Lectures 6
The Sense of Hearing

Chapter 53

Audition

- Sound =waves of compression (increase in pressure) and decompression (decrease in pressure)
- No vacuum transmission
- Highest speed-solid

- **Loudness or intensity**
- depends upon amplitude of sound waves.
- units for expressing sound amplitude/ loudness/ intensity are decibels (dB)
- dB = 20 log P/P_0
- dB = Decibel
- P = Sound pressure being measured
- $P_{0=}$ Reference pressure measured
- A reference, 0 dB, is the average threshold for hearing at 1000 Hz.

question

- if a sound pressure is 10 times the reference pressure, calculate the intensity?

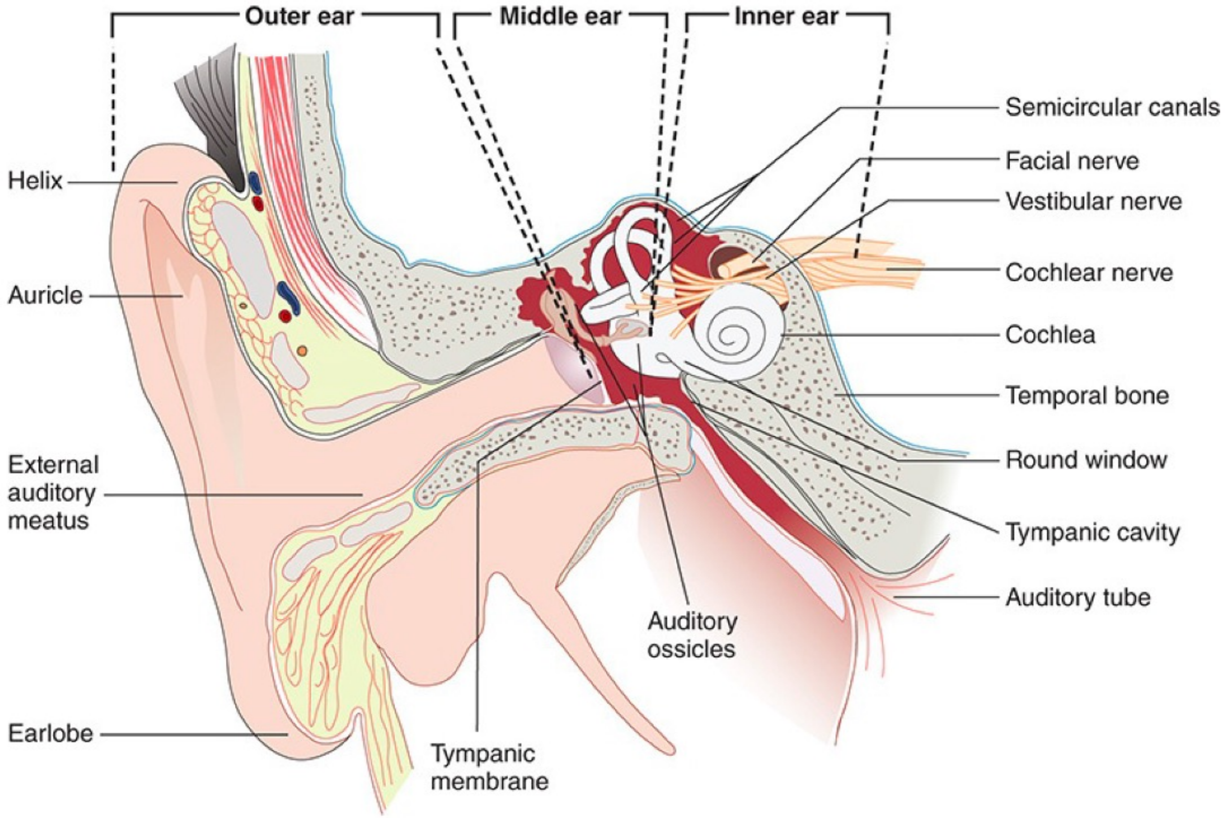
- dB = 20 log P/P0
- dB = 20 log 10
- dB = 20 × 1 =20

Audition

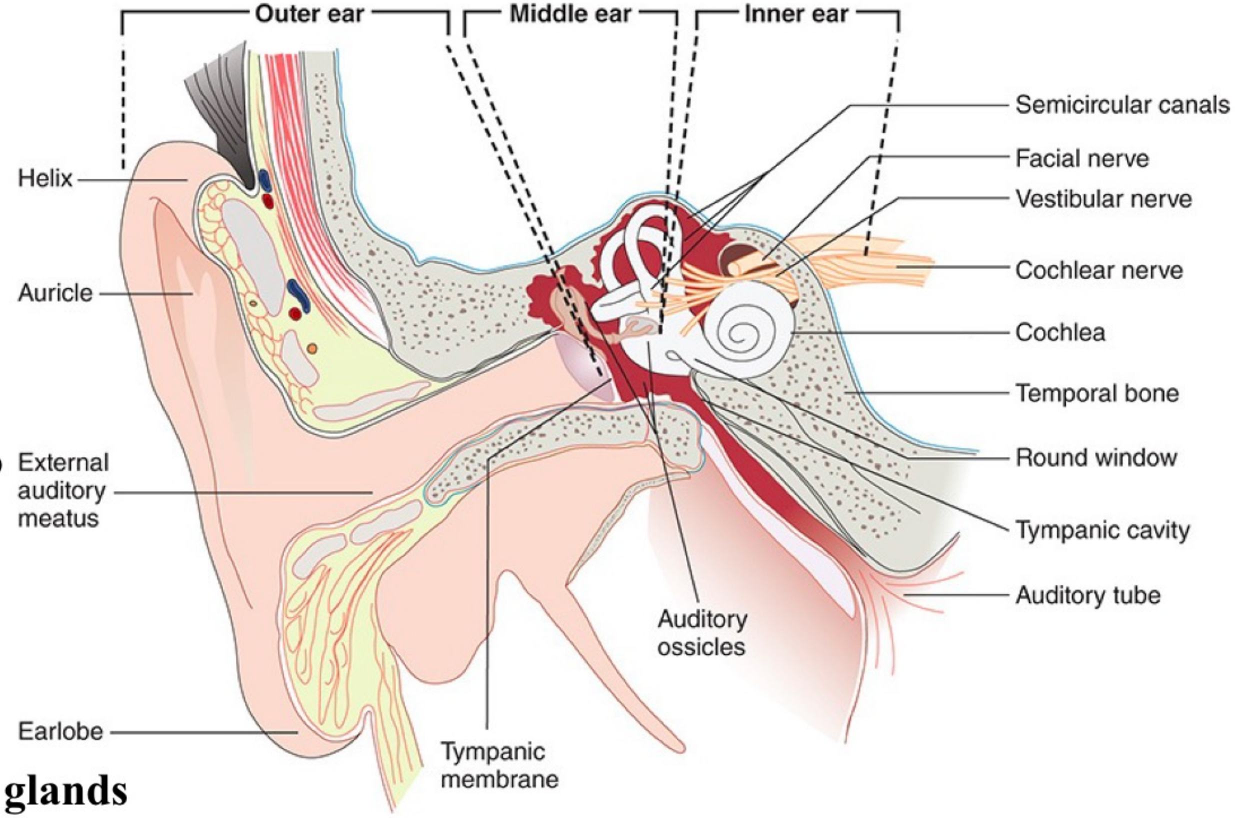
- **Sound frequency** (pitch/tone) is measured in cycles/second or hertz (Hz).
- Human ear is sensitive frequencies between 20 and 20,000 Hz and is most sensitive between 2000 and 5000 Hz.
- The usual range of frequencies in human speech is between 300 and 3500 Hz- sound intensity is about 65 dB.
- Sound intensities > 100 dB can damage the auditory apparatus
- >120 dB can cause pain.

