

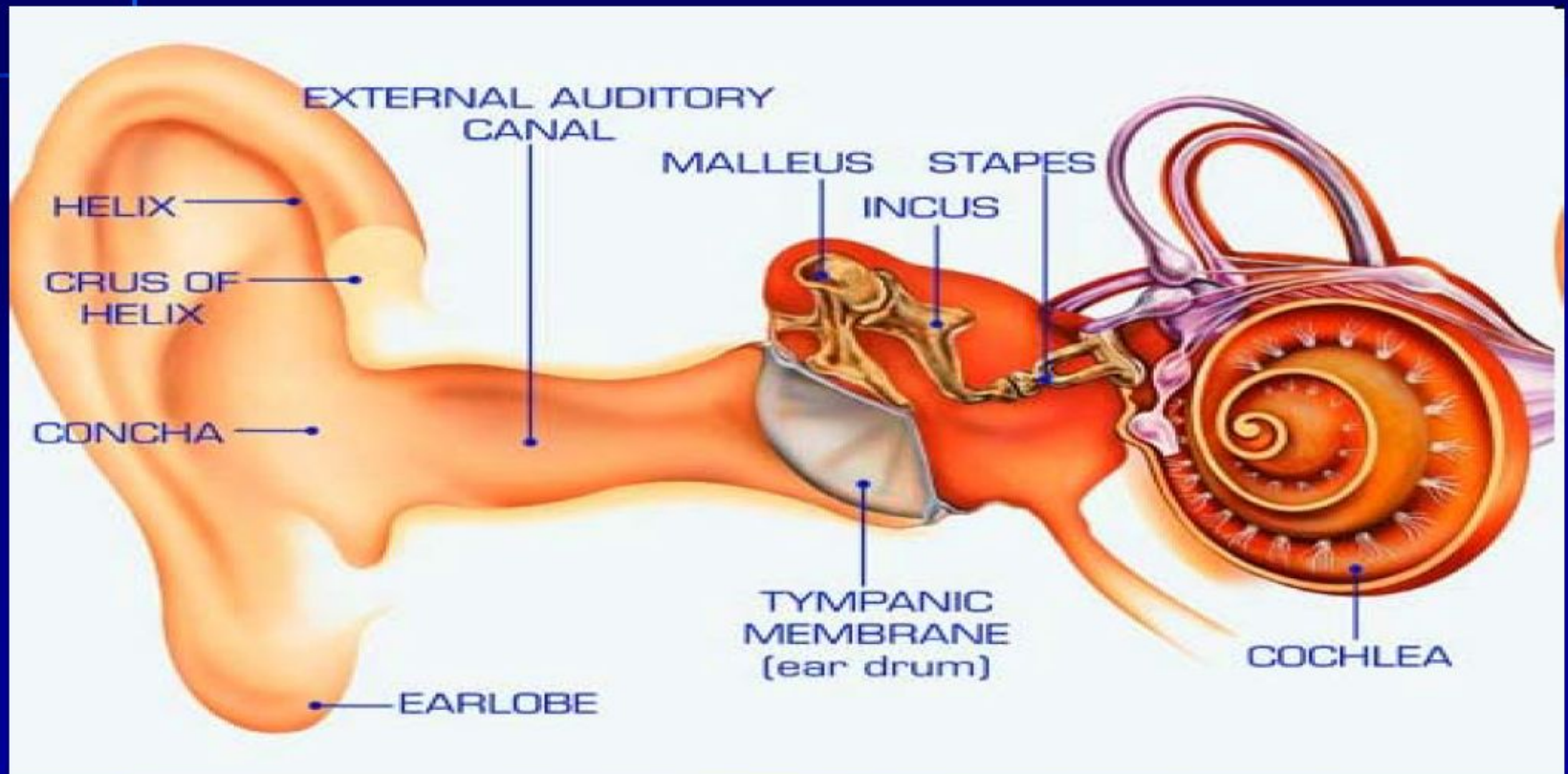
Functional Anatomy of Ear & Functions of Middle Ear

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Functional Anatomy of Ear

- Divided into three main parts
 - External ear
 - Middle ear
 - Internal ear

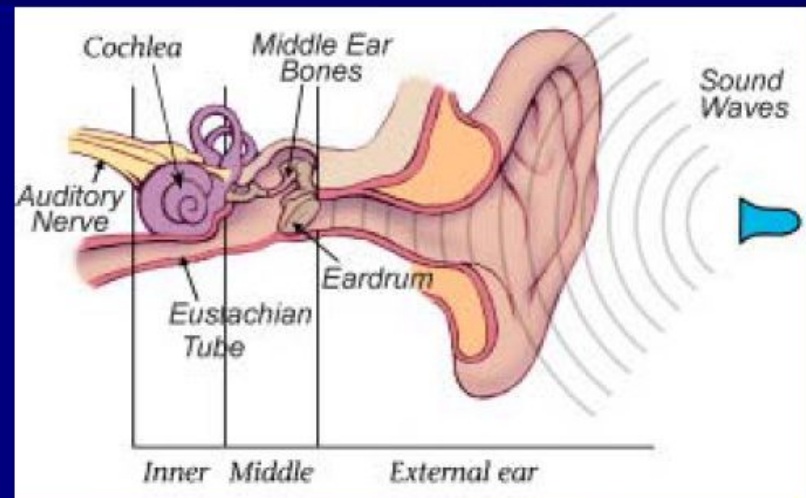
Sound conduction in the ear:



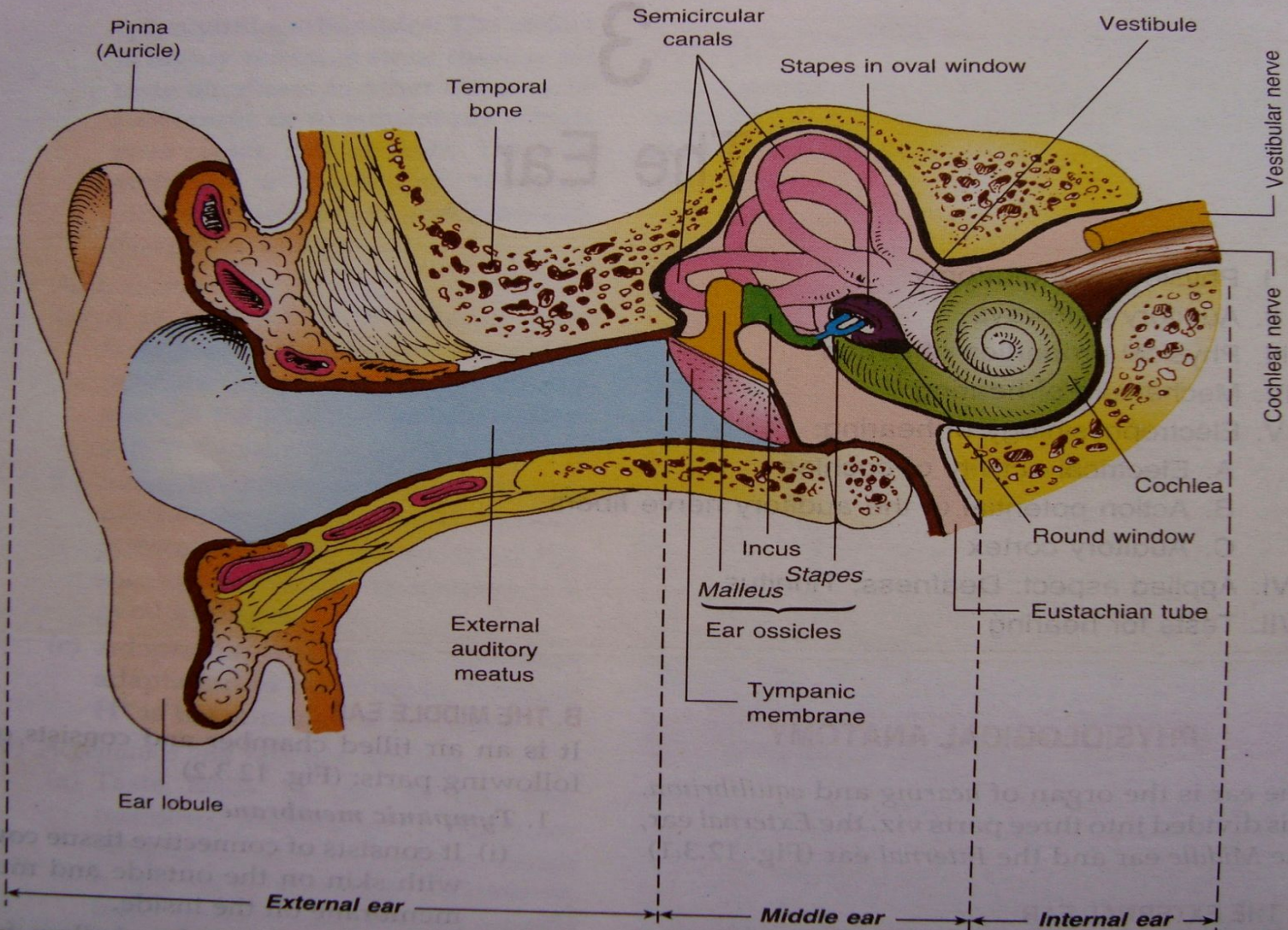
Structure of the human ear

External ear functions:

- **Collecting** sound waves
- **Amplification** of frequencies 2000 - 4000 Hz (resonant frequency of EAC)
- Providing cues about the vertical **localization** of a sound source (by the degree of sound waves reflection over the pinna)



Structure of three subdivision of the Ear



Functional Anatomy of Middle Ear

- Middle ear
 - **Tympanic membrane**
 - Consists of connective tissue
 - Acts as a pressure receiver
 - Acts as a resonator
 - Critically dampens sound waves

The Tympanic Membrane and the Ossicular System

- Tympanic membrane functions to transmit vibrations in the air to the *cochlea*
- Amplifies the signal because the area of the tympanic membrane is 17 times larger than the oval window
- Tympanic membrane connected to the ossicles
 - malleus
 - incus
 - stapes

Functional Anatomy of Middle Ear

- **Ear ossicles:**

- Malleus, Incus and Stapes
- Magnify the intensity of sound by 1.2 to 1.3 times
- Opposite wall contains **oval window** above and **round window** below

- Middle ear
 - Eustachian tube
 - 4-5 cm long
 - Connects middle ear cavity with pharynx
 - Equalize the pressure on two sides of tympanic membrane

Contd.....

- Skeletal Muscles
 - **Tensor tympani**
 - attached to neck of malleus.
 - Contraction increases tension of tympanic membrane
 - **Stapedius**
 - Attached to neck of stapes
 - Contraction pulls foot plate of stapes out from oval window
- Both muscles are reflexly activated and decreases amplitude of vibration of tympanic membrane
(**Tympanic or acoustic reflex**)

Functional Anatomy of Internal Ear

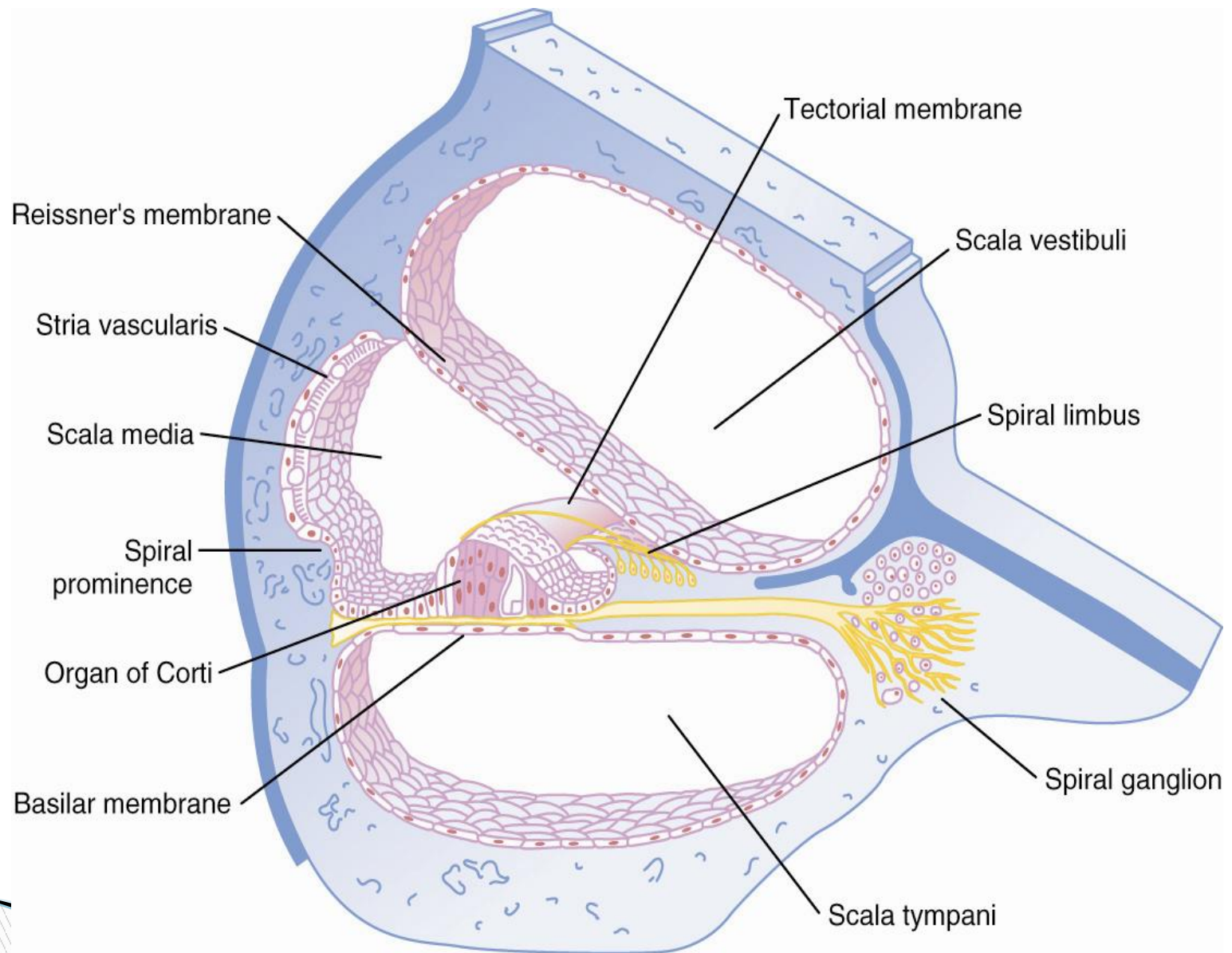
- **Internal ear**

- Bony labyrinth
 - One vestibule
 - Three semicircular canals
 - One cochlea
- Membranous labyrinth lodged within bony labyrinth.
 - filled with endolymph & surrounded by perilymph.

