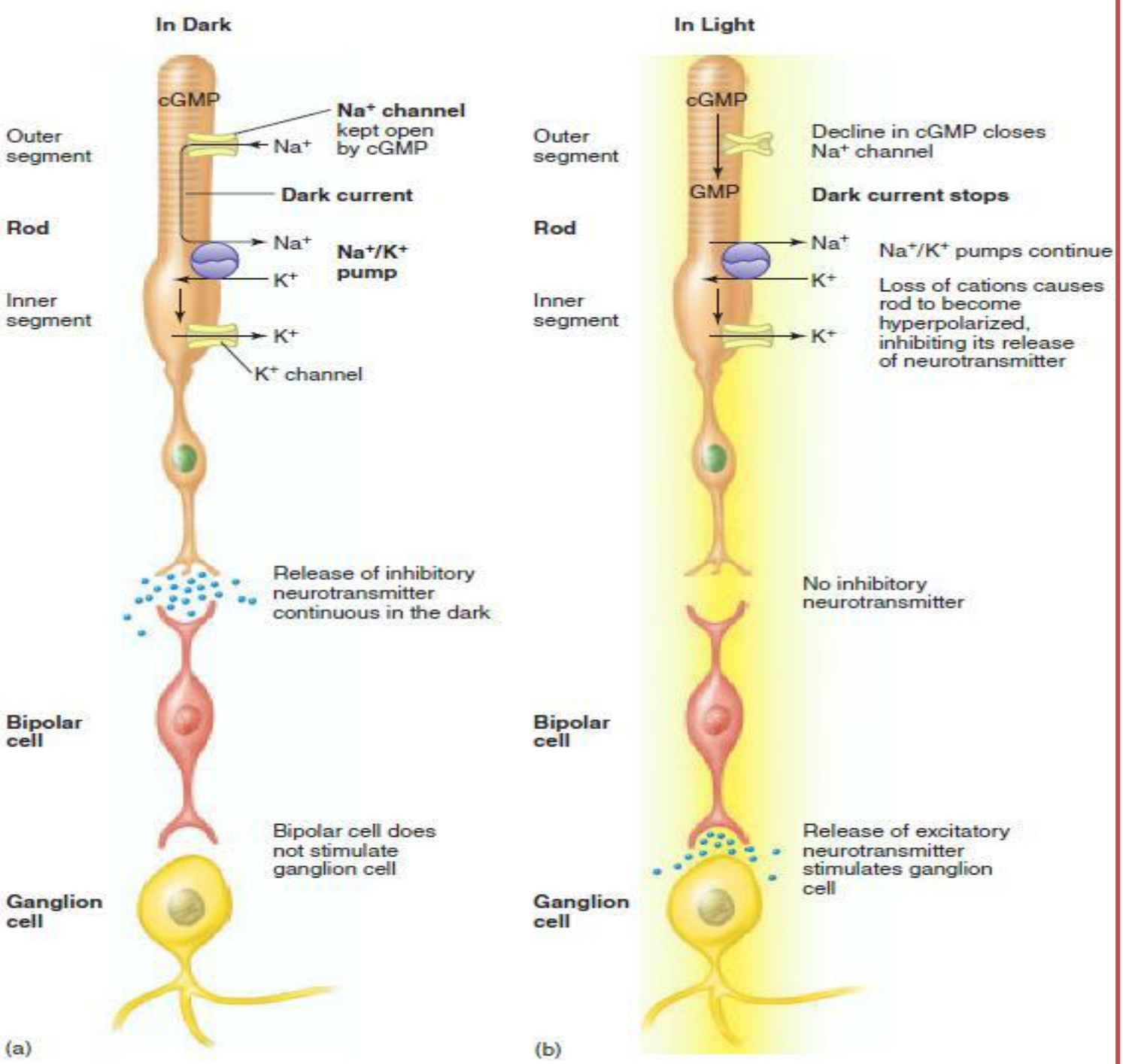
Retina: Neural Circuitry

Light hits photoreceptors, sends signal to the bipolar cells

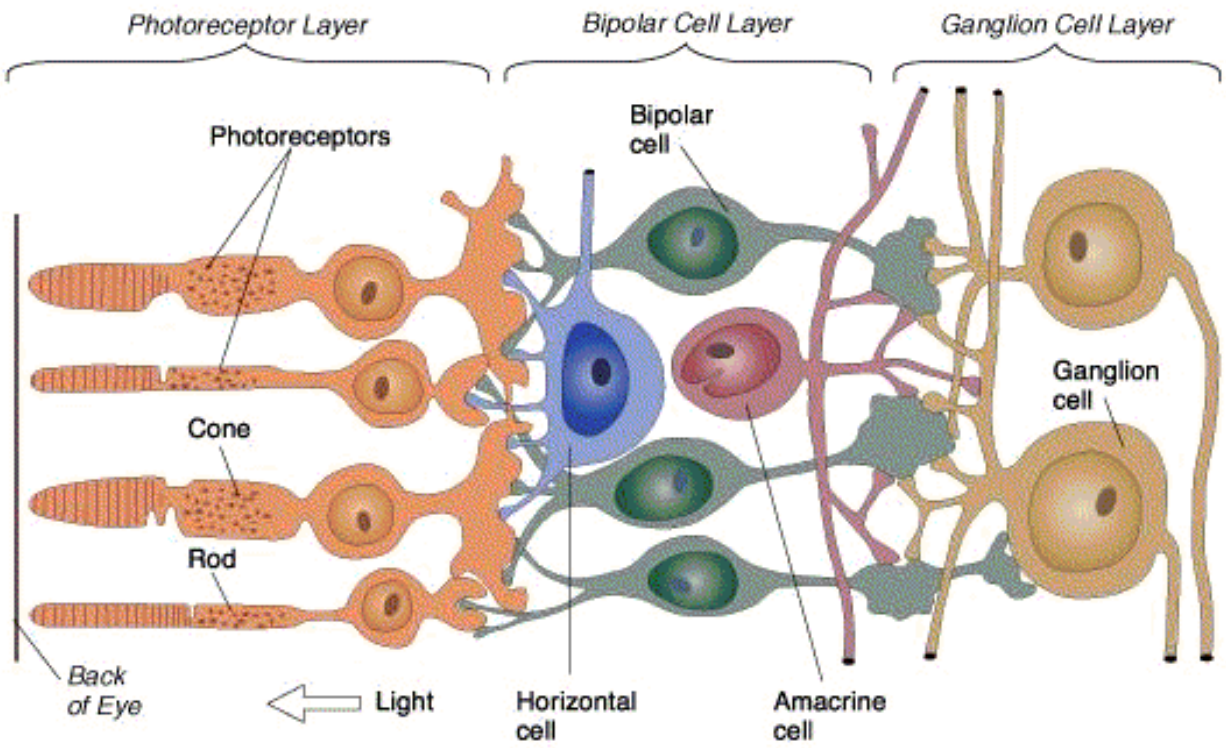
Bipolar cells

Ganglion




In Dark
cGMP
Na+ channel kept open by cGMP
Outer segment
Na+
Dark current
Rod
Na+
Na+/K+ pump
K+
Inner segment
K+
K+ channel
Release of inhibitory neurotransmitter continuous in the dark
Bipolar cell
Bipolar cell does not stimulate ganglion cell
Ganglion cell
(a)
In Light
cGMP
Decline in cGMP closes Na+ channel
Outer segment
GMP
Dark current stops
Rod
Na+
Na+/K+ pumps continue
K+
Loss of cations causes rod to become hyperpolarized, inhibiting its release of neurotransmitter
Inner segment
K+
No inhibitory neurotransmitter
Bipolar cell
Release of excitatory neurotransmitter stimulates ganglion cell
Ganglion cell
(b)

Retina


Photoreceptor Layer
Bipolar Cell Layer
Ganglion Cell Layer
Photoreceptors
Bipolar cell
Ganglion cell
Cone
Rod
Back of Eye
Light
Horizontal cell
Amacrine cell

Electrophysiology of Vision

Electric recording in Retinal cells:

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

Photoreceptor pigments

Photoreceptor pigments

- **Composition:**
  - **Retinine1 (Aldehyde of vitamin A)**
    - Same in all pigments
  - **Opsin (protein)**
    - Different amino acid sequence in different pigments
    - Rhodopsin (Rod pigment):
      - **Retinine + scotopsin**

