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Aqueous Humor

→ protein - free clear fluid

→ nourishes lens & cornea

→ turnover time ≈ 1 hour

→ composition – similar to plasma
– lacks in proteins
– higher conc. of ascorbic acid

→ formed in ciliary chamber by ultrafiltration, diffusion & active transport

ciliary process
↓
aqueous humor
↓
posterior chamber
↓
pupil
↓
anterior chamber

Posterior Chamber: (Triangular space)

Boundaries:

Anteriorly: back of iris

Posteriorly: anterior surface of lens

Laterally: ciliary body

Medially: meeting point of pupillary margin with lens

Anterior Chamber:

Boundaries:

Anteriorly: posterior surface of cornea

Posteriorly: anterior surface of iris & anterior surface of lens

Aqueous pressure: 15–18 mm Hg higher than intracranial pressure.

↓

- helps to maintain shape of eye & keep vitreous humor pressurised

Drainage of Aqueous Humor: Anterior Chamber → Spongy meshwork of trabecular tissue → Canal of Schlemm

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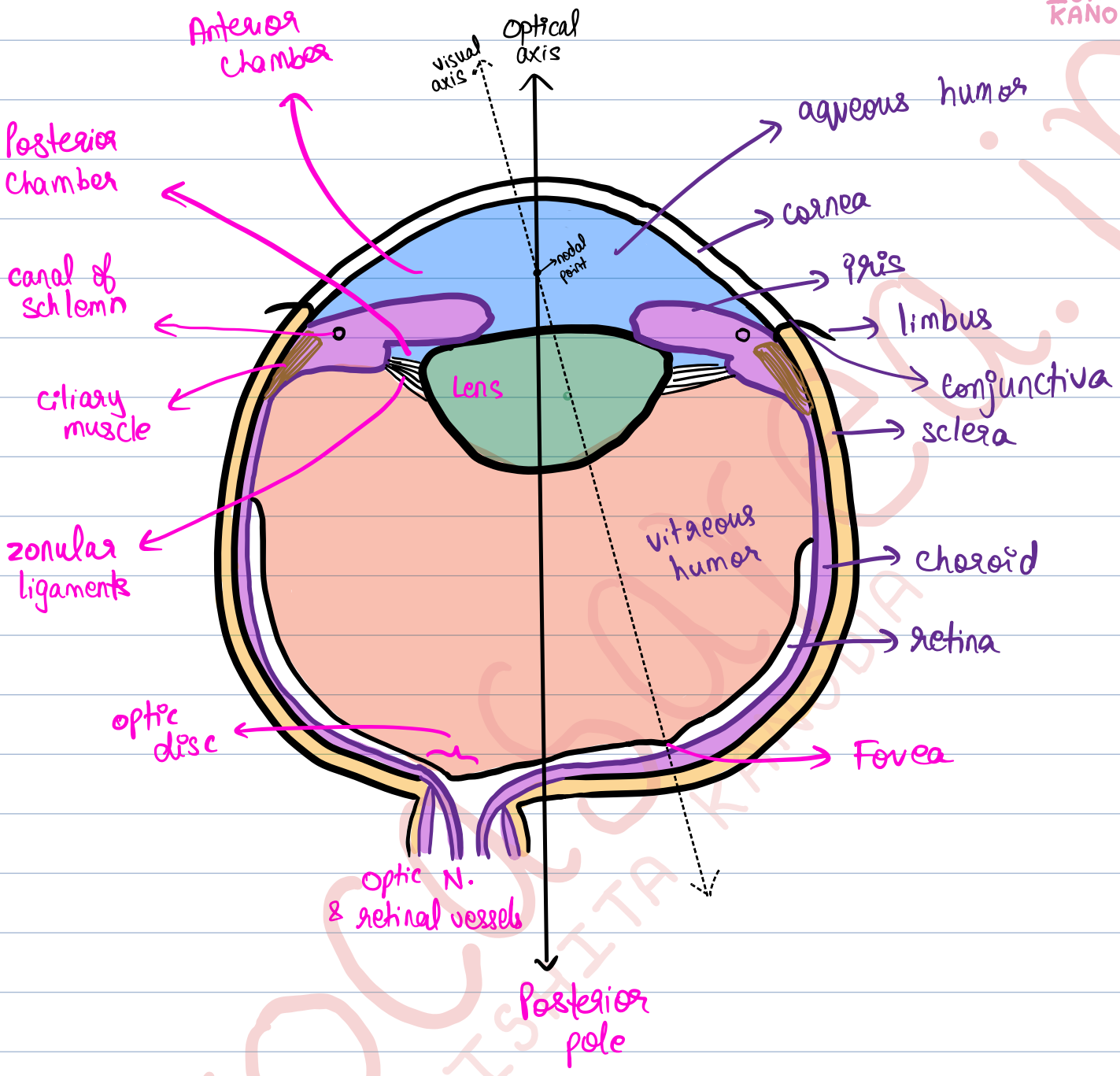