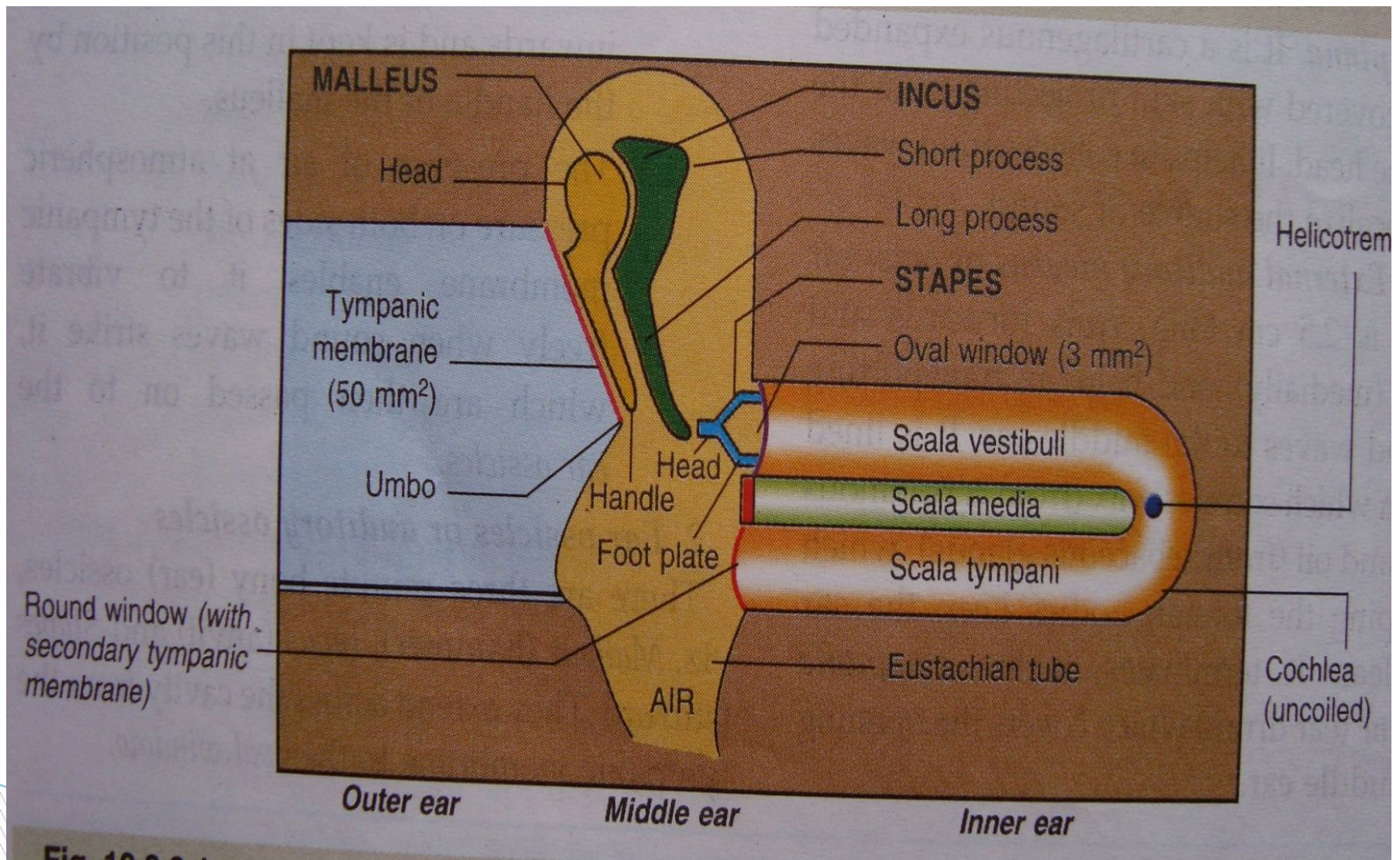
Functional Anatomy of Internal Ear

- **Cochlea**

- Coiled tube, 35 mm long
- Three compartments
 - Scala vestibuli
 - Scala media
 - Scala tympani
- Receptor of hearing – **The Organ of Corti**



Middle and Internal Ear



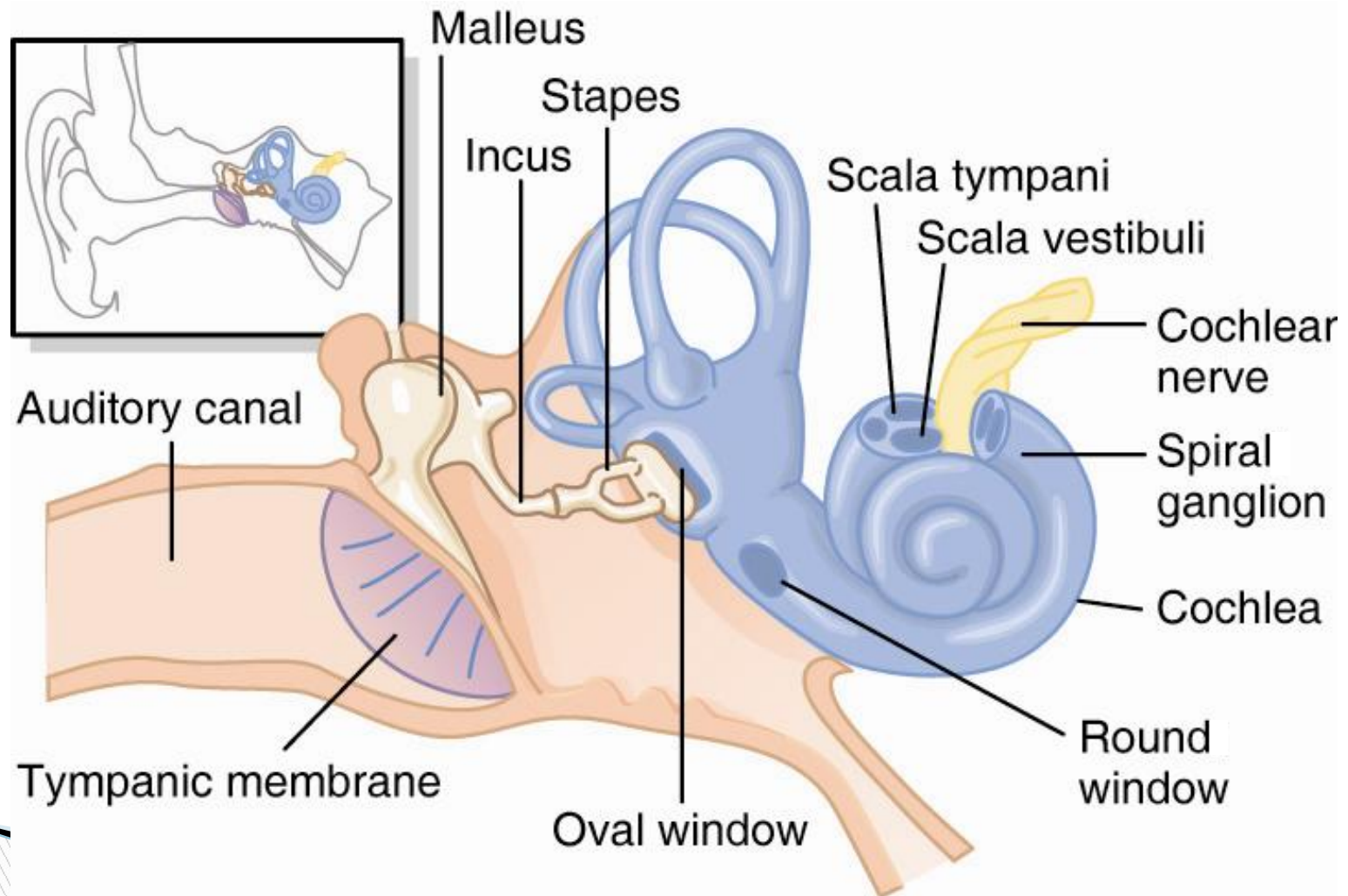
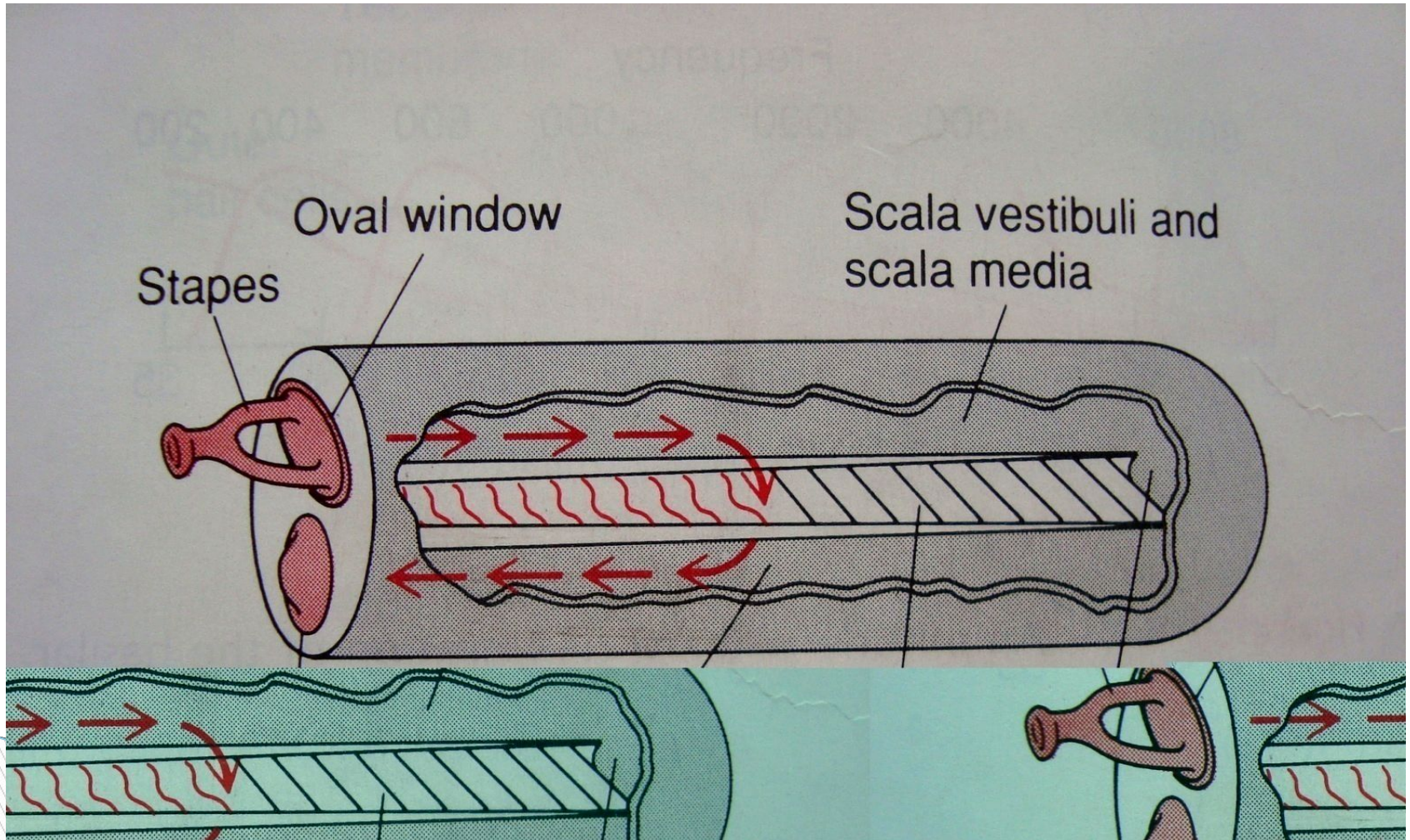


Figure 52-1; Guyton & Hall

Cochlea

- sound waves cause back and forth movement of the tympanic membrane which moves the stapes back and forth
- this causes displacement of fluid in the cochlea and induces vibration in the *basilar membrane*

Perilymphatic system; three compartments of cochlea:



Basement Membrane

- Separates scala media and scala tympani
- contains about 30,000 fibers which project from the bony center of the cochlea, the modiolus.
- fibers are stiff reed-like structures fixed to the modiolus and embedded in the loose basilar membrane
- because they are stiff and free at one end they can vibrate like a musical reed.