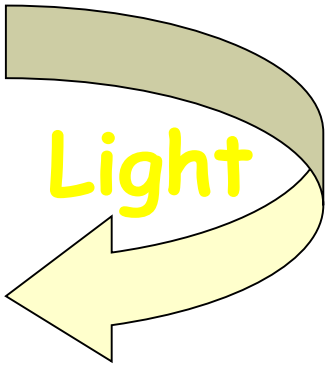
Photoreceptor compounds-cont

Rhodopsin (visual purple, scotopsin):

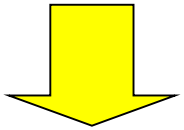
Activation of rhodopsin:

- **In the dark:**

retinine1 in the 11-*cis* configuration



All-*trans* isomer



Metarhodopsin II

Closure of Na channels

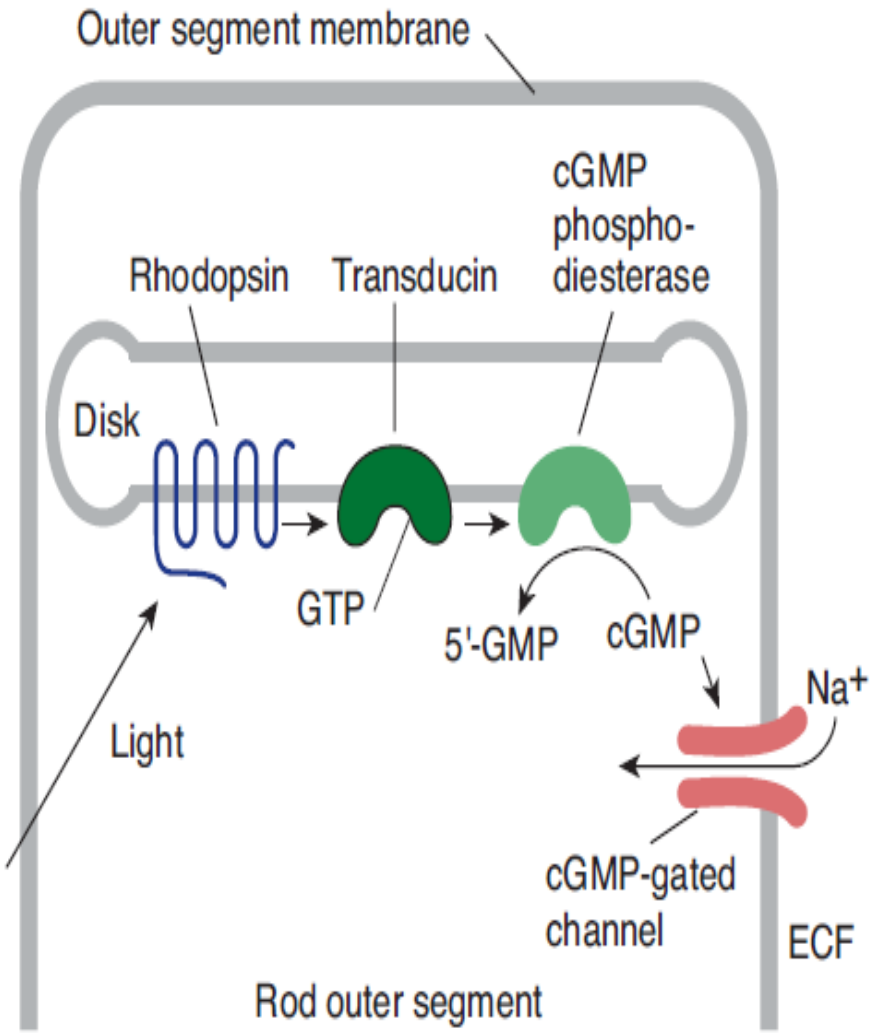


FIGURE 12–14 **Initial steps in phototransduction in rods.**
Light activates rhodopsin, which activates transducin to bind GTP. This activates phosphodiesterase, which catalyzes the conversion of cGMP to 5'-GMP. The resulting decrease in the cytoplasmic cGMP concentration causes cGMP-gated ion channels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

