Vision Part 3

Photo Transduction in Light & The Dark

Color index

- Important
- Further Explanation

Physiology Team 434
contact us : physiology434@gmail.com

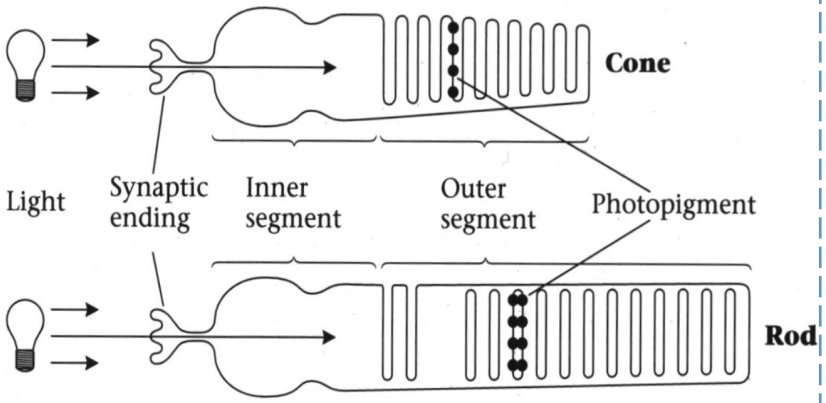
Contents

Recommended Videos!

Please check out this link before viewing the file to know if there are any additions/changes or corrections. The same link will be used for all of our work Physiology Edit

Visual Receptors

	Rods	Cons
Location	Abundant in the periphery of the retina	Abundant in & around fovea
Light level	Best for low light dimlight) conditions	Best for bright light conditions
Colors	See black/white and shades of gray	See all colors
Morphology	Cylindrical (rod like) outer segment, big, and contain one type of rhodopsin	Conical outer segment, small and contain 3 types of cones pigments



1-Outer segment (modified cilia) has disks full of photosensitive pigment (rhodopsin) react with light to initiate action potential.

2- Inner segment full of mitochondria (source of energy for Na-K pump), it is thick in cones

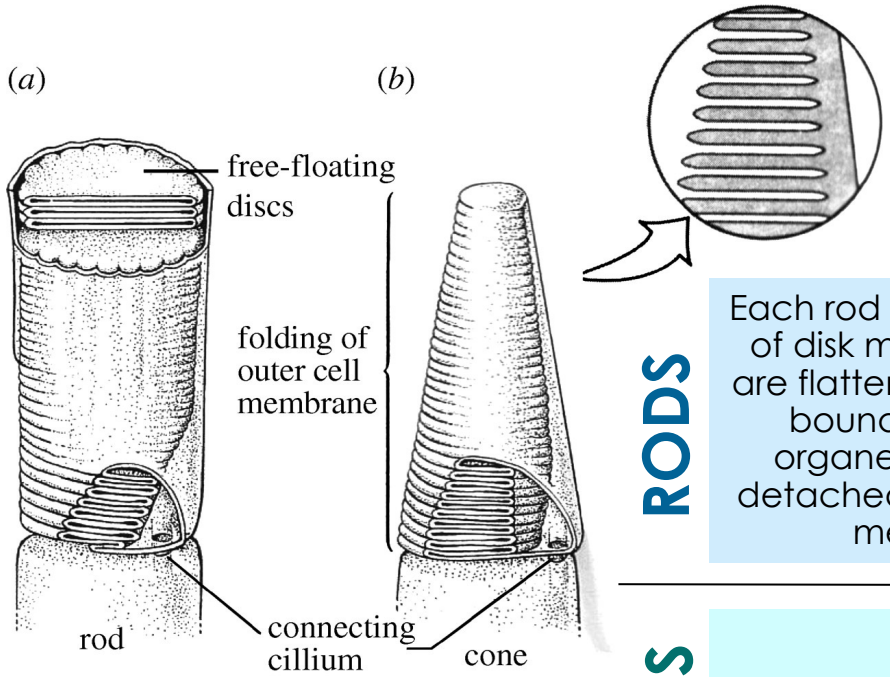
3- There are Na-K pump in inner segment

4- There are Na channels in the outer segment.

