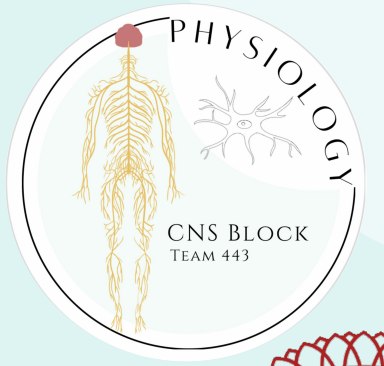
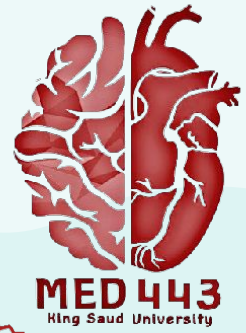
7



# Mechanism of Hearing





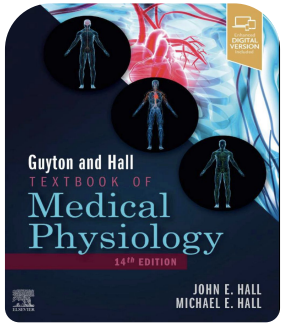
## Color Index:

- Main text
- Important
- Girls Slides
- Boys Slides
- Notes
- Extra

[Editing File]

# Objectives:

1. Structure and function of the ear.
2. Appreciate the function of outer(External), middle & inner ears.
3. Describe nature of sound and its characteristics.
4. Function of semicircular canals & utricle & saccule .
5. Understand the role of middle ear in sound transmission, magnification and tympanic reflex effect .
6. Recognize the function of hair cells of the inner ear.
7. Auditory pathway(Nervous pathway of hearing)
8. Air conduction & bone conduction.
9. Differentiate between conductive & perceptive deafness.
10. Hearing tests.




helpful video

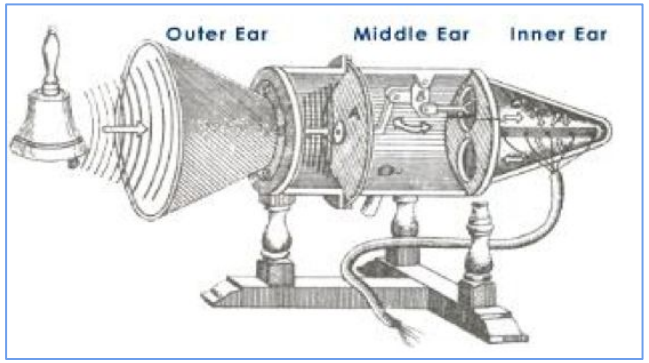
# Hearing Loss: WHO Report 2023

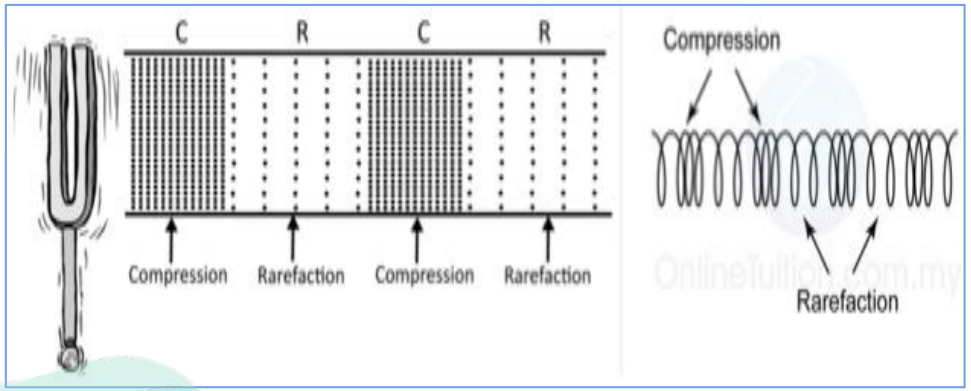
- Over 5% of world's population (432 million adults & 34 million children) require rehabilitation for disabling hearing loss.
- By 2050 nearly 2.5 billion people are projected to have some degree of hearing loss & 700 million require hearing rehabilitation.
- Over I billion young adults are at risk of permanent, avoidable hearing loss due to unsafe listening practices.
- About 80% of people with disabling hearing loss live in low- and middle-income countries.
- The prevalence of hearing loss increases with age, among those older than 60 years.

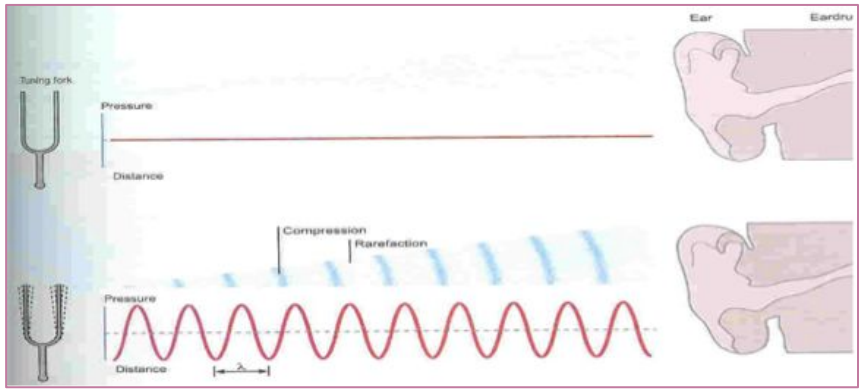
World Health Organization

# Sound nature \ Mechanism of hearing

- **Sound:** is produced from **alternate compression and rarefaction** of air molecules by a vibrating body.
- **Sound:** is a vibration that propagates as an audible wave of the pressure, through a transmission medium such as **gas, liquid or solid**
- In human physiology and psychology sound is the reception of waves and their perception by the brain.
- **Ear:** Receives sound waves, discriminates frequencies, and transmits auditory information into the CNS, where meaning is deciphered.
- **Hearing:** Hearing is the ability to perceive sound by detecting vibrations through the ear.
- Human hearing range: **20 Hz-20,000 Hz.**