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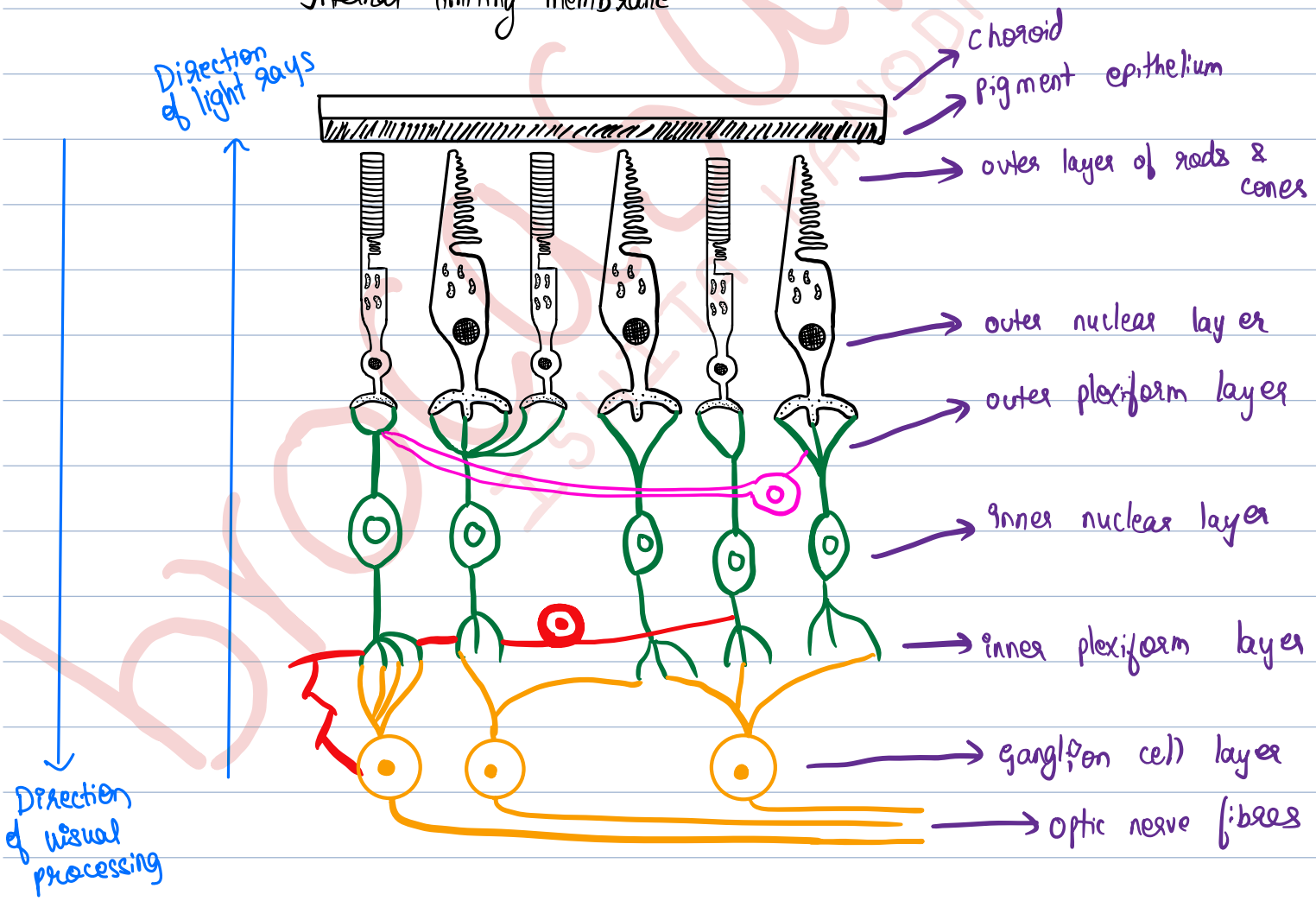
Retina (200 μm):

Ten Layers
- Layer of pigment epi.
- Layer of rods & cones
- External limiting membrane
- Outer nuclear layer
- Outer plexiform layer
- Inner nuclear layer
- Inner plexiform layer
- Layer of ganglion cells
- Layer of nerve cells
- Internal limiting membrane

(amacrine cells & horizontal cells are interneurons)



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Intraocular Pressure: (IOP)

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→ 10 - 20 mm Hg

→ IOP - maintains shape of eyeball

- Keeps the retina pressed against choroid so that retinal surface is even for clear image formation

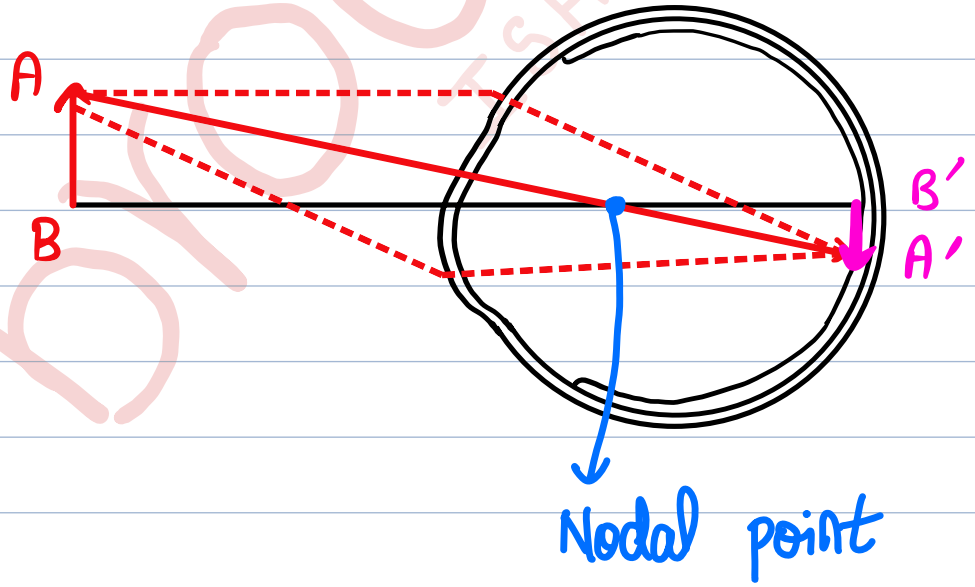
→ volume of lens, aqueous humor, vitreous humor, & blood vessels inside eye contribute to development of IOP.

