

The logo consists of a grey outline of a human head in profile, facing right. Inside the head, there is a stylized grey ear. To the right of the ear, there are three blue curved lines representing sound waves.

Anatomy and Physiology of Hearing

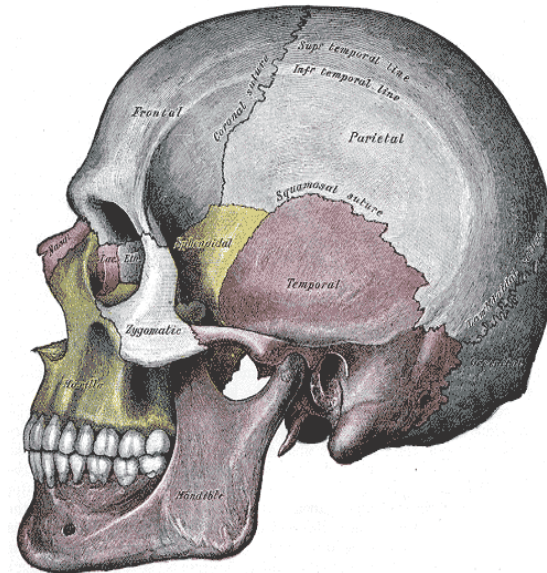
BHPI
hearing for all 2024

The Human Ear



Temporal Bone

- Found on each side of the skull and contains the organs for hearing and balance
- Divided into four major portions:
 - squamous
 - mastoid
 - tympanic
 - petrous



Temporal Bone

Squamous

- Appears as a thin bony (connected to the cranium) fanlike projection superior and anterior to the opening of the external auditory meatus

Mastoid

- Posterior and inferior to the ear canal that produces a slight bulge felt behind the ear and has numerous air-filled spaces or air-cells

Temporal Bone

Tympanic

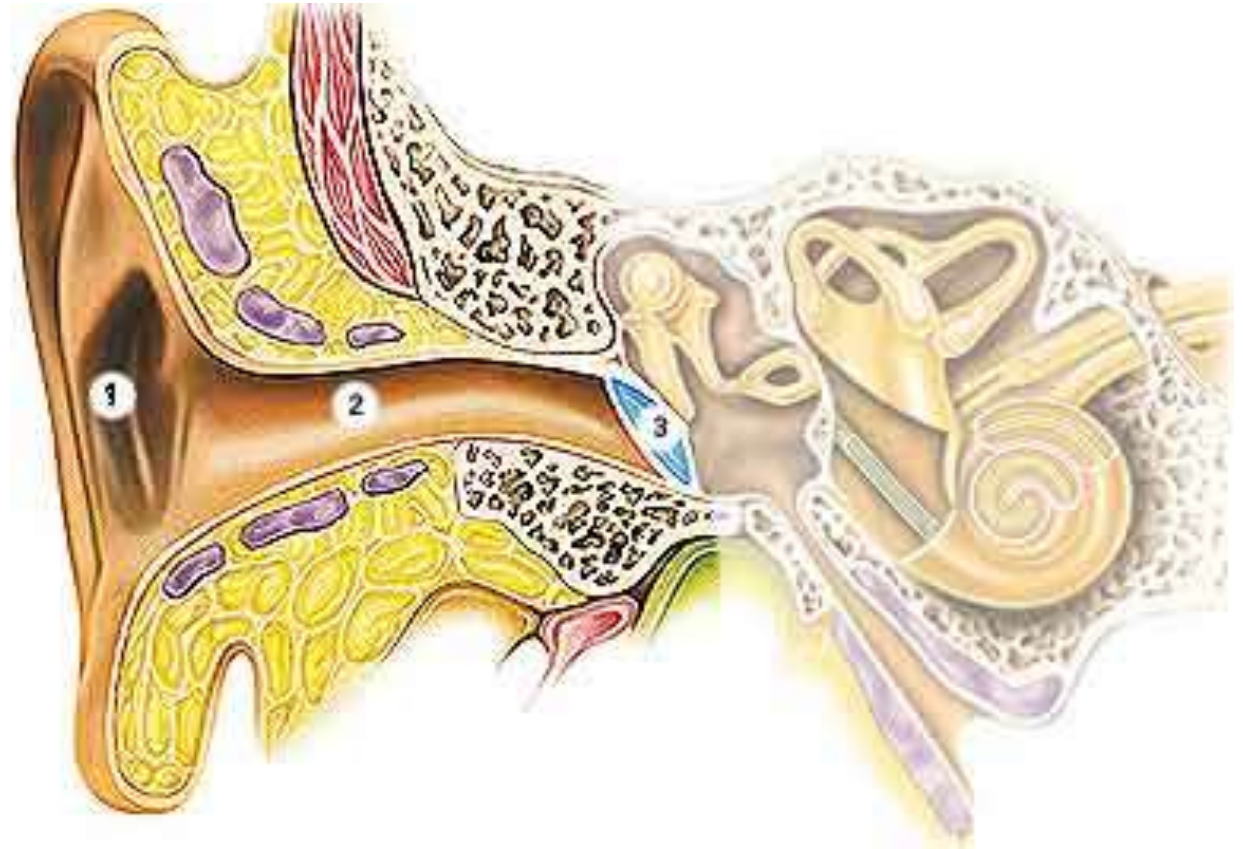
- Forms the floor and part of the anterior and posterior walls of the external canal

Petrous

- Projects medially from the other three portions where the sensory organs are found

External Ear

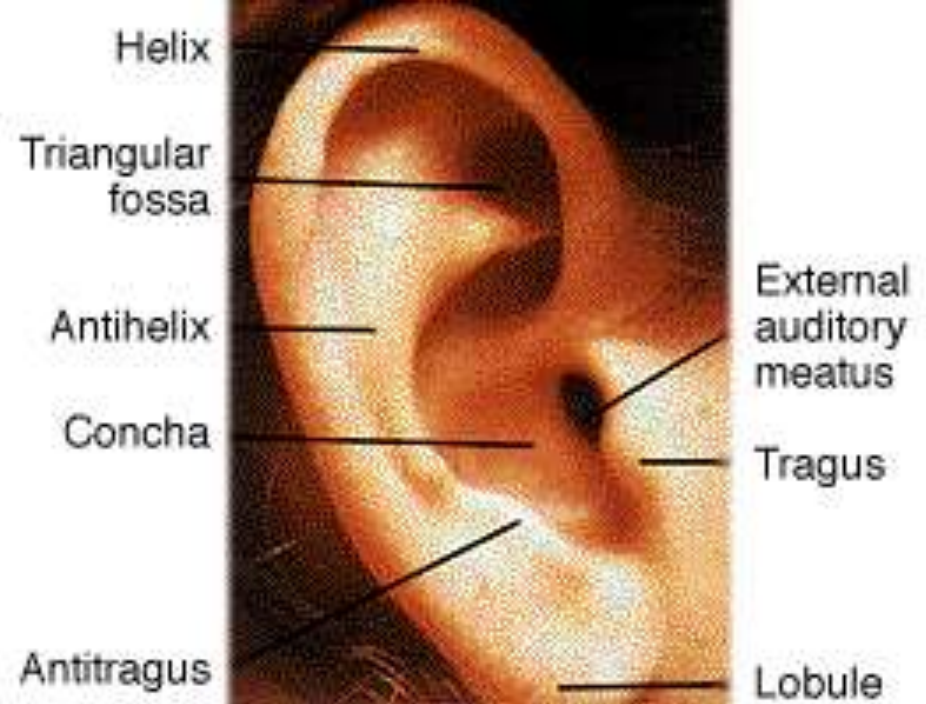
- 1) Pinna
- 2) Ear canal
- 3) Ear drum





Pinna/Auricle

- Composed entirely of cartilage and skin except for the dependent lobule, which contains no cartilage
- Attached muscles are innervated by the facial nerve

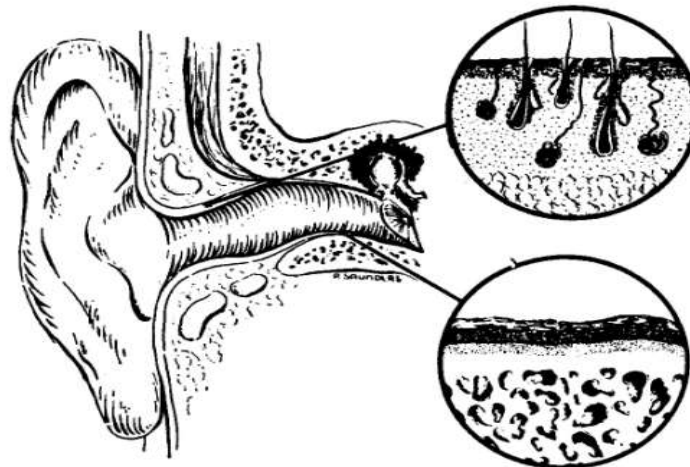


Pinna/Auricle

- aids in sound localization
- boosts acoustic pressure
- sound collector, intercepting sound energy and deflecting it to the auditory canal

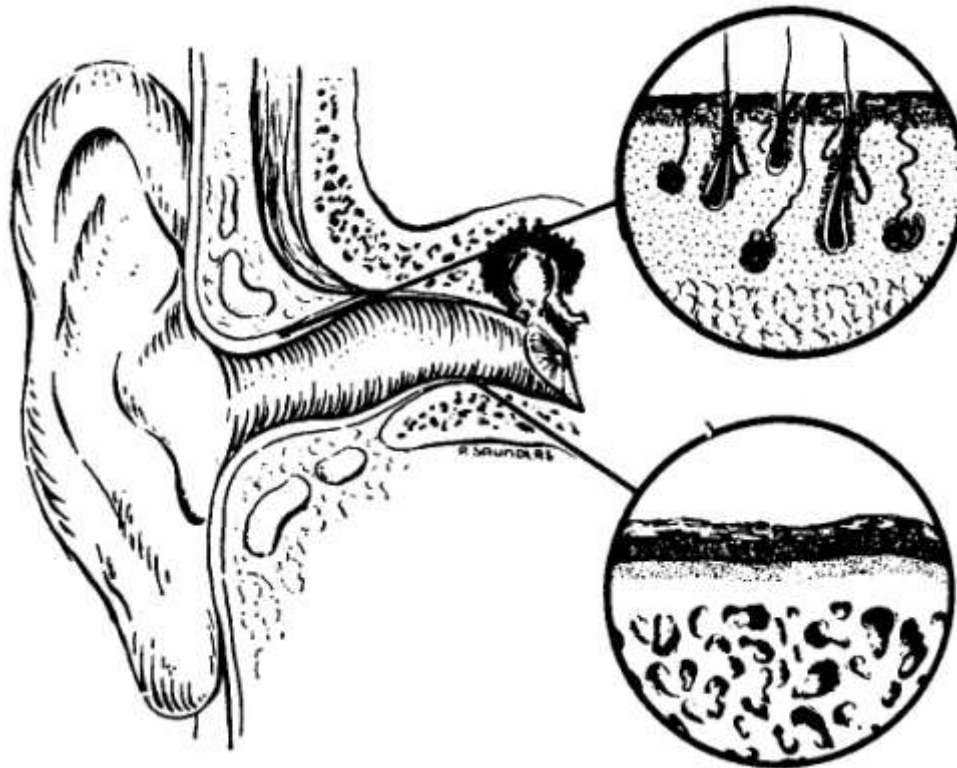
External Auditory Canal

- Ending at the tympanic membrane, its superior wall is about 5mm shorter than its anteroinferior wall, thus accounting for the oblique positions of the tympanic membrane
- Outer half is cartilaginous and the inner half is bony
- approximately 7mm diameter by 28mm length