5- Both 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)

Mind Map

Structure of Photoreceptors



RODS

Each rod contains a stack of disk membranes that are flattened membrane-bound intracellular organelles that have detached from the outer membrane

Disks are free floating

CONES

The saccules of the cones are formed by infolding of the membrane of the outer segment.

The saccules and disks contain the photosensitive compounds that react to light, initiating action potentials in the post synaptic cells

Cons (low convergence)

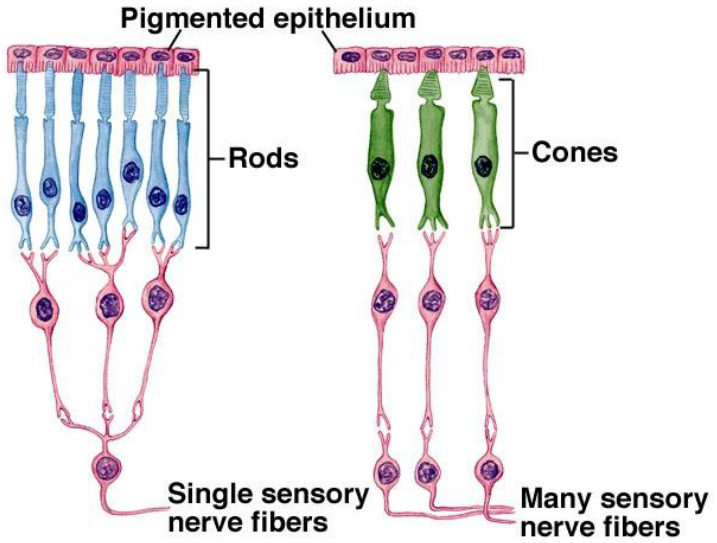
Each foveal cone synapse with →one bipolar cell →one ganglion cell →single optic nerve fiber.

- Advantage: Increases visual acuity → integrated information from small area of retina
- Disadvantag: Decreases sensitivity to light i.e need high threshold of illumination to stimulate cones)

Rods (high convergence)

Several rodes about 300 synapse with one bipolar cell & one ganglion cell.

- Advantage: increases sensitivity to light i.e so low light threshold stimulate the rods
- Disadvantage: decreases visual acuity = integrated information from large area of retina.



120 million rode & 6 million cone converge on 1.2 million optic nerve fibers.

So convergence is 105 receptor : 1 optic fiber.

Photosensitive Compounds

RODS

- Rhodopsin formed of Scotopsin protein(opsin) + retinal
- Rhodopsin of the rods absorbs green-blue light and appears reddish-purple, which is why it is also called "visual purple"
- Cis rhodopsin (inactive) is converted to trans(active)

CONES

- Iodopsine (cones pigments) formed of Opsin protein + retinal
- There are 3 types:
  Photopsine I,II,III each respond to a certain wave length of light for color vision.

NOTE THAT:

1- CELLS RELEASE NEUROTRANSMITTERS WHEN DEPOLARISED

2-LIGHT HYPERPOLARISES PHOTORECEPTORS

Genesis of Photoreceptor Potential

- Rodes & cones potentials are graded, local potential (generator potential) propagated as A.P in ganglion cells.
- Ganglion cell action potential (all or none A.P) transmitted to optic nerve.
- 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.

Electrophysiology of Vision (Phototransduction)

At Dark

The electronegativity inside the membrane of the rod = -40mv rather than the usual which is -70mv

Rhodopsin in inactive form (11cis retinal)

↓

c-GMP bind to Na+ channel --> opening the channel

↓

Na+ influx (depolarization)

↓

Glutamate release

↓

Depolarization of bipolar cells "off –center" and ganglion cells

Electrophysiology of Vision (Phototransduction) cont.

At Light

When the rod is exposed to light , excitation of the rod causes increased negativity of the rod membrane potential, which is a state of hyperpolarization, meaning that there is more negativity than normal inside the rod membrane.