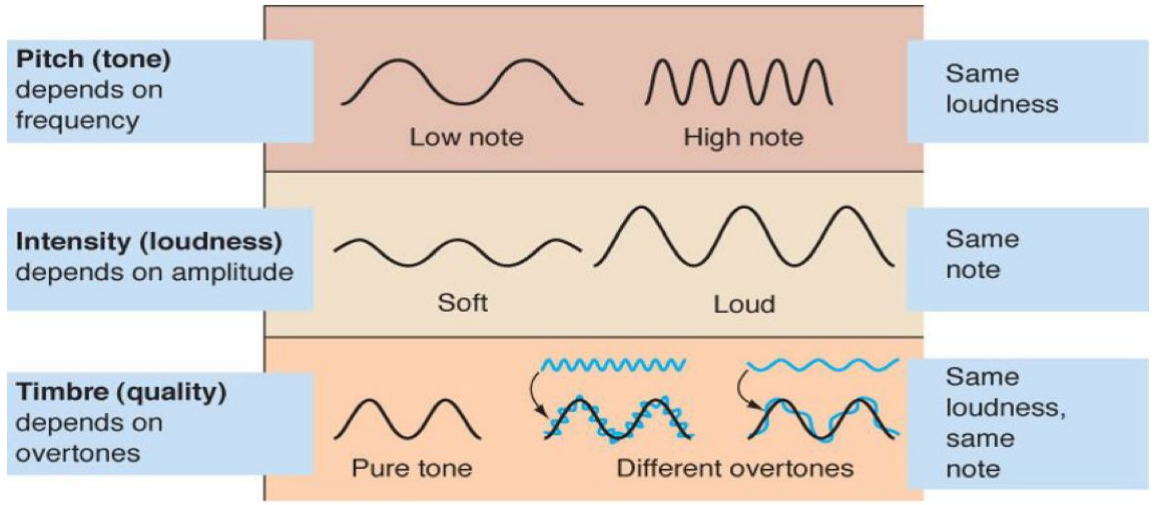



**Characteristics of Sound**

1. **Quality**
   Depend on the **overtone or interference**

2. **Intensity (Loudness)**
   **Depend on amplitude**

3. **Pitch (Tone)**
   Depend on **No.of cycle/sec.**
   (Human ear can detect sound waves with freq.. 20-20000 cycle /sec)



# Ears: Hearing and Equilibrium

- The ears detect the sounds and maintain the balance.
- Hearing and equilibrium sensory receptors are housed in the ear.
- **The external ear, the middle ear, and the cochlea of the inner ear are involved with hearing.**
- **The semicircular canals, the utricle, and the saccule of the inner ear are involved with equilibrium.**
- Both hearing and equilibrium rely on receptors called **hair cells.**
- **There are six groups of hair cells in each inner ear:** One in each of the three semicircular canals, one in the utricle, one in the saccule, and one in the cochlea.
- Receptors in the semicircular canals detect rotational acceleration, those in the utricle detect linear acceleration in the horizontal direction, and the ones in the saccule detect linear acceleration in the vertical direction.

## ❖ Normal Frequency Range of Hearing:

➢ **Young Person**: Between 20 and 20,000 cycles/sec.
➢ Sound range depends to a great extent on loudness.
➢ **Old age**: Frequency range is shortened 50 to 8000 cycles/ sec or less

Female slides

# Anatomical Consideration

## 1 Outer ear

- Pinna
- External canal *
  it contains wax secreting glands and hair which grab pollutants filtering the air entered.
  *Due to the presence of blood surrounding the ear canal, air temperatures that don't match the body temperature will be modified before reaching the tympanic
- Tympanic Membrane (funnel shaped,pointing inward)