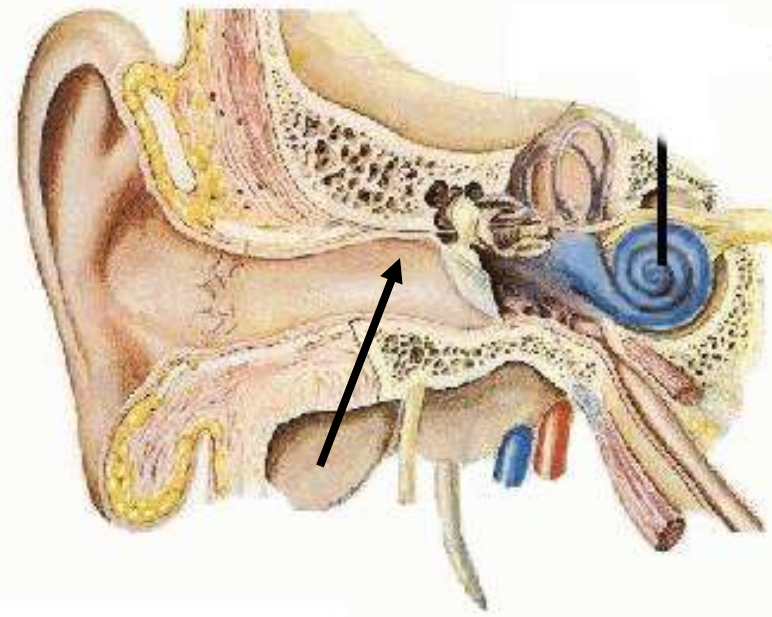
External Auditory Canal

- the skin of the cartilaginous portion of the canal contains glands which secrete cerumen



External Ear

- the skin lining the cartilaginous canal is thick and contains fine hairs, sebaceous glands, and special glands that produce cerumen
- among adults, it is approximately 24mm long with the bony canal being longer than the cartilaginous one



External Auditory Canal

- Protection against physical trauma and entry of foreign bodies
- Protects the tympanic membrane and ossicles
- Permit sound waves to reach the tympanic membrane

Middle Ear

4) Malleus

5) Incus

6) Stapes

7) Eustachian tube



Middle Ear

- Roughly oblong space lined with mucous membrane
- All walls are bony except the lateral part, which is the tympanic membrane
- The eustachian tube is located in the anterior portion leading downward and medially to the nasopharynx

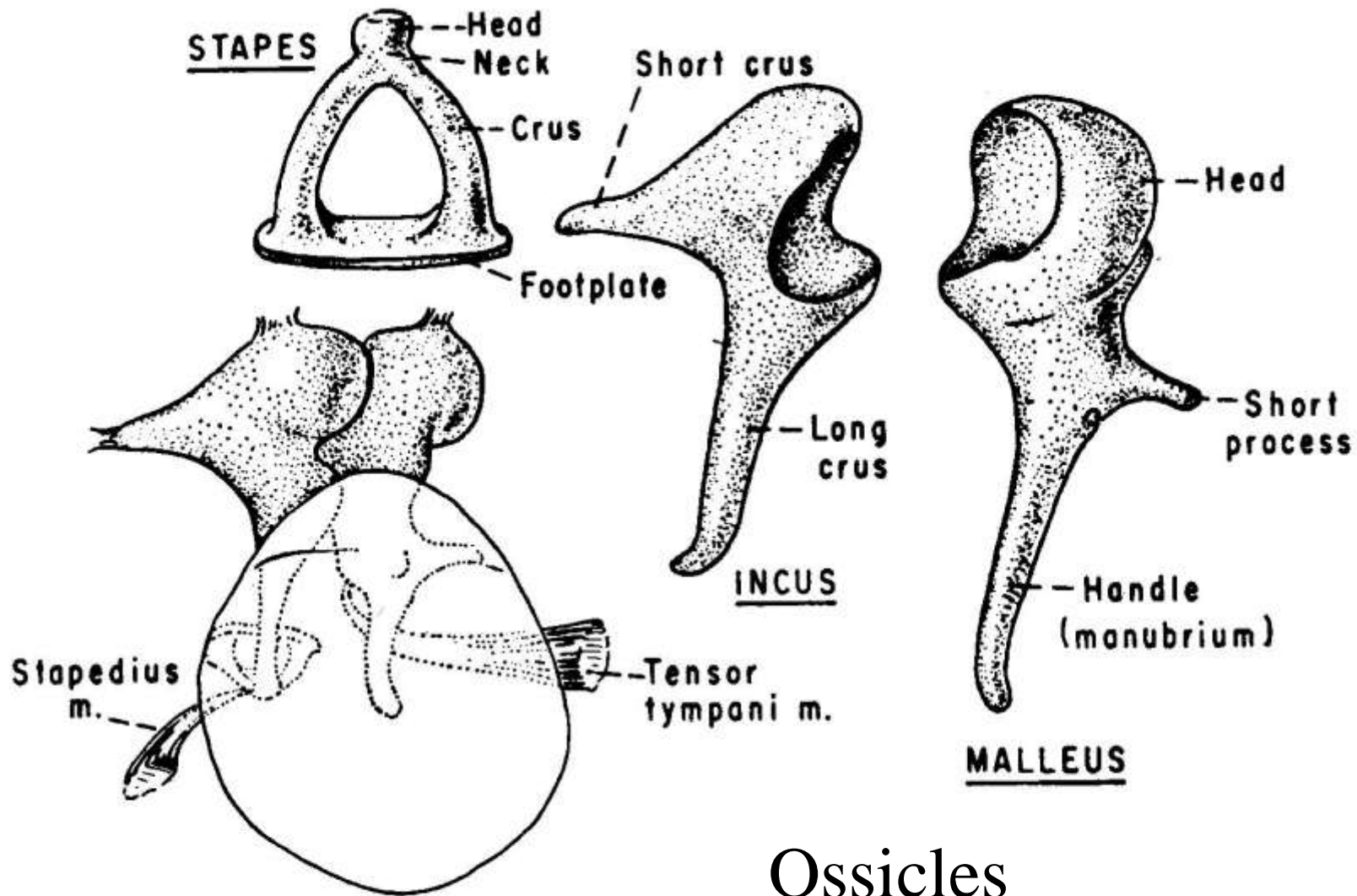
Middle Ear

- The middle ear cavity consists of several inter-connected air-filled spaces:
 - tympanic cavity (lying between the inner and outer ear)
 - epitympanic recess or attic (above the eardrum)
 - mastoid antrum (extending posteriorly from the attic via the aditus)

Middle Ear

Ossicles

- tiny bones entirely covered with middle ear mucosa
- Connects the tympanic membrane with the oval window and represent the normal pathway of sound transmission across the middle ear space



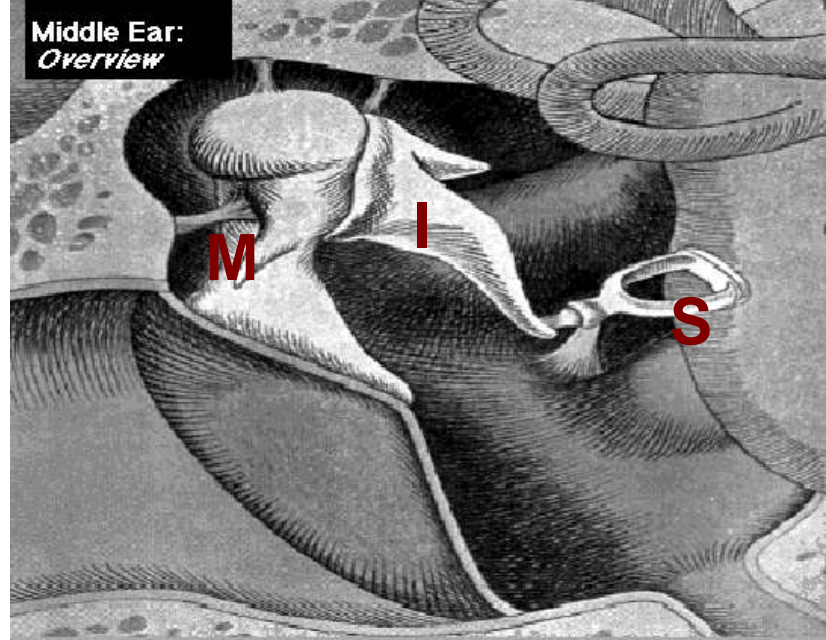
Ossicles articulated —
seen through eardrum

Ossicles

Middle Ear

Promontory

- A dome like prominence medially and directly opposite the tympanic membrane
- The basal turn of the cochlea
- Posteriorly and superiorly, the stapes fits into the oval window
- Inferiorly is the round window niche



Ossicular Chain (Malleus and Incus)

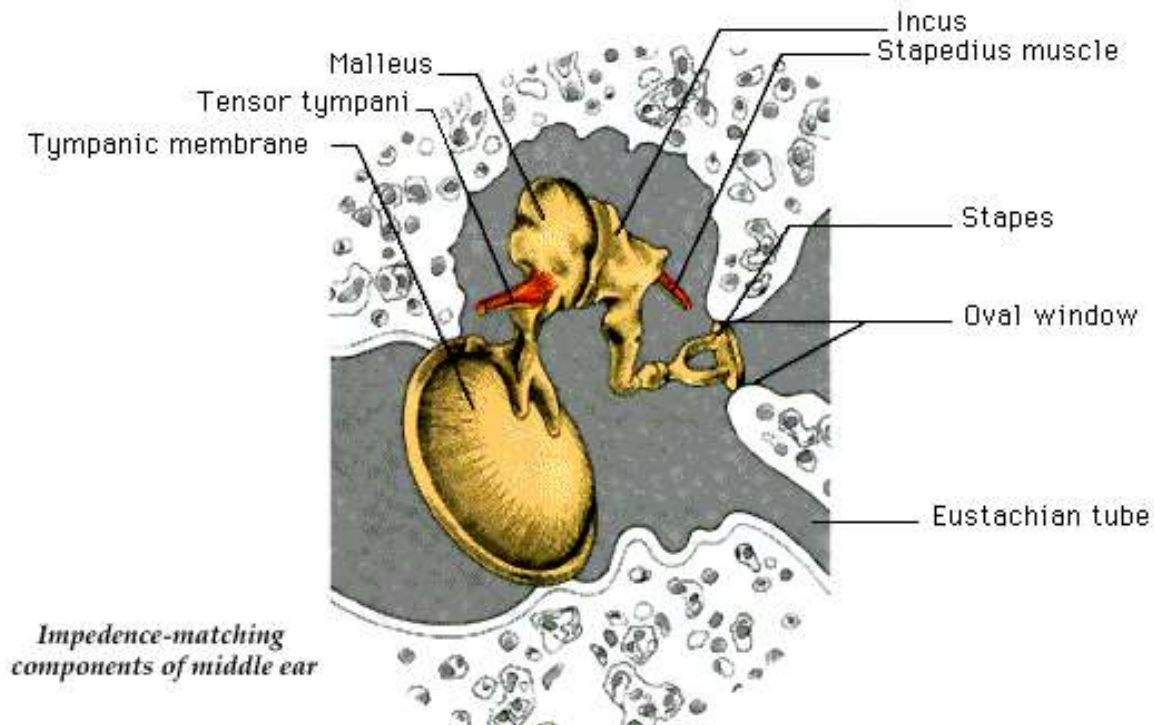
- vibrate as a unit, rocking on a linear axis which runs from the anterior ligament of the malleus to the attachment of the short process of the incus in the fossa incudis