Light energy is absorbed by rhodopsin leads to instantaneous change of the cis form of retinal into an all-trans form "metarhodopsin II"

↓

the activated rhodopsin stimulates a G-protein called transducin

↓

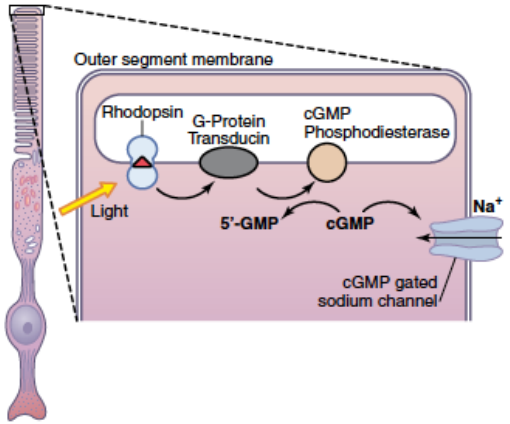
activates cGMP phosphodiesterase; this enzyme catalyzes the breakdown of cGMP to 5'-cGMP

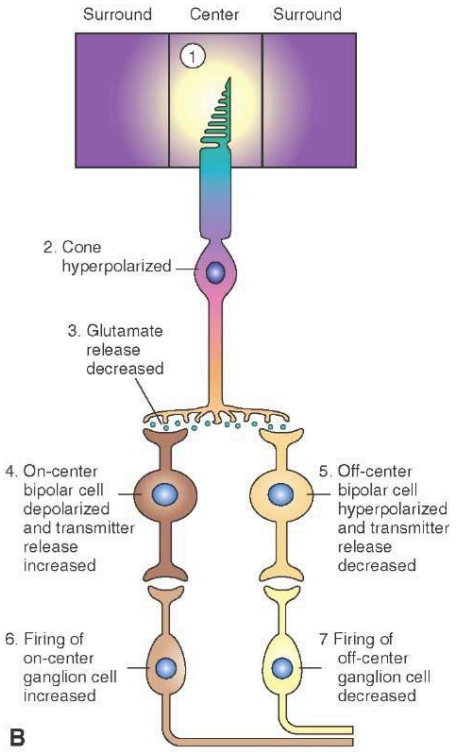
↓

The reduction in cGMP closes the cGMP-gated sodium channels and reduces the inward sodium current.

↓

Hyperpolarization





hyperpolarize ON- center bipolar cells

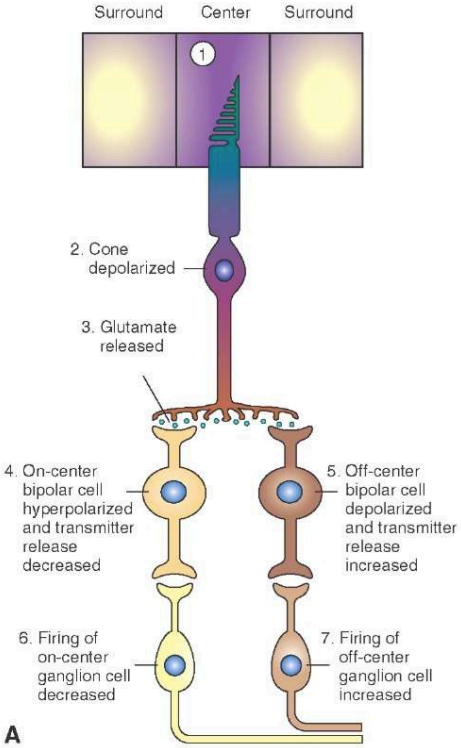
At Dark

Depolarize photoreceptors

"increase glutamate release"

depolarize OFF-center bipolar cells

- ON center bipolar synapse with center photoreceptors " CONES"
- OFF center bipolar synapse with peripheral photoreceptors = "RODS"



