



CNS revision (Part 4)

By

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Cornea

Causes of transparent cornea:

Anatomic factors

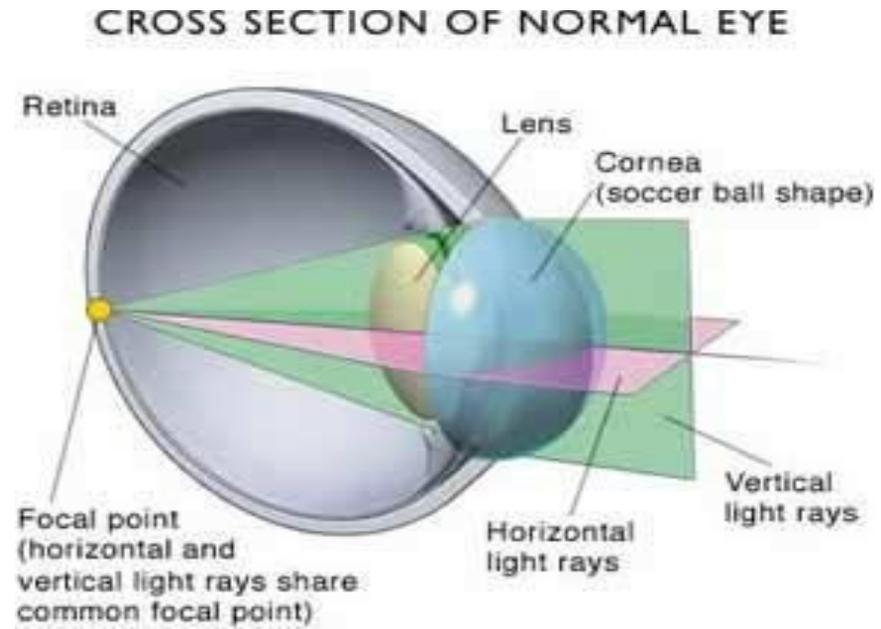
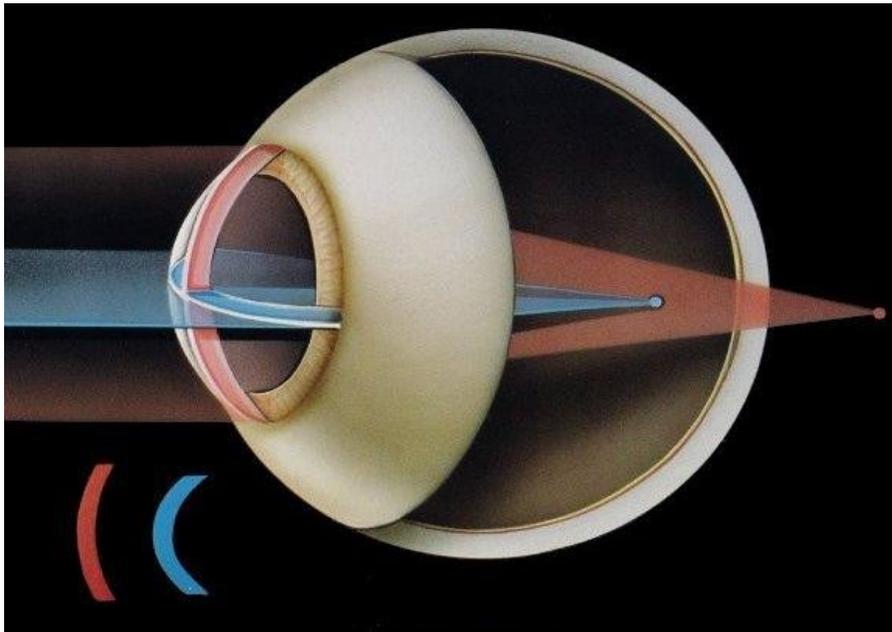
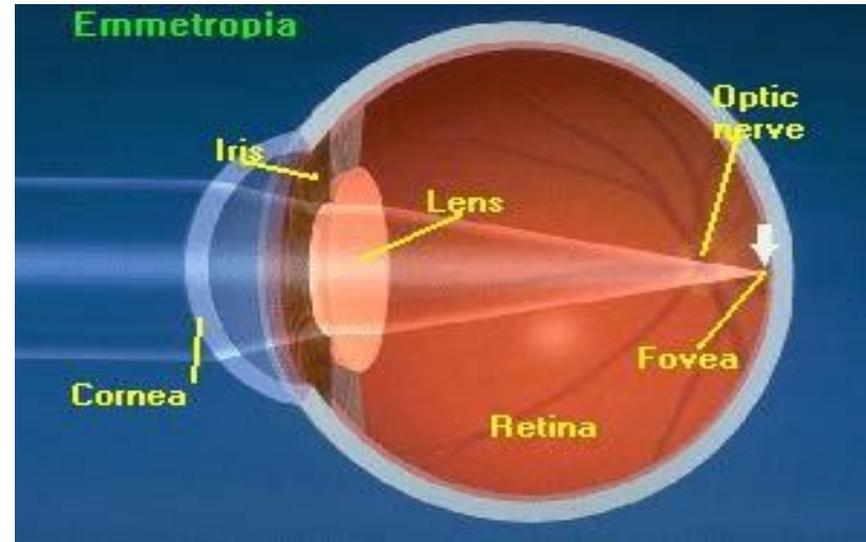
1. **Regular** & uniform **arrangement** of the **epithelial cells** & **lamellae**.
2. **Absence** of **blood vessels** & **myelinated nerve** fibers

Physical factors

1. The **refractive index** of various layers of cornea is the **same**.
2. Relative **corneal dehydration** by **osmotic pump** and **metabolic pump** mainly **in the endothelial cells**.
 - **Osmotic pump**: The **aqueous humor & tears** are **hypertonic** relative to corneal tissue, so they draw water from the cornea.
 - **Metabolic pump** (Na⁺ pump in endothelium) is an **active process** using energy produced by corneal metabolism. It **pumps Na⁺ from the cornea** to aqueous humor followed with water.

Functions of the cornea

1. It is **transparent** structure allowing the **passage of light** rays into the eye.
2. The **regular curvature** of the corneal surface helps the formation of **sharp clear images** on the retina.



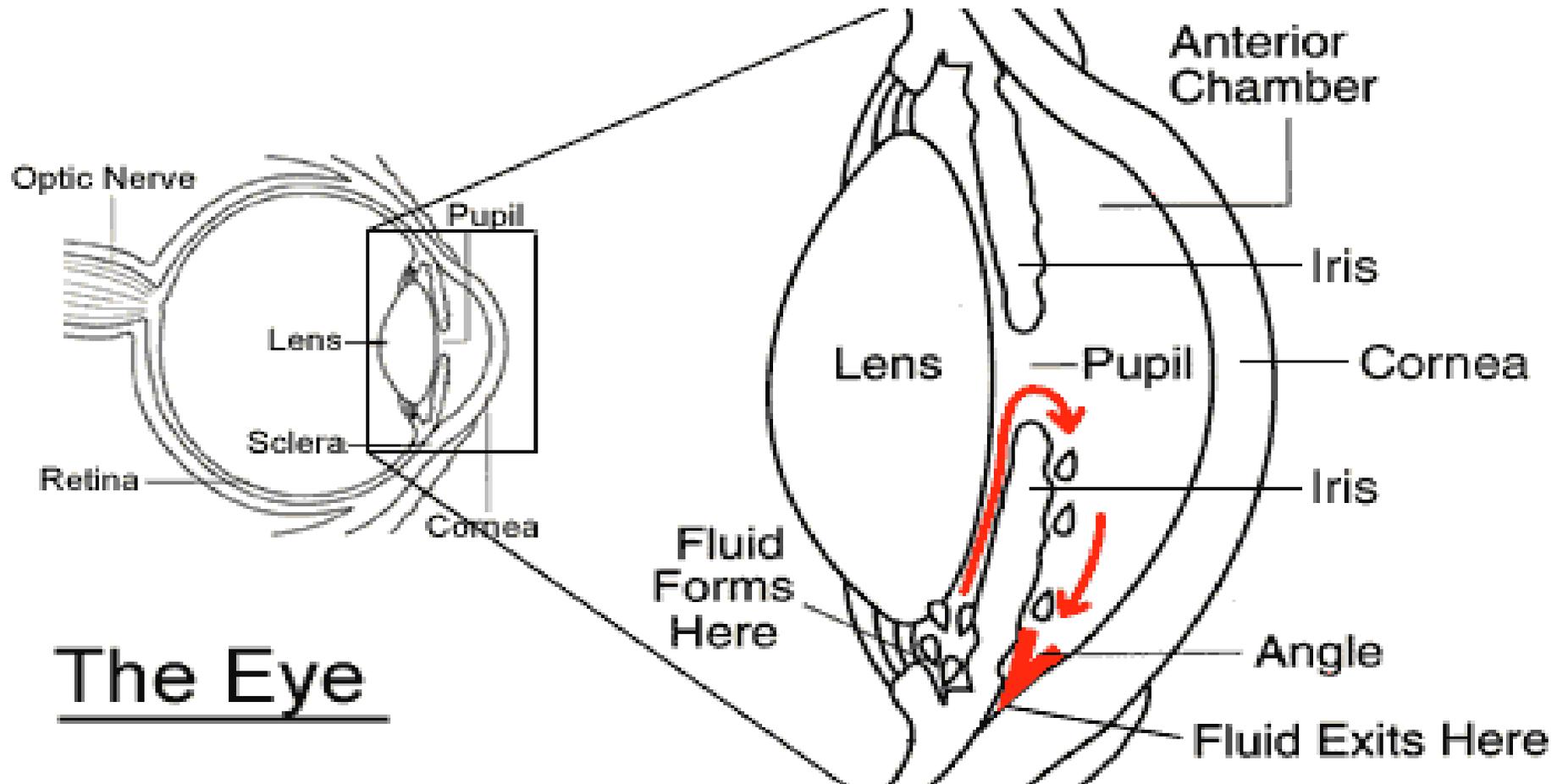
Functions of the cornea

3. It acts as a powerful **convex lens** (+ 39- 43 diopters) having 70% of total dioptric power of the eye

4. **Protection** of inner structures of the eyeball by
 - a. Its **fibrous structure**
 - b. It **absorbs ultraviolet rays** that fall on the eye (protect the retina)
 - c. The **corneal reflex** (touch of the cornea by any foreign body e.g. piece of cotton results in reflex blinking of both eyes)

The Aqueous Humour

- Transparent colorless **alkaline?? fluid**
- **Fills** the **anterior** and **posterior chambers** of the eye



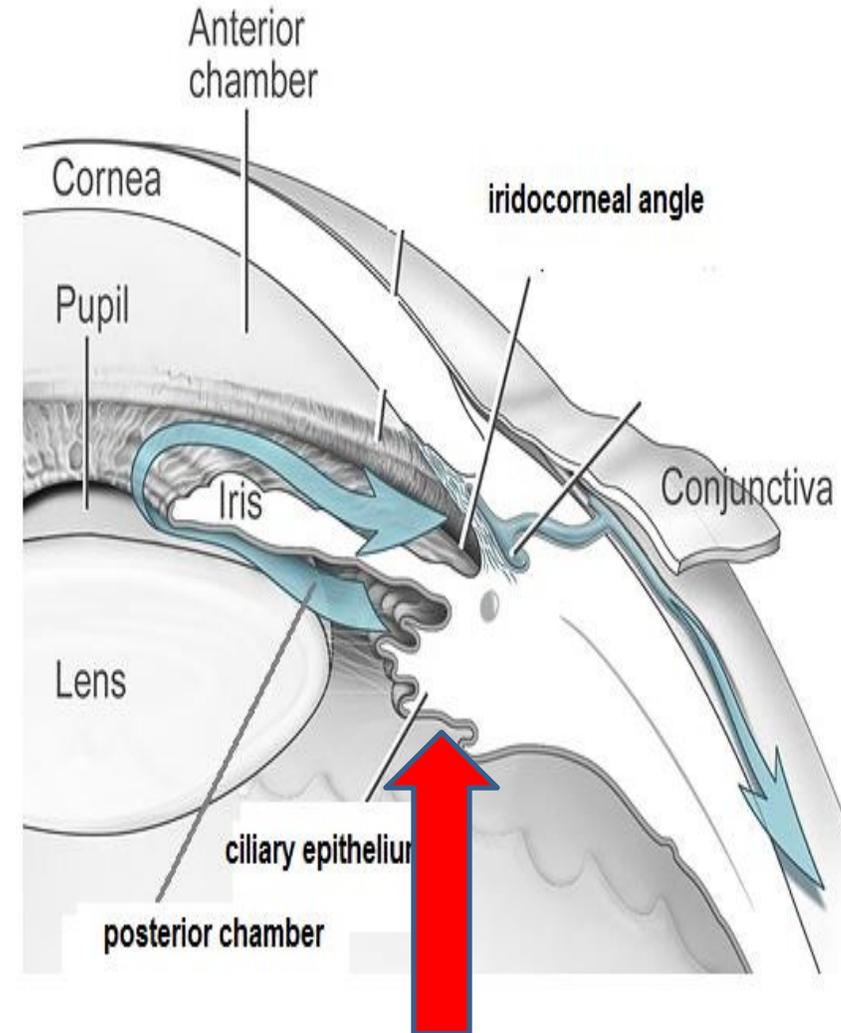
The Aqueous Humour

Mechanism of formation

- **Formed** continuously by the **Ciliary epithelium** by **facilitated diffusion** and **active transport** mechanisms
- **Na** by active transport
- **Cl** and **HCO₃ ??** and **H₂O** follow Na passively

Rate

- At a rate **1-2 $\mu\text{L}/\text{min}$**



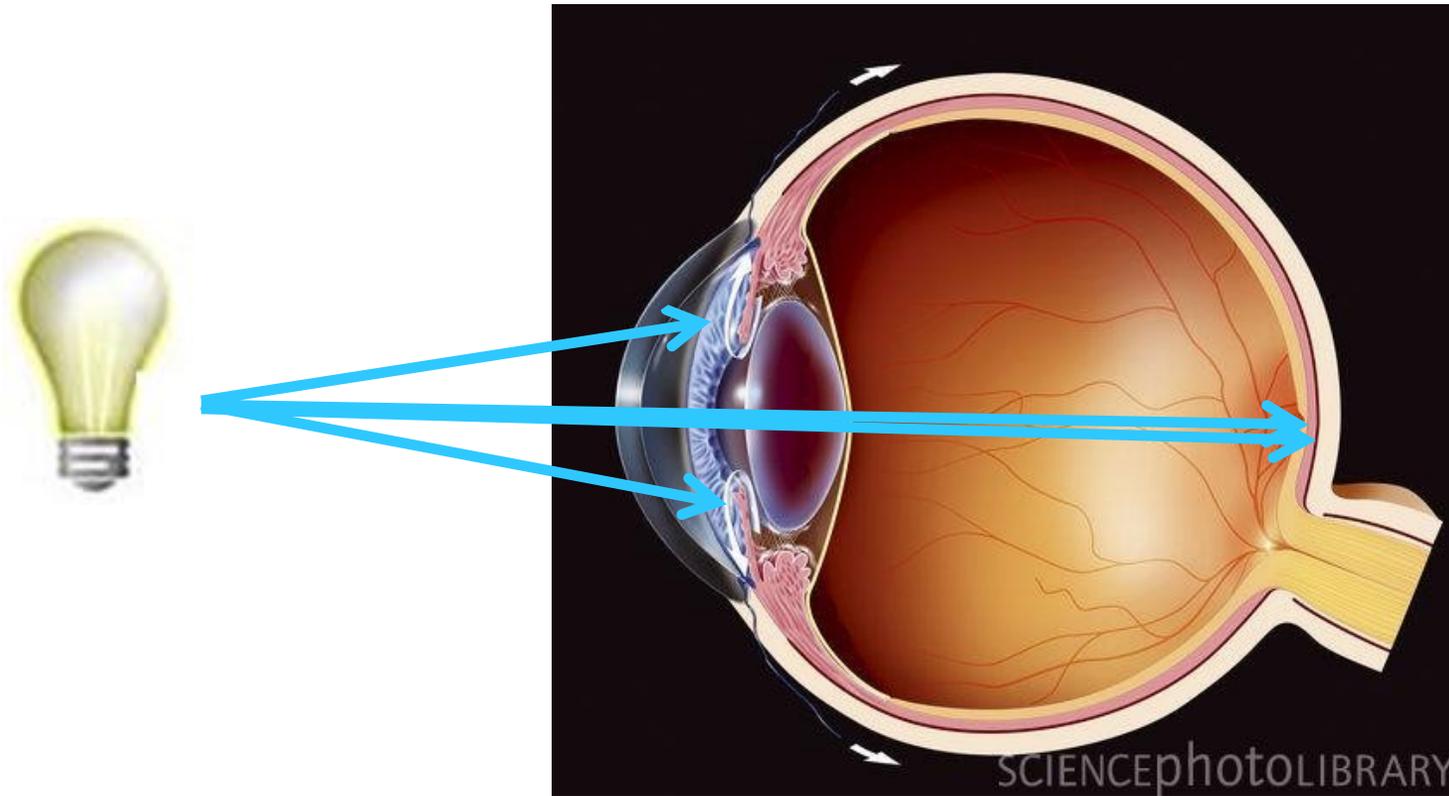
The Aqueous Humour

Functions:

- 1. One of the important refractive media of the eye**
- 2. Nourishes the avascular cornea and lens.**
- 3. Buffers the acid produced by the anaerobic metabolism of the cornea and lens.**
- 4. Has a mechanical function to keep the eyes rigid and to maintain its refractory power.**
- 5. Maintains the intraocular pressure (12 - 20 mmHg) constant by means of its steady formation and drainage**

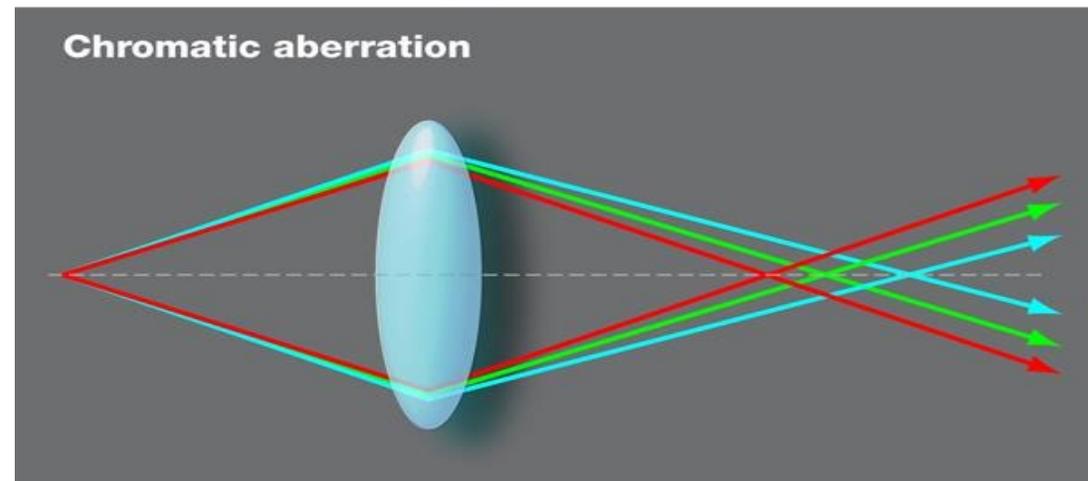
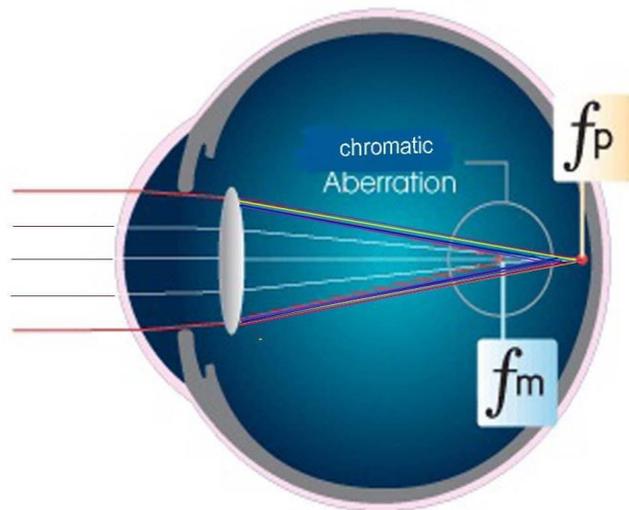
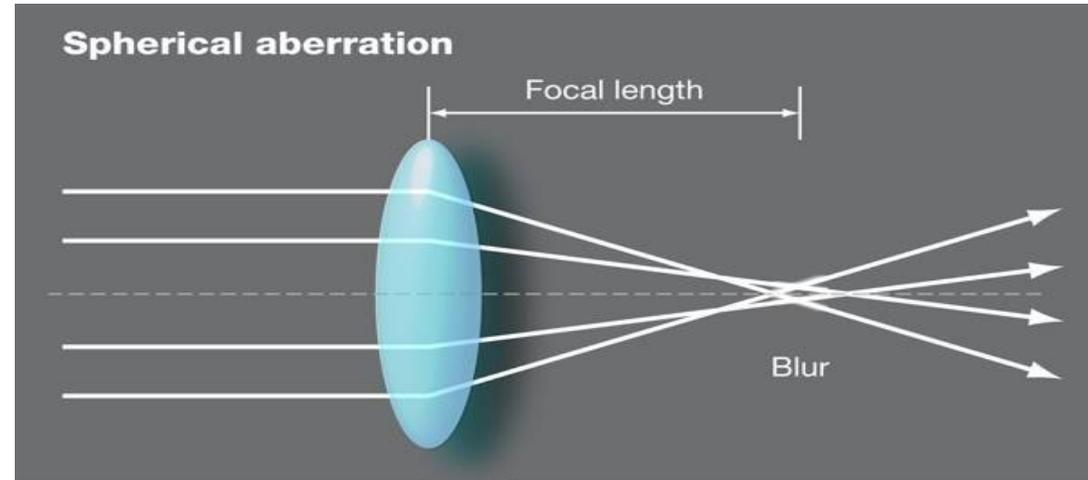
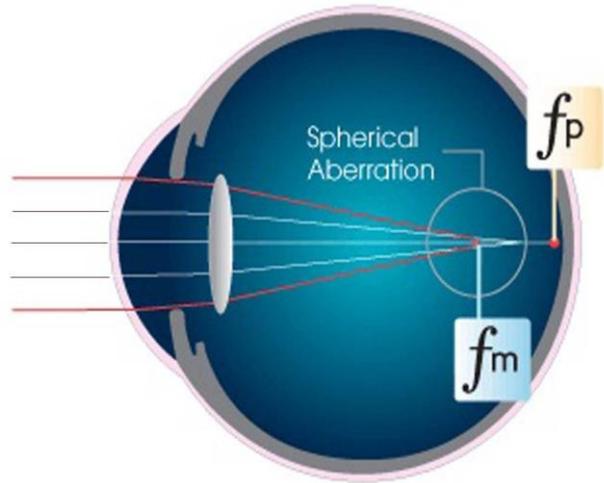
Functions of the Iris

1. Pigments of iris **absorb** all light rays which enter into the eye except through which pass through the pupil.



Functions of the Iris

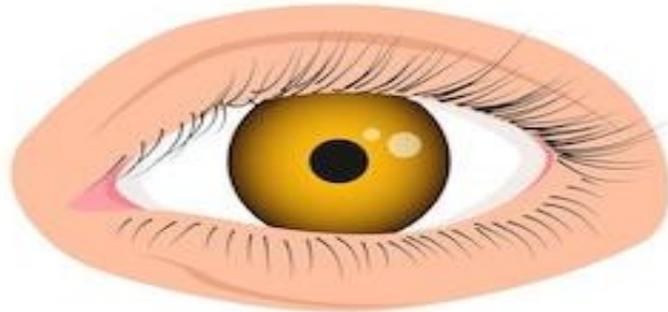
2. Prevents light from falling on the peripheral parts of the lens. Thus, it prevents spherical and chromatic aberration.



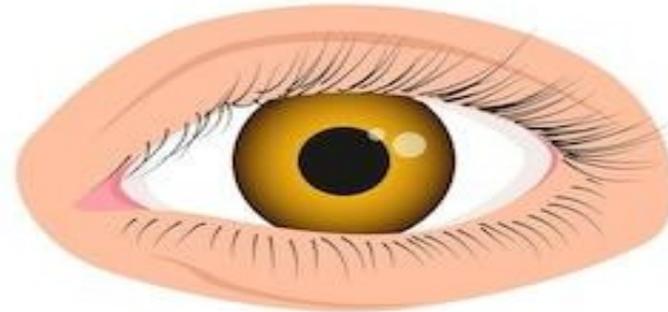
Functions of the Iris

3. **Regulates** the **amount of light** which enters the eye by regulating the size of the pupil (**pupillary light reflex**).