Eustachian Tube

- Opens from the lateral wall of the nasopharynx just above the plane of the floor of the nose
- The cartilaginous medial portion is about 24mm long and the osseous portion is approximately 12mm long

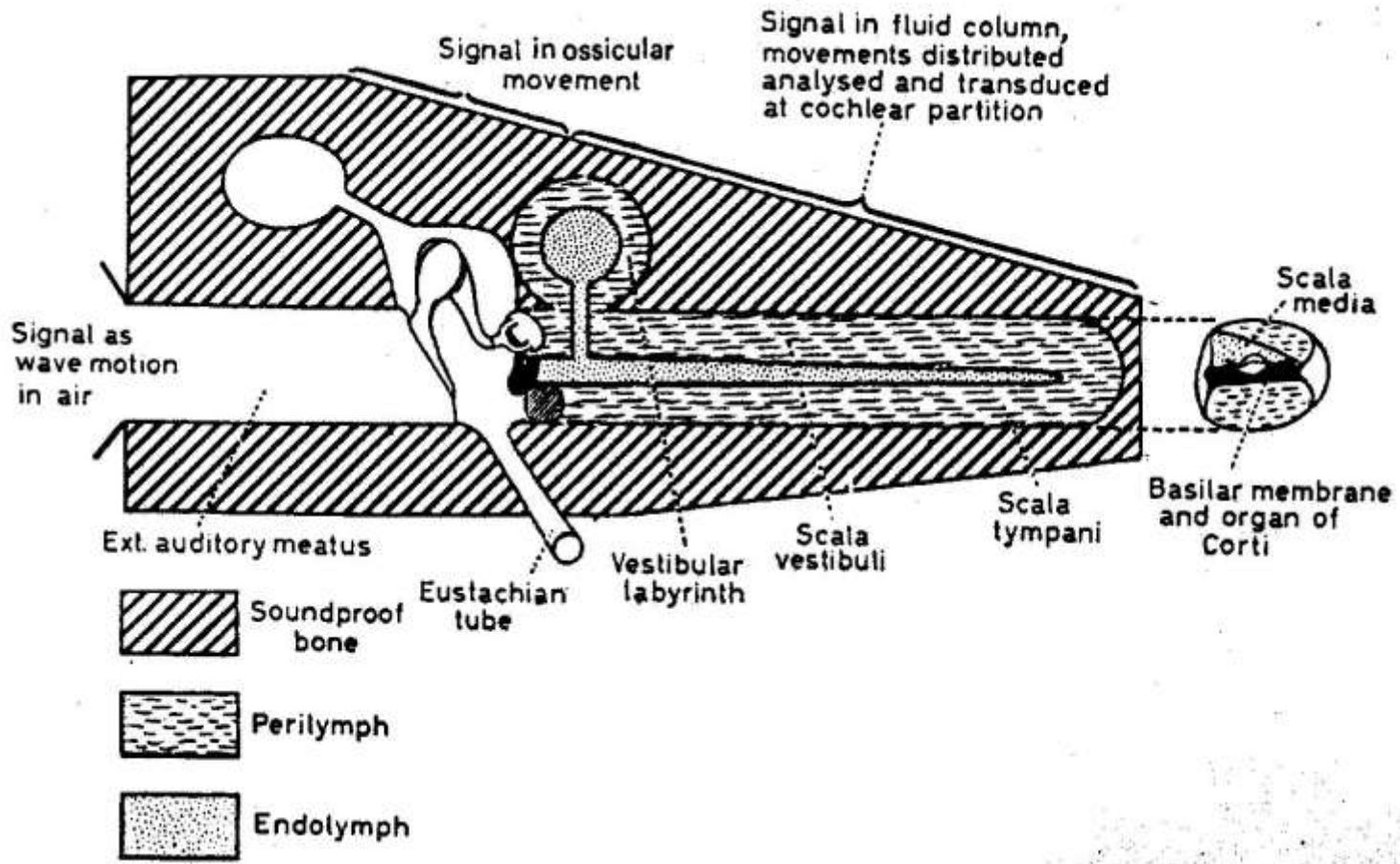
Tympanic Membrane

- Major portion is formed with layers of tissue known as pars tensa
- The most lateral layer is simply skin which is continuous with the lining of the external auditory canal
- The most medial layer is a part of the mucous lining which covers the inner surfaces of the middle ear cavity
- In between are dense fibrous layers which gives the membrane some stiffness



Tympanic Membrane

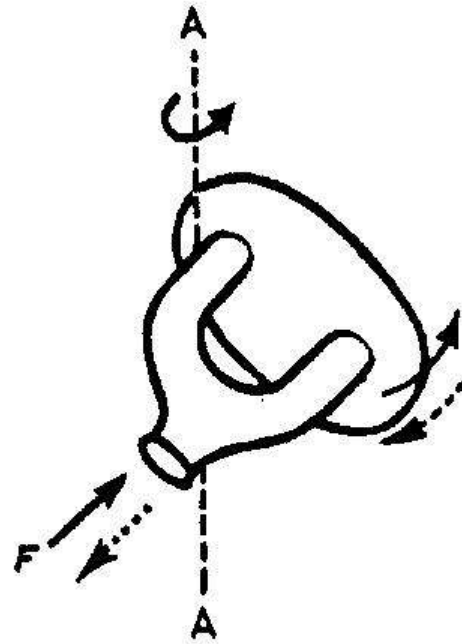
- "protects" the round window while "feeding" the ossicular chain and oval window



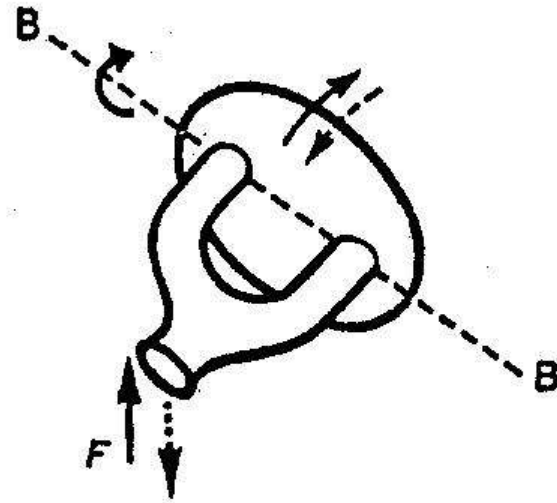
Ossicular Chain (Stapes)

Moderate Intensity Sound

- anterior end of the footplate with a greater amplitude than the posterior end
- rocking movement occurs about the transverse axis near the posterior end
- fibers of the annular ligament are longer at the anterior end than those at the posterior



(a)



(b)

Ossicular Chain (Stapes)

High Intensity Sound

- side to side rocking movement is seen about an axis running longitudinally through the length of the footplate

Tensor Tympani

- originates from a bony semicanal above the eustachian tube
- emerges as a tendon near the neck of the malleus
- supplied by a branch of the fifth nerve
- tense the TM by pulling the handle of the malleus inward

Stapedius Muscle

- smallest muscle in the body
- arises from the bony pyramid in the posterior wall of the middle ear and attaches to the neck of the stapes
- supplied by a branch of the seventh nerve
- tilt the stapes posteriorly and to fix it in the oval window

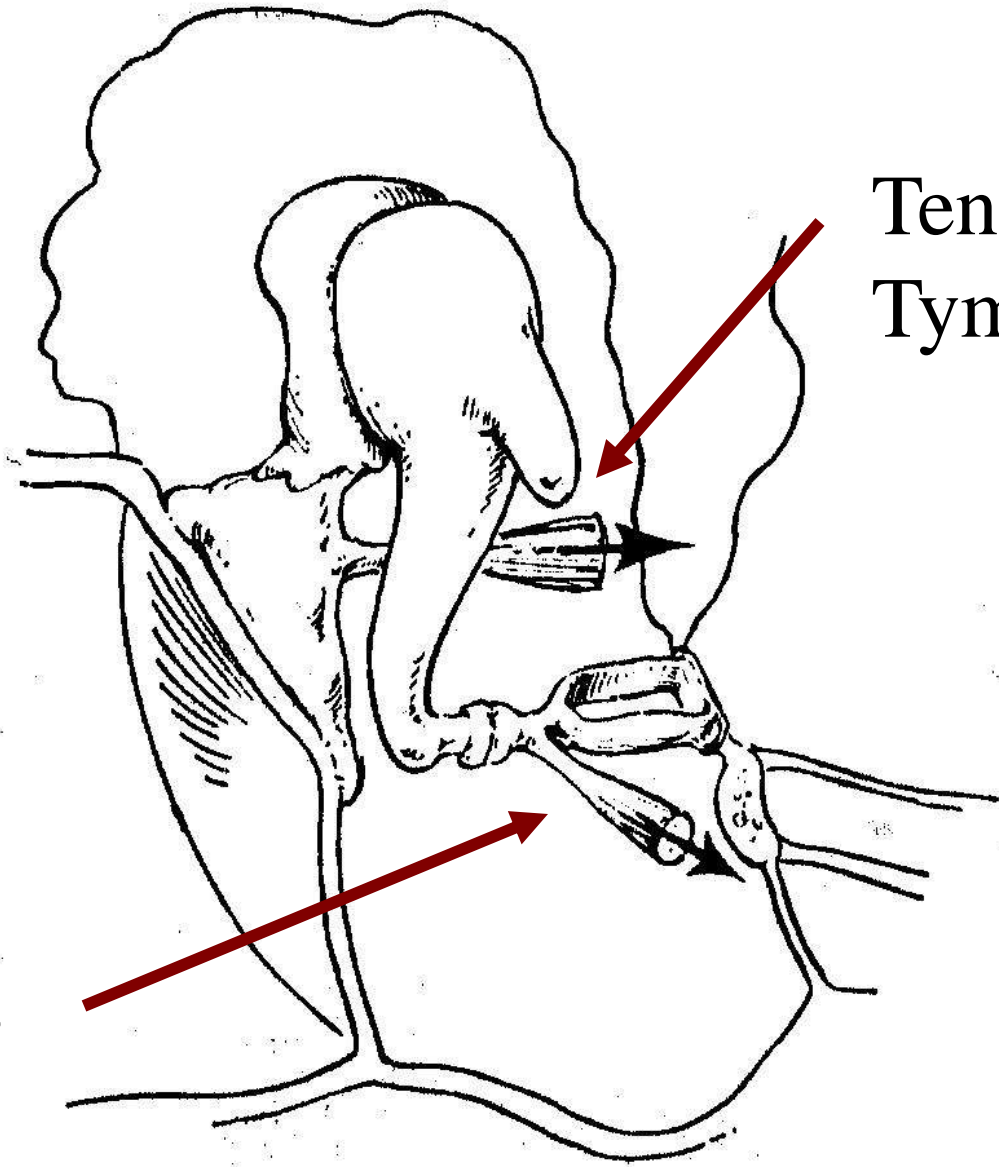
Stapedius

- pulls the stapes footplate backward and into the oval window

Tensor Tympani

- pulls the handle of the malleus inward

Stapedius



Tensor
Tympani

Tympanic Muscle Reflex

- cause alteration in tension and stiffness as well as movement of the structures to which they are attached.
- provide stability of suspension for the ossicular chain