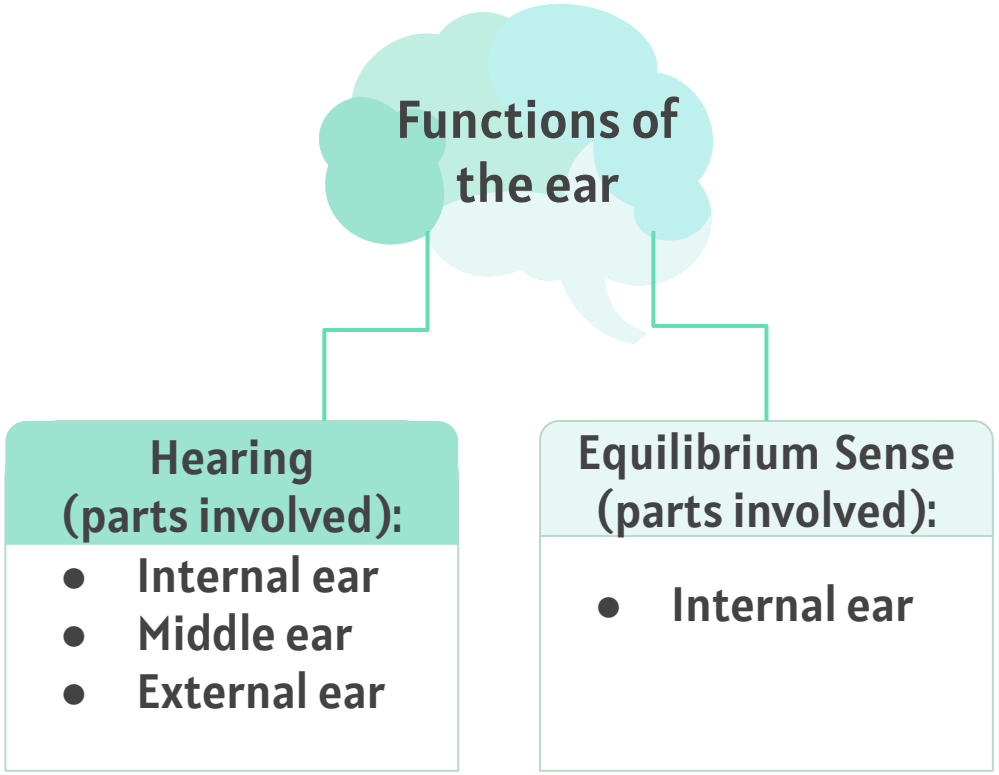
## 2 Middle ear

- Air filled cavity
  (if the cavity filled with water for any reason its function will be disturbed)
- Three bones:

I- Malleus
2-incus
3-stapes (with its foot sitting on the oval window of the inner ear)

## 3 Inner ear

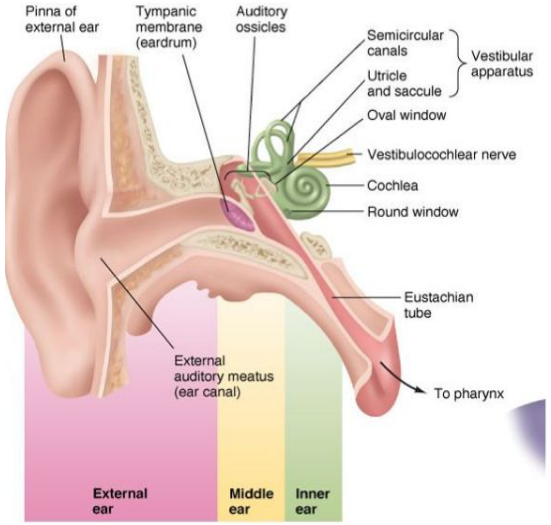
- Bony and membranous labyrinth



# Functions of the ear

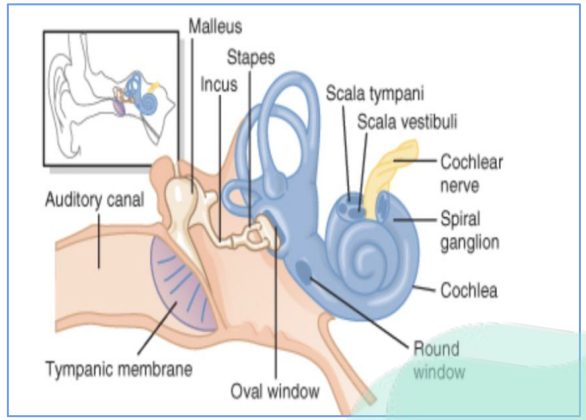
## 1 External ear :

1. **Protection**
   From anything in the external environment like pollution, dust particles, extreme temperatures
2. **Sound localization** (front, back, high, low).
   The arrival of sounds coming from the back will be a bit delayed while the sounds coming from the front enter directly to the ear, this due to the shape of the ear pinna
3. Act as funnel to **collect sound.**
   The ear pinna collects maximum sound waves and it will be concentrated in the tympanic membrane
4. Alter amplitude (Pinna)
5. Wax




## 2 Middle ear :

It is a space between tympanic membrane and the inner ear (opens via Eustachian tube -which equalize air pressure between the middle ear and external pressure- into nasopharynx)



# Functions of the ear, Count...

- **Content** and **Functions of the middle ear:**

1 **Air**

2 **Ossicles**

1. Malleus 2. Incus 3. Stapes

- Manubrium of the **malleus attached** to the back of the **tympanic membrane** and its short **process attached** to the **incus.**
- The **incus then articulates** with the head of the **stapes**, and its foot plate attached to the **oval window.**
- **Malleus and Incus act as a single lever.**
- Tympanic membrane (Eardrum) and ossicles, conduct sound from the tympanic membrane through the middle ear to cochlea (the inner ear).
- **In the absence of the ossicular system and tympanic membrane:** Sound waves can still travel directly through the air of middle ear and enter the cochlea at the oval window. However, the sensitivity for hearing is 15 to 20 decibels less than for ossicular transmission.

3 **Muscles** Protective mechanism

1. Tensor tympani
2. Stapedius

- Tensor tympani and Stapedius muscles contract reflexly in response to constant loud sounds (over 70 dB)
- Contraction of the tensor tympani pulls the manubrium & makes the tympanic m. tens (it will become straight instead of the funnel shape creating a gap between tympanic m. and malleus) Thus decreasing transmission of sound waves \ vibration from external to middle ear.
- Contraction of the stapedius pull the footplate of stapes bone outward so that sound waves transmission "vibration" are reduced
- Protection from constant loud noise, but not sudden noise, latency of 40-80 msec.

