Physiology Team

Lecture : 15

Photo-transduction in Light and Dark

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OBJECTIVES

- List and compare functional properties of rods and cones in scotopic and photopic vision
- To know the convergence and its value
- To know the photosensitive compounds
- Contrast the photo-transduction process for rods and cones in light and dark and the ionic basis of these responses
- To know the synaptic mediators at retina
- To know the process of rhodopsine regeneration
- To know the meaning of nyctalopia
- Contrast the dark and light adaptation
- To know the visual cycle and rhodopsine regeneration

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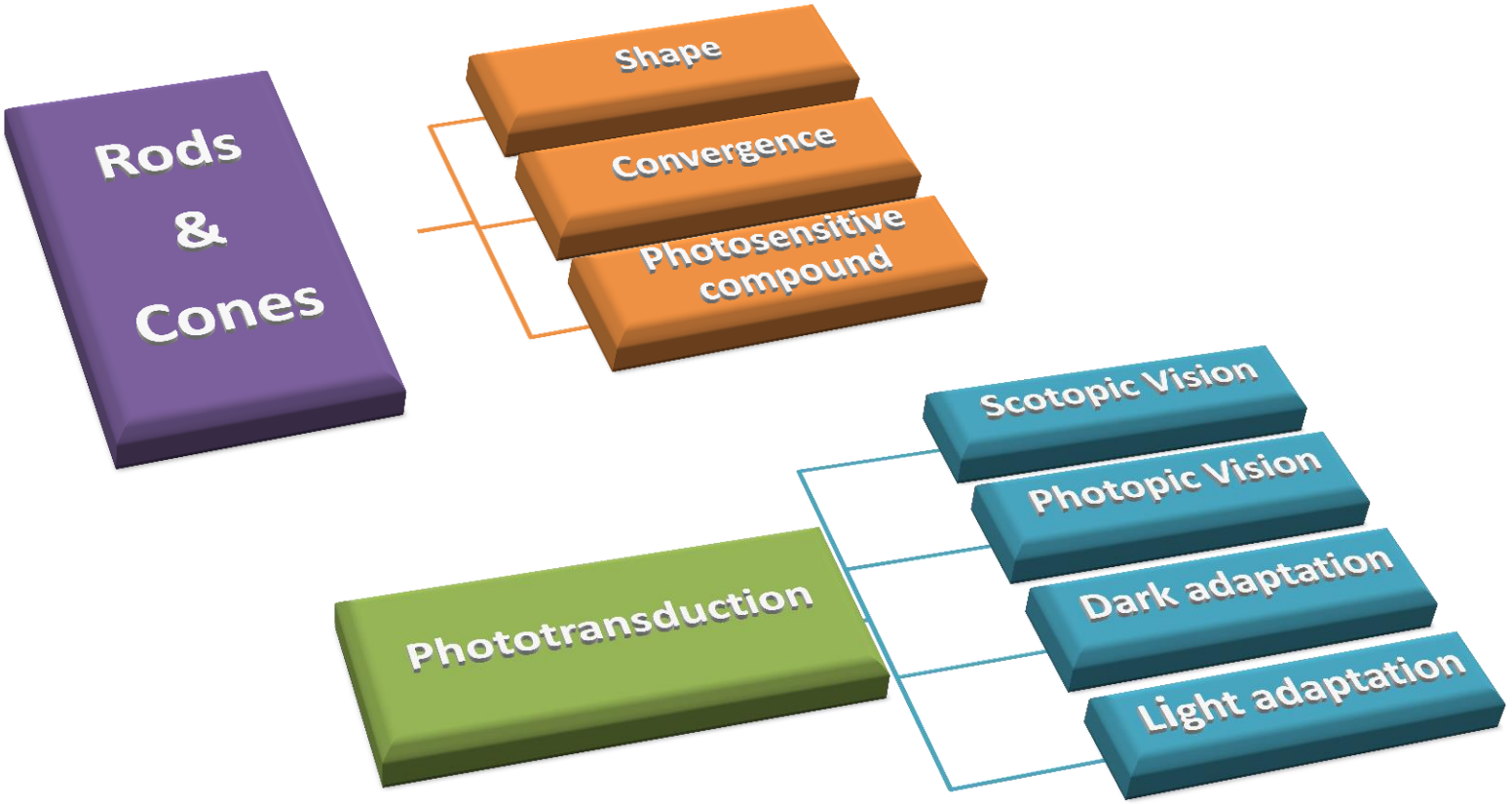
MIND MAP