Tympanic Muscle Reflex

- selectively augments auditory function at low and moderate sound levels (at high sound levels the attenuation of the masking effect of low frequency noise by the muscle reflex may will be valuable in making more intelligible the wanted middle and high frequencies)

Tympanic Muscle Reflex

Function of the Middle Ear Muscles

- support and stiffen the ossicular chain
- protect the Inner Ear against over stimulation by loud sounds
- Attenuate low frequency masking sounds

Transformer Mechanism of the Middle Ear

ME matches the low impedance of the air with the high cochlear impedance by concentrating the incident sound pressure from the large area of the tympanic membrane onto the small area of the oval window.

Transformer Mechanism of the Middle Ear

The ossicular chain also contributes to transformer action of the middle ear by bringing down the vibration amplitude.

Transformer Mechanism of the Middle Ear

- while the amplitude is greatly reduced at the oval window as compared with the amplitude at the tympanic membrane, the force of vibrations at the oval window is increased on the same proportion

Transformer Mechanism of the Middle Ear

Area Ratio

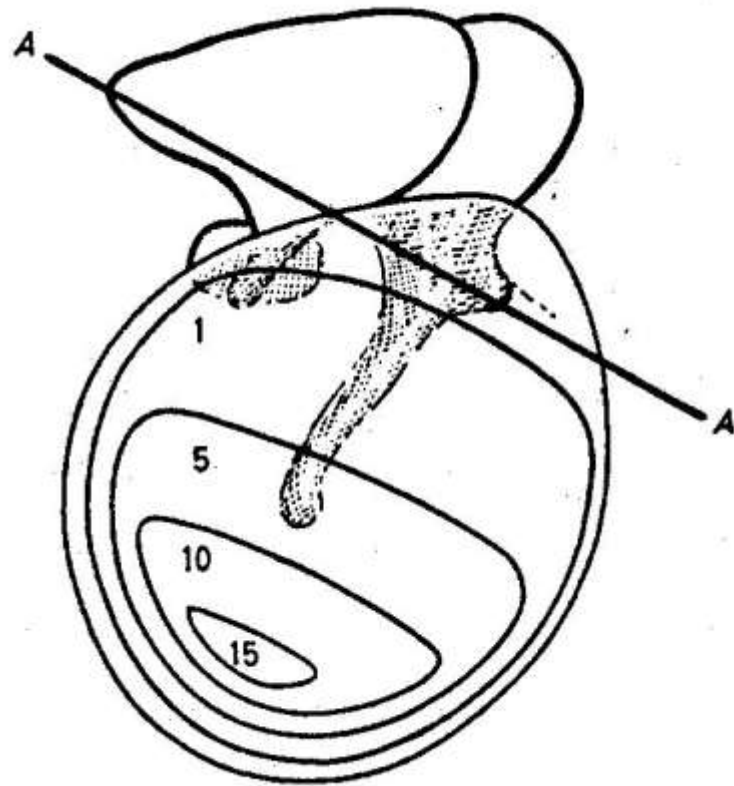
Tympanic Membrane : Oval Window
20 : 1

Ossicular Chain Lever Ratio

Mallelar Arm : Incudal Arm
1.3 : 1

Effective Area Ratio

14 : 1



Inner Ear

8) Vestibular apparatus

9) Cochlea

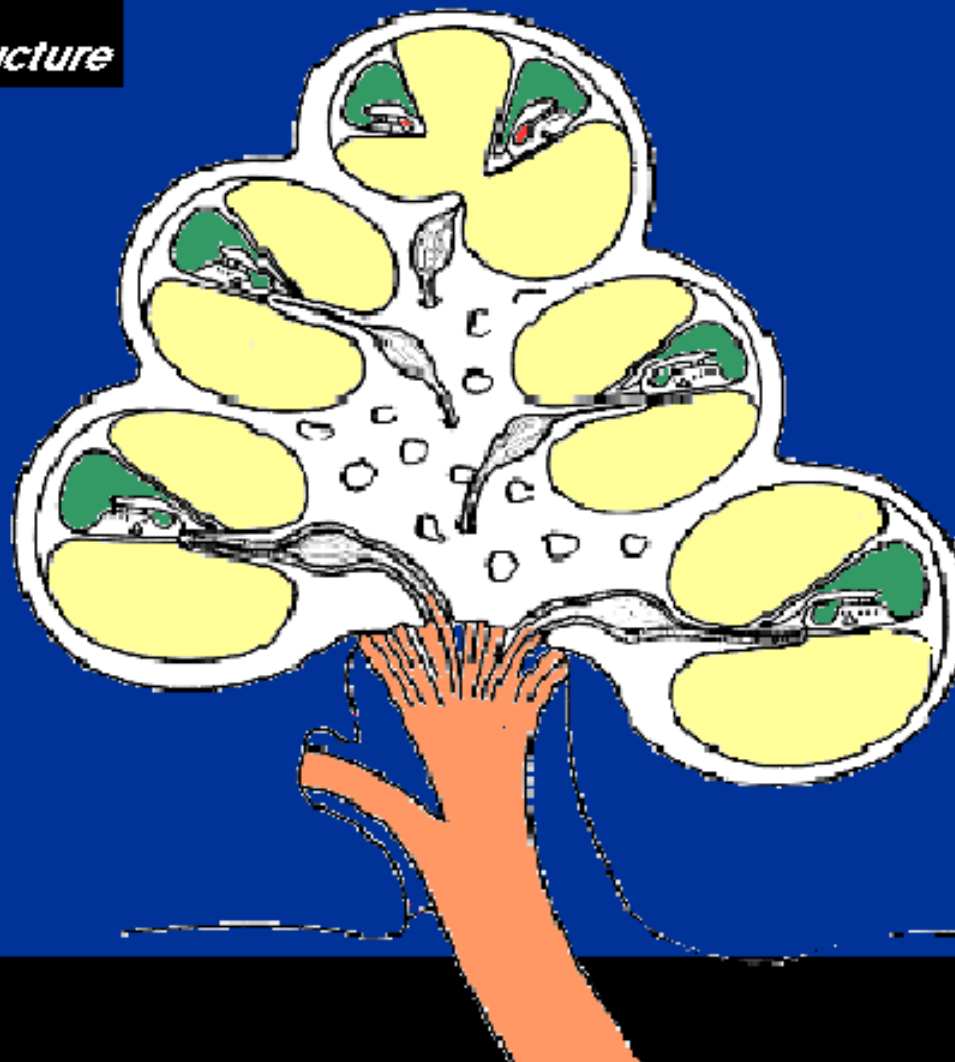
10) Cochlear nerve



Inner Ear

- composed of the end organ receptors for hearing and equilibrium
- Contained in the petrous portion of the temporal bone

Inner Ear
Cochlear Structure





11) Inner hair cells

12) Outer hair cells

13) Tectorial membrane

14) Cochlear nerve

Inner Ear

Cochlea

- coiled upon itself like snail shell and makes two and one-half turns
- Lies in a horizontal plane
- The basal end is the medial wall of the middle ear

Cochlea

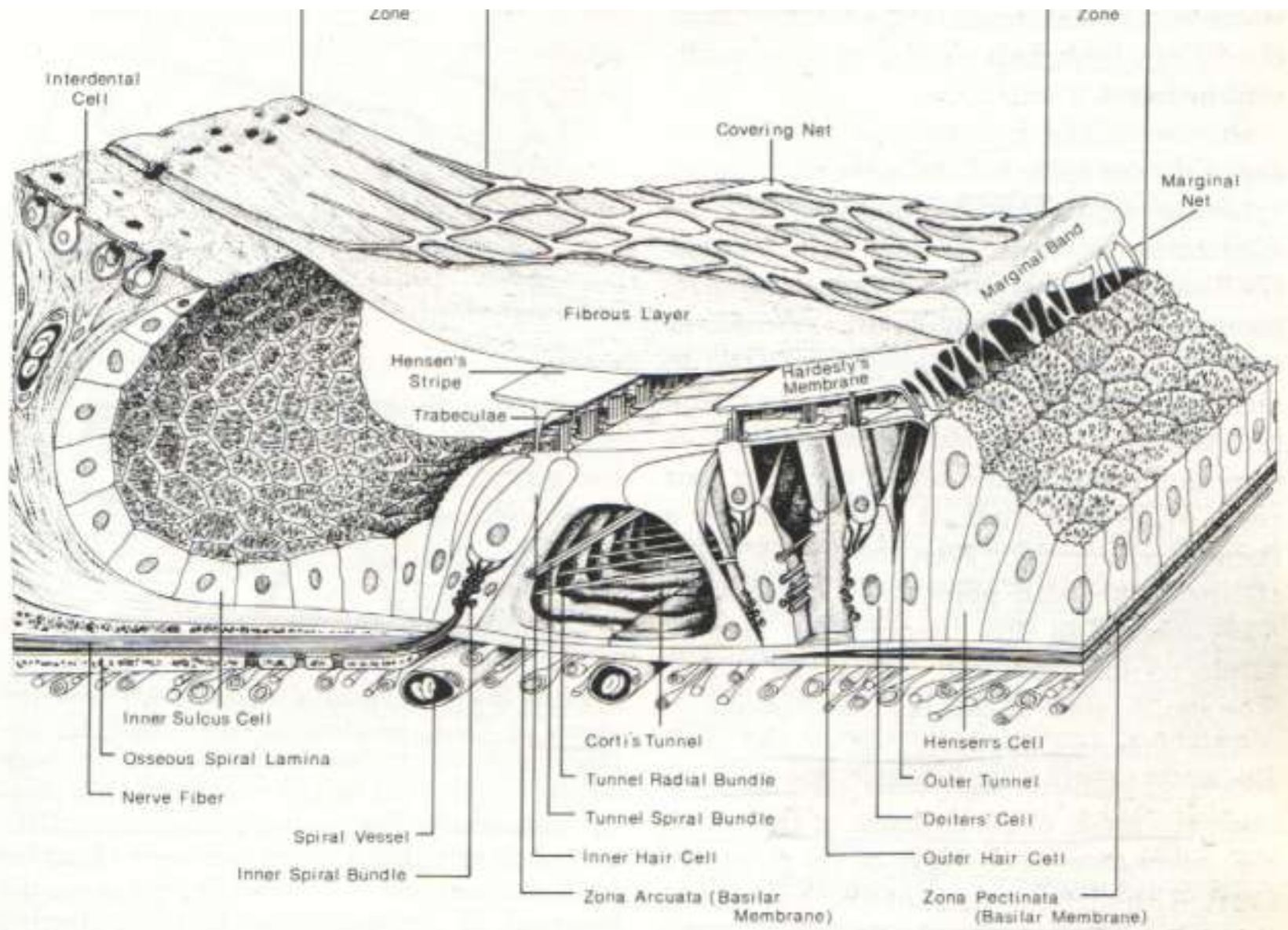
- Composed of three compartments:

