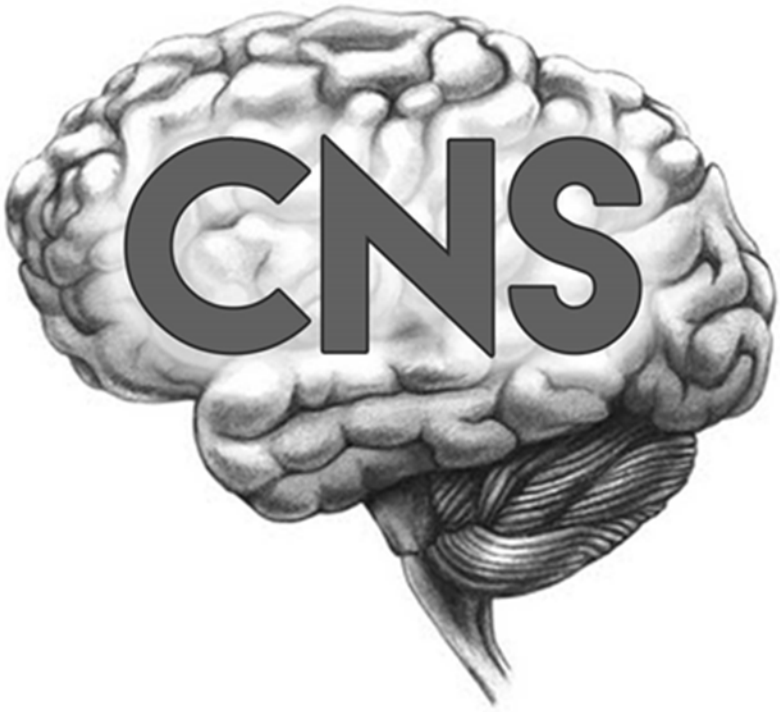


PHYSIOLOGY

○ Sheet ☑ Slide ○ Handout

Number

13

Subject

Auditory Sensation (Hearing)

Doctor

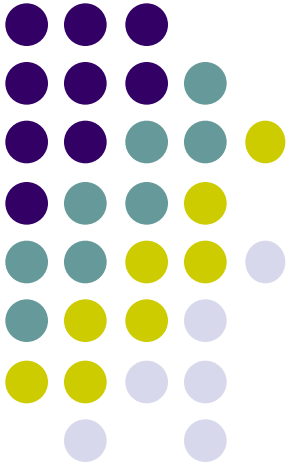
Faisal Mohammed

Date: **00/00/2016**

Price:

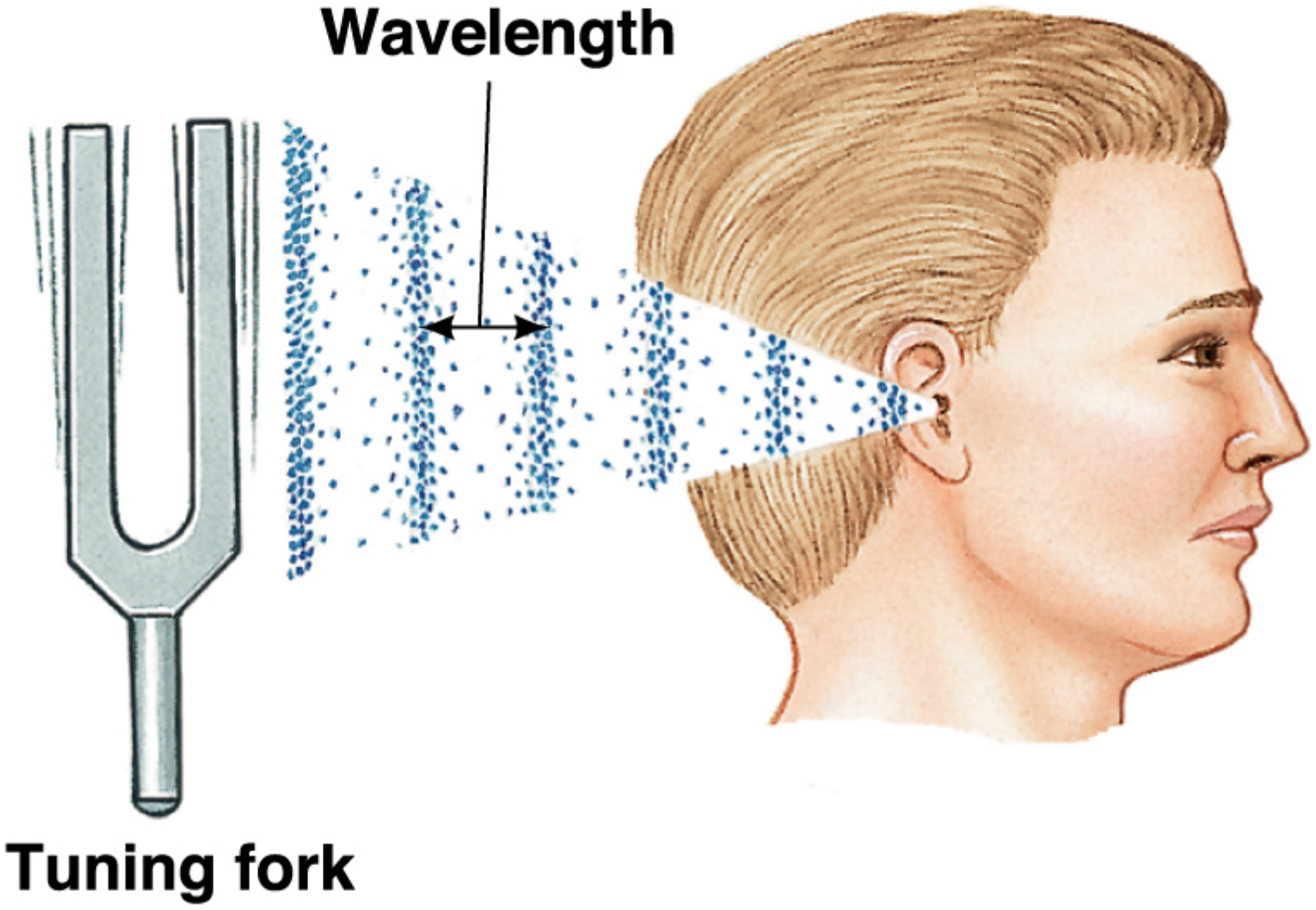
Auditory Sensation (Hearing)

Faisal I. Mohammed, MD, PhD

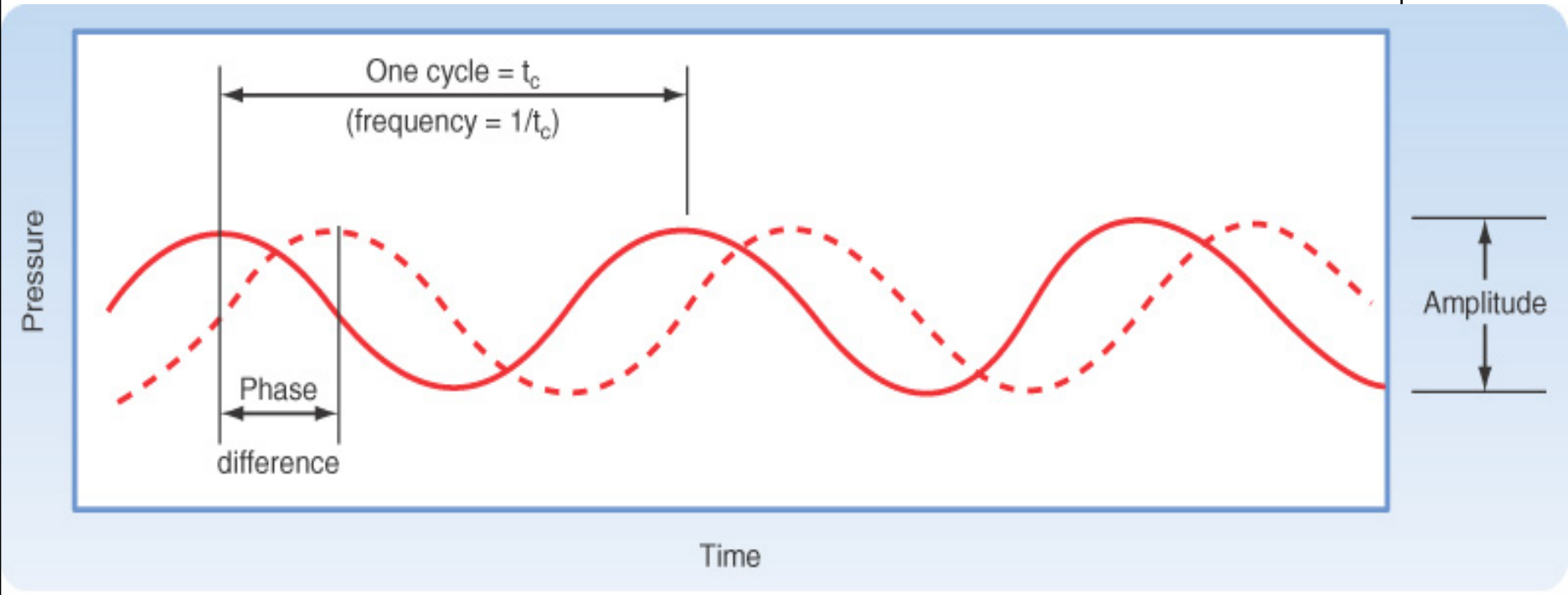


Objectives

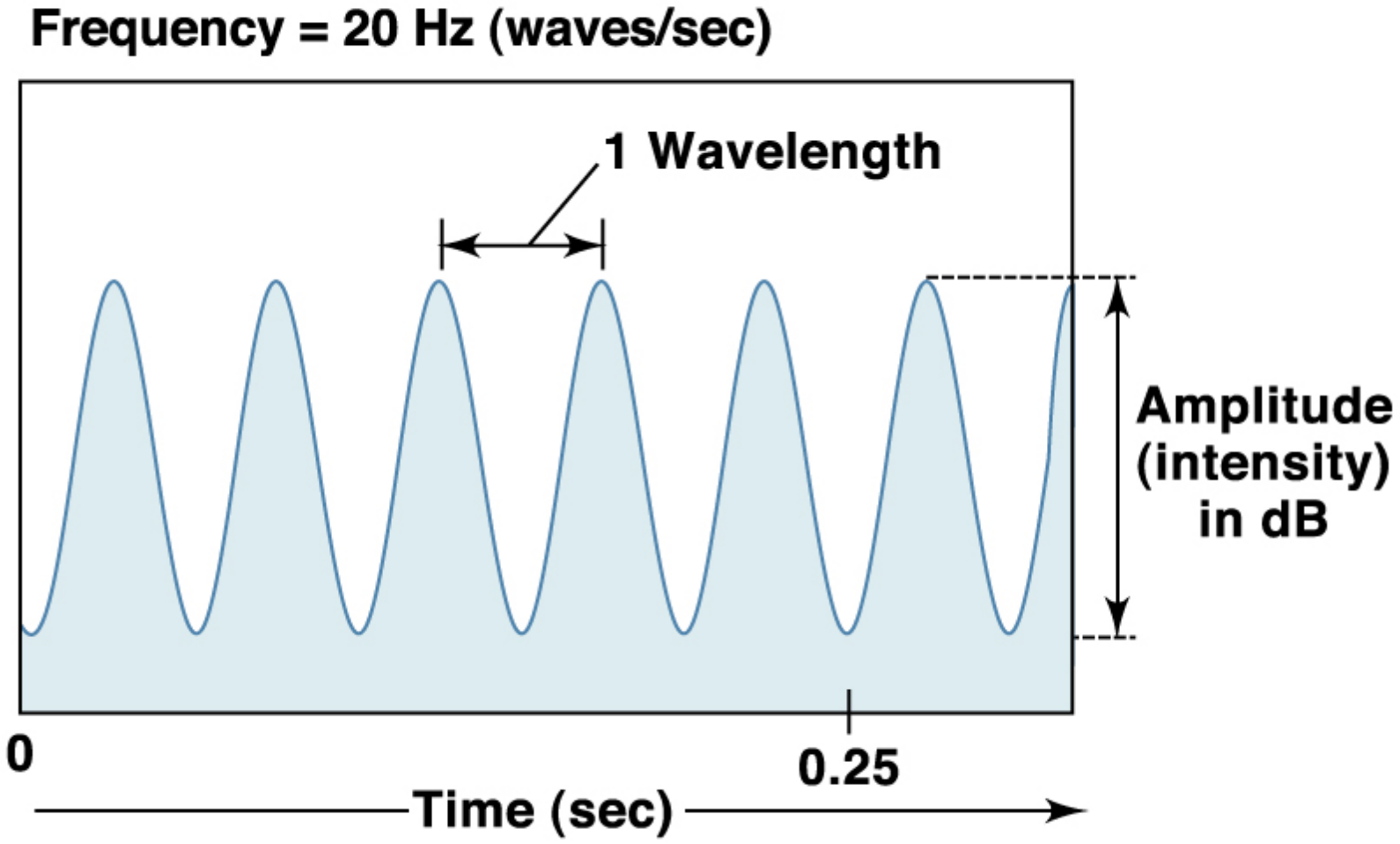
- Define decibel (intensity) and Hz (frequency)
- Describe the ossicular system and explain its function
- Follow up sound transmission up to the cochlea
- Outline the structure of cochlea, and the organ of Corti
- Describe the mechanism of sound transduction
- Follow up the auditory pathway to the cerebral cortex
- Describe auditory abnormalities (types of deafness)

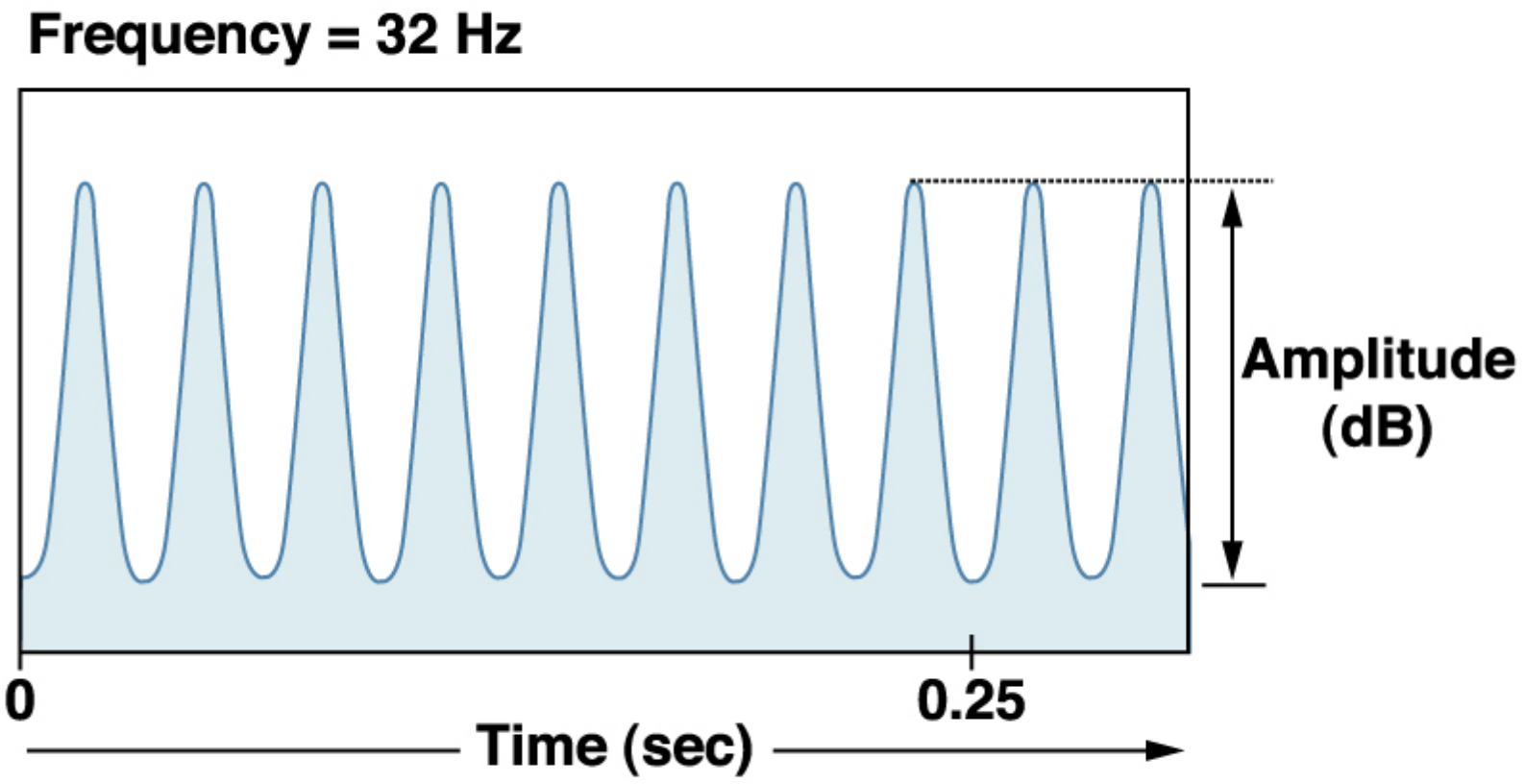

Wavelength
Tuning fork

Frequency of sound wave:
Audible sound wave pure tones
20 – 20,000 Hz



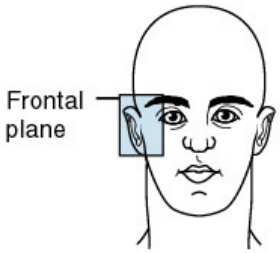
Speed of sound is 335 m/sec in Air

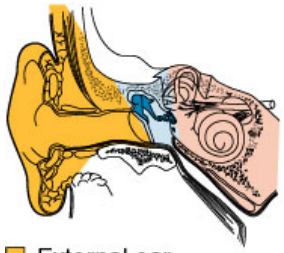

Frequency = 20 Hz (waves/sec)
1 Wavelength
Amplitude
(intensity)
in dB
0
0.25
Time (sec)