# Functions of the ear, Count...

- Transmission of sound through the middle ear:

Sound waves vibrate **Tympanic membrane** → tympanic membrane moves the **handle of malleus** → **Incus** moves → Stapes move in & out of the **oval window.** The pressure transmitted through cochlea cause stimulation of hair cells in the **organ of corti**, which will stimulate the auditory nerve

- Middle ear magnifying effect: Female slides

1. The force from a large surface area (Tympanic m.) are concentrated to a small (oval window) the ratio is 17=1.

2. Lever action of ossicles = the lever action of ossicles increase the force of movement 1.3 times.

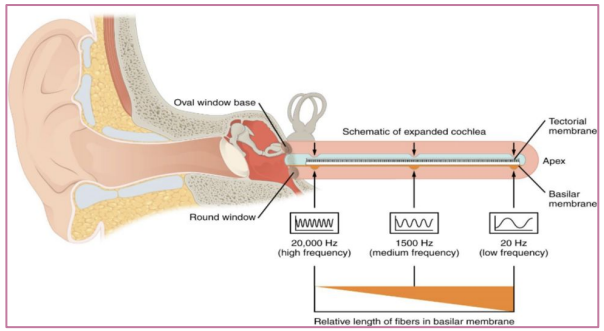
- the total increase 17 X 1.3 = 22 times

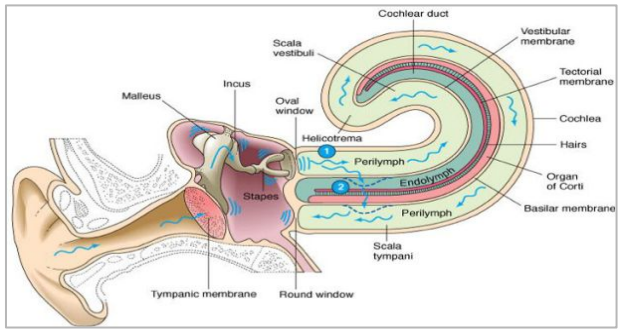
# Functions of the ear, Count...

## 3 Inner ear :

-Anatomy:

- **Cochlea** (snail like, coiled tubular system laying deep in the temporal bone)
- **Bony labyrinth**
- **Membranous labyrinth**



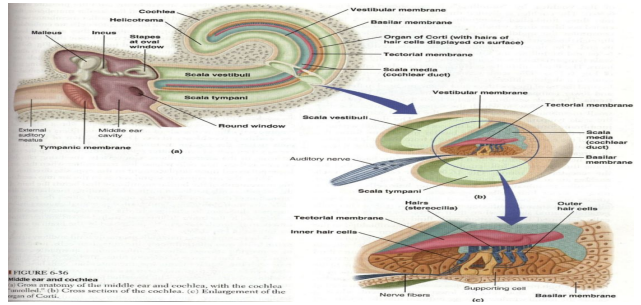

Each frequency will be received by special area in the cochlea.

- ❖ High frequency sound waves received at the base of the cochlea.
- ❖ Low frequency waves are received at its apex of the cochlea.

## Cochlea:

- It is a system of three coiled tubes through its length.
- The **basilar membrane** and the **reissner's membrane** divide it into **three canals:**

**1.Scala Vestibuli.**
**2.Scala Tympani.**
**3.Scala Media.**




| Composition | | |
|---|---|---|
| Scala Vestibuli (Similar to EC fluid) | Na high | K low |
| Scala Tympani (Similar to EC fluid) | Na high | K low |
| Scala Media (Similar to IC fluid) | Na low | K high |

# Organ of corti

1. **Located (resting) on the basilar membrane** within the cochlea. **Extend from base to apex** in the scala media.

2. **Contain inner & outer hair cells** (Hearing receptors on the basilar membrane).
**Anatomy Definition**: formed by specialized epithelium on the floor of cochlear duct that contains sensory receptors for hearing. from the lower end they have nerve fibres making the cochlear nerve and from the top extensive stereocilia

3. Gel-like tectorial membrane is capable of bending hair cells. It covers them.

4. Cochlear nerve attached to hair cells transmits nerve impulses to auditory cortex on temporal lobe.

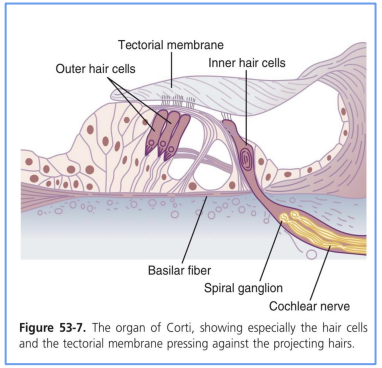


**Figure 53-7.** The organ of Corti, showing especially the hair cells and the tectorial membrane pressing against the projecting hairs.

