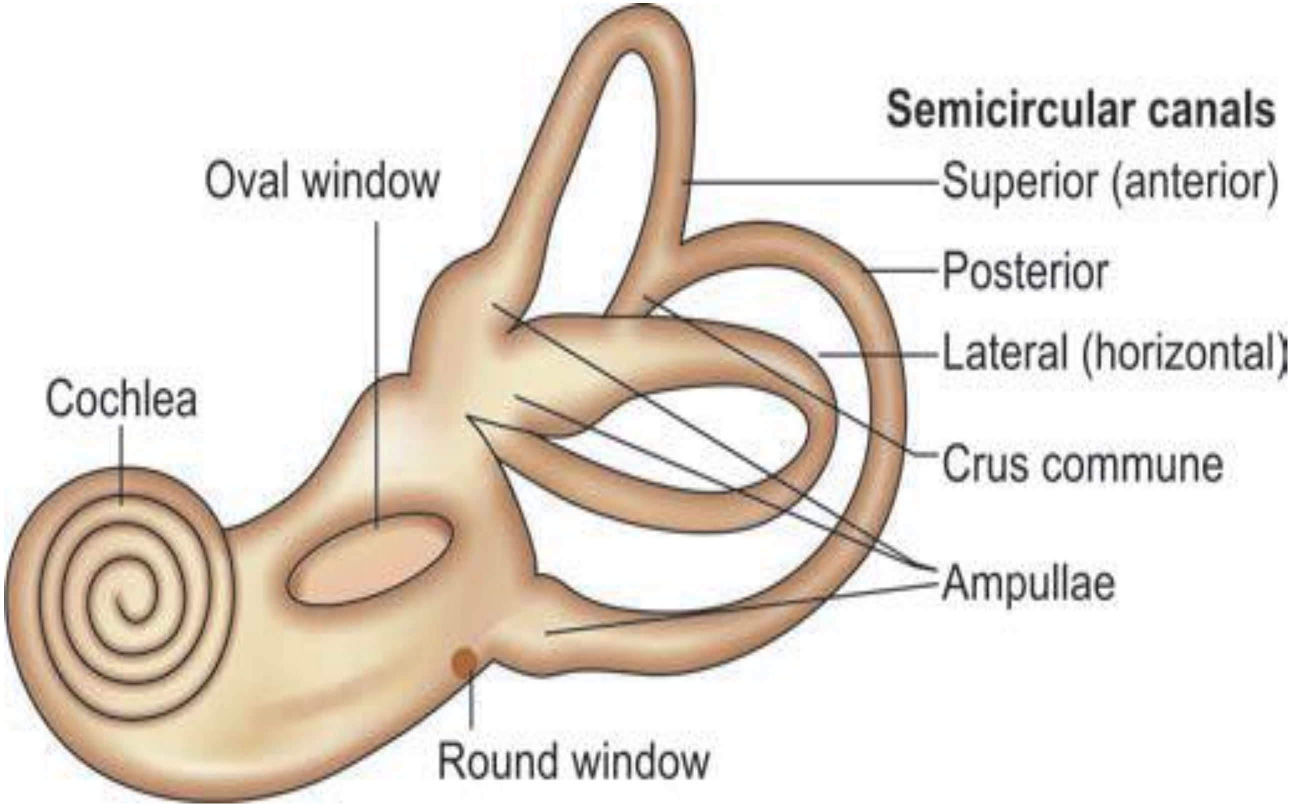
ANATOMY OF INTERNAL EAR

The internal ear (labyrinth), which has organs of both hearing and balance, is divided into bony and membranous labyrinth. The membranous labyrinth is filled with endolymph. Perilymph is filled in the space present between membranous and bony labyrinths.



Bony labyrinth

Bony labyrinth .consists of three parts: vestibule, semicircular canals and cochlea.

A-vestibule The lateral wall of labyrinth is medial wall of middle ear.it has Oval window (fenestra -vestibuli): It lies in the lateral wall and closed by footplate of stapes surrounded by annular ligament.