Depolarize ON- center bipolar cells

At Light

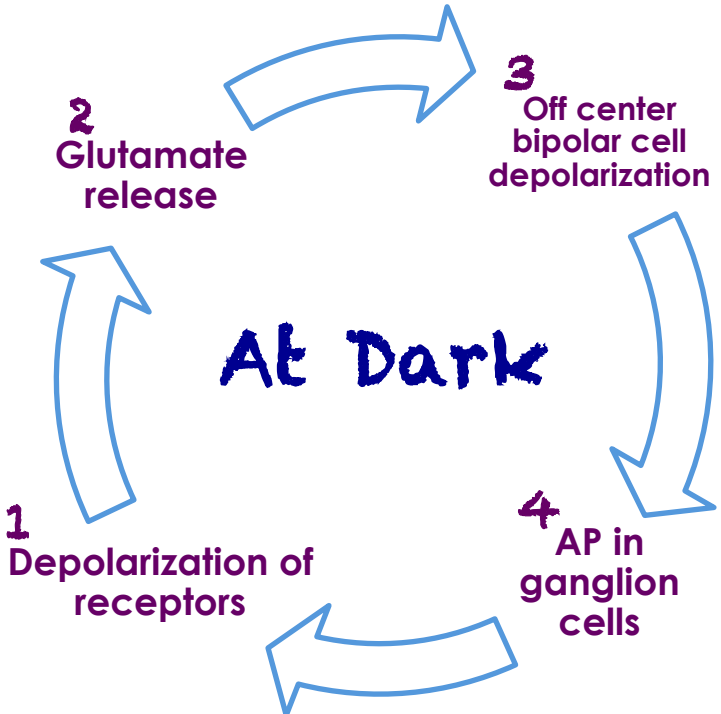
Hyperpolarize photoreceptors

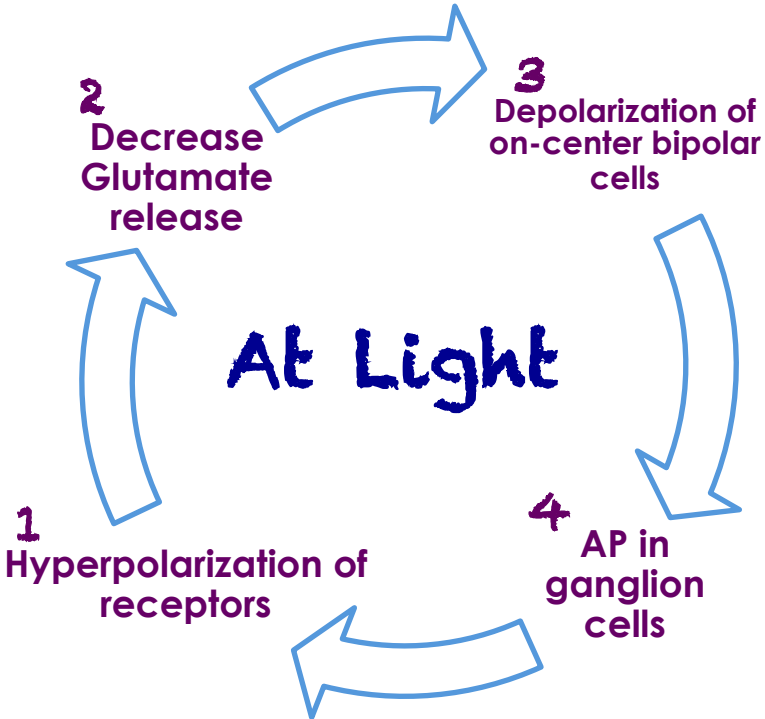
"decrease glutamate release"