→ measured by tonometry

→ Decreased absorption of aqueous humor causes rise in IOP

- Open angle glaucoma: due to reduced permeability through trabecular tissue
- Closed angle glaucoma: due to obstruction of passage by anterior displacement of iris

Reduced Eye:



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Accomodation :

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→ normal eye ⇒ ciliary muscles are relaxed, lens is stretched, eye is focused at distant object at more than 6m distance

→ to focus on object within 6m, eye increases its refractive power by increasing curvature of lens (by contraction of ciliary muscles) — This is called accomodation.

Near Point: nearest point to eye at which object is seen clearly

- ↳ at this point, maximum accomodation is exerted
- increases with age due to progressive loss of elasticity of lens.

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Defects of Image Formation:

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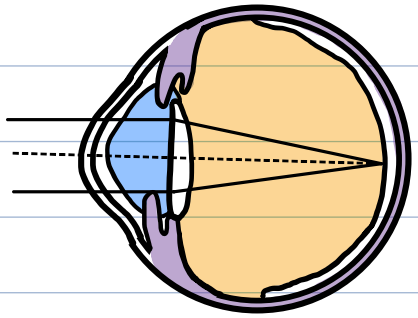
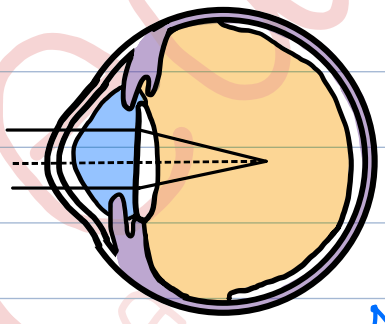


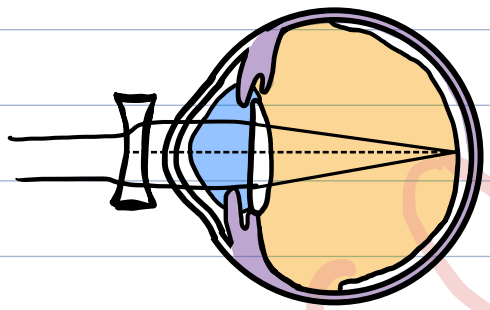
Normal Eye



Myopia — Near-sightedness

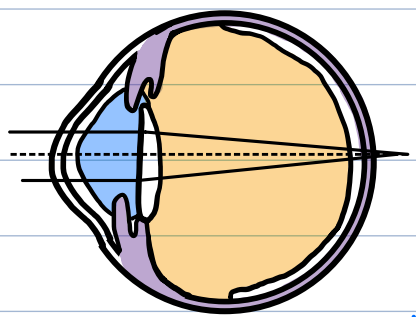
↓

lens becomes more convex



Corrected Myopia

(biconcave lens)

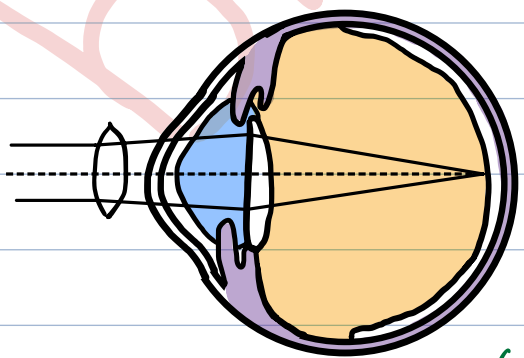


Far-sightedness

Hypermetropia

↓

decreased antero-posterior diameter of eye



Corrected Hypermetropia

(Biconvex lens)