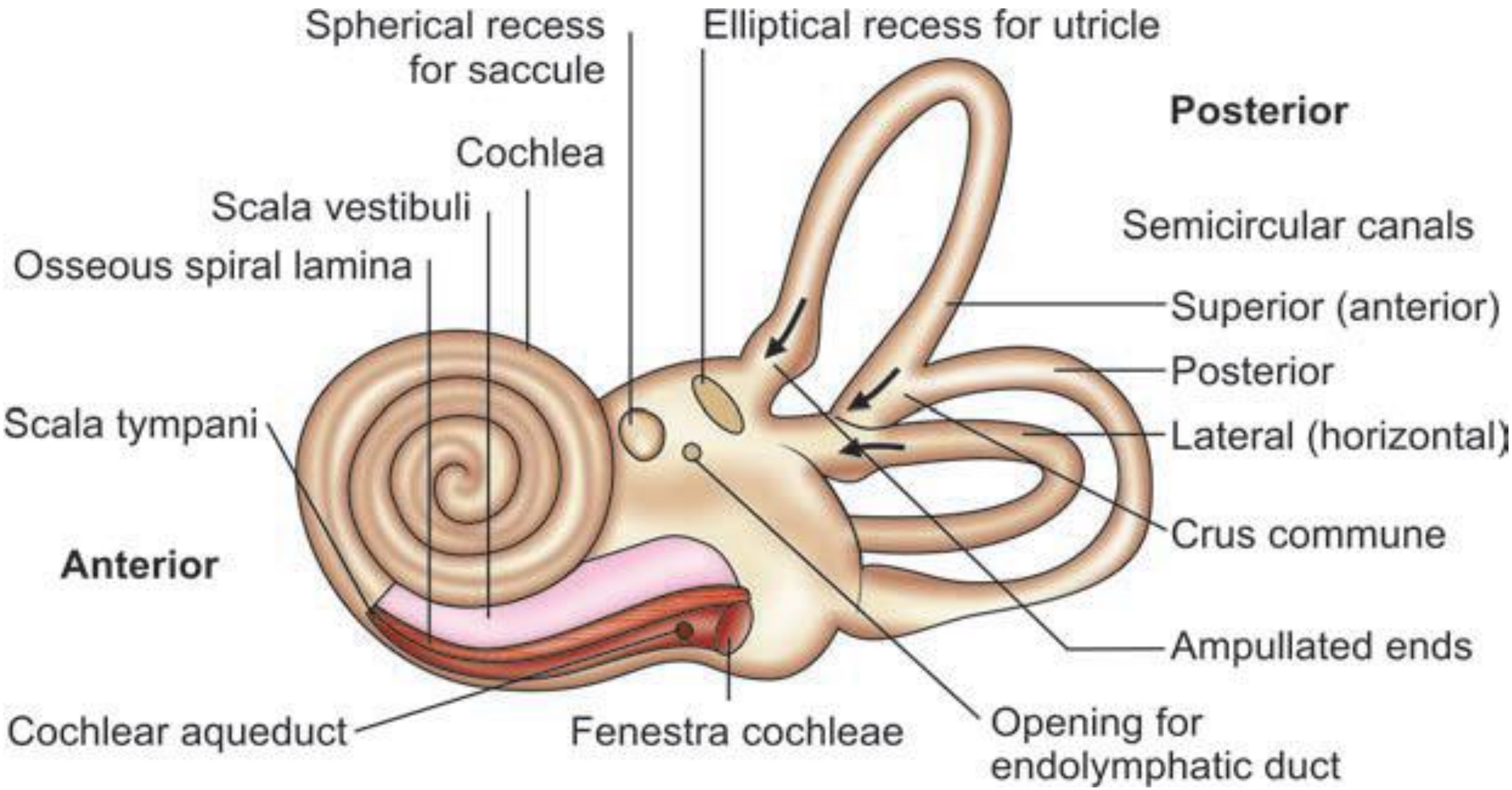
*B-Semicircular Canals (*There are three SCCs: lateral (horizontal), posterior and superior (anterior). Each canal occupies 2/3rd of a circle and has a diameter of 0.8 mm. They lie in planes at right angles to one another. Each canal has two ends: ampullated and nonampullated. All the three ampullated ends and nonampullated end of lateral SCC openindependently and directly into the vestibule.

1*. Superior SCC*: It is 15–20 mm long and situated transverse to the axis of petrous part of temporal bone. Its anterolateral end is ampullated and opens in the superolateral part of vestibule.

