Vision

Phototransduction of light

By

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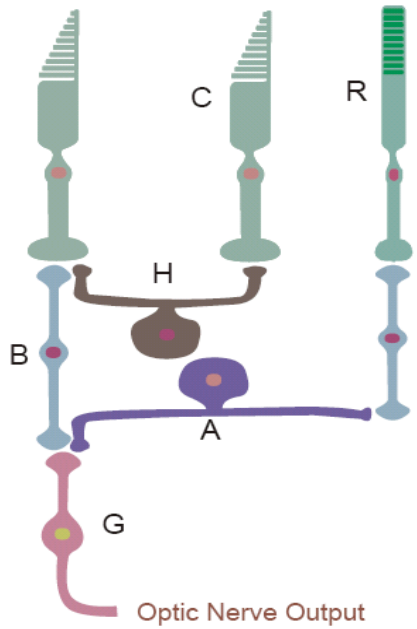
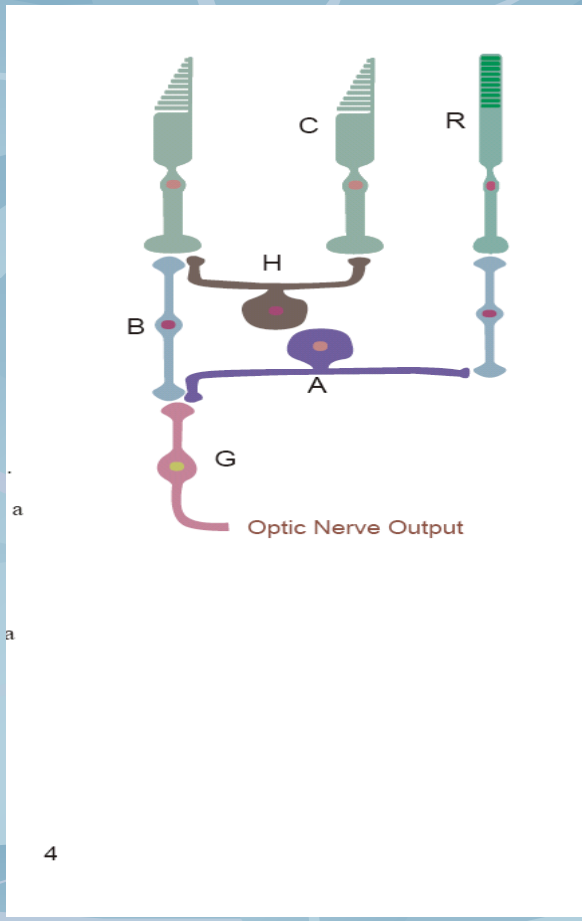
Objectives:

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 phototransduction 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

Shape of rodes& cones



- **Receptors of vision (Rods&cones):-**
- 1- 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 rhodopsin
- - in rods it is big, rode like and contain one type of rhodopsin
- -There are Na channels in the outer segment
- 2- 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