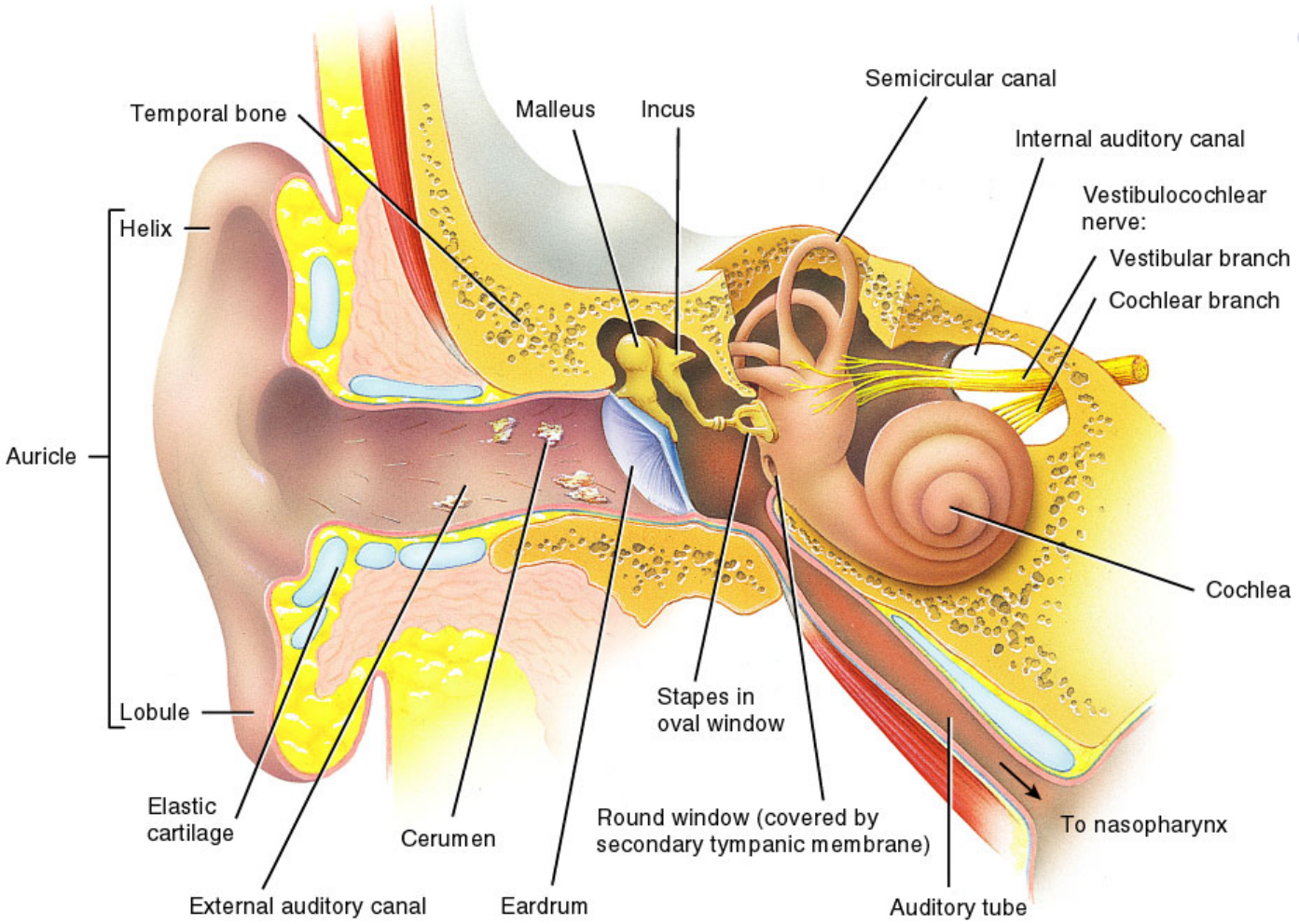

Frequency = 32 Hz
Amplitude
(dB)
0
0.25
Time (sec)

Decibel: a measure of sound intensity

- Decibel (dB) = 10 log I/I_R
  - I = intensity of sound, I_R= reference intensity
  - Acoustic intensity is proportional to the square of sound pressure level
  - Sound pressure is more conveniently measured than sound intensity
- Sound pressure level (SPL) unit is decibel
  - SPL (dB) = 20 log P/P_R
    - P= the sound pressure in N/m^2 (N=Newton, m = meter)
    - P_R= reference pressure (either 0.0002 dynes/cm^2, the absolute threshold for human hearing and equal 20 micropascal, or 1 dyne/ cm^2)





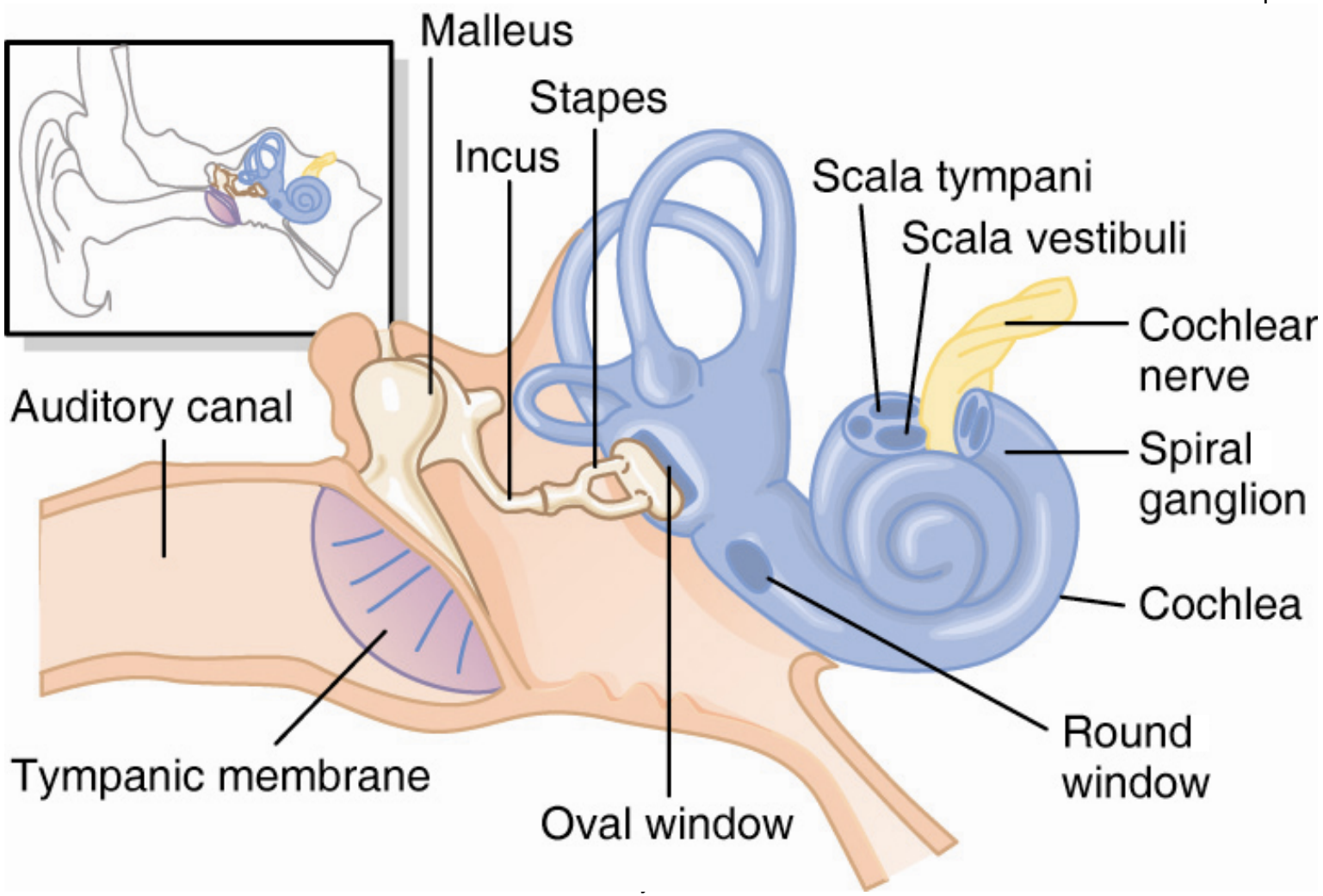


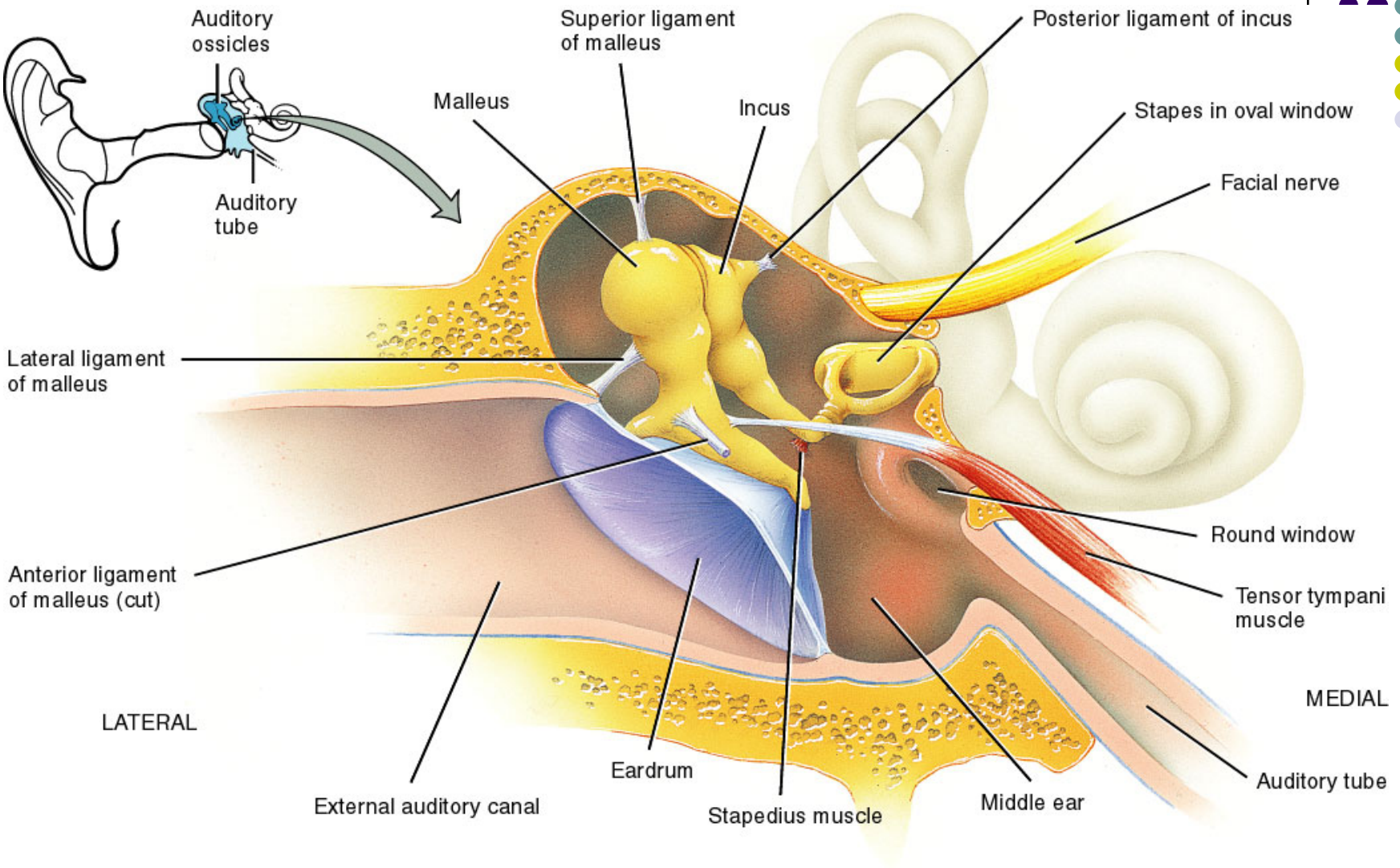
Frontal section through the right side of the skull showing the three principal regions of the ear