2*. Lateral SCC*: It is 12–15 mm long and projects as a rounded bulge into the middle ear, aditus and antrum.It makes an angle of 30° with the horizontal plane. Its anterior end is ampullated and opens into the upper part of vestibule. The posterior nonampullated end opens into the lower part of vestibule below the orifice of crus commune.

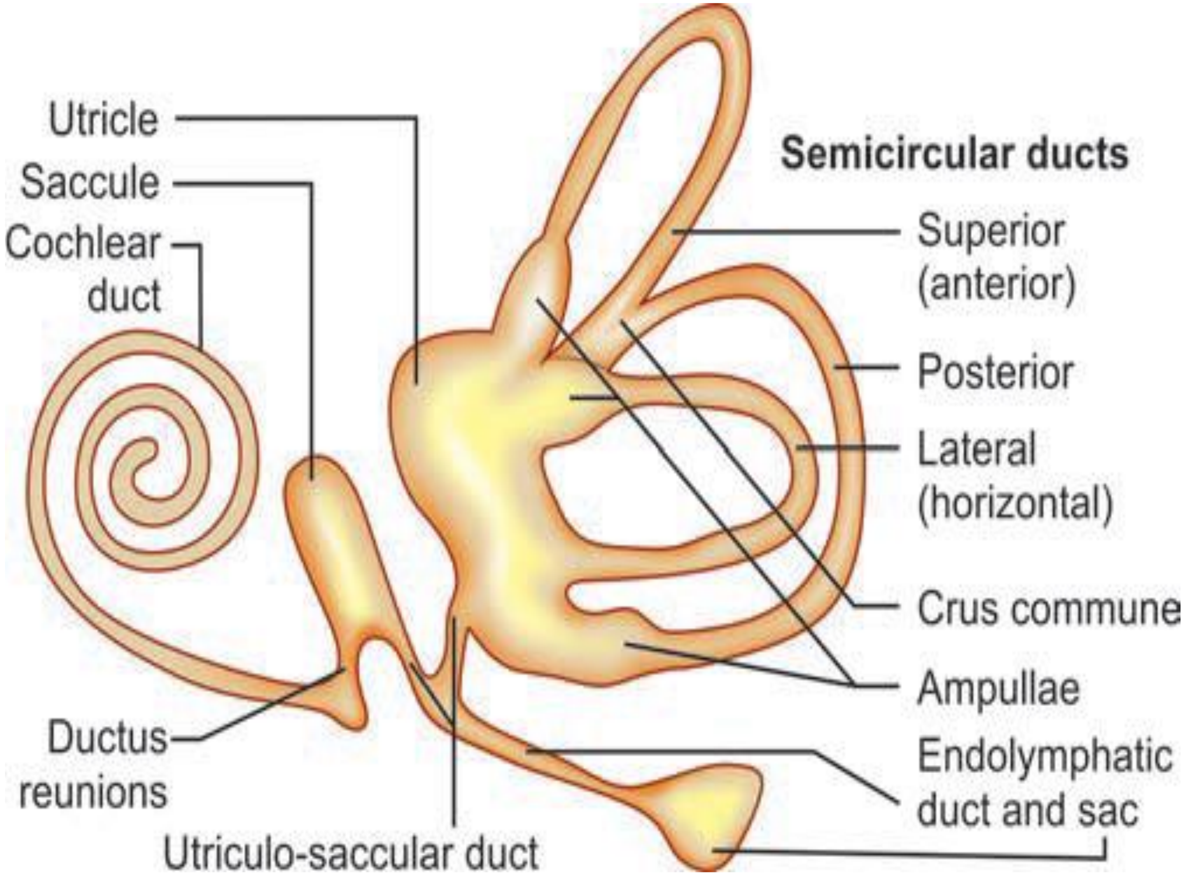
3*. Posterior SCC*: It is 18–22 mm long and situated parallel and close to the posterior surface of petrous part of temporal bone. Its lower end is ampullated and opens into the lower part of vestibule. Its upper limb joins the crus commun