Slides | Important | Doctor's Notes | Explanation | Boy's Slides

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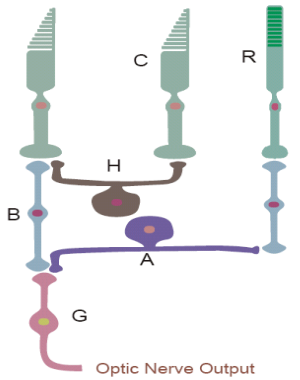
Shape of Rodes & Cones



1- Outer segment (modified cilia)

Has disks full of photosensitive pigment (rhodopsin) react with light to initiate action potential

1- In cones is conical , small and contain 3 types of rhodopsin

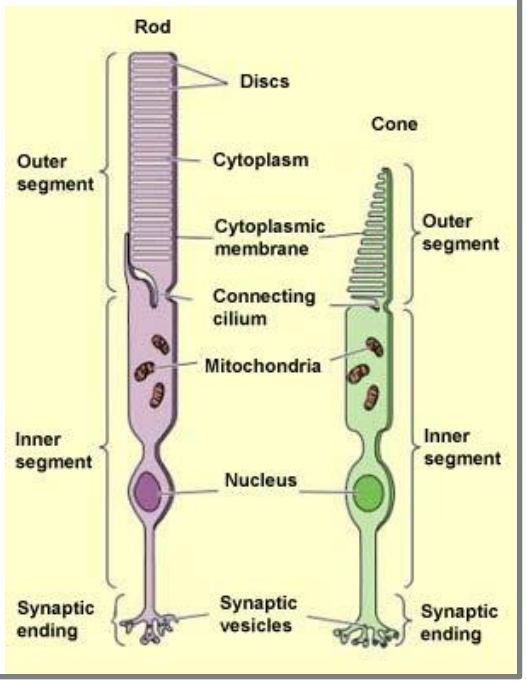
2- in rods it is big, rode like and contain one type of rhodopsin

3- There are Na channels in the outer segment.

2- Inner segment full of mitochondria (source of energy for Na-K pump)