Hyperpolarize Off-center bipolar cells

Important Synaptic Mediators in Retina

Ach	Glutamate "Rods & cones"	Dopamine	Serotonine	GAPA





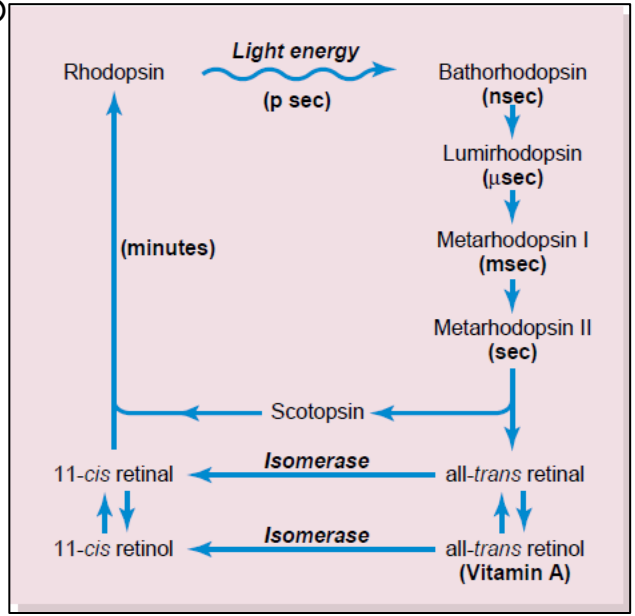
Visual Cycle

- Retinal is a type of Vitamin A from dietary beta- carotene.
- Light induces the change of 11-cis-retinal into metarhodopsin I --> metarhodopsin II by a conformational change (bleaching).
- 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.
- At dark :

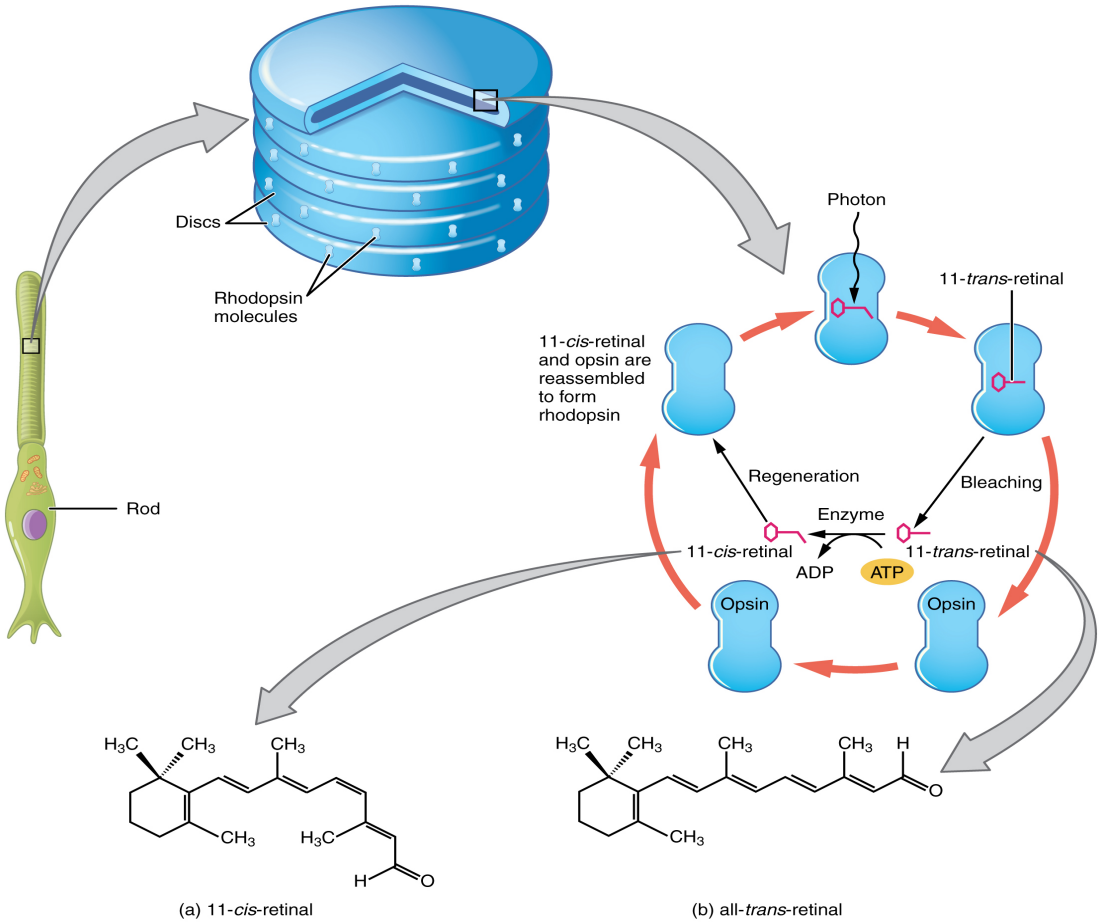
Rods = 11cis-Retinal + scotopsin → rhodopsin

Cones = 11cis-Retinal + photopsin → Cone pigments

Photopsins are the photoreceptor proteins found in the cone cells of the retina that are the basis of color vision.