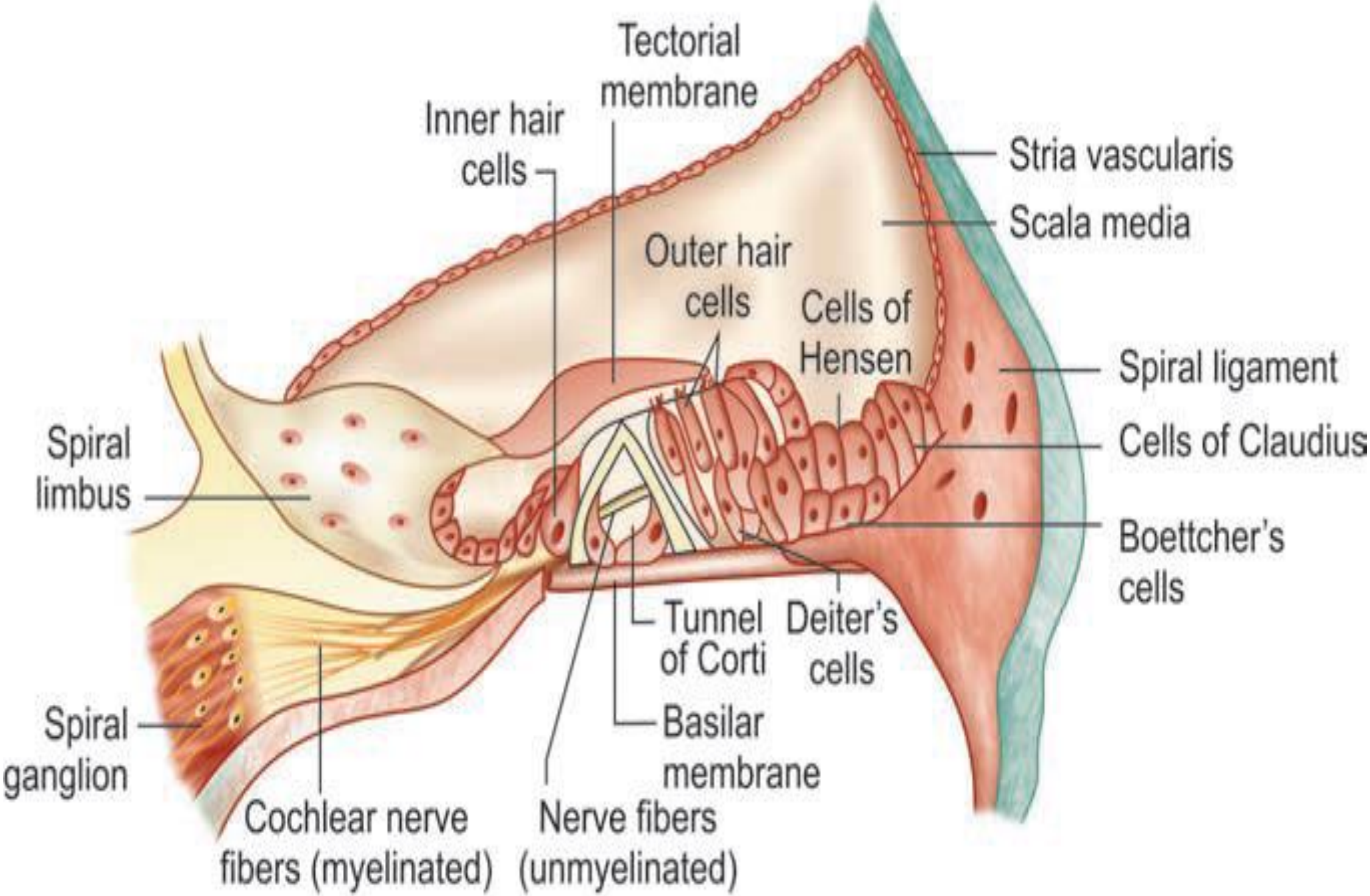
c. Cochlea .The bony cochlea, which is a coiled tube, looks like snail. Cochlear canal makes 2.5–2.75 turns round a central pyramid of bone called modiolus. The cochlear tube is 30 mm long. It is 5 mm from base to apex and 9 mm around its base.