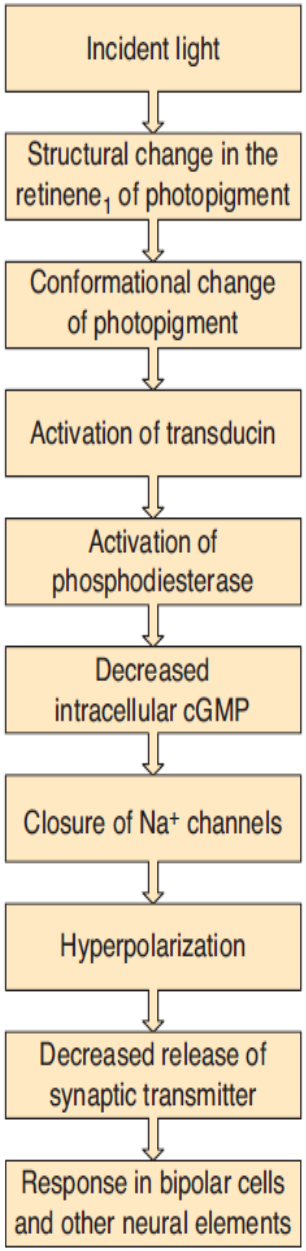


FIGURE 12–15 **Sequence of events involved in phototransduction in rods and cones.**

Change in photopigment

Metarhodopsin II

Activation of transducin

Activation of phophodiesterase

Decrease IC cyclic GMP

Closure of Na channels

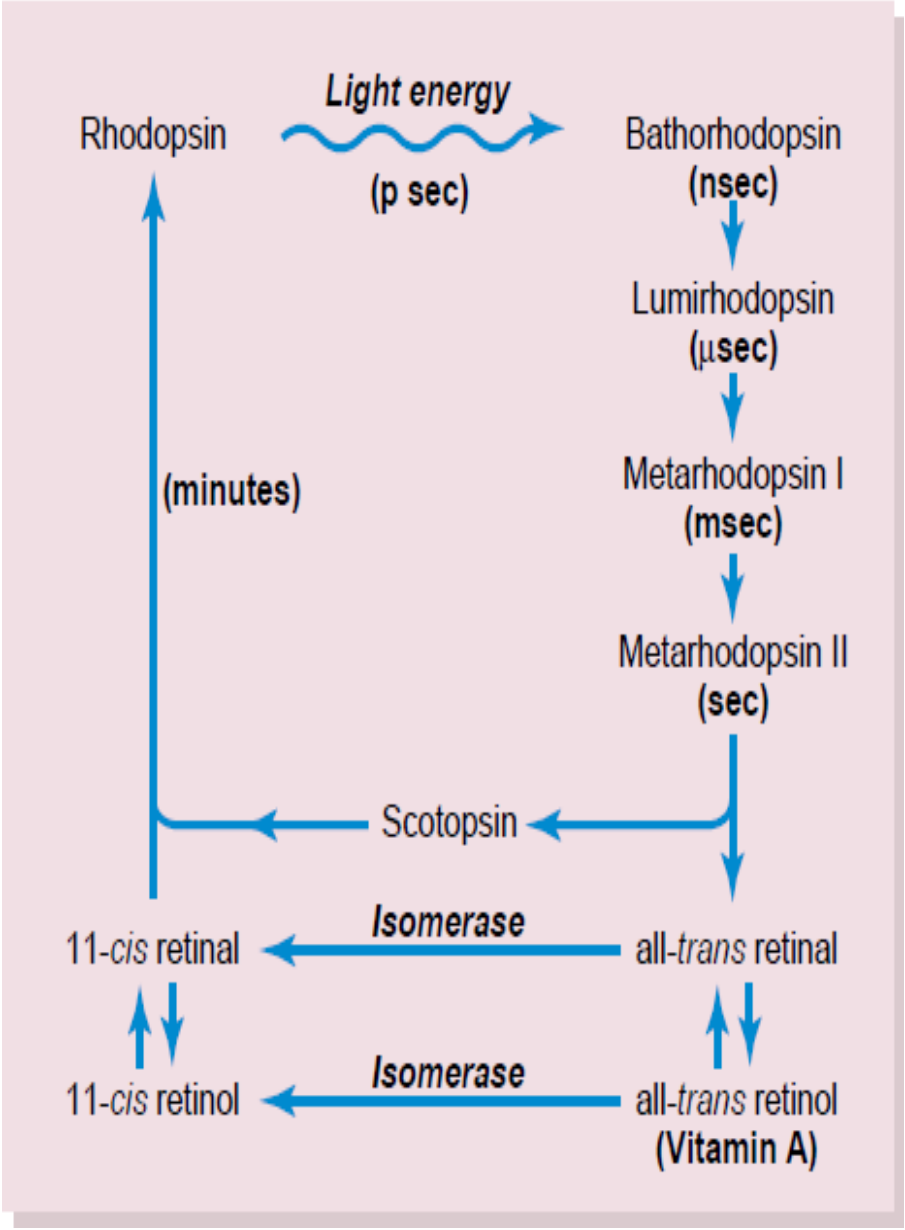
Hyperpolarization of receptor
Decrease release of synaptic tramitter
Action potential in optic nerve fibres