Visual Receptors: Rods and Cones

Rods

-abundant in the periphery of the retina

-best for low light conditions

-see black/white and shades of gray

Cones

- abundant in & around fovea

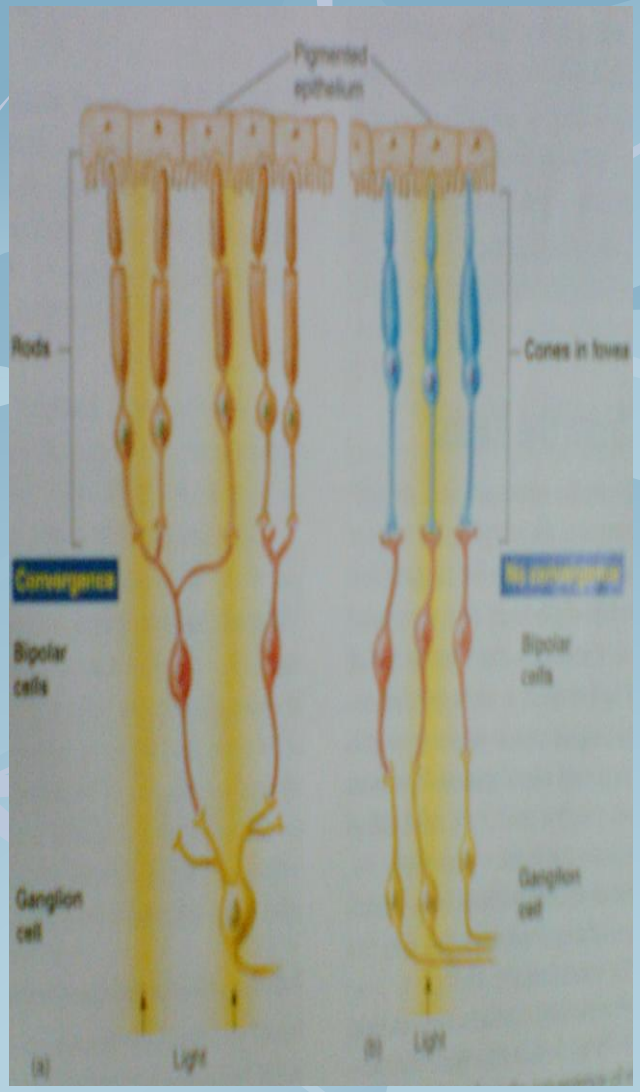
- best for bright light conditions

-see all colors

- **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

- 2- high convergence of rods/
- several rodes about 300 synapse with one bipolar cell& one ganglion cell
- -high convergence/// decreases visual acuity acuity = integrated information from large area of retina
- - but increases sensitivity to light


Pigmented epithelium
Rods
Cones in fovea
Convergence
No convergence
Bipolar cells
Bipolar cells
Ganglion cell
Ganglion cell
Light
Light
(a)
(b)

Photosensitive compounds:-

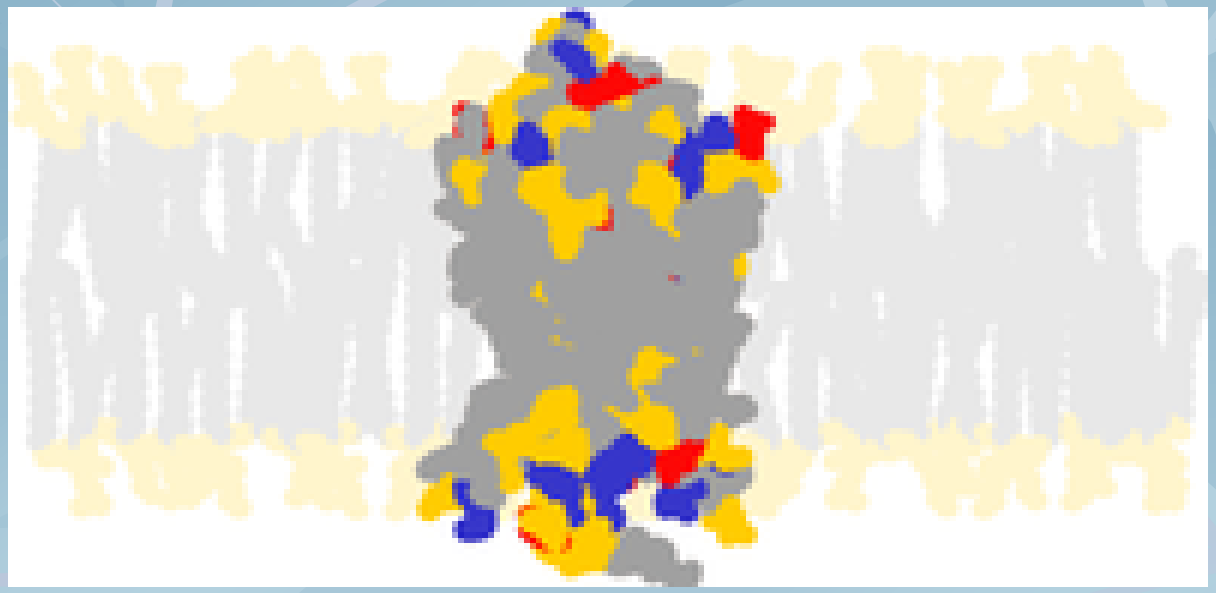
1- In cones it is rhodopsin (iodopsine) formed of :-
Opsin protein + retinal (retinene 1 = aldhyde form of Vit A)

2-There are 3 types of rhodopsin 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(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



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.)

