VISION

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VISION

- Vision is mediated by the "visual system" which includes:-
- The eye which is special organ that can transform light into action potential.
- Visual pathway which is group of nerve fibers and nerve cells that transmits this action potential till the Visual center in the brain.
- Visual centers which lie in the visual cortex in the occipital lobe and it can receive and translate this action potential into seen objects.

The eye is composed of 3 coats

A- The outer coat

- Its posterior 5/6 is opaque protective membrane called the "sclera" which is relatively vascular
- The anterior1/6 is circular disc highly transparent membrane called the "cornea".
- The sclera is covered by thin membranous sac called the "conjunctiva" which is absent on the cornea but is reflected to line the inner surface of the eye lids.
- The junction of the sclera with the cornea is called the 'limbus".

B- The middle coat

- It is loosely attached to the sclera, its posterior 2/3 is formed of the *"choroids"* (tuft of blood vessels for nourishing the retina).
- The anterior third forms the *"ciliary body"* which includes the:

a- Ciliary muscles which control the process of accommodation.

b- The ciliary processes which secret the **aqueous humor**.

c- The suspensory ligament which holds the lens in it's position.

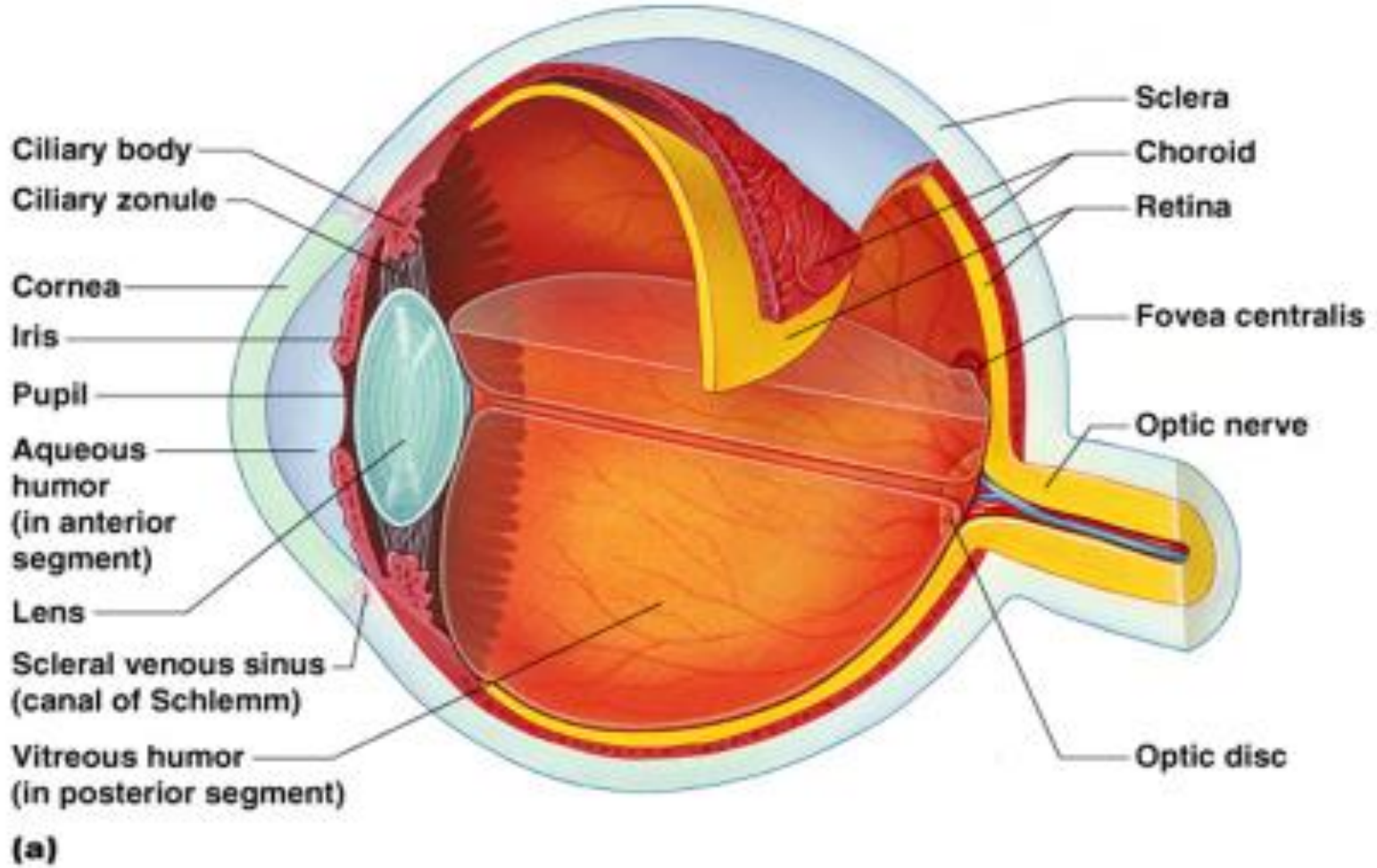
- The anterior continuation of the ciliary body forms the *"iris".*
- The space between the cornea anteriorly and the iris posteriorly is called the *anterior chamber*.
- The space between iris anteriorly and the lens posteriorly is called the *posterior chamber*.
- Both chambers are filled with *the aqueous humor*.

C-The inner coat,

- It is formed of the "retina" the ***queen of the eye***
- The retina contains :

1. photoreceptors which transform light into action potential i.e. rods and cones
2. neural elements which starts the visual pathway.

- It extends anteriorly and ends just behind the ciliary body.
- In the posterior part of the retina there is a small area called the ***macula lutea,*** and vision is most acute in the central part of this area, which is known as the ***fovea centralis.***
- The space between the lens and the retina is filled with gel like structure i.e. ***Vitreous humor***.


Ciliary body
Ciliary zonule
Cornea
Iris
Pupil
Aqueous humor (in anterior segment)
Lens
Scleral venous sinus (canal of Schlemm)
Vitreous humor (in posterior segment)
Sclera
Choroid
Retina
Fovea centralis
Optic nerve
Optic disc
(a)

THE OPTICAL SYSTEM OF THE EYE

The eye contains many refractive media in which light waves must pass through it before reaching the retina: they are:

- Cornea,
- Aqueous humor,
- Lens,
- Vitreous humor.