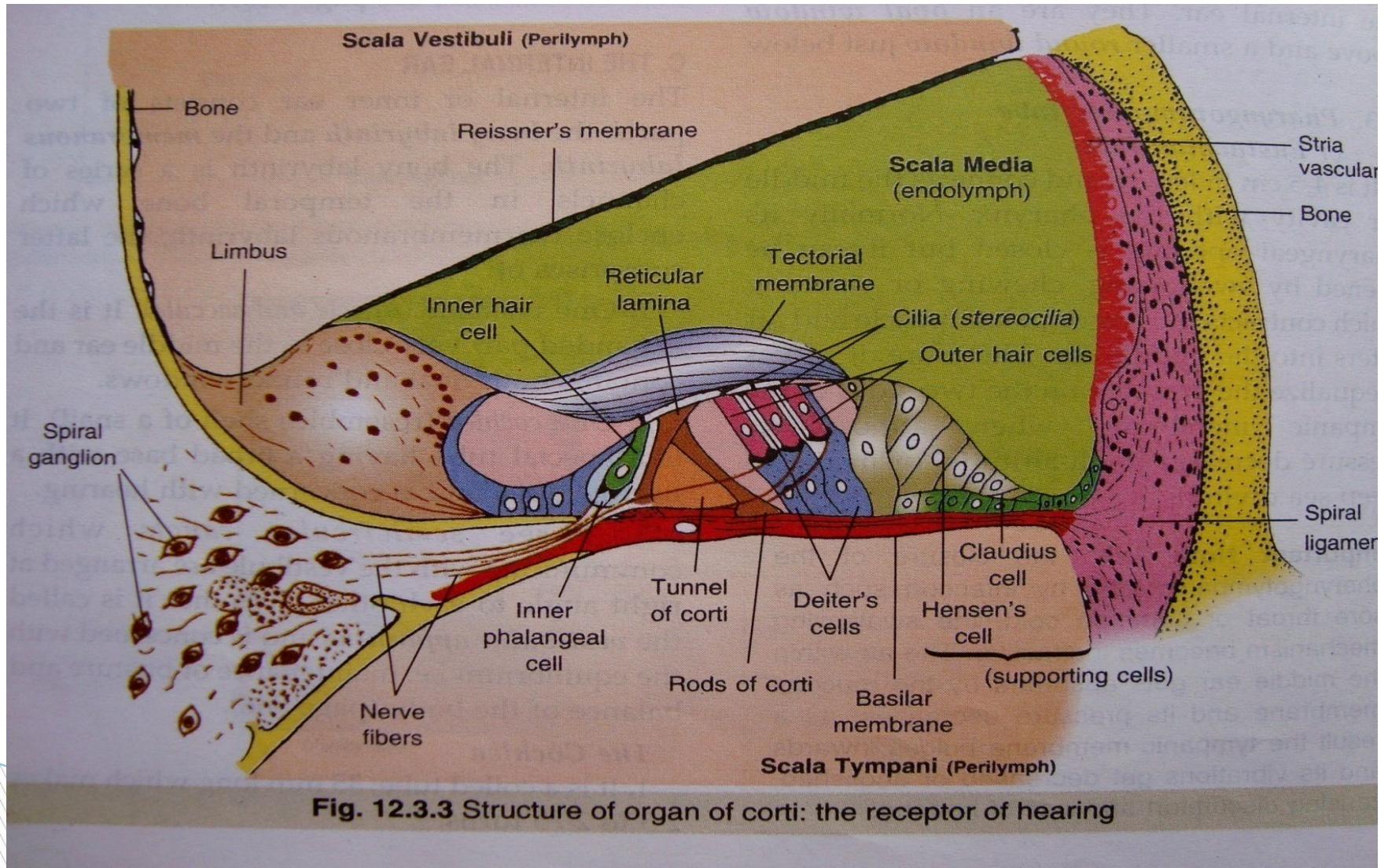
Organ of Corti

- receptor organ that generates nerve impulses in response to vibration of the Basilar membrane.
- lies on the surface of the basilar membrane, contains rows of cells with stereocilia called **hair cells-receptors of the Organ of Corti**.
- the **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.

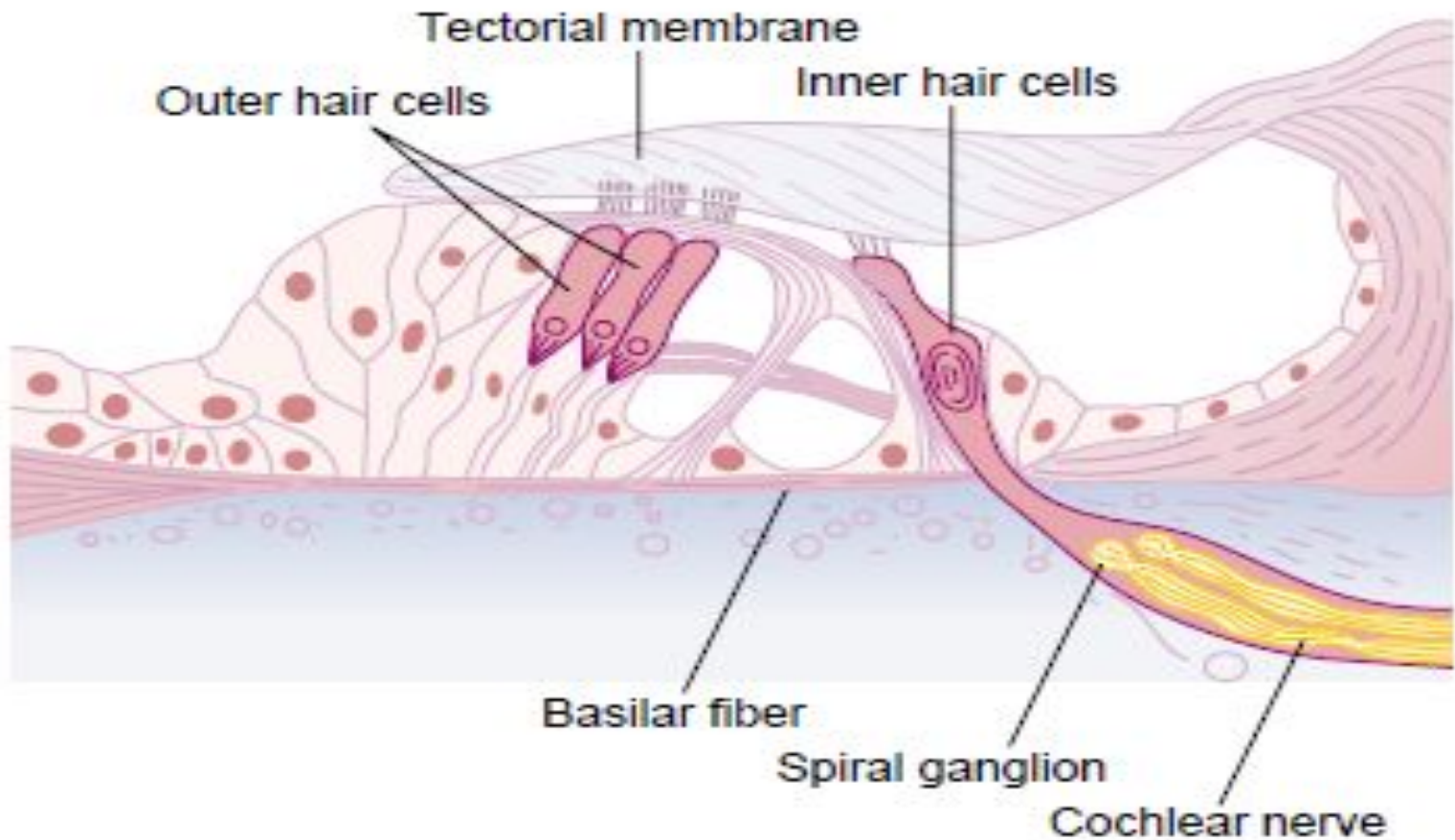
Contd..

- Hair cells base & sides-
- synapse with nerve endings of cochlea
- -spiral ganglion of Corti which lies in the modiolus of the cochlea-
- sends axon to the cochlear nerve

Organ of Corti



ORGAN OF CORTI



Structure of Organ of Corti:

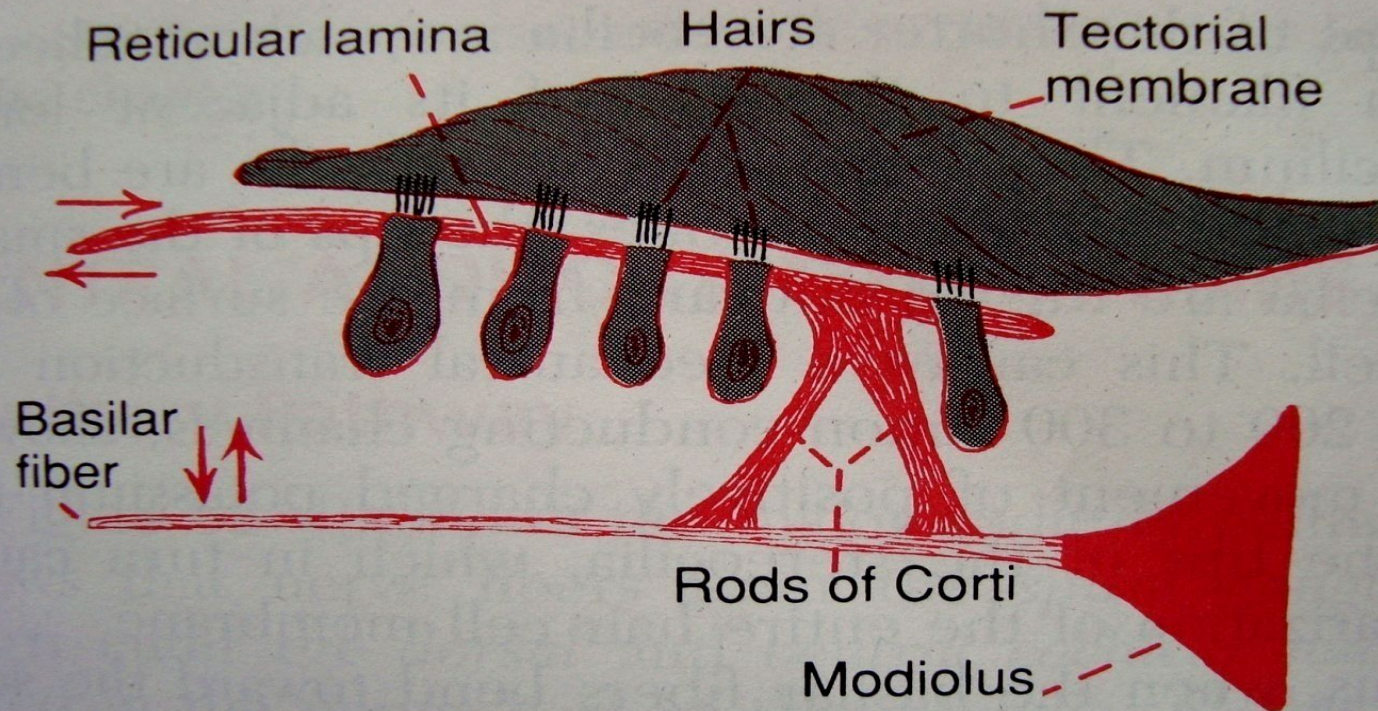


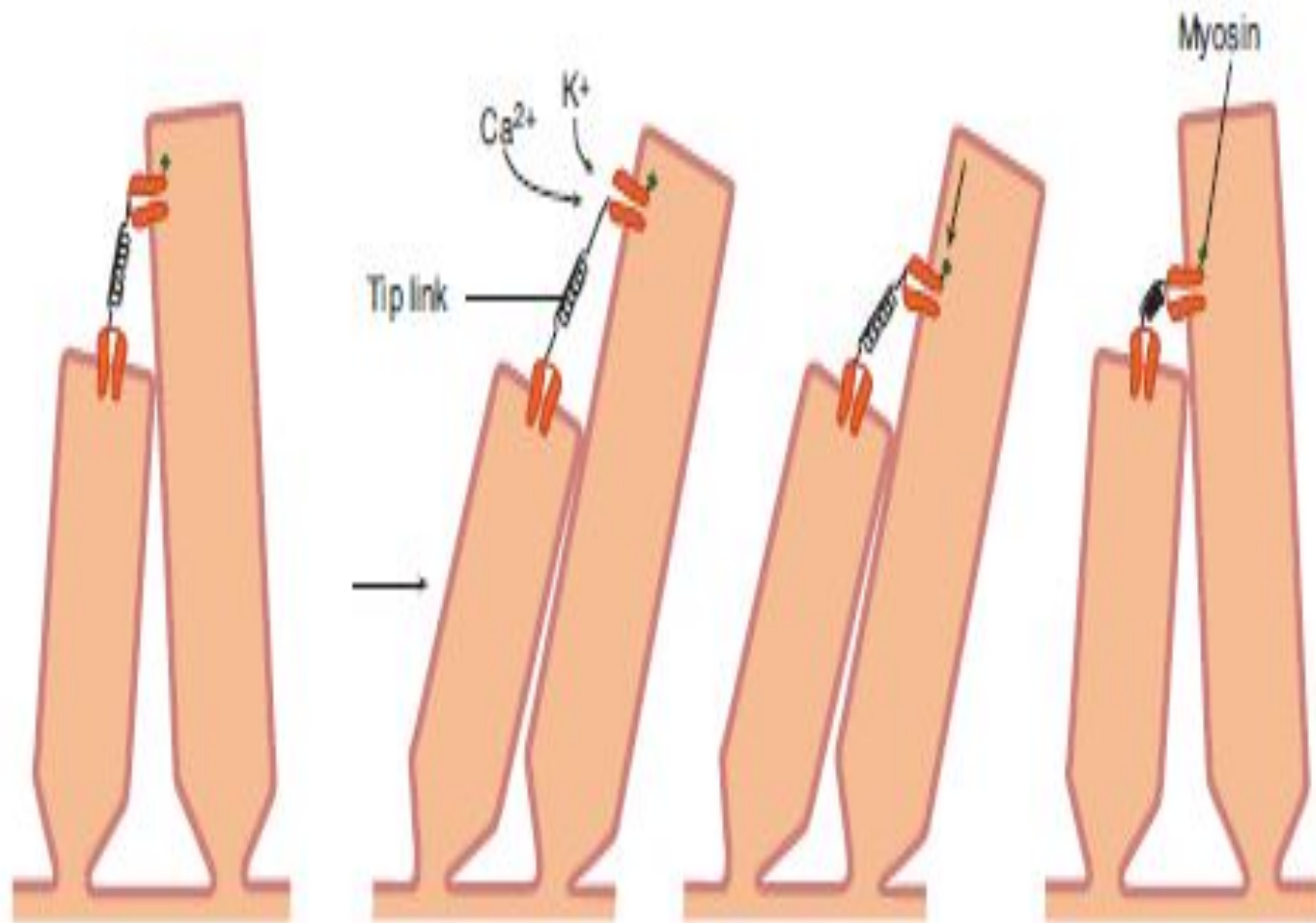
Figure 52-8. Stimulation of the hair cells by the to-and-fro movement of the hairs projecting into the gel coating of the tectorial membrane.