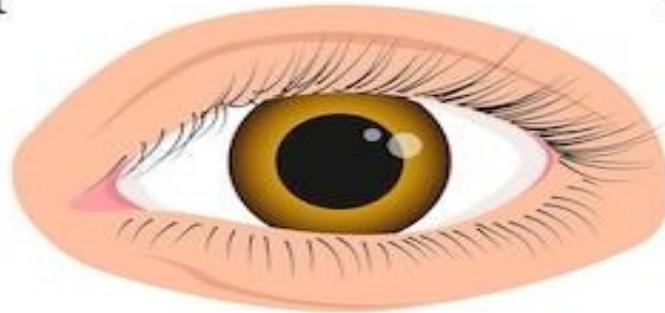
PUPILLARY LIGHT REFLEX



Bright Light



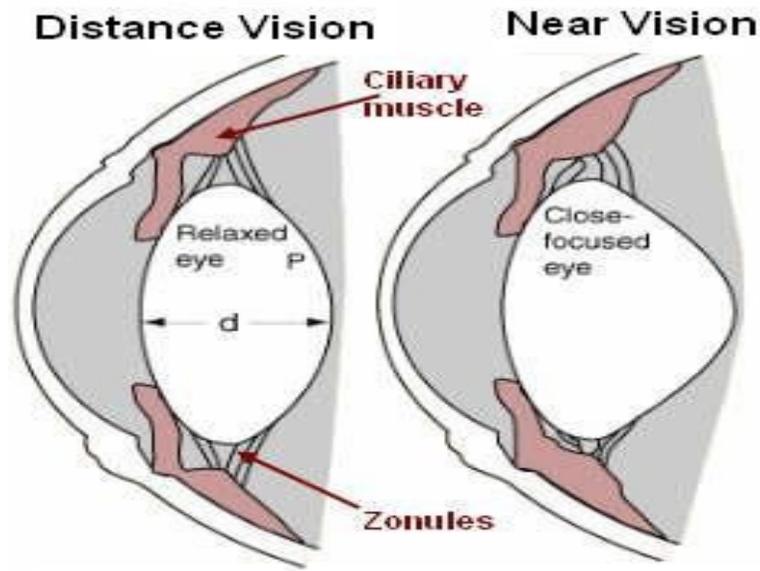
Normal Light



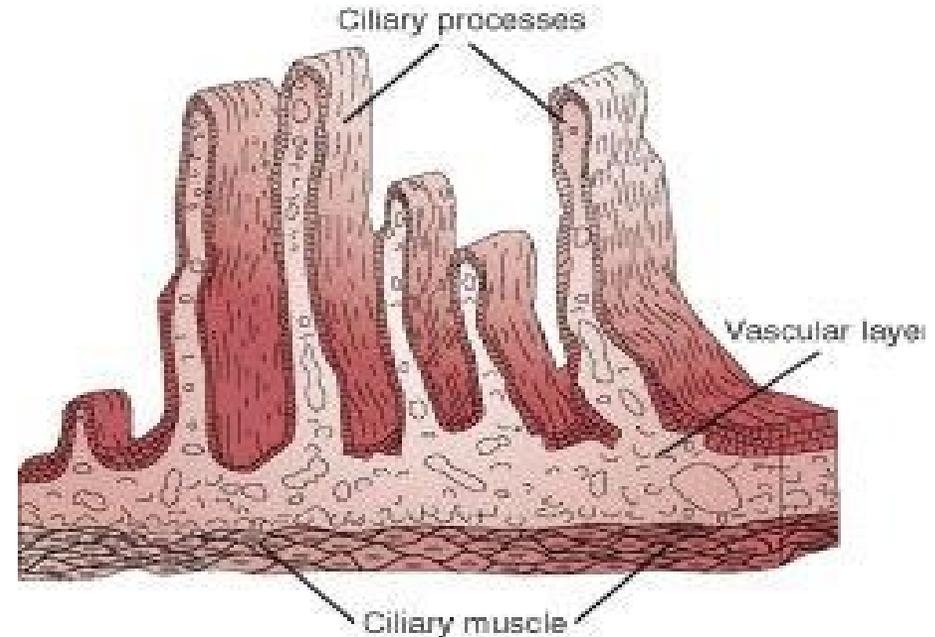
DIM Light

Functions of the Ciliary Body

1. Ciliary muscle is essential for accommodation
2. Ciliary processes secrete the aqueous humor into the posterior chamber & give attachment to the suspensory ligament of the lens.

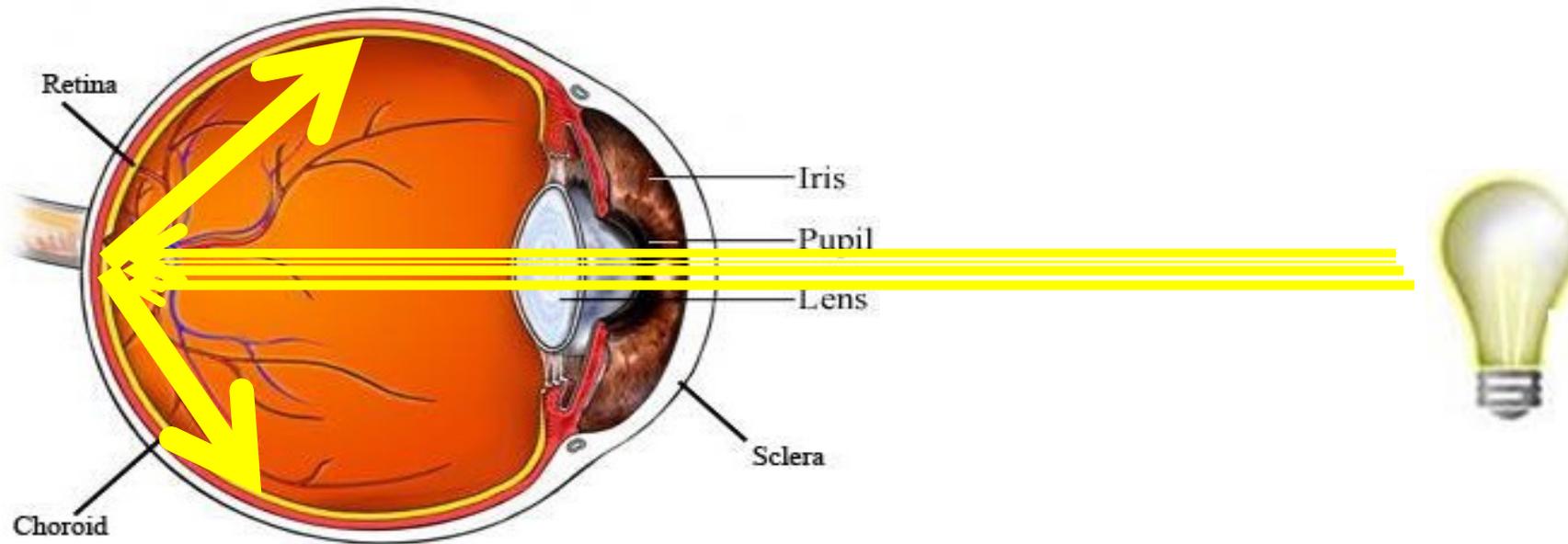


For near vision, the ciliary muscles contract and the central lens thickness increases to increase its power.



Functions of the Choroid

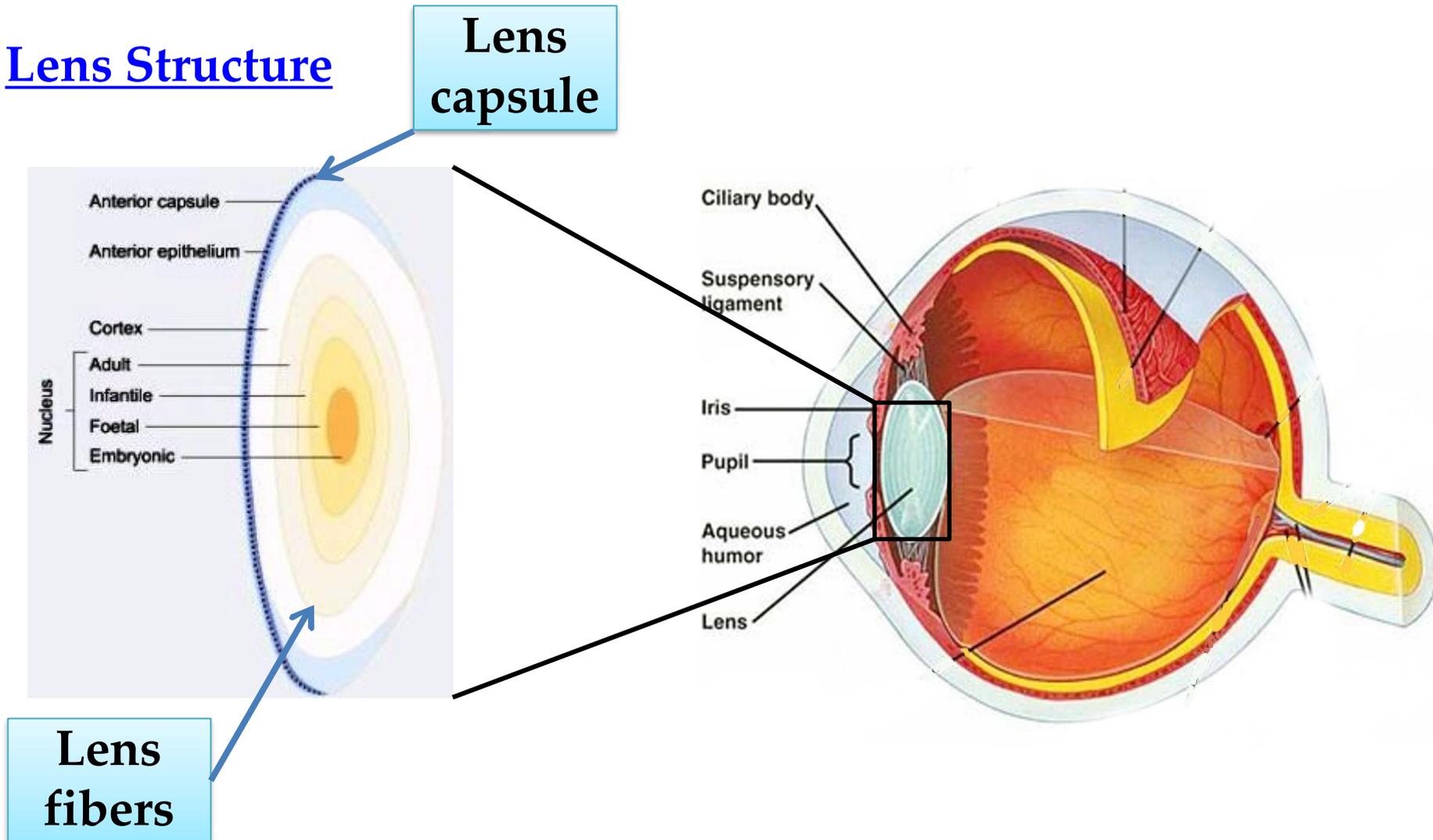
1. **provides blood supply** to the eye
2. **Pressure** inside its vessels **maintains** the **intraocular pressure**
3. Contains **melanin pigments** which **absorb light** & prevent its reflection inside the eye which cause **blurring of vision**



The Crystalline Lens

- It is **avascular, transparent** biconvex elastic structure

Lens Structure



The Crystalline Lens

Lens transparency

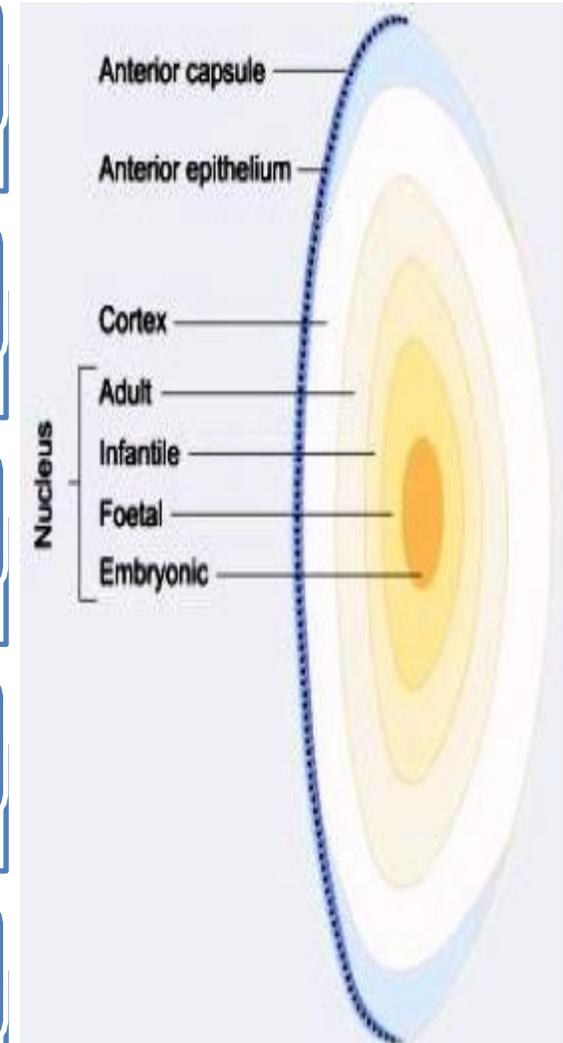
Uniform arrangement of lens fibres

Absence of blood vessels

Dehydration maintained by an active process

Constancy of its chemical composition

The refractive indices of the various materials in the lens are nearly equal



The Crystalline Lens

Functions of the lens:

Provides about 30% of the total dioptric power of the eye. Its R.I. is 1.4

Protects the retina by absorbing ultraviolet waves

Accommodation to near vision: the lens enables the eye to see far and near objects clearly by the mechanism of accommodation that changes its power from 20 to 32 D

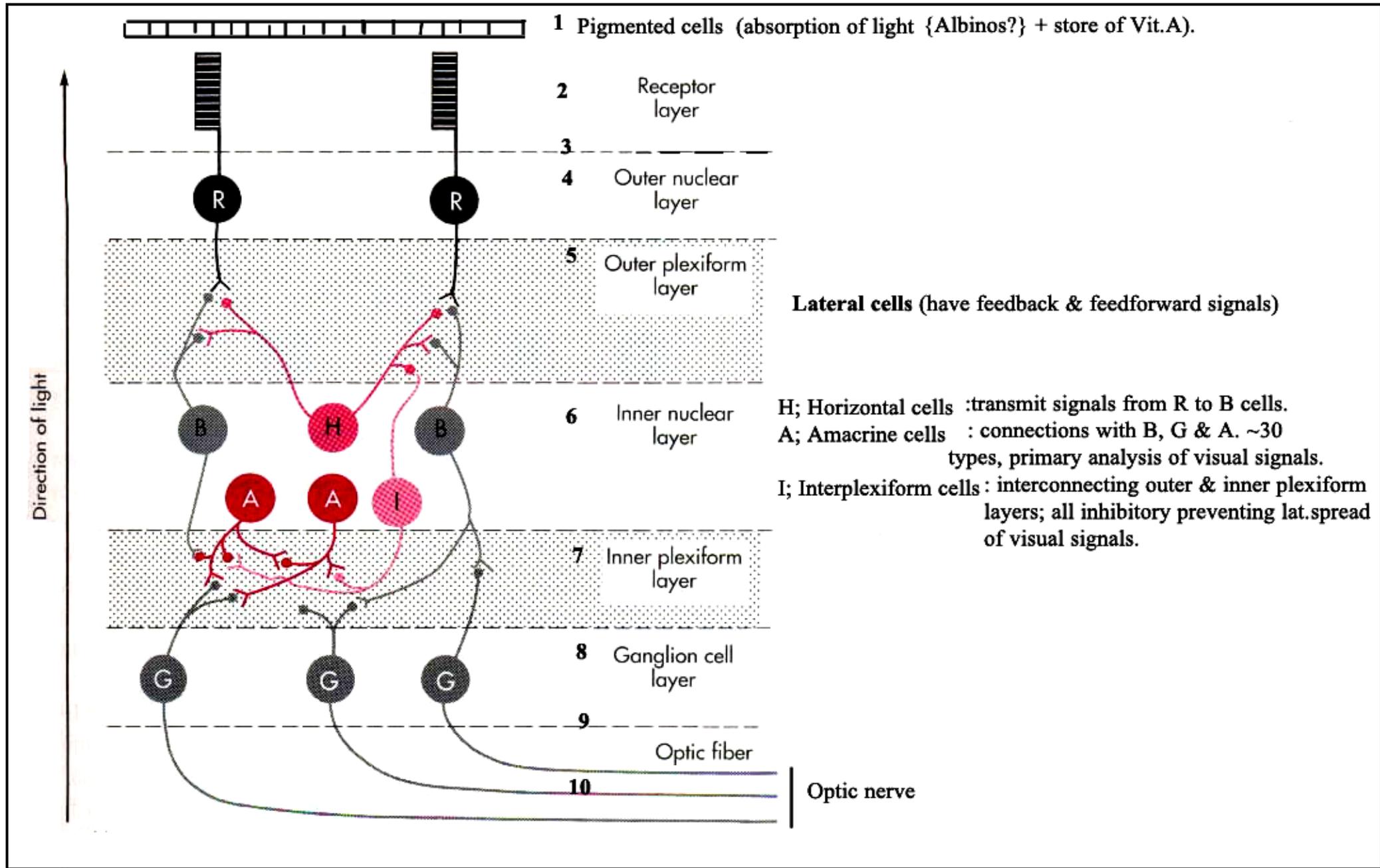


Phototransduction and retinal adaptation

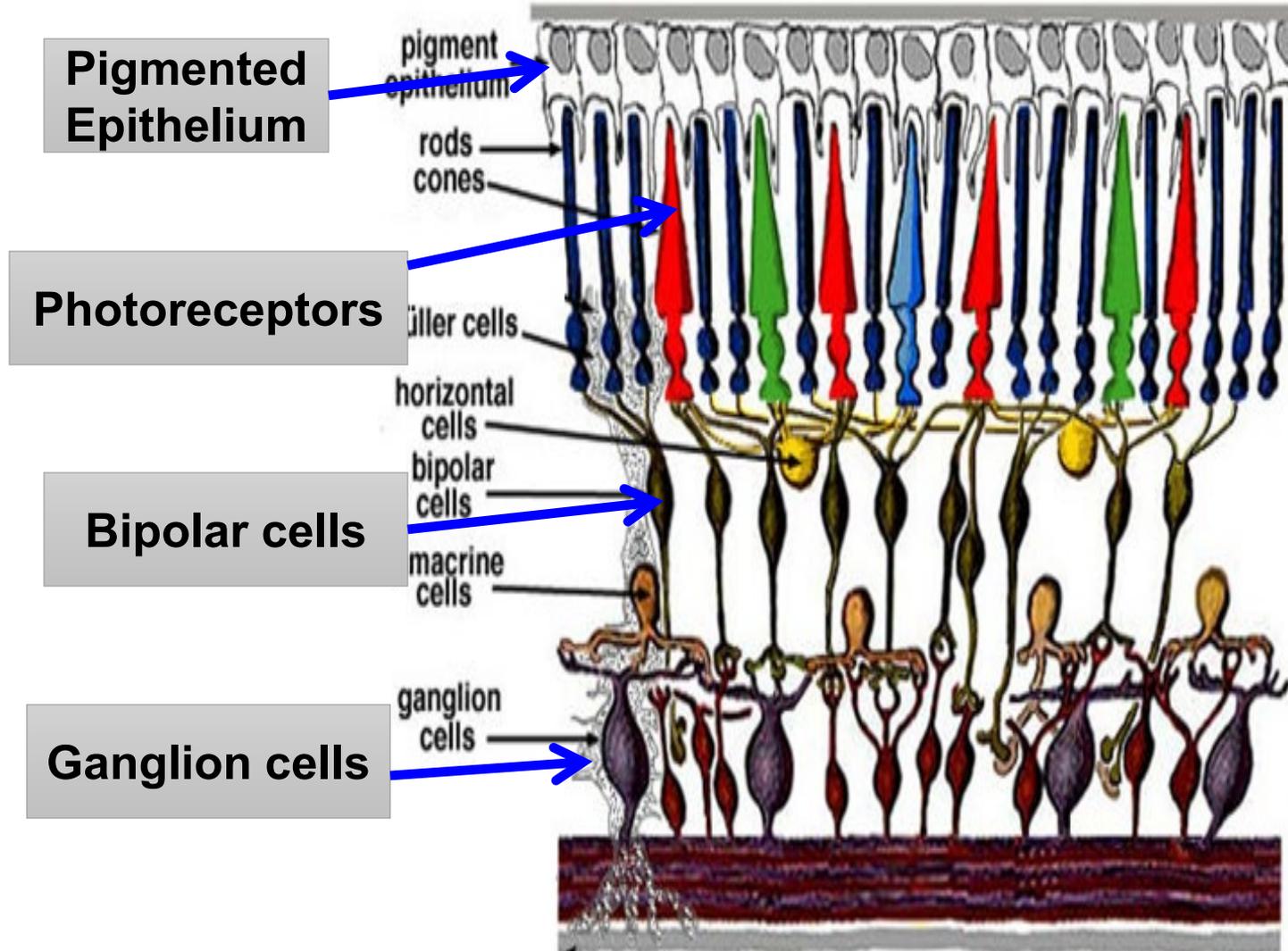


Retina

- ❑ The retina is the innermost photosensitive layer of the eyeball.
- ❑ Histologically, it is formed of 10 layers
- ❑ Physiologically, 4 layers have special importance
 - a. Layer of pigmented epithelium.
 - b. Layer of rods and cones.
 - c. Layer of bipolar cells.
 - d. Layer of ganglion cells.



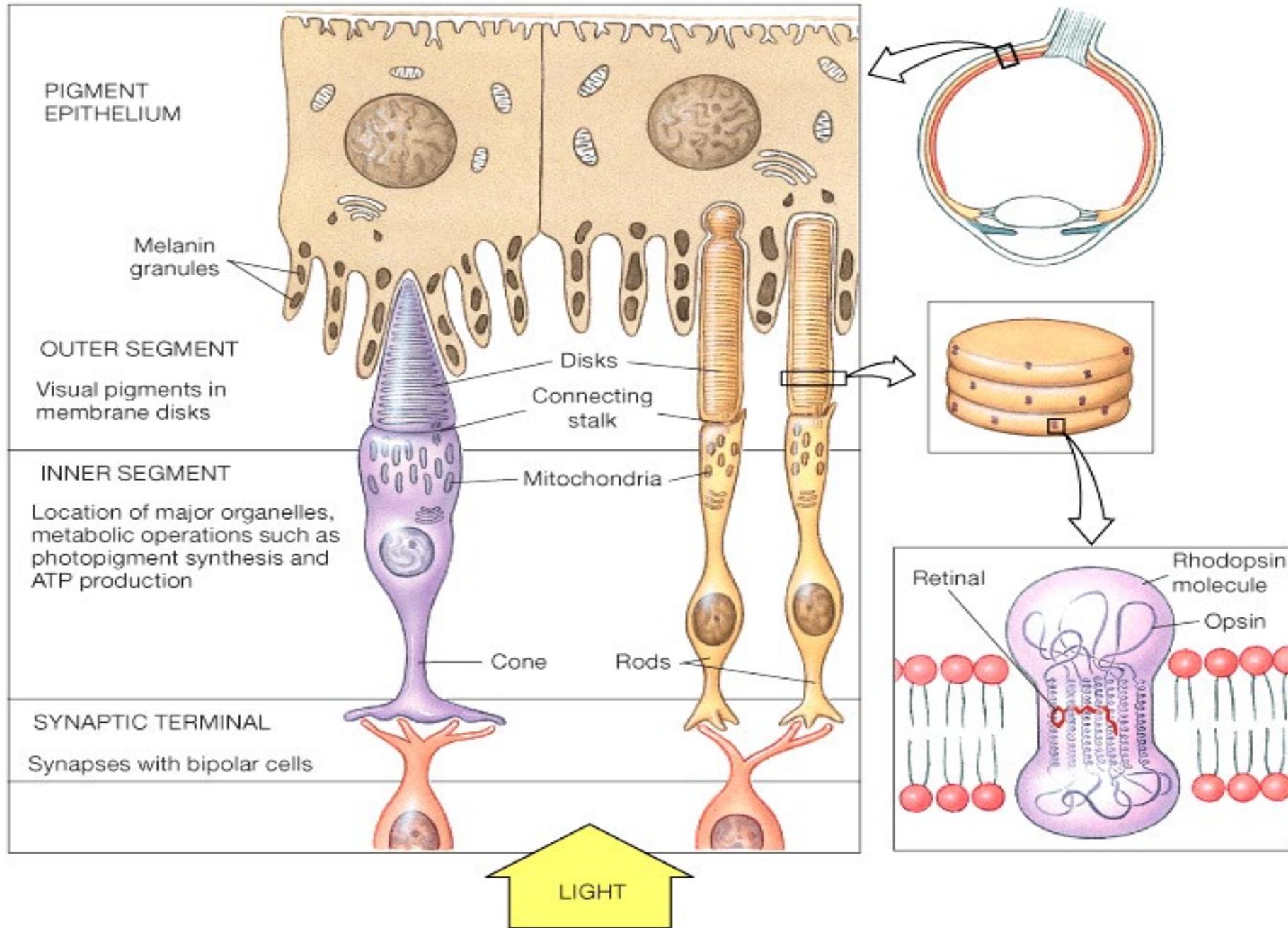
Functional Layers





(I) Retinal Pigmented Epithelium (RPE)

- It is a monolayer of pigmented epithelial cells; its outer side is in contact with the choroid and its inner side with the rods and cones.
- Functions:
 1. It contains large amounts of melanin pigments which absorb light and prevent its reflection inside the eyeball which cause glare.