Structure of Ear

external, middle, and inner ear



External Ear



capture& direct sound waves towards external acoustic meatus

conducts sound waves to tympanic membrane

sebaceous glands and ceruminous glands

secrete brown pigment granules and fat droplets.

Secretions of ceruminous & sebaceous glands and desquamated epithelial cells form the **earwax.**

Middle Ear-Tympanic Membrane & Ossicular System

- **tympanic membrane:**

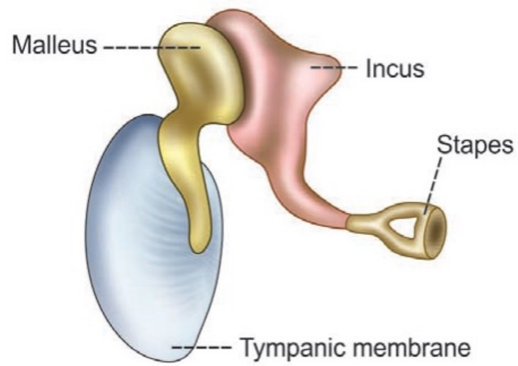
✓transmit vibrations in the air to the cochlea through ossicles

✓kept tensed by **tensor tympani muscle**

- tympanic membrane connected to the ossicles
  - malleus
  - incus
  - Stapes

  ossicles are combined as a single **lever** by ligaments

  articulation of incus with stapes pushes cochlear fluid forward and backward on TM movement



Components of the auditory system

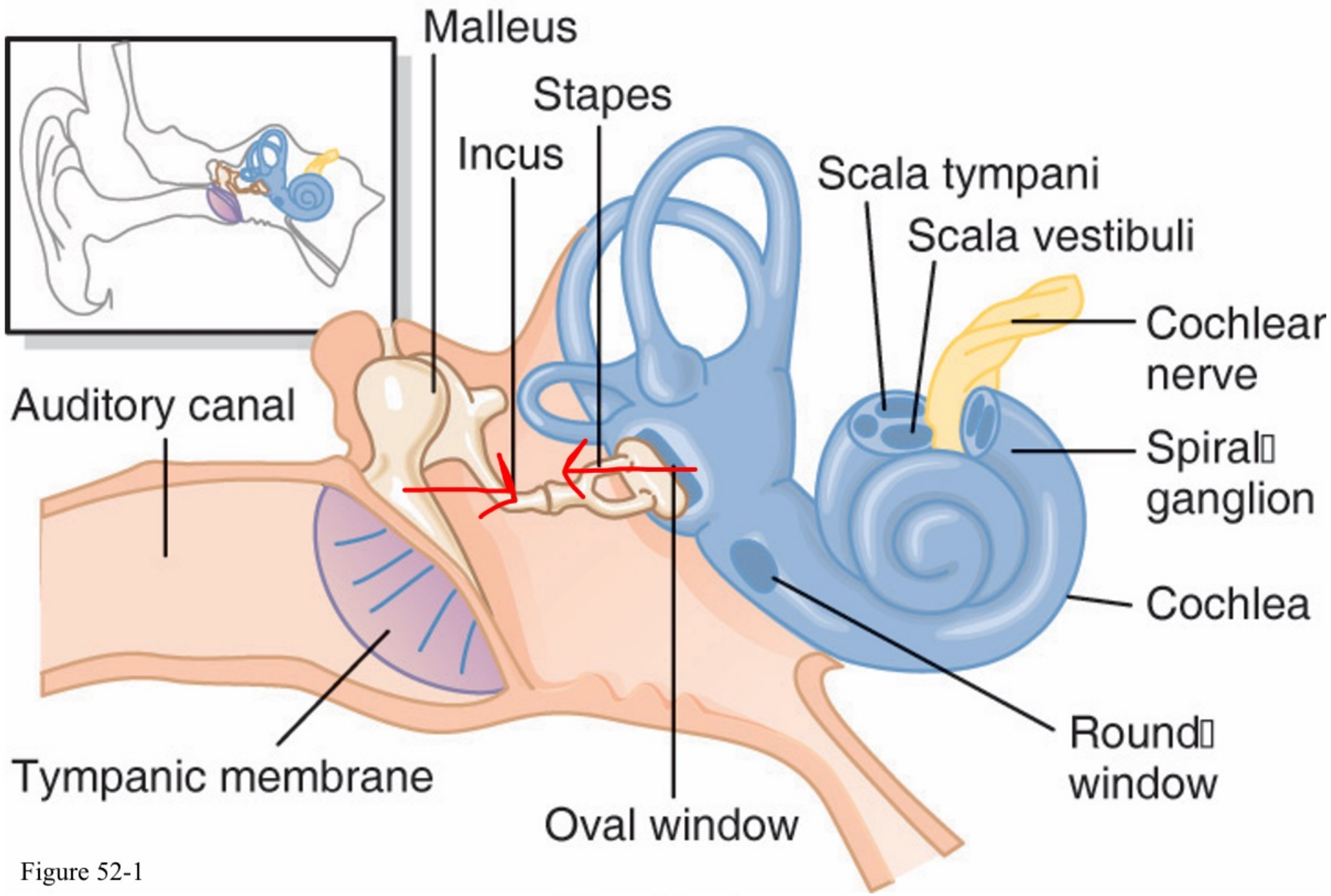
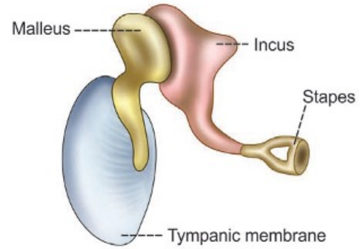


Figure 52-1

Attenuation of Sound by Muscle Contraction



- a loud noise initiates **tympanic reflex** (after 40 - 80 ms)→ contraction of:
  - tensor tympani-mandibular nerve →pulls the handle of the malleus **inward**)
  - Stapedius-facial nerve→ pulls the stapes **outward**)

attenuates vibration going to cochlea.