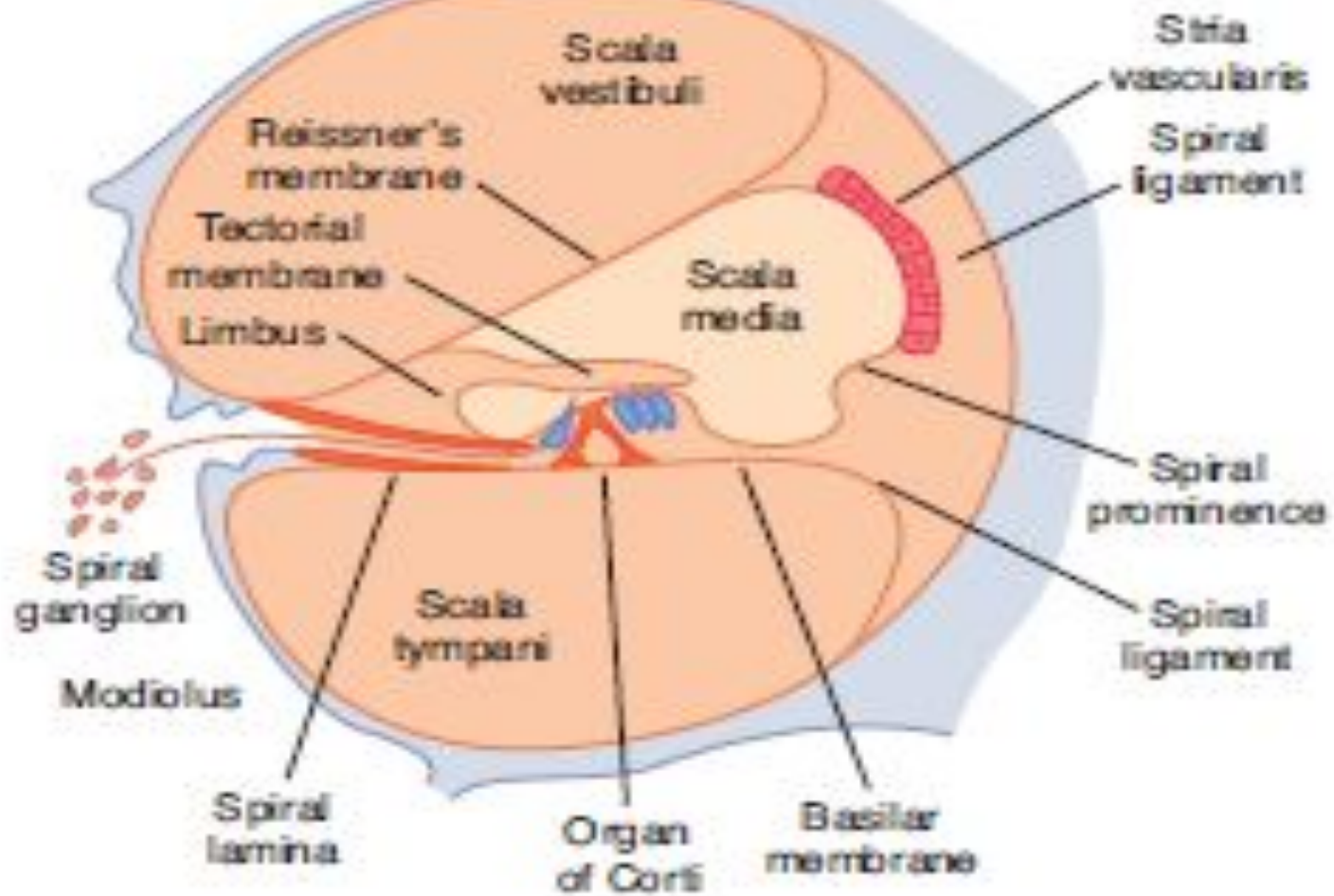
Nerve Impulse Origination

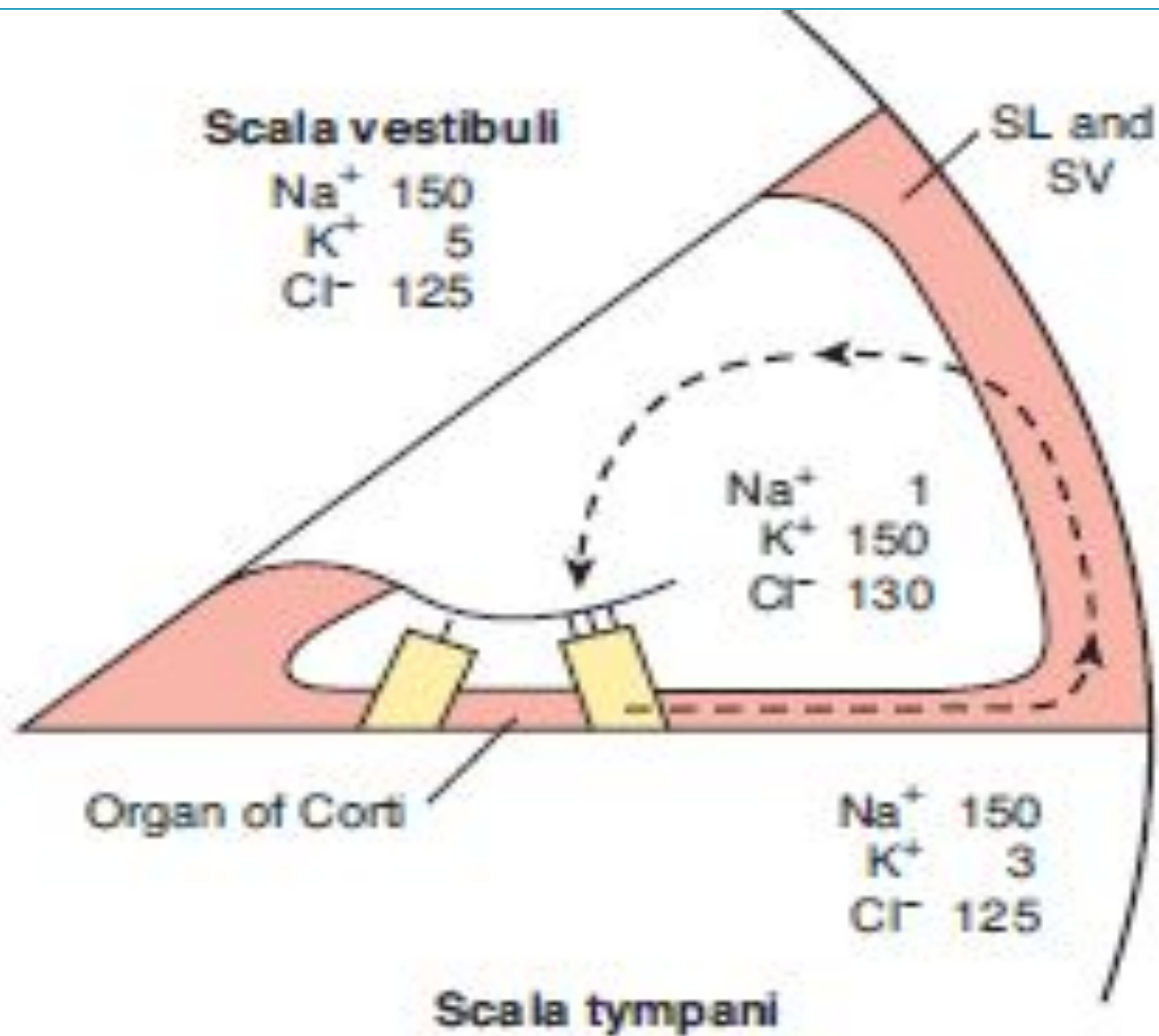
- The stereocilia, when bent in one direction,(inward movement) cause the hair cells to **depolarize**, and when bent in the opposite direction **hyperpolarize**.
 - this is what begins the neural transduction of the auditory signal
- Auditory signals are transmitted by the **inner hair cells** which are **primary auditory receptors** generating action potential.
 - 3-4 X as many outer hair cells than inner hair cells
 - **outer hair cells** may control the sensitivity of the inner hair cells for different sound pitches-increase clarity and amplitude of sound.

Basilar membrane & resonance in cochlea

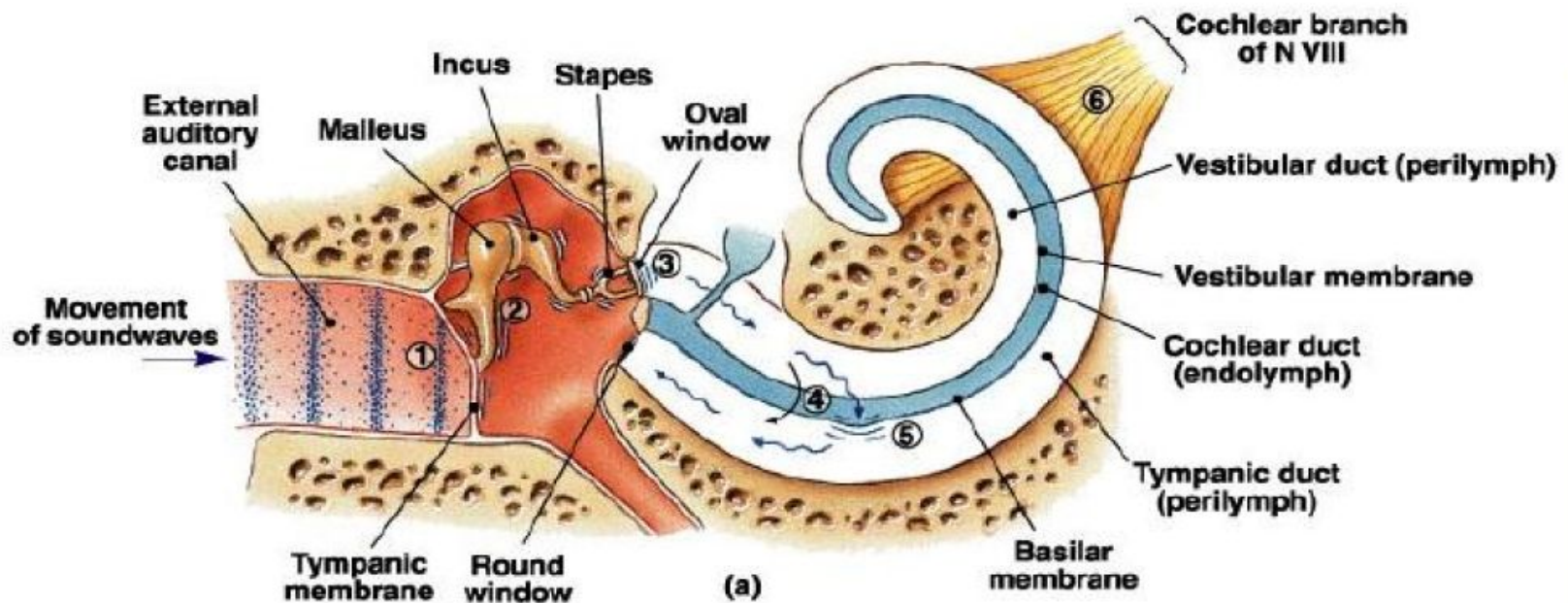
- Auditory receptors-hair cells present on basement membrane move with its movement
- Length of the fibers increases from base to apex, while diameter of the fiber decreases 100 X
-
- **Pitch differentiation:** due to different regions of basilar membrane vibrating to different frequency of sound
- high freq. sound produces maximum vibration of basal portion of basement membrane.
- Low freq. sound produces maximum vibration of apical portion of basement membrane.