2. It produces a **sticky extracellular matrix material** that keeps the outer segments of rods and cones straight and aligned.
3. It participates in the **breakdown and resynthesis of the photopigments.**
4. It helps the **continual renewal of the outer segment** by ingesting the old outermost tips of the rods and cones.
5. It stores large amount of **vit. A** needed for **photopigments recycling.**



(II) Photoreceptors (rods and cones)

➤ Structure of photoreceptors: Each rod or cone is formed of:

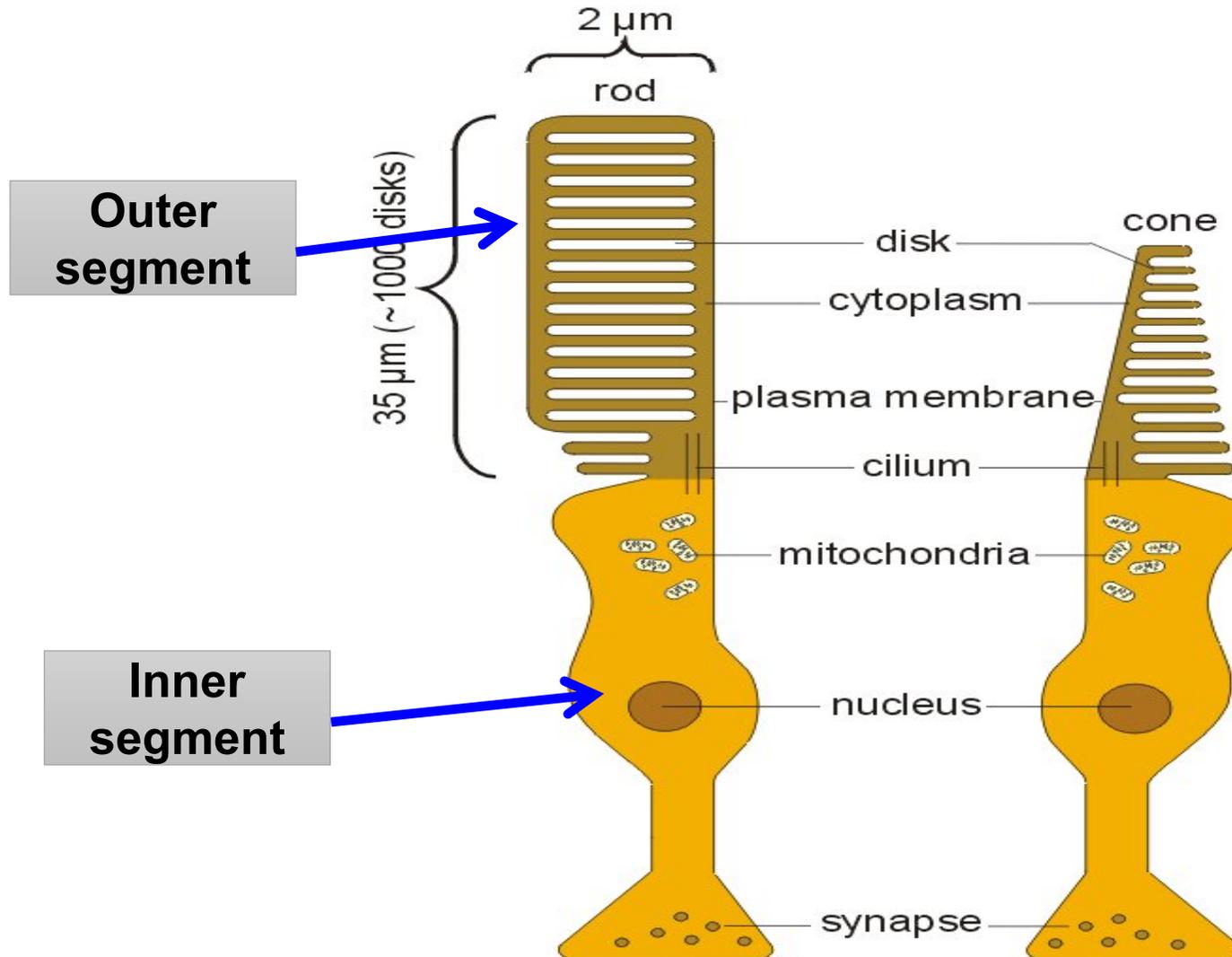
(i) An outer segment:

- They are modified cilia which are long cylindrical in rods and short conical in cones.
- They contain a great number of disc-shaped shelves which are composed of folds of the cell membrane.



- **The disc membrane contains:**
 - Photosensitive pigments e.g. rhodopsin.
 - G protein called transducin.
 - c GMP phosphodiesterase (PDE).
- **The membrane of the outer segment of rods and cones** contains **cGMP-gated ion channels** selective for Na^+ , Ca^{++} and Mg^{++} .

Structure of rods and cones





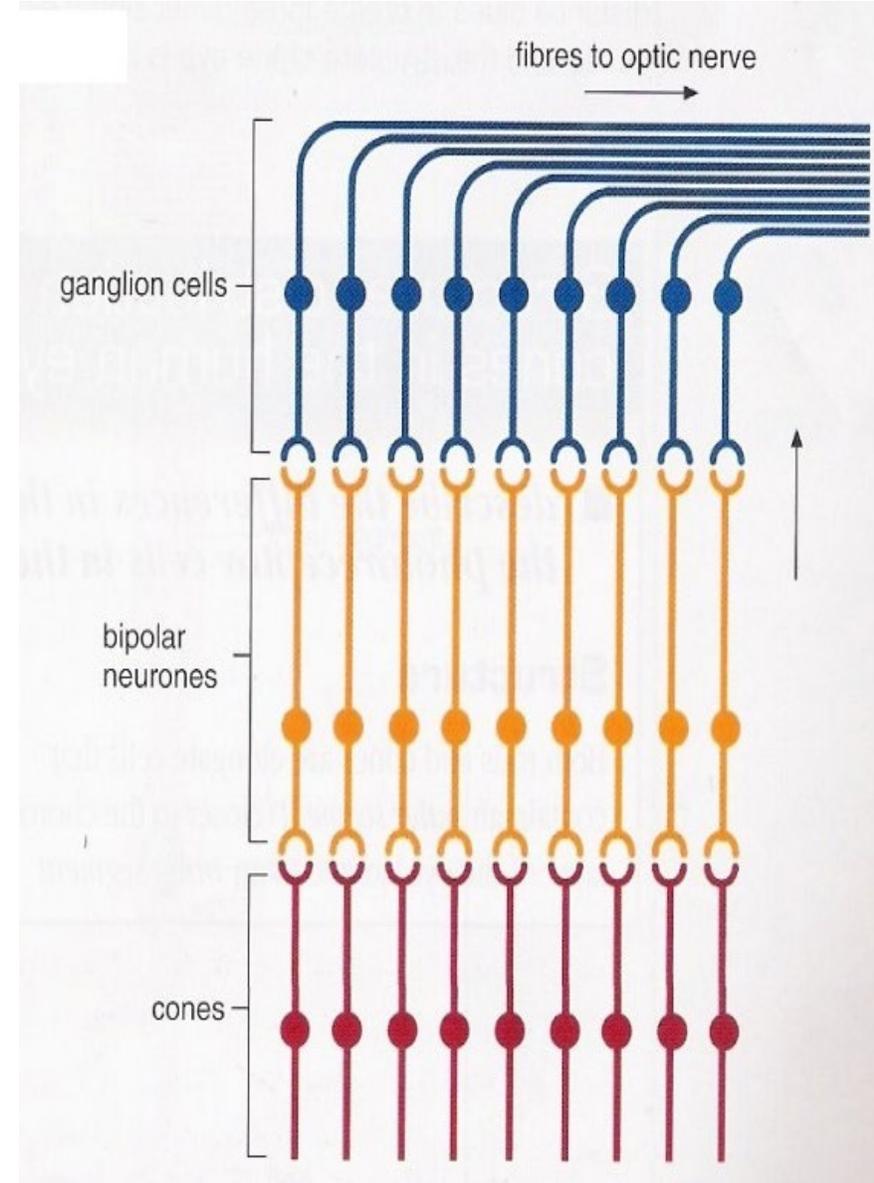
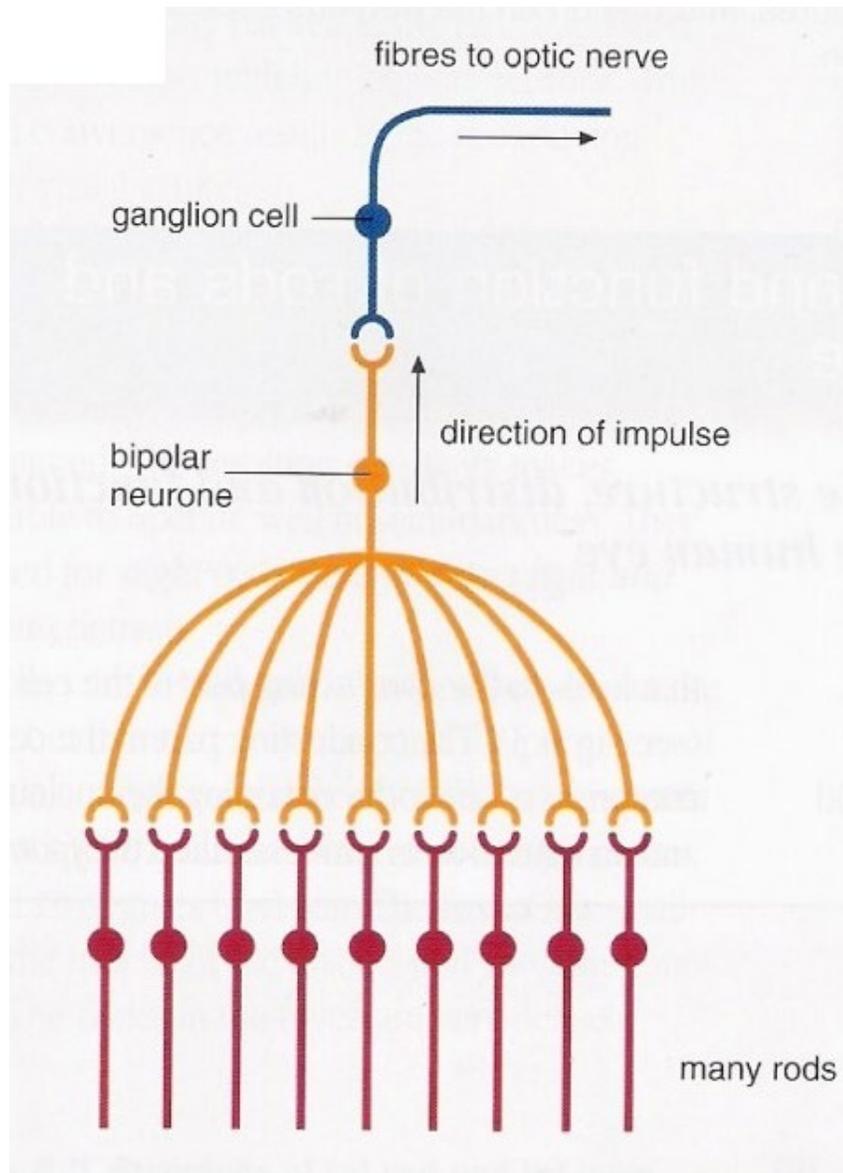
(ii) An inner segment:

- They contain nucleus and mitochondria.
- The membrane of inner segment contains an active Na^+ - K^+ pump and K^+ channels.
- They have synaptic body that synapses with bipolar cells (contains transmitter **glutamate**).

	Rods	Cones
<i>Number:</i>	120 millions	6-7 millions
<i>Shape</i>	Cylindrical	Conical
<i>Distribution</i>	<p>-Mainly in peripheral part of retina</p> <p>-Less in the middle part</p> <p>-Absent in fovea centralis & optic disc</p>	<p>-Mainly in fovea centralis.</p> <p>-Less in the middle part.</p>
<i>Photosensitive pigments</i>	Rhodopsin (visual purple)	Iodopsin (3 types)

	Rods	Cones
Connection	<p>Many rods converge to one bipolar cell</p> <p>Many bipolar cell converge to one ganglion cell (300:1)</p>	<p>One cone to one bipolar cell that can be connected to one ganglion cell (1:1:1)</p>
Functions	<ul style="list-style-type: none"> - more sensitive to light - less accurate vision i.e. can not perceive the details of the subject - can not differentiate colours - responsible for night vision 	<ul style="list-style-type: none"> - less sensitive to light - more accurate i.e. can perceive fine details of subject - can differentiate colours - responsible for day vision

Convergence of Rods and Cones



Photopic Vision



Blue Cone



Green Cone



Red Cone

Scotopic Vision



Rod



Rod



Rod



Rod



Rod

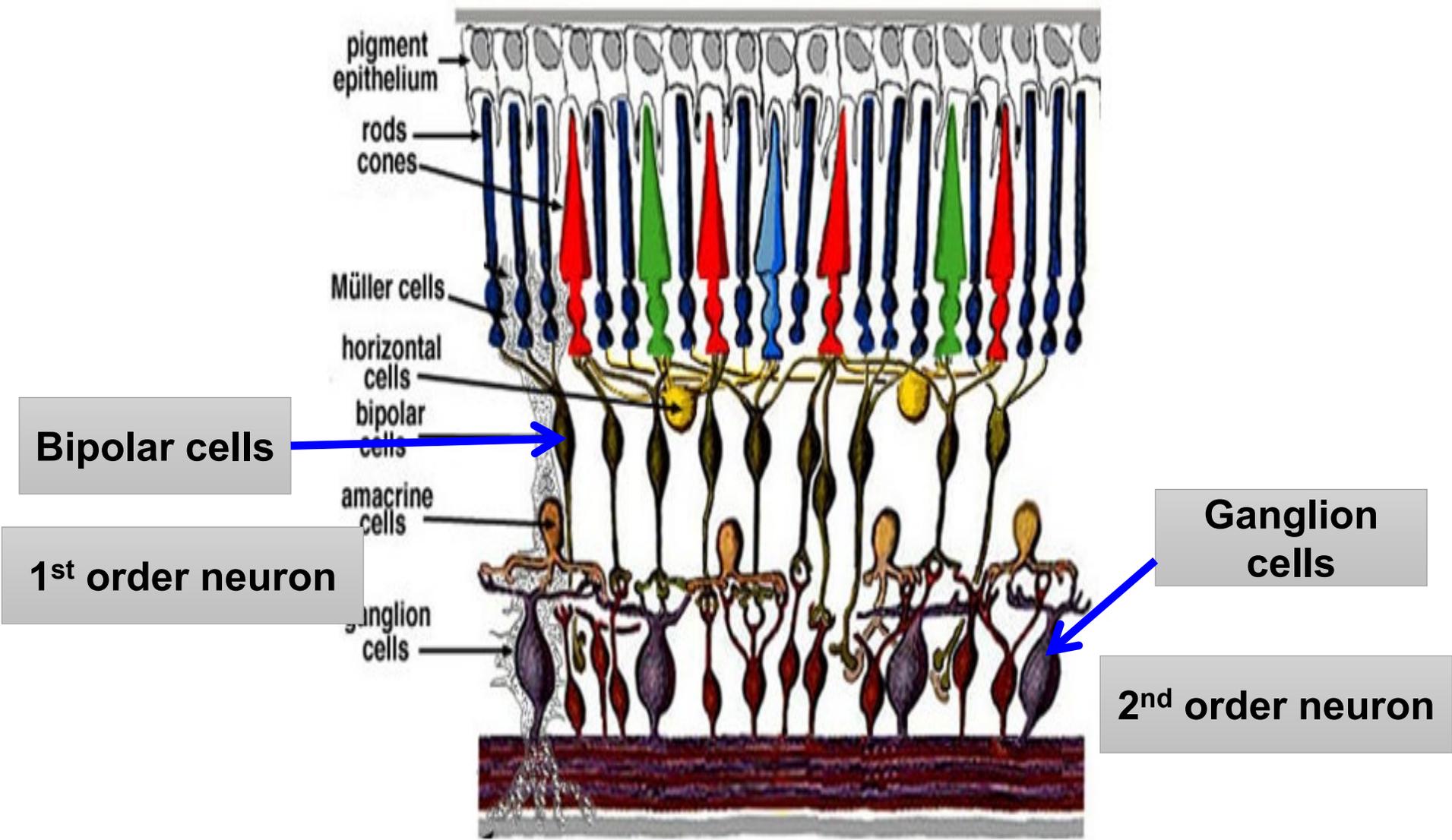


Rod

(III) Layer of bipolar and ganglion cells

- They constitute 1st and 2nd order neurons in visual pathway.
- Bipolar cells transmit signals from **photoreceptors** to **ganglion** cells, while ganglion cells transmit signals from **bipolar** cells to **brain** through the optic nerve.

Ganglion and Bipolar cells

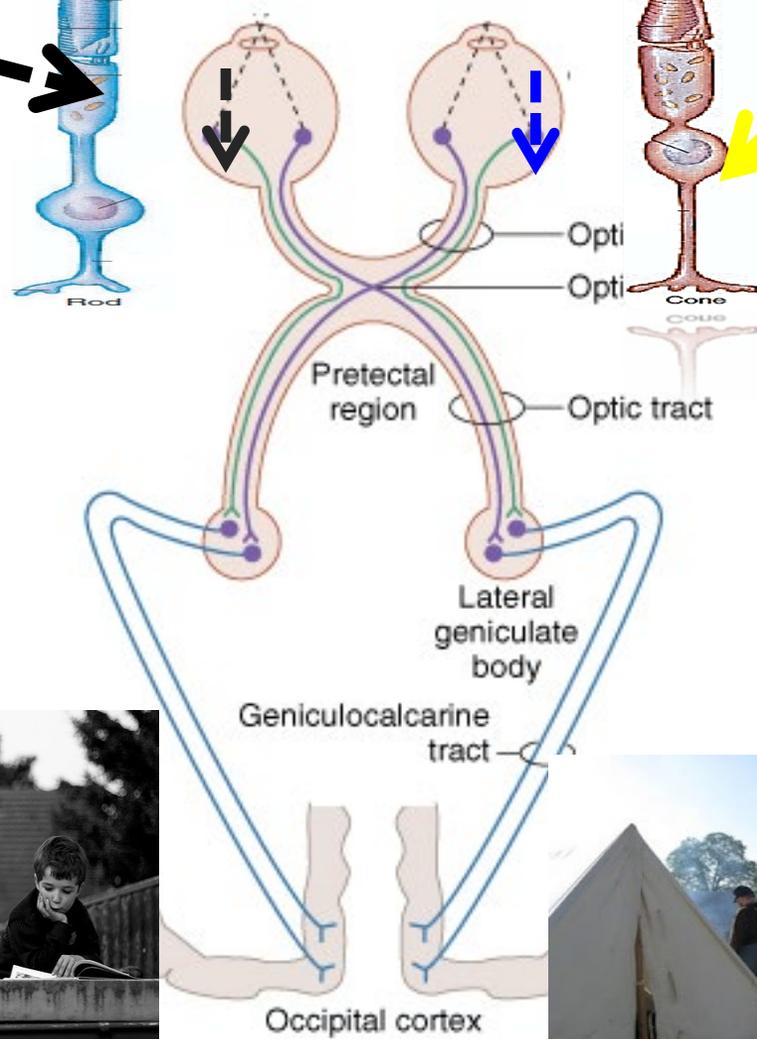
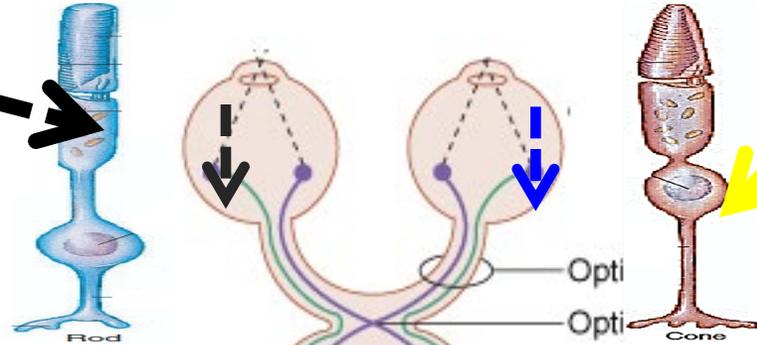


Duplicity theory of retinal function



- This theory states that retinal function is double in nature depending on the properties of its 2 photoreceptors.
- It assumes the existence of 2 different inputs from the retina (one from rods & the other from the cones) to the CNS, each input works maximally under a different condition of illumination.
- Cones are used for bright day light (photopic vision) while rods are used for dim night light (scotopic vision).

Duplicity Theory of Retinal Function



Scotopic Vision



Photopic Vision



Duplicity theory of retinal function



	Photopic Vision	Scotopic Vision
Receptors	Cones.	Rodes
Site	Central part of the retina	Peripheral part of retina
Threshold	Is high.	Is low.
Sensitivity to light	low	high
Accuracy	High (can perceive the fine details of the object)	Less (cannot perceive the fine details of the object)
Colour vision	Can perceive colours	Cannot perceive colours
Adaptation	rapid	slow

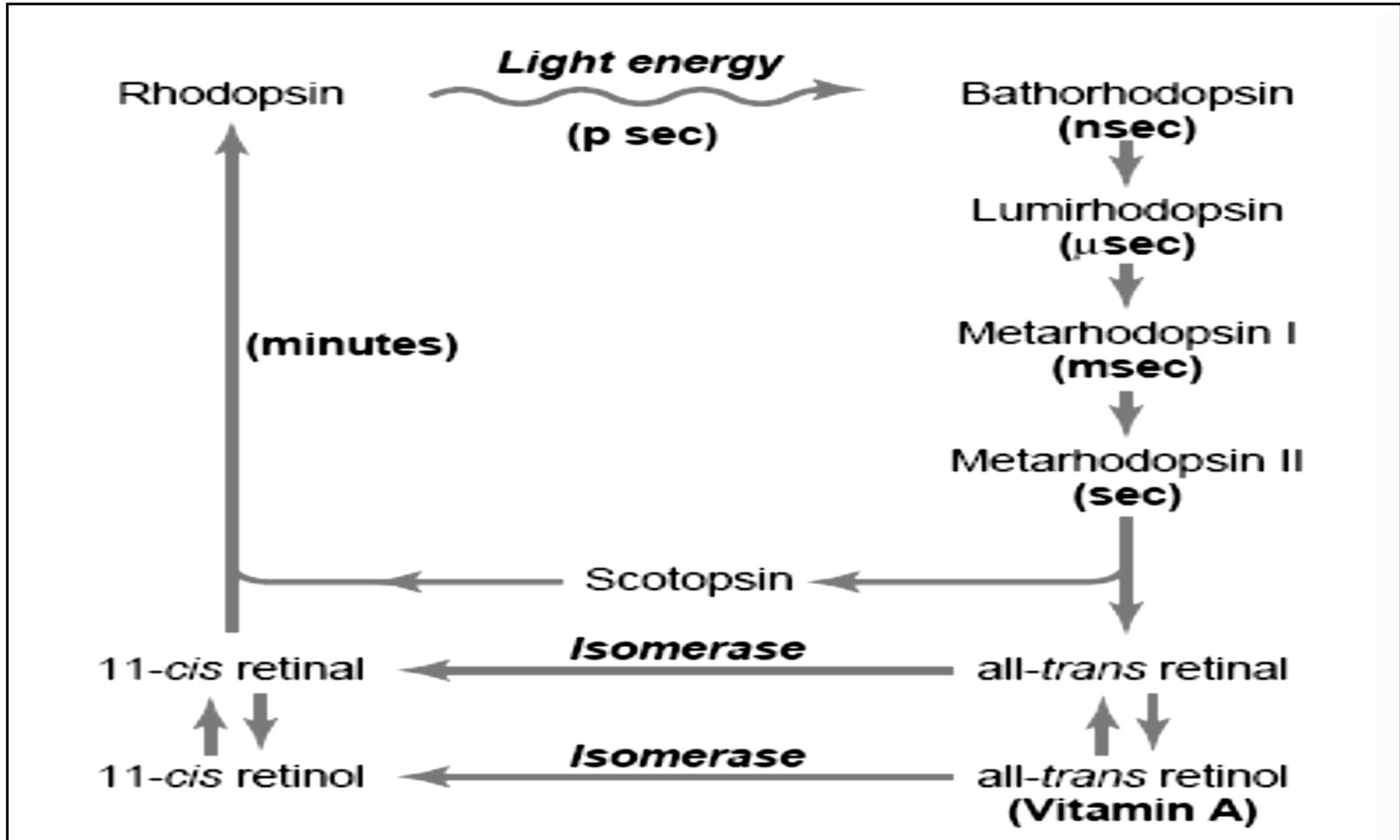
Phototransduction (mechanism of vision)



- **Def:** It is a process by which light is converted into signals in the rods & cone cells and photosensitive ganglion cells of the retina of the eye.
- **It consists of 4 steps:**
 1. Decomposition of photosensitive pigment in rods & cones
 2. Excitation of the photoreceptors by activated rhodopsin and generation of photoreceptor potential
 3. Termination of excitation
 4. Regeneration of photopigments

a) Decomposition of photosensitive pigment

- Rhodopsin consists of protein (scotopsin) and pigment (11-cis retinal).
- Light converts the angulated 11-cis retinal to straight all-trans retinal → enhance splitting between scotopsin & all-trans retinal, thus rhodopsin is converted to bathorhodopsin → lumirhodopsin → metarhodopsin I → metarhodopsin II (activated rhodopsin).
- Metarhodopsin II splits slowly (in seconds) into scotopsin and all-trans retinal by rhodopsin kinase enzyme.



b) Generation (ionic basis) of photoreceptor potential

□ In Dark:



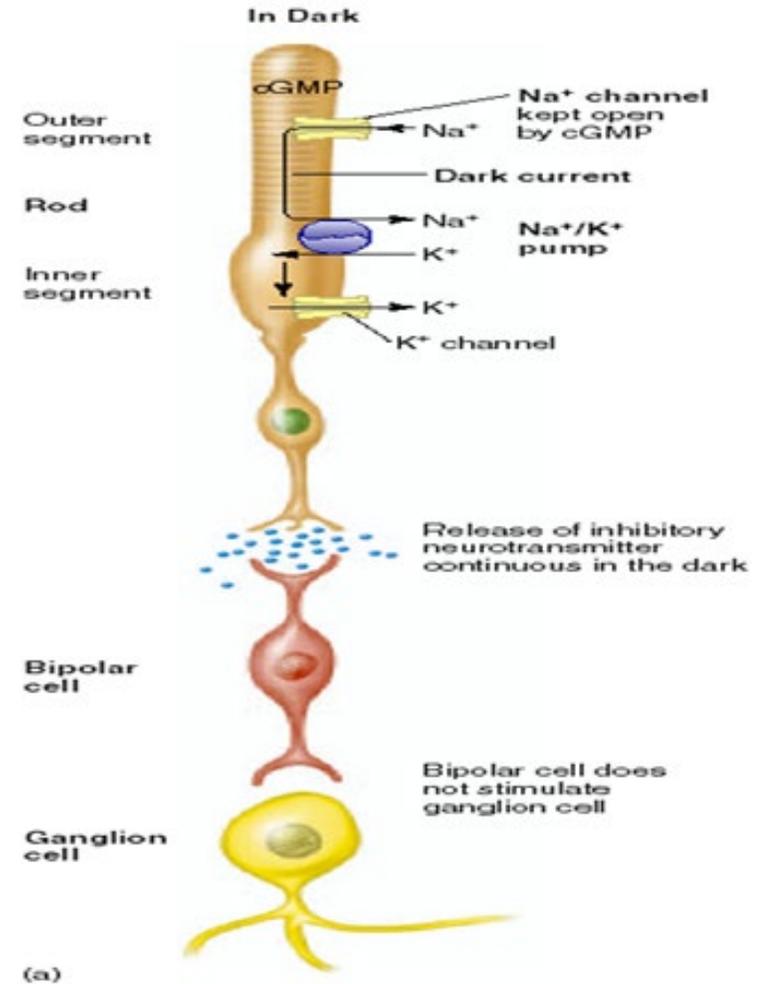
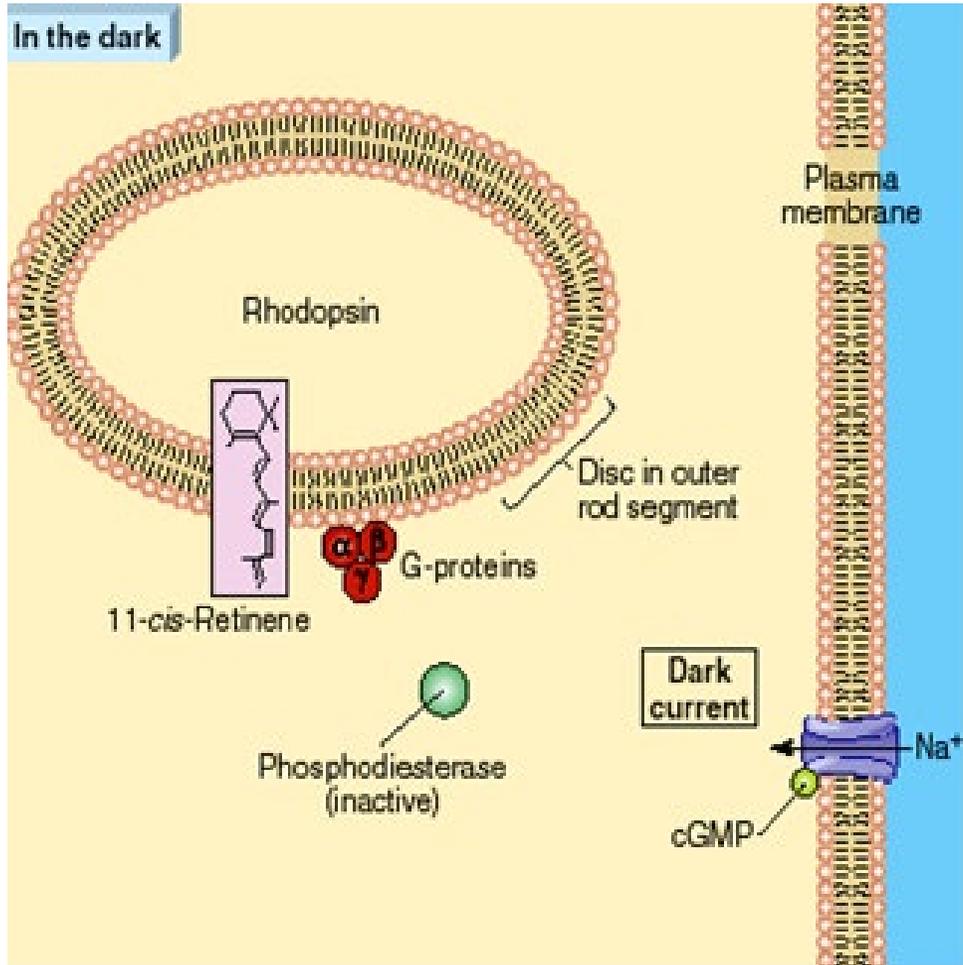
- In dark, the intracellular concentration of cGMP is high → open cGMP dependent cation channels in the outer segment of the photoreceptor cells.
- Na⁺ ions enter the outer segment & diffuse into the inner segment where it is pumped out.