Astigmatism: due to unequal refraction at different meridians

→ light rays are focused on retina at different points

→ corrected by cylindrical lens

Presbyopia: seen in all people > 40 y/o

↳ near point recedes

→ due to progressive loss of plasticity of lens

→ corrected by bifocal lens

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Photoreceptors

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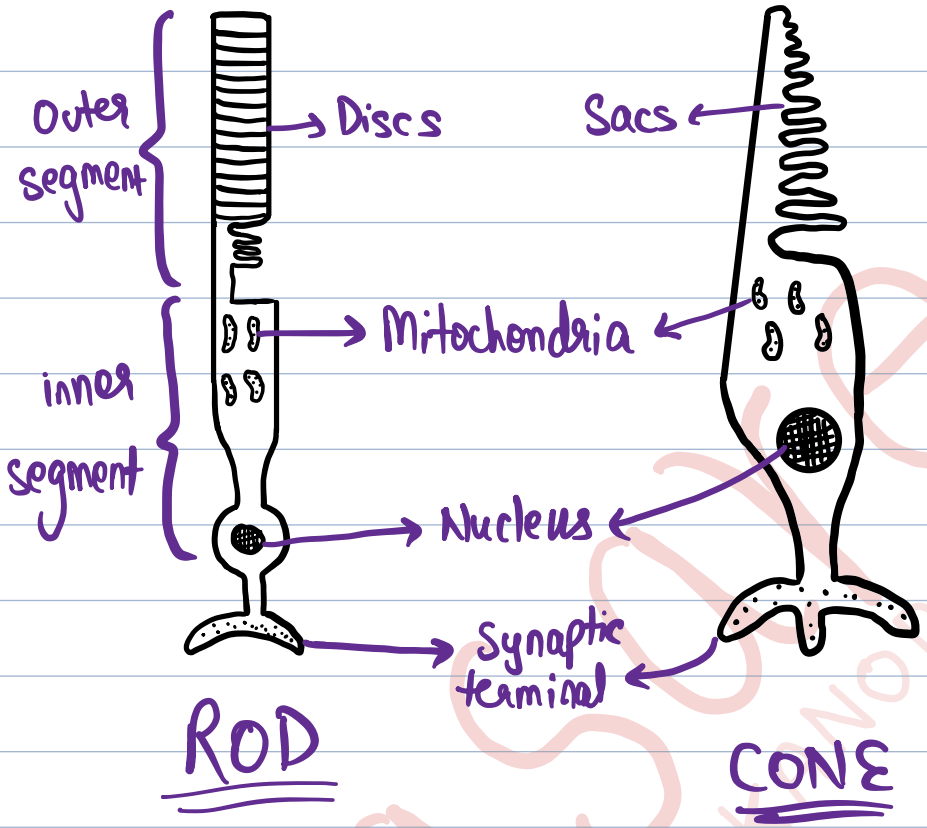

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Visual Pathway:

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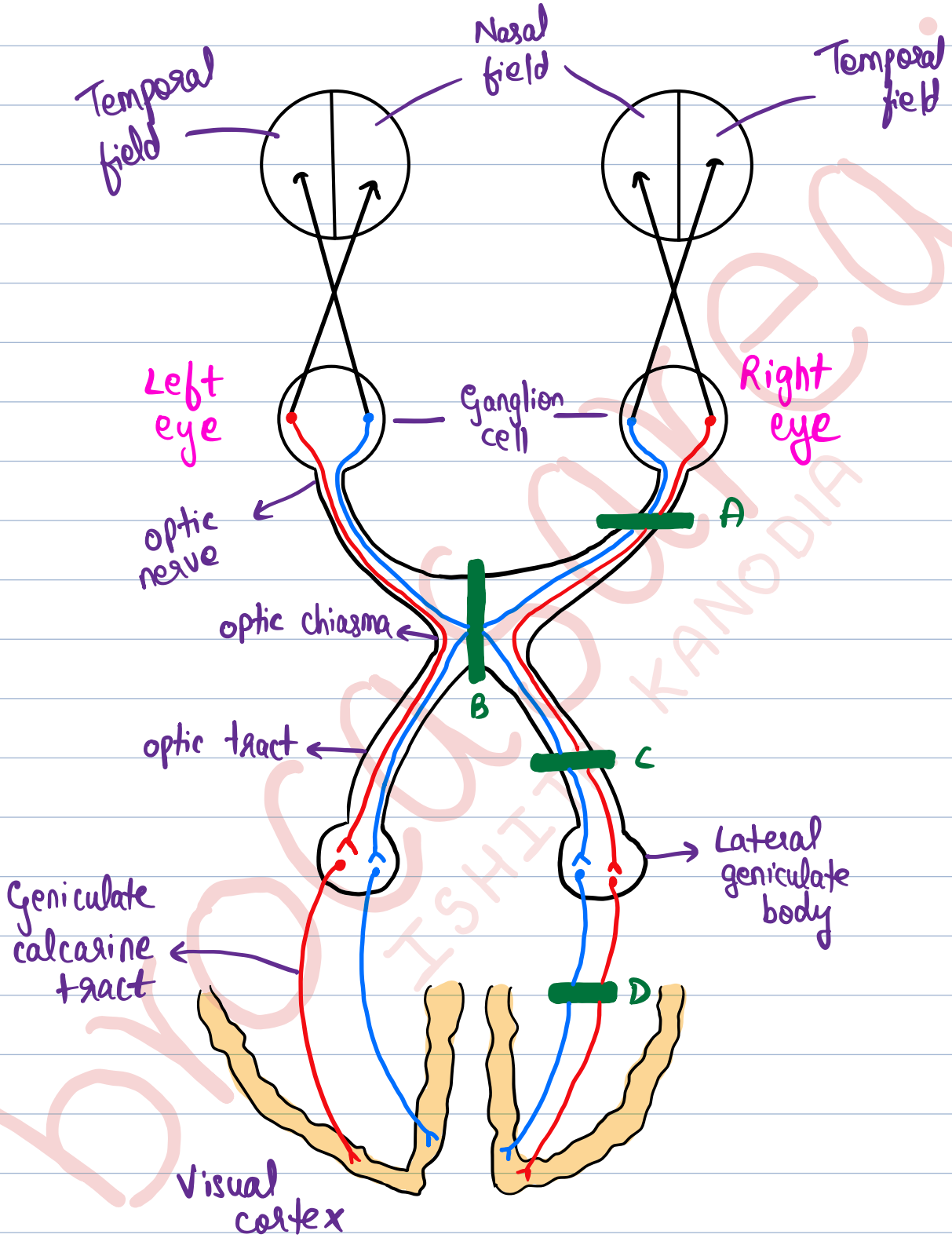