THE CORNEA

- The cornea resembles a disc of about 11 mm in diameter and a thickness of about 1mm at the periphery and only 0.5 mm at the center which is the most sensitive part in the body due to the very rich free nerve ending.

- The cornea has alone a refractive power of about 44 diopters (75 % the total refractive power of the whole eye).

- This high refractive power is due to the high difference between its refractive index (1.37) and the refractive index of the air (1).

Functions of the cornea

1. It allows light to enter the eye because of its transparency.
2. It acts as strong refractive media (44 diopters).
3. The great sensitivity of cornea acts as protective mechanism for the inner delicate structure through the corneal reflex (touching cornea leads to strong closure of lids).
4. Corneal reflex indicate degree of anesthesia.

Causes of corneal transparency:

1. The avascularity of the cornea (no blood vessels)

- only some capillaries at limbus
- The cornea gets its O2 from aqueous humor and from the tears.
- Aqueous is main source of glucose (main source of energy)

2. The corneal collagen bundles are regularly arranged parallel to the surface with uniform length and thickness

3. Absence of myelin sheath in the corneal nerve fibers.

4. Relative corneal dehydration:

- (a) Metabolic pump: active pumping of fluid into the aqueous humor.
- (b) Osmotic pump: the osmolality of the aqueous humor & tears are relatively greater than that of the cornea. So fluids move from the cornea outwards

5. Vitamins :

vitamin "A" which prevents dryness of cornea

vitamin " B2 " prevents corneal vascularization.

The precorneal film

- covers the cornea protecting it and enables it to act as refractive media
- It is formed of 3 layers:
- - Superficial oily layer from meibomian glands.
- - Middle layer of tears (supply atmospheric O2 to eye).
- - Deep mucous layer from goblet cells to make corneal epithelium hydrophilic.

THE AQUEOUS HUMOR

- It is a clear transparent alkaline fluid.
- It carries nutrients to the non vascular structures of the eye e.g. cornea and lens.
- The viscosity of the aqueous humor is low.
- It has a high oxygen tension.

Outflow of aqueous humor from the eye:

- The aqueous humor is formed by the ciliary processes and enters the posterior chamber, it flows through the suspensory ligament of the lens,
- then through the pupil into the anterior chamber of the eye.
- Here, the fluid flows into the angle between the cornea and iris and then to spaces of fontana to reach the canal of Schlemm.
- The aqueous finaly drained into ocular veins.

Outflow of aqueous humor

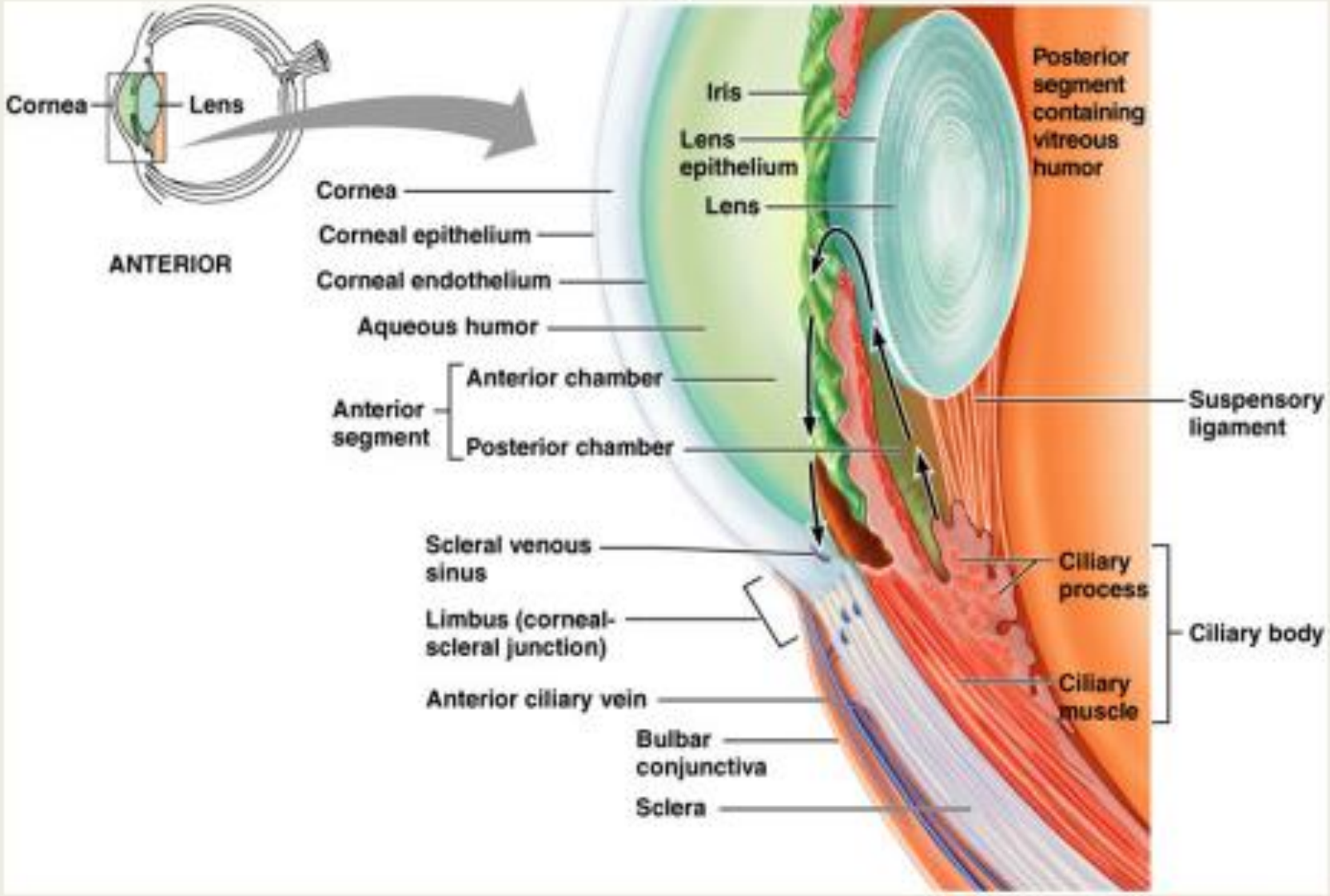


Figure 15.12

Function of the aqueous humor

1. It supplies the avascular cornea and lens with nutrients glucose, amino-acids and removes waste products.
2. It maintains the intraocular pressure.
3. It plays a role as a refractive medium in the eye.