1- it is thick in cones

2- There is Na-K pump in inner segment



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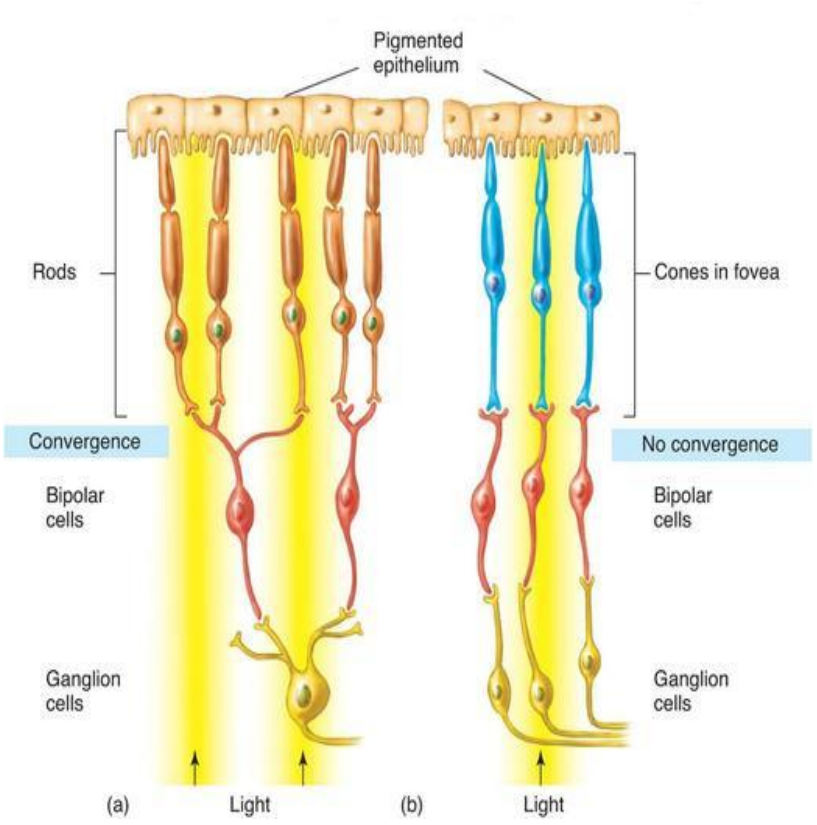
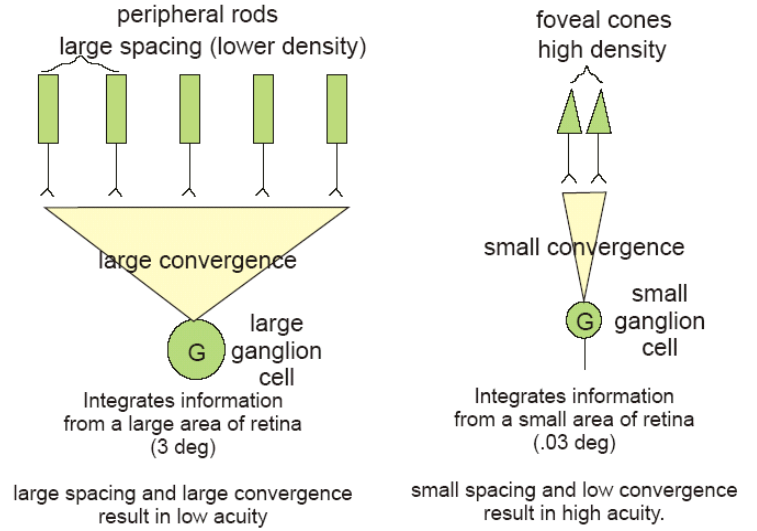
Rods and Cones

	Cons	Rods
Visual Receptors	• abundant in & around fovea • best for bright light conditions • see all colors	• abundant in the periphery of the retina • best for low light conditions • see black/white and shades of gray
Convergence	**low convergence in cones** each foveal cone synapse with →one bipolar cell →one ganglion cell →single optic nerve fiber	**high convergence of rods** several rodes about 300 synapse with one bipolar cell& one ganglion cell
Visual acuity	**Value of low convergence** increases visual acuity → integrated information from small area of retina	decreases visual acuity → integrated information from large area of retina
Sensitivity to light	Disadvantage decreases sensitivity to light so, it needs high threshold of illumination to stimulate cones.	increases sensitivity to light so low light threshold stimulate the rods





By daylight, only the central fovea sees clearly & in color.
On a dark night, only the periphery sees, only in black & white, and with poor resolution.
The fovea is blind. only the periphery sees, only in black & white and with poor resolution.
The fovea is blind.

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- Ganglion cell action potential (all or none A.P)transmitted to optic nerve.
- Rodes & cones & horizontal cells & Bipolar cell responses are depolarization at dark and hyperpolarization at light
- Cones respond to high levels of light intensity (illumination)
- Rods respond to levels of light intensity (illumination) below threshold levels for cones, so rods are more sensitive.

Photosensitive Compounds

1- In **Cones**, it is rhodopsin **(iodopsine or photopsin)** formed of :

Opsin protein + retinal (retinene 1 = aldhyde form of Vit A)

- There are **3 types of rhodopsin** in cones (photopsine I,II,III) each respond to a certain wave length of light for color vision.