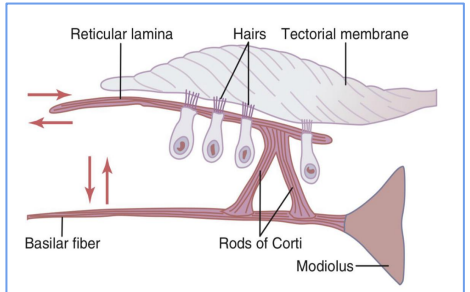
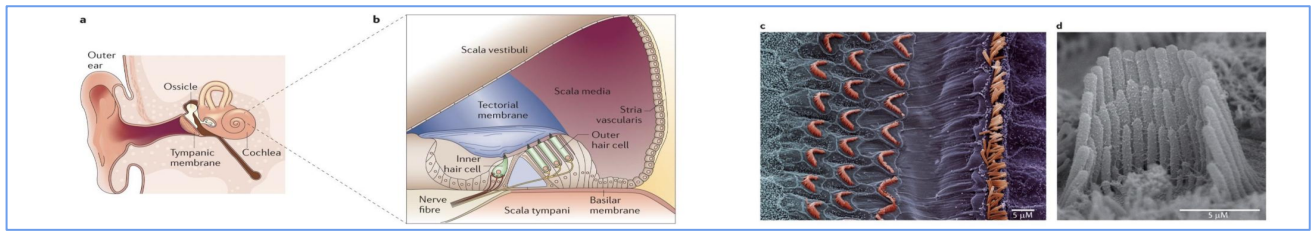


**Figure 53-8.** Stimulation of the hair cells by to-and-fro movement of the hairs projecting into the gel coating of the tectorial membrane.

# Hair cells (stereocilia)

- Stereocilia extend from the top

| | Inner hair cells | Outer hair cells |
|---|---|---|
| **Arrangement** | **One row** of inner hair cells (**not attached** to tectorial membrane). | **Three rows** of outer hair cells (attached to the reticular lamina or tectorial membrane). |
| **Function** | ❖ Striocellia not embedded in tectorial membrane. but bent by fluid movement under the tectorial membrane.<br>❖ They are **primary receptors** for sound, transducing fluid movement in cochlea into action potential in the auditory nerve | ❖ Large number, but stimulate only small fraction of nerve fibres in the cochlear nerve.<br>❖ If damaged, significant loss of hearing **(they control the sensitivity of inner hair cells** to particular sound frequency) by making the membrane more tense or more loose<br>❖ embedded in the tectorial membrane |



## Receptors & Endocochlear potentials

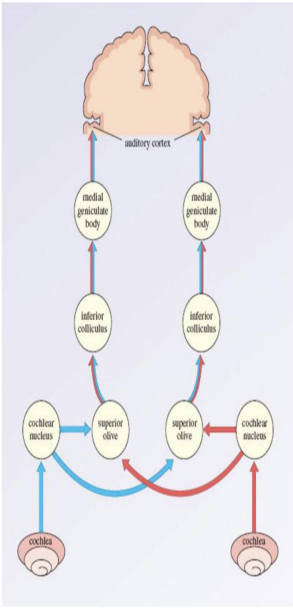
1. Sound transmission into the inner ear cause **upper & lower movements of the reticular membrane. (tectorial m.)**
2. produce bending of stereocilia of the hair cells alternatively **open & close cation channels** **at the tip of the stereocilia**
3. →(inward current) depolarization
   →(outward current) hyperpolarization
4. = the net results is **depolarization**
5. Production of cells **receptors potentials**
6. **release of neurotransmitter**
7. production of **action potentials**

## The Central Auditory pathway

This pathway **begins in the organ of corti**

End in the **primary auditory cortex** (area 41 & 42, superior temporal gyrus in the temporal lobe of the brain)

Fibres end in the auditory area, where it is heard, the interpretation occurs in the auditory association areas (wernicke's area)



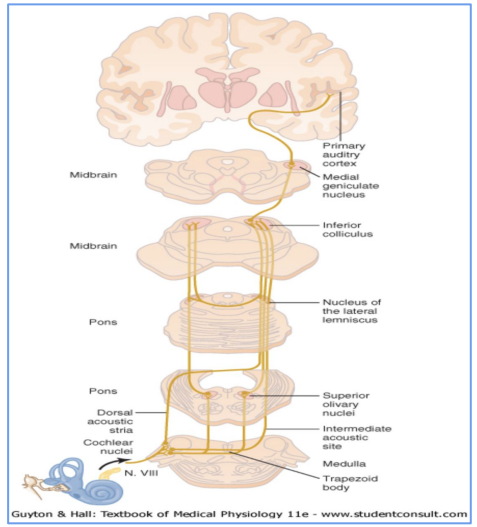

❖ There is a **bilateral** cortical connection of auditory area

❖ Thus Damage to one side only **slightly** reduces hearing

❖ Destruction of both primary auditory cortices greatly reduces sensitivity for hearing.

❖ Destruction of one side slightly reduces hearing in the opposite ear;

❖ It does not cause deafness in the ear because of many **crossover** connections from side to side in the auditory neural pathway. However, it does affect ability to localize the source of a sound.