Intraocular pressure (IOP)

- The intraocular pressure is 15–20 mmHg.
- The intraocular pressure remains constant in spite of wide changes in the arterial blood pressure.
- It is measured indirectly by an apparatus called "Tonometer".
- The IOP is caused by:–
- Aqueous humor pressure.
- Capillary pressure in the choroids vessels.
- Vitreous humor pressure.

Importance of IOP

a- The focusing mechanism of the eye depends upon a normal intraocular pressure.

b- It gives the eye its globular shape which is important for focusing mechanism.

c- It keeps the lens in its normal position.

- In excessive increase of intraocular pressure, the suspensory ligaments of the lens will be stretched and accommodation for near vision cannot occur.

- Excessive reduction of intraocular pressure will lead to relaxation of the suspensory ligaments of the lens which become more spherical and its diopetric power is increased.

THE CRYSTALLINE LENS

- It is avascular transparent biconvex lens.
- The lens is gelatinous structure enclosed in an elastic capsule.
- The lens measures about 10 mm in diameter and 4 mm in thickness and its anterior surface is less convex than its posterior surface.

- The refractive power of the lens during rest (non accommodated) = 15 Δ in adult and up to 30–32 Δ during maximum accommodation to near vision.

Functions of the lens

- 1 – It is a transparent media which allows light to reach the retina.
- 2– Acts as an important refractive media .
- 3– Accommodation to near vision for accurate focusing.
- 4– Absorbs ultraviolet rays so protect retina from their harmful effects.

Causes of lens transparency

- 1- Uniform arrangement of its fibers.
- 2-The refractive indices of its different layers are similar.
- 3- It is avascular.

The avascular lens gets its nutrition from aqueous which supplies it with O2 and glucose (the main fuel as cornea).

THE VITREOUS HUMOR

- It is avascular transparent jelly like substance which fills the space between lens and the retina.
- It contains albumin and hyaluronic acid (high viscosity).
- The whole vitreous is enclosed in a thin membrane
- The vitreous takes its nutrition from choroid vessels.

Functions of the vitreous:-

1- Shock absorber to protect retina from injury.
2- Support lens in its position.
3- Maintain normal globular shape of the eye.
4- It plays a role as a refractive medium in the eye.

CHOROID

The choroid is highly vascular darkly pigmented layer lies between retina and the sclera.

Function of choroid:

1. The melanin pigment in it absorbs light and prevents its reflection inside the eye.
2. The choroid vessels supply retina with oxygen and nutrients.
3. The choroid vessels share in formation of intraocular pressure.

THE IRIS

- It is a thin disc like diaphragm arises from the anterior surface of the ciliary body and lies between the cornea and lens.
- It contains a pigment which gives the eye its characteristic color.
- The central aperture in the iris (pupil) is controlled by the circular and radial muscle fibers of the iris.
- The radial muscle fibers form the dilator pupillae muscle. It is supplied by the sympathetic nerves (superior cervical sympathetic ganglia).
- The circular muscle fibers form the constrictor pupillae muscle that is controlled by parasympathetic nerve fibers (oculomotor nerve).

Functions of the iris:

1. Control amount of light entering the eye, via controlling the diameter of the pupil.

- The pupil of the human eye can become as small as 1.5 mm and as large as 8 mm in diameter.
- Therefore the quantity of light entering the eye may vary 30 times.

2. It prevents light rays from falling on the periphery of the lens to decrease the spherical and chromatic aberrations.

3. Constriction of the pupil increases the depth of focus of the eye

Depth of focus is the distance the object can move but its image still focused on the retina without new change in accommodation.