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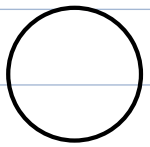
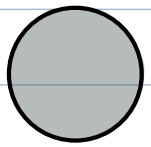
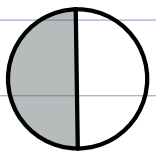
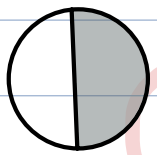
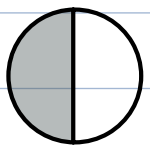
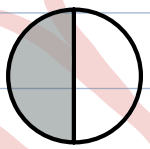
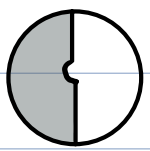
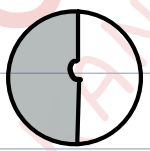
Left visual field		Right visual field	
	A		Right Anopia
	B		Bitemporal hemianopia
	C		Left homonymous heminanopia
	D		Left homonymous hemianopia with macular sparing

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Visual Acuity:

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→ ability of eye to identify 2 closely placed points as 2 distinct points.

→ shortest distance which are distinguishable = Minimum Separable distance.

→ Visual acuity is a function of cones

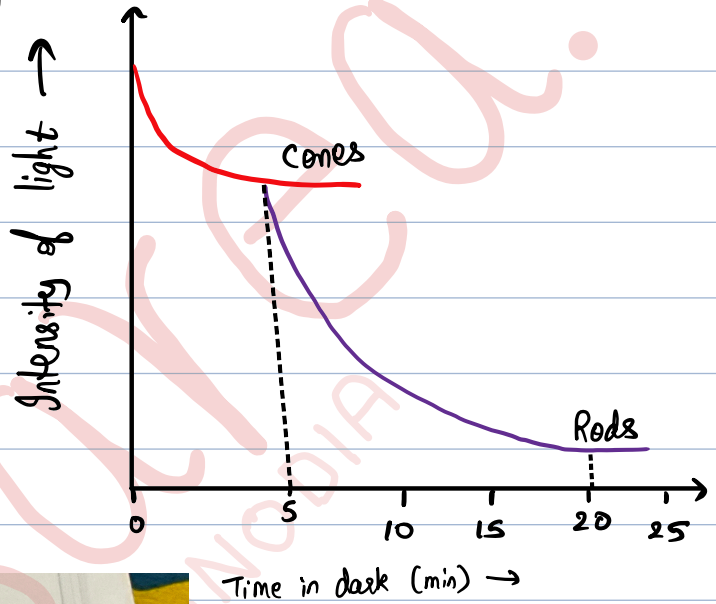
→ It expresses resolving power of eye.

Dark Adaptation:

❑ Dark Adaptation (Fig. 60.3)

When a person moves from a brightly lit area to a dark area, the retina becomes more sensitive to light and visual threshold decreases. This is known as **dark adaptation.** These changes help in better visibility in the dark.

The perception of bright light and color vision is due to cones. When the subject enters a dark room, the rod vision takes over.