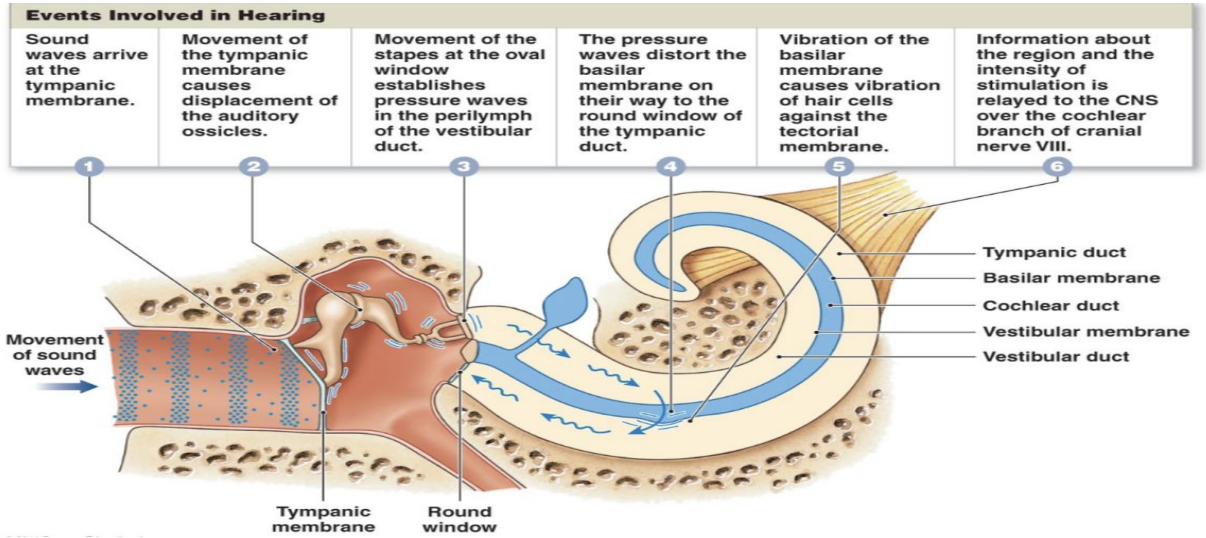


# General mechanism of hearing

Male slides

1. Sound Waves
2. Outer ear: Tympanic membrane
3. Middle Ear: Bones (Malleus, incus and stapes)
4. Movement of Stapes
5. Fluid Filled inner ear: Pressure Waves
6. Inner ear: Hairs to move in the inner ear
7. Auditory nerve stimulation

**Pinna → Ear Canal → Eardrum → Ossicles → Oval Window → Cochlea → Auditory nerve→ Brain**



## Sound localization Girls slide only

- ❖ Differences in the time arrival of the sound wave at the ears. (time-lag)
- ❖ Differences in the loudness.

## Masking Effect: Produced by organ of corti

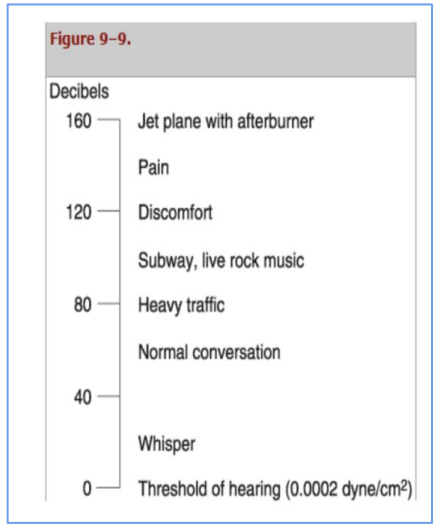
- ❖ Presence of one sound decreases an individual's ability to hear other sounds. This phenomenon is known as **masking**
- ❖ Presence of background noise affect the ability to hear another sound, due to some receptors are in refractory period
- ❖ Masking is more clear if two sound are having the same frequencies *Same area in organ of corti

# Noise pollution

Noise pollution is an environmental hazard.

Exposure to sound intensity above **80 dB** may **damage outer hair cells** leading to hearing loss.

Any sound frequency above 80 is considered as noise , threshold of pain is **140db**

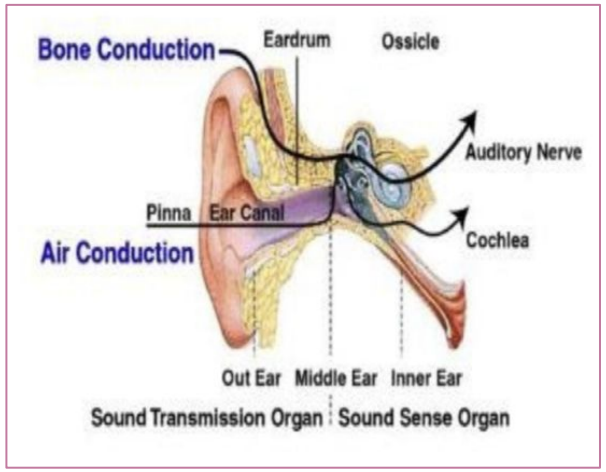




<-- It's important to know the frequencies especially for : whisper, normal conversation, heavy traffic.