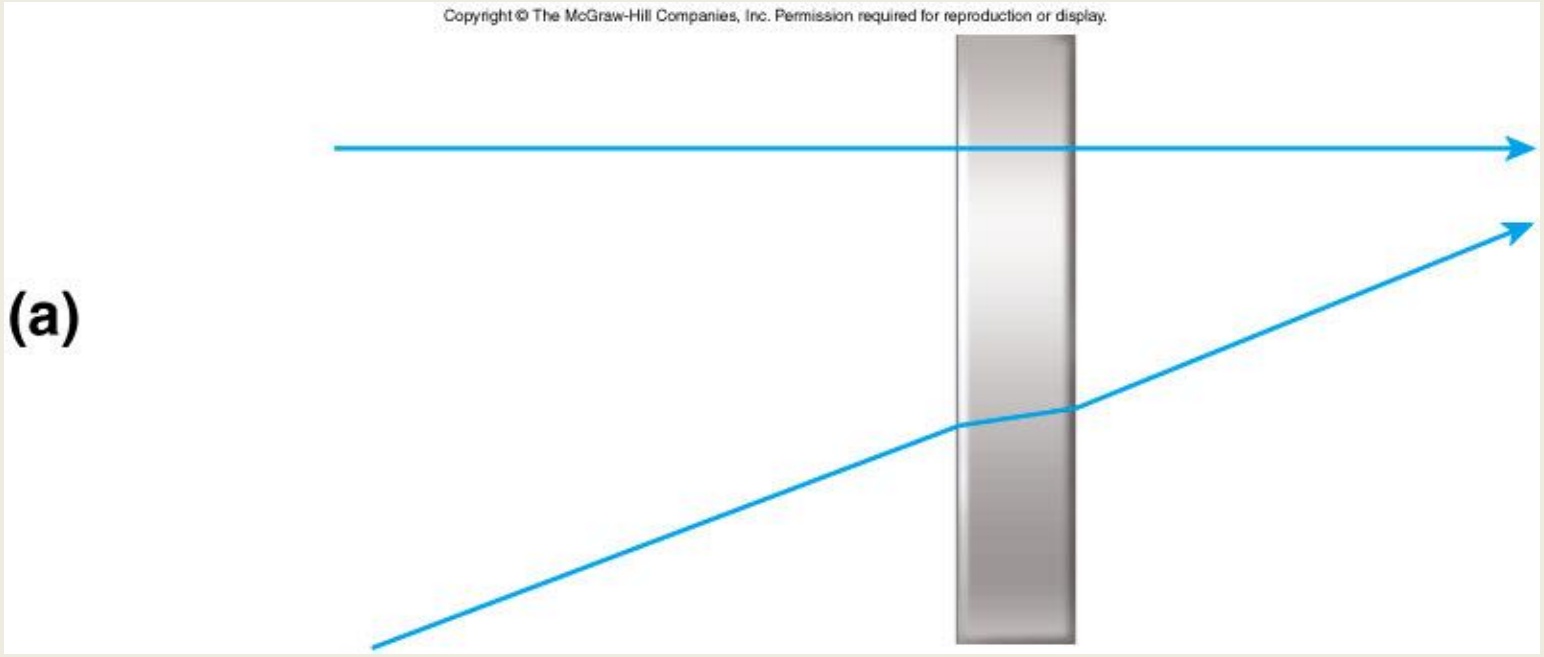
LIGHT

- Light is the adequate stimulus of the photoreceptors in the retina.
- Visible light is a form of electromagnetic energy travelles in waves having a wave lengths between 4000 - 7000 A° (angstrom) (10^{-10} meter).
- Each separate wave length gives different color sensation ranges from red color (7000 A°) till the violet color (4000 A°)
- Mixing of all wave lengths of visible spectrum together gives the sensation of day light.
- adjacent to the visible spectrum are the areas of the ultraviolet and infrared radiations which are not perceived by the eye

When light strikes a surface it either:-

- **Reflected** from the surface in which it lies, thus the surface becomes visible.
- **Refracted,** this occurs when light rays pass from one transparent media to another. This means that the light rays bend and the extent of bending depends on the density of the media (refractive index of the media).
- Refractive index is the ratio between velocity of light in air and its velocity in the transparent media e.g., refractive index of air is 1 while refractive index of water = 1.33
- **Absorbed** by the molecules of the object in which the light pass through. The light here is converted to another form of energy e.g. heat.

Principle of Refraction



Light striking the lens or cornea at a 90 degree angle is not bent.

Structure of the retina

The retina is formed of ten layers, these from outside to inside are:-

1- The pigmented cell layer in direct contact with the choroid and contain dark melanin pigment.

Functions :-

a- The pigmented epithelium absorb excess light rays which are not absorbed by the rods and cones. If this excess light is not absorbed it will stimulate large number of photoreceptors leading to blurred vision.

b- Store large amounts of vitamin A which is the precursor of visual pigments.

c- Phagocytic action to debris of photoreceptors.

2- Layers of rods and cones (receptor layer).

- There are about 120 millions rods and only 6 millions cones.
- Rods are concentrated in the periphery of the retina and less in the middle.
- Rods are more sensitive to light than cones but less accurate in visual acuity and function more in dim (night vision).
- Rods can't determine color vision.
- Cones are more concentrated in the middle of the retina (fovea centralis contains cones only).
- Cones are less sensitive to light than rods
- It is more accurate in determining visual acuity.
- Cones are specialized in color vision and day vision".

3-Outer limiting membrane.

4- Outer nuclear layer. Contains inner segments of the rods and cones.

5- Outer plexiform layer

in which horizontal cells connect receptor cells to other cells.

6- Inner nuclear layer

which contains bipolar cells (first order neuron in visual pathway).

7- Inner plexiform layer

contains the synapse between the bipolar cells and the ganglion cells.