2-In **Rods**, its rhodopsin formed of :

Scotopsin protein (opsin) + retinal (retinene 1 = aldhyde 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 is stored in disks of rods at outer segment -It forms (90% of its protein)
- At dark, rhodopsin is in 11-cisretinal form **(inactive)** but light sensitive form which increase sensitivity of rods to light.

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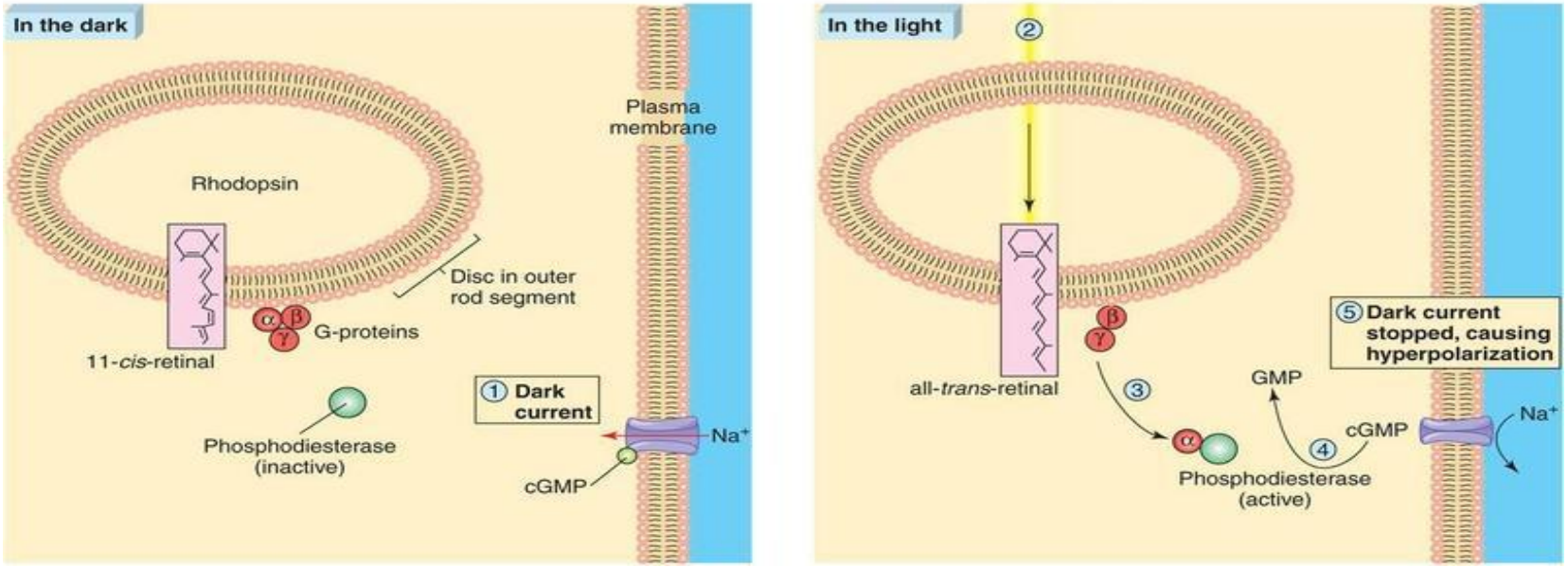
Photosensitive Compounds



- In dark, Na channels in rods (outer segment) are lined by cGMB that keep it open all the time
- Na-K pump in inner segment pump (moves 3 sodium ions out and moves 2 potassium ions in)
- Na flow from inner to outer segment (called Na current) →Depolarization flow to synaptic endings →steady release of neurotransmitter at synapses with bipolar cells →which get depolarization potential →ganglion cells

Electrophysiology Of Vision (Phototransduction)

A- At Dark (scotopic vision, dimlight vision):-

1. Rhodopsin in 11-cisretinal (inactive form-light sensitive form which increase sensitivity of rods to light)
2. (5 –GMP) in the c-GMP form , c-GMP at c-GMP gated Na channels, it bound to proteins at Na channel membrane & keep them open) → → depolarization.
3. Dark current (Na current):- At the inner segment Na pumped by Na- K pump to outside & re-entered through Na channels (at outer segment) .
4. A wave of depolarization spread to synaptic terminals.
5. Synaptic mediators are continuously (steadily) released (mainly excitatory glutamate (Ach + dopamine + GABA.)
6. Response in bipolar cells(depolarization) → ganglion cells- → AP in optic nerve- → vision at dark.