- The flow of Na^+ between outer and inner segments forms a current flow called dark current of about -40 mV (depolarization) → continuous release of synaptic transmitter (glutamate) from the synaptic terminals → hyper polarization (inhibition) of bipolar cells by opening of Cl⁻ channels → ↓ release of excitatory transmitter from bipolar cells → disfacilitation (inhibition) of ganglion cells → no action potentials in optic nerve.

Photoreceptor Potential



In Dark



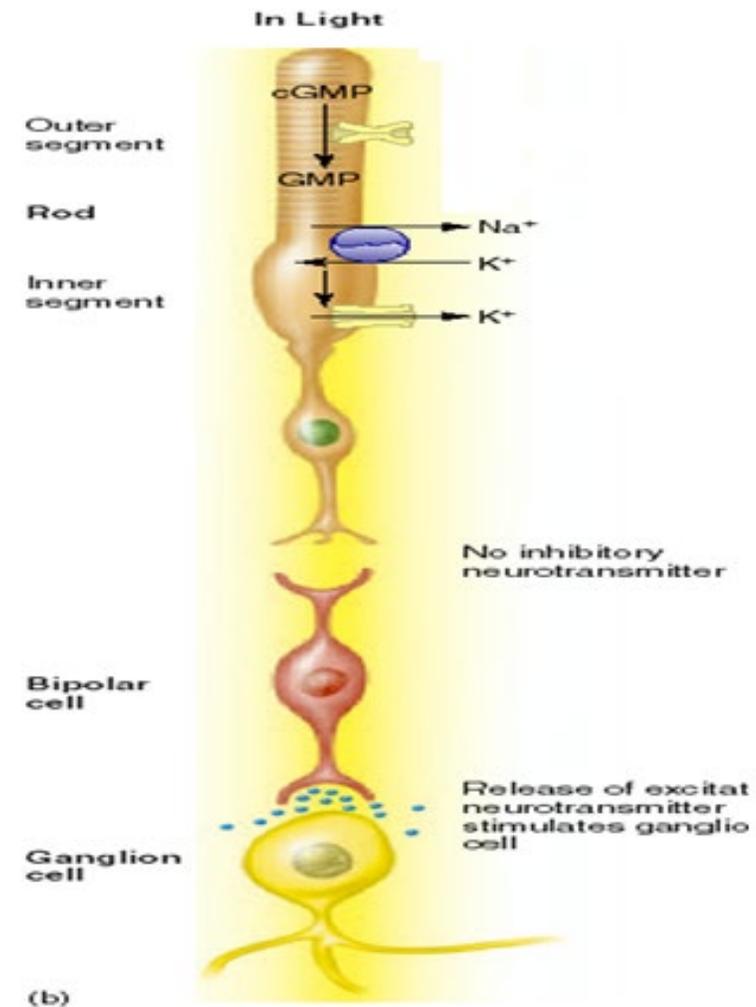
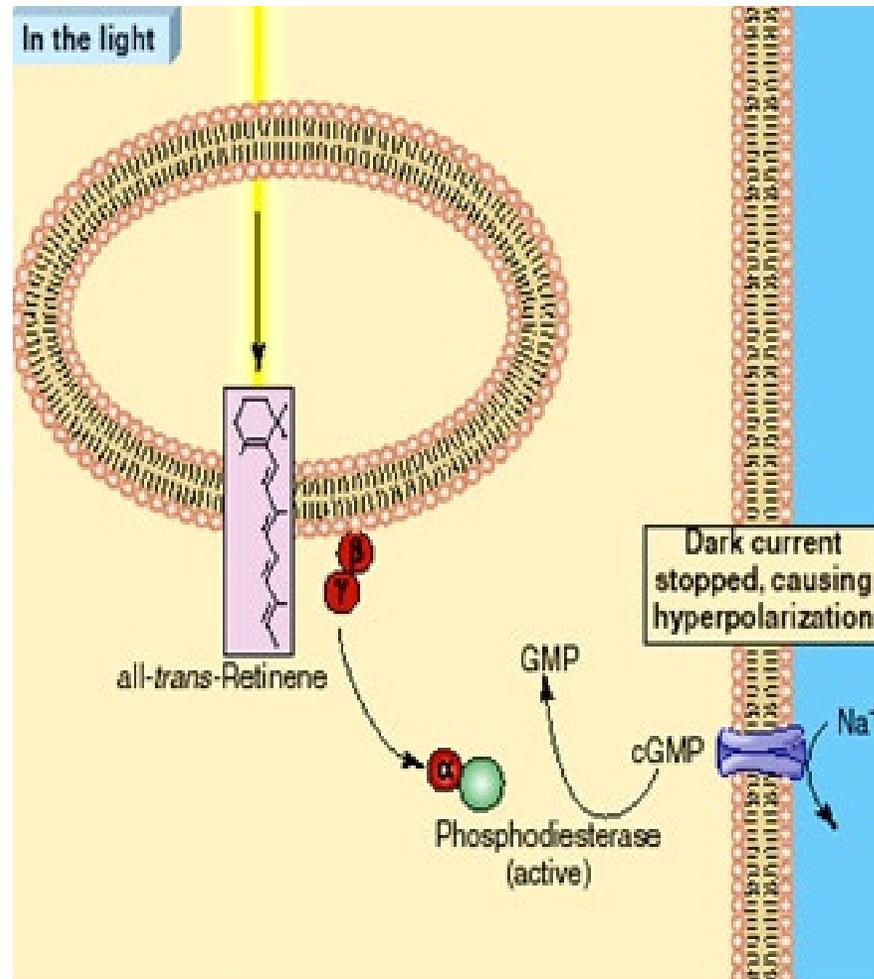


In Light:

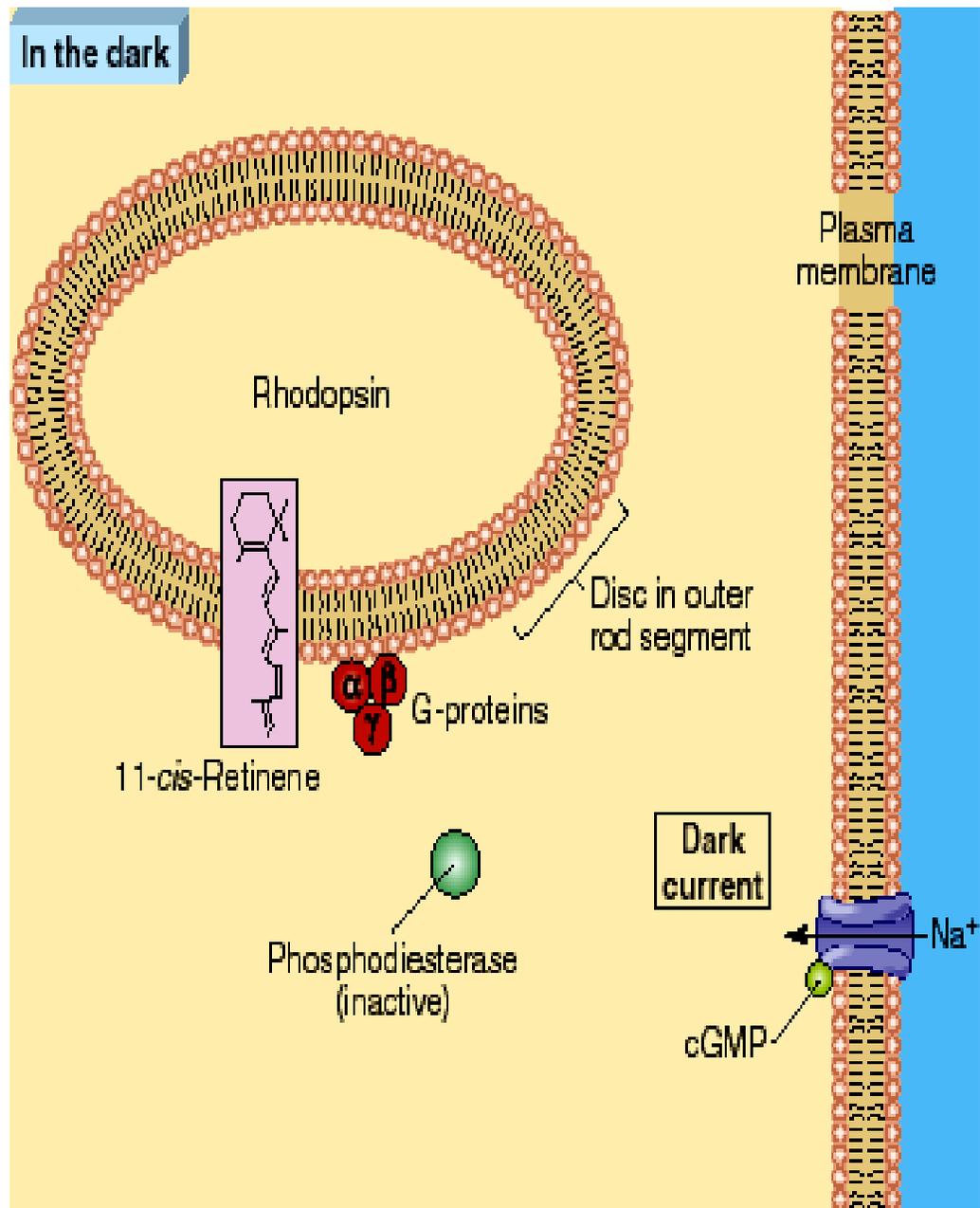
The activated rhodopsin activates G- protein transducin which in turn activates phosphodiesterase enzyme → breakdown of cGMP → closure of cGMP dependent Na⁺ channels → ↓ Na entry to outer segment (with Na⁺ still pumped out of inner segment) → hyperpolarization of rod to -80 mv → ↓ transmitter (glutamate) release in synaptic terminal → stimulation of bipolar cells → excitation of ganglion cells that respond by generation of action potential in optic nerve → visual pathway

Photoreceptor Potential

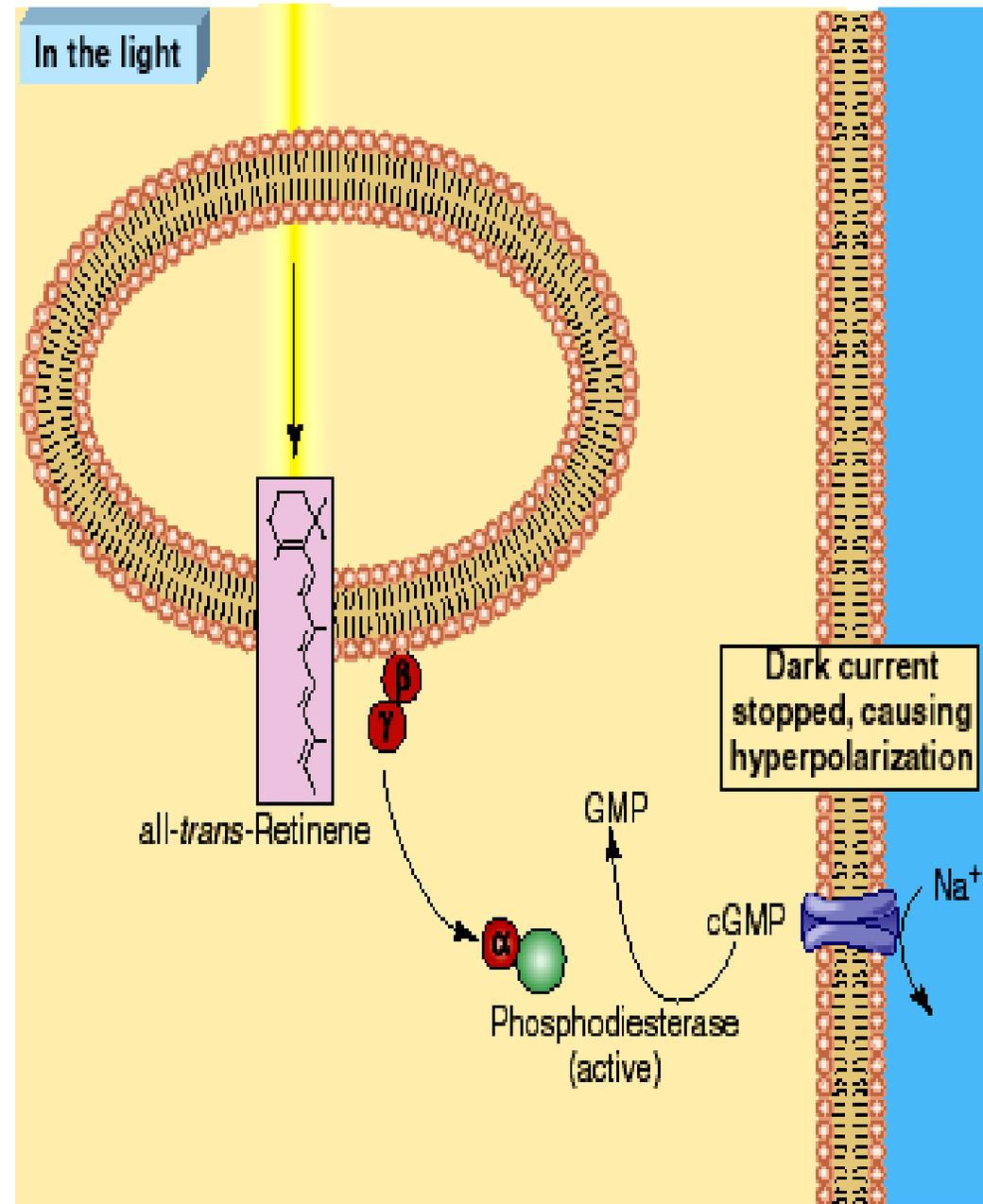
In Light



In the dark



In the light



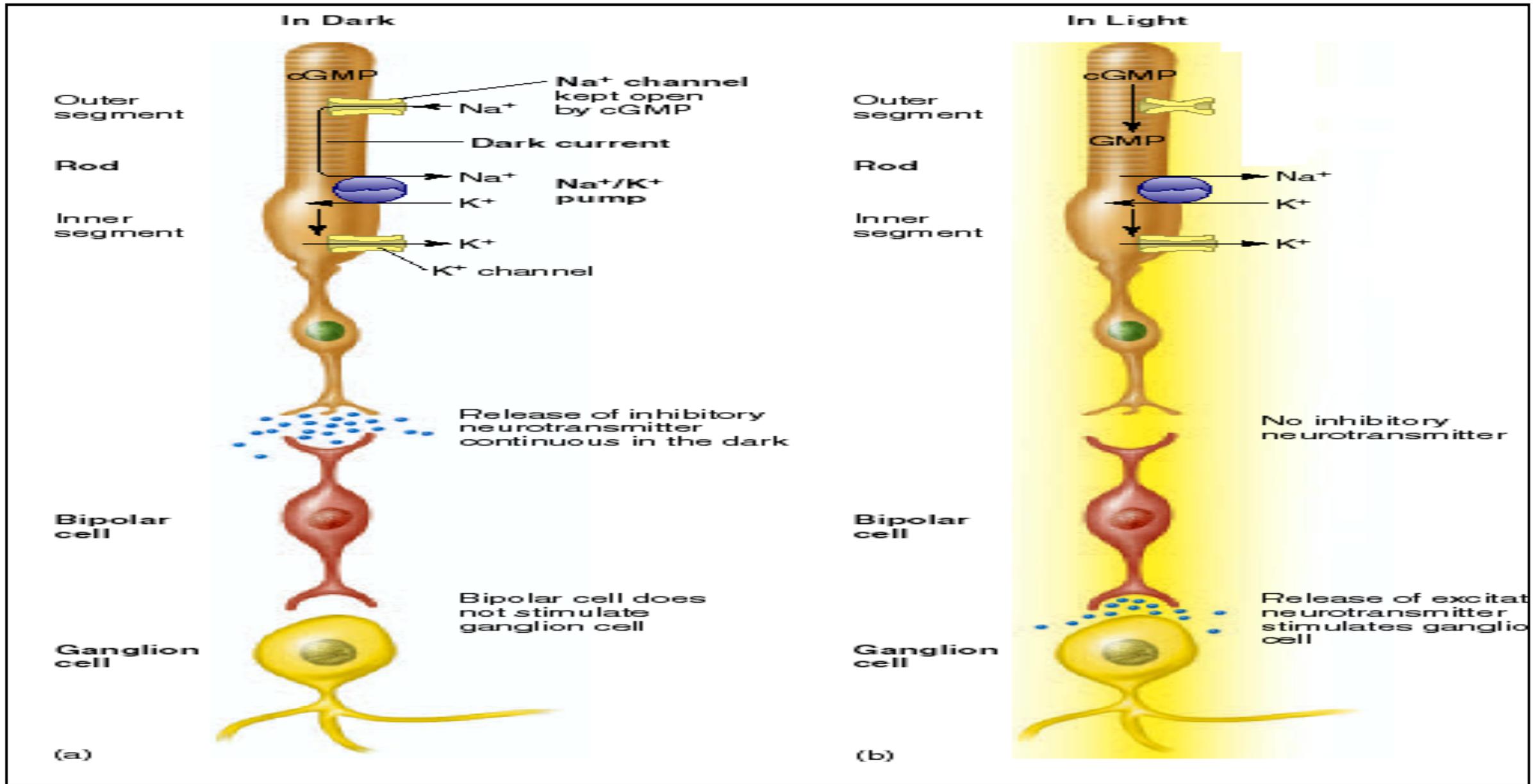


Fig: Mechanism of phototransduction. In the dark, Na⁺ channels in the outer segment are held open by cGMP. Light leads to increased conversion of cGMP to 5'-GMP, and some of the channels close. This produces hyperpolarization of the synaptic terminal of the photoreceptor and decrease in release of inhibitory chemical transmitters.



c) Termination of excitation

- Within a second the activated rhodopsin is inactivated by the enzyme rhodopsin kinase → reversal of all reactions → regeneration of cGMP → reopening of Na^+ channels → termination of excitation.

d) Regeneration of the photopigment

- All-trans retinal is taken up by pigmented epithelium where it is converted to 11-cis retinal by isomerase enzyme then sent back to rods to recombine with opsin.



Retinal adaptation

- **Def:** Change in the sensitivity of the retina according to the **intensity of light**. So, retinal sensitivity increases in **dark** and **decreases in light**.
- **Types:**

	Dark Adaptation	Light adaptation
1) Def	The ability of the retina to becomes more sensitive to faint light .	A decrease in the retinal sensitivity which occurs in bright light.
2) Mechanism	Due to regeneration of photosensitive pigments (rhodopsin& iodopsin).	Due to degeneration of the photosensitive pigments (rhodopsin & iodopsin).

	Dark Adaptation	Light adaptation
3) Example	<p><u>*When a person enters a dark room</u> after being previously exposed to bright light, he cannot see anything at the start in spite of the rapid pupillary dilatation.</p> <p><u>*After a few minutes</u>, he becomes accustomed to the dark and can see well, i.e. the retina become more sensitive to light. The sensitivity of the retina ↑ by 10,000 - 100,000 times.</p>	<p><u>*When a person moves from a dark place to bright light</u>, at the start even moderate light seems to be very intense and uncomfortable.</p> <p><u>*After about 5 minutes</u>, this sensation disappears due to the decrease in the retinal sensitivity,</p>

	Dark Adaptation	Light adaptation
4) Duration	becomes completed <u>after 30 minutes</u> (Slow process)	<u>About 5 minutes,</u>
5) Phases	<p><u>Dark adaptation occurs in 2 phases:</u></p> <p><u>A) Cone adaptation:</u> due to regeneration of <u>iodopsin</u> → a slight ↑ in the retinal sensitivity and completed within <u>5 minutes</u>.</p> <p><u>B) Rod adaptation:</u> due to regeneration of <u>rhodopsin</u> → a marked ↑ in the retinal sensitivity and completed within <u>30 minutes</u>.</p>	

	Dark Adaptation	Light adaptation
4) Changes in the eye	<ol style="list-style-type: none">1. <u>Dilatation of the pupils</u> which allows more light to enter the eye and stimulates more rods.2. <u>Regeneration of the pigments</u> in the rods and the cones which ↑ retinal sensitivity to dim light.3. <u>↑ in the retinal sensitivity</u> due to regeneration of the photosensitive pigments of the rods and cones.4. <u>↓ visual acuity</u> so that the fine details and colours of the object cannot be seen	<ol style="list-style-type: none">1. <u>Constriction of the pupils (miosis)</u> to ↓ the amount of light entering the eye.2. <u>Breakdown of the pigments</u> in the rods and cones, so photopigments are decreased.3. <u>↓ in the retinal sensitivity</u> due to degeneration of the photosensitive pigments of the rods and cones.4. <u>↑ visual acuity</u> so that the fine details and colours of the object can be seen

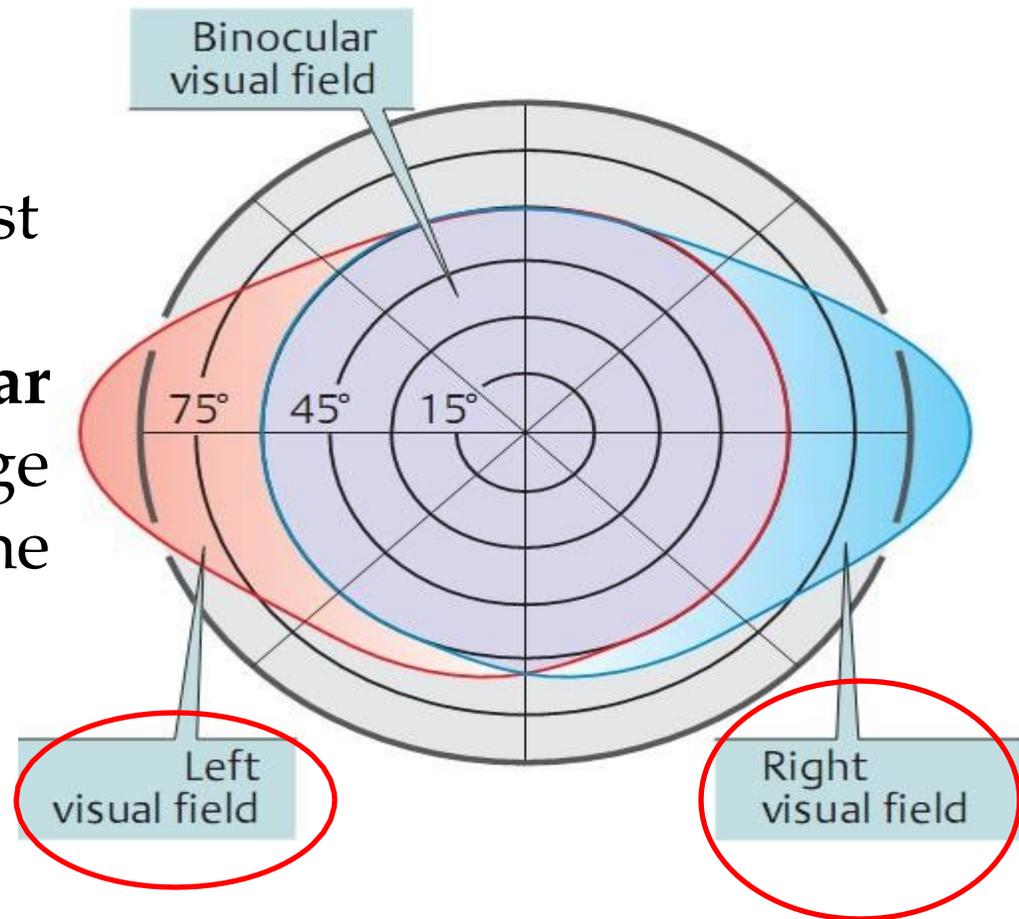
Binocular Vision

Def.