Scala Vestibuli

Scala Tympani

Scala Media

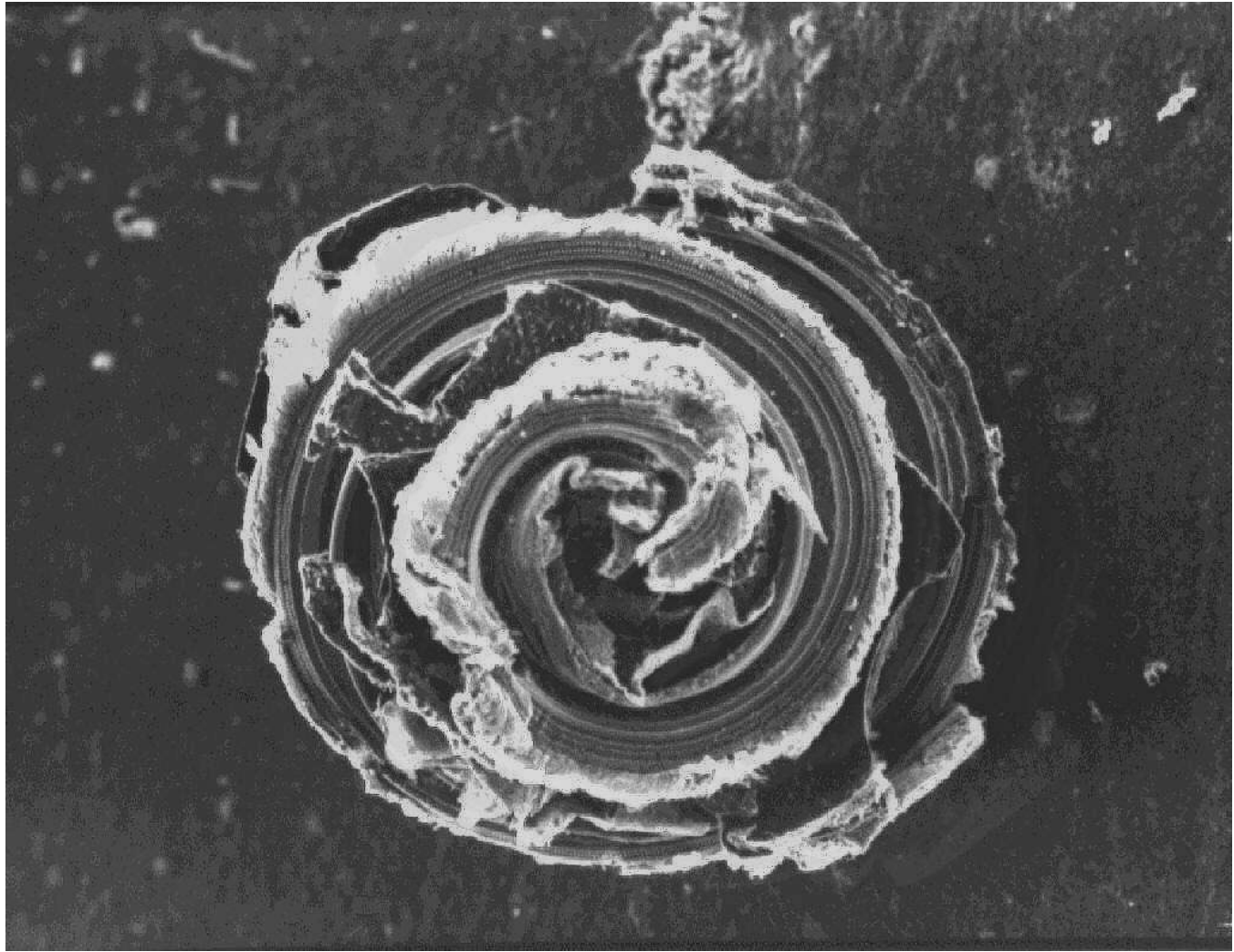




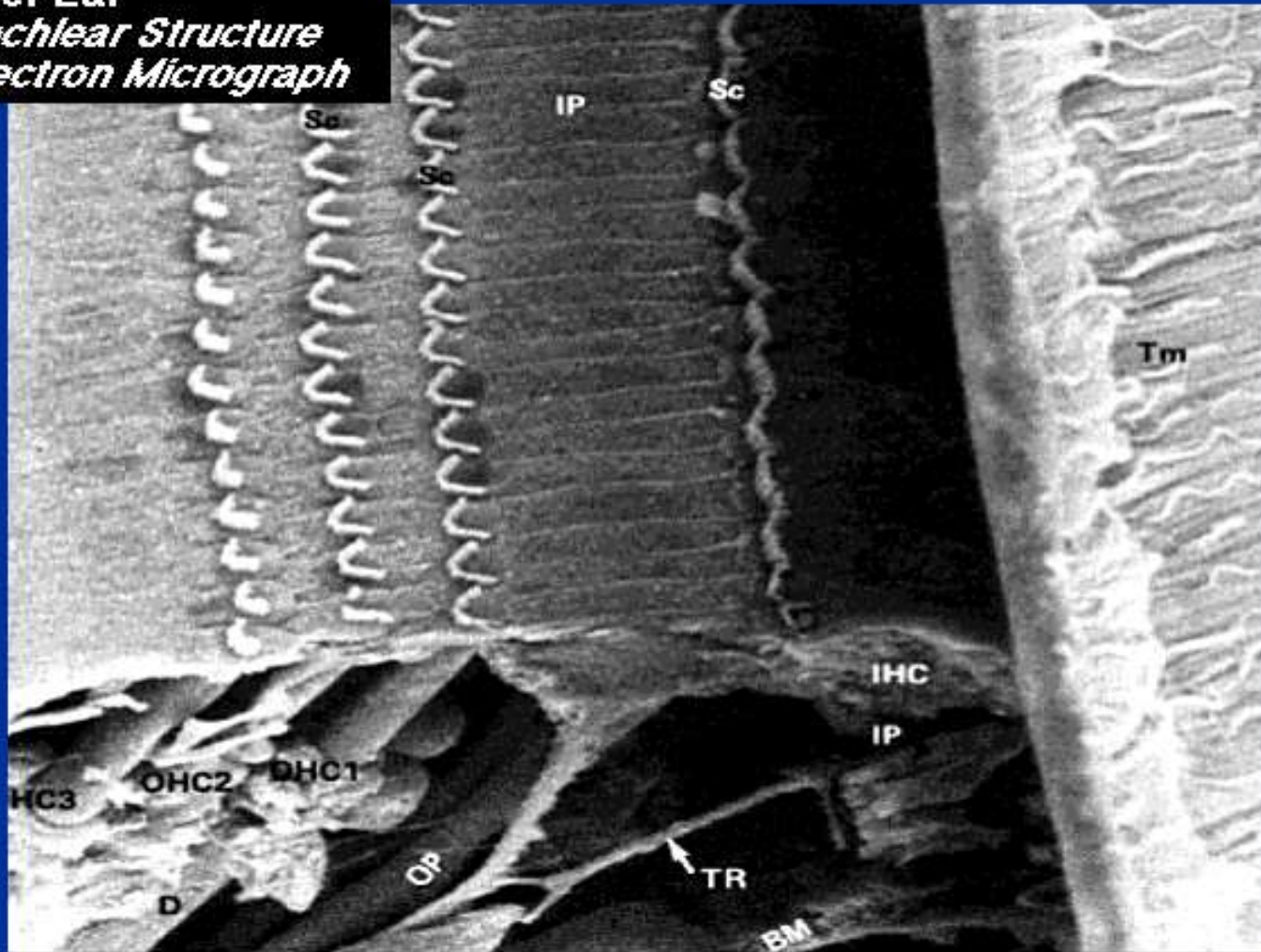
Inner Ear

Cochlea

- translates the sound energy into a form suitable for stimulating the auditory nerve
- Codes acoustical parameters so that the brain can process the information contained in the sound stimulus