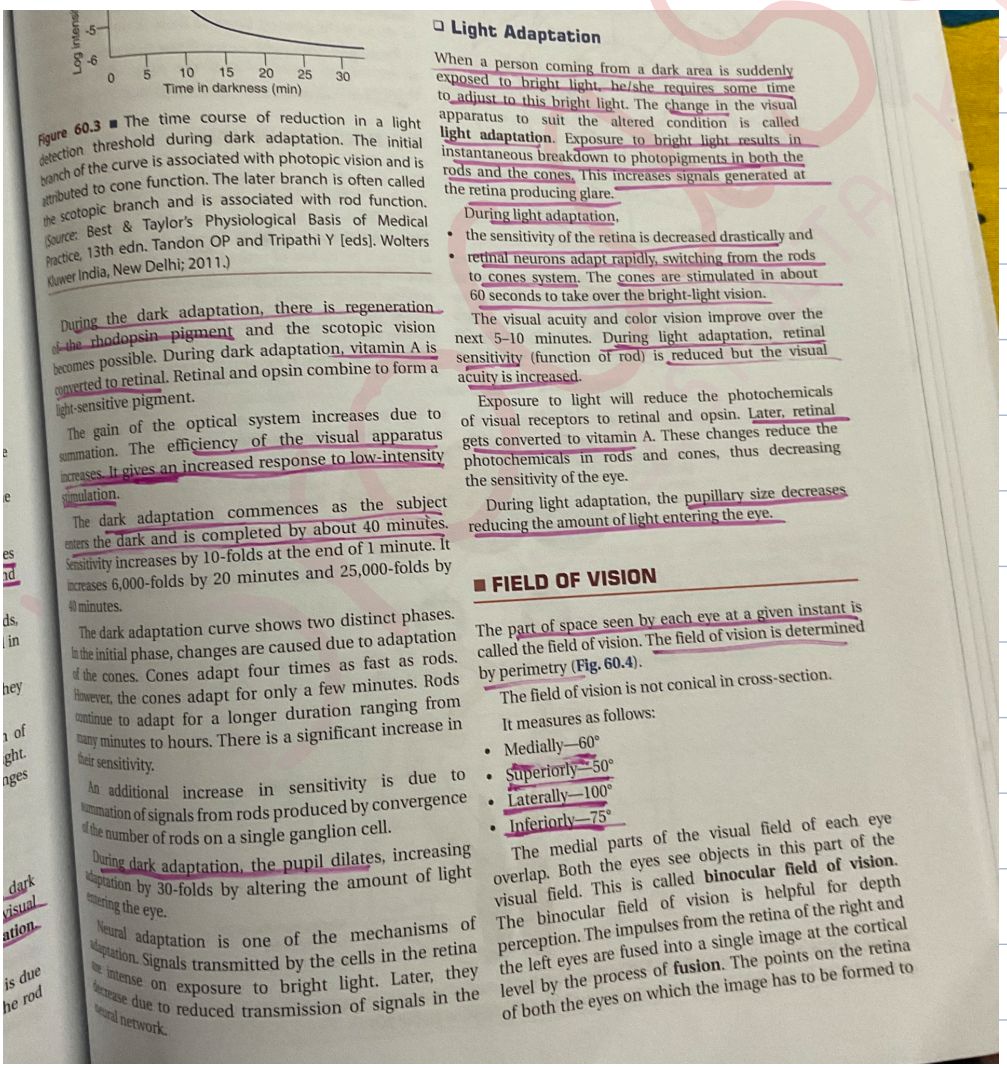


Figure 60.3 ■ The time course of reduction in a light detection threshold during dark adaptation. The initial branch of the curve is associated with photopic vision and is attributed to cone function. The later branch is often called the scotopic branch and is associated with rod function. (Source: Best & Taylor's Physiological Basis of Medical Practice, 13th edn. Tandon OP and Tripathi Y [eds]. Wolters Kluwer India, New Delhi; 2011.)

During the dark adaptation, there is regeneration of the rhodopsin pigment and the scotopic vision becomes possible. During dark adaptation, vitamin A is converted to retinal. Retinal and opsin combine to form a light-sensitive pigment.

The gain of the optical system increases due to summation. The efficiency of the visual apparatus increases. It gives an increased response to low-intensity stimulation.

The dark adaptation commences as the subject enters the dark and is completed by about 40 minutes. Sensitivity increases by 10-folds at the end of 1 minute. It increases 6,000-folds by 20 minutes and 25,000-folds by 40 minutes.

The dark adaptation curve shows two distinct phases. In the initial phase, changes are caused due to adaptation of the cones. Cones adapt four times as fast as rods. However, the cones adapt for only a few minutes. Rods continue to adapt for a longer duration ranging from many minutes to hours. There is a significant increase in their sensitivity.

An additional increase in sensitivity is due to summation of signals from rods produced by convergence of the number of rods on a single ganglion cell.

During dark adaptation, the pupil dilates, increasing adaptation by 30-folds by altering the amount of light entering the eye.

Neural adaptation is one of the mechanisms of adaptation. Signals transmitted by the cells in the retina are intense on exposure to bright light. Later, they decrease due to reduced transmission of signals in the neural network.

❑ Light Adaptation

When a person coming from a dark area is suddenly exposed to bright light, he/she requires some time to adjust to this bright light. The change in the visual apparatus to suit the altered condition is called **light adaptation.** Exposure to bright light results in instantaneous breakdown to photopigments in both the rods and the cones. This increases signals generated at the retina producing glare.

During light adaptation,

- the sensitivity of the retina is decreased drastically and
- retinal neurons adapt rapidly, switching from the rods to cones system. The cones are stimulated in about 60 seconds to take over the bright-light vision.

The visual acuity and color vision improve over the next 5–10 minutes. During light adaptation, retinal sensitivity (function of rod) is reduced but the visual acuity is increased.

Exposure to light will reduce the photochemicals of visual receptors to retinal and opsin. Later, retinal gets converted to vitamin A. These changes reduce the photochemicals in rods and cones, thus decreasing the sensitivity of the eye.

During light adaptation, the pupillary size decreases reducing the amount of light entering the eye.

■ FIELD OF VISION

The part of space seen by each eye at a given instant is called the field of vision. The field of vision is determined by perimetry (Fig. 60.4).

The field of vision is not conical in cross-section.

It measures as follows:

- Medially—60°
- Superiorly—50°
- Laterally—100°
- Inferiorly—75°

The medial parts of the visual field of each eye overlap. Both the eyes see objects in this part of the visual field. This is called **binocular field of vision.** The binocular field of vision is helpful for depth perception. The impulses from the retina of the right and the left eyes are fused into a single image at the cortical level by the process of **fusion.** The points on the retina of both the eyes on which the image has to be formed to

Light Reflex:

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Light falls on one eye

↓

Optic Nerve

↓

Optic Tract

↓

Pre-tectal nucleus & superior colliculi

Direct Light Reflex

Edinger-Westphal Nucleus

↓ oculomotor nerve

Ciliary ganglion

↓ short ciliary nerves

Sphincter pupillae

↓

Pupillary Constriction

Consensual Light Reflex

Activation of contralateral Edinger-Westphal Nucleus

↓ occulomotor nerve

Ciliary ganglion

↓ short ciliary nerves

Sphincter pupillae

↓

Pupillary constriction of other eye

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Accomodation Reflex:

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Gaze shifts from far object to near object

↓ visual pathway

visual cortex (area 17)

↓ occipitomesencephalic pathway

Edinger-Westphal Nucleus

↓

Occulomotor Nerve

↓

Contraction of ciliary muscle, sphincter pupillae & medial rectus

↓

↑ convexity of lens, constriction of pupil, medial rotation of eyeball

Argyll Robertson Pupil:

→ loss of direct & consensual light reflex

→ accomodation reflex present

→ occurs in neurosyphilis

→ due to neurological lesion in pretectal - superior colliculi region of mesencephalon