16.17

The Tympanic Membrane and the Ossicular System

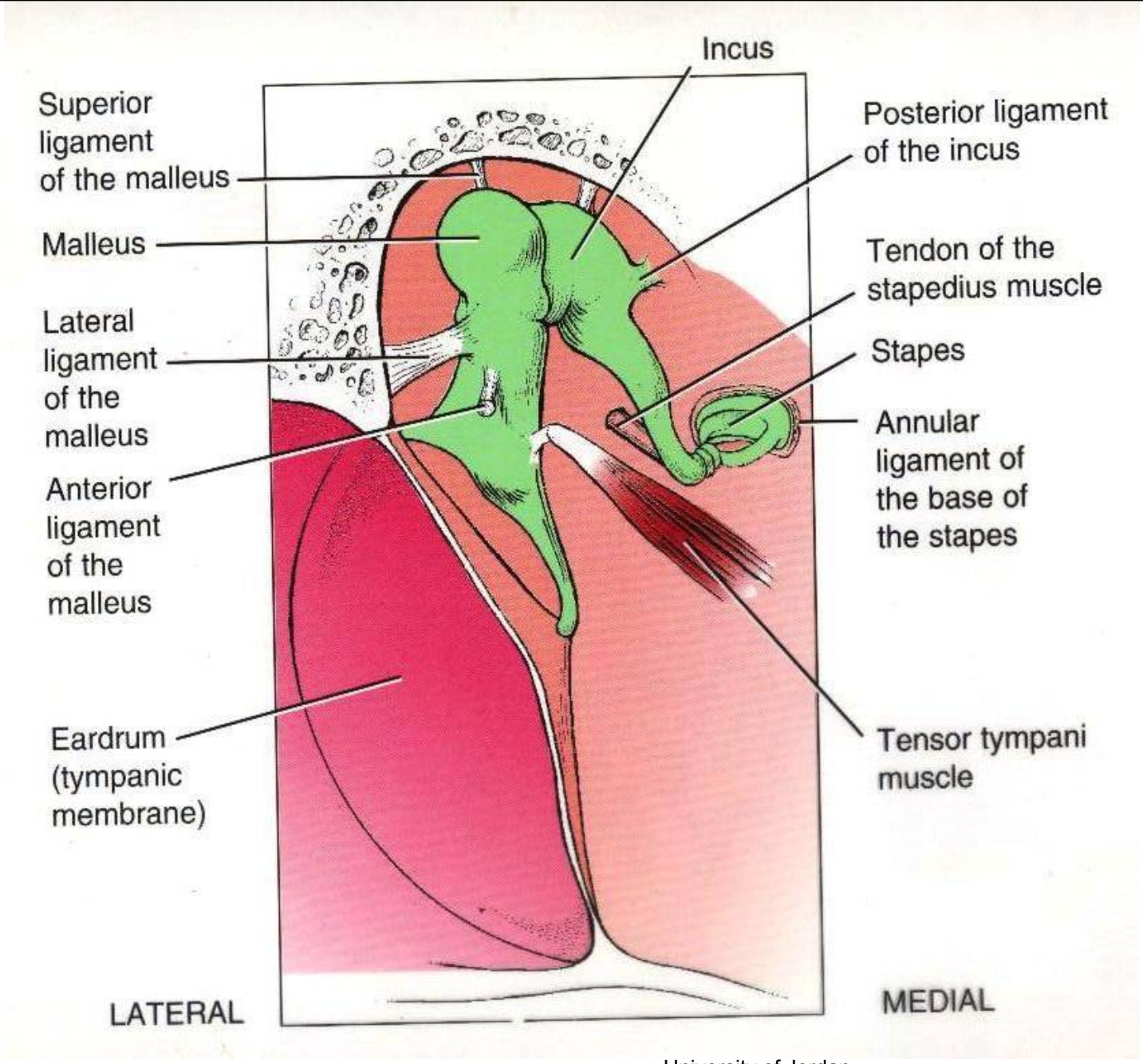
- Tympanic membrane functions to transmit vibrations in the air to the ***cochlea***
- Amplifies the signal because the area of the tympanic membrane is 17 times larger than the oval window (55 sq. mm Vs. 3.2 sq. mm)
- Tympanic membrane connected to the ossicles
  - malleus
  - incus
  - Stapes
- Ossicular system works as a lever system and amplifies the sound 1.3 time
- Total amplification is 22 times (17x1.3) called ***Impedance Matching*** (match the resistance of sound wave movement in fluid vs. the resistance in air)


Malleus
Stapes
Incus
Scala tympani
Scala vestibuli
Cochlear nerve
Auditory canal
Spiral ganglion
Cochlea
Round window
Tympanic membrane
Oval window



Frontal section showing location of auditory ossicles

16.18

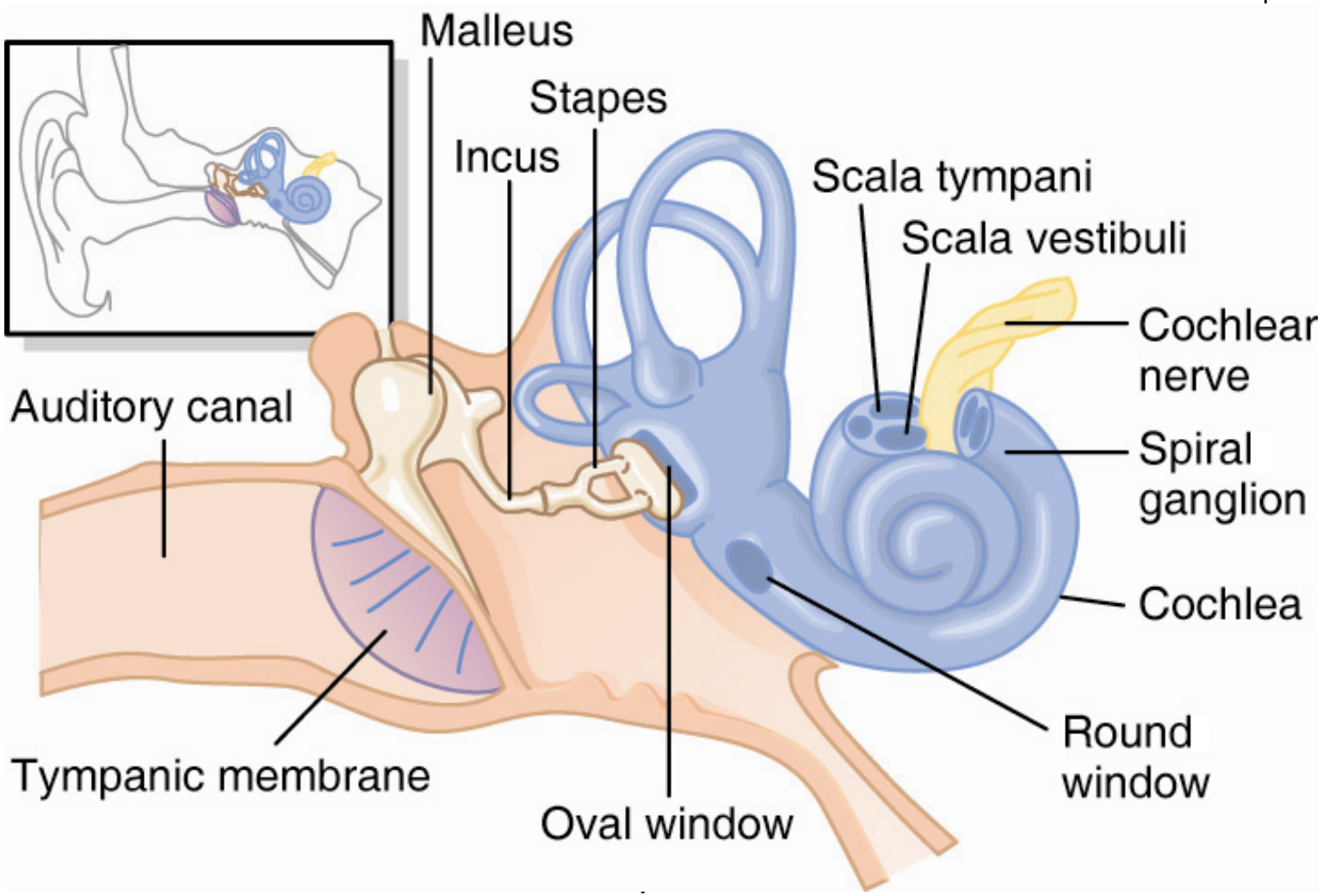

Incus
Superior ligament of the malleus
Posterior ligament of the incus
Malleus
Tendon of the stapedius muscle
Lateral ligament of the malleus
Stapes
Annular ligament of the base of the stapes
Anterior ligament of the malleus
Eardrum (tympanic membrane)
Tensor tympani muscle
LATERAL
MEDIAL

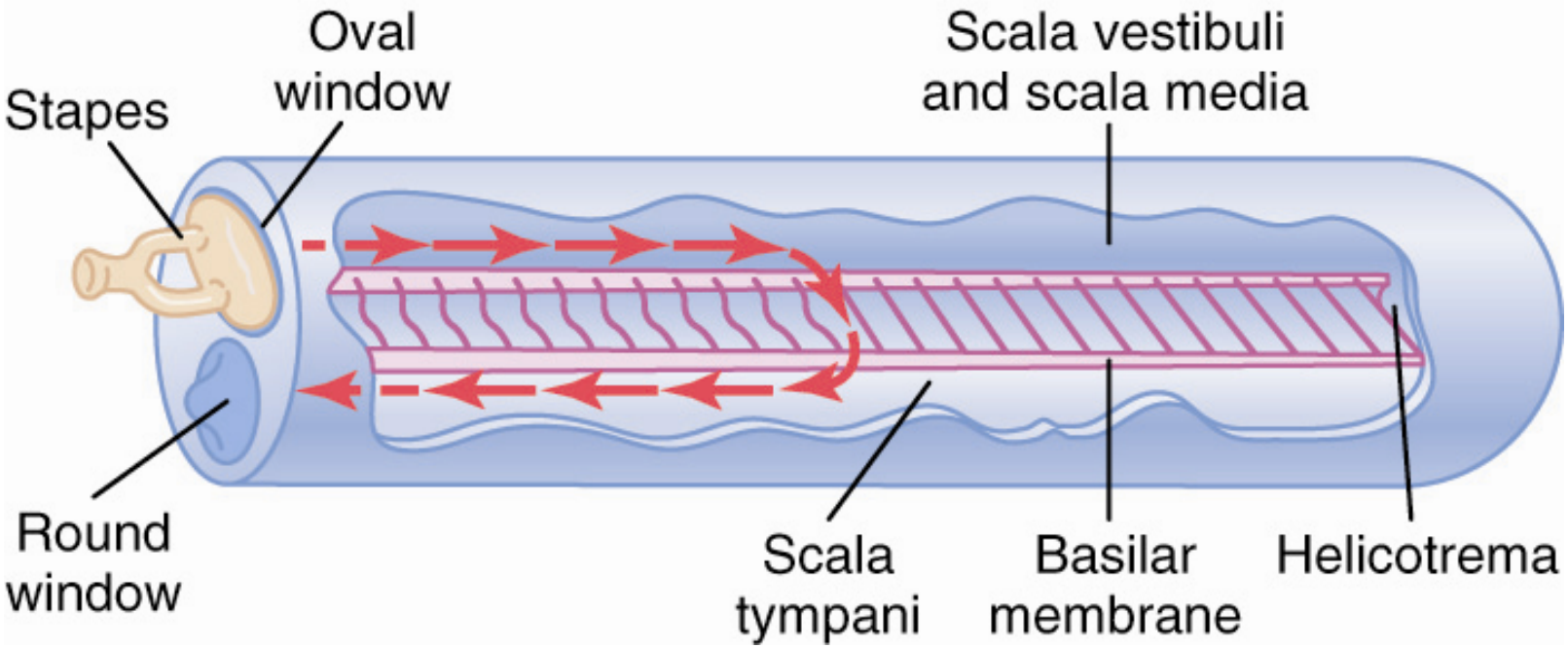
Attenuation of Sound by Muscle Contraction

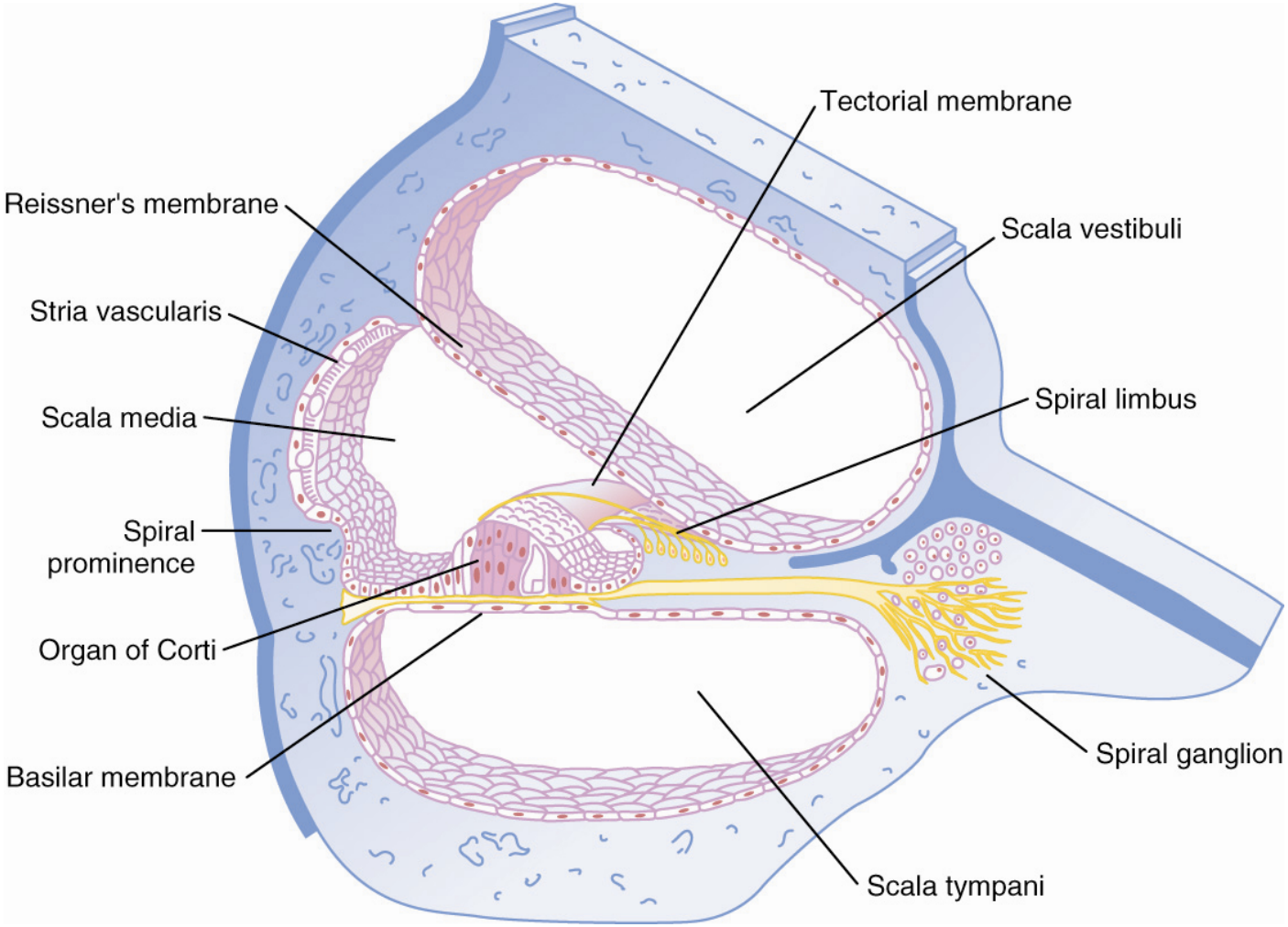
- Two muscles attach to the ossicles
  - Stapedius (supplied by facial Nn VII)
  - tensor tympani (supplied by Trigeminal Nn V)
- A loud noise initiates reflex contraction after 40 - 80 milliseconds
- Attenuates vibration going to cochlea (**Attenuation reflex**)
- Serves to protect cochlea and damps (mask) low frequency sounds in loud environment .i.e., your own voice