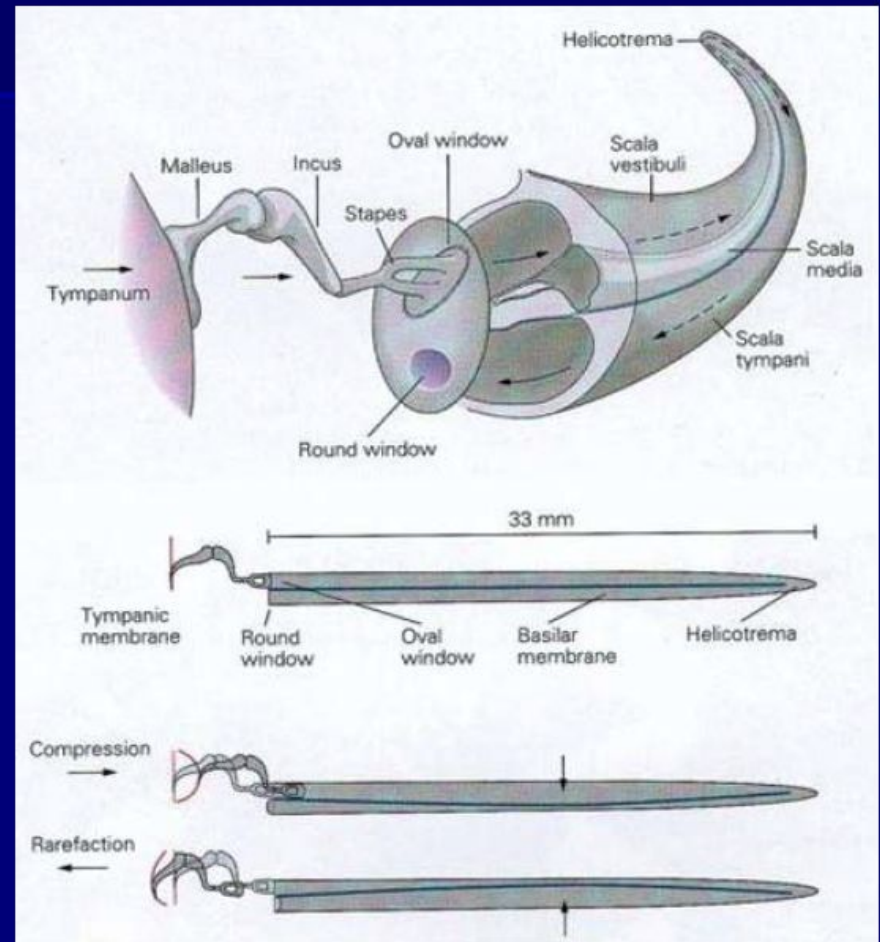
Sound conduction in the ear:



- **TM** vibrates in response to sound and moves the ossicles
- The **ossicles** vibrate the OW membrane

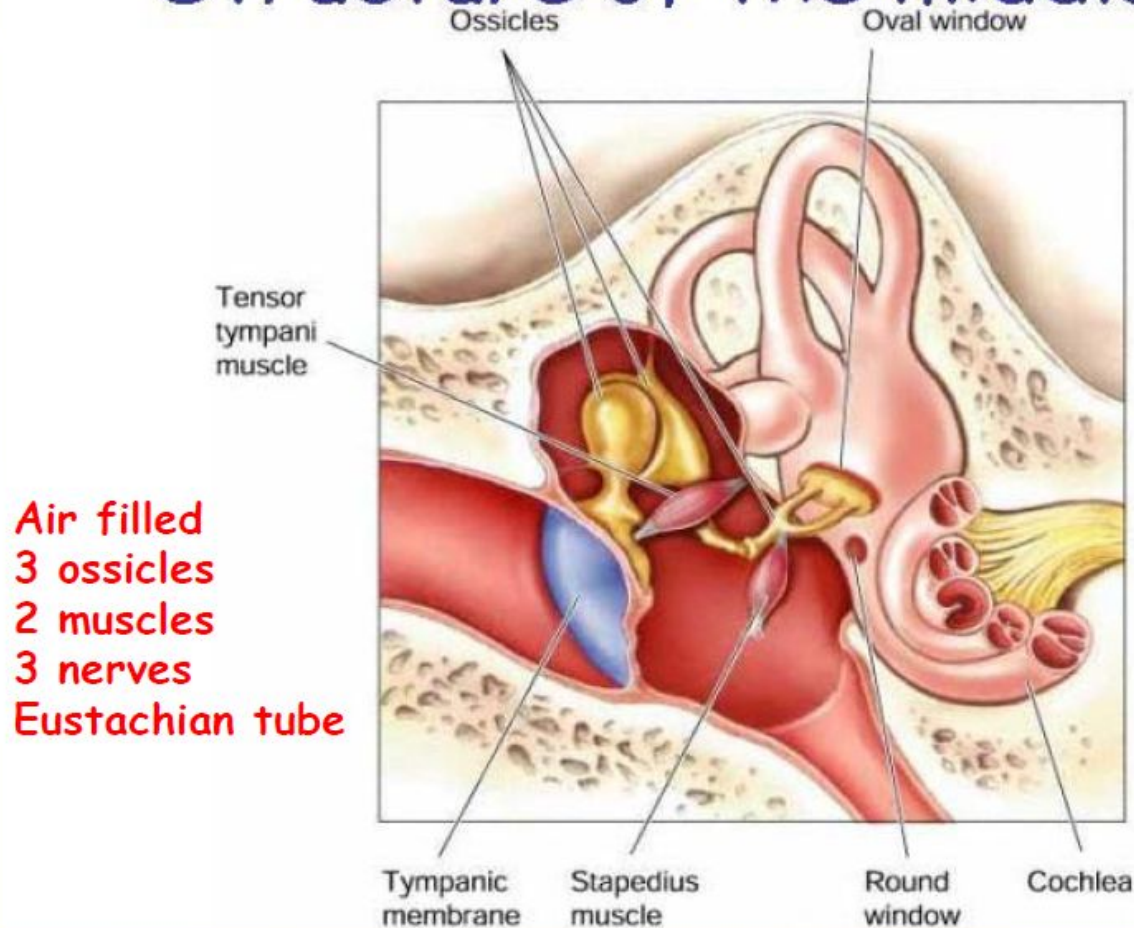
Sound conduction in the ear:

The **OW** membrane vibrations are transmitted to the **inner ear fluids** in scala vestibuli, scala tympani and scala media (cochlear duct) where the **organ of Corti** vibrates in turn

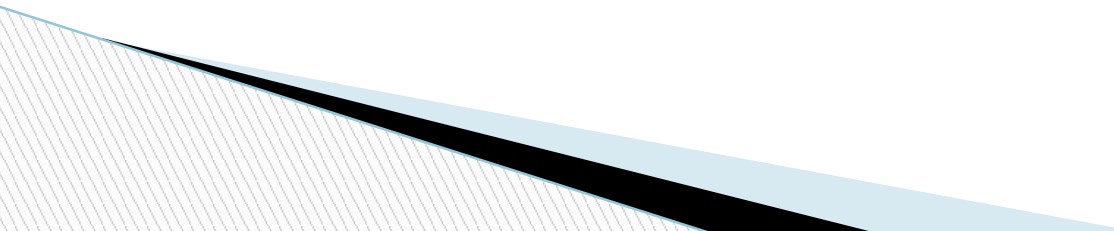


Middle ear functions:

Structure of the middle ear



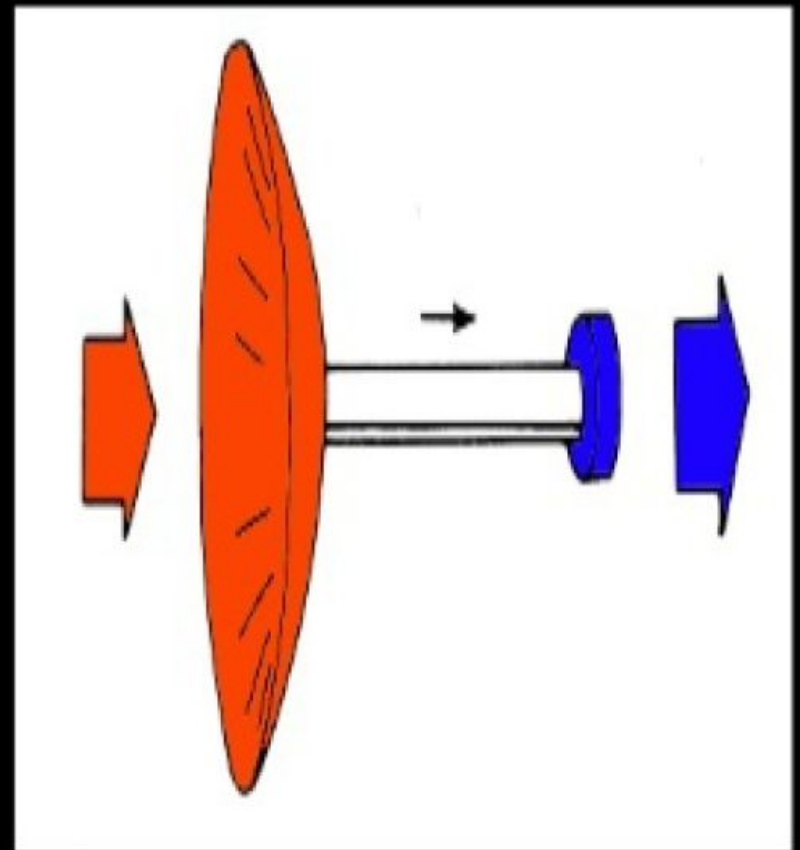
Functions of middle ear

1. Conduction of sound from air in external ear to fluid in middle ear.
 2. Impedence matching
 3. Attenuation reflex
 4. Masking
- 

IMPEDANCE MATCHING BY EAR OSSICLES BY 3 MECHANISMS

■ CURVED MEMBRANE EFFECT.

- Movement of Tympanic membrane more at Periphery than at Center where Malleus is attached.
- So provide some leverage.

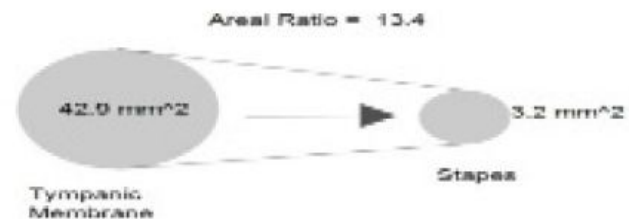


IMPEDANCE MATCHING BY EAR OSSICLES BY 3 MECHANISMS

■ **HYDROLIC ACTION OF TYMPANIC MEMBRANE –**

- Effective vibratory area of tympanic membrane (55mm²) is more than stapes oval window surface area (3.2mm²)
- So force produced by sound concentrated over small area
- Amplifying Pressure on Oval Window

Areal Ratio of Tympanic Membrane to Stapes



Middle ear impedance matching

1. Area ratio

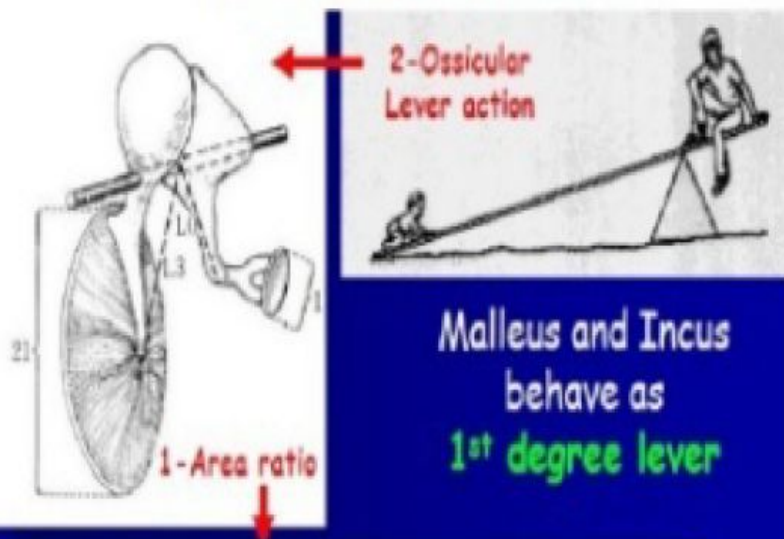


IMPEDANCE MATCHING BY EAR OSSICLES BY 3 MECHANISMS

- **LEVER ACTION OF VESICLES.**
 - **Handle of Malleus** 1.3 times longer than **Long process of Incus**, providing Mechanical Leverage Advantage.
 - So Ossicles increases force of movement by **1.3 times**.

FUNCTIONS OF MIDDLE EAR:

1. IMPEDANCE MATCHING



Malleus and Incus
behave as
1st degree lever

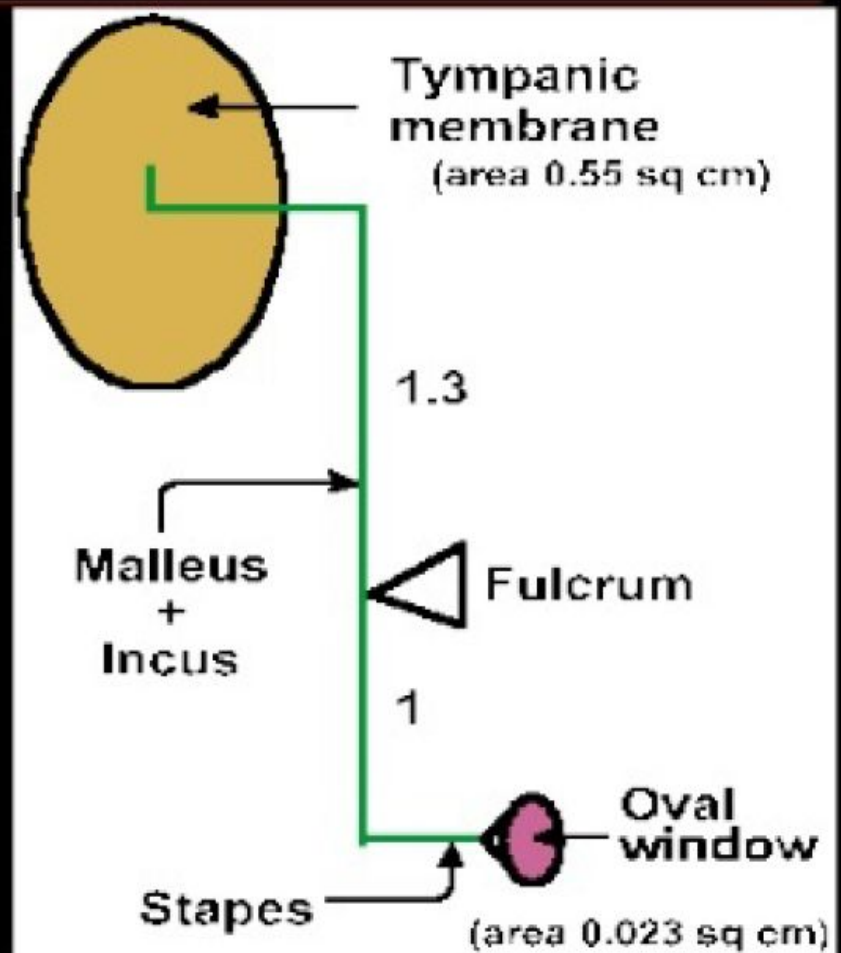
Diameter of TM

Diameter of OW

= **Area ratio 21:1**

IMPEDANCE MATCHING BY EAR OSSICLES BY 3 MECHANISMS

- So all these together **Increase sound pressure 22 folds**
- Impedance Mismatching is mostly compensated.
- If remove ossicles loud sound hear as whisper.