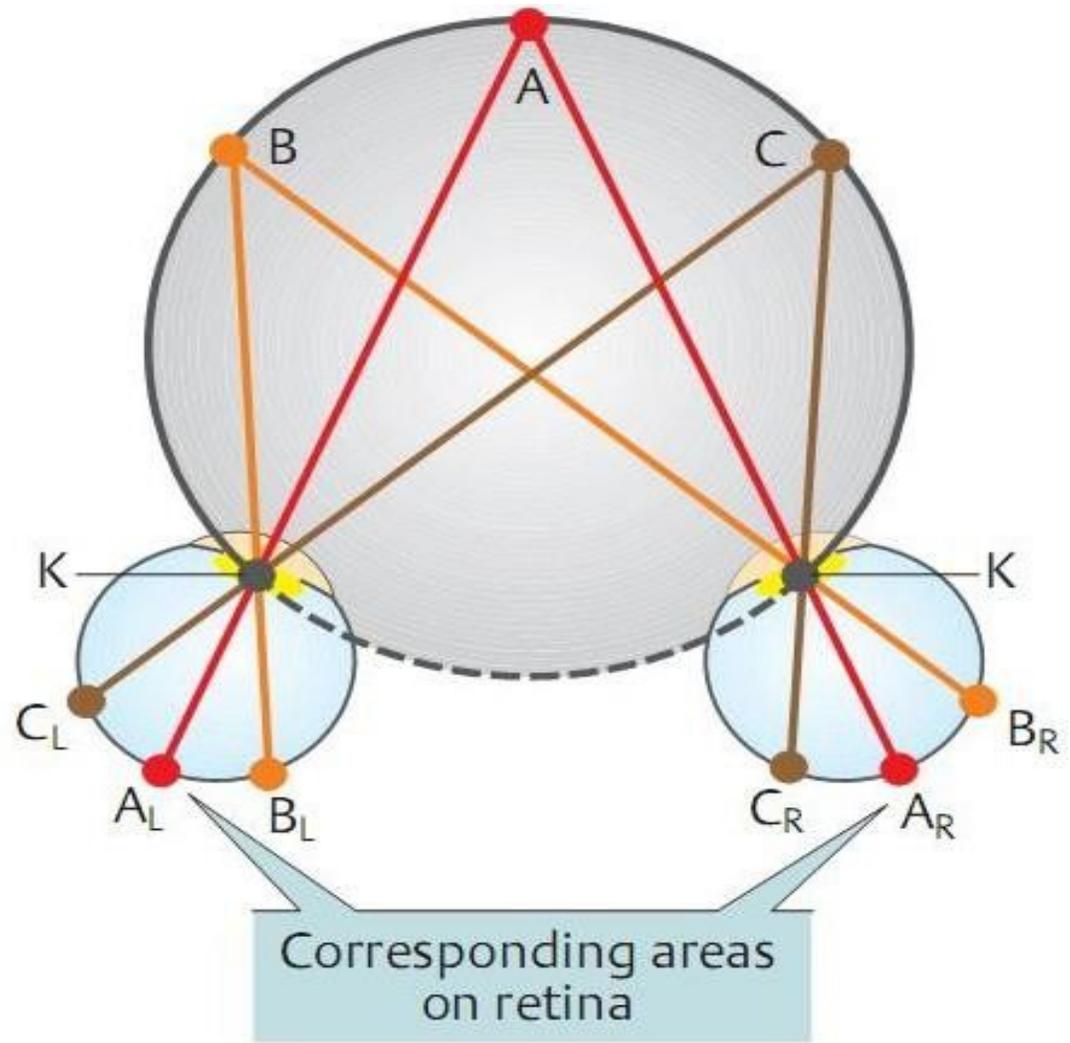
- Is the ability to see an object with 2 eyes without **double vision (diplopia)**.

Requirements

1. The **visual fields** must **overlap** to a great extent
2. **Intact neuromuscular** apparatus to allow image to fall on the **corresponding points**



Corresponding Points

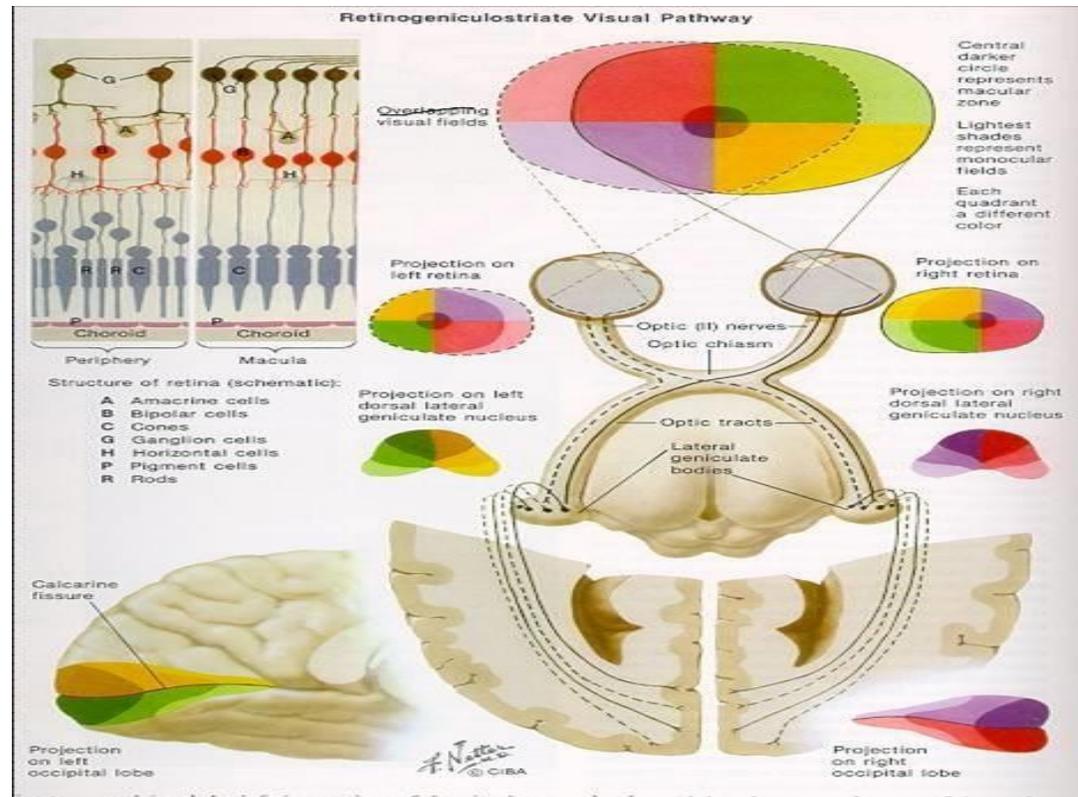


Binocular Vision

Requirements of binocular vision

3. A nearly normal refractive power in both eyes

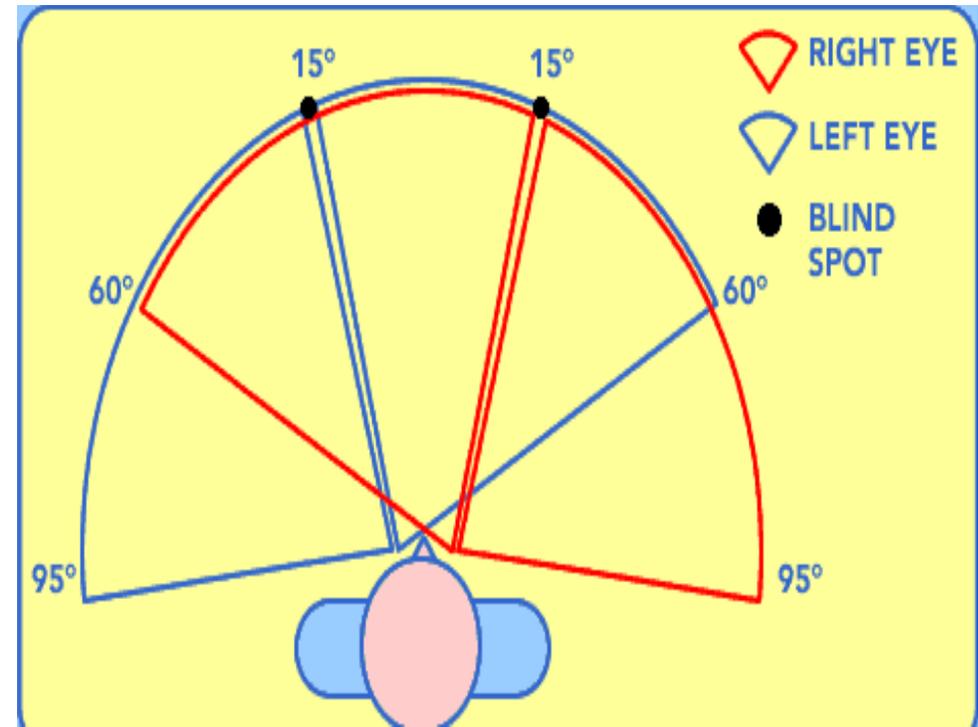
4. Intact visual cortex where fusion of images occur



Binocular Vision

Advantages of binocular vision

1. Increases the visual field **horizontally** from **160 to 200 degrees**
2. Corrects the **minor defects** in one eye by the other eye
e.g. **blind spot** of **one eye** is corrected by the **other eye**



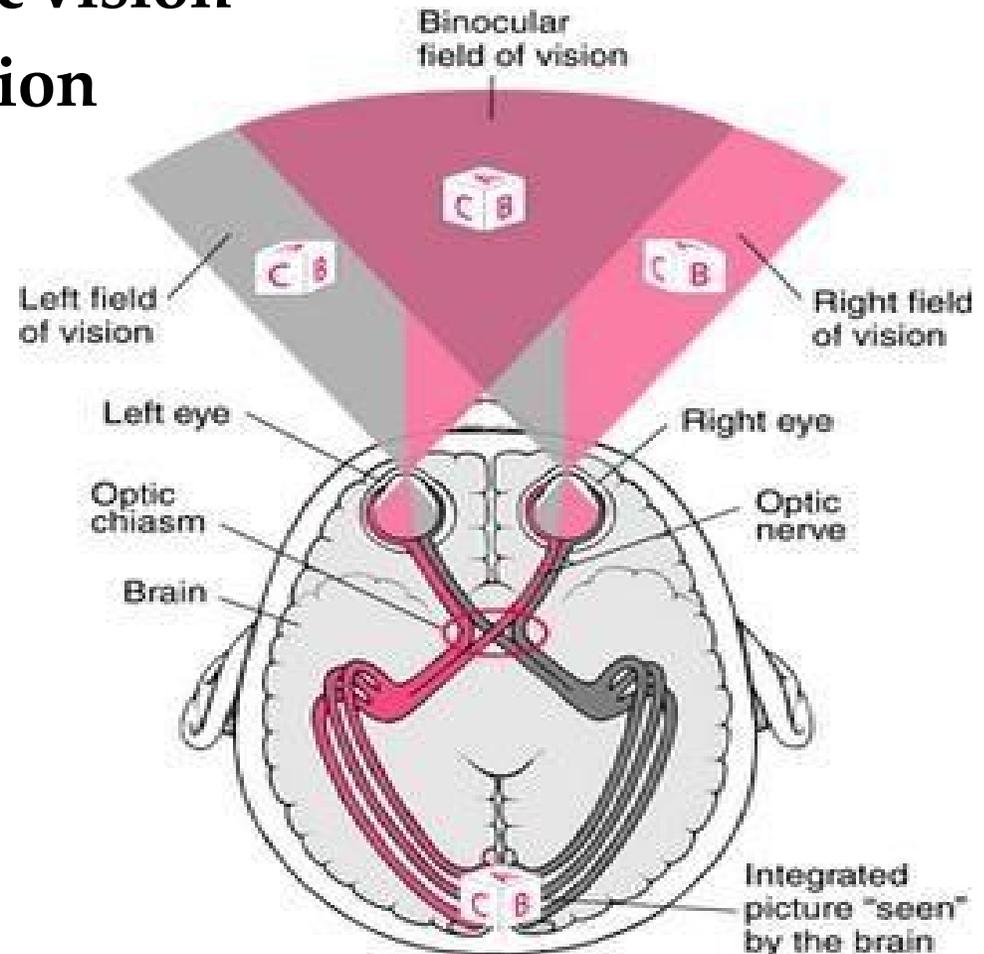
Binocular Vision

Advantages of binocular vision:

3. Is important for **stereoscopic vision**
4. Improves the **depth perception**

Fusion and corresponding points:

- The 2 images of an object placed in the area of binocular vision (one from each retina) are fused at the level 1ry visual area (17) into a single image



Depth Perception

Def.

- Is the ability to know the **relative distance** of the objects from the eyes.
- It is principally a monocular property, but it becomes more accurate by binocular vision.



Depth Perception

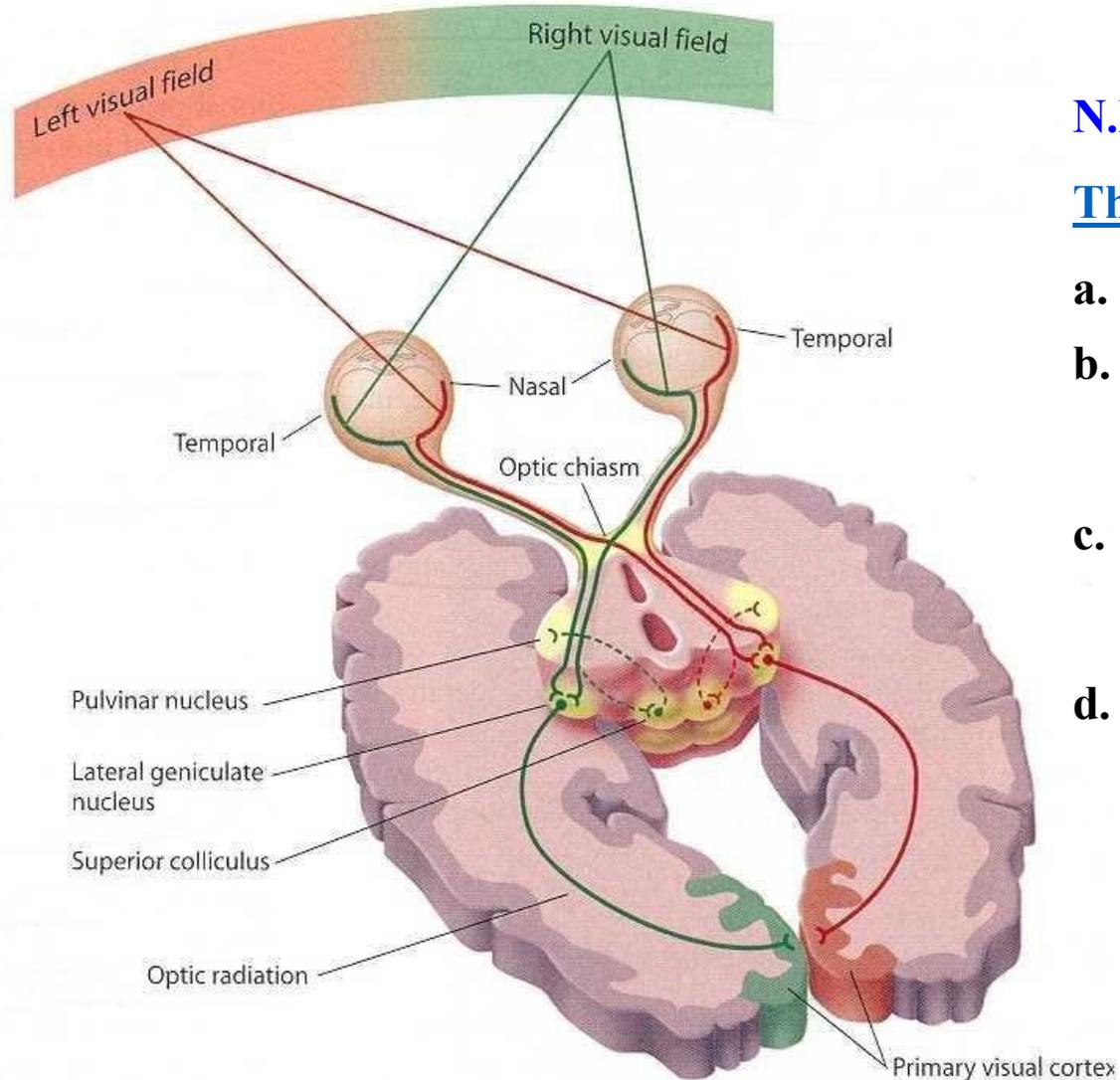
Mechanisms depth perception:

- The **depth perception** depends on the followings factors;
 1. **The relative sizes** of objects
 2. **The occlusion of part** of a distant object by a nearer one
 3. **The fade of the colours and details of distant objects** as their distances from the eyes are increased
 4. **Parallel lines** appear to converge with distance
 5. **Movement parallax:** the nearer objects appear to move in the opposite direction and distant objects move in the same direction

Visual Pathway

- **Photoreceptors** (rods and cones) → **bipolar cells** (1st order neuron) → **ganglion cells** (2nd order neuron) → their axons form the **optic nerve** → **optic chiasma**, where the **nasal fibers cross to the opposite** side while the temporal fibers pass in the same side
- **Optic tract** (ipsilateral temporal fibers + contralateral nasal fibers of retina) → **lateral geniculate body** (3rd order neuron) in thalamus
- **Optic radiation** → **visual cortex** in the occipital lobe (1^{ry} and 2^{ry} visual areas).

Visual Pathway



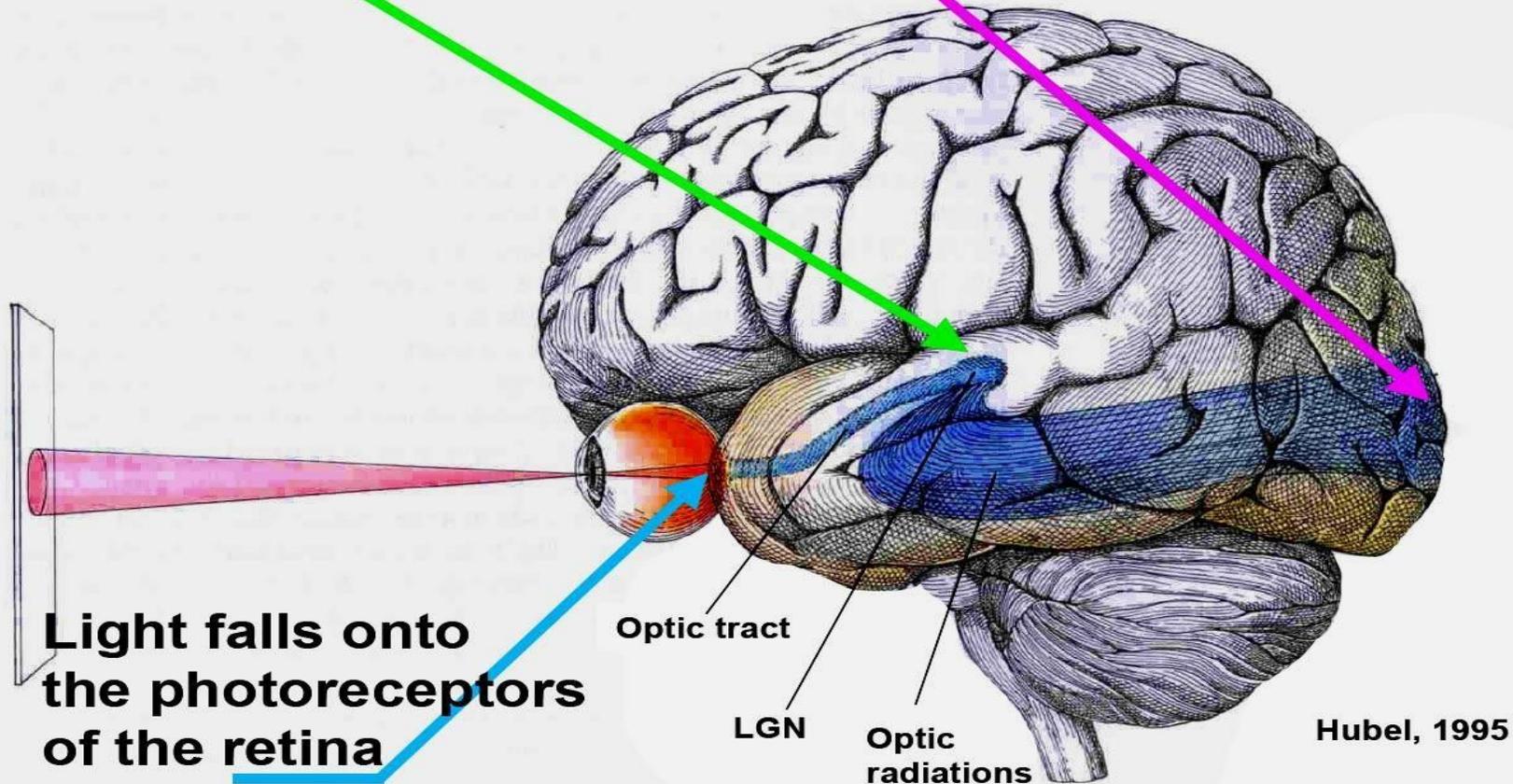
N.B.

The optic tract fibers terminate on:

- a. Lateral geniculate body (LGB)**
- b. Pretectal nucleus** in the midbrain
(center of pupillary light reflex).
- c. Superior colliculus** in midbrain
(center of visuo-spinal reflex).
- d. Supra-chiasmatic hypothalamic nucleus** for control of circadian rhythm.