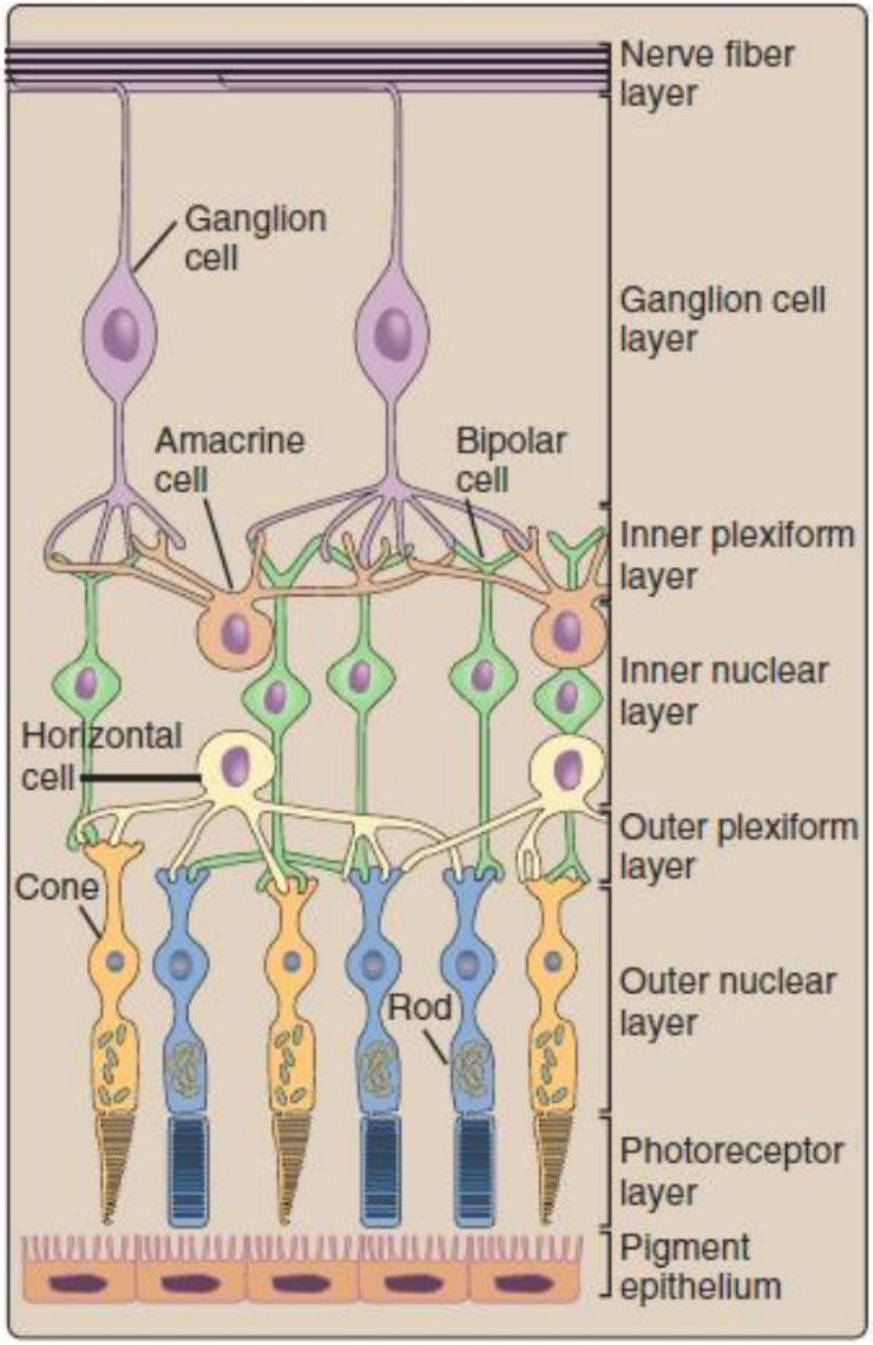
8- Ganglion cell layer

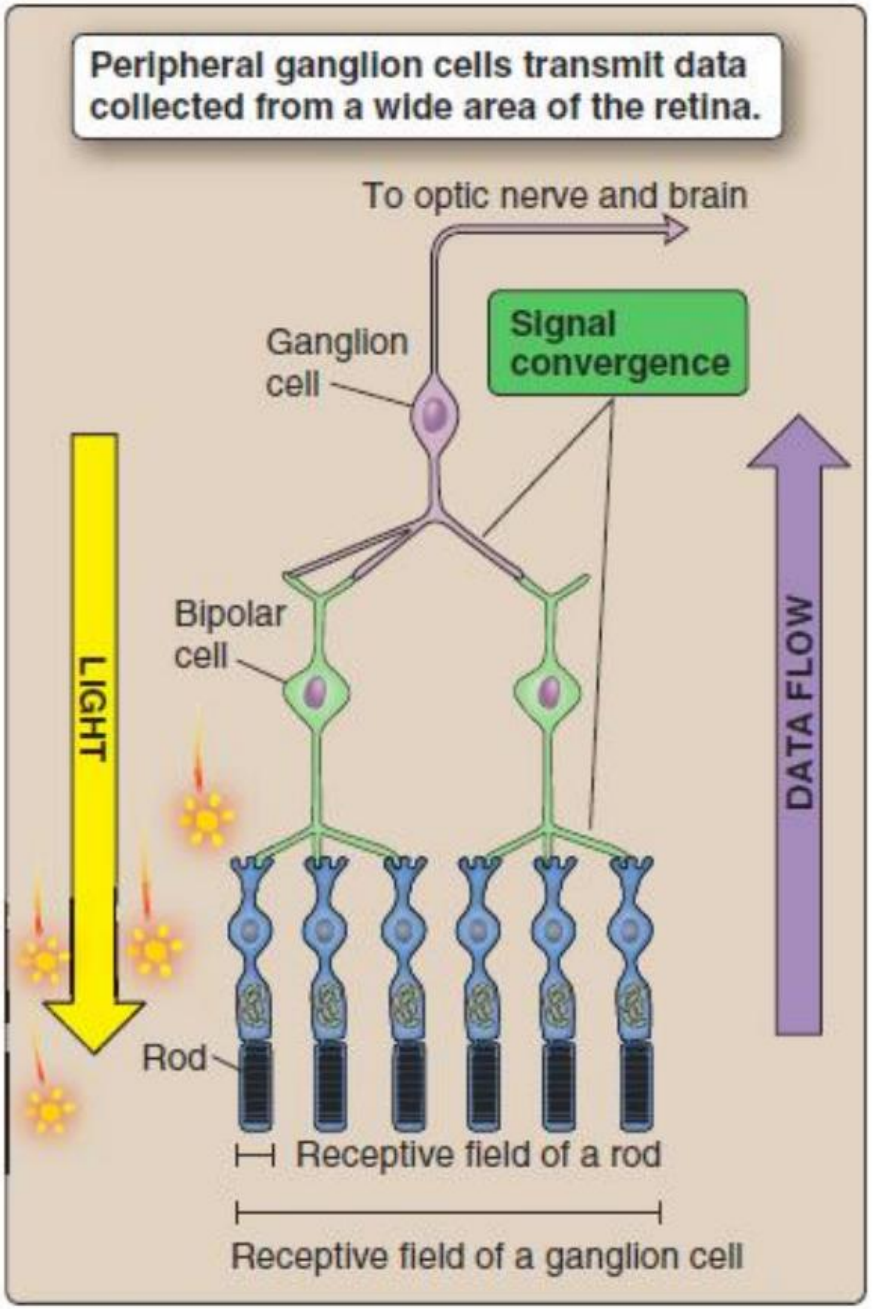
(second order neuron in visual pathway).

9- Layer of optic nerve layer

(axons of ganglion cells).

10- Inner limiting membrane.