❑ At dark, rhodopsin is regenerated from (retinal + scotopsin)

NB/

- ❖ At dark. Rhodopsin is inactive (cis-retinal needs light for its activation) / inactive rhodopsin is essential for depolarization
- ❖ its inactivation keeps Na channels open& Na current occurs, this is the causative factor for depolarization.

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- **B-Incident light (PHOTOPIC VISION)**

- - Light- → Conformational change تغير شكلي of photopigment retinine-1 in rhodopsin (11-cisretinal form changed to →
- all-trans isomer called metarhodopsin II which is an active rhodopsin) →Activation of G – protein (transducin) → activation of phosphodiestrase enzyme → conversion of c-GMP to 5- GMP → Decreased intracellular c-GMP → closure of Na channels in outer segment .
- -but still Na pump out of inner segment → Hyperpolarization of photoreceptors (-70 ~ -80)

- Hyperpolarization → Decreased release of synaptic transmitter → Response in bipolar cells (hyperpolarization) (this cause decreased release of inhibitory synaptic transmitter) → Generator potential in amakrine cells & ganglion cells (depolarize) → AP → optic nerve → optic pathway

B- Incident light (Photopic vision)

11-cisretinal

↓ **Light**

All-tarns isomer (metarhodopsinII)

↓ **Activate**

G-protein (transducin)

↓ **Activate**

Phosphodiestrase

C-GMP

5-GMP

Closure of Na channels

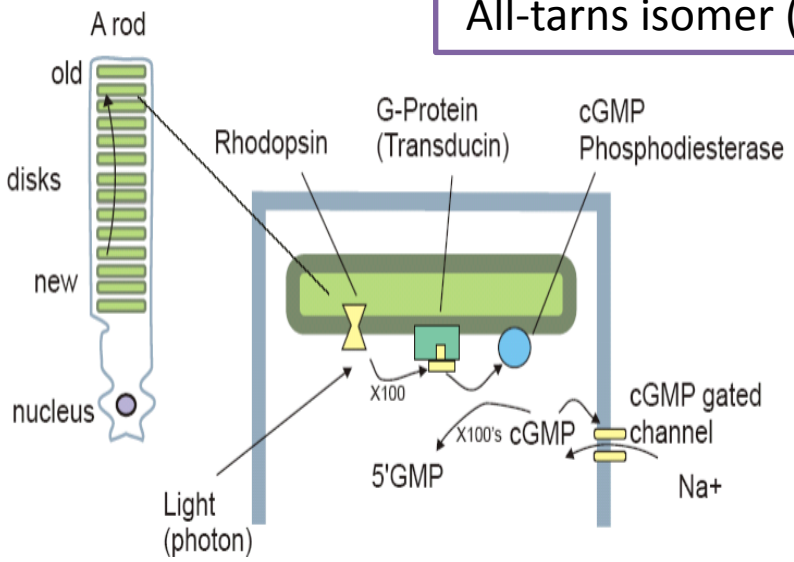
Hyperpolarization (-70, -80 mv)

Decrease release of inhibitory synaptic transmitter

Generate potential in amakrine cells and ganglion cells (depolarize)

Action potential

Optic nerve



(decrease intracellular c-GMP and still Na pump out of inner segment)

Synaptic mediators in retina

Neurotransmitter involved in vision:

1- Ach	**2- glutamate**
3- dopamine	**4- serotonin**
5- GABA	**6- substance P**
7- somatomedin	**8- VIP (Vasoactive intestinal peptide)**
9- enkephalins	**10- glucagons**
11- neurotensin.	