Impedance matching

- Force of movement is 1.3 times increased
- Surface Area of tympanic membrane is 55sq mm
- Surface Area of stapes face plate is 3.2 sq mm
- 17 fold difference in surface area multiplied by 1.3 fold ratio of lever system increases 22 times force to cause vibration of fluid in cochlea

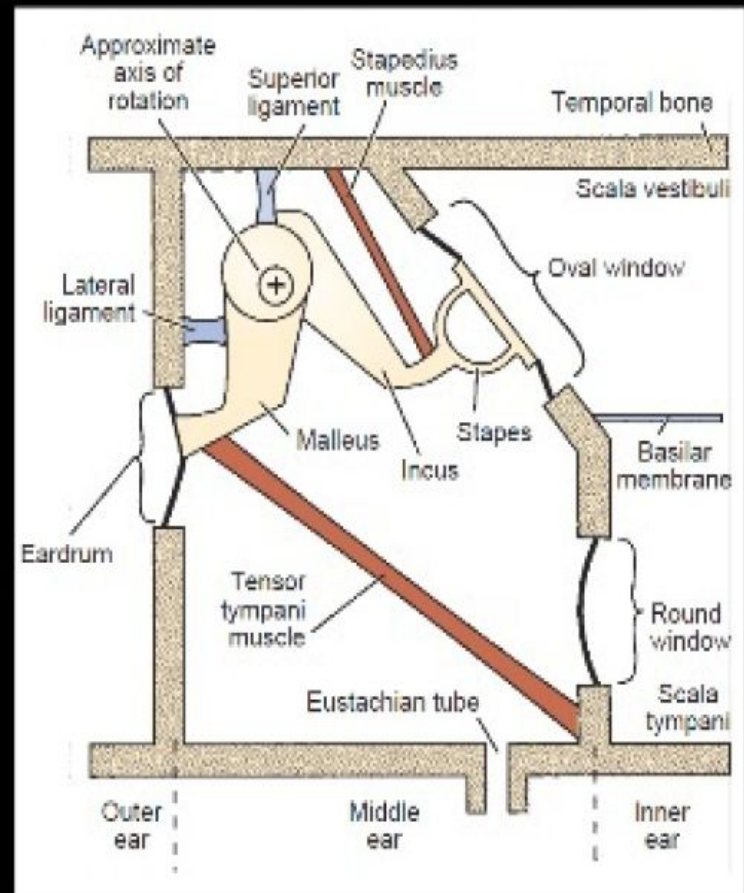
- ▣ ATTENUATION REFLEX
- ▣ MASKING

ATTENUATION REFLEX.

- **Tympanic reflex/Acoustic reflex**
- **Protective reflex.**
- Reduces sound pressure amplitude by Changing mobility & Transmission properties of Ear ossicles.

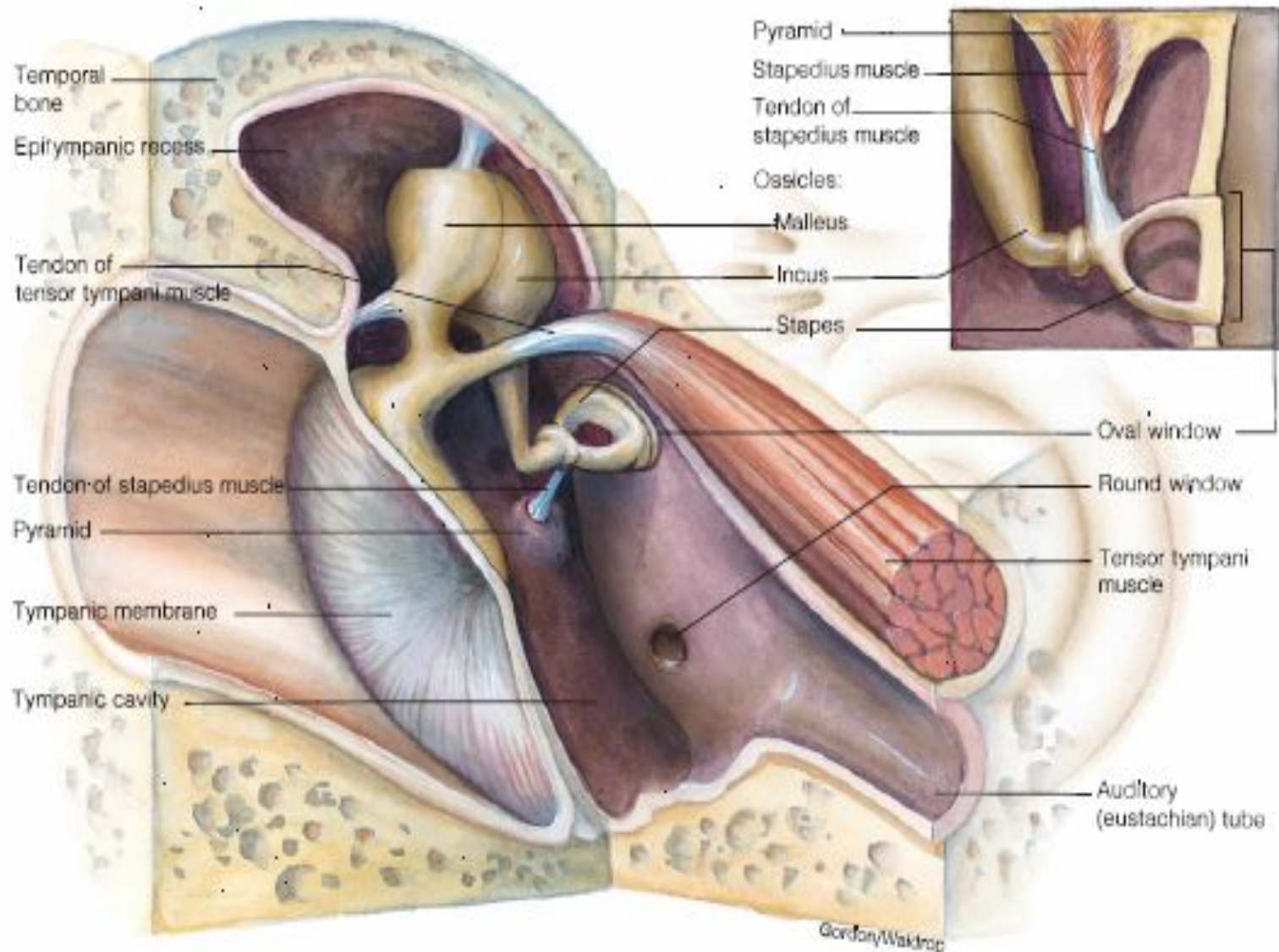
ATTENUATION REFLEX.

- **Tensor Tympani** – pull Malleus inwards
- **Stapedius** – pulls stapes outwards.
- Both makes Ossicular system rigid & no vibrations.
- Sound intensity **Decreased** by 30-40 db.



Attenuation of Sound by Muscle Contraction

- two muscles attach to the ossicles
 - stapedius
 - tensor tympani
- a loud noise initiates reflex contraction after 40 - 80 milliseconds
- attenuates vibration going to cochlea
- serves to protect cochlea and damps low frequency sounds i.e., your own voice



PHYSICS OF SOUND

- Wavelength
- Amplitude
- Frequency
- Loudness/Intensity-measured in decibels
 - 0dB-doesnot means absence of sound
 - 30dB-whisper
 - 40-50-moderate(normal conversation)
 - 60-80-loud(traffic)
 - 90-110-extremely loud(drum,Chain saw)
 - 120-160-painful(firearm,jet plane)

Contd..

- Sound >85 dB can cause hearing loss
- Audible sound frequency 20 to 20000 Hz
- Best appreciate sound frequency 1000 to 10000 Hz

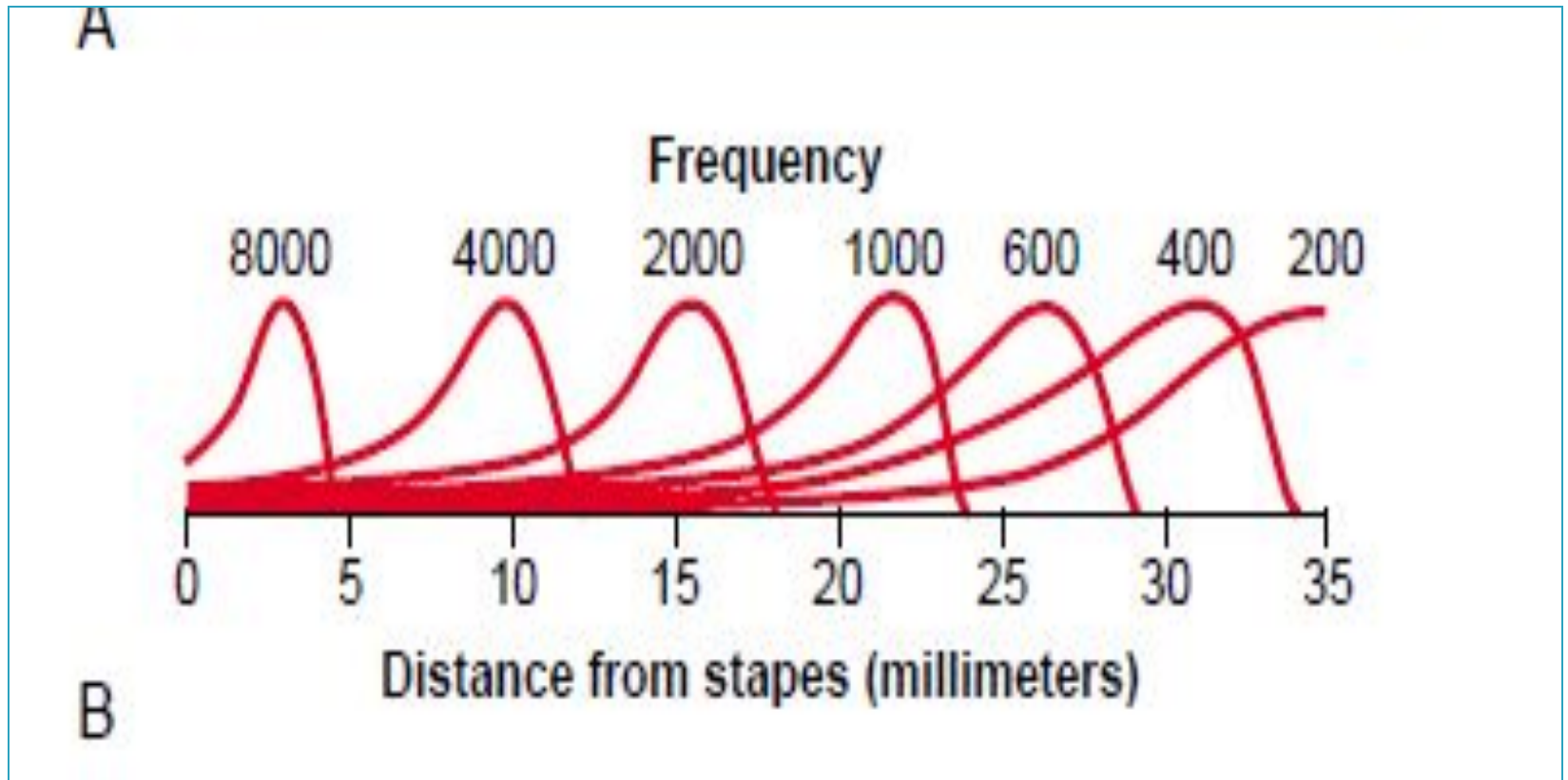
Decibel Unit of Sound

- unit of sound
- expressed in terms of the logarithm of their intensity
- a 10 fold increase in energy is 1 bel
- 0.1 bel is a decibel
- 1 decibel is an increase in sound energy of 1.26 times