Rhodopsin Cycling



Nyctalopia "Night Blindness"

- Cause: vitamine A deficiency cause rods, cones degeneration & loss of rods .
- Treatment: intravenous vit A if receptors are well.
- Nyctalopia is the inability to see well at night or in poor light.

Dark Adaptation

- **Guyton definition** If a person remains in darkness for a longtime, the retinal and opsins in the rods and cones are converted back into the Rhodopsin. Furthermore, vitamin A is converted back into retinal to increase light sensitive pigments, the final limit being determined by the amount of opsins in the rods and cones to combine with the retinal. This is called dark adaptation.

- **Ganong's definition:** Moving from lighted environment to 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)

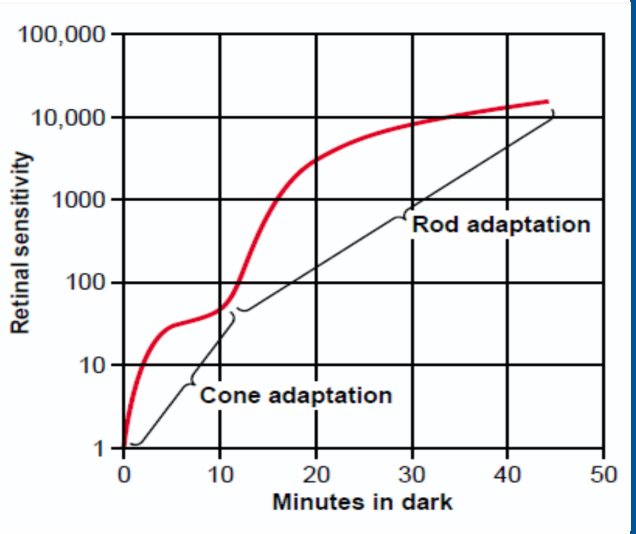
Dark Adaptation Has 2 Components:

1- Rapid (about 5 minutes) drop in visual threshold .

- Fast dark adaptation of cones , only in fovea
- half of the cone rhodopsin regenerate in only 90 seconds

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



NOTE THAT:
(20MIN FOR DARK ADAPTATION ARE FOR REGENERATION OF RHODOPSIN→ INCREASE SENSITIVITY OF RODES TO LIGHT → A DROP IN VISUAL THRESHOLD

Why radiologists & aircraft pilots wear red goggles in bright light?

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 and form large amounts of rhodopsin while the person in bright light. and when person enter dark places he can see well & not remain 20 minutes.

Types of Retinal Ganglion Cells and Their Respective Fields

The receptive field Is the particular region of the sensory space (e.g., the body surface, or the retina) in which a stimulus will trigger the firing of that neuron. is composed of input from all of the photoreceptors which synapse with it, and a group of ganglion cells in turn forms the rece ptive field for a cell in the brain. This process is called convergence

Types of ganglion cells :

1-W cells:
Sensitive for detecting directional movement in the field of vision, and they are probably important for much of our rod vision under dark conditions.