(excitatory and inhibitory neurotransmitters)

- **In dark:**

  all transmitters are continuously (steadily) released by depolarization of rods depolarize bipolar cell.

- **In light:**

  hyperpolarization of the receptors decrease inhibitory transmitter release

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Visual Cycle

- **Retinal is produced in the retina from Vitamin A, from dietary beta-carotene.**
- light induces Isomerization of 11-cis-retinal into all-trans-retinal by a conformational change (bleaching) in opsin and all trans-retinal separate from opsin by light and opsin remains alone.

- **In dark**,11-trans-retinal(meta-rhodopsin) is enzymatically re-converted to the 11-cis-retinal form via an isomerase enzyme. Since the opsin moiety 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 + scotopcin → → rhodopsin regeneration

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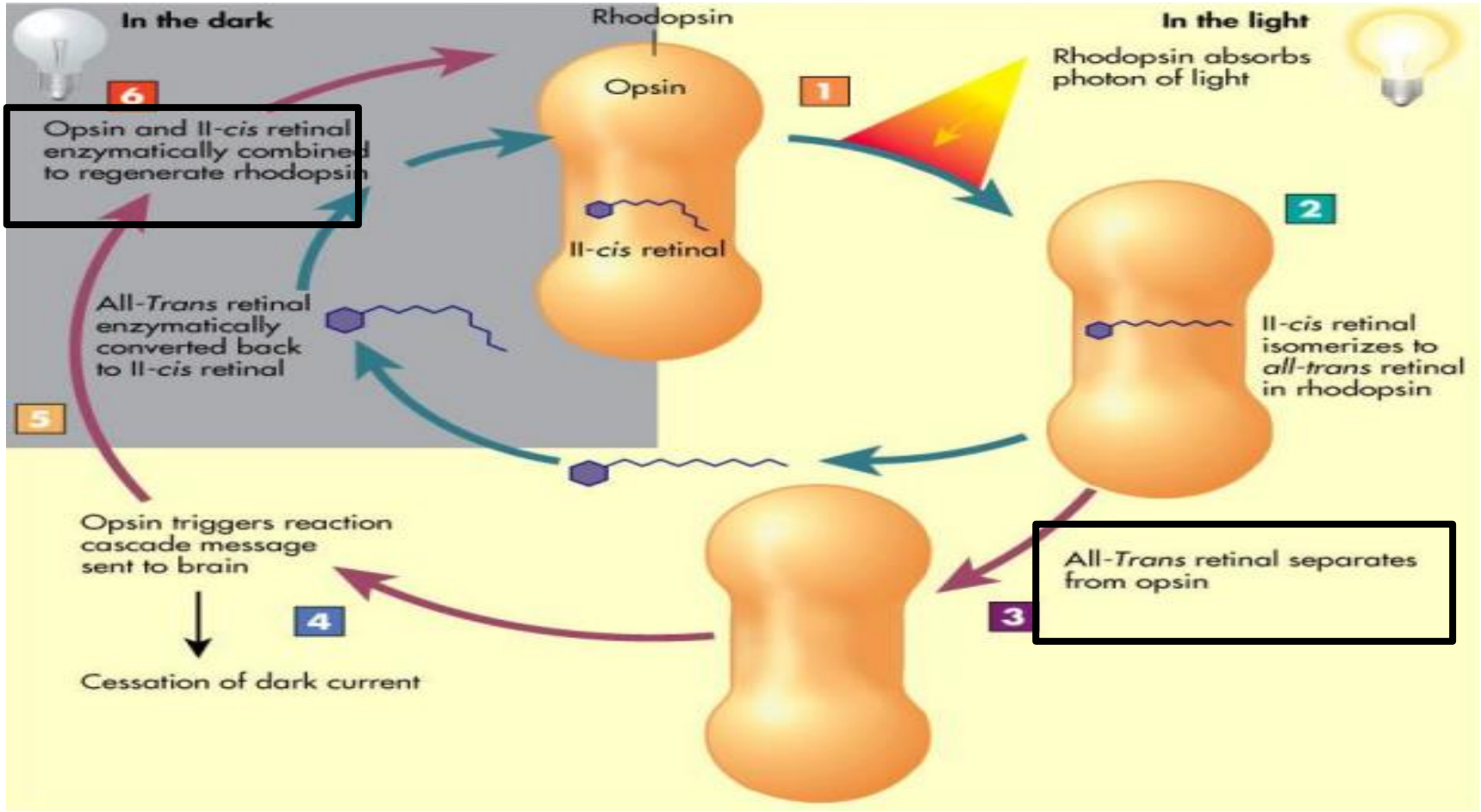
Visual Cycle