- serves to protect cochlea and damps low frequency sounds i.e., your own voice.

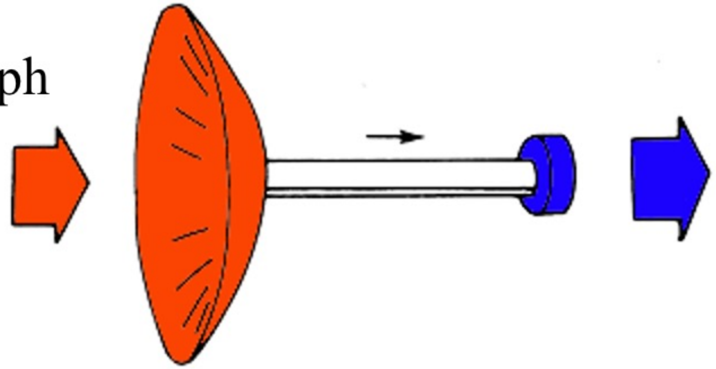
Impedance Matching

- Impedance= opposition to passage of sound waves- perilymph in cochlea offers impedance to sound waves due to its own inertia.

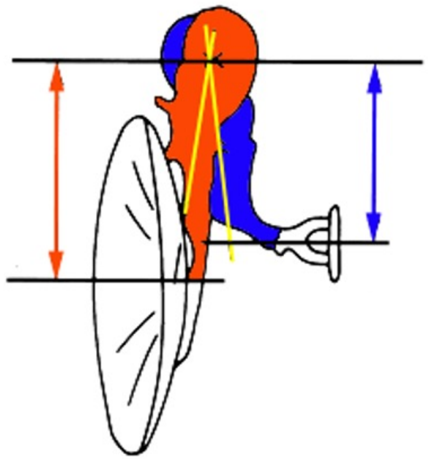
- Impedance matching is the process by which TM and the auditory ossicles are capable of converting sound energy into mechanical vibrations in cochlear fluid with minimum loss of energy/intensity

- **<u>How?</u>**
- Surface area of TM (55 sq mm)>footplate of stapes (3.2 sq mm)→amplifies the signal because the area of the tympanic membrane is 17 times larger than the oval window.

- ossicles act like a lever system → amplifies the signal 1.5X→vibrations



Surface area



lever

Middle Ear-Tympanic Membrane & Ossicular System

- Eustachian tube middle ear with nose to nasopharynx
- Equalize pressure on both sides of tympanic membrane
- Usually closed
- Opens with jaw movement & ascend
- Descends
- Cilia-drainage
- Shorter, wider &more strait in children → OM

Inner ear - Cochlea

- three coiled tubes separated by membranes into:
  - ✓ *scala tympani-perilymph*
  - ✓ *scala media-endolymph*
  - ✓ *scala vestibuli-perilymph*

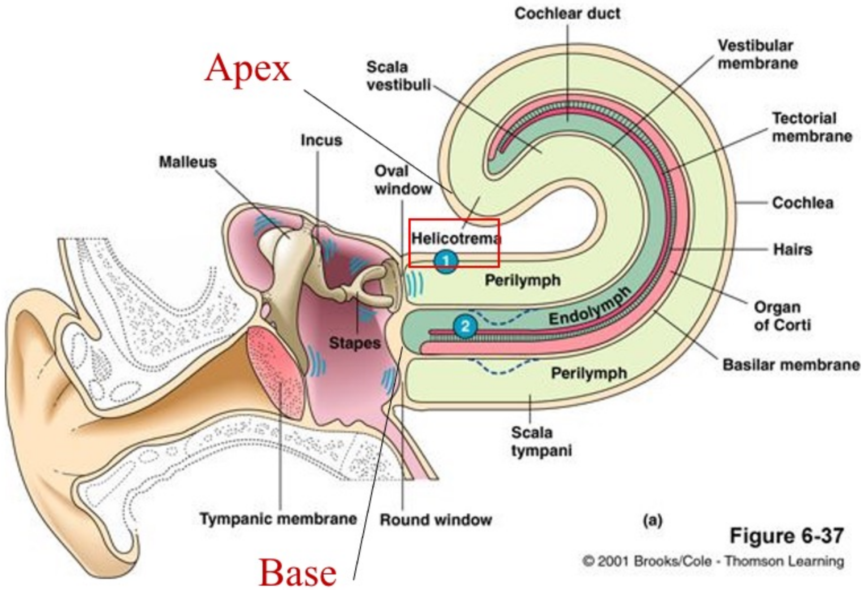
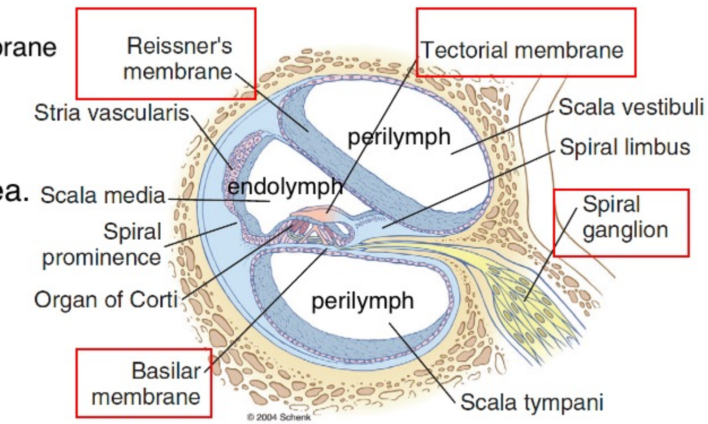


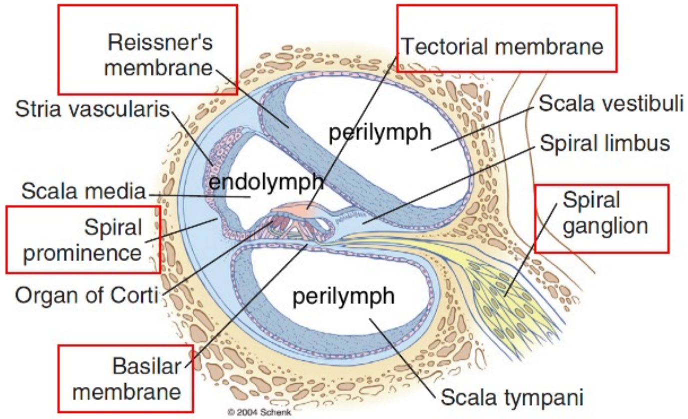
Figure 6-37

Vestibular Membrane

cochlear duct, membranous cochlea or otic cochlea.