Nerve fiber layer
Ganglion cell
Ganglion cell layer
Amacrine cell
Bipolar cell
Inner plexiform layer
Inner nuclear layer
Horizontal cell
Outer plexiform layer
Cone
Rod
Outer nuclear layer
Photoreceptor layer
Pigment epithelium

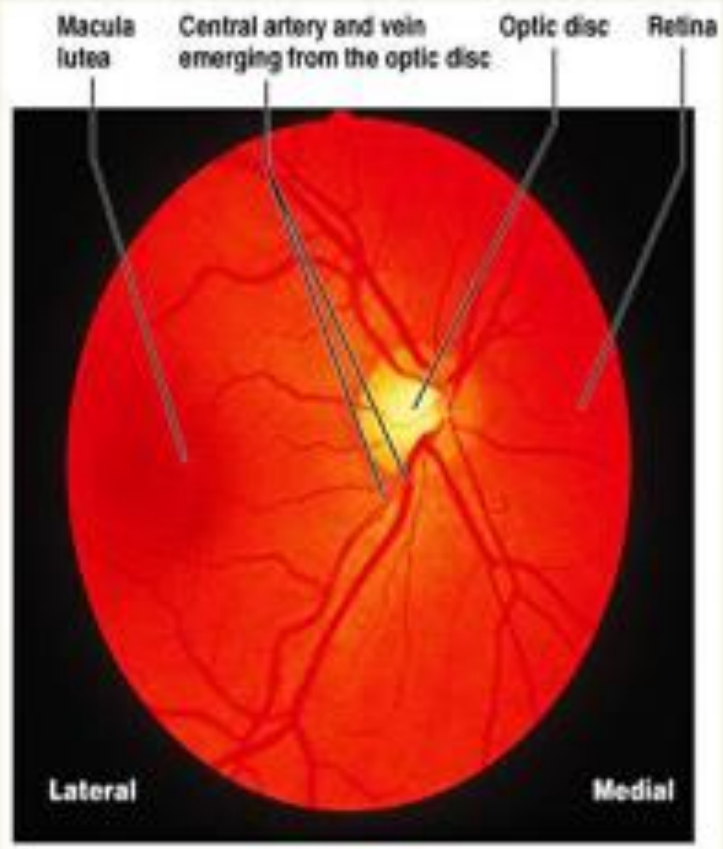

Peripheral ganglion cells transmit data collected from a wide area of the retina.
To optic nerve and brain
Signal convergence
Ganglion cell
Bipolar cell
LIGHT
DATA FLOW
Rod
Receptive field of a rod
Receptive field of a ganglion cell

The optic disc:

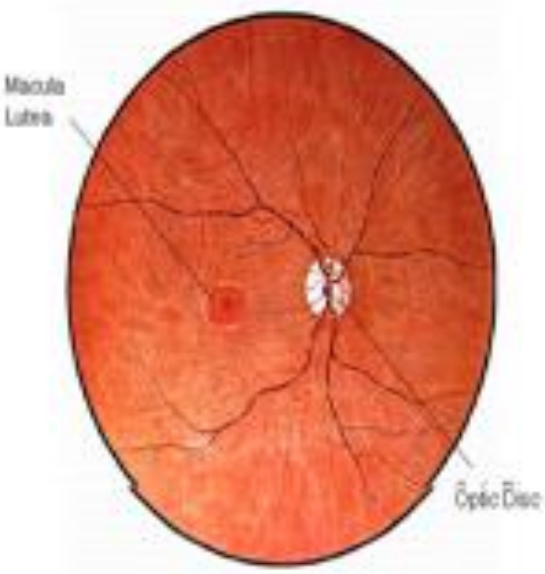
- It the site of the optic nerve exit from the retina, it is about 1.5 mm diameter and located about 3 mm to the nasal side.
- It does not contain photoreceptors, hence it is the cause of the physiological blind spot in the visual field which is not noticed because the two blind spots of both eyes do not lie in corresponding retinal points.
- Also using one eye the blind spot is not appear because the continuous fine movement of eye ball.

The macula lutea

- It is a yellowish spot located about 3 mm to the temporal side of the optic disc opposite to the posterior pole of the eye.
- The central part of the macula contains the fovea centralis
- The fovea is composed of cones only while the other nervous elements are shifted to its surrounding area, thus the light falls directly on the receptors (cones) without passing through many layers.
- In the fovea each one cone is connected to one bipolar cell and this bipolar cell is connected to one ganglion cell which its axon form separate fiber in the optic nerve.
- The pigmented epithelium layer is highly developed in the fovea.



Opthalmoscopic view of the retina



Structure of rods and cones:

Each rod or cone consists of :

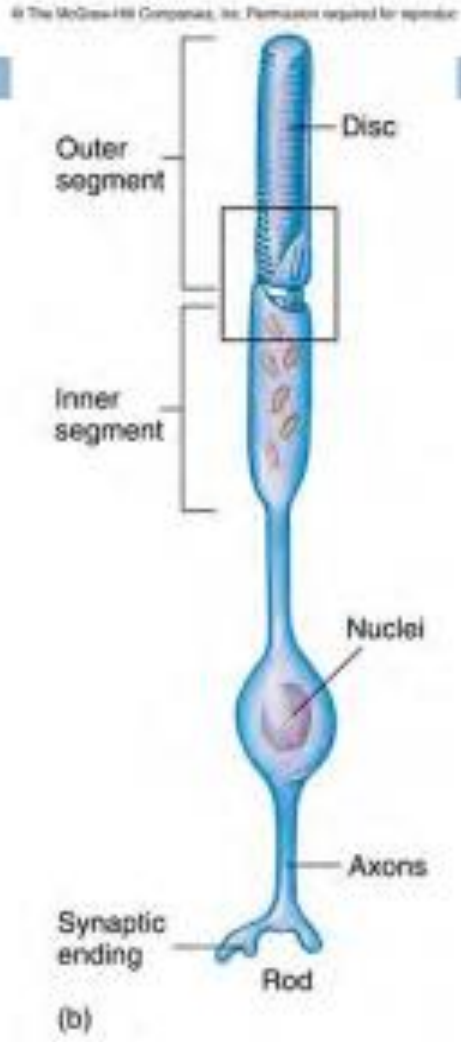
1- Outer segment:

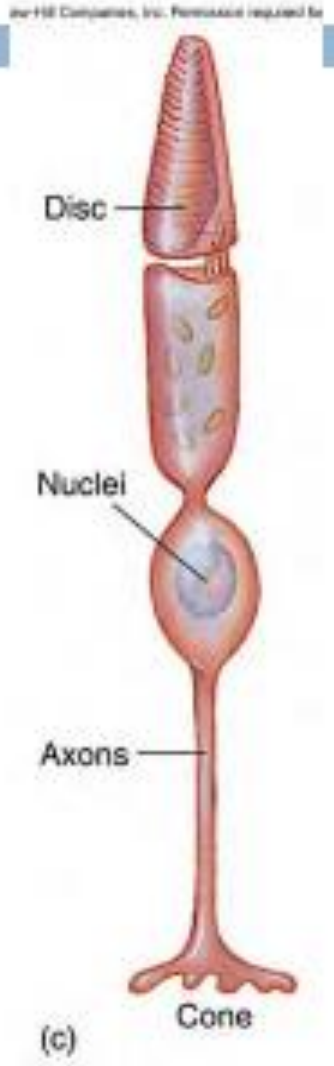
contains discs or shelves which contain the visual pigment (rhodopsin in rods and iodopsin in cones).