Membranous labyrinth

Membranous labyrinth .consists of cochlear duct, utricle, saccule, three semicircular ducts and endolymphatic duct and sac





Tectorial membrane
Inner hair cells
Stria vascularis
Scala media
Outer hair cells
Cells of Hensen
Spiral ligament
Spiral limbus
Cells of Claudius
Boettcher's cells
Tunnel of Corti
Deiter's cells
Spiral ganglion
Basilar membrane
Cochlear nerve fibers (myelinated)
Nerve fibers (unmyelinated)

Organ of corti

This sensory organ of the hearing, is situated on the basilar membrane. It is spread like a ribbon along the entire length of basilar membrane. It consists of following important components:

1. *Tunnel of Corti*: This tunnel, which is situated between the inner and outer rods, contains a fluid called cortilymph. The functions of the rods and cortilymph are yet not clear

2. *Hair Cells*: These important receptor cells of hearing transduce sound energy into electrical energy. There are two types of hair cells—inner and outer. At low magnification stereocilia. The stereocilia have mechanically activated ion channels which are opened by the sound stimuli. With the advancement of age there is generalized reduction in the number of hair cells. Differences between inner and outer hair cells are given in Table 3.

Difference between inner hair cells (IHCs) and outer hair cells (OHCs)

	Inner hair cells	*Outer hair cells*
Cells numbers	3500	12000
Rows	One	Three or four
Shape	Flask	Cylindrical
Nerve supply	Mainly afferent fibers	Mainly efferent fibers
Development	Early	Late
Function	Transmit auditory stimuli	Modulate function of inner hair cells
Ototoxicity	More resistant	More sensitive and easily damaged
High intensity noise	More resistant	More sensitive and easily damaged
Generation of otoacoustic emissions	NO	YES

Internal auditory canal

Internal auditory canal (IAC) is about 1 cm long and passes into petrous part of temporal bone in a lateral direction. It is lined by dura. At its lateral end (fundus) IAC is closed by a vertical cribriform plate of bone that separates it from labyrinth .A transverse crest divides this plate into smaller upper and larger lower parts. Upper part is further divided into anterior and posterior quadrant by a vertical crest called Bill's bar.

Contents

1. Vestibulocochlear nerve.
2. Facial nerve including nervous intermedius.
3. Internal auditory artery and vein.

Mechanism of Hearing

A sound signal in the environment is collected by the pinna, passes through external auditory canal and strikes the tympanic membrane. Vibrations of the tympanic membrane are transmitted to stapes footplate through a chain of ossicles coupled to the tympanic membrane Movements of stapes footplate cause pressure changes in the labyrinthine fluids which move the basilar membrane.

This stimulates the hair cells of the organ of Corti. It is these hair cells which act as transducers and convert the mechanical energy into electrical impulses which travel along the auditory nerve.

The mechanism of hearing can be broadly divided into:

l. Mechanical conduction of sound (conductive apparatus) .

2. Transduction of mechanical energy to electrical impulses (sensory system of cochlea).

3. Conduction of electrical impulses to the brain (neural pathways).

.Conduction of *Sound*

A person under water cannot hear any sound made in the air because 99.9% of the sound energy is reflected away from the surface of water because of the Impedance Matching Mechanism offered by it. A similar situation exists in the ear when air-conducted sound has to travel to cochlear fluid. Middle ear compensates for this loss of sound energy. Middle ear converts sound of greater amplitude, but lesser force, to that of lesser amplitude and greater force. This function of the middle ear is called impedance matching mechanism or the transformer action.

It is accomplished by:

A-*Lever* action *of the ossicles.* Handle of malleus is 1.3 times longer than long process of the incus, providing a mechanical advantage of 1.3.

B-*Hydraulic action of tympanic membrane_* The area of tympanic membrane is much larger than the area of stapes footplate, the average ratio between the two being 21:1. As the effective vibratory area of tympanic membrane is only two-thirds, the effective areal ratio is reduced to 14: I, and this is the mechanical advantage provided by the tympanic membrane .The product of areal ratio and lever action of ossicles is 18: l.

According to some workers (Wever & Lawrence) the 90 mm2 area of human tympanic membrane, only 55 mm2 is functional and given the area of stapes footplate (3.2 mm2), the areal ratio is 17: 1 and total transformer ratio (17 X l.3) is 22.1

C-*Curved membrane effect.*

Movements of tympanic membrane are more at the periphery than at the centre where malleus handle is attached. This too provides some leverage

Phase differential between oval and round windows.

Sound waves striking the tympanic membrane do not reach the oval and round windows at the same time. There is a preferential pathway to the oval window because of the ossicular chain. Thus,

when oval window is receiving wave of compression, the round window is at the phase of rarefaction. If the sound waves were to strike both the windows at the same time, they would cancel each other's effect with no movement of the perilymph and no hearing.