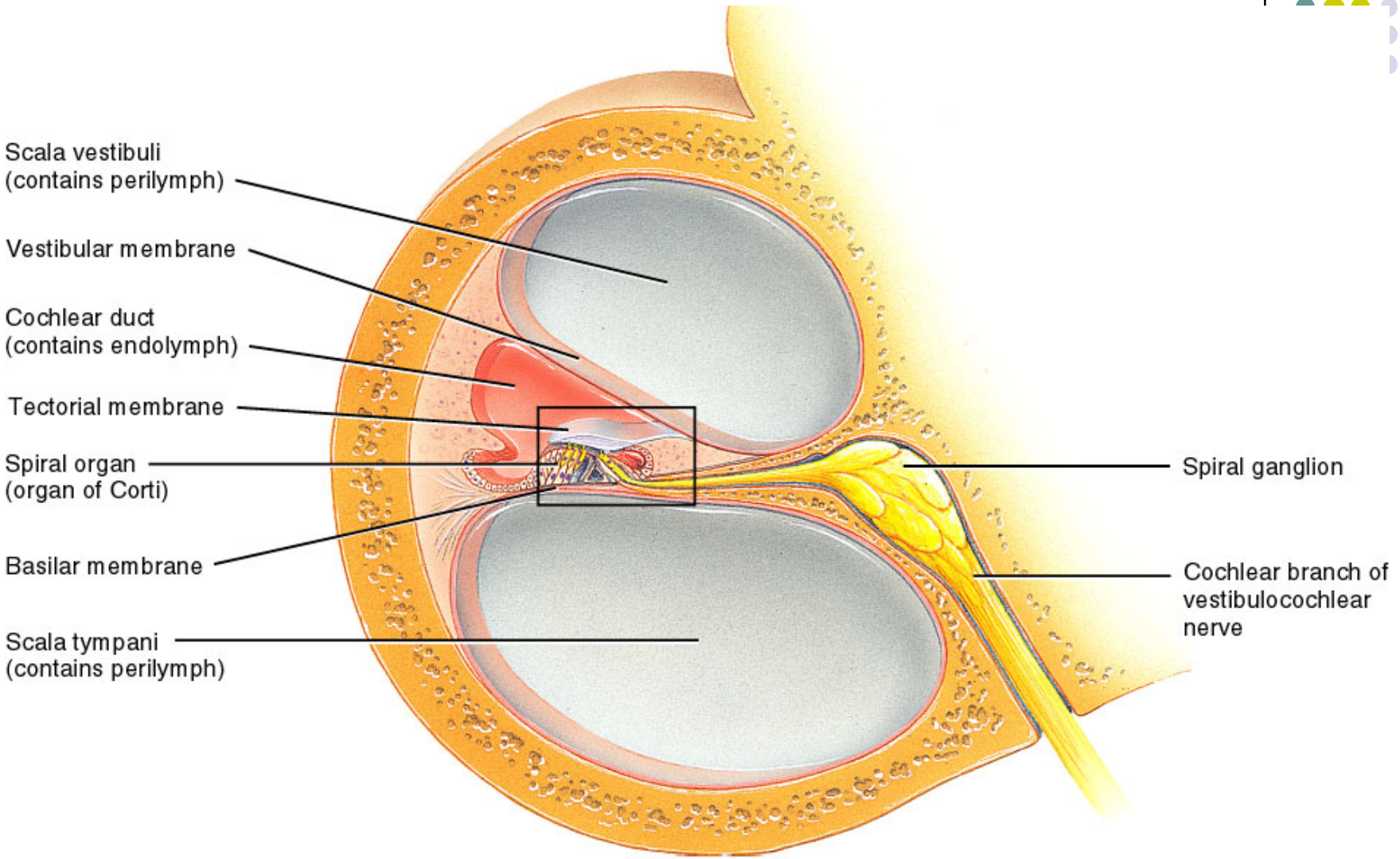
Cochlea

- system of three coiled tubes separated by membranes into the *scala tympani, scala media, scala vestibuli*
- 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*


Malleus
Stapes
Incus
Scala tympani
Scala vestibuli
Cochlear nerve
Auditory canal
Spiral ganglion
Cochlea
Round window
Tympanic membrane
Oval window

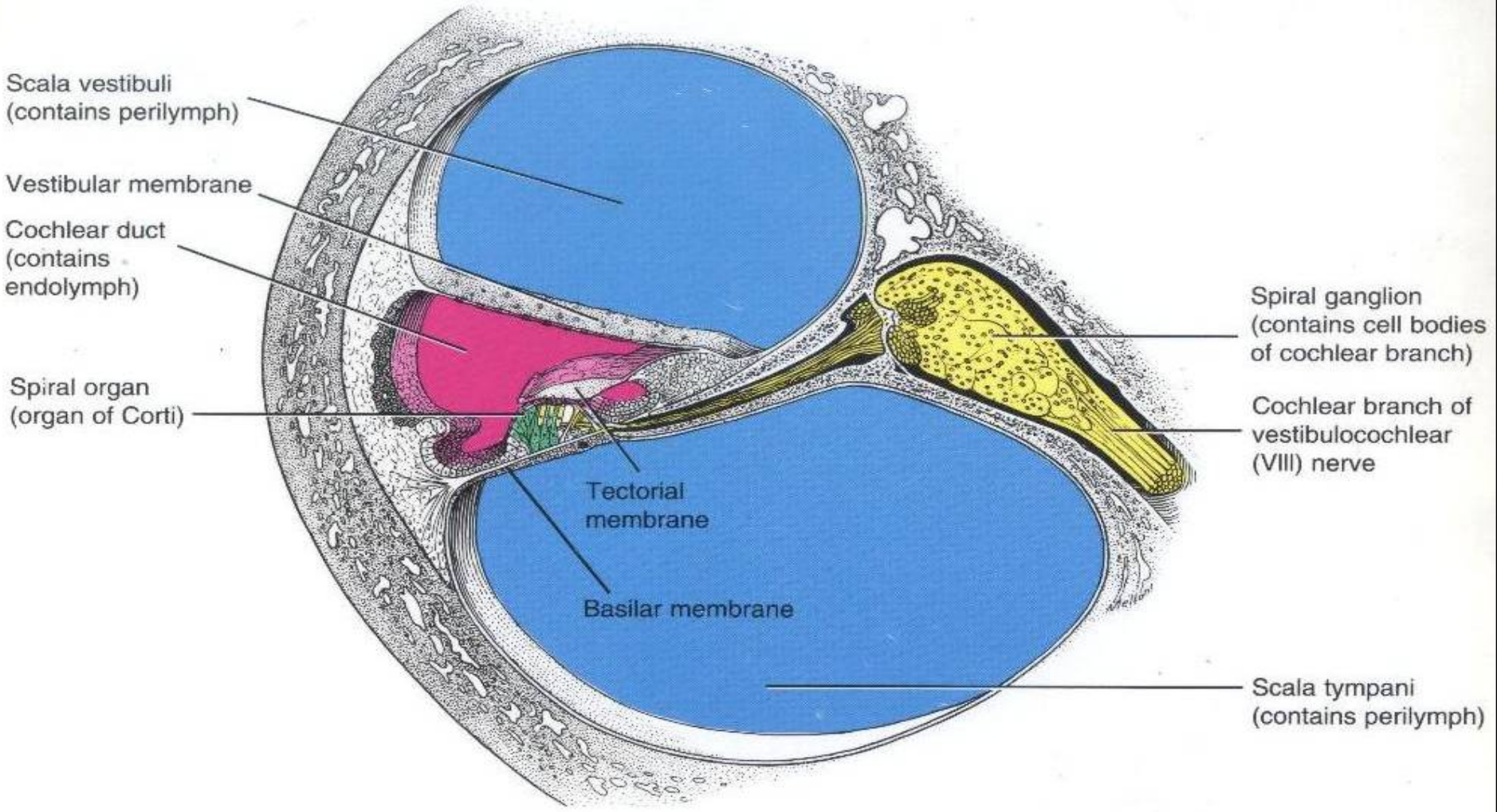

Stapes
Oval window
Scala vestibuli and scala media
Round window
Scala tympani
Basilar membrane
Helicotrema


Tectorial membrane
Reissner's membrane
Scala vestibuli
Stria vascularis
Scala media
Spiral limbus
Spiral prominence
Organ of Corti
Basilar membrane
Spiral ganglion
Scala tympani



(c) Section through one turn of the cochlea

16.20c

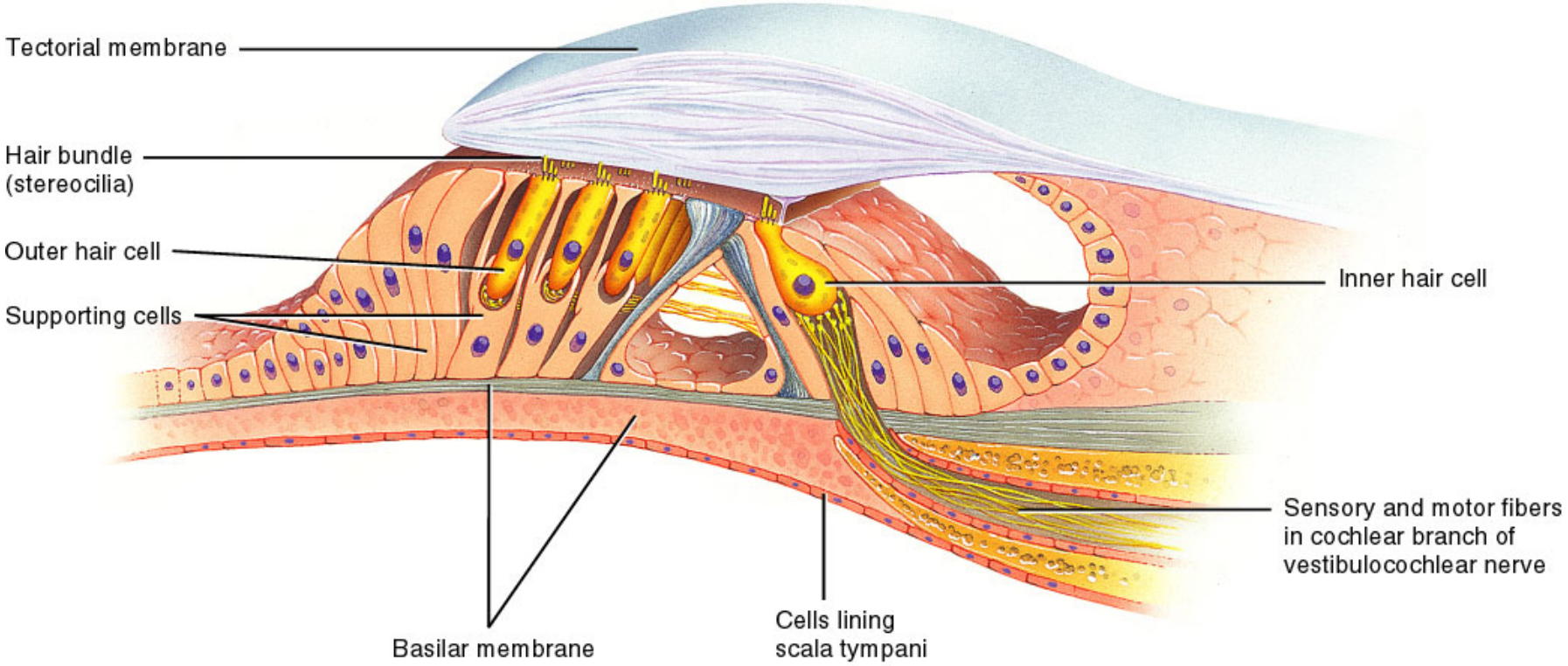

Scala vestibuli
(contains perilymph)
Vestibular membrane
Cochlear duct
(contains
endolymph)
Spiral organ
(organ of Corti)
Tectorial
membrane
Basilar membrane
Spiral ganglion
(contains cell bodies
of cochlear branch)
Cochlear branch of
vestibulocochlear
(VIII) nerve
Scala tympani
(contains perilymph)

BasilarMembrane

- 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
- the length of the fibers increase and the diameter of the fibers decrease from base to the helicotrema, overall stiffness decreases 100 times, high frequency resonance occurs near base, low near apex

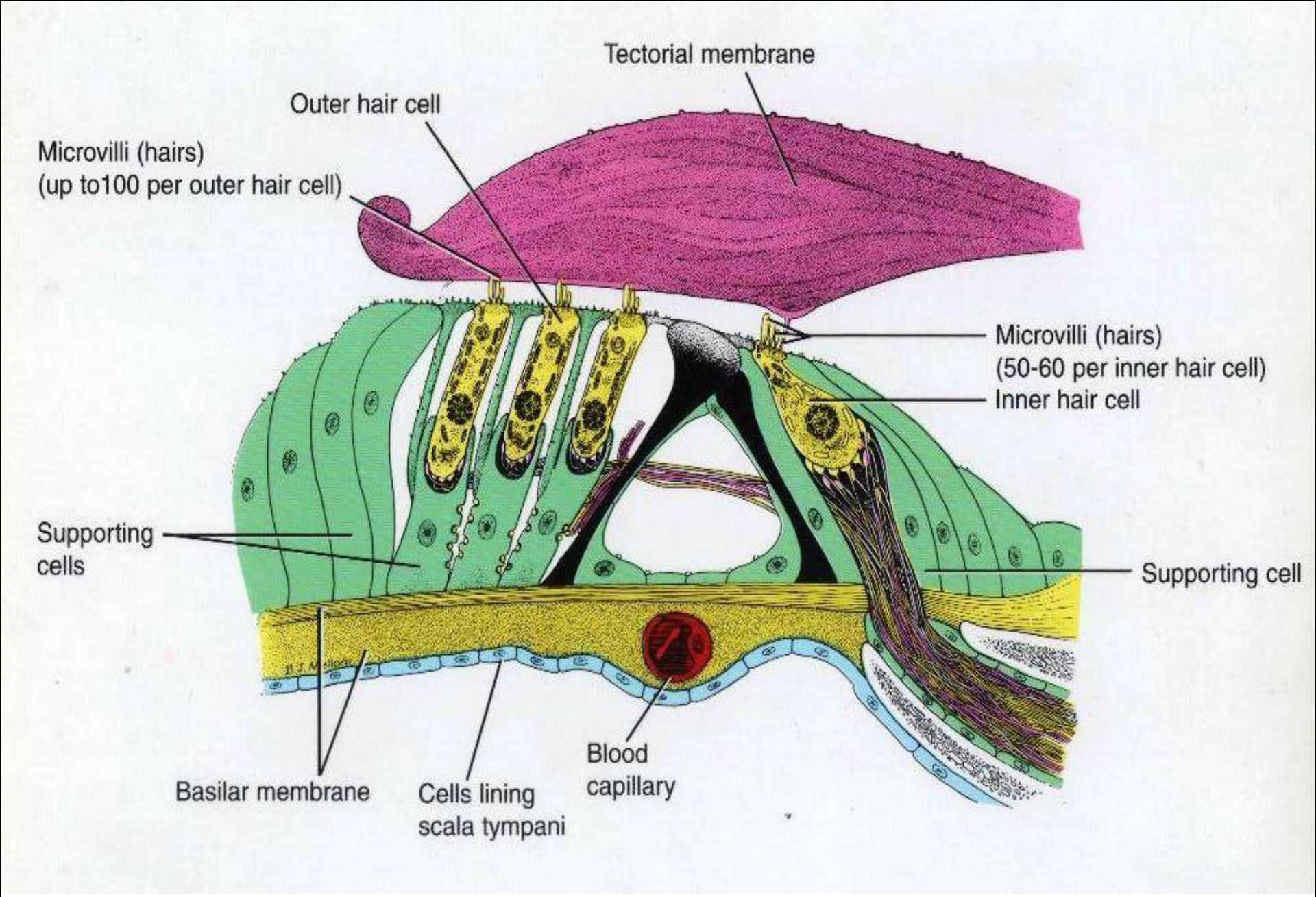
Organ of Corti

- receptor organ that generates nerve impulses
- lies on the surface of the basilar membrane, contains rows of cells with stereocilia called hair cells
- 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