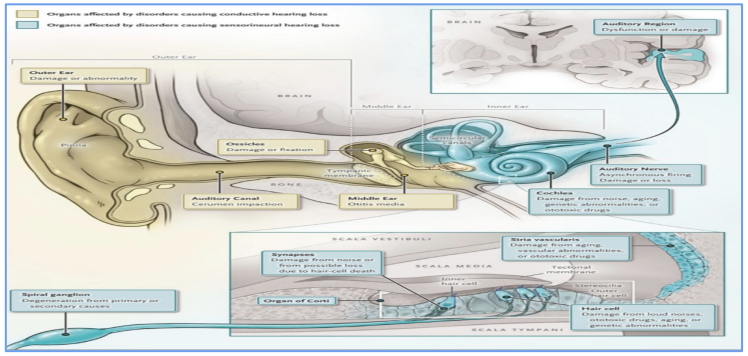
## Conducting of sound waves

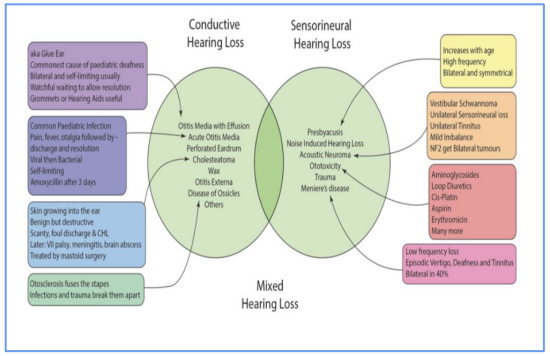
| Air conduction | Bone conduction |
|---|---|
| Normal situation of hearing, sound travel in air causes vibration of Tympanic membrane transmitted by ossicles to the oval window | Sound cause vibration of skull bones directly transmitting the sound vibration to the cochlea (**E.g** when placing tuning fork on the head or mastoid process)<br>E.g. talking while covering your ears or Chewing sounds |



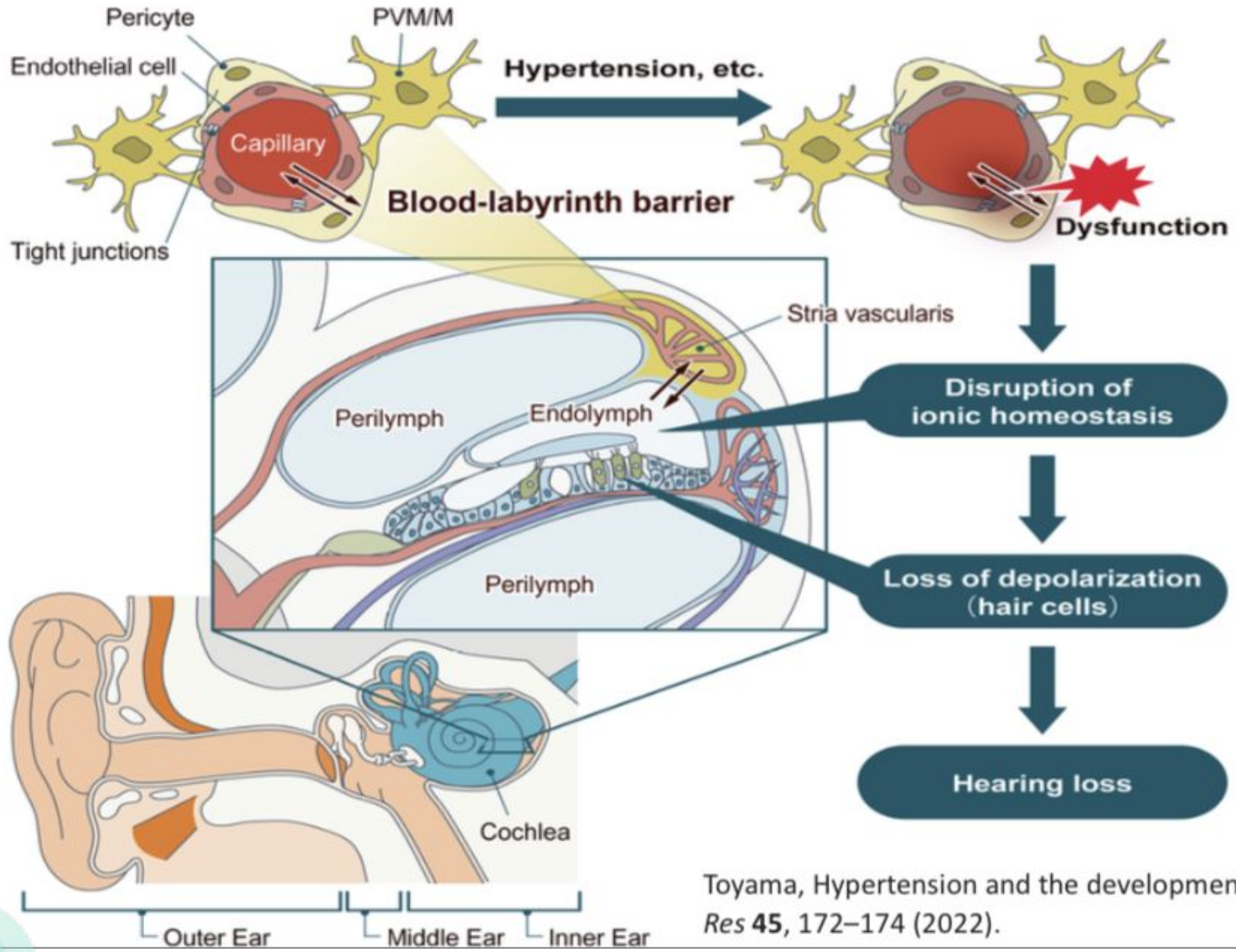

## Deafness

| Conductive deafness | Perceptive deafness |
|---|---|
| ❖ Impairment of sound transmission through external or middle ear **due to:**<br>➢ Wax<br>➢ Repeated infection<br>➢ Perforated drum<br>➢ Destruction of ossicles<br>➢ Osteosclerosis (pathological fixation of stapes on the oval window)<br>❖ **All sound frequencies are equally affected**<br>❖ **Bone conduction is better than air conduction** | ❖ Due to congenital or damage to cochlea or auditory nerve pathway due to:<br>➢ Toxins (antibiotics, gentamicin)<br>➢ Inflammation<br>➢ Vascular (Hemorrhagic or ischemic)<br>➢ Tumour<br>❖ **Both air and bone conduction are affected** |





# Hypertension and hearing loss




Toyama, Hypertension and the development of hearing loss. *Hypertens Res* **45**, 172–174 (2022).