Inner Ear
Cochlear Structure
Electron Micrograph

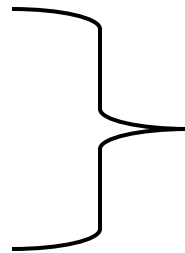


Cochlear Electrical Potentials

Endocochlear potentials

- present at rest

cochlear microphonic
summating potential



appears when
sound stimulates
the ear

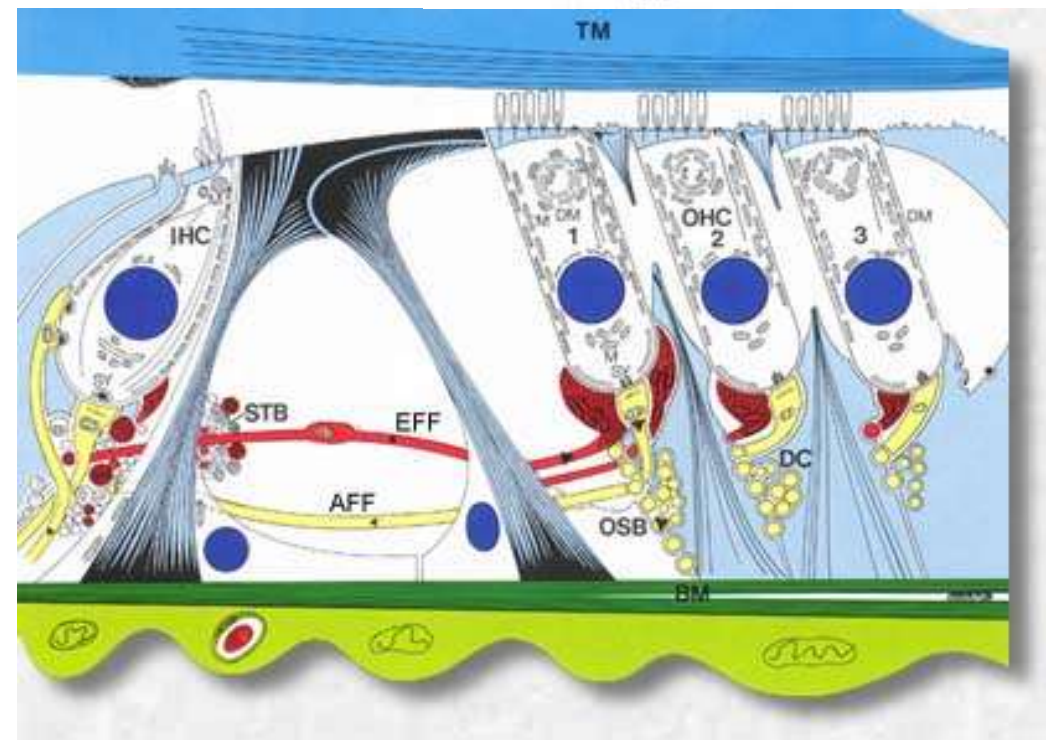
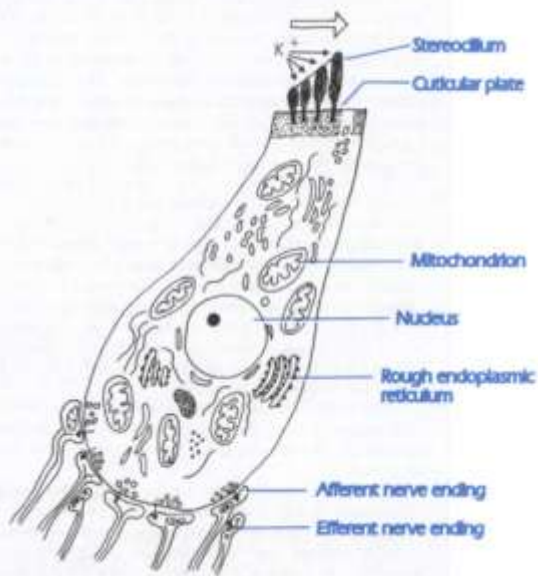
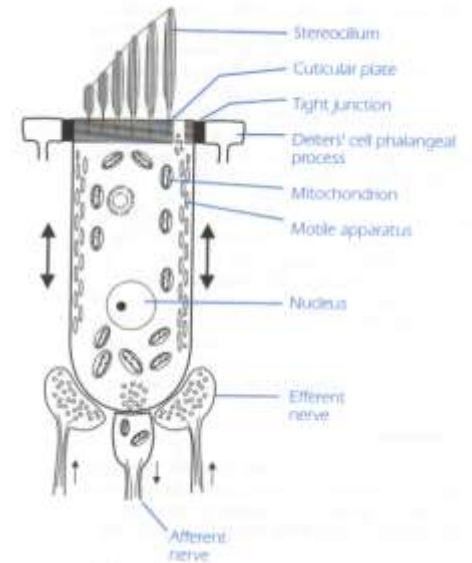
Cochlear Electrical Potentials

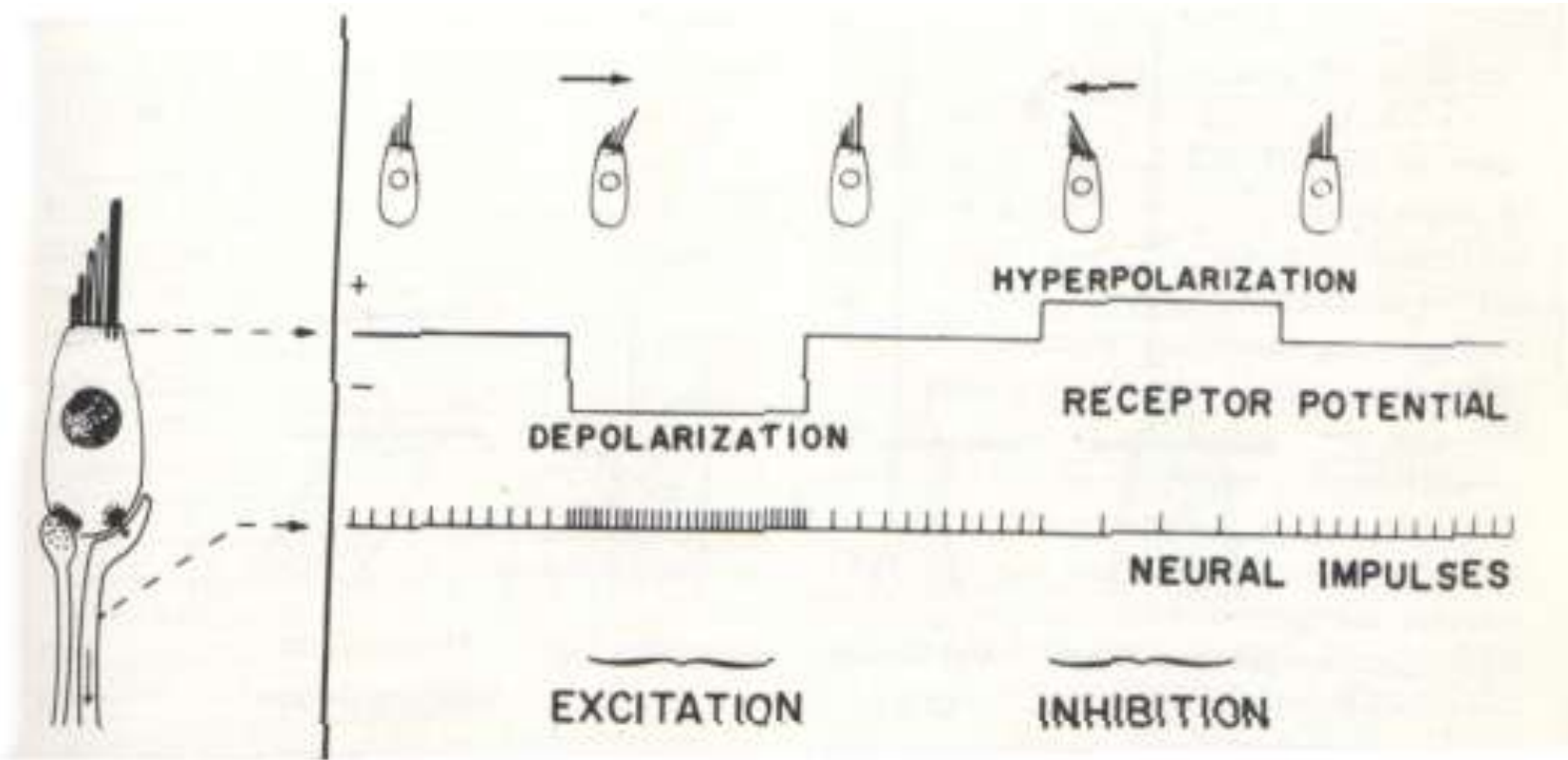
Endocochlear Potential

- generated by stria vascularis

Inner Hair Cells – generates summing
potential

Outer Hair Cells – generates cochlear
microphonic





Coding in the Cochlea

Acoustic Parameters

- frequency
- intensity
- temporal pattern

Coding in the Cochlea

Basic Parameters available for Neural

- coding place
- amount of neural firing
- temporal pattern of firing

Frequency Coding

Helmholtz Place Theory

- basilar membrane acts as if it were a series of tuned resonators, analogous to a set of piano strings
- each pitch would cause resonant vibration of its own particular “place” on the basilar membrane

C ₁		32.7	Hz
D ₁		36.7	39
E ₁		41.2	
F ₁		43.7	
G ₁		49.0	46.4
A ₁		55.0	52
B ₁		61.7	58.3
C ₂		65.4	
D ₂		73.4	
E ₂		82.4	77.8
F ₂		87.3	
G ₂		98.0	92.5
A ₂		110	103.8
B ₂		123	116.5
C ₃		131	
D ₃		147	138.6
E ₃		165	155.6
F ₃		175	
G ₃		196	185.0
A ₃		220	207.6
B ₃		247	233.1
C ₄		262	
D ₄		294	277.2
E ₄		330	311.1
F ₄		349	
G ₄		392	370.0
A ₄		440	415.3
B ₄		494	467.0
C ₅		523	
D ₅		587	466.2
E ₅		659	622.2
F ₅		698	
G ₅		784	740.0
A ₅		880	830.6
B ₅		988	932.3
C ₆		1047	
D ₆		1175	1110
E ₆		1319	1246
F ₆		1397	
G ₆		1578	1487
A ₆		1760	1669
B ₆		1976	1868
C ₇		????	2227
D ₇		2349	2508
E ₇		2637	
F ₇		2794	
G ₇		3136	2965
A ₇		3520	3328
B ₇		3591	3555
C ₈		4186	
D ₈		4699	4442
E ₈		5274	4986