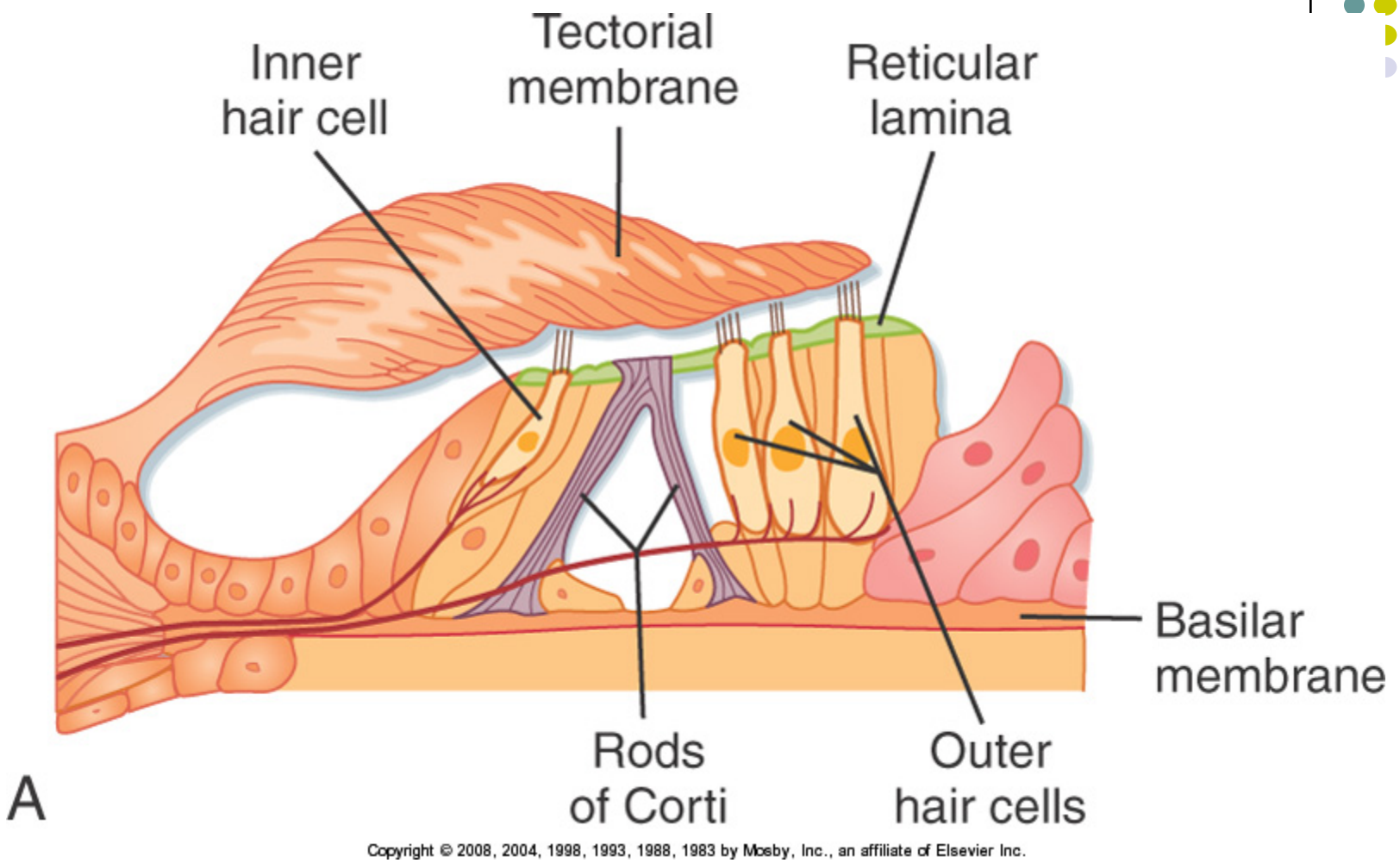


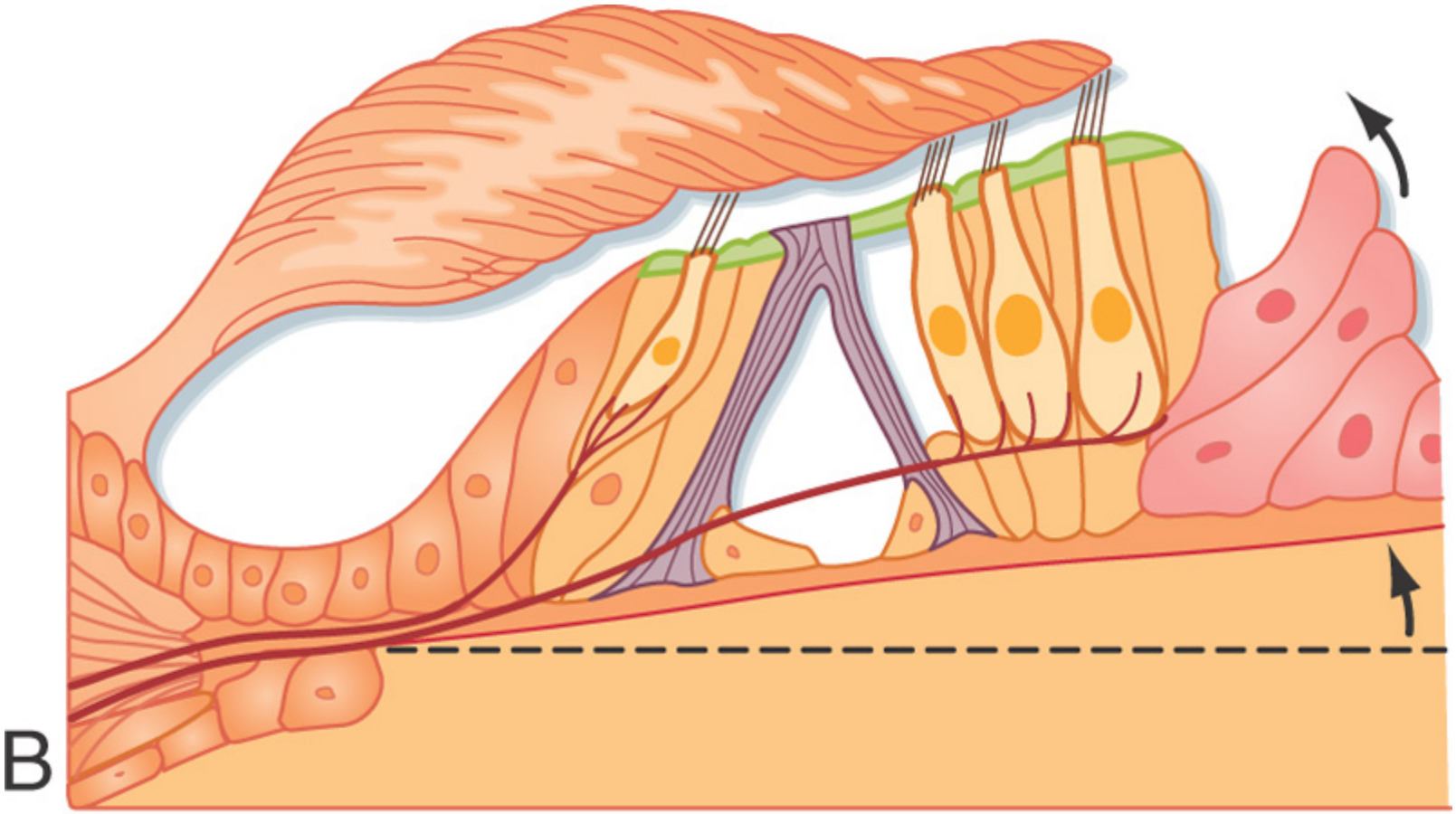
(d) Enlargement of spiral organ (organ of Corti)

16.20d

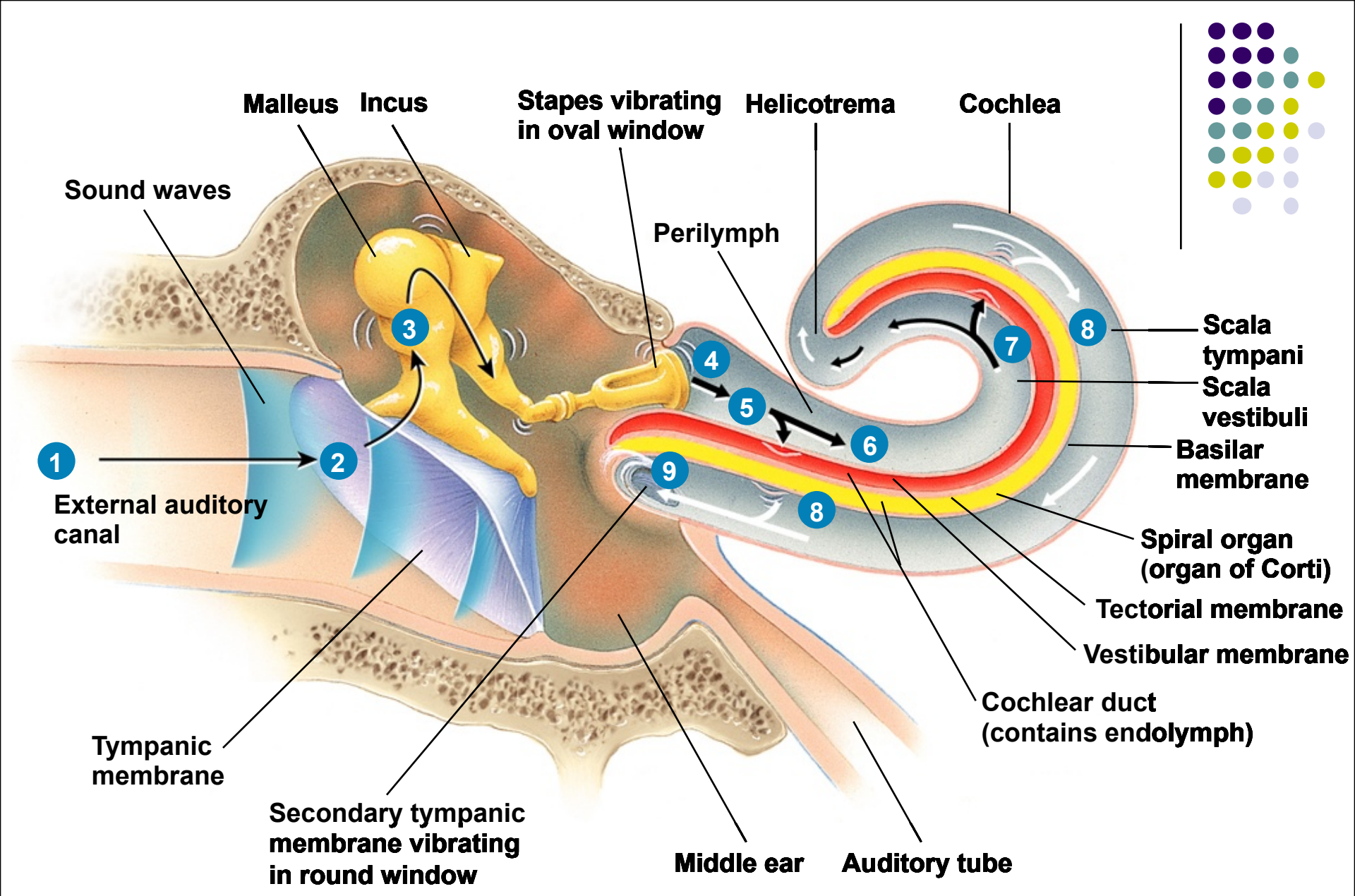

Tectorial membrane
Outer hair cell
Microvilli (hairs)
(up to100 per outer hair cell)
Microvilli (hairs)
(50-60 per inner hair cell)
Inner hair cell
Supporting
cells
Supporting cell
Basilar membrane
Cells lining
scala tympani
Blood
capillary

The Organ of Corti



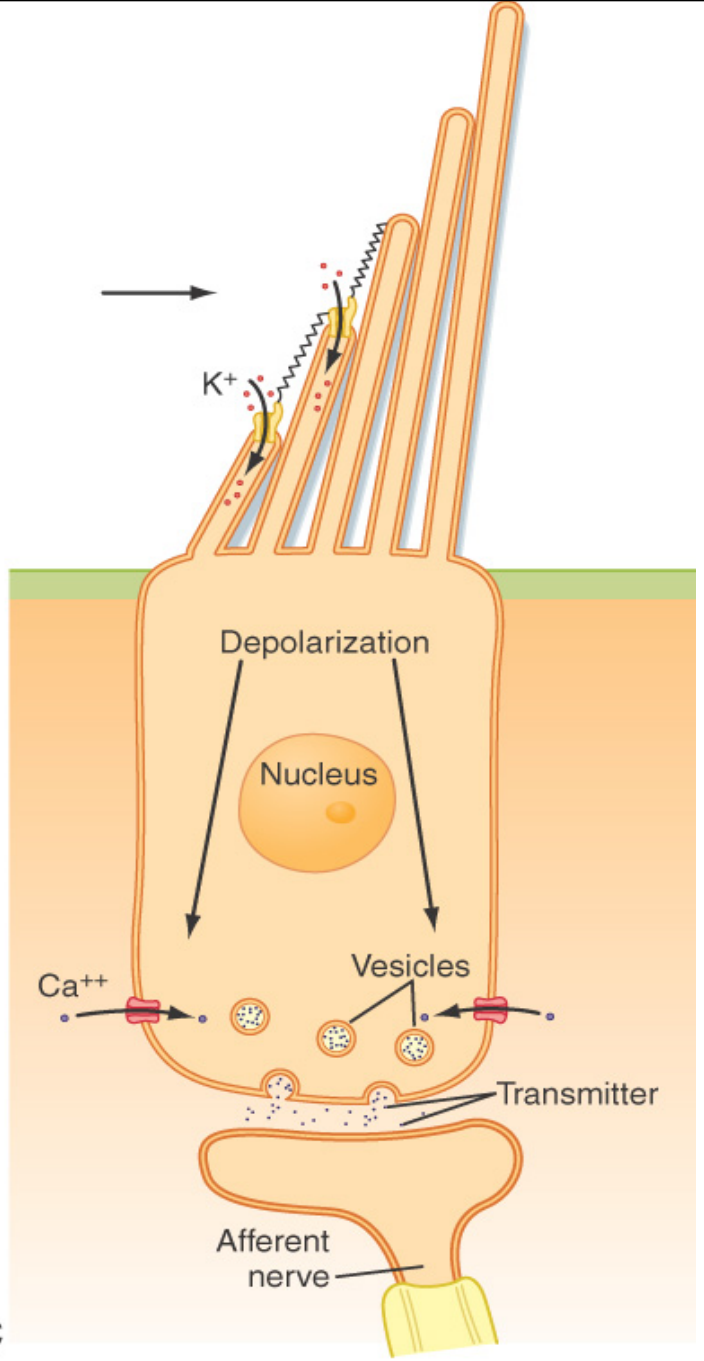


movement of the basilar membrane causes the stereocilia of the hair cells to shear back and forth against the tectorial membrane.