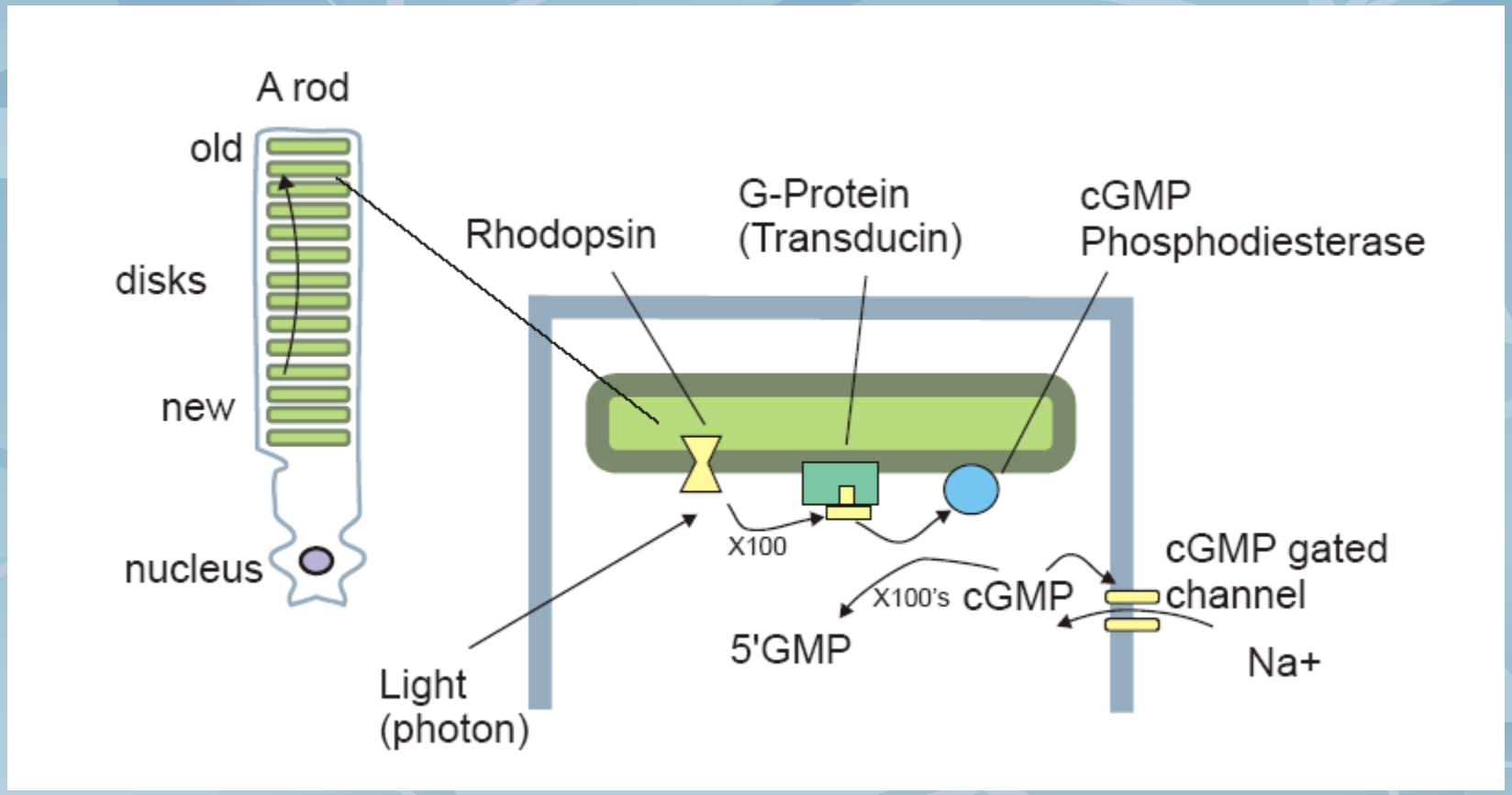
6- Response in bipolar cells(depolarization) → ganglion cells- → AP in optic nerve- → vision at dark.

-at dark rhodopsin is regenerated from (retinal + scotopsin)

B-Incident light (PHOTOPIC VISION)

- - Light- ⟶ Conformational change 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**


A rod
old
disks
new
nucleus
Rhodopsin
G-Protein
(Transducin)
cGMP
Phosphodiesterase
X100
X100's cGMP
5'GMP
cGMP gated
channel
Na+
Light
(photon)

- **Synaptic mediators in retina:-**
- **Ach, glutamate, dopamine, serotonine,GABA, substance P,somatomedin, VIP, enkephalins, glucagons,neurotensin.**
- **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**