Male voice

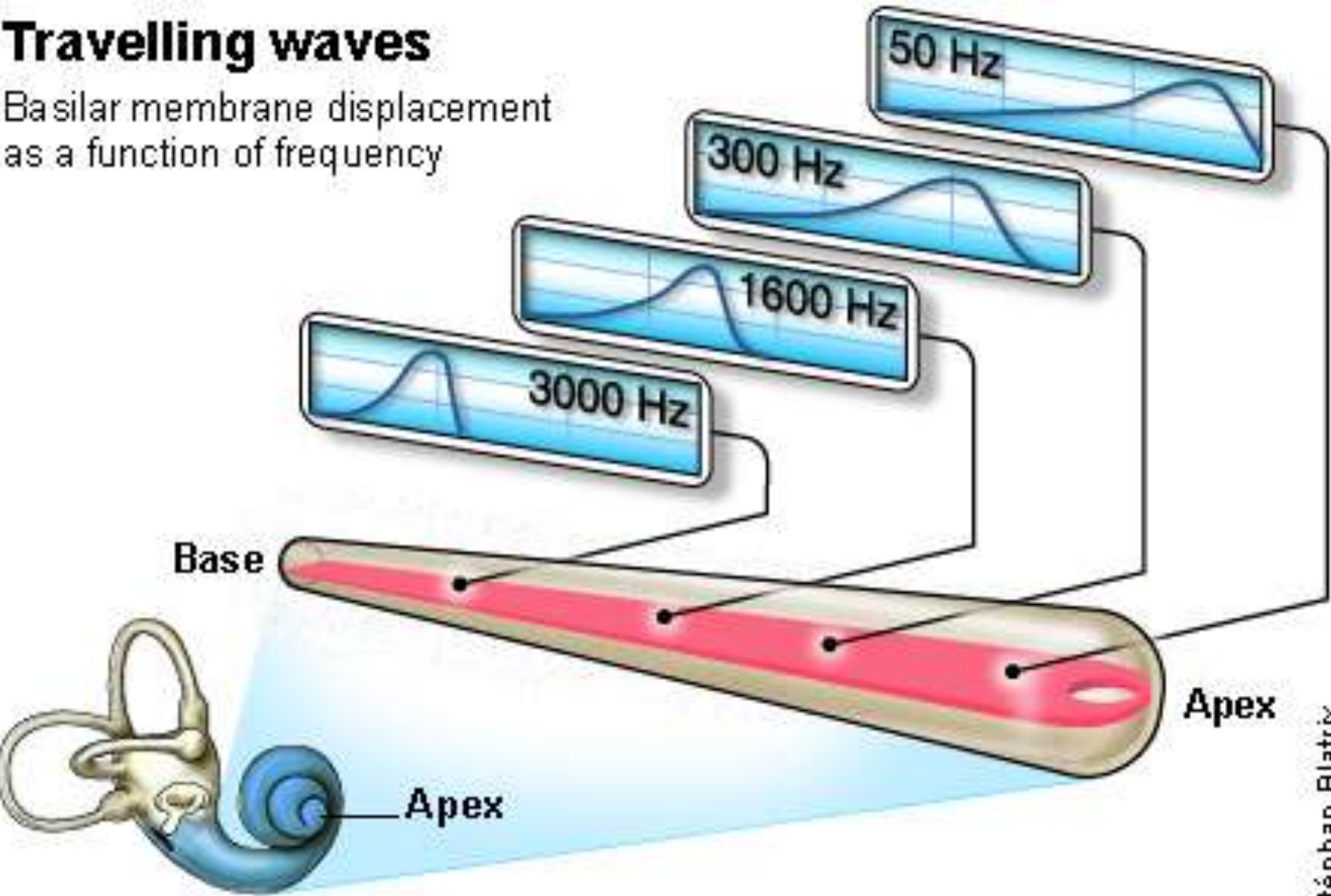
Female voice

Middle C

More
The
VSV

Travelling waves

Basilar membrane displacement as a function of frequency



Frequency Coding

Rutherford's Telephone Theory

- all frequencies activate the entire length of the basilar membrane, which transmits, essentially unchanged the temporal pattern of the auditory stimulus. It then, remains for more central neural structures to decode the acoustic parameters

Frequency Coding

Rutherford's Telephone Theory

- telephone hypothesis of cochlear action suggested that the basilar membrane vibrates uniformly in all its parts and that its amplitude represents the intensity of the signal. Frequency of the signal is represented by the rate of the firing of the auditory nerve fibers

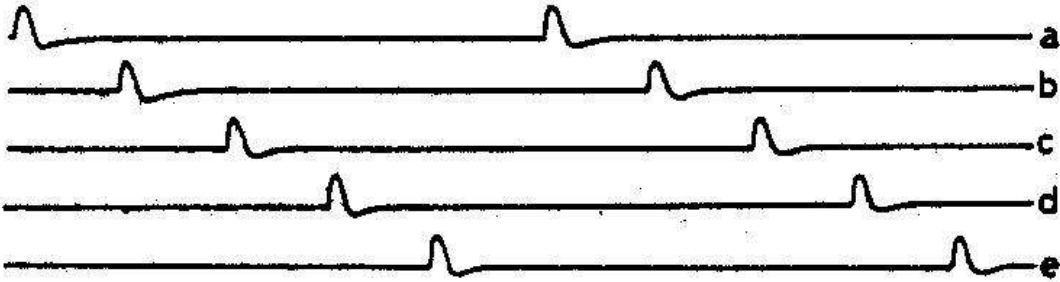
Frequency Coding

Wever's Volley Theory

Intensity Coding – loudness – amount of number of fibers firing and rate at which they are firing.



Sound wave



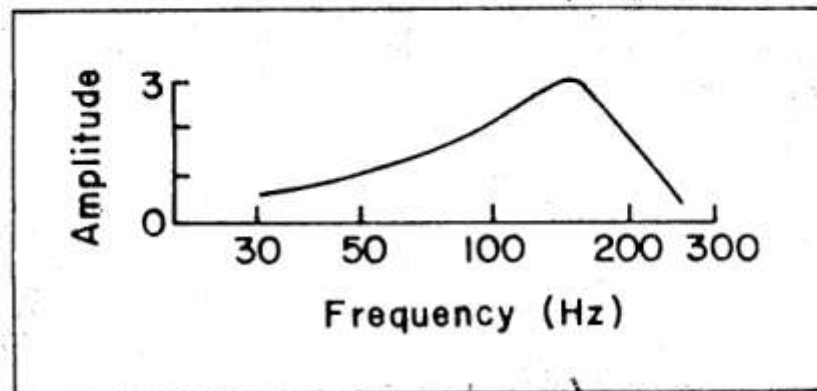
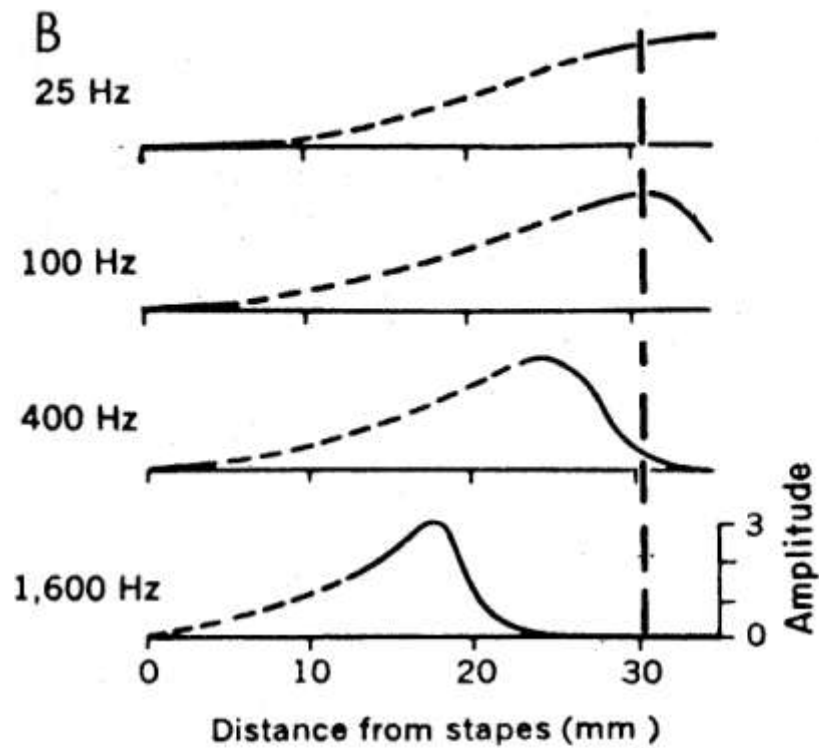
Individual nerve action potentials



Fibres a-e combined

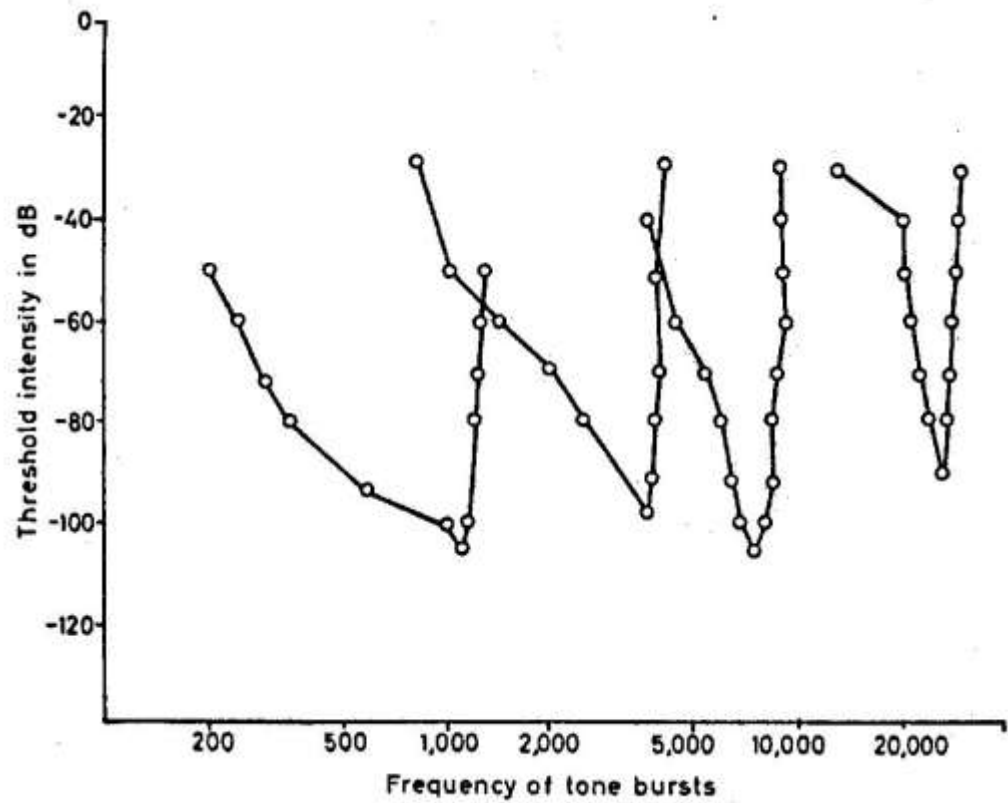
Evidence for place coding – mechanical and neural tuning curves

Von Bekesy – each pure tone cycle elicits a traveling wave that moves along the cochlear partition from base to apex.



Neural tuning curve

- sharply tuned tip region with the peak of the tip at the CF.
- sharpening mechanism within the cochlear



1 20 40 60 80 100 120

Hearing by Bone Conduction

Translatory or inertial mechanism

- when the head vibrates as a whole the ossicular chain because of its inertia lags behind the general vibration of the skull.

Hearing by Bone Conduction

Compressional Mechanism

- bony capsule of the labyrinth is alternately compressed and decompressed by fluctuating twisting forces in the surrounding bone.