Basilar Membrane

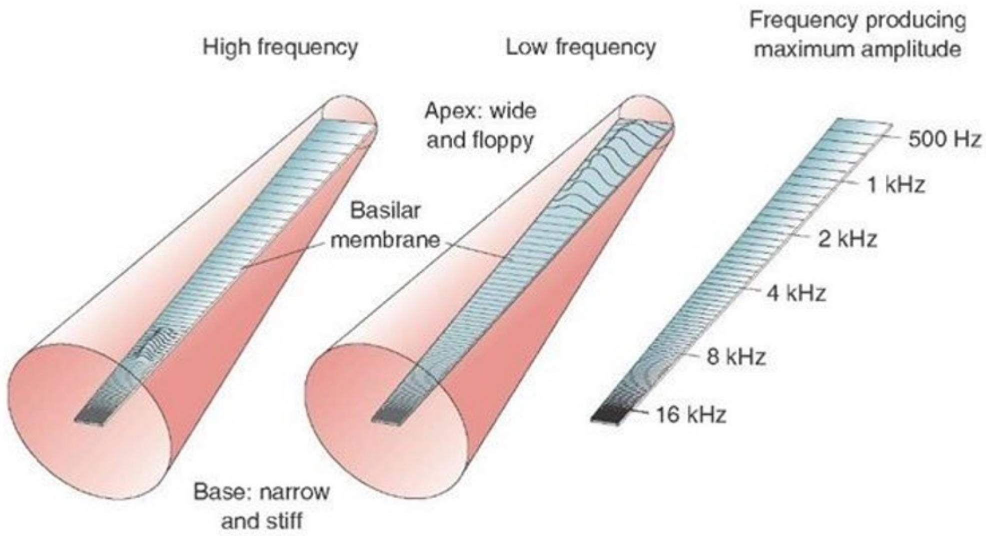


- contains about 20,000-30,000 basilar fibers

Characteristics of basilar fibers

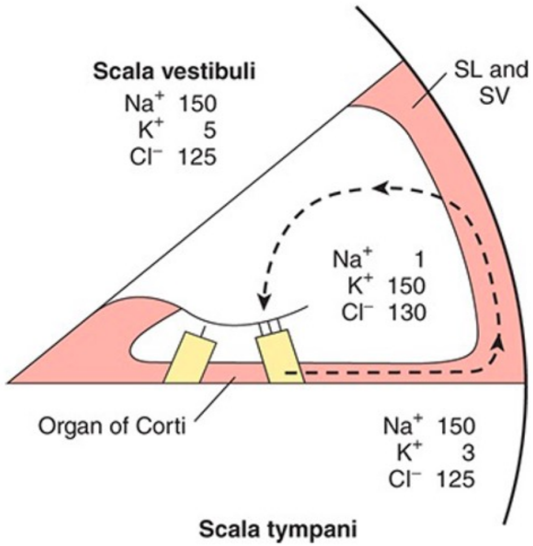
- different size and shape
- fixed to modiolus and free at one end → they can vibrate

- Elastic
  - near base→ short, thick & stiff→ high freq. sounds
  - near apex→ long, thin & soft→ low freq. sounds



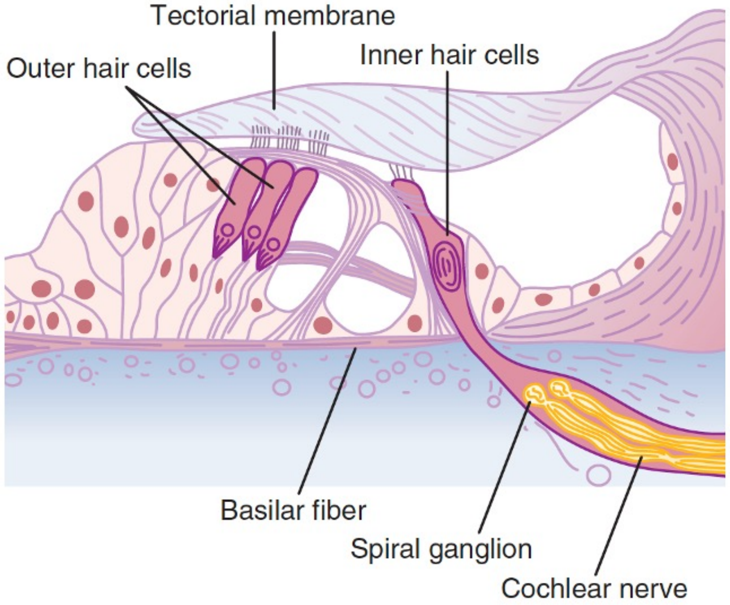
Perilymph & Endolymph

- perilymph → scala vestibuli & scala tympani (high Na low K)
- Endolymph→ scala media similar to CSF (high K low Na)→ generated by continual secretion of K into the scala media by stria vascularis



Organ of Corti

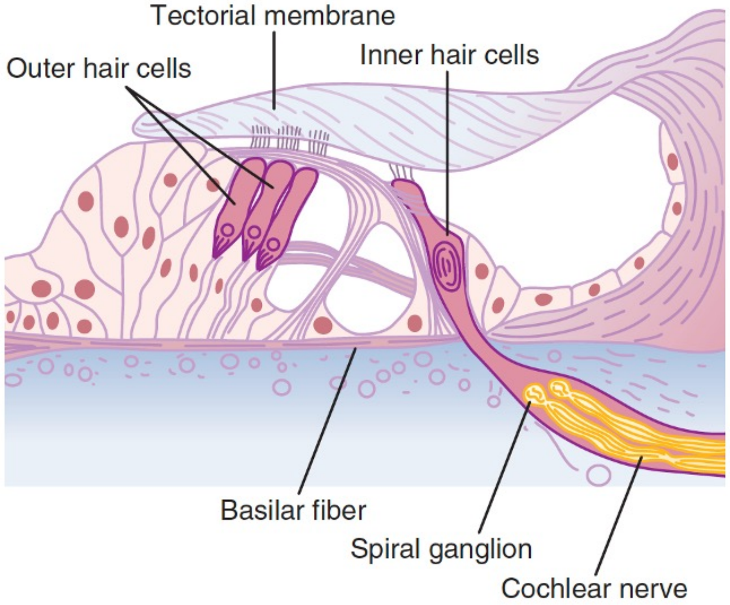
- **receptor organ**
- on the surface of the basilar membrane
- contains rows of electromechanically sensitive cells with stereocilia called **hair cells**.
- 2 types of hair cells: outer - 3 rows(12K) & inner-single row (3K).
- hair cells synapse with **cochlear nerve endings**.
- 90 -95% of cochlear nerve endings on **inner** hair cells-receptors
- Outer: larger diameter-efferent-increases the amplitude and sharpness of sound