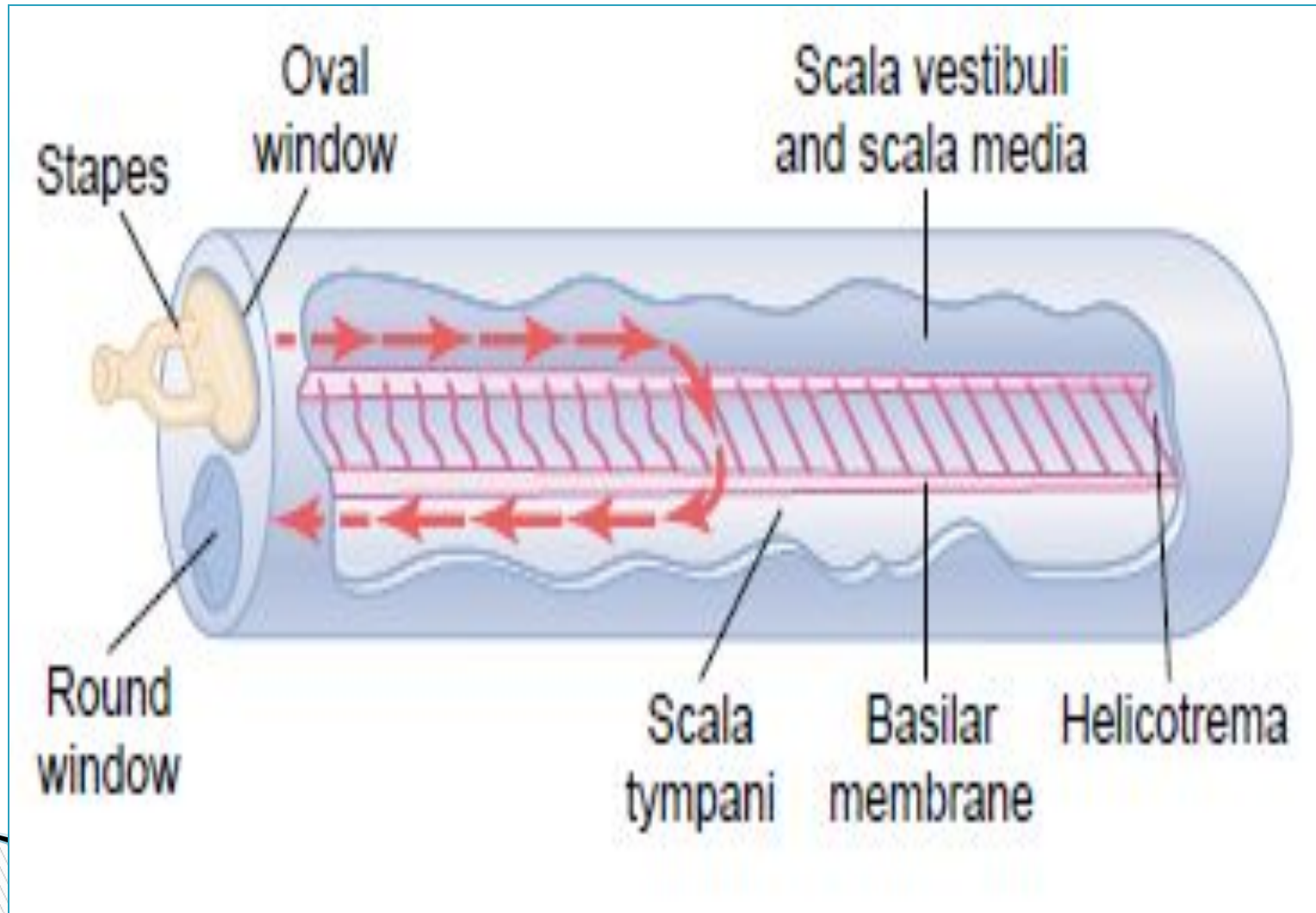
Determination of Sound Frequency and Amplitude

- *Place principle* determines the **frequency** of sound perceived.
 - Different frequencies of sound will cause the basilar membrane to oscillate at different positions.
 - Position along the basilar membrane where hair cells are being stimulated determines the pitch of the sound being perceived.
- **Amplitude** is determined by how much the basilar membrane is displaced.

Place principle



Travelling wave Theory

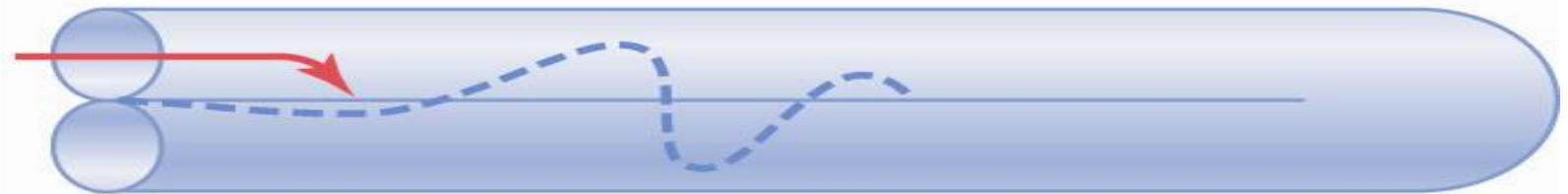


Resonance Point



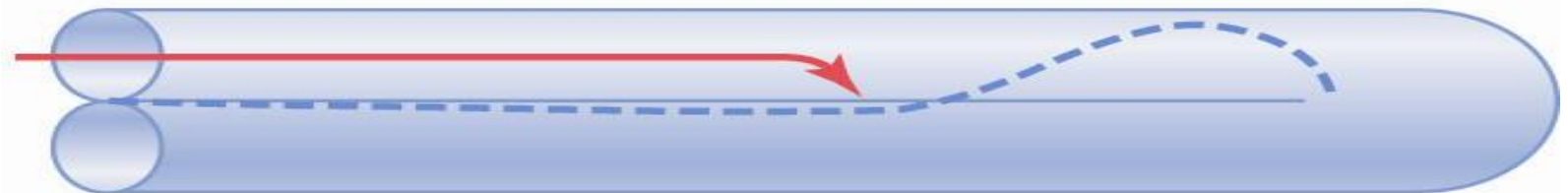
A

High frequency



B

Medium frequency



C

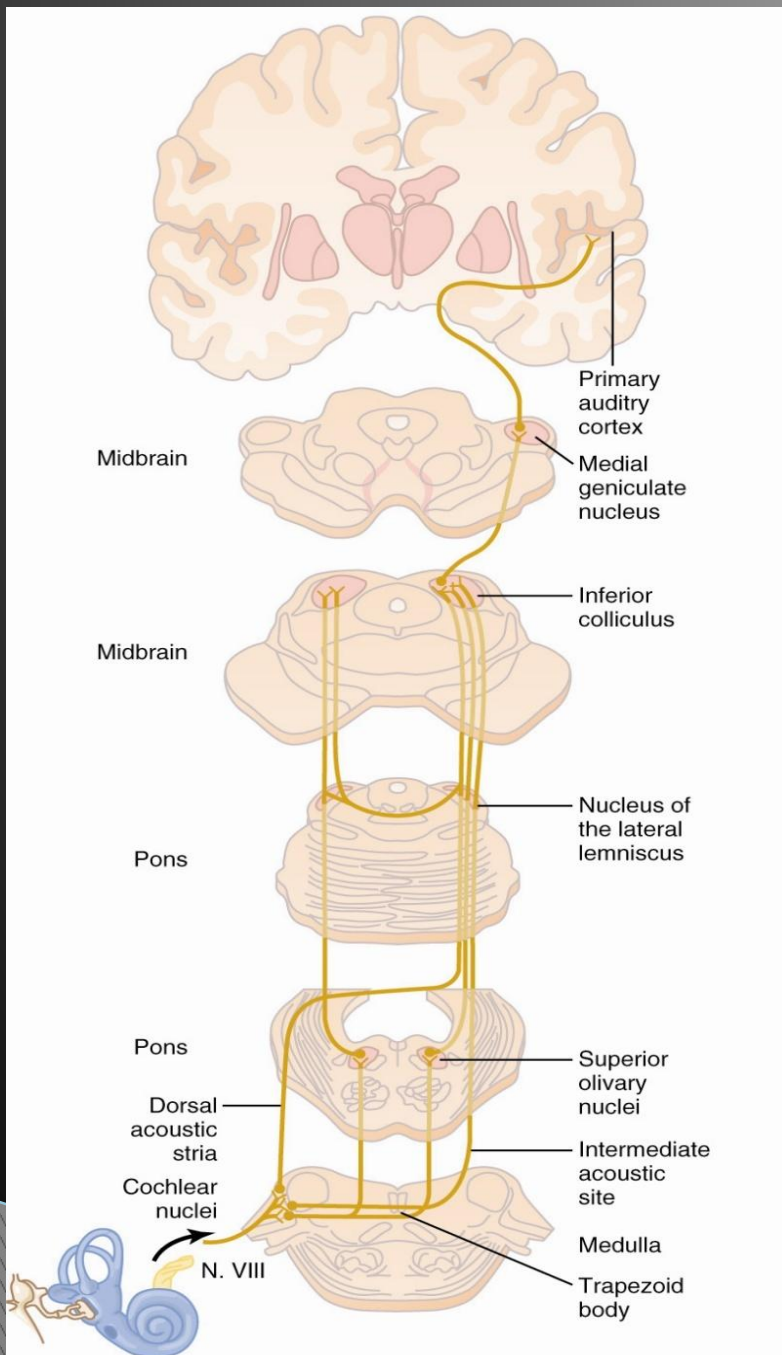
Low frequency

Detection of direction of sound

- Time lag- medial superior olivary nucleus
- Intensity lag-lateral superior olivary nucleus

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



Central Auditory Pathway

Figure
52-10;
Guyton &

from medial geniculate
to auditory cortex
from inferior colliculus
to medial geniculate

from superior olivary
nucleus to inferior
colliculus via the lateral
lemniscus
some fibers pass to the
ipsilateral superior
olivary nucleus.

2nd order neurons project
through trapezoid body to
the contralateral superior
olivary nucleus.

fibers enter dorsal and
ventral cochlear nuclei of
the upper part of the
medulla.

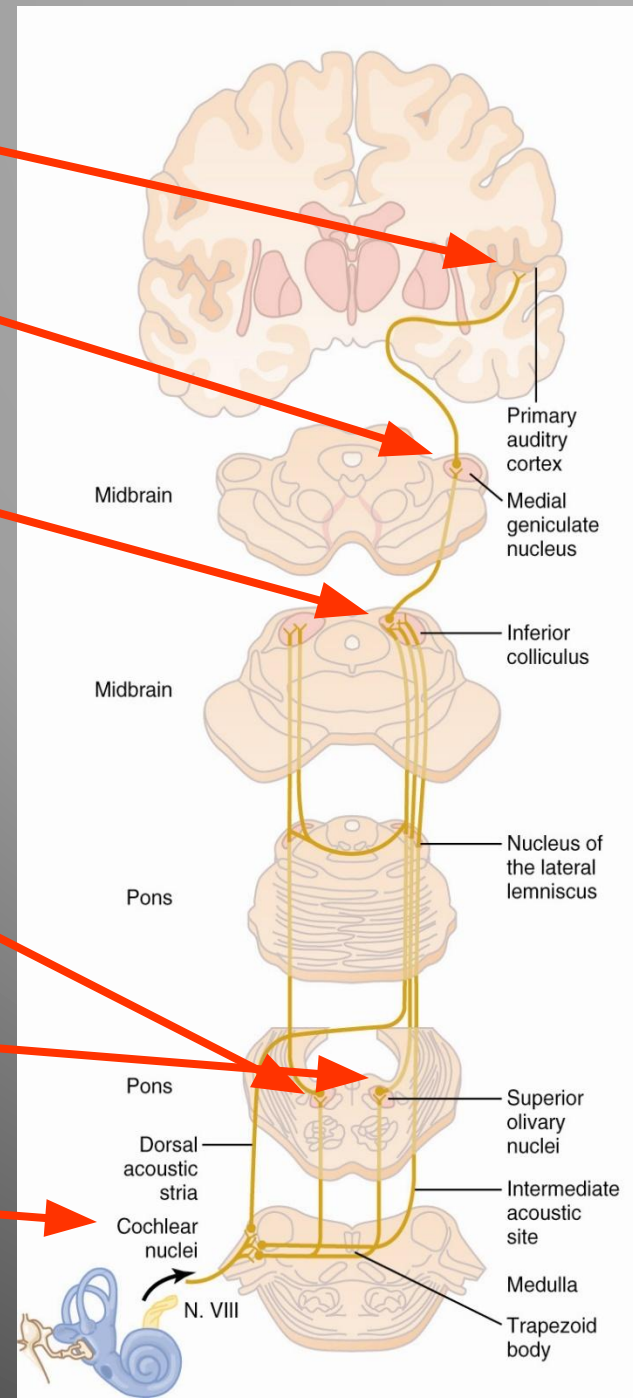
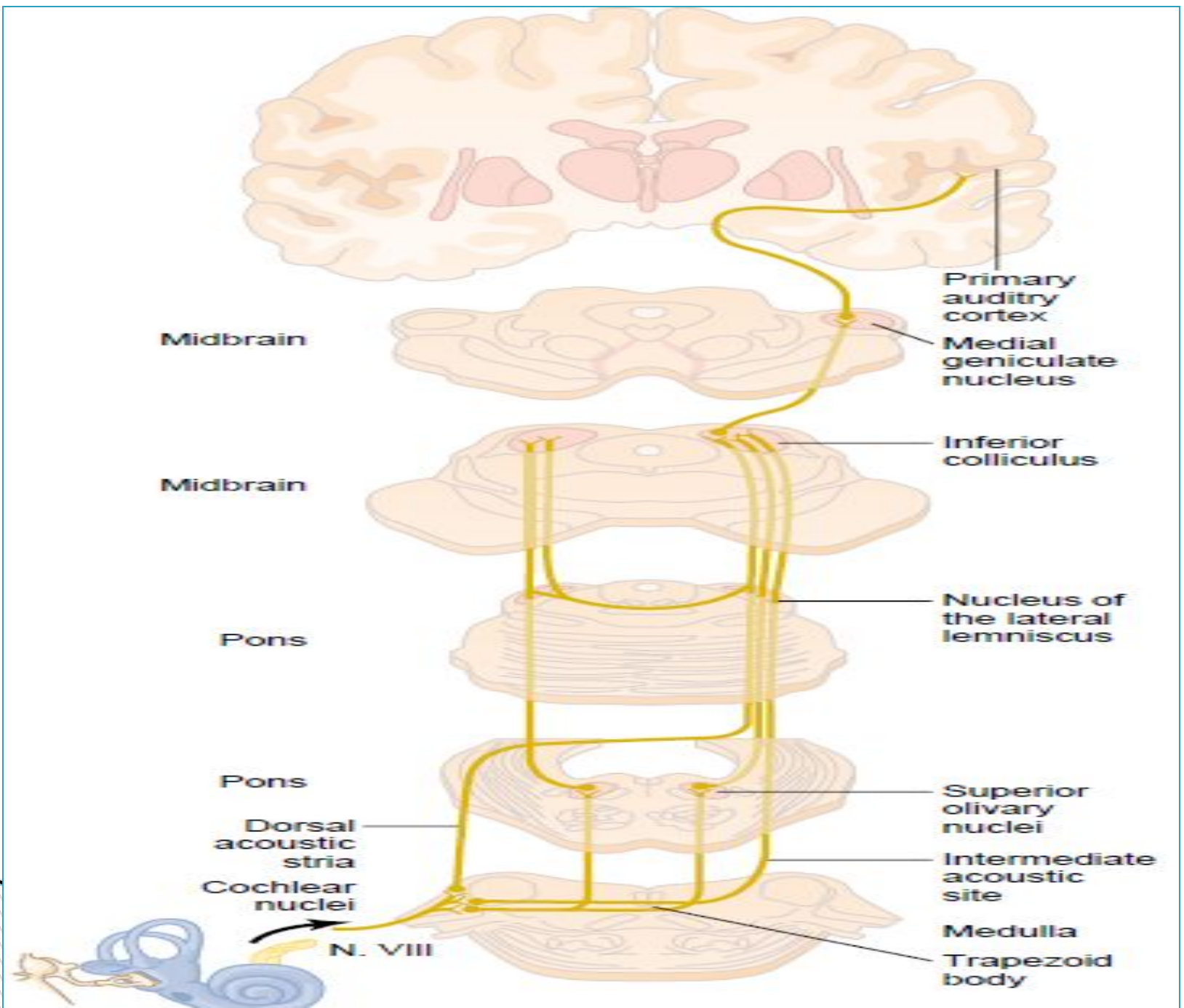
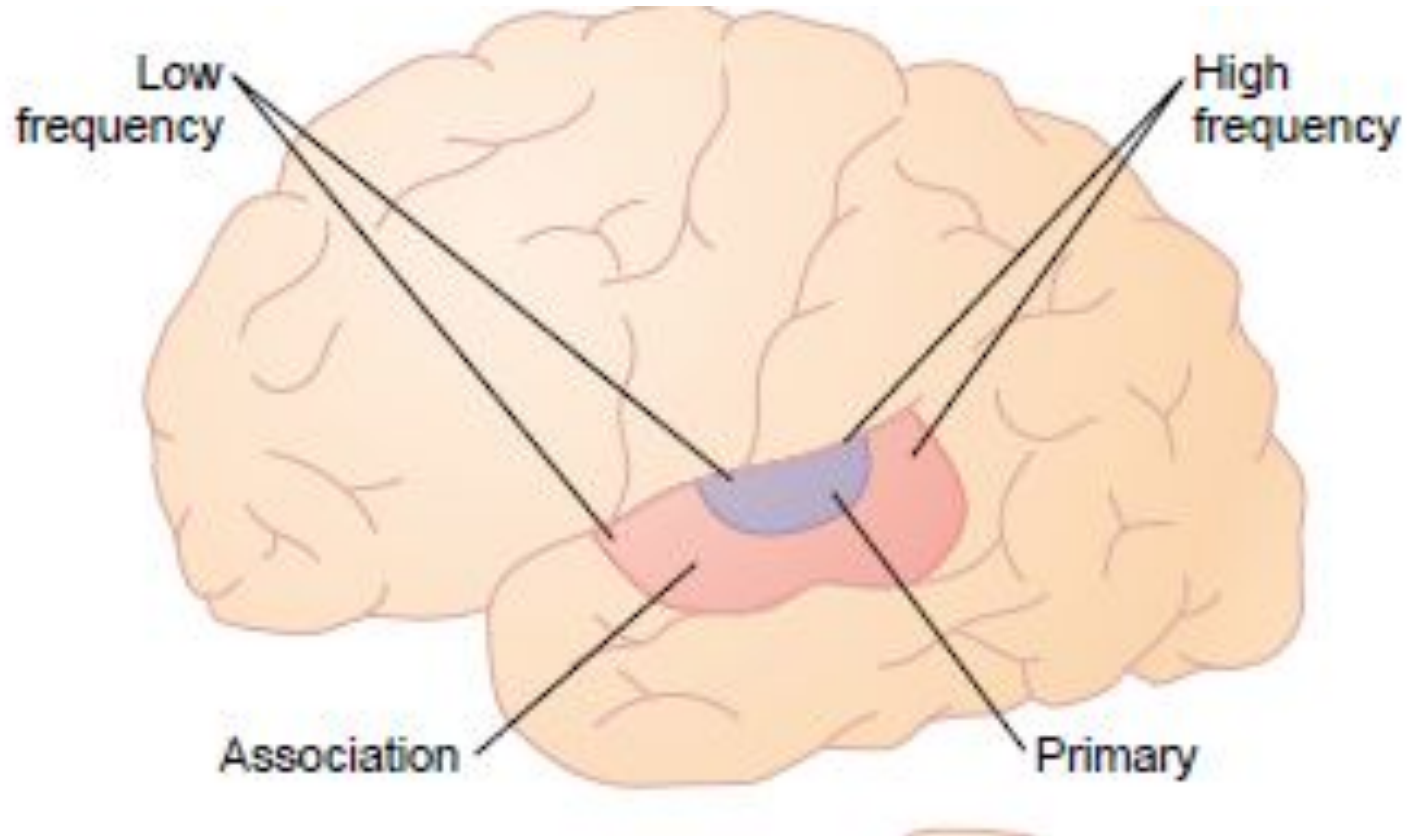