This acoustic separation of windows is achieved by the presence of intact tyrnpanic membrane and a cushion of air in the middle ear

Transduction of *Mechanical Energy* to *Electrical Impulses*

Transduction is the conversion of mechanical energy to electrical energy. Movements of the stapes footplate are transmitted to the cochlear fluids, which move the basilar and tectorial membranes differentially and sets up shearing force that bends the stereocilia. Movement of stereocilia opens and closes ion channels and produces receptor potential in the IHCs. This cochlear microphonics triggers the nerve impulse by releasing neurotransmitters onto afferent nerve fibers

Neural Pathways

Hair cells get innervation from the bipolar cells of spiral gangl ion. Central axons of these cells collect to form cochlear nerve which goes to ventral and dorsal cochlear nuclei . From there, both crossed and uncrossed fibres travel the superior olivary nucleus, lateral lemniscus, inferior colliculus, medial geniculate body and finally reach the auditory cortex of the temporal lobe

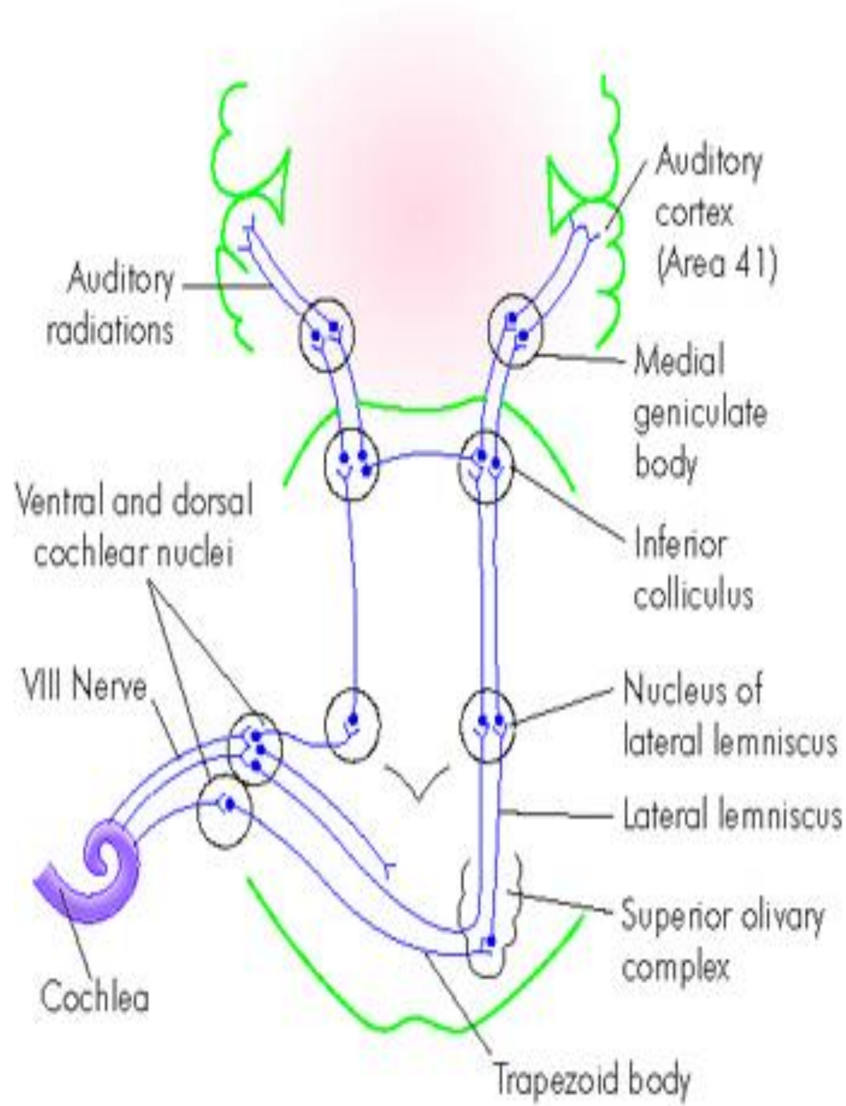


Fig. 2.2 Auditory pathways from the right cochlea. Note bilateral route through brainstem and bilateral cortical representation.