Organ of Corti

- Gelatinous tectorial membrane lies above the stereocilia of the hair cells.

- movement of the basilar membrane causes the stereocilia of the hair cells to shear back and forth against the **tectorial membrane**→generate nerve impulses



The end

Lectures 7
The Sense of Hearing

Chapter 53

Mechanism of hearing

- Transmission of sound
- Stimulation of receptors
- Central neurophysiology of hearing

Transmission of sound

Types of sound conduction

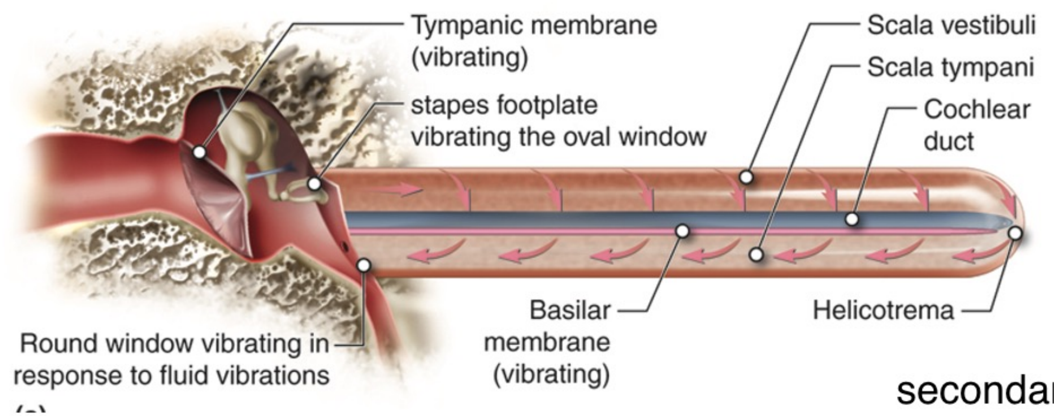
1. **<u>Ossicular conduction</u>**
- ✓ conduction of sound waves through middle ear by auditory ossicles

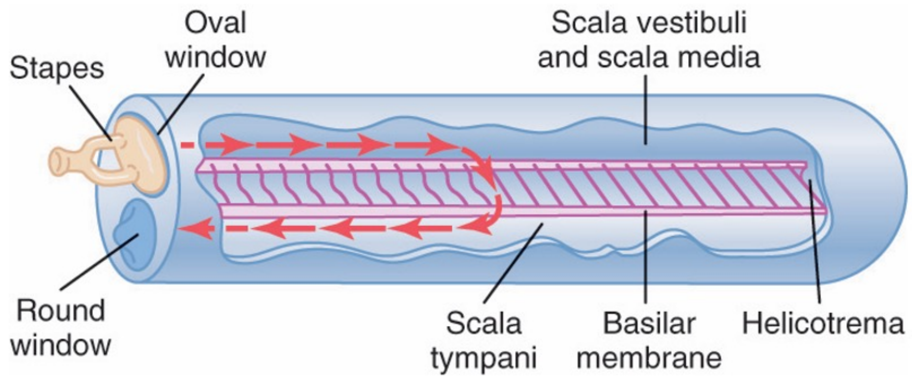
<u>2. Air conduction</u>
- ✓ ossicular system and TM absence (otosclerosis/OM) →sound waves travel **through air**
- ✓ sensitivity for hearing is 15-20 db < ossicular transmission→ equivalent to decrease from medium to a barely perceptible voice level.

<u>3. Bone conduction.</u>
- ✓ sound waves are transmitted vibrations of skull →fluid vibrations in cochlea.
- ✓ tuning fork on mastoid process → sound is heard

Transmission of sound waves in the cochlea -“traveling wave”

TM→ossicles →oval window/fenestra vestibuli → scala vestibuli→ fluid wave toward helicotrema→ scala tympani→ basilar membrane bending → round window



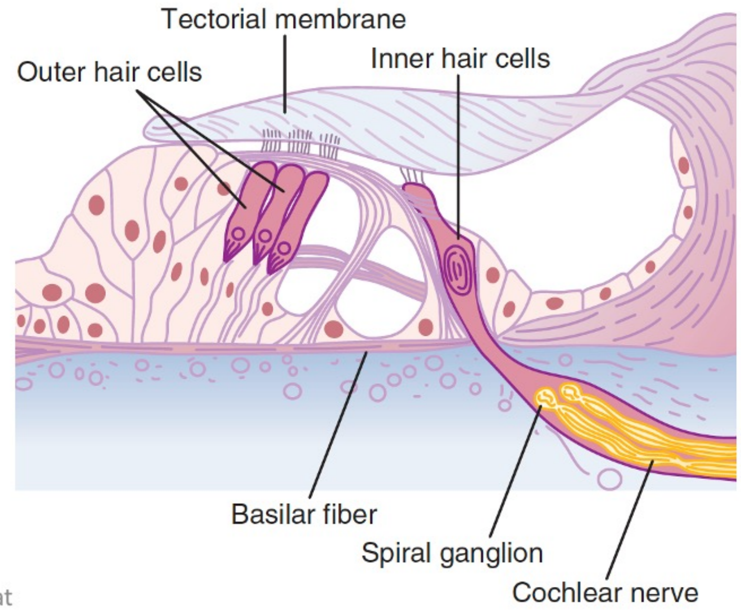


secondary tympanic membrane

Auditory receptors stimulation

Nerve Impulse Origination

- auditory signals are transmitted by the **inner hair cells**.
- basilar membrane bending →bending of stereocilia of hair cells→ depolarization/ hyperpolarizaton.