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

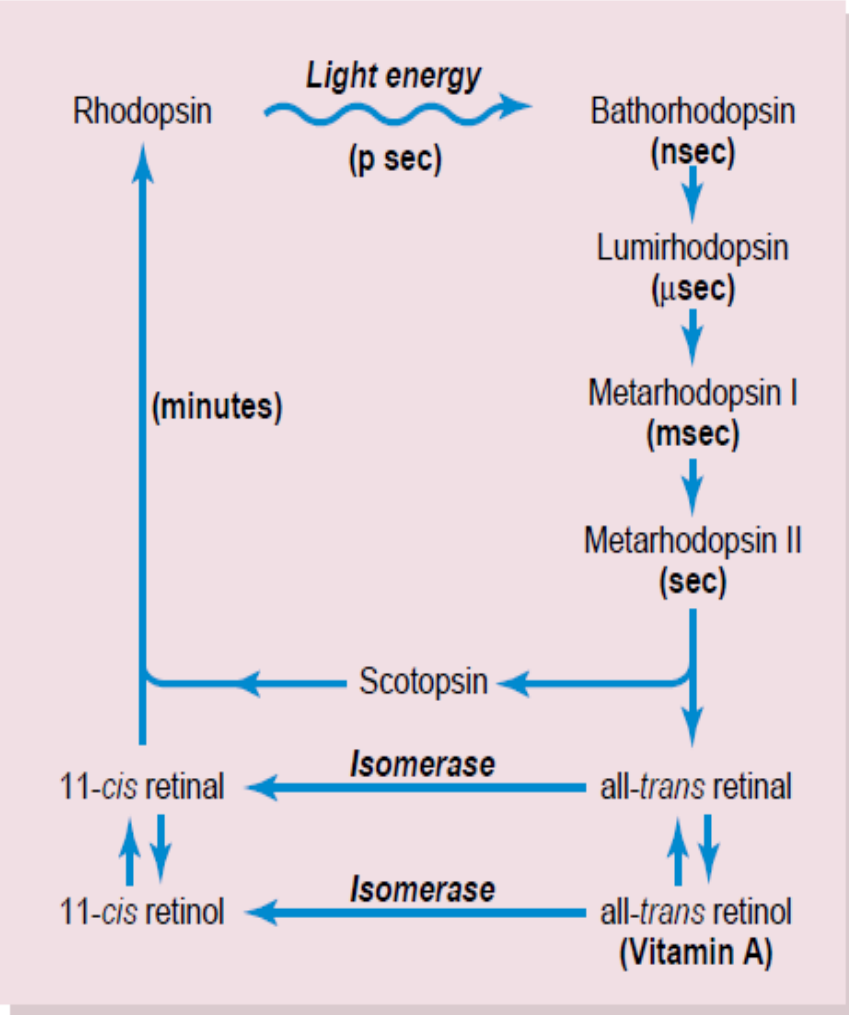
- The amount of rhodopsin in the receptors therefore varies inversely with the incident light level.
- When there is excess retinal in the retina, it is converted back into vitamin A, thus reducing the amount of light-sensitive pigment in the retina.