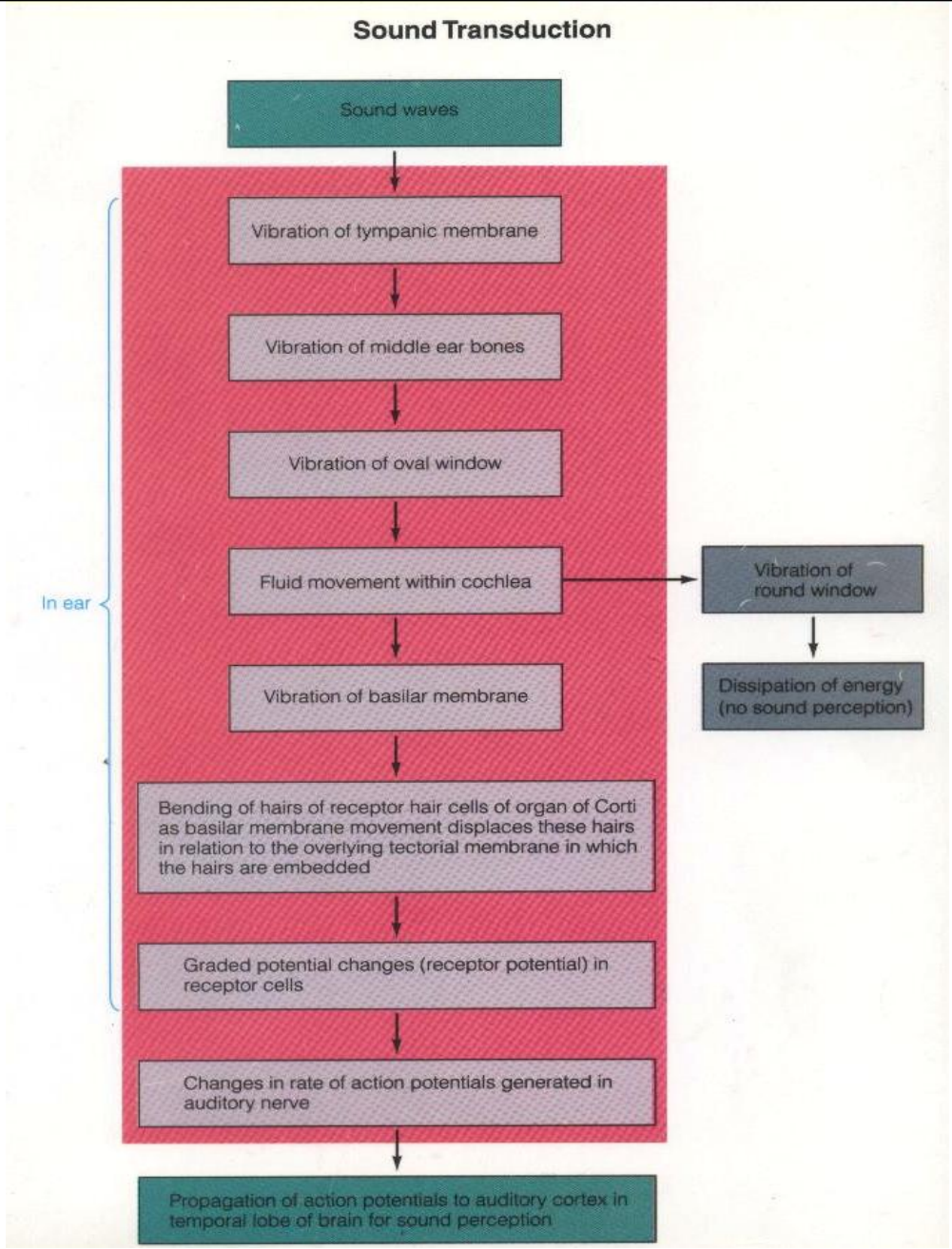

Malleus
Incus
Stapes vibrating in oval window
Helicotrema
Cochlea
Sound waves
Perilymph
Scala tympani
Scala vestibuli
Basilar membrane
Spiral organ (organ of Corti)
Tectorial membrane
Vestibular membrane
Cochlear duct (contains endolymph)
External auditory canal
Tympanic membrane
Secondary tympanic membrane vibrating in round window
Middle ear
Auditory tube
1
2
3
4
5
6
7
8
9

Nerve Impulse Origination

- The stereocilia, when bent in one direction 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.
  - 3-4 times as many outer hair cells than inner hair cells around 12000 outer hair cells and 3500 inner hair cells
  - outer hair cells may control the sensitivity of the inner hair cells for different sound pitches



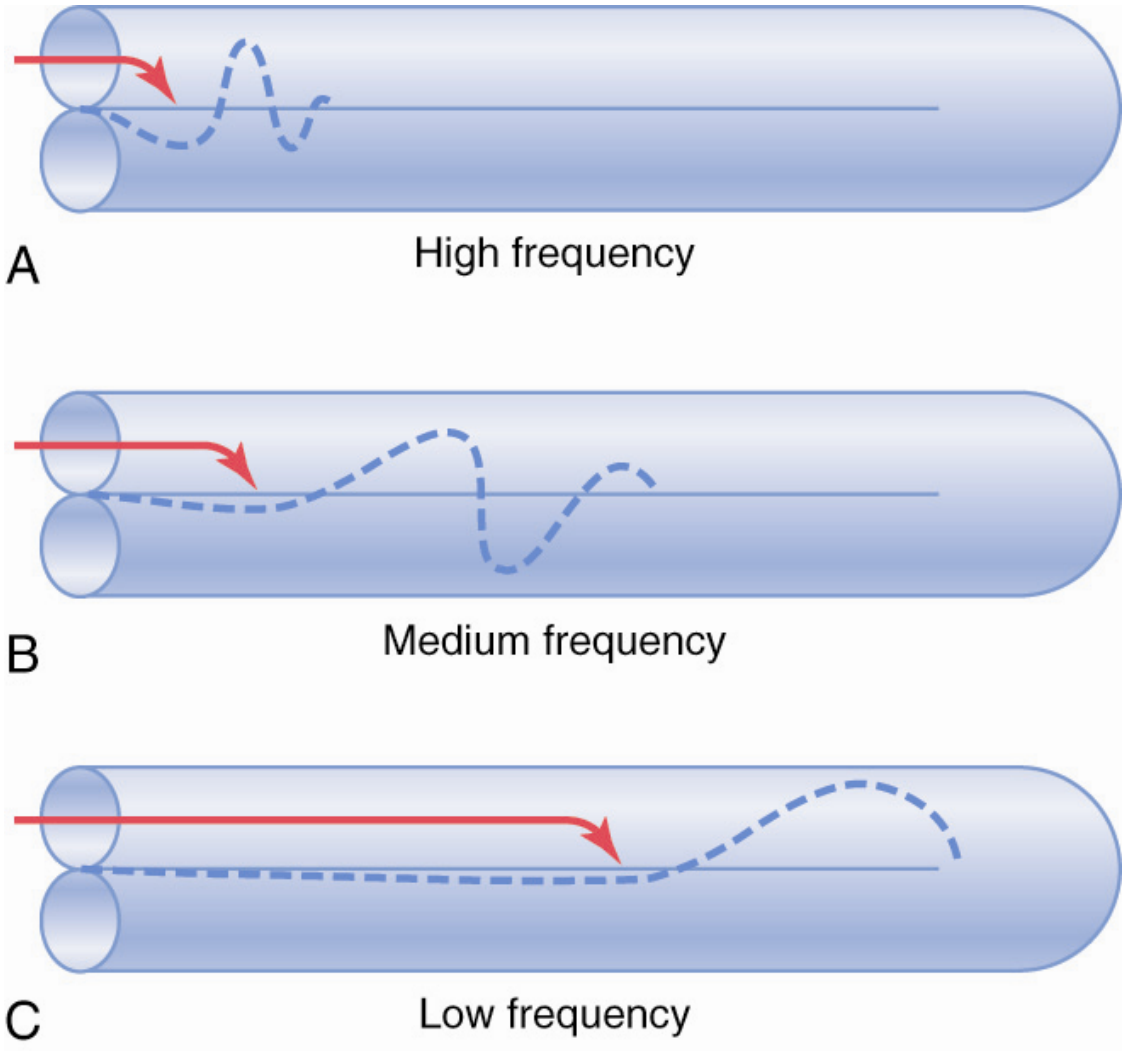
C


Sound Transduction
Sound waves
Vibration of tympanic membrane
Vibration of middle ear bones
Vibration of oval window
Fluid movement within cochlea
Vibration of round window
Dissipation of energy (no sound perception)
Vibration of basilar membrane
In ear
Bending of hairs of receptor hair cells of organ of Corti as basilar membrane movement displaces these hairs in relation to the overlying tectorial membrane in which the hairs are embedded
Graded potential changes (receptor potential) in receptor cells
Changes in rate of action potentials generated in auditory nerve
Propagation of action potentials to auditory cortex in temporal lobe of brain for sound perception

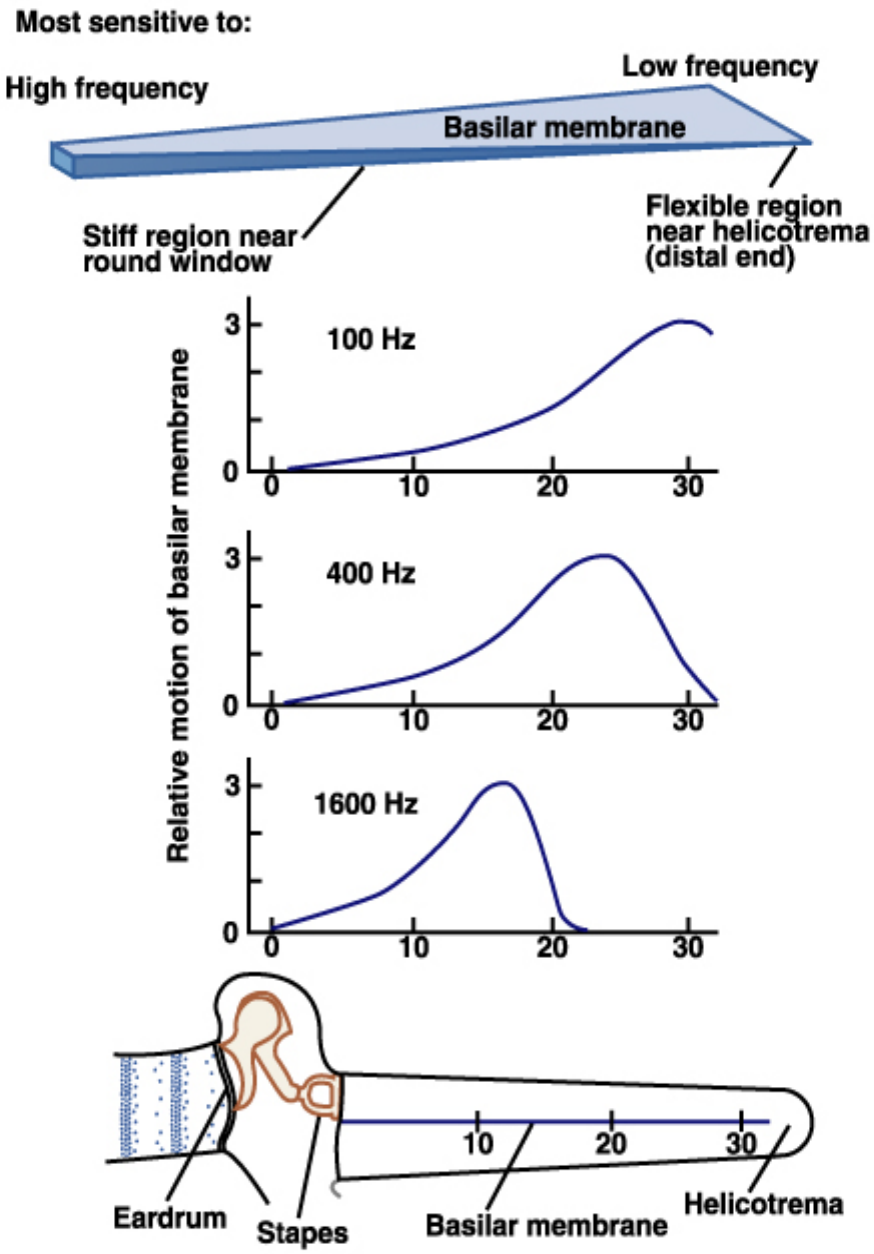
Determination of Sound Frequency and Amplitude (sound intensity)

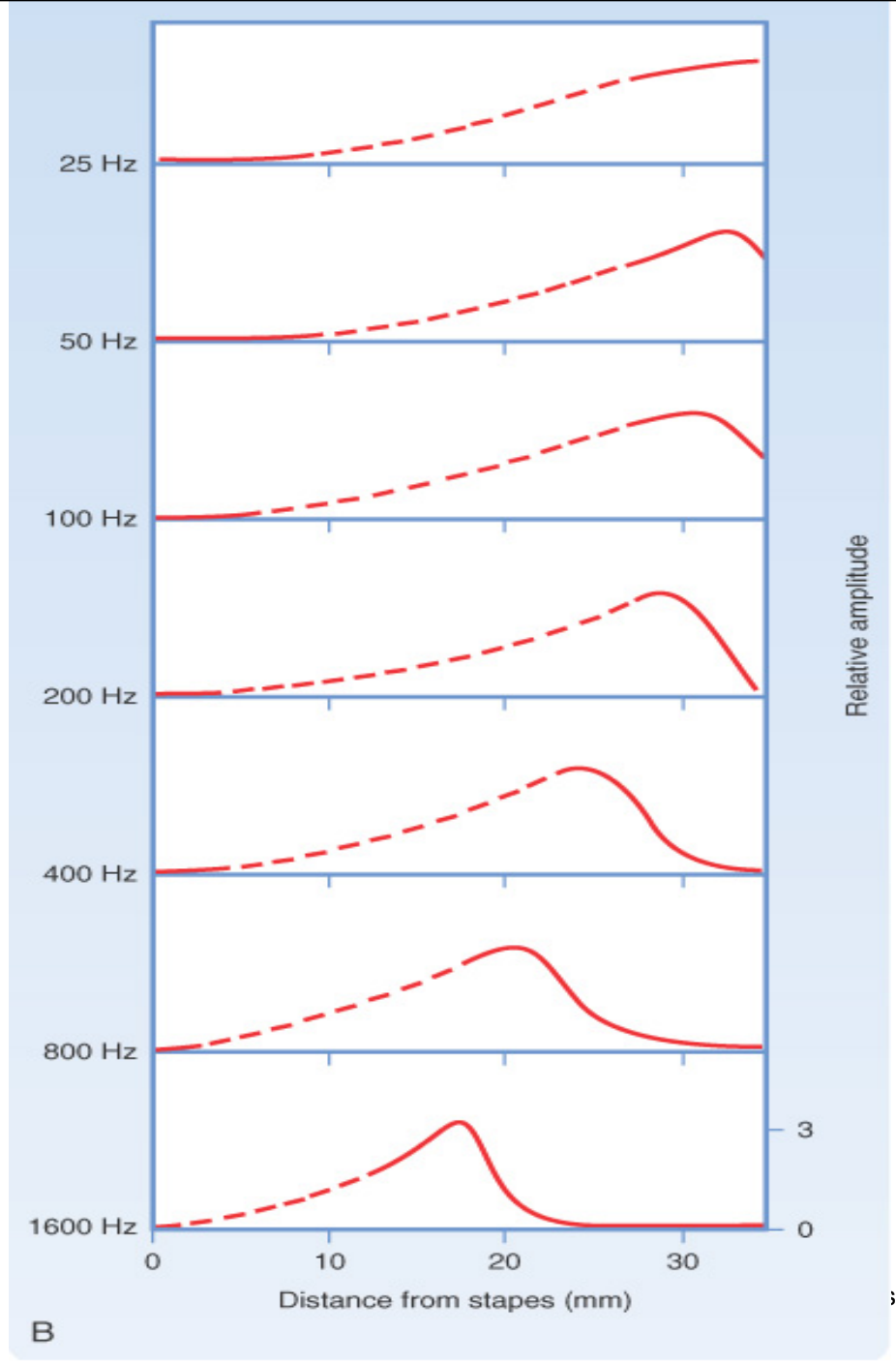
- *Place principle* determines the frequency of sound perceived.
  - Different frequencies of sound will cause the basilar membrane to oscillate at different positions (basilar membrane is tonotopically organized)
  - Position along the basilar membrane where hair cells are being stimulated determines the pitch of the sound being perceived.
- *Phase-locked (volley)* principle at lower frequencies of sound where firing rate determines the phase of sound wave (i.e frequency of sound wave)
- Amplitude is determined by how much the basilar membrane is displaced (by frequency of impulses from the nerve fiber and the No. of nerve fibers stimulated)

The “Place Principle”