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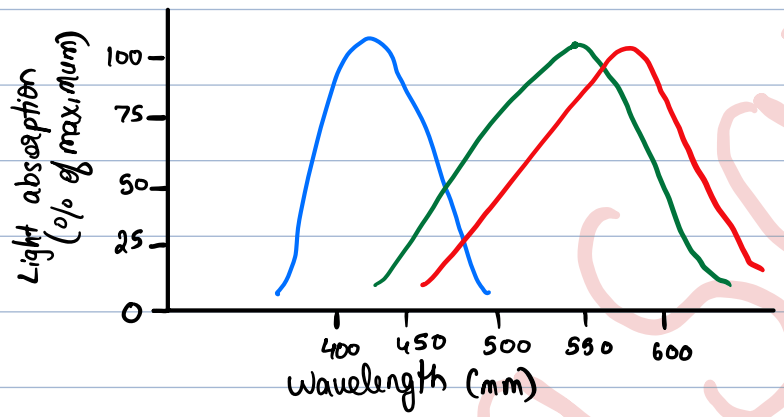
Theories of Colour Vision:

Pigment Theory / Retinal or Trichromatic Theory:

→ 3 types of cones
→ each has a pigment with different absorption spectrum
→ Red-sensitive pigment absorbs light maximally in yellow portion of spectrum
Green-sensitive " " " " " green " " "
Blue-sensitive " " " " " blue-violet " " "



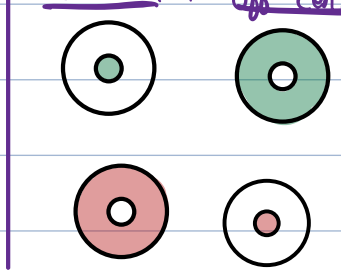
Human rhodopsin gene – chromosome 3
Blue-sensitive cone gene – chromosome 7
Red-sensitive cone gene } q-arm of
Green-sensitive " " } X chromosome

Opponent Theory / Hering's Theory:

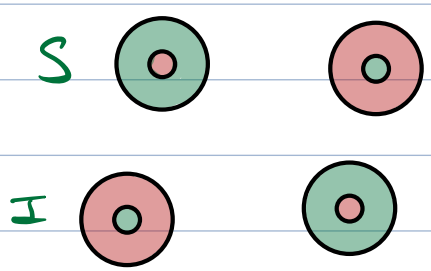
→ there is no greenish-red or bluish-yellow color
→ Red & green colours oppose each other
Blue & yellow " " " " .

S = stimulation
I = inhibition

Single Opponent Property



Double Opponent Property



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Olfactory Pathway

Olfactory receptor cell → olfactory nerve

↓

olfactory bulb

↓

olfactory tract

↓

Medial olfactory stria → Septal nuclei → Hipothalamus, Limbic system

Very old olfactory system

Lateral Olfactory strip → Prepyriform cortex, Pyriform cortex, Amygdala → Limbic system

Less old olfactory system

Lateral Olfactory strip → Thalamus → orbitofrontal cortex

Newer System

Taste Pathway:

- Tongue Anterior 2/3 by chorda tympani nerve (VII)
- " Posterior 1/3 by X cranial nerve

↓

NTS (via medial lemniscus)

↓

VPM nucleus of thalamus (ipsilateral)

↓

Sensory cortex (ipsilateral foot plate of post central gyrus)

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Auditory Pathway:

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Hair cells

↓

Spiral ganglion

↓

Cochlear nuclei

↓

Superior olivary nuclei

↓

Inferior colliculi

↓

Medial geniculate body

↓

Primary auditory cortex

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Middle Ear Cavity:

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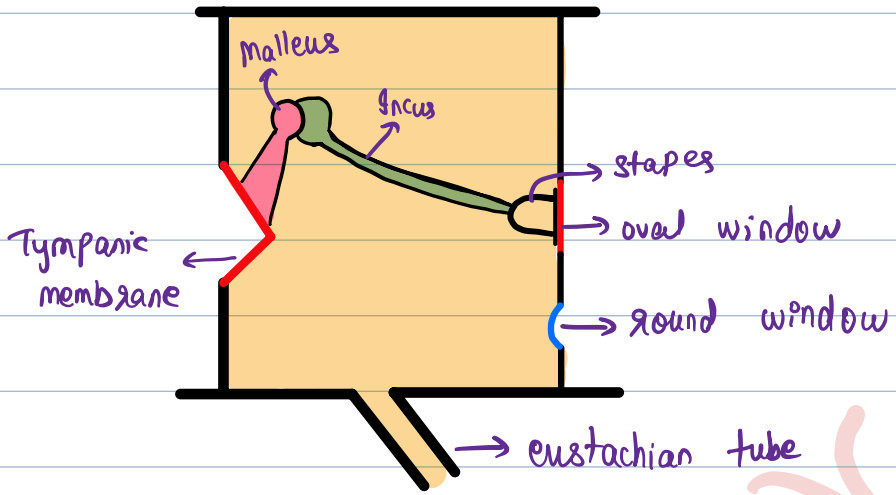

Tympanic membrane: – acts as resonator
– critically dampens sound waves

Eustachian tube: – equalizes pressure on both sides of tympanic membrane

Functions of Middle Ear Cavity:

→ receives sound waves from external ear

→ transmits sound waves to inner ear

→ amplification of sound waves – due to surface area of tympanic membrane being much larger than that of oval window (17:1)
– handle of malleus is 1·3 times longer than long process of incus (lever mechanism amplifies force by 1·3 times)
– Total amplification = 17 x 1·3 = 22

→ equalize air pressure through eustachian tube

→ protects against prolonged, loud sound by activation of tympanic reflex.