2- Inner segment contains mitochondria and nucleus.

3- The Synaptic zone which is the area of junction between rods or cones and the dendrites of the bipolar cells.

RODS & CONES

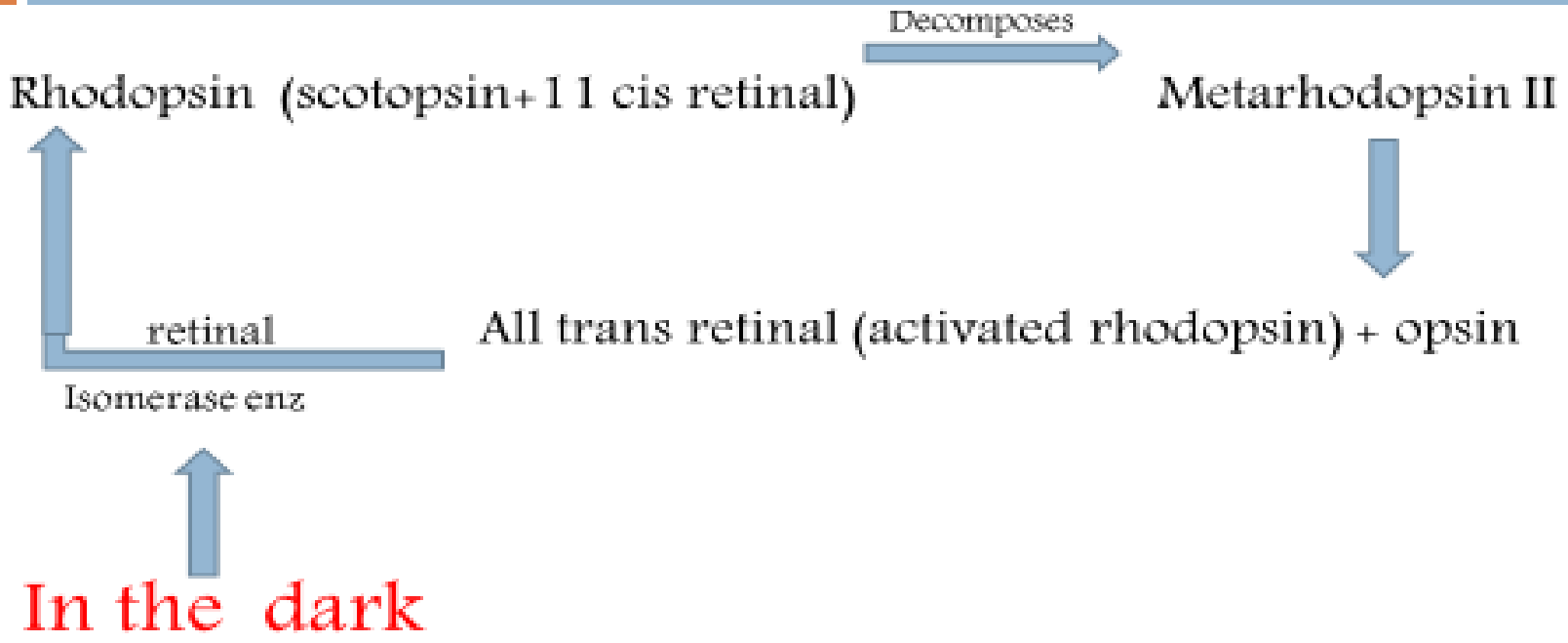

Outer segment
Inner segment
Disc
Nuclei
Axons
Synaptic ending
Rod
(b)


Disc
Nuclei
Axons
Cone
(c)

Mode of stimulation of the photoreceptors

- The outer segment of the rods contain rhodopsin
- This rhodopsin consists of protein part called "Scotopsin" and an aldehyde of vitamin A called (11- cis retinal)
- The outer segment of the cones contain iodopsin
- This iodopsin consists of protein part called "photopsin" and an aldehyde of vitamin A called (11- cis retinal)
- There are three types of the photopsin , each one is sensitive to one of the three primary colors i.e. red, blue and green.

On exposure to light



PHOTORECEPTOR POTENTIAL

I- In the dark,

- Na+ is continuously pumped from the inner segment of the rods and cones to flow inside again at the outer segment in which its Na+ channels remain opened by cGMP.
- The continuous inflow of Na+ ions inside outer segment of rods decreases negativity inside them and thus the resting membrane potential (r.m.p) of them becomes low (only –40 mv).
- The movements of Na+ from inner segment to enter into outer segment is called "dark Na+ current".
- The low r.m.p causes continuous release of an inhibitory chemical transmitter that inhibits synaptic transmition.

II- On exposure to light

- When light stimulates the photoreceptors and activated rhodopsin is formed it leads to activation of cGMP phosphodiesterase enzyme which transform cGMP into 5'GMP
- lowering concentration of cGMP in the cytoplasm of photoreceptors causes closure of Na+ channels in the outer segment.
- Thus, Na+ is continuously pumped from inner segment but now is accumulated outside at the outer segment leading to hyperpolarization reaching up to -70 mv instead of -40 mv.