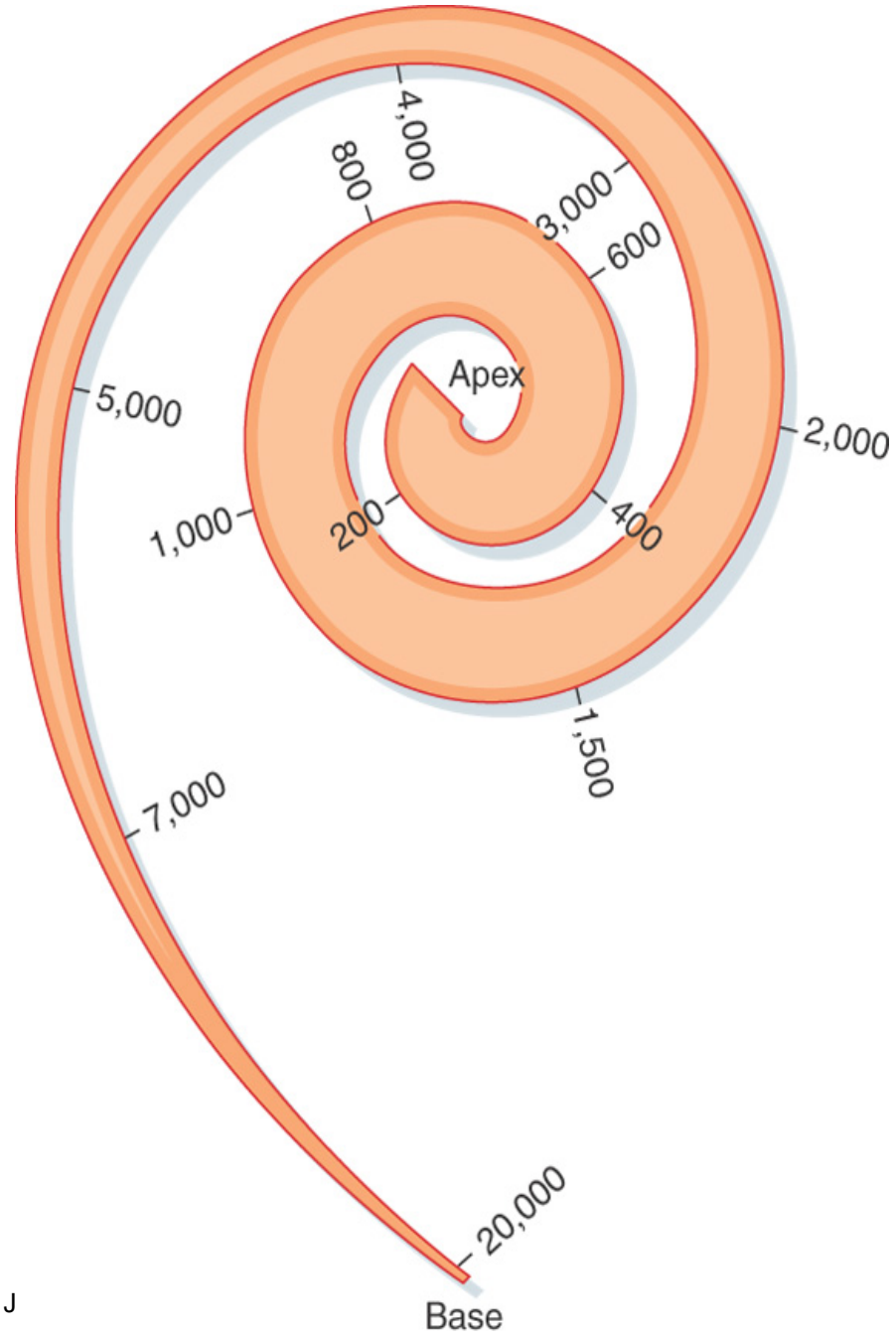
Phase-locked (volley) principle





(Redrawn from von Bekesy G: Experiments in Hearing. New York, McGraw-Hill, 1960.)

sity of J



(Redrawn from Stuhlman O: An Introduction to Biophysics. New York, John Wiley & Sons, 1943.)

Threshold of hair cells

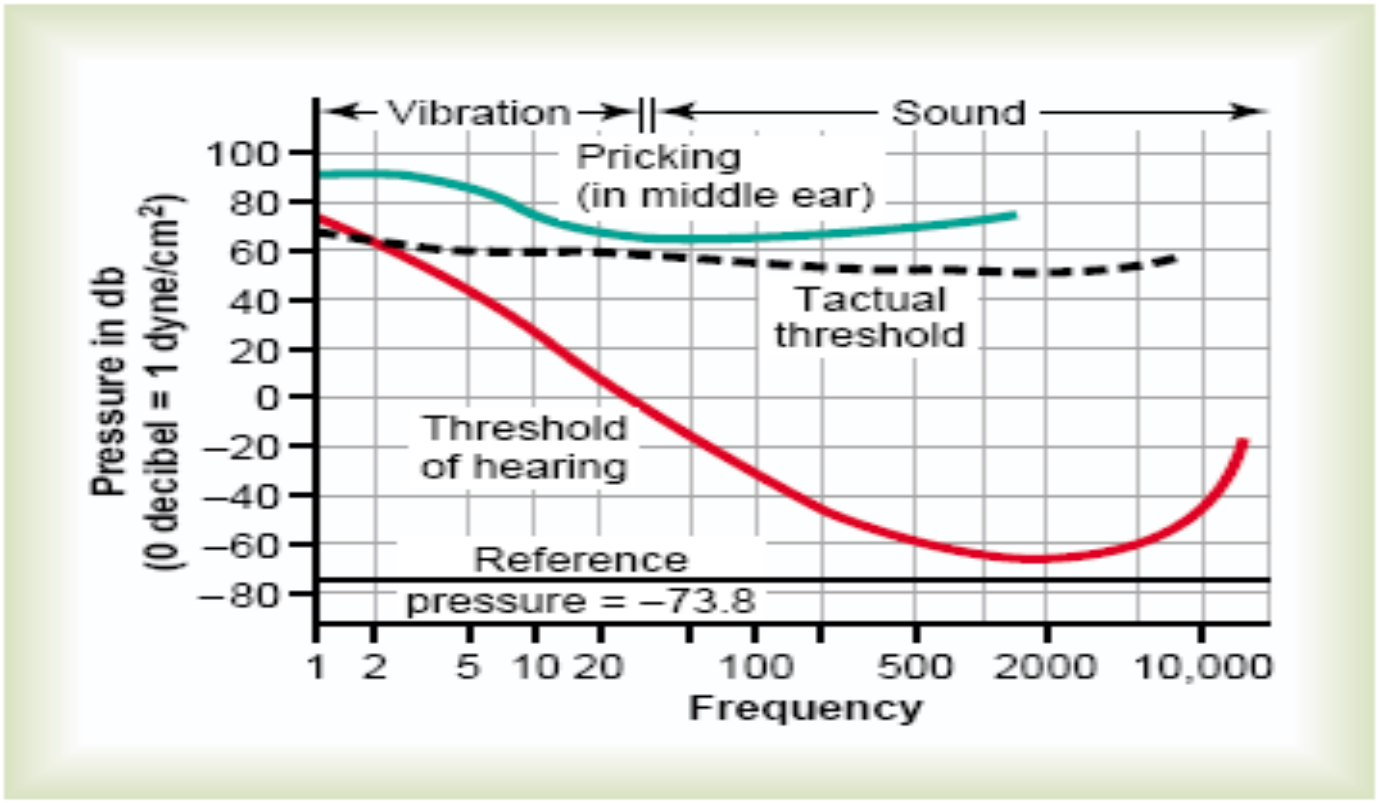
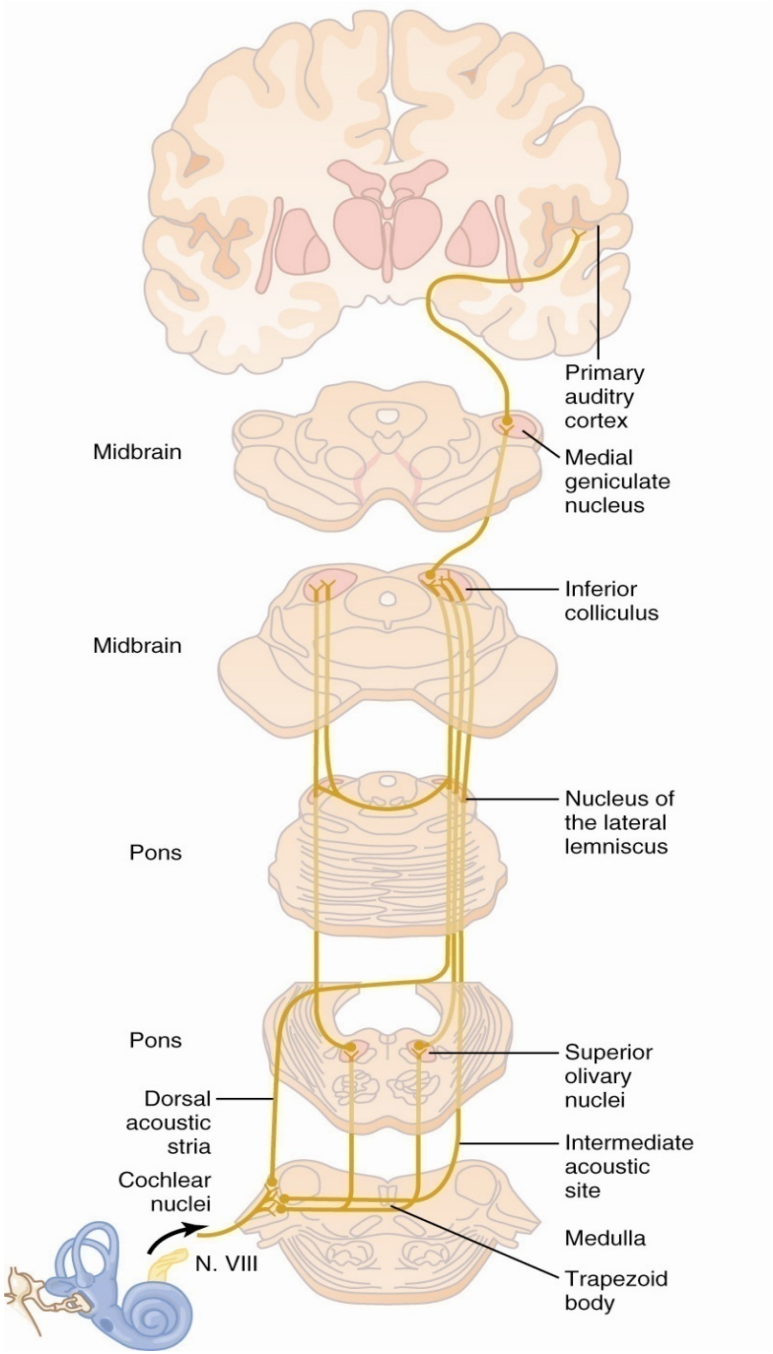


Figure 52–9

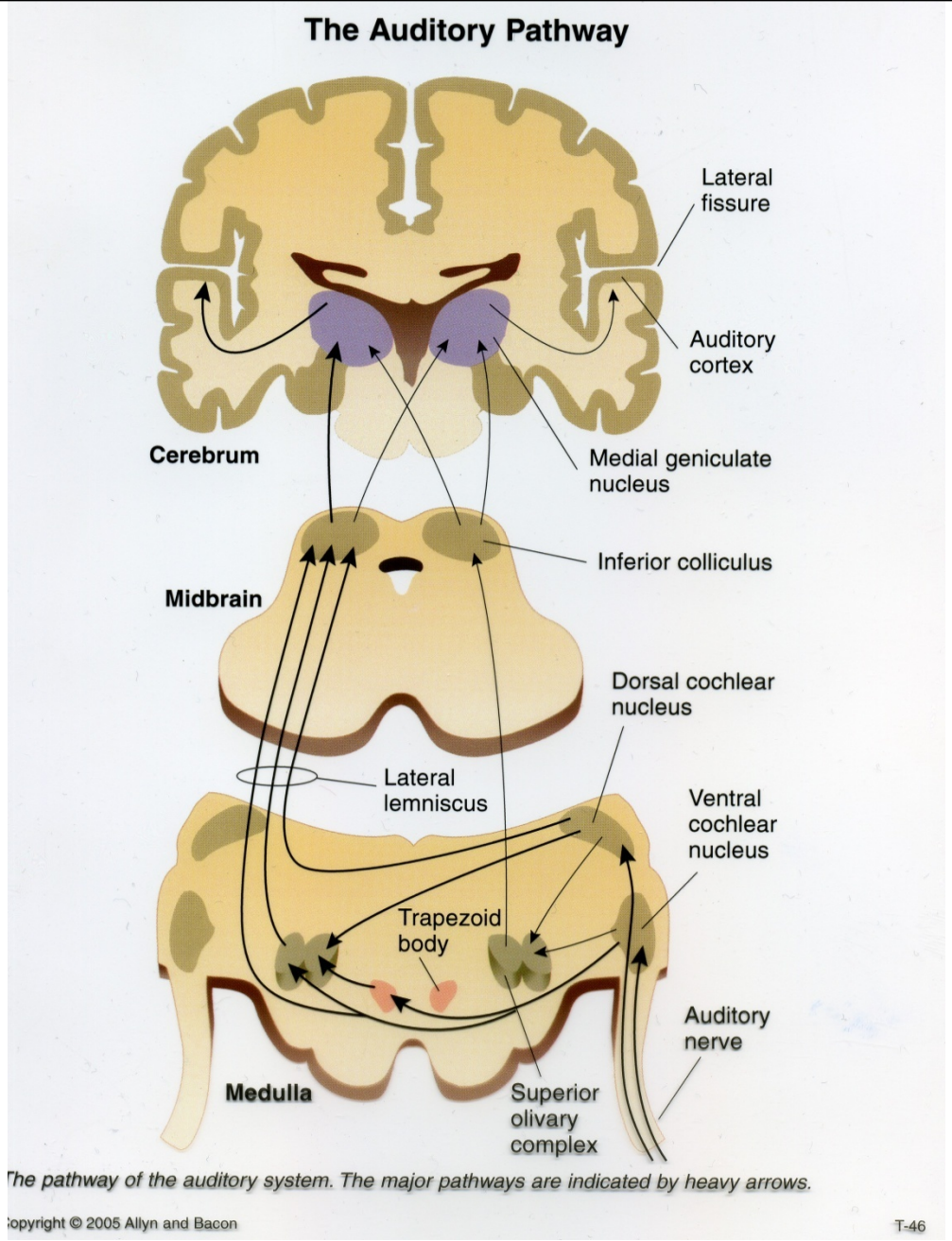
Relation of the threshold of hearing and of somesthetic perception (pricking and tactual threshold) to the sound energy level at each sound frequency.