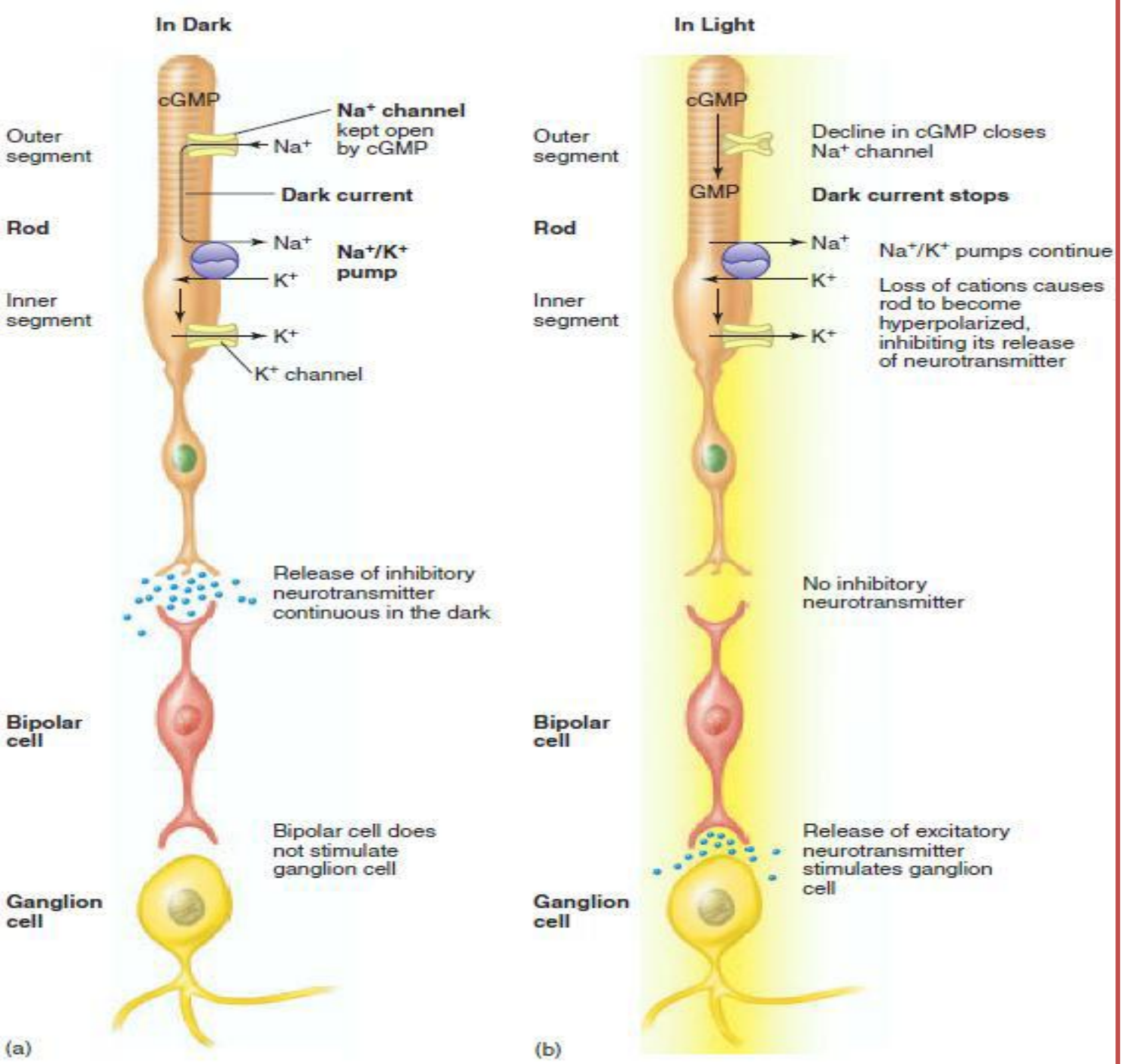


Photochemistry of Color Vision by the Cones

Photopsins Retinal Visual Cycle

- The cones are about 30 to 300 times less sensitive than rods to light

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Na+ channel kept open by cGMP
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Na+
Dark current
Rod
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Na+/K+ pump
K+
Inner segment
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Inner segment
K+
No inhibitory neurotransmitter
Bipolar cell
Release of excitatory neurotransmitter stimulates ganglion cell
Ganglion cell
(b)