Role of different parts of Visual Pathway in visual perception

Thalamus (LGN) serves strategic role in gating of information flow to cortex



Retinal Cells

- **Analysis** of the visual image occurs early in the retina

Role of Bipolar Cells

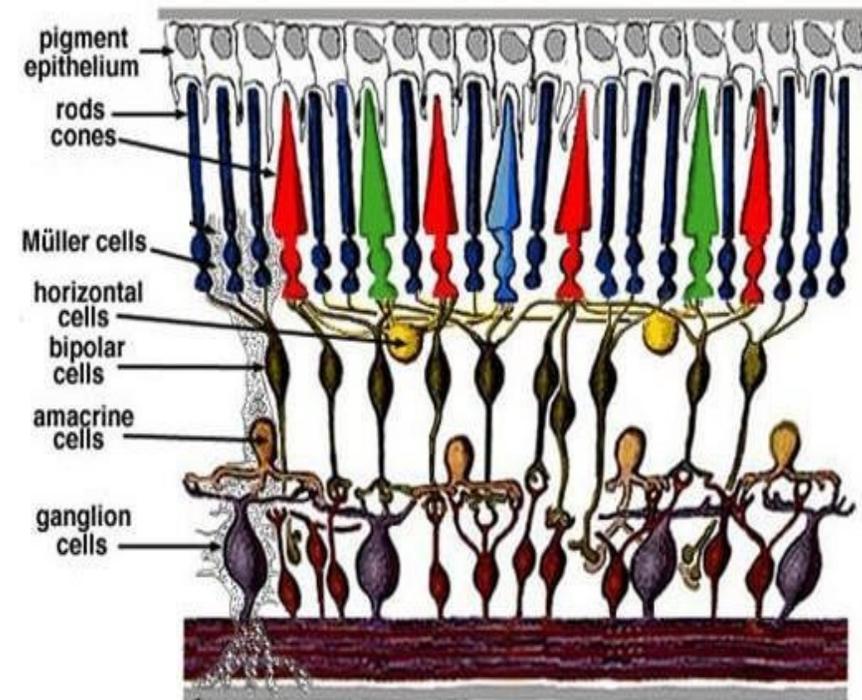
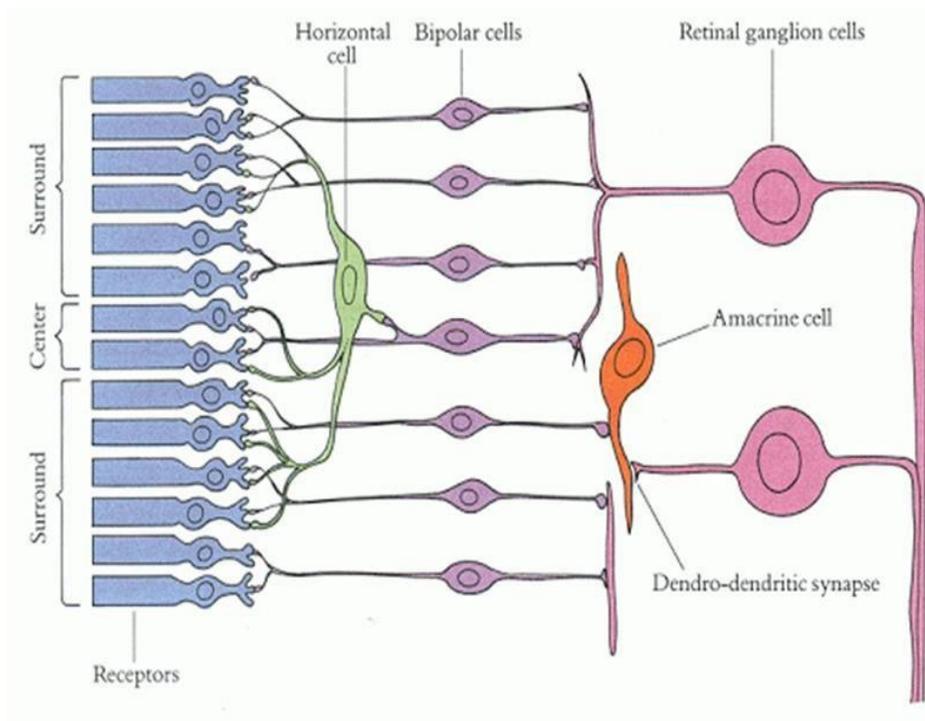
- They **constitute direct pathway** between photoreceptors and ganglion cells, release glutamate

2 types;

- a) **Depolarizing bipolar (on-bipolar) cells**
- b) **Hyperpolarizing bipolar (off-bipolar) cells**

Role of Lateral Cells

- **Horizontal cells** represent **lateral inhibitory** pathway in the retina
- **Amacrine Cells** help in the **analysis** of the visual signals before leaving retina



Role of Ganglion Cells

- About 1.6 millions cells
- The only retinal cells that respond to stimulation by a **full action potential** i.e depolarization

Types of ganglion cells:

a) Magnocellular (M) (10%):

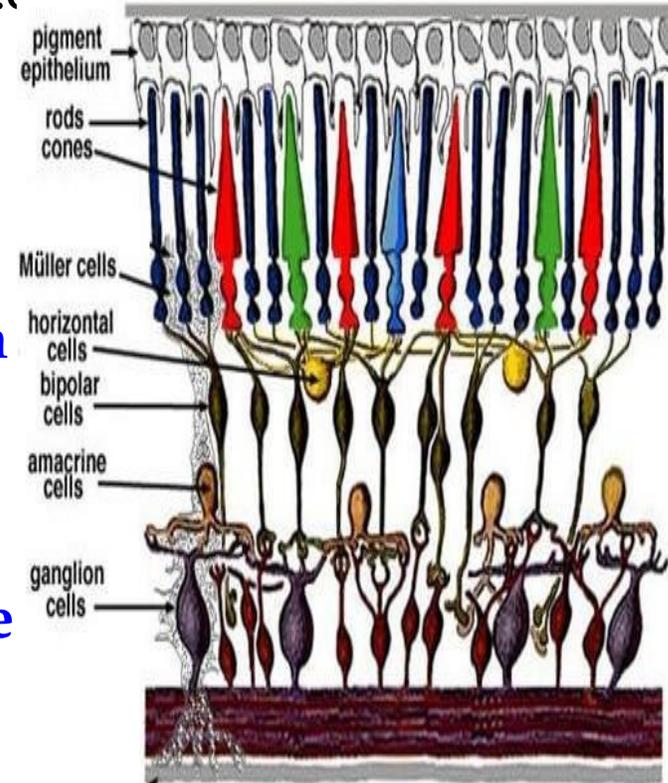
- Large ganglion cells.
- Concerned with **gross analysis & location of objects** in visual field and motion

b) Parvocellular (P) (80%):

- Small ganglion cells.
- Responsible for **fine detailed vision (shape & texture) and color vision**

c) Coniocellular (10%):

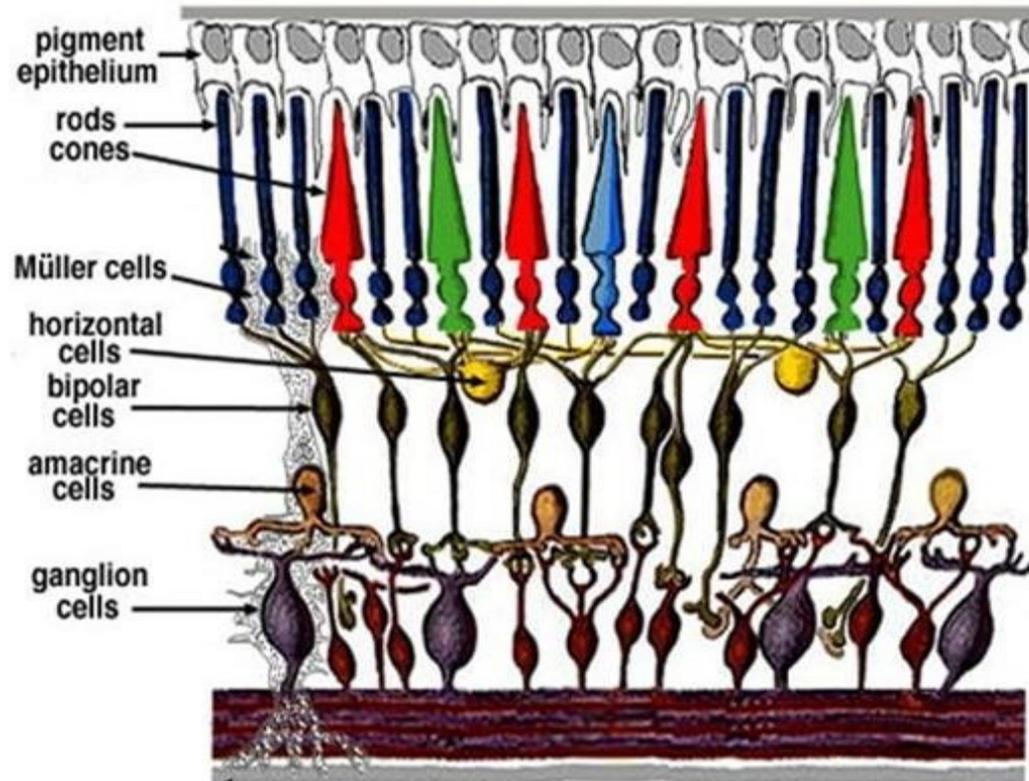
- Medium in size
- Concerned with controlling **pupillary reflexes**



Role of Ganglion Cells

Functions of Ganglion Cells:

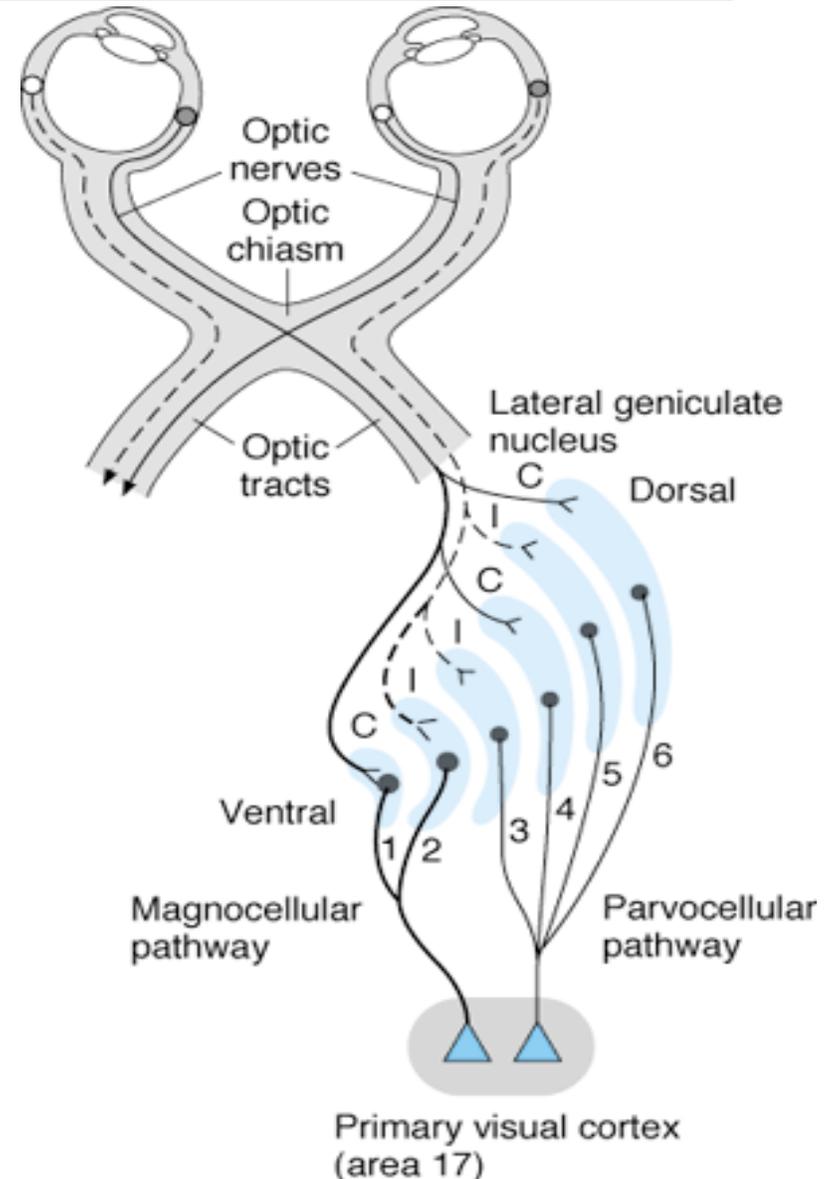
1. **Detection of 2 point discrimination** in the visual scene
2. **Detection of the contrast** in the visual scene
3. **Detection of the movement** and its orientation in the visual scene
4. **Colour analysis**



Lateral Geniculate Body (LGB)

Functions of LGB

1. Plays a part in **fusion of retinal images** from the 2 eyes.
2. Plays a part in **stereoscopic vision** by comparing the visual images from both eyes and detection of minimal differences.
3. **Magnocellular neurons** are concerned with perception of white and black, shape and motion.
4. **Parvocellular neurons** are concerned with perception of color vision and accurate point-point spatial information

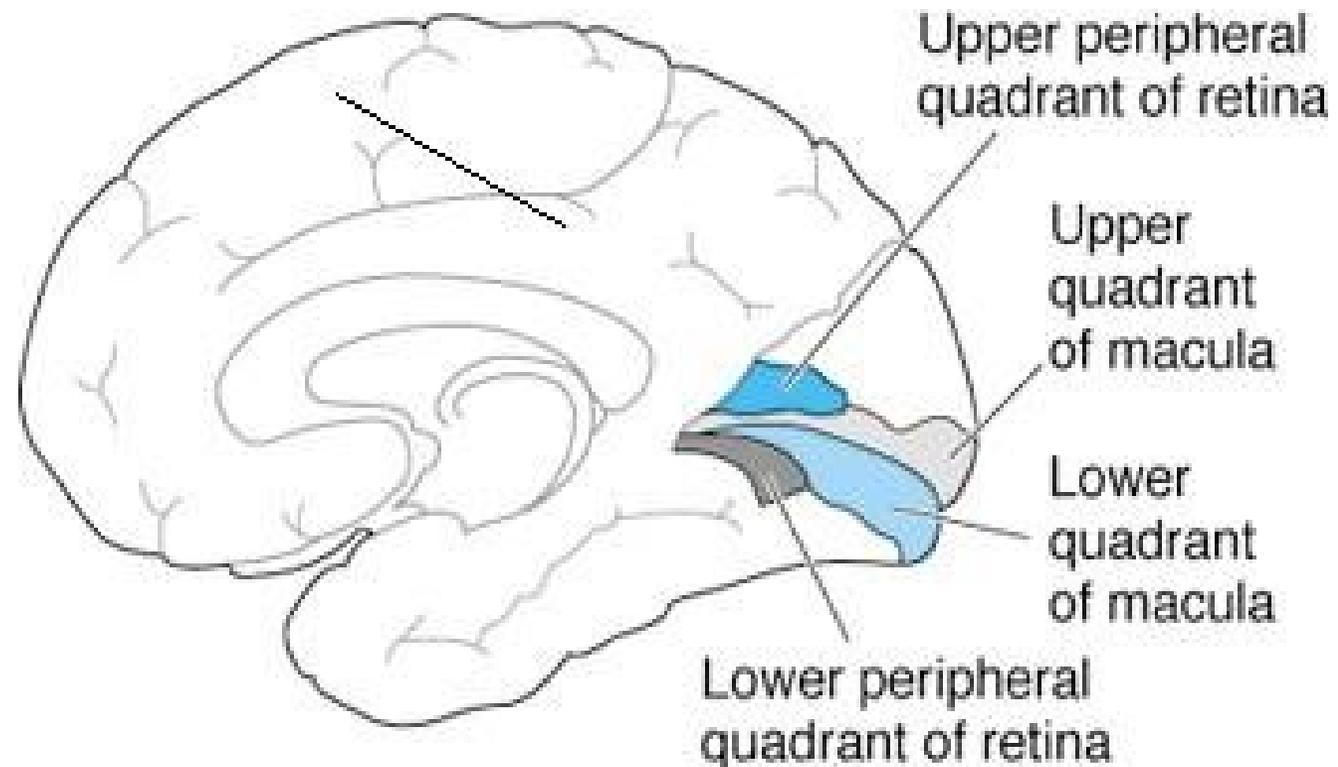


Primary Visual area (area 17)

Site

- Surrounds the **calcarine fissure** on the occipital lobe

Representation of retina in area 17



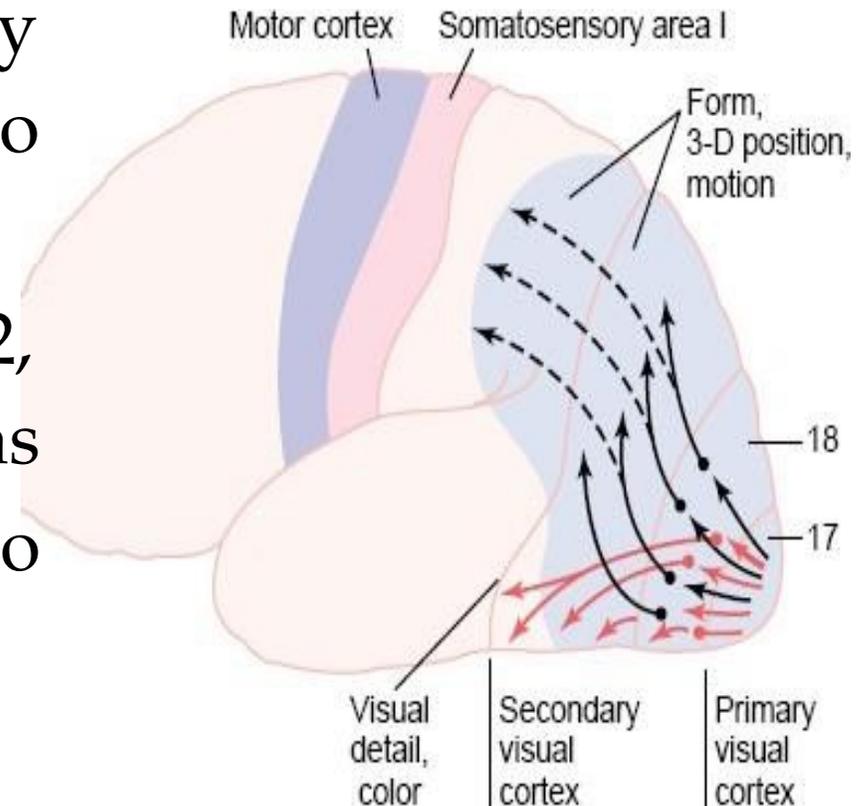
1ry Visual area (area 17)

- Function:
 1. Detection of **lines and borders**
 2. Detection of the **orientation of lines and borders**
 3. **Analysis of colors**
 4. Fusion of the **images from the 2 eyes**
 5. Perception of **luministy**

2ry Visual area (areas 18-19)

Site:

- Occipital lobe around 1ry visual area and extend to parietal & temporal lobes
- Areas 18 is called area V-2, more distant 2ry visual areas are assigned V-3, V-4 and so no.



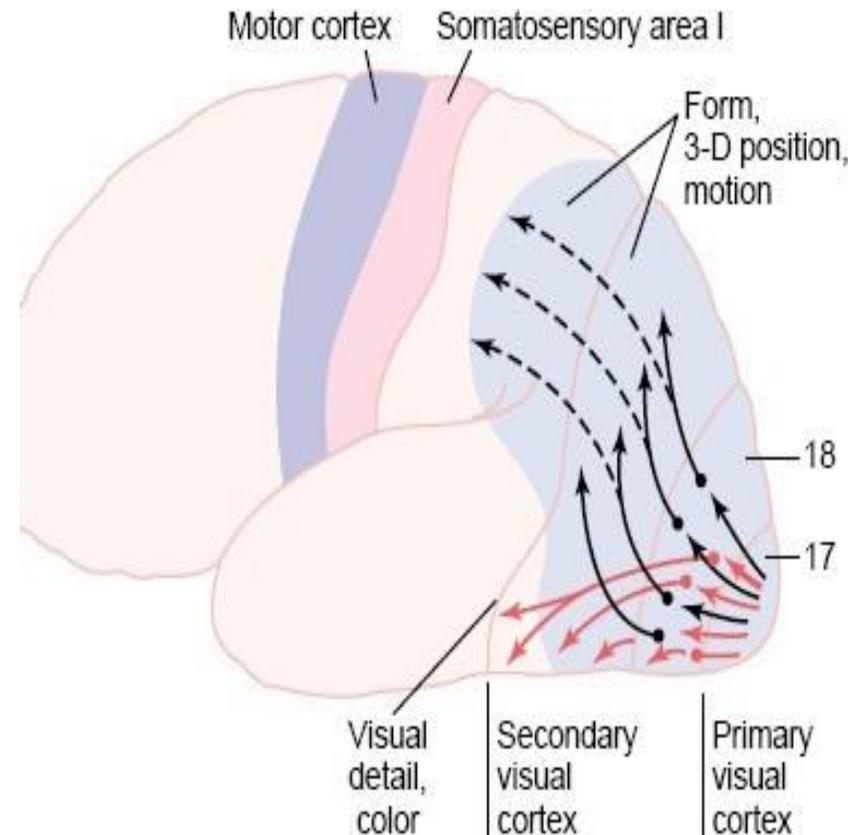
2ry Visual area (areas 18-19)

Functions:

Area 18

- It is also known as visuopsychic area which is concerned with;
 - a. Recognition the **nature of the objects** and **correlates their colours**
 - b. Interpretation of **visual sensations**
 - c. Localization of object in space i.e. **depth perception**

Lesion → visual agnosia

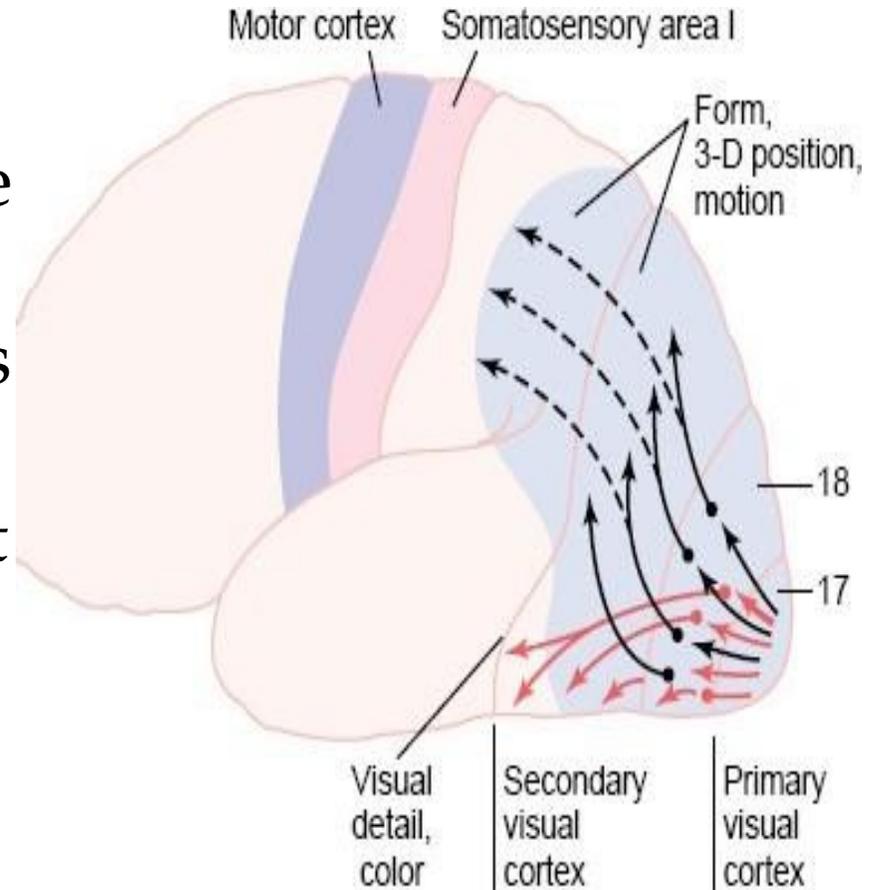


2ry Visual area (areas 18-19)

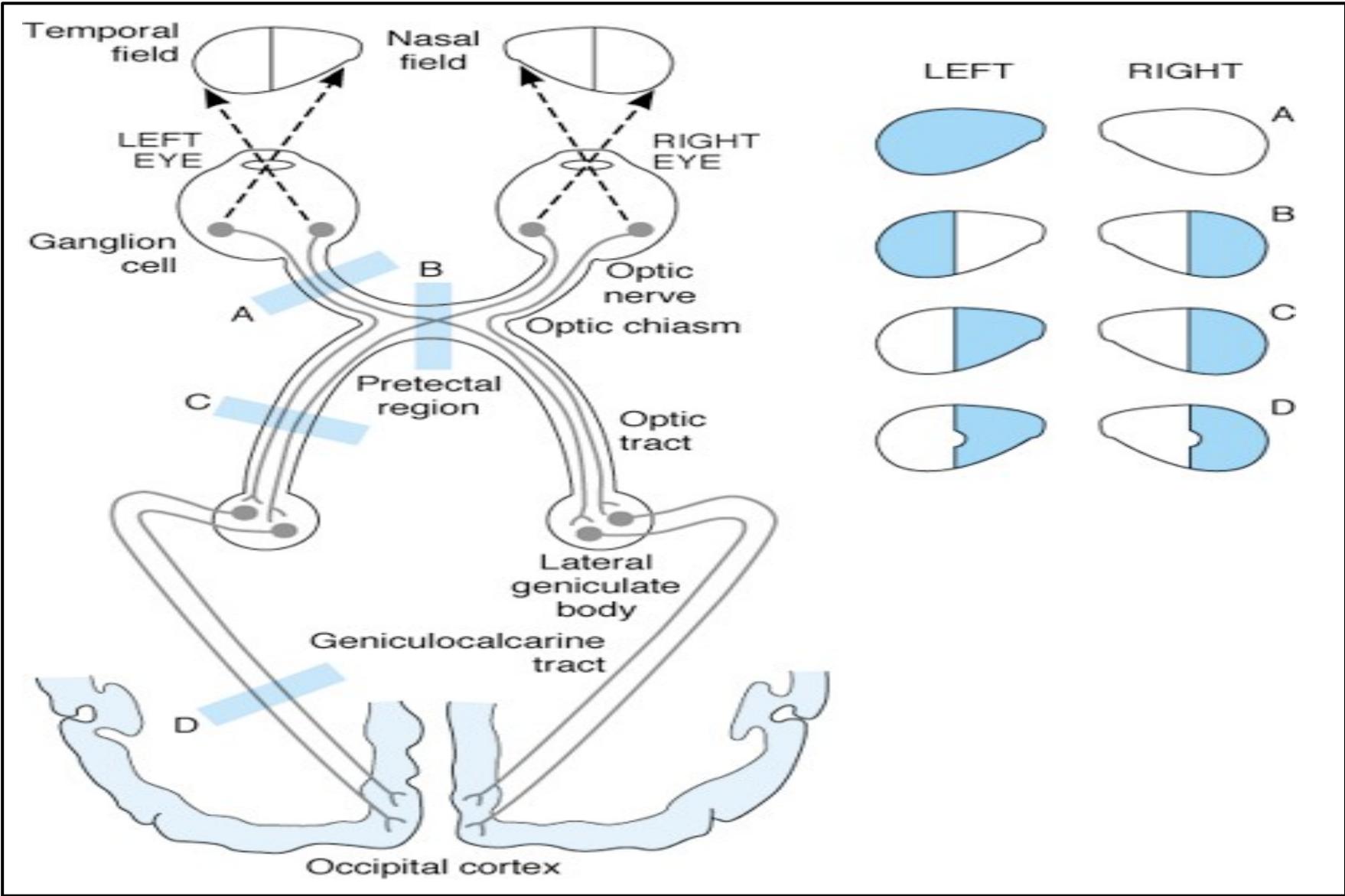
Functions:

Area 19

- It is also known as the **occipital eye field area**.
 - a. It shares area 18 its functions.
 - b. It **controls** the different types of eyeball movements.



Lesions in the Visual Pathway





External and middle ear



External ear

- The external ear consists of:

a. Ear pinna.

b. External auditory meatus.



(I) Ear pinna (Auricle)

- **Def:** It is the cartilaginous external flap.