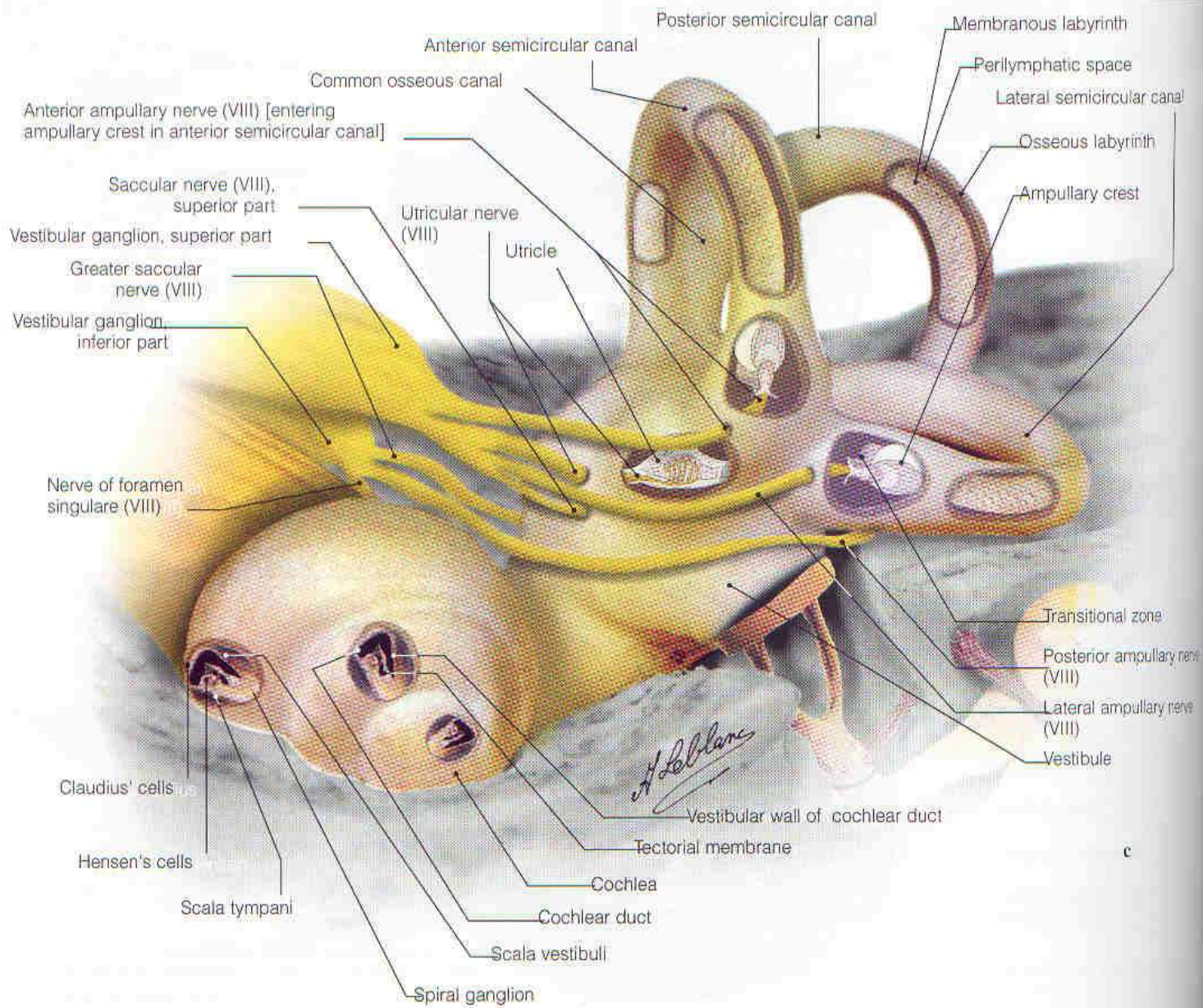
Hearing by Bone Conduction

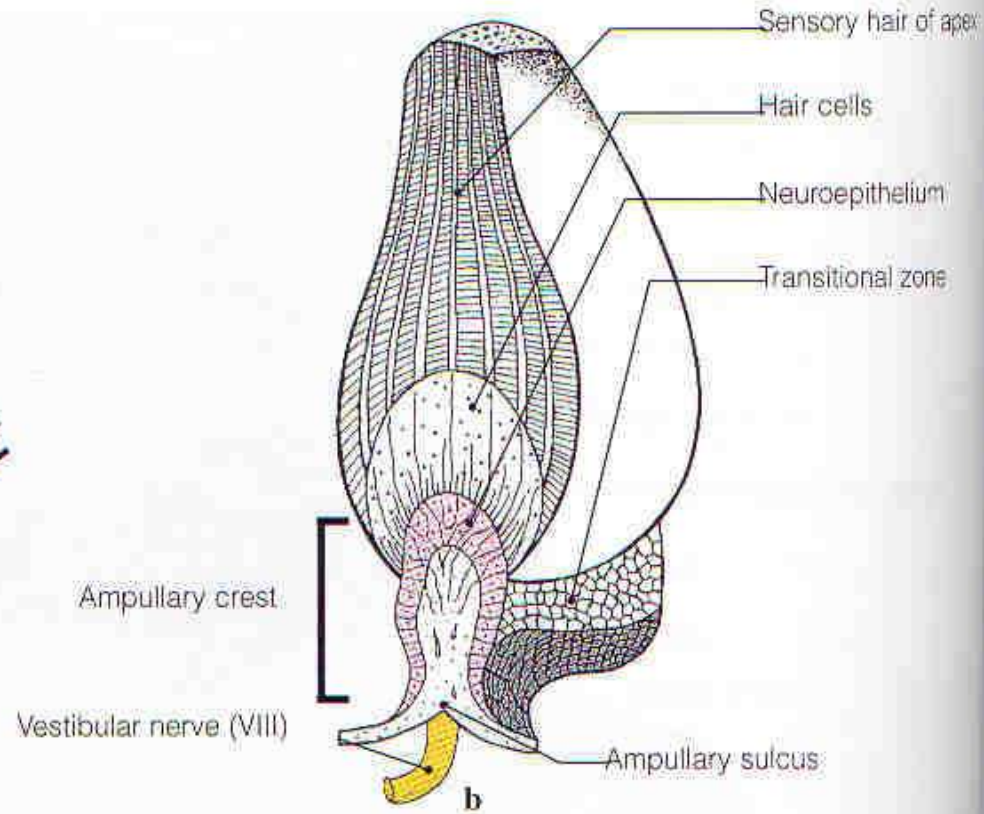
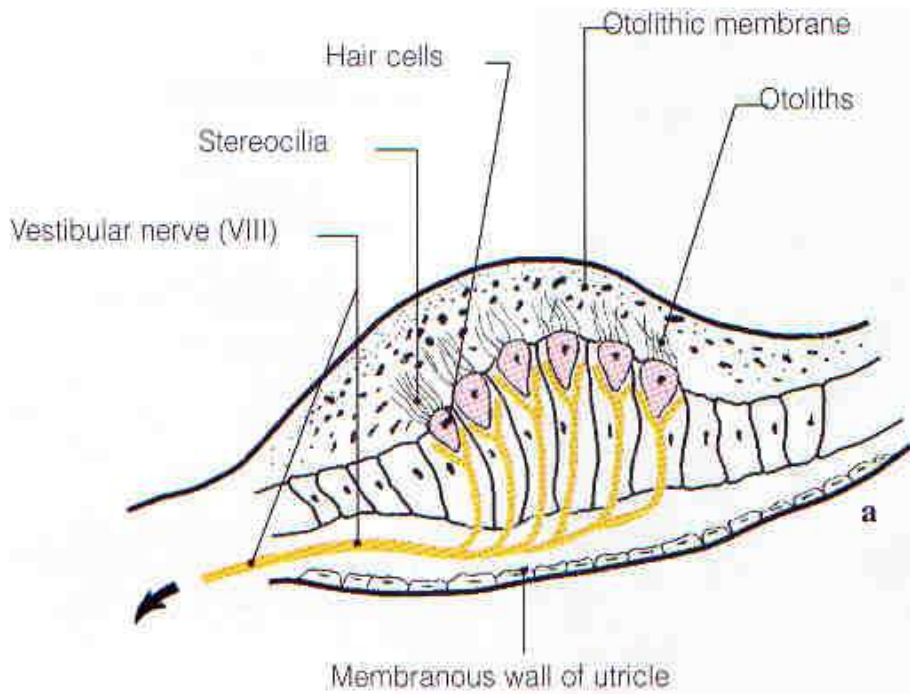
Effect of the Mandible

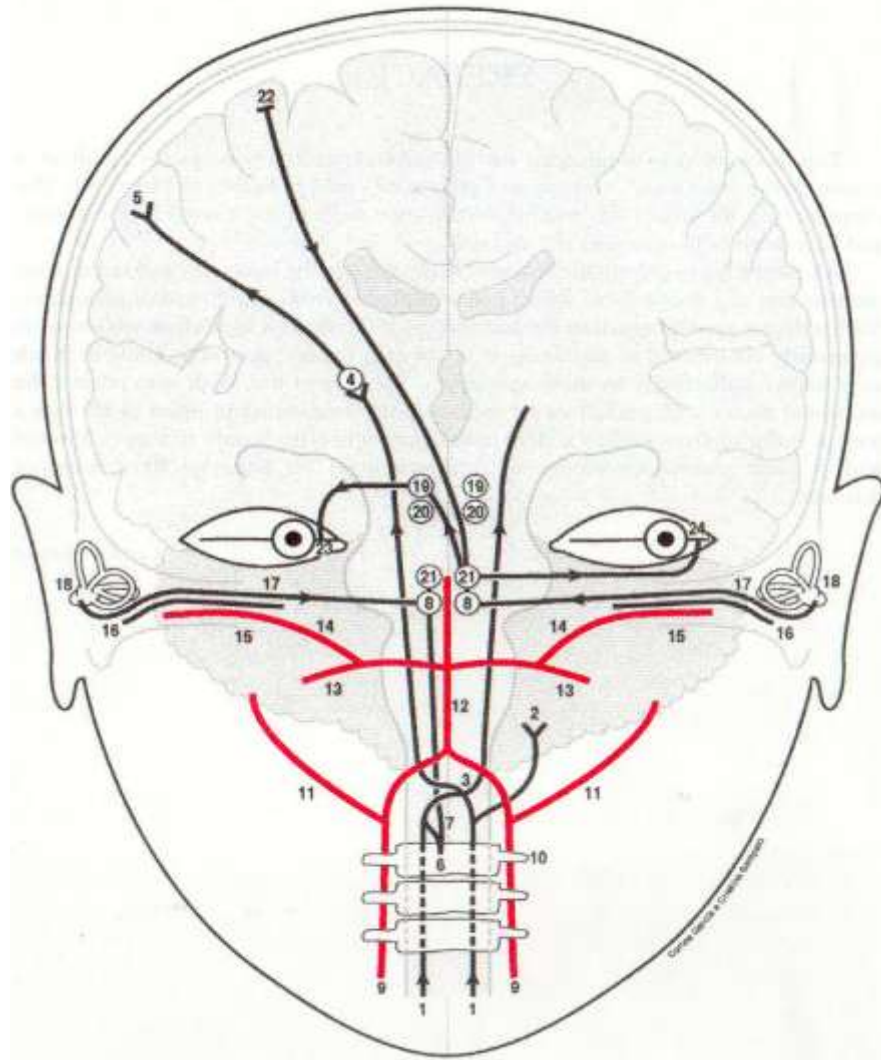
- mandible lays behind the vibration of the skull so that the head of the mandible causes vibrations of the cartilaginous

Meatus – transmitted by the round air conduction route to the cochlea

Physiology of the Balance System







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