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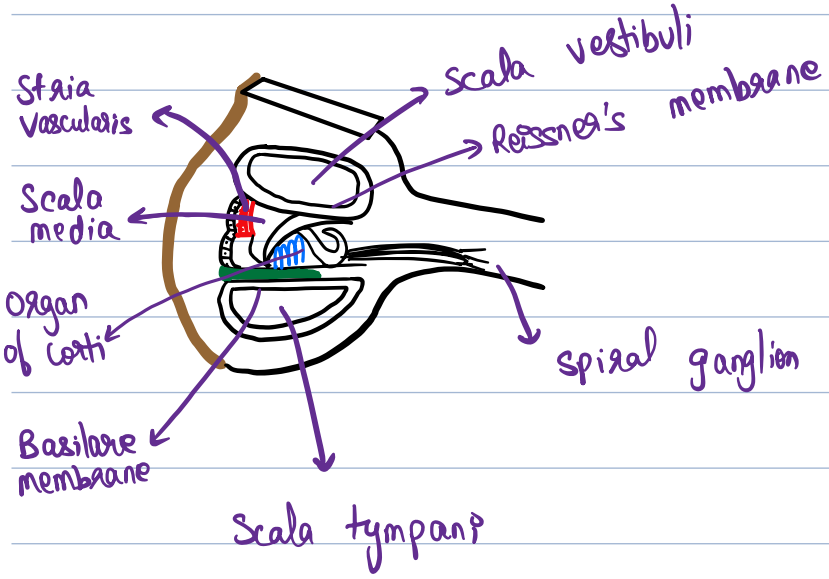

Impedance Matching:

→ when sound waves travel from air to water, about 99.9 % of sound energy gets reflected away from surface of water

→ so conduction of sound from air to fluid meets with considerable acoustic impedance (resistance)

→ if sound waves were to strike oval window directly (without traversing through tympanic membrane & ossicular chain), only 0.5% of sound energy would have reached the endolymph in inner ear

→ amplification process helps to compensate for the loss
This is called impedance-matching in middle ear.

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Tympanic / Acoustic Reflex:

→ protective reflex that decreases damage to inner ear from loud sound

→ activation time = 40 - 160 ms (∴ does not protect from gunshot or bomb blast sounds)

Prolonged Long Noise

↓

Tensor tympani & stapedius contract reflexively

↓

- outward movement of malleus
- inward " " stapes

↓

ossicular chain comes closer together

↓

vibration transmitted through ossicles to inner ear is reduced

↓

lesser degree of stimulation of hair cells in inner ear

↓

over-stimulation & damage to cochlea is prevented

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6. The hair cells are surrounded by the supporting or ***sustentacular cells***. The apical ends of the hair cells contain cilia (hair) that pass through the reticular lamina supported by the rods of Corti.
7. The cilia of the outer hair cells project into a thin flexible gelatinous **tectorial membrane** that covers the rows of hair cells, whereas the cilia of the inner hair cells do not touch the membrane. The viscous membrane contains collagen and glycoprotein and is firmly attached only along its medial edge.

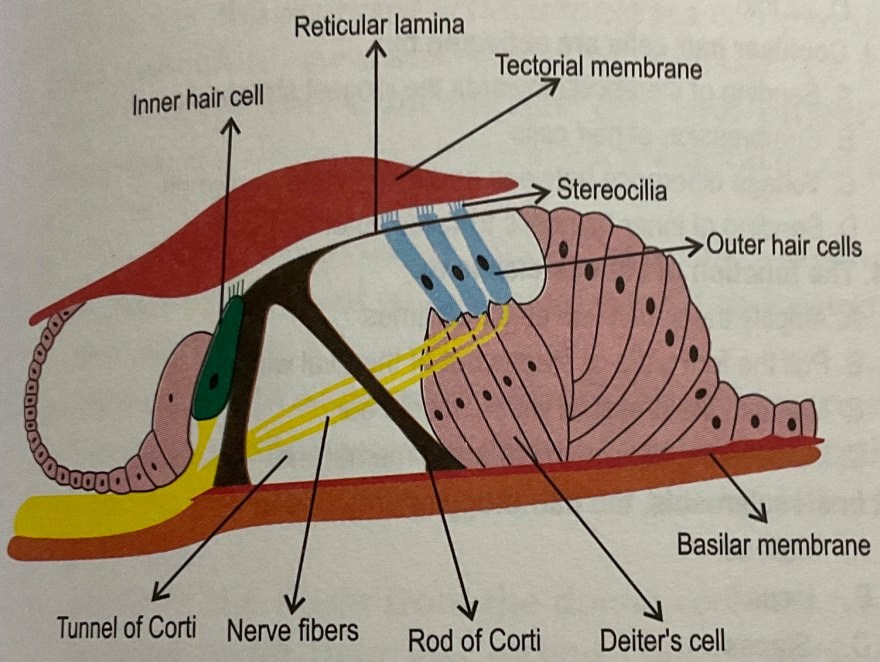

Fig. 125.5: The Organ of Corti

Hair Cells

Structure

The structures of inner and outer hair cells are anatomically similar, but the **outer hair cell is longer than the inner hair cell.**

(GK Pal Physiology)