- **Functions:**

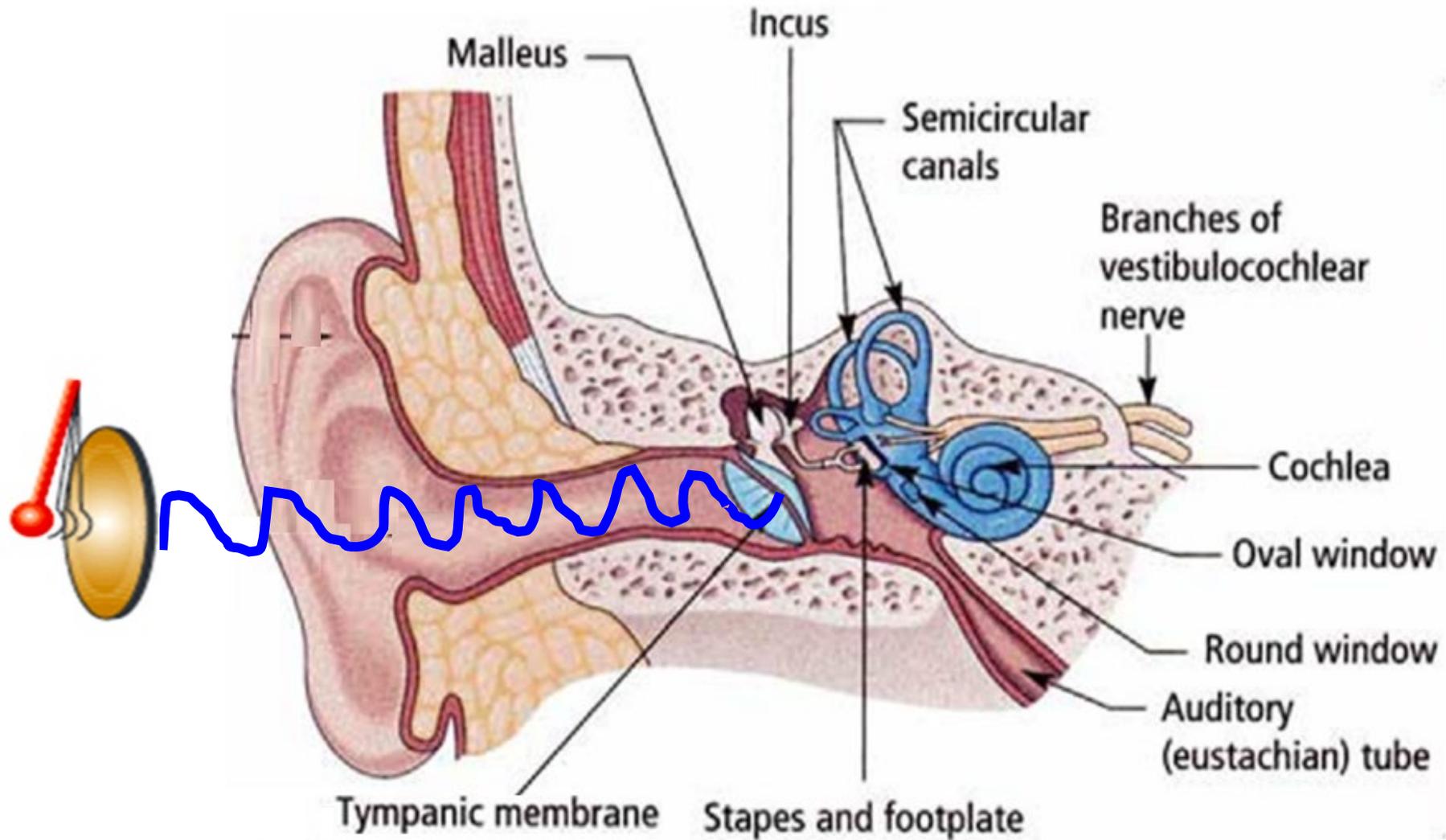
- a. It collects and directs sound waves into the external auditory meatus.

- b. Sound localization.



(II) External auditory meatus

- It is an oblique tortuous skin-lined canal of about 2.5cm length in the temporal bone.
- The tympanic membrane (ear drum) exists at the end of the canal and completely separates the external ear from the middle ear.
- Functions:
 1. It conducts and concentrates the sound waves to the tympanic membrane.
 2. It produces resonance which amplifies the sound and increases its pressure at the ear drum.

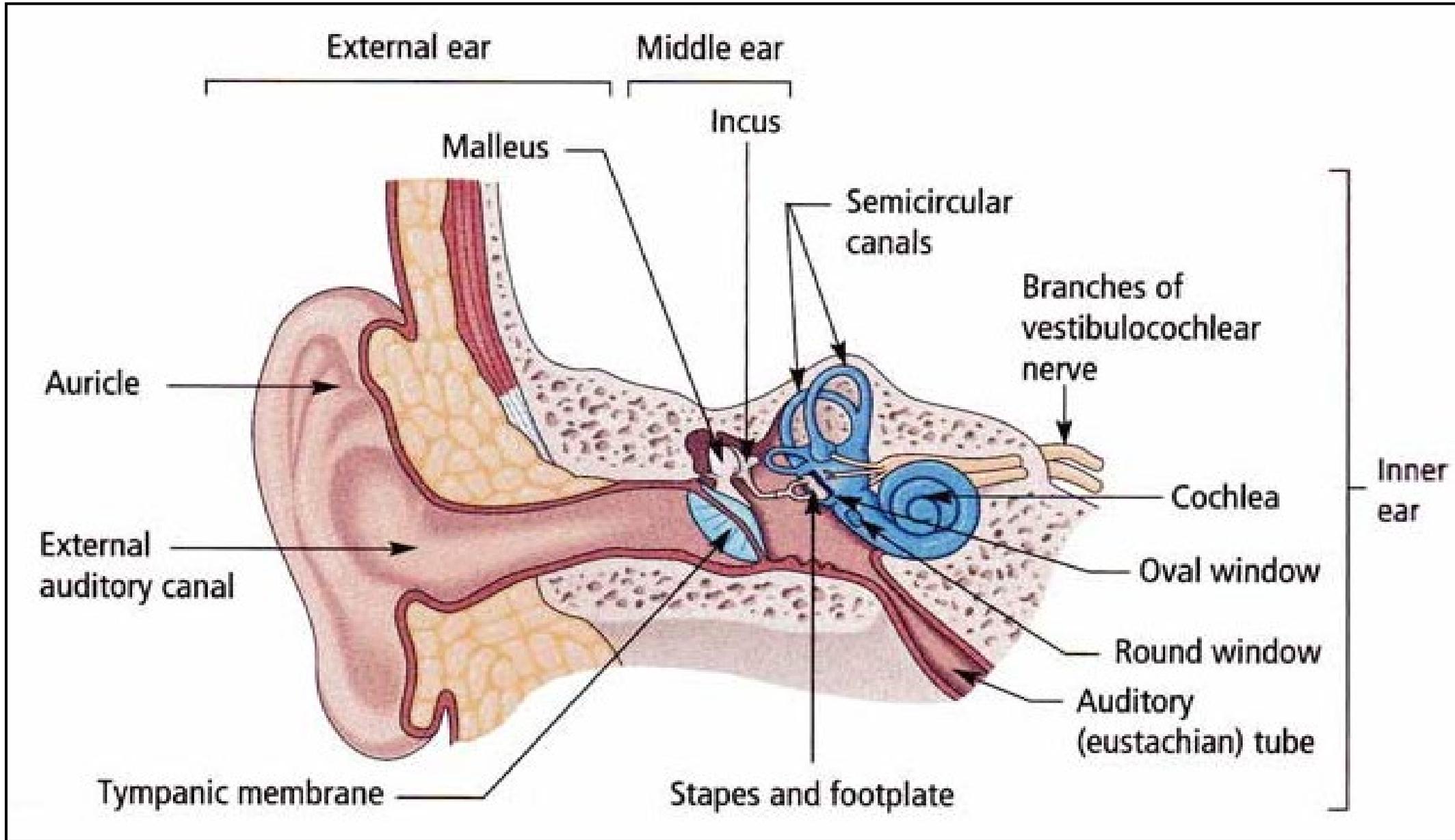




3. It protects the tympanic membrane:

- a) From external trauma by being *long and tortuous*.
- b) From entrance of foreign bodies or insects by *hairs & wax*.
- c) From growth of microorganisms because the *wax is of acidic pH and contains lysozymes and immunoglobulins*.

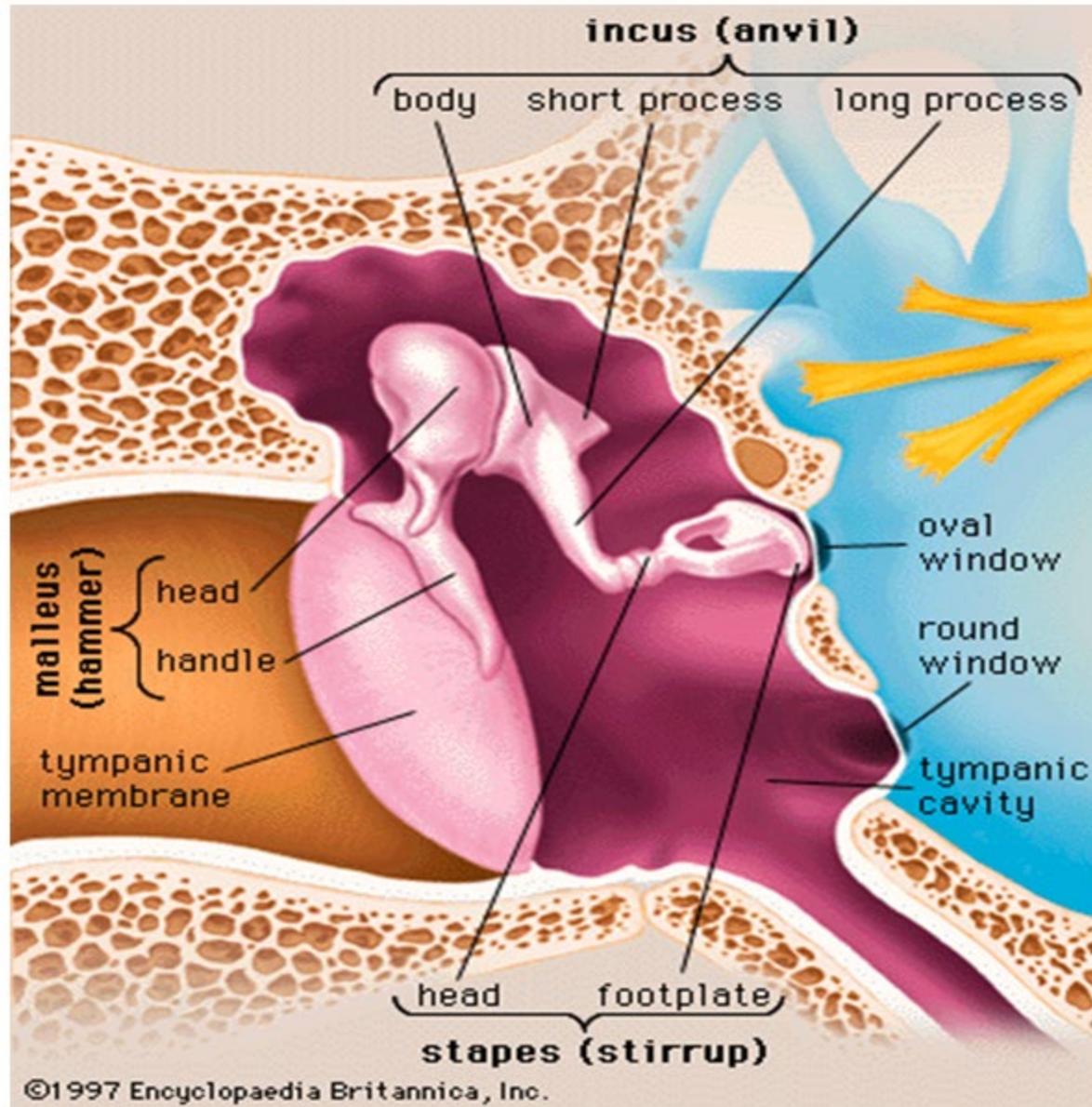
4. It maintains the proper temperature and humidity of the air inside, which is essential for the proper function of the ear drum.



Middle ear

*Anatomy of Middle Ear:

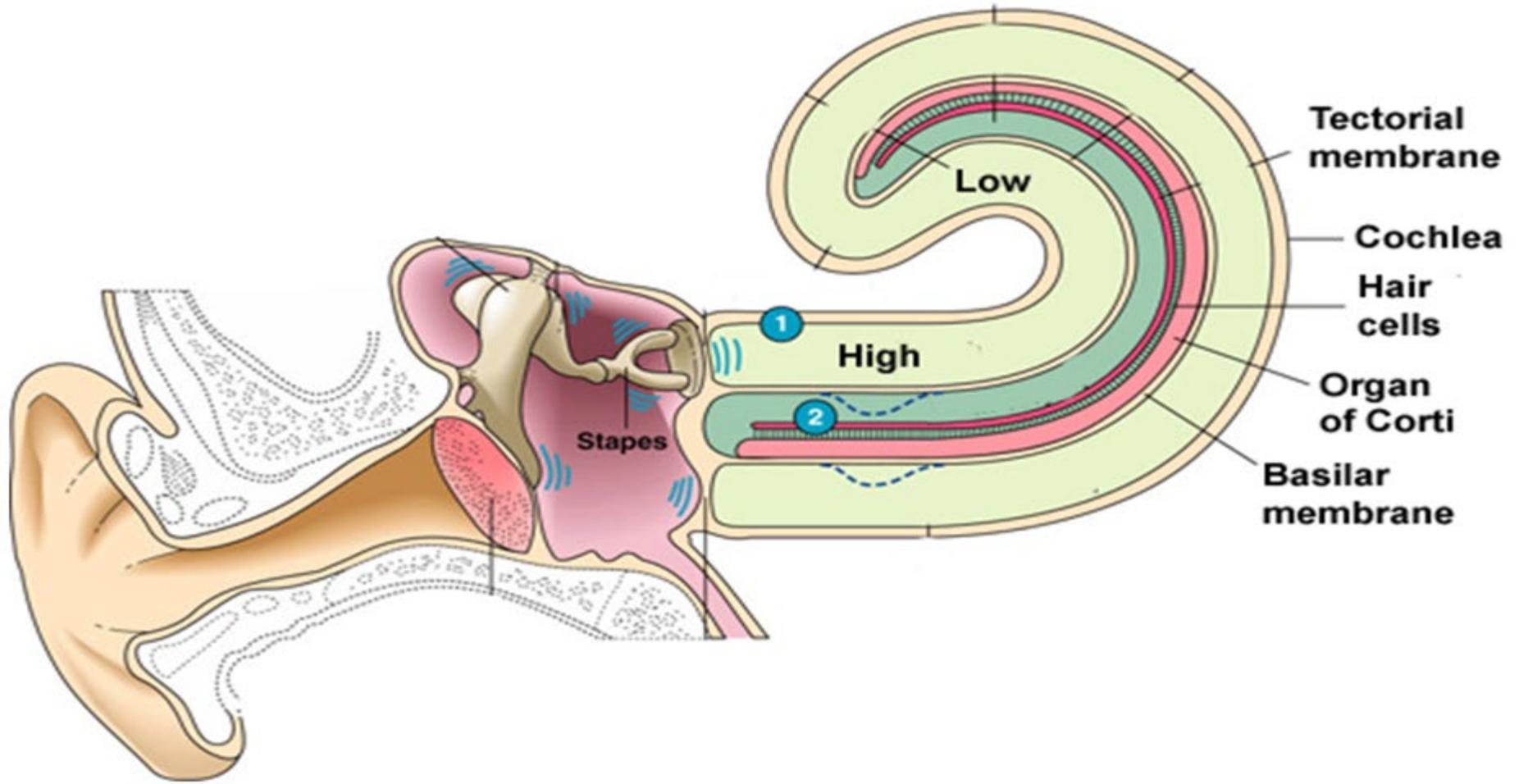
- **Def:** It is an **air-filled cavity in the temporal bone.**
- **It contains:**
 - 3 bony ossicles:** the malleus (hammer), incus (anvil), and the stapes (stirrup).
 - 2 skeletal muscles:** the tensor tympani muscle (supplied by the 5th cranial nerve) and the stapedius muscle (supplied by the 7th cranial nerve).





- It is bounded by:
 - Tympanic membrane on lateral side and
 - Oval and round windows on the medial side.
- It is connected with the naso-pharynx by the Eustachian tube.

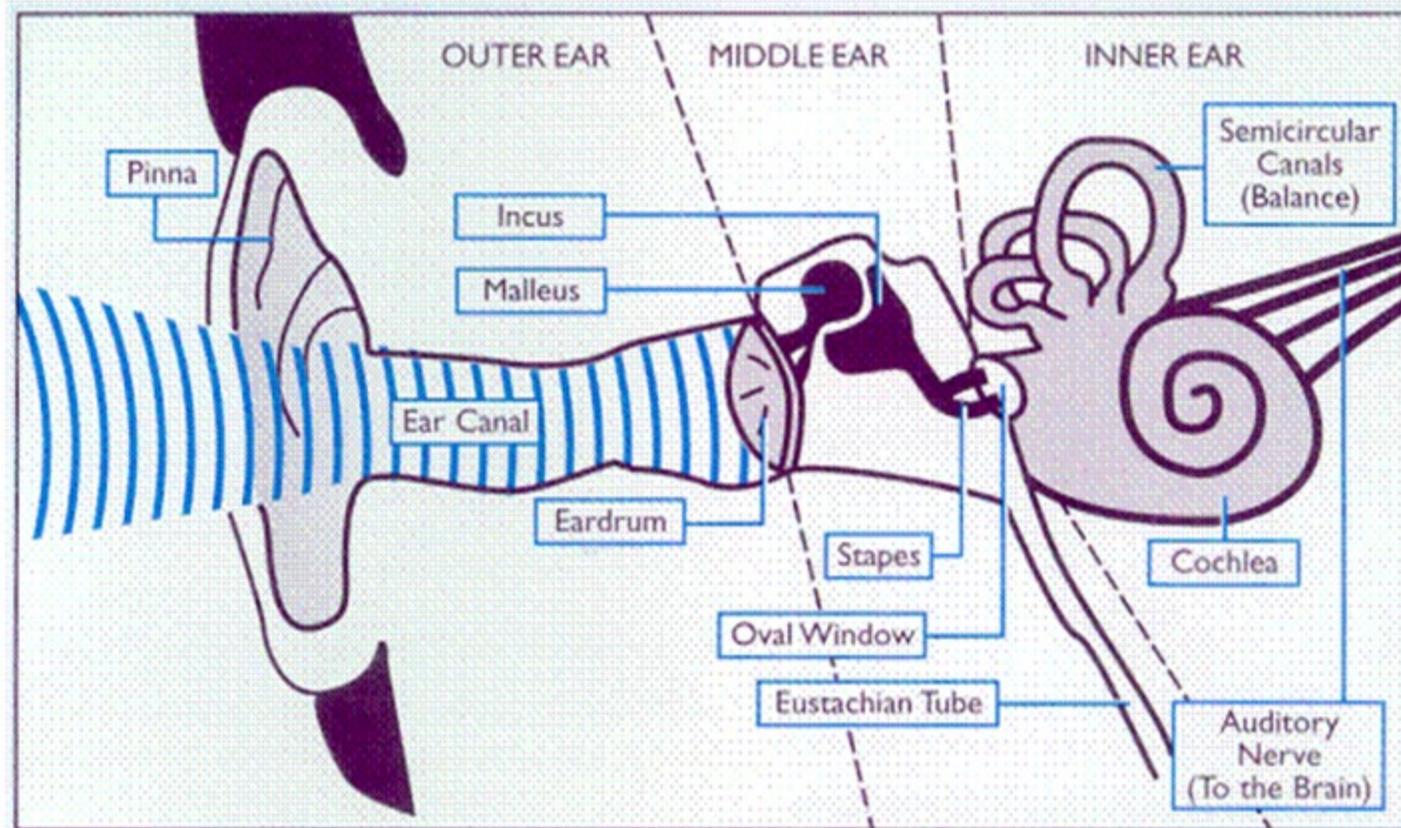
***Functions of Middle Ear:** Transfer sound from the external ear to inner ear.





(I) Tympanic membrane

- **Def:** It is a **thin semi-translucent** membrane.
- **Shape:** Conical with its **concavity** directed **laterally.**
- **Surface area:** 55 mm²
- **Thickness:** 0.1 mm.



- **Functions:**

1. It **acts as a resonator** that reproduces the vibrations of the sound source **i.e.** vibrates in and out according to the frequency and intensity of the sound introduced.
2. It is **highly damped** **i.e.** its vibration stops when the applied sounds stop, this prevents the unnecessary sound prolongation.
3. It is **aperiodic** **i.e.** it has no natural frequency, but takes up the characteristics of the vibrations applied on it.

(II) Functions of ossicular system (Amplification and impedance matching)

- The **transmission** of sound waves from air in the external ear to endolymph in the inner ear results in a great loss of energy.
- More than 97% of a sound's energy would be reflected at the surface of water (i.e. sound of loud speaker would be lowered to just whisper).

- This impedance sound transmission can be matched by 2 mechanisms:

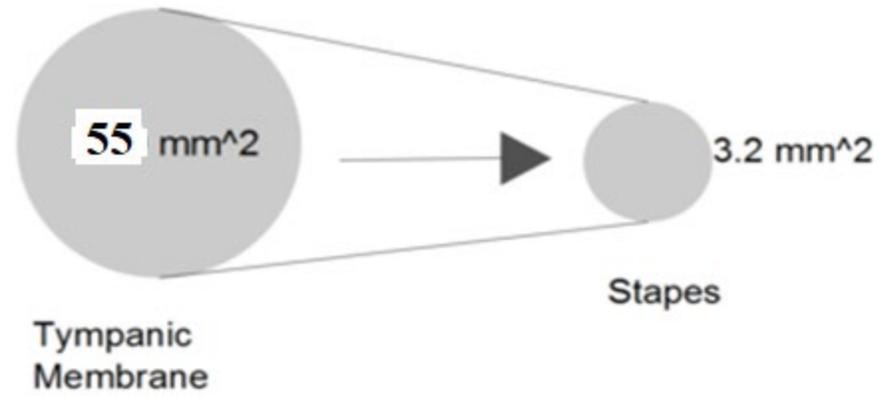
1) The areal ratio of the tympanic membrane and the oval window:

- The surface area of the drum (55 mm²) is about 17 times greater than that of the foot plate of the stapes (3.2 mm²).

- This areal ratio produces an amplification of sound waves about 20 folds at the oval window.

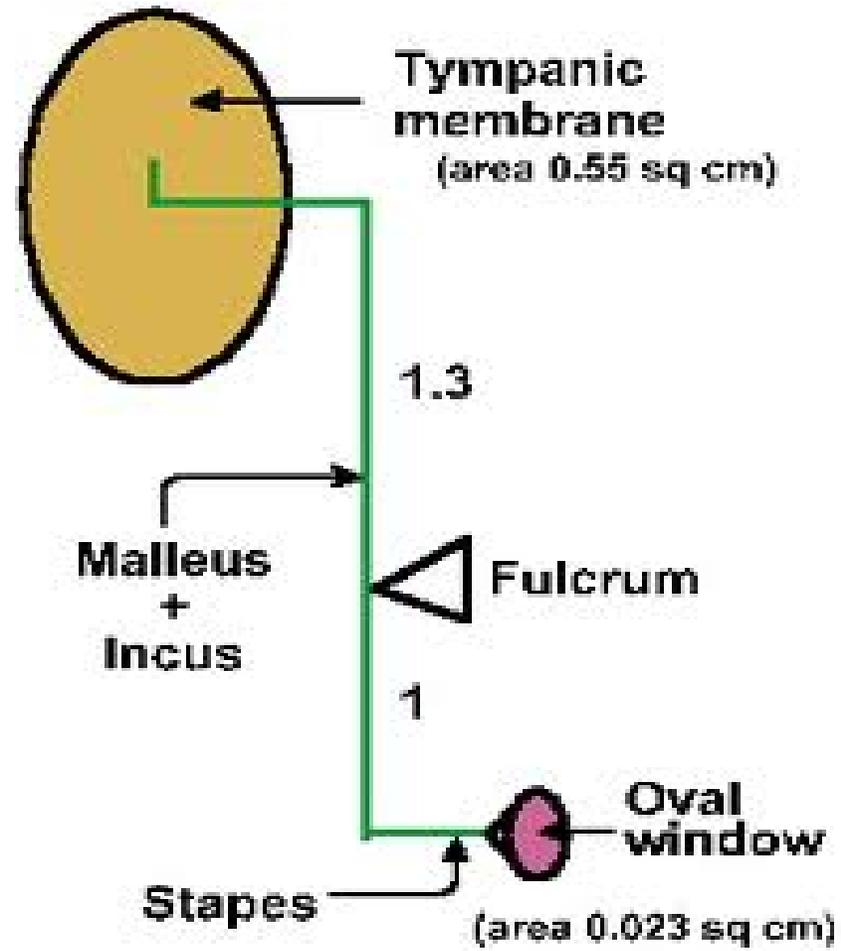
Areal Ratio of Tympanic Membrane to Stapes

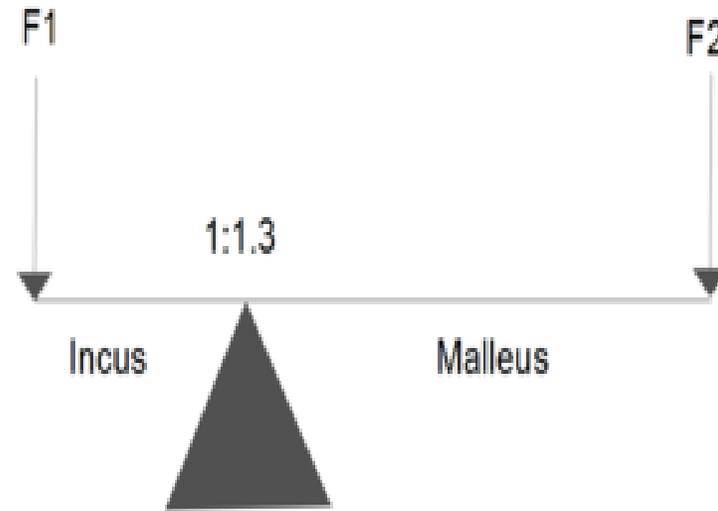
Areal Ratio = 13.4



2) The lever system of the bony ossicles:

- The bony ossicles are arranged in such a manner that they function as a series of levers. The handle of the malleus is about 1.3 times that of long process of the incus. This lever action of the malleus and incus increases the force of movement of the stapes about 1.3 times.