2-X Cells:
Transmission of the of the fine details of the visual Image and Color Vision

3-Y Cells:
To Transmit Instantaneous & rapid Changes in the Visual Image, either rapid movement or rapid change in light intensity

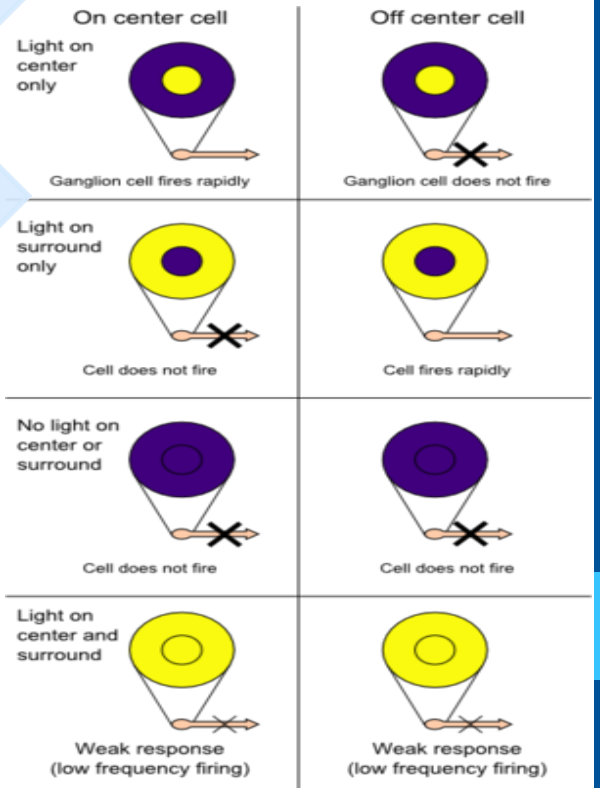
Retinal Ganglion Cells

On-center

- Stimulated when the center is exposed to light. --> depolarization
- Inhibited when the surround is exposed to light --> hyperpolarization

Off-center

- Inhibited when the center is exposed to light.
- Stimulated when the surround is exposed to light



Stimulation of both the center and surround produces only a mild response (due to mutual inhibition of center and surround).

You have to differentiate between on-center bipolar cells and on-center gangilion cells

1- activated transducin activates the effector protein phosphodiesterase which converts?
A. GTP to GDP
B. cGMP to GMP
C. cis retinal to all-trans retinal
D. all-trans retina to cis retinal

2- Cons are mostly abundant at?
A. in and around the fovea
B. periphery of the retina
C. in the sclera
D. mixed with the vitreous humor

3- the saccules of the cones are formed by:
A. by the ciliary stalk
B. by the synaptic endings
C. by infolding of the membrane of the inner segment
D. by infolding of the membrane of the outer segment

4- which of the following is true about the cons?
A. low convergence
B. high convergence
C. several cons synapse with one bipolar cell
D. see black/white and shades of grey only

5- In cones rhodopsin is formed of :
A. Scotopsin protein + retinal
B. Scotopsin protein + retinol
C. Opsin protein + retinal
D. Opsin protein + retinol

6- electronegativity inside the membrane of the rod is about?
A. –20 millivolts
B. –40 millivolts
C. –60 millivolts
D. –80 millivolts

7- with light, hyperpolarization of the receptors cause:
A. no effect on glutamate release
B. increase in glutamate release
C. decrease in glutamate release

8- X Cells of the Retinal ganglion cells function is for:
A. detecting directional movement
B. Transmission of the fine details of visual Image and Color
C. Changes in the Visual Image

1. B
2. A
3. D
4. A
5. C
6. B
7. C
8. B

MCQs

1- Discuss the role of calcium in the modulation of the phototransduction current.

modulating the cGMP-gated channels as well as cGMP synthesis and breakdown. $Ca^{2+}$is involved in a negative feedback that is essential for photoreceptor adaptation to background illumination.

2- How does the eye adapt to the darkness?

retina becomes more sensitive to light & the person will see at dark in about 20 min with no details. that is due to the depolarization of rodes by the dim light which causes AP in ganglion cells.

3- differentiate between the Convergence of cons and rods:

in cons: there is an increases in visual acuity → integrated information from small area of retina. however, this leads to decreases sensitivity to light

in rods: decreases visual acuity → integrated information from large area of retina. which results in an increases sensitivity to light

THANK YOU FOR CHECKING OUR WORK!

BEST OF LUCK

Done By:

- Nawaf Alfawzan
- Moath Aleisa