# Test of hearing

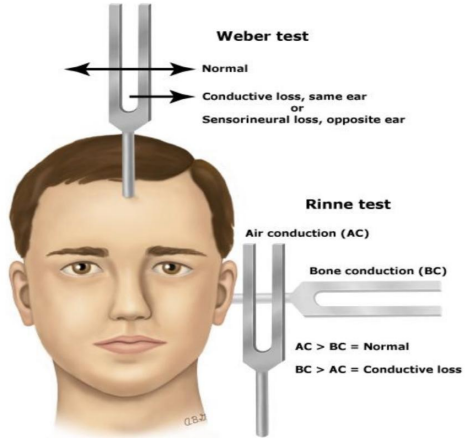


## Audiometer

a machine used for evaluating hearing acuity.

## Weber Test

A tuning fork is placed on the patient's forehead (or in the middle line).




## Rinne test

The base of the tuning fork placed on mastoid process until the sound is not heard Then the prongs of the fork held in air near the ear

- Normal subject continue to hear near ear (Positive Test)
- If not, reveres the test (if heard near the mastoid process, negative test)

## Common tests with a tuning fork to distinguish between sensorineural and conduction hearing loss.

| | Weber | Rinne | Schwabach |
|---|---|---|---|
| **Method** | Base of **vibrating tuning** fork placed on the vertex of skull | Base of **vibrating tuning fork placed on mastoid process** until subject no longer hears it, then held in air next to ear. | **Bone conduction of patient compared with that of healthy subject** |
| **Normal** | Hears **equally** on both sides | Hears vibration in air **after bone conduction is over.** | - |
| **Conduction deafness (one ear)** | **Sound louder in diseased ear** because masking effect of environment noise is absent on diseased side. | **Vibrations in air not heard** after bone conduction is over. | **Bone conduction better than normal** (conduction defect excludes masking noise) |
| **Sensorineural deafness (Nerve deafness) (one ear)** | Sound **louder** in normal ear | Vibration heard in **air after bone conduction is over**, as long as nerve deafness is **partial.** | Bone conduction **worse** than normal |

# TEST YOURSELF !

**1- What is the primary receptor of hearing?**

A) Outer hair cells

B) Inner hair cells

C) Tympanic membrane

D) Basilar membrane

**2- A 28 years- old male went to the ENT outpatient clinic suffering from pain in both ears. He said he is living in a motor vehicle noise polluted area at which level of sound intensity his ears will start to feel pain?**

A) 30dB

B) 50dB

C) 80dB

D) 140dB

**3-A teacher entered the classroom, and while he was teaching he heard two students at the back whispering to each other, which of the following represents the intensity of those whispers?**

A) 100-120 dB

B) 70-80 dB

C)45-60 dB

D) 10-20 dB

**4- Which one of the following known as the function of the middle ear bones (ossicles)?**

A)Enhance the vibration frequencies discrimination

B) Localize the source of the sound

C)Magnify the sound wave

D) Transduction

Answers: B, D, D, C.

# SAQ

From team 439

## 1- what is the function of external ear?

Collect sound,sound localization,protection,alter amplitude,wax

## 2- how are the hair cells arranged within the cochleae?

Three rows of outer hair cells (attached to the reticular lamina or tectorial membrane)
One row of inner hair cells (not attached to tectorial membrane)

## 3- describe the masking effect?

Presence of one sound decreases an individual's ability to hear other sounds.

# Team Leaders

Rafan Alhazzani
Aseel Alsaif
Aldanah Alghamdi
Huda bin Jadaan

Sultan Albaqami
Fahad Almughaiseeb

PHYSIOLOGY
CNS Block
Team 443

# Team Members

Bayan Alenazi
Renad alshehri
Layan Alruwaili
Norah Alhazzani
Haya Alzeer
Huda bin Jadaan
Haya Alajmi
Reena alsadoni
AlJoharah AlWohaibi

Rahaf Alslimah
Jana Alshiban
Razan Alsoteehi
Lena Alrasheed
Layan Aldosary
Shahad Alzaid
Norah Almania
Lama Almutairi
Raghad Alhamid

Layla Alfrhan
Farah Aldawsari
Manar Aljanubi
Waad Alqahtani
Salma Alkhlassi
Shoug Alkhalifa
Sarah Alajajii
Sarah Alshahrani
Wafa Alakeel
Remaz Almahmoud
Sarah Alshahrani

Hamad Alyahya
Mishal aldakhail
Ziyad Alsalamah
Omar Alamri
Sultan almishrafi
Mohammad Alzahrani
Khalid Alanezi
Sami Mandoorah
Abdullah alzamil
Mohammed Alqutub

Salmam Althunayan
faisal alzuhairy
Mohammed Alarfaj
Ryan alghizzi
Mohammed Maashi
Zeyad Alotaibi
Nazmi Adel Alqutub
Faisal Alshowier
Ziad Alhabardi
Osamah almubbadel

Special Thanks to Physiology **Team441**
Team logo and design was done by **Rafan Alhazzani**
Thanks to **ALEEN ALKULYAH** for Helping with the design!

med443physioteam@gmail.com