Lever Principle For Malleus and Incus

- The lever action of ossicles and areal ratio of the tympanic membrane and oval window amplify the sound pressure at the oval window about 22 times.
- The efficiency the impedance matching device is not 100%, but it is about 50 to 75% for sound frequencies between 300 and 3000Hz

Facial nerve



(3.2 mm)

Stapes



Malleus

Incus

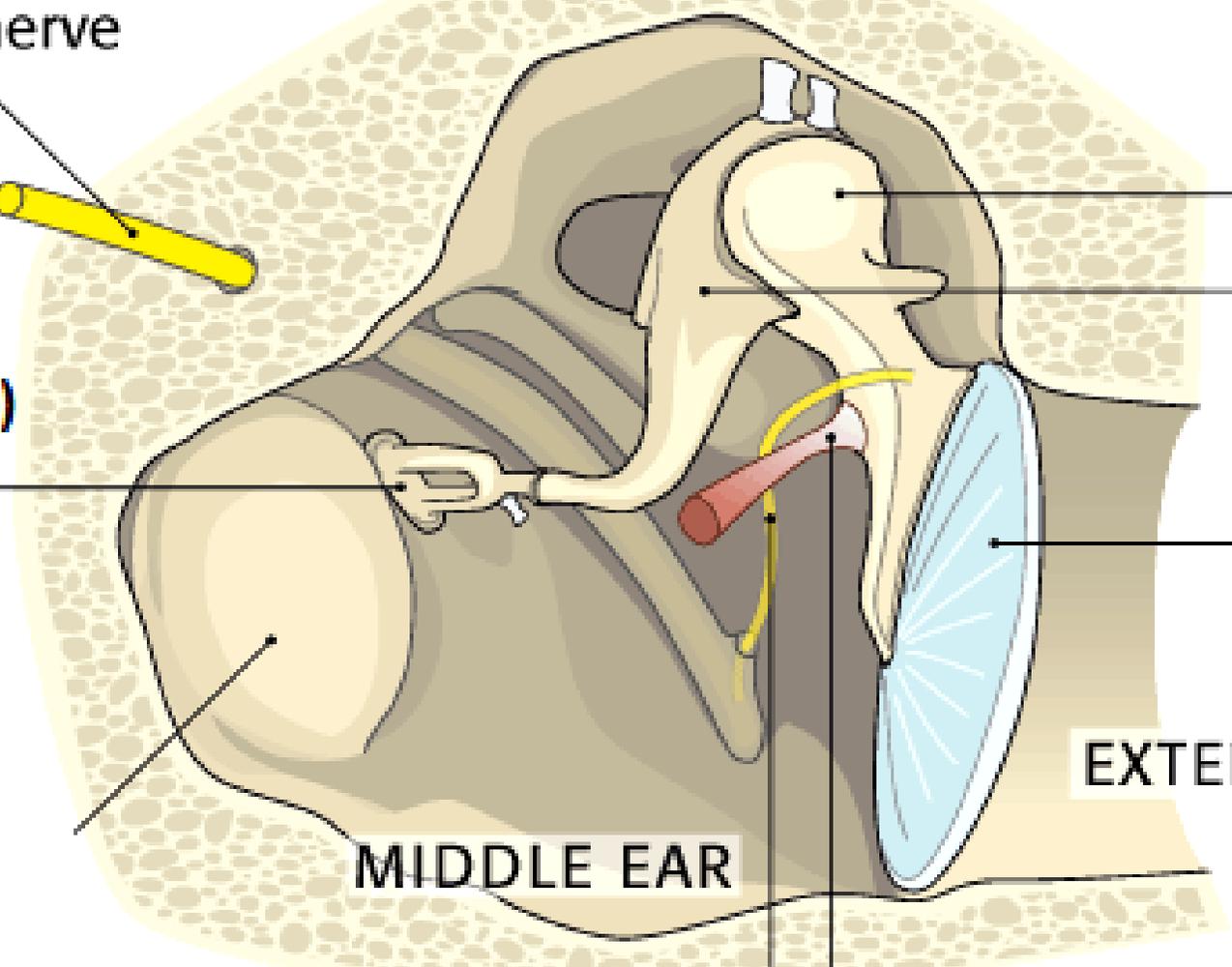
Tympanic **(55 mm)**
membrane

EXTERNAL EAR

MIDDLE EAR

Chorda
tympani

Tensor
tympani

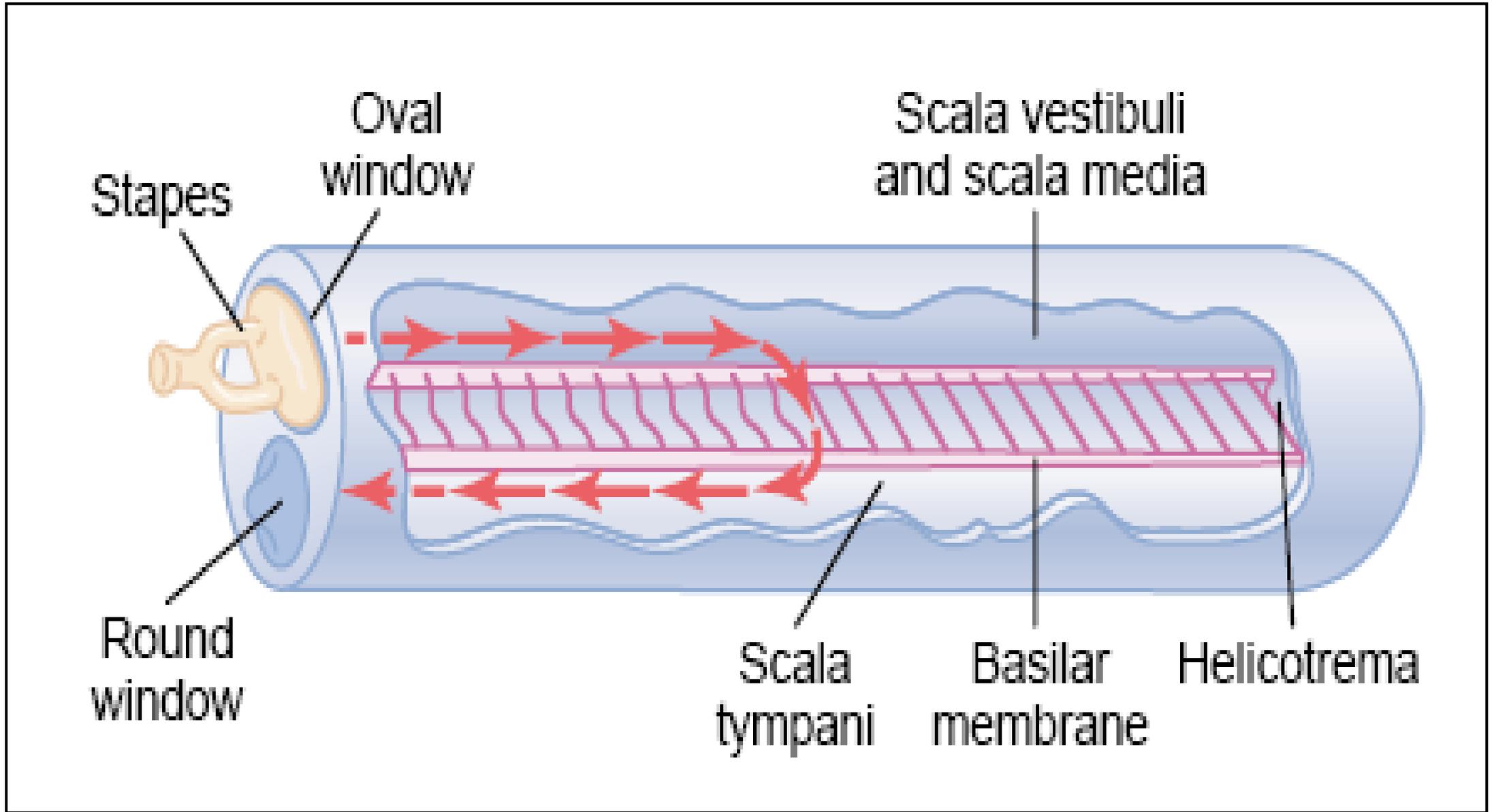


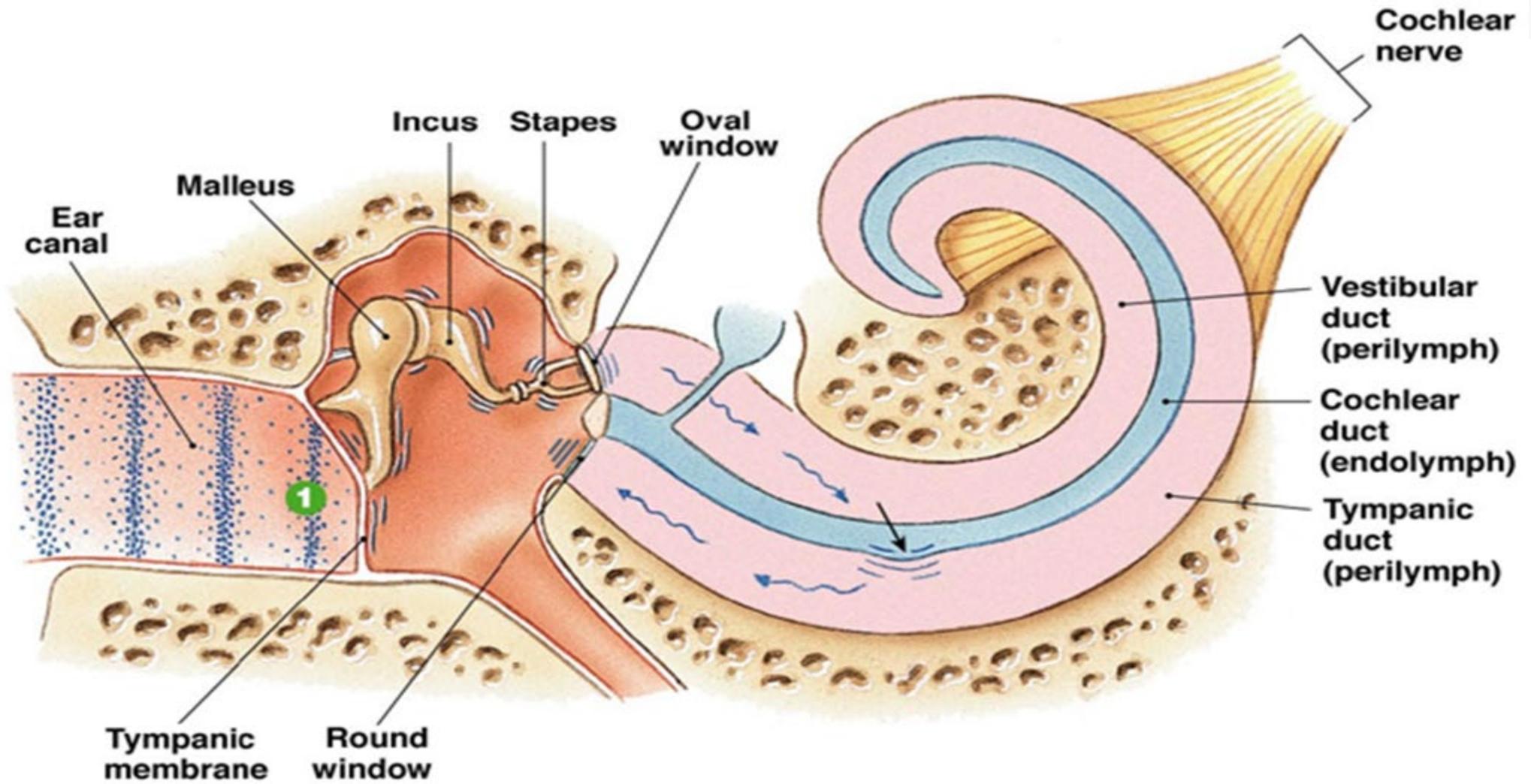


(III) Role of round window in sound transmission

- The oval window opens into the scala vestibuli and the round window opens into the scala tympani.
- If sound waves strike the two windows simultaneously (as that occur when the transformer action of the middle ear is not present) → the effect could be the same as that produced by making equal pressure on the two ends of an open U tube filled with water i.e. there would be no displacement of fluid, this is called cancellation effect.

- In intact ear, sound is applied to the ear drum → vibrations are transmitted to the ossicular bones → to the oval window → then through the scala vestibuli and scala tympani to the round window.
- Therefore, when there is condensation phase, at the **oval window** there will be rarefaction phase at the **round window** i.e. the two windows vibrate reciprocally in response to sound energy.
- So the round window serves as a relief hole in the bony cochlea.







(IV) Eustachian tube

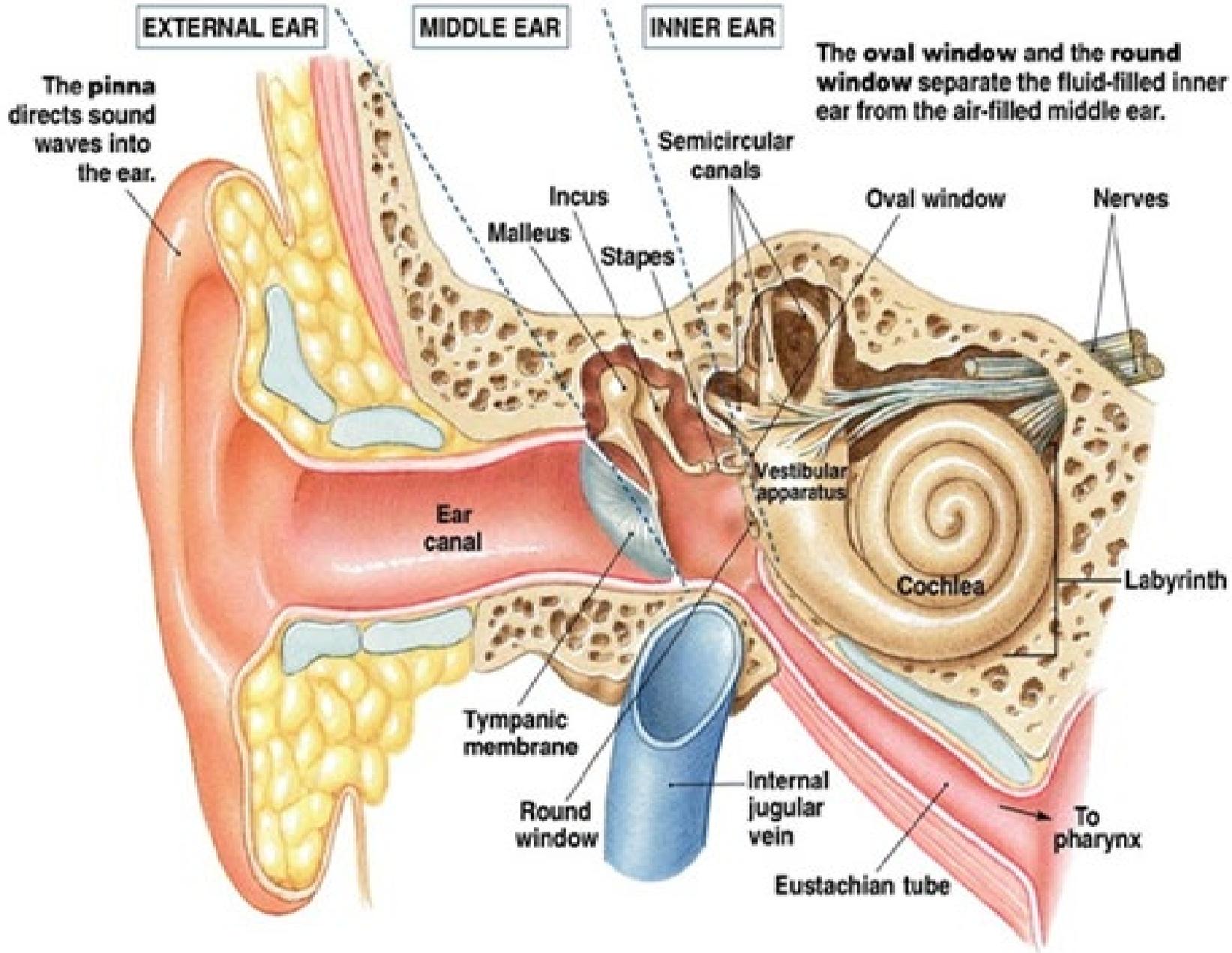
- It connects the middle ear with the nasopharynx.

- Functions:

1. It equalizes pressure on both sides of tympanic membrane:

- Normally the tube is closed but it opens during swallowing, chewing, yawning, blowing the nose, and sneezing.

- If the tube is continuously opened → the sounds of breathing and talking will produce noise and interfere with normal hearing.



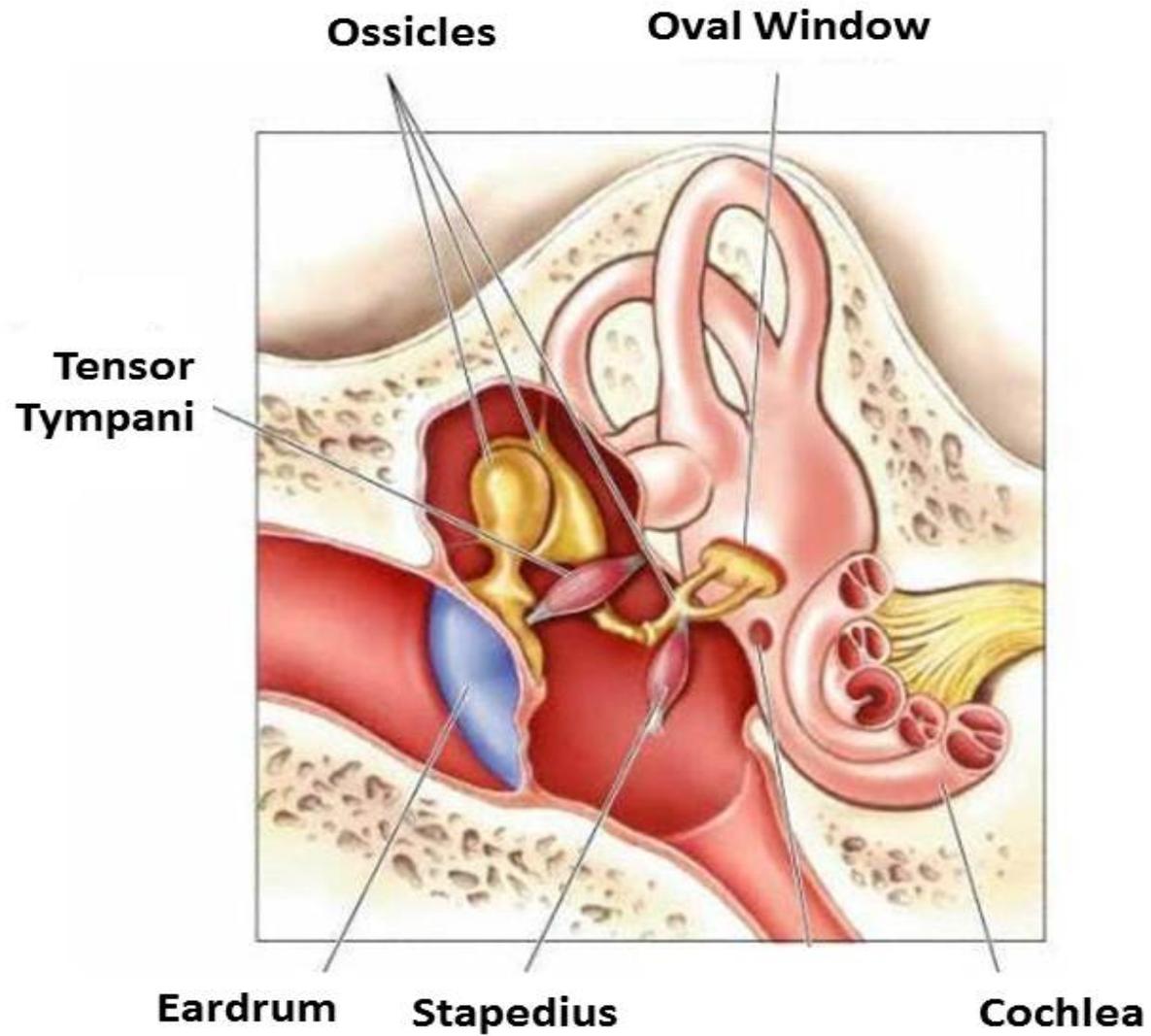
➤ If the tube is continuously closed (as in common cold) → the air in the middle ear will be absorbed → a negative pressure in the middle ear → sucking of the tympanic membrane inwards → limitation of its movement and ↓ hearing.

2. Continual renewal of air in the middle ear.



(V) Tympanic (attenuation) reflex (Functions of middle ear muscles)

- Def: This is a reflex contraction of both **tensor tympani** and **stapedius** muscles in response to sounds of **high intensity** and **low frequency** (above **80 dB** and below **1000 Hz**).



• Mechanism:

- The tensor tympani muscle pulls the handle of the malleus inward while the stapedius muscle pulls the stapes outward.
- These two forces cause the entire ossicular system to develop a high degree of rigidity and greatly reduce the transmission of loud sound.
- This reflex has a long latent period (about 40 m.sec).



• Importance:

1. It protects the cochlea from the damaging vibrations caused by very loud sound which is usually of low frequency. The effect of the reflex is not complete because of its long latent period.

2. It masks low frequency sounds in loud environments i.e. it provides selective attenuation of low frequency sounds so removes a major part of the background noise and allows a person to concentrate on sounds above 1000 Hz.
3. It decreases the person's hearing sensitivity to his own speech, (this effect is activated by collateral signals transmitted to these muscles during speech).

Auditory cortex

- Primary auditory area (areas 41 & 42):

- Located in the upper part of temporal lobe.

- Receive auditory impulses from **both ears** from **ipsilateral Medial geniculate body (MGB)**.

- Anterolateral part receives impulses from the apex of the cochlea (low pitched sounds).

- Posteromedial part receives impulses from the base of the cochlea (high pitched sounds).



□ Functions:

- 1) Conscious perception of **pitch, amplitude, and sound pattern** without understanding its meaning.
- 2) Perception of the **source of the sound**.

□ Lesion:

- **Bilateral damage**: greatly ↓ the person's capacity for hearing
- **Unilateral damage** slightly ↓ hearing of the opposite ear.

- **Secondary (associated) auditory area (area 22):**

- **Location:** Surrounds the **primary area** and covers the **insular cortex**.

- **It receives** impulses from the primary auditory area.

- **Functions:**

associate **sound information** with **afferent information** from other **sensory areas of the cortex** for **interpreting and understanding the meaning** of sounds.

- **Lesion:**

The person will be **unable to interpret the meaning of the heard sound (auditory aphasia or word deafness)**.

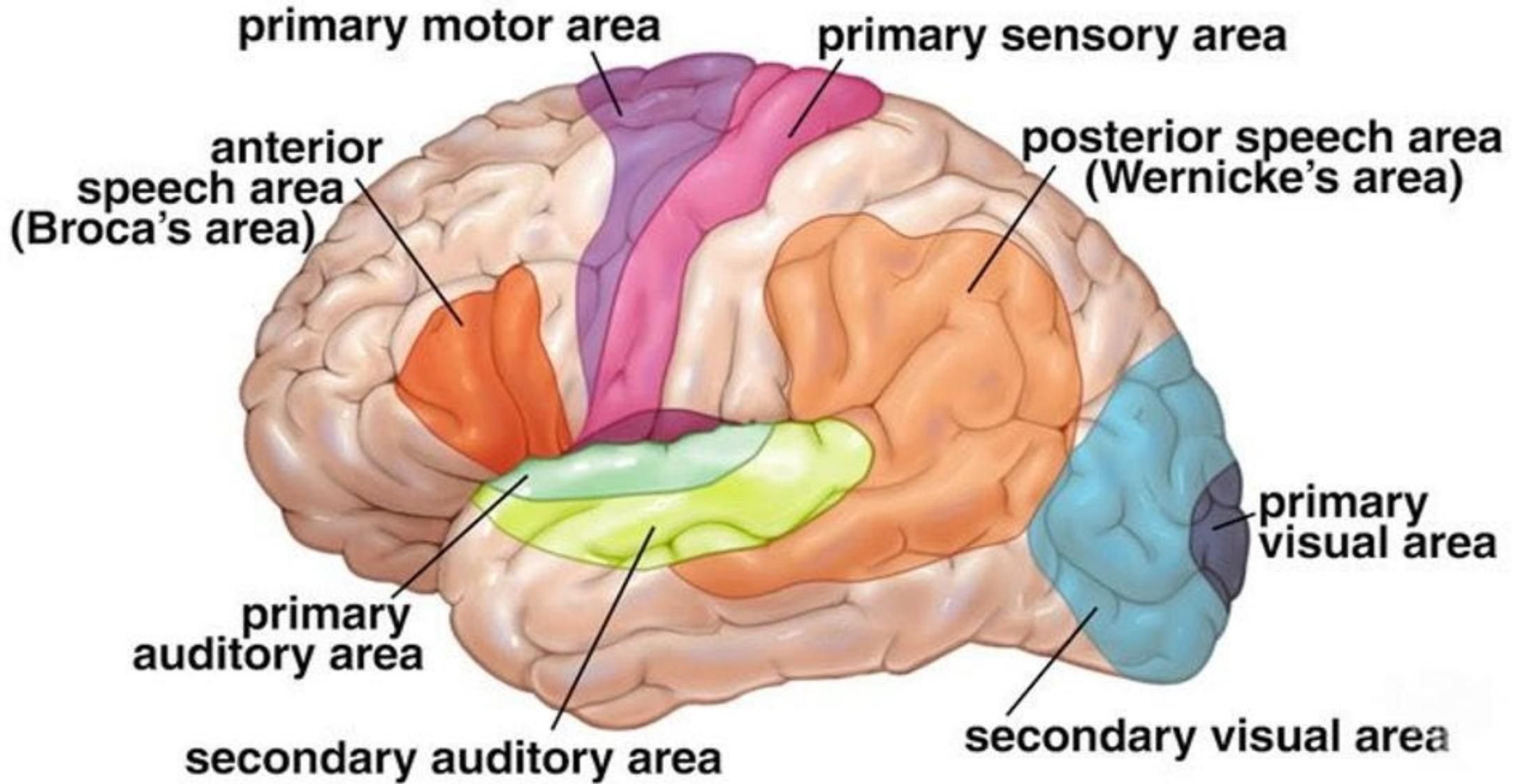


Figure: Primary and secondary auditory areas