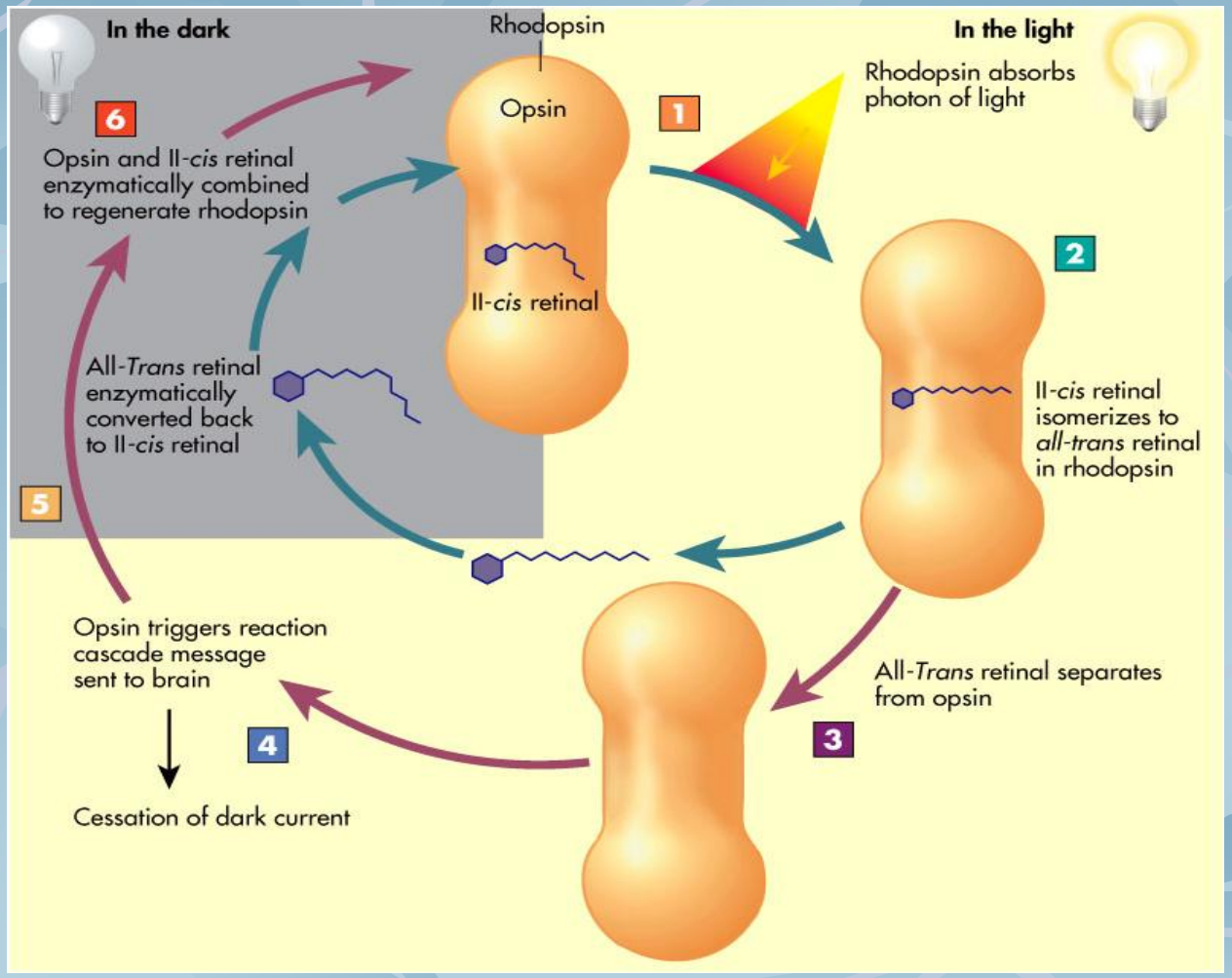
VISUAL CYCLE:-

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


In the dark
Rhodopsin
In the light
Rhodopsin absorbs photon of light
Opsin
1
6
Opsin and 11-*cis* retinal enzymatically combined to regenerate rhodopsin
11-*cis* retinal
2
All-*Trans* retinal enzymatically converted back to 11-*cis* retinal
11-*cis* retinal isomerizes to *all-trans* retinal in rhodopsin
5
Opsin triggers reaction cascade message sent to brain
All-*Trans* retinal separates from opsin
3
4
Cessation of dark current

- **NYCTALOPIA:- (night blindness)**

-- Vitamine A (main source of retinal of rhodopsin) deficiency cause rods , cones & retinal degeneration & loss of rods

-- R / vit A if receptors are well.

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 (trans-retinal)metarhodopsin initiates cycle of events for light vision.

- **Dark adaptation has 2 components:-**

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

- **2- less rapid (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 , so summation at ganglion cells potential will increase sensitivity of rods to light)**

- **N.B (20 min for dark adaptation are for regeneration of rhodopsin → increase sensitivity of rodes to light → a drop in visual threshold**

- **Q- Why radiologists & aircraft pilots wear red goggles in bright light?**
- **A- Light wavelength of the red stimulate the cones & stimulates rods to some extent, so 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.**

- ## 2-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**