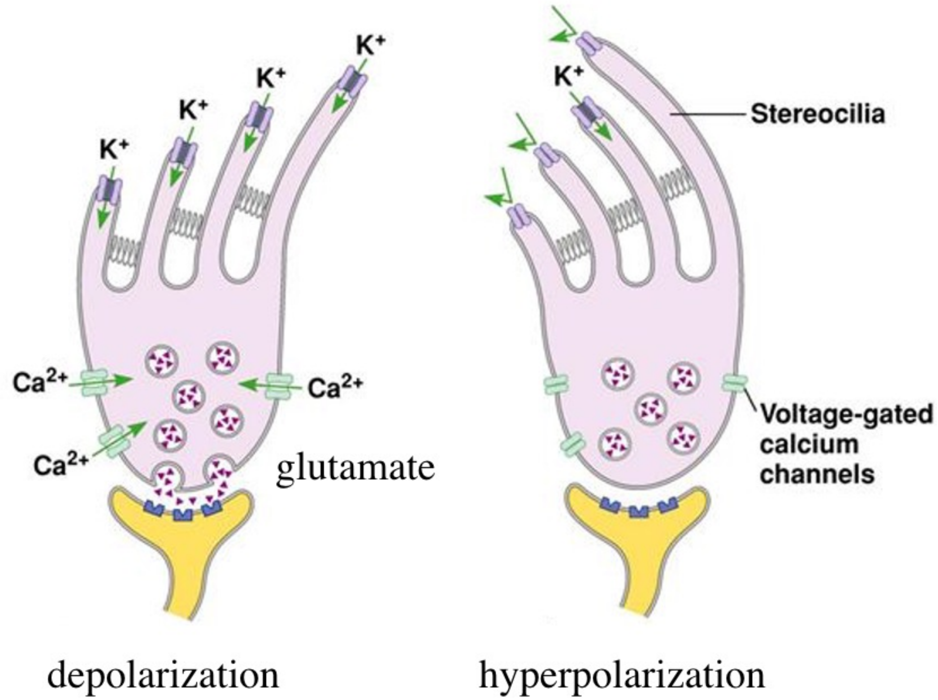
Hair Cell Receptor Potentials

- stereocilia become progressively longer on the side of the hair, and the tops of the shorter stereocilia are attached by thin filaments

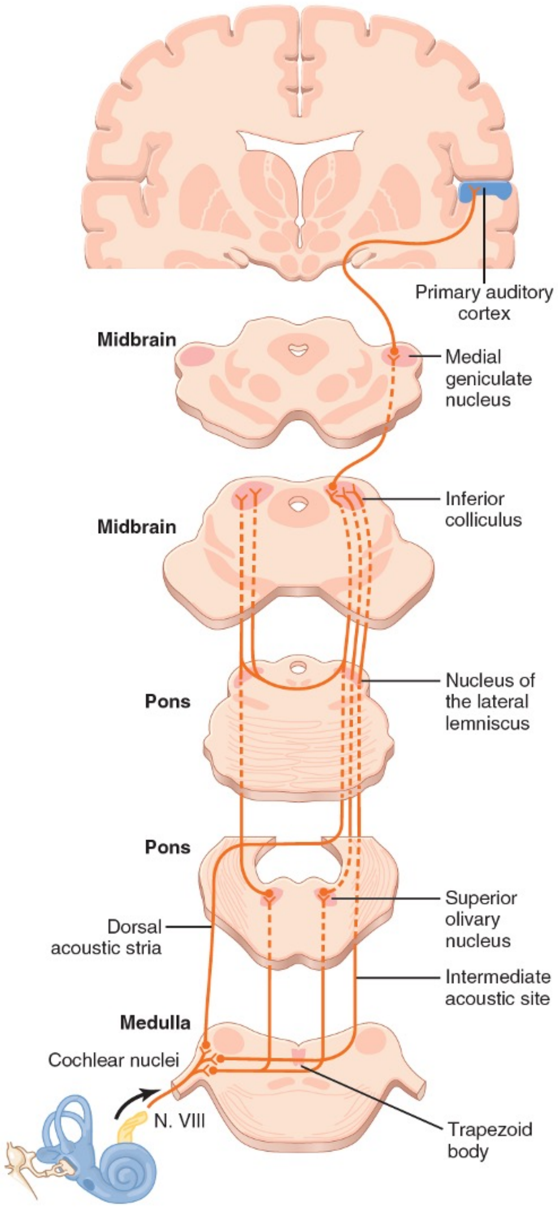
- When a stereocilium is pushed toward a taller stereocilium (away from limbus), cation channels opens → K efflux→ depolarization→ Ca entry→ NT release

- When a stereocilium is pushed away from a taller stereocilium→ cation channels close→ hyperpolarization

- Alternating hair cell receptor potential stimulates cochlear nerve endings



Central neurophysiology of hearing



Auditory Pathway

- Signals from both ears are transmitted through the pathways of **both** sides of brain, with **majority** of transmission in **contralateral** pathway.

- crossing over :