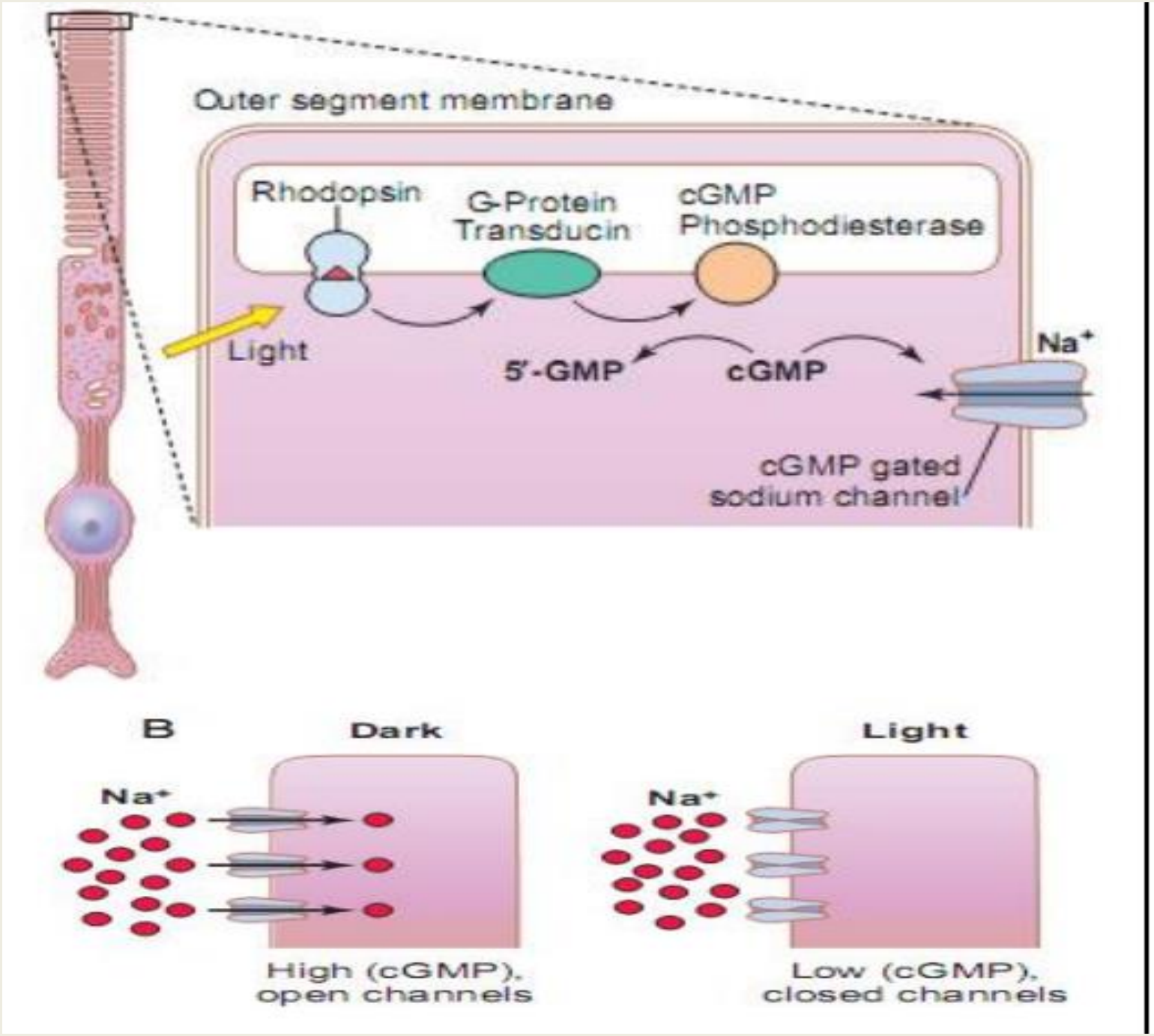
continue

- This hyperpolarization leads to reduction of the release of the inhibitory chemical transmitter (glutamate) which facilitates synaptic transmition of the visual pathway.

- Thus the only receptor in the body which its receptor potential is generated by state of hyperpolarization instead of normal depolarization is the photoreceptors.

On removal of light

- Re synthesis of cGMP occurs with subsequent opening of Na+ channels and the membrane potential returns back to –40 mv which causes release of glutamate again


Outer segment membrane
Rhodopsin
G-Protein
Transducin
cGMP
Phosphodiesterase
Light
5'-GMP
cGMP
Na+
cGMP gated
sodium channel
B
Dark
Na+
High (cGMP),
open channels
Light
Na+
Low (cGMP),
closed channels

DUPLICITY THEORY OF VISION

Because there are two types of receptors in the retina, it was found that there are two types of vision:

A- Photobic vision: (day or bright light vision)

Performed by the cones. In this type of vision the details, the boundaries and the color of objects are well detected.

B- Scotopic vision: (dim or dark vision)

Performed by the rods details, boundaries and color of objects are not well detected,

The vision is less accurate in rods because each 200 rods converge on only one bipolar cell, then many bipolar cell converge on only one ganglion cell.

Primary colors

- Are those colors that when mixed in an equal proportion give the sensation of white color.
- They are red, blue and green.
- Mixing of wave lengths of these colors can form any other spectral color.
- These colors cannot be formed from mixing of any other colors.
- For any color there is a complementary color, when mixed together can give the sensation of white color
- Black is that sensation which produced by complete absence of light

A- Trichromatic theory (Young - Helmholtz theory)

- It depends on the presence of 3 types of cones each one is sensitive to one of the primary colors.
  - First cone contains pigment that is sensitive to blue.
  - Second cone contains pigment that is sensitive to green.
  - Third cone contains pigment that is sensitive to the red.
- Different colors stimulate the three cones in an unequal manner and thus number of impulses transmitted from these cones to the visual cortex differ in frequency and number and this difference gives the specific sensation of that color.

- Equal stimulation of all the three cones gives the sensation of white color.

B-Neural theory of color vision

- Neural theory states that **perception of colors** is mainly a function of **group of neural cells** starts at **X ganglion** cells in the retina.
- Then from these X ganglion cells to another group of cells in the **lateral geniculate body in the thalamus** called **"parvocellular neurons"**
- Finally impulses reach color sensitive neurons in **visual cortex** called neurons of **"blobs"** to relay in lingual and fusiform gyri of the occipital cortex which were proved to be concerned with color vision.


Best
Wishes
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