Figure 52-10;
Guyton & Hall



Auditory cortex



Auditory Cortex and Association

- arranged by tonotopic maps
- high frequency sounds at one end of map
- low frequency sounds at other end
- discrimination of sound patterns

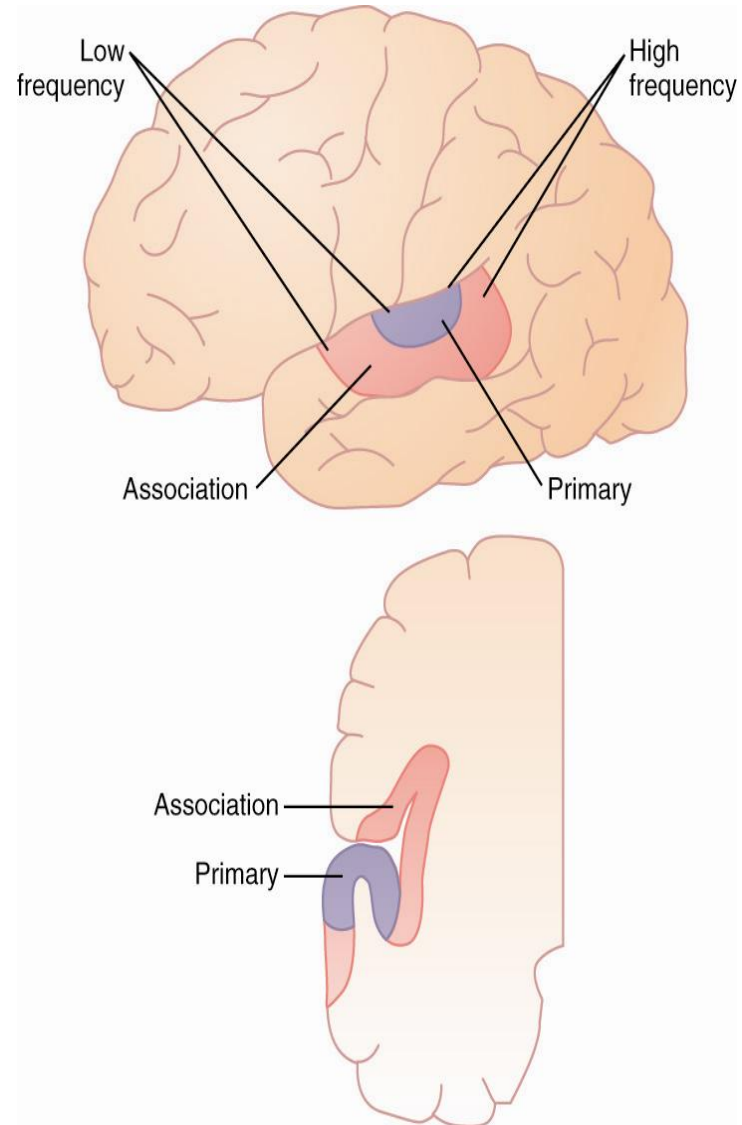


Figure 52-11;
Guyton & Hall

Deafness

- Sensorineural
- Conductive

Deafness

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

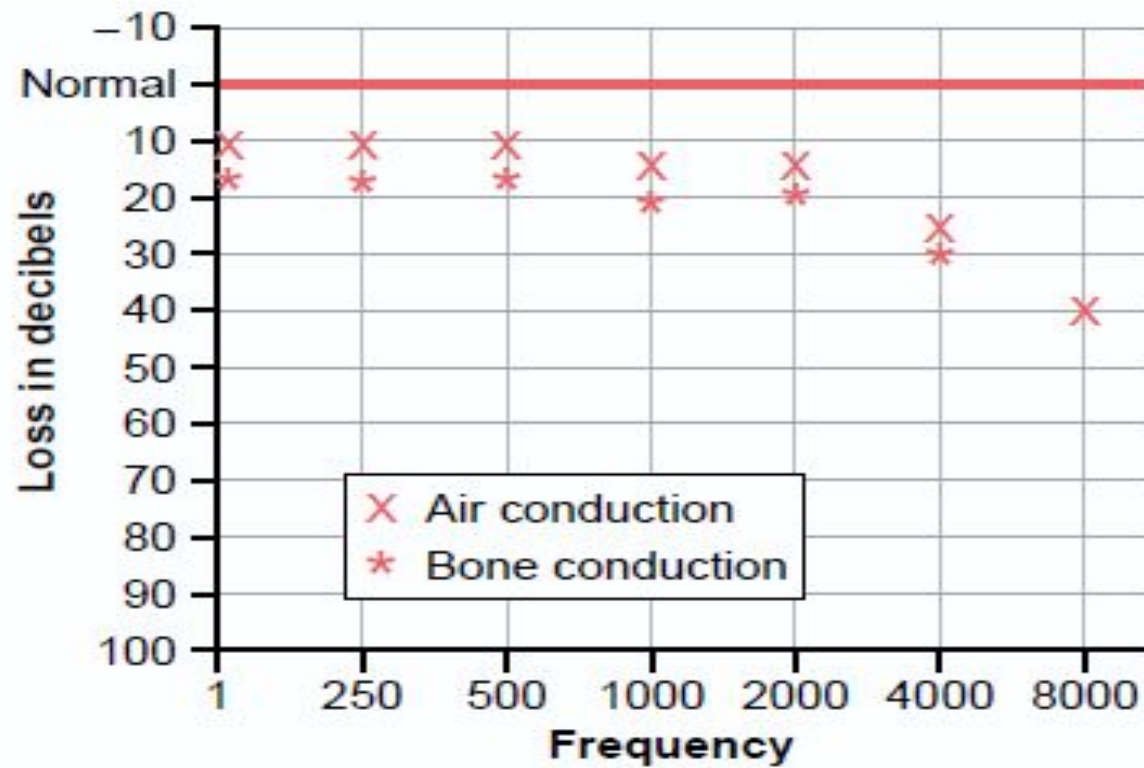


Figure 52-12

Audiogram of the old-age type of nerve deafness.

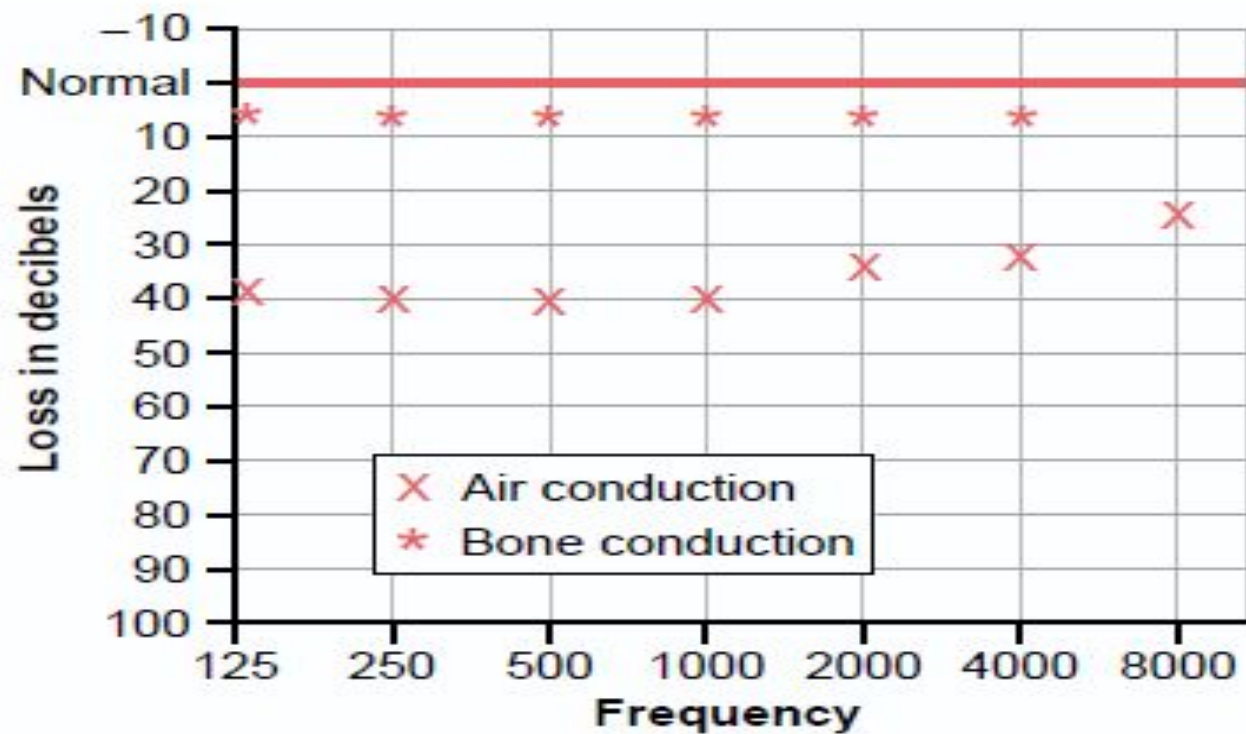


Figure 52–13

Audiogram of air conduction deafness resulting from middle ear sclerosis.

Thank You !