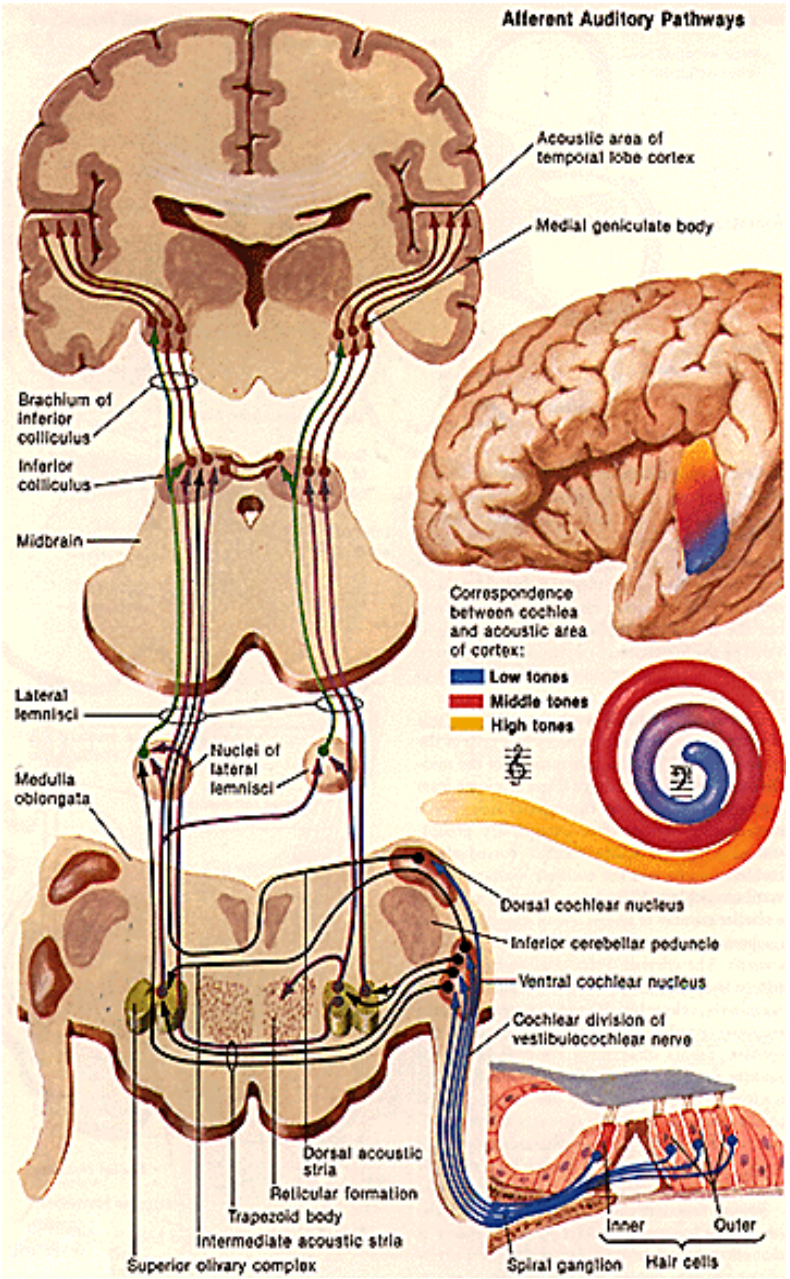
Decibel Unit of Sound

- 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



Central Auditory Pathway


The Auditory Pathway
Lateral fissure
Auditory cortex
Cerebrum
Medial geniculate nucleus
Inferior colliculus
Midbrain
Dorsal cochlear nucleus
Lateral lemniscus
Ventral cochlear nucleus
Trapezoid body
Auditory nerve
Medulla
Superior olivary complex
The pathway of the auditory system. The major pathways are indicated by heavy arrows.
Copyright © 2005 Allyn and Bacon
T-46


Afferent Auditory Pathways
Acoustic area of temporal lobe cortex
Medial geniculate body
Brachium of inferior colliculus
Inferior colliculus
Midbrain
Correspondence between cochlea and acoustic area of cortex:
Low tones
Middle tones
High tones
Lateral lemnisci
Nuclei of lateral lemnisci
Medulla oblongata
Dorsal cochlear nucleus
Inferior cerebellar peduncle
Ventral cochlear nucleus
Cochlear division of vestibulocochlear nerve
Dorsal acoustic stria
Reticular formation
Trapezoid body
Intermediate acoustic stria
Superior olivary complex
Inner
Outer
Spiral ganglion
Hair cells

from medial geniculate to auditory cortex

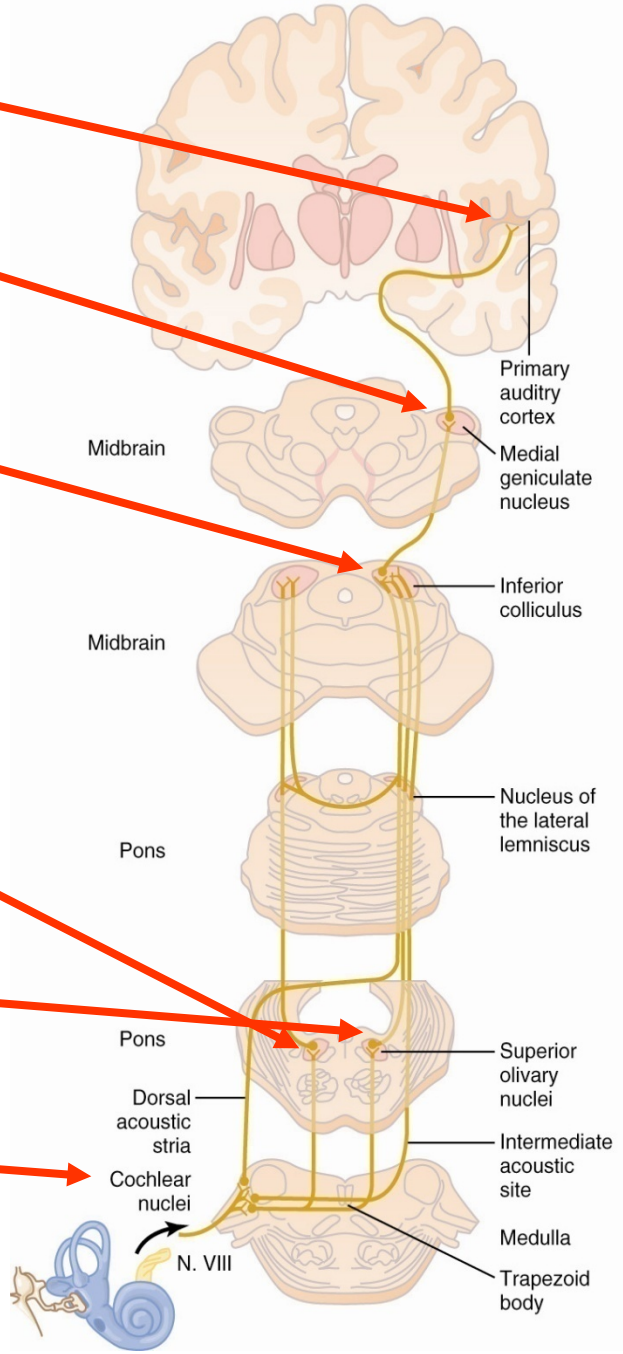
from inferior colliculus to medial geniculate

from superior olivary nucleus to inferior colliculus via the lateral lemniscus

some fibers pass to the ipsilateral superior olivary nucleus.

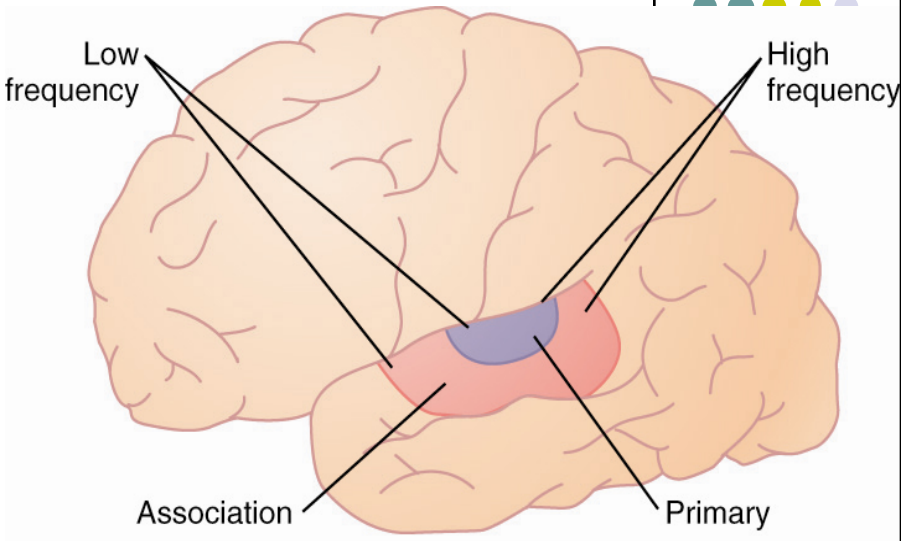
2nd order neurons project through trapezoid body to the contralateral superior olivary nucleus.

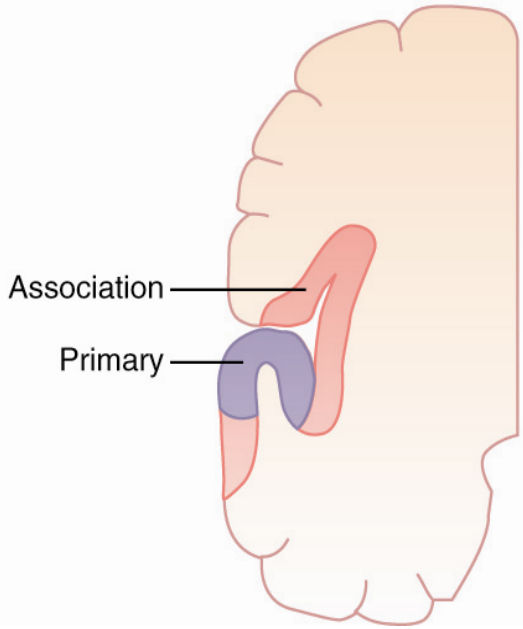
fibers enter dorsal and ventral cochlear nuclei of the upper part of the medulla.



Auditory Cortex and Association Areas

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





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 two 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

Audiometery

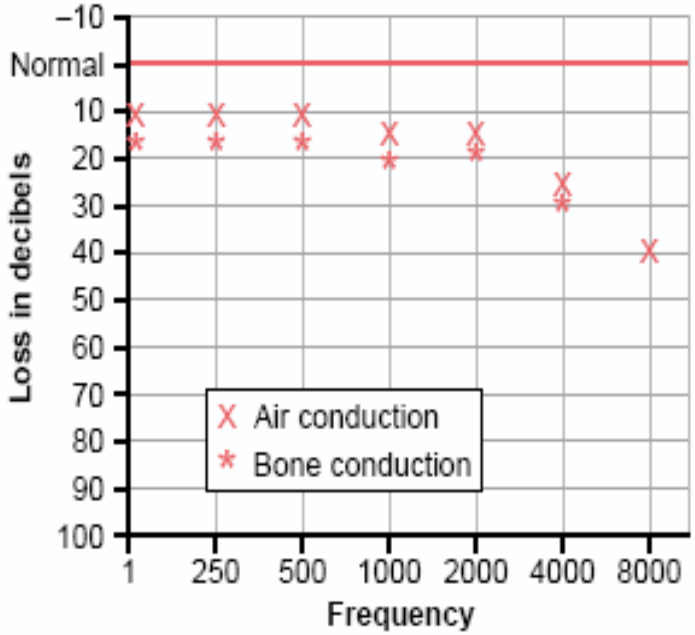


Figure 52–12

Audiogram of the old-age type of nerve deafness.

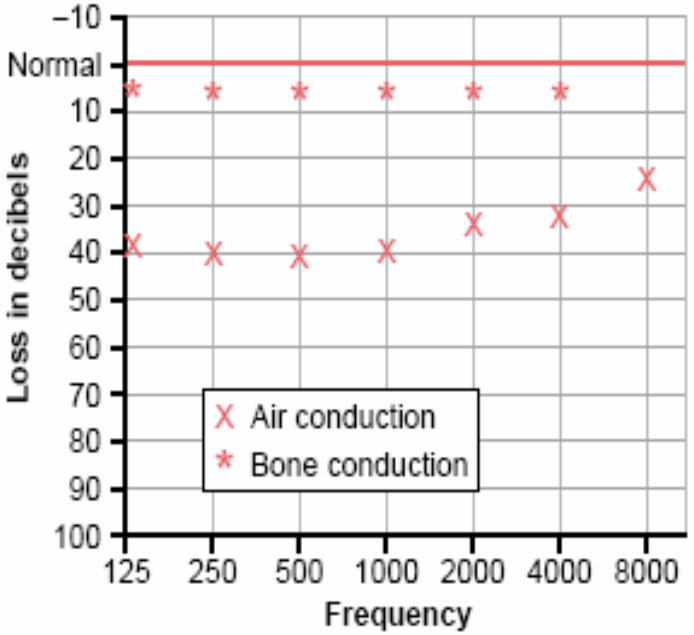


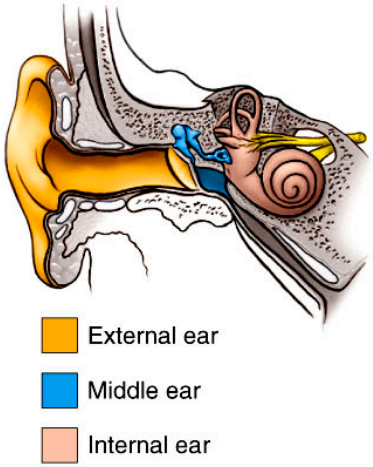
Figure 52–13

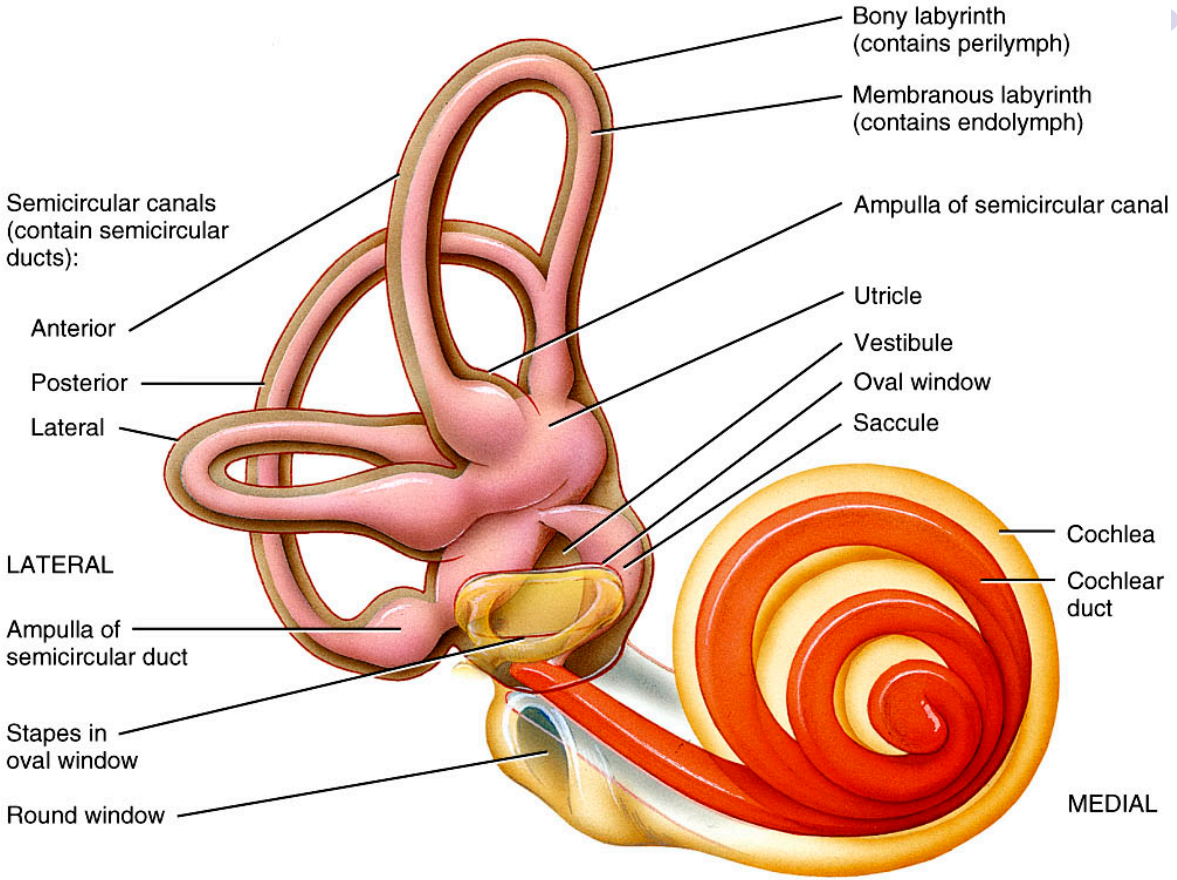
Audiogram of air conduction deafness resulting from middle ear sclerosis.

Weber test

Rinne test

The Internal Ear (Site of Equilibrium Receptors)





(a) Components of the right internal ear

Figure 17.20 Tortora - PAP 12/e

Thank You