1-in the trapezoid body

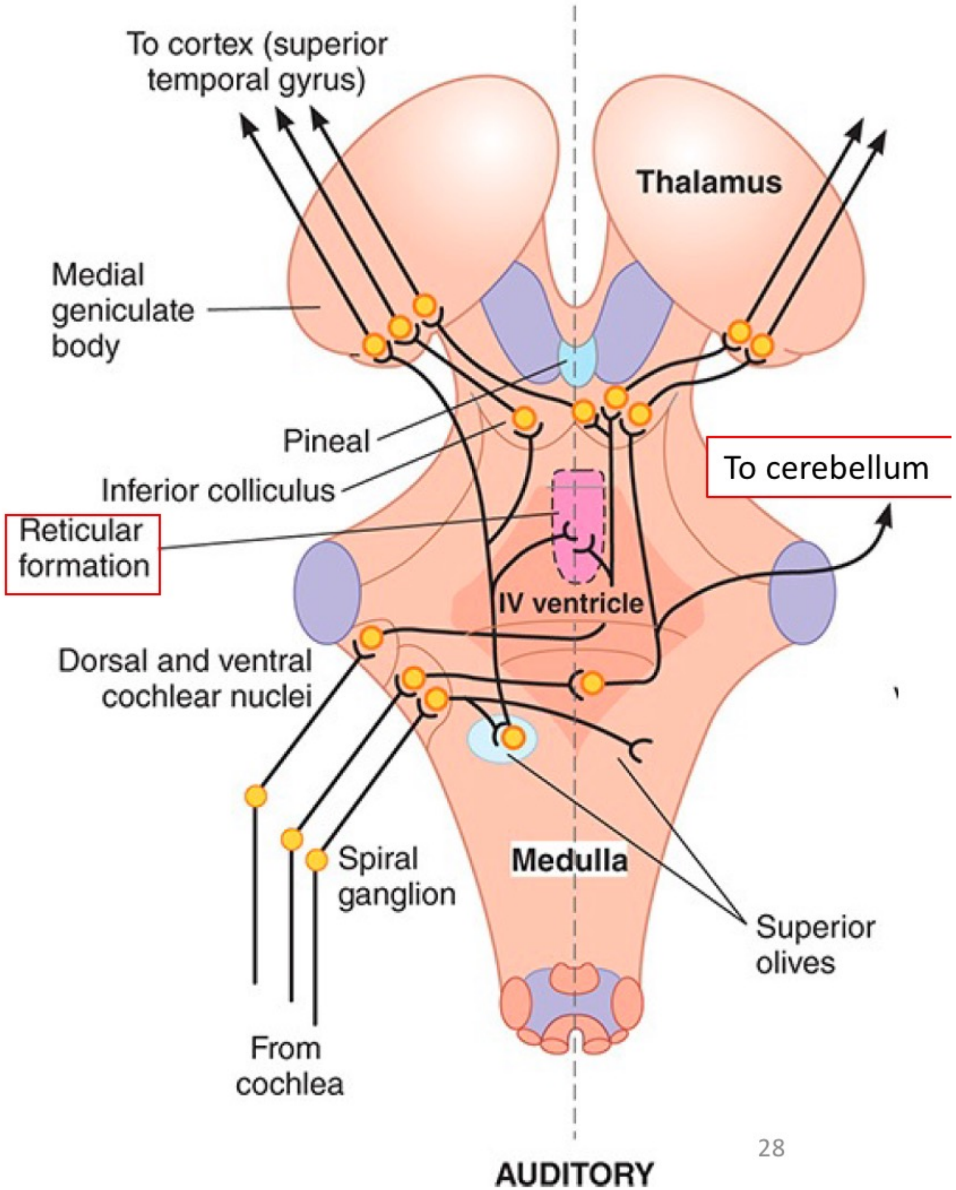
2-commissure between two nuclei of lateral lemnisci

3-commissure connecting two inferior colliculi

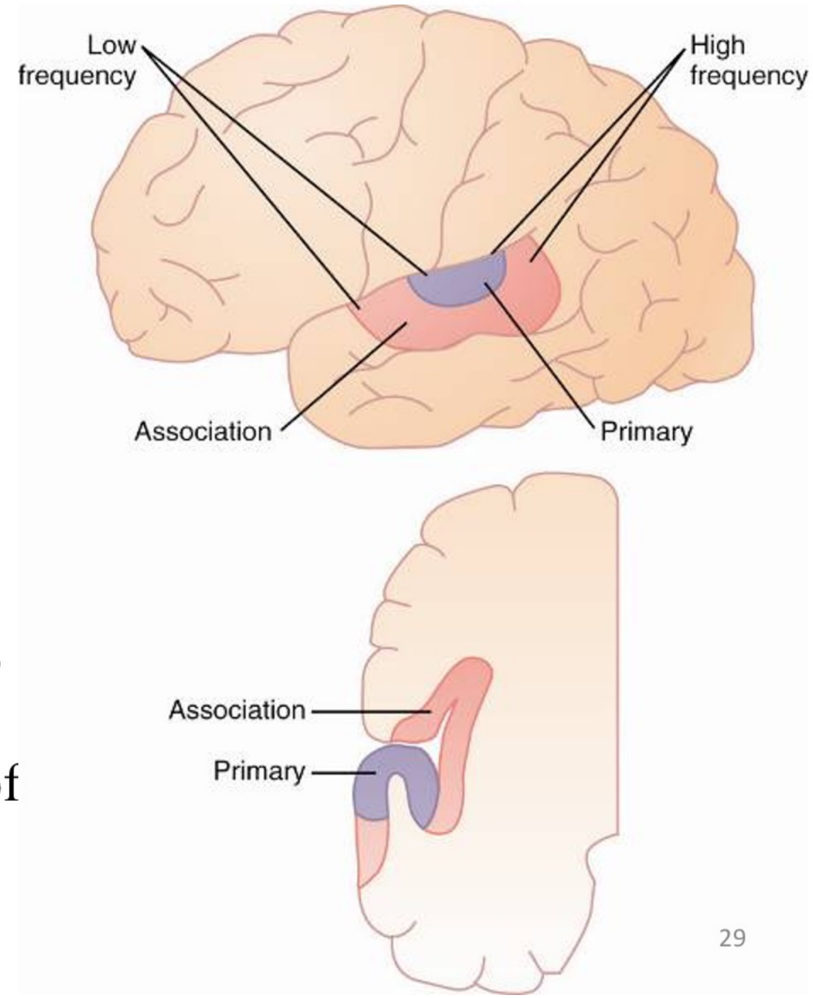
Central Auditory Pathway

collateral into
1- reticular activating system→ activates the entire nervous system in response to loud sounds.

2-vermis of cerebellum → activated in sudden noise.



Auditory Cortex and Association Areas



primary auditory cortex

- area 41, area 42 and Wernicke area
- excited by → medial geniculate body

Secondary auditory area

- auditopsychic area/area 22
- excited by→ primary auditory cortex & thalamic association areas

- Areas 41 and 42→ Perception of auditory impulses only
- Wernicke & area 22→ analysis and interpretation of sound.

Applied physiology – effect of lesion

- Degeneration of hair cells leads to presbycusis (gradual loss of hearing). common in old age.
- Unilateral lesion of **auditory pathway**, above level of cochlear nuclei causes **diminished hearing**
- Lesion in superior olivary nucleus results in poor localization of sound.