Retinal is produced in the retina from Vitamin A, from dietary beta-carotene.

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Nyctalopia (night blindness)

- Vitamin A (main source of retinal of rhodopsin).
- Deficiency of Vit. A causes: rods , cones & retinal degeneration & loss of rods.
- Treatment: Vit. A injection if the receptors are well (not damaged yet).

Dark adaptation

- When a person moves from lighted environment → a dimly lighted environment, the retina becomes more sensitive to light & the person will see at dark (accustomed to dark) in about 20 min.(only gross features but no details or colors).
- Rhodopsin in darkness is essential for depolarization of rodes to see in dark (Na channels to open & for dark adaptation)
- Once light enters the eye (transretinal) metarhodopsin initiates cycle of events for light vision.

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Dark Adaptation Components

Rapid Adaptation:

- (about 5 minutes) drop in visual threshold.
- Fast dark adaptation of cones , only in fovea

(when person enters a dark room he still can see by the cons but with time cons will loss its function and rods start to work)

(Rods are more sensitive to light and so take longer to fully adapt to the change in light. Rods, whose photopigments regenerate more slowly, do not reach their maximum sensitivity for about half an hour. Cones take approximately 9–10 minutes to adapt to the dark).

Less Rabid:

- (till 20 min) drop in visual threshold .
- dark adaptation of rodes in the peripheral retina
- sensitivity of rodes to light increase, in 1 min increase 10 folds
- (rodes increase their sensitivity to light by convergence 300:1 ganglion cell (300 fibers from rods to one ganglion cell), so summation at ganglion cells potential will increase sensitivity of rods to light)

(20 min for dark adaptation are for regeneration of rhodopsin → increase sensitivity of rodes to light → a drop in visual threshold)

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Dark Adaptation Components

Why radiologists & aircraft pilots wear red goggles in bright light?
red goggles for rods act as dimlight, so with it rods are adapted to darkness & form large amounts of rhodopsin while the person in bright light & when person enter dark places he can see well & not remain 20 minutes.

Light adaptation

When light switched on again, the rodes 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.

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SUMMARY

- Photosensitive compounds:-
  - 1- cones
  - 2- Rodes
- Now their shape – distribution - Convergence – visual acuity – sensitivity to light
- Electrophysiology of vision (phototransduction)
  - A- At Dark (scotopic vision, dimlight vision)
  - B- Incident light (Photopic vision)
- Visual cycle :
  - Dark adaptation:
    - 1- Rapid (5 min)
    - 2- Less Rapid (20 min)
  - Light adaptation

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QUESTIONS

1. B
2. C
3. A
4. C

Q1: where are photopigments found ?

A. Inner segment
B. Outer segment discs
C. Cell body

Q2: Rodes, cones, horizontal cells & Bipolar cell responses at light __ and at dark __

A. depolarization , hyperpolarization
B. depolarization , repolarization
C. Hyperpolarization , depolarization

Q3: What is the enzyme that convert c-GMP to 5-GMP in photopic vision?

A. Phosphdiesrase
B. Cathepsin
C. Protease

Q4: Which one of the following is true:

A. Rhodobsin observed light and all trans retinol separates from opsin
B. To see in dark, opsin must attached with all trans retinol
C. hyperpolarization of the receptors decrease inhibitory transmitter release

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THE END

If there are any Problems or Suggestions,
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THANK YOU