Dark adaptation

Dark adaptation:

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

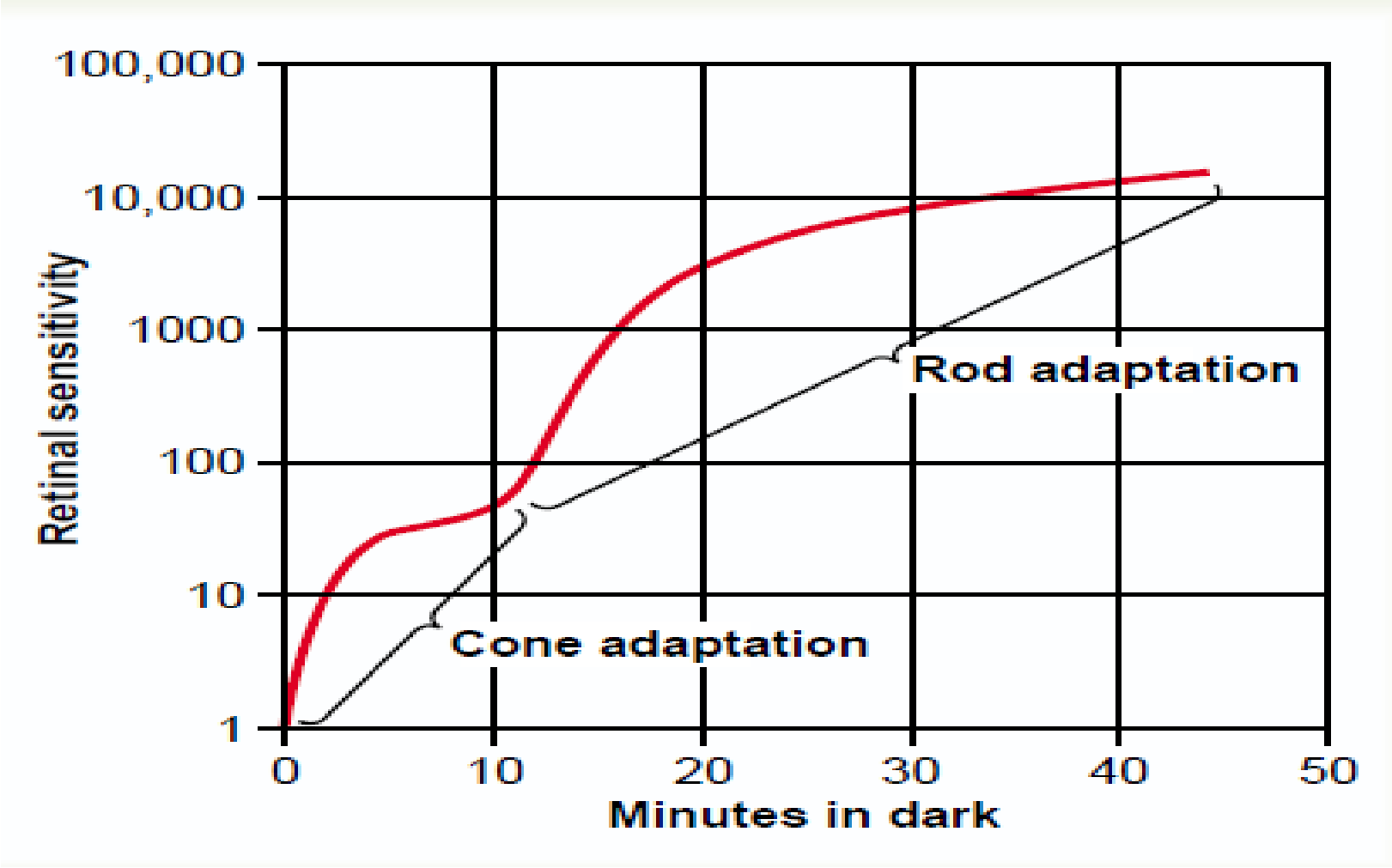
Dark adaptation

- 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



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

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.*


THANK YOU