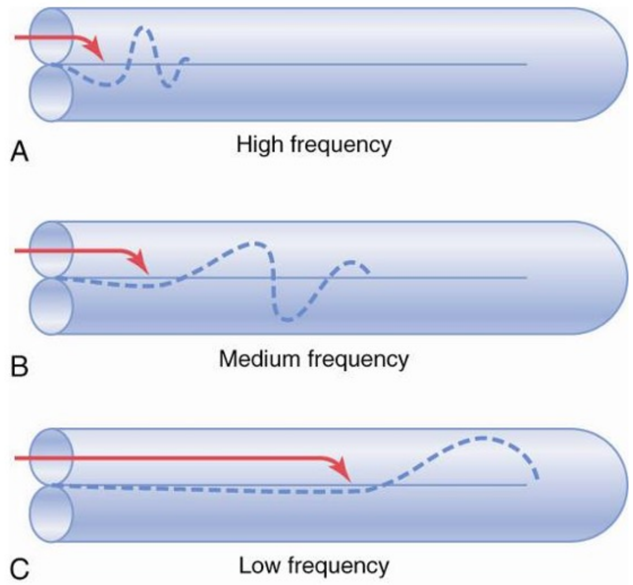
Frequency discrimination

Resonance Point

- traveling wave → traveling through basilar membrane→ the wave becomes stronger→ and at one point (resonance point)→ it becomes **very strong** → **vibration of basilar membrane** →The traveling wave stops immediately and does not travel further

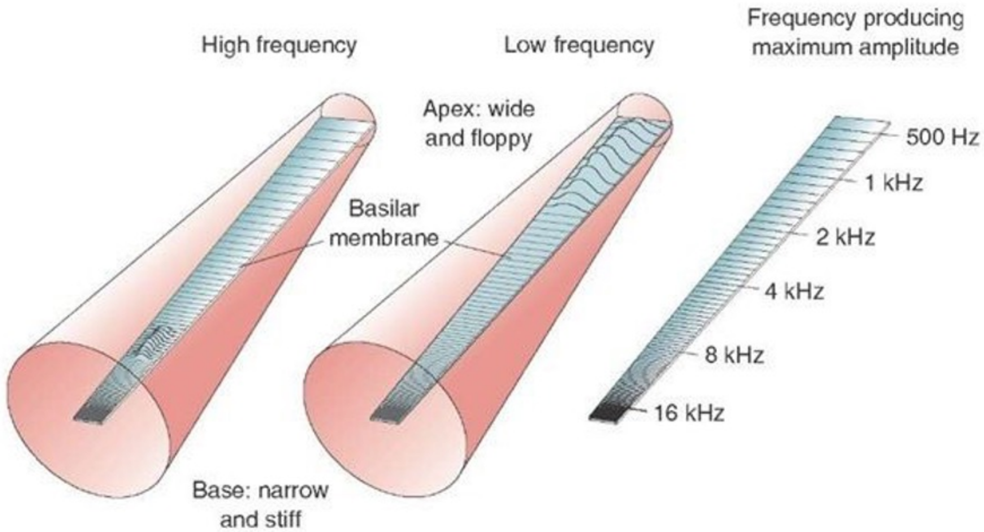
- **high-frequency** sound wave travels a **short distance** before it reaches its resonant point and dies

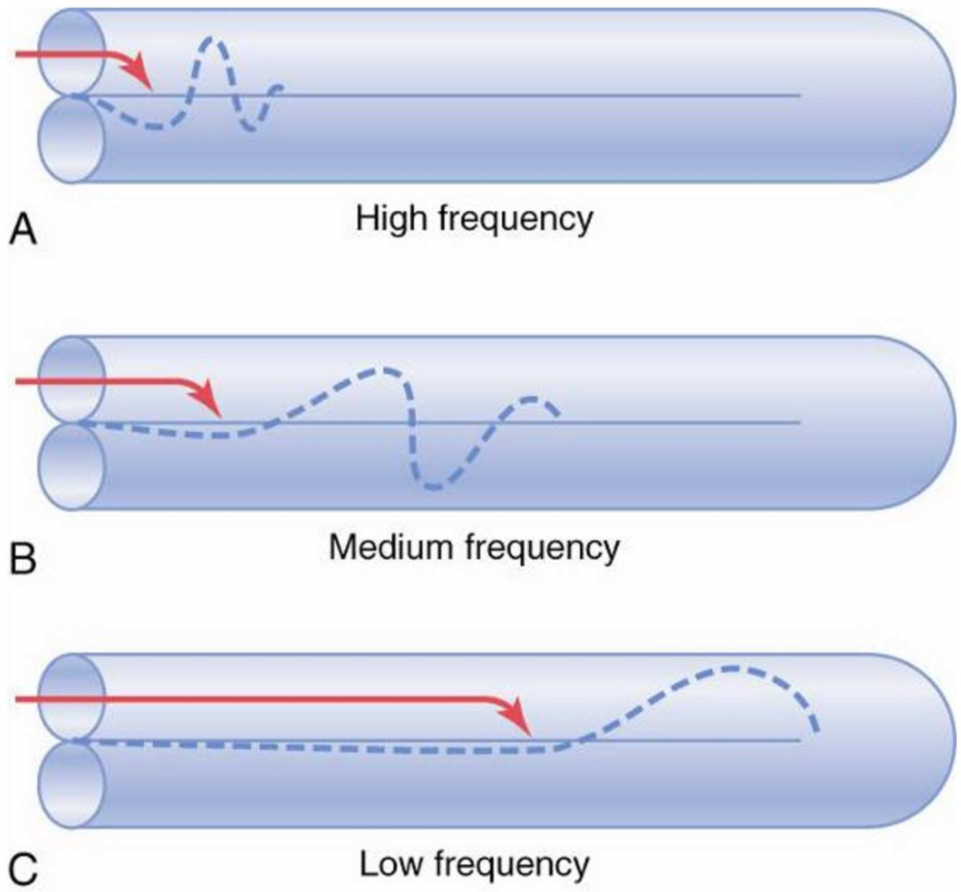
- **medium-frequency** sound wave travels about halfway and then dies
- **very low frequency** sound wave travels the entire distance along the membrane.



The "Place Principle"

sound frequencies are discriminated from one another is based on the "**place" of maximum stimulation** of the nerve fibers from the organ of Corti lying on the basilar membrane





Determination of Amplitude/loudness

- Number of stimulated hair cells on the resonating points (more nerve fibers)
- Frequency of AP generated by receptors stimulation

Determination of Amplitude/loudness

- outer hair cells may control the sensitivity of the inner hair cells for different sound pitches (tuning).

- there are nerve fibers running from **brain stem** to the vicinity of the **outer hair** cells, may function to adjust sensitivity by acting on these cells
- Inhibitory signals from superior olivary nucleus to hair cells→reducing their sound sensitivities →attention to sounds of particular qualities

- Damage to outer hair cells: hearing loss.

Determining the Direction of Sound

- superior olivary nucleus divided into lateral and medial nuclei.
- **lateral nuclei** →detects direction by the difference in sound **intensities** between the 2 ears.
- **medial nuclei** →detects direction by the **time lag** between acoustic signals entering the ears.

Deafness

- nerve deafness
  - impairment of the cochlea or the auditory nerve
- conduction deafness
  - impairment of tympanic membrane or ossicles

The end