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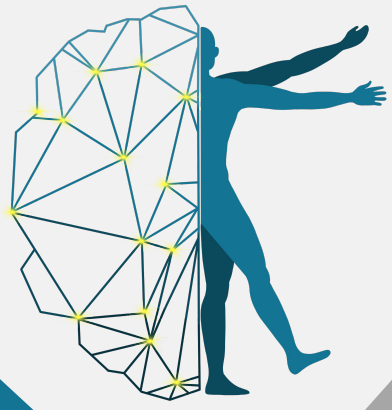


# Physiology Of Hearing

# Objectives:

- Appreciate the functions of outer,middle and inner ear.
- Describe nature of sound and its characteristic.
- Function of semicircular canals & utricle & saccule.
- To understand the role of middle ear in sound transmission, magnification and tympanic reflex effect.
- Recognize the function of hair cells of inner ear.
- Auditory pathway.
- Differentiate between conductive and perceptive deafness.
- Hearing tests.

**Color index:**

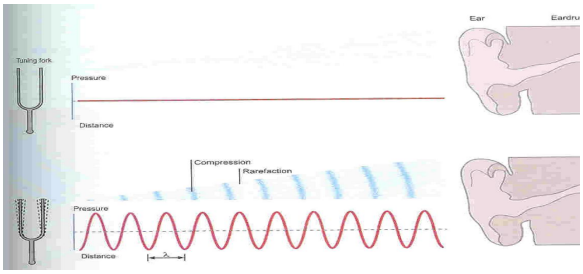
- Important.
- Girls slide only.
- Boys slide only.
- Dr's note.
- Extra information.

**Editing File**

# NATURE OF SOUND

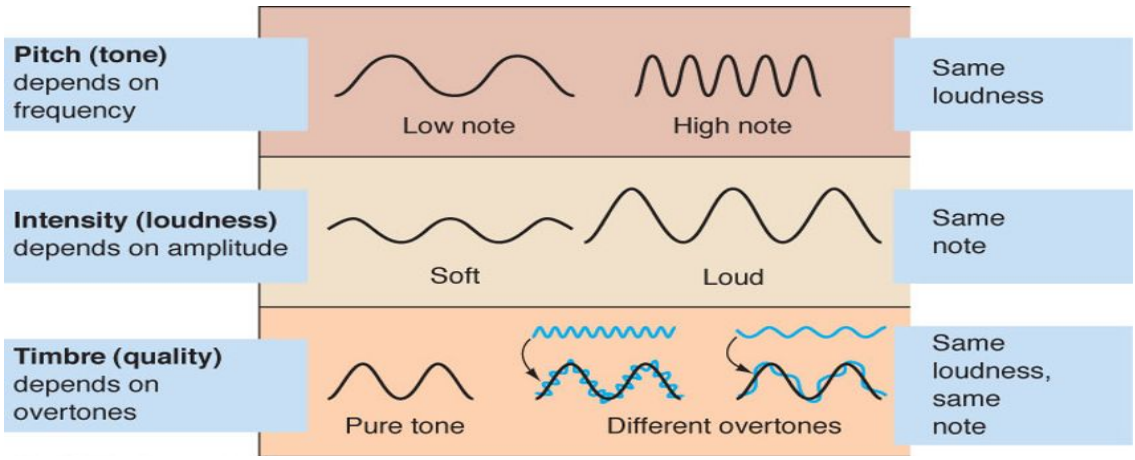
L8

- 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

| **Quality** | **Intensity** (Loudness) | **Pitch** (Tone) |
|---|---|---|
| depend on the overtone or interference. | Depend on amplitude | depend on No.of cycle/sec. (Human ear can detect sound waves with freq.. 20-20000 cycle /sec) |



# 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:
  1- Malleus
  2-incus
  3-stapes (with its foot sitting on the oval window of the inner ear

3

## Inner ear:

- Bony and membranous labyrinth

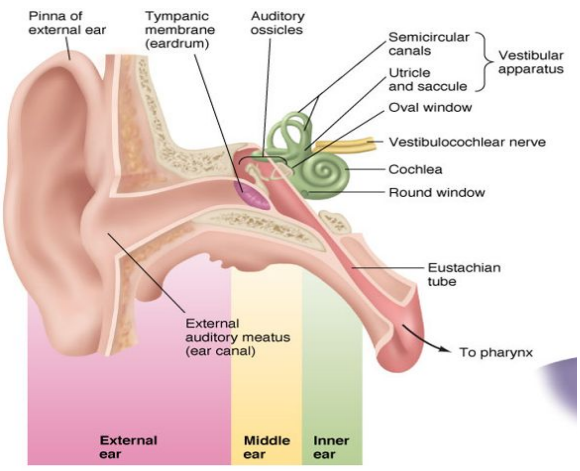
In Girls slide only

**Functions of the ear**

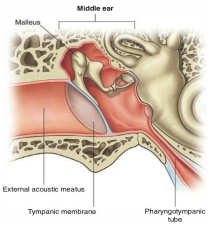
- **Hearing** (Parts involved):
  - External ear
  - Middle ear
  - Inner ear
- **Equilibrium** sense (Parts involved):
  - Internal ear (the vestibular apparatus)

## 1) External ear functions:

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 collect maximum sound waves and it will be concentrated in the tympanic membrane
4. Alter amplitude (Pinna)
5. Wax



# 2) Middle ear:




Itis 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)

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

## 1 Air

## 2 Ossicles

1. Malleus
2. Incus
3. Stapes

- Manbrium 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
- Magnify the sound waves
- 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

1. Tensor tympani
2. Stapedius

- These muscles contract reflexly in response to constant loud sounds (over 70 dB)
- Contraction of the tensor tympani pulls the manubruim & makes the tympanic m. tens (it will become straight instead of the funnel shape creating a gap between tympanic m. and malleus) Thus decreasing the vibration. عشان تحمي الأذن من الأصوات العالية
- Contraction of the stapeduis pull the foot plate outward so that vibration reduced
- Protection from <u>constant</u> loud noise, but not sudden noise, latency of 40-80 msec.

## - Transmission of sound through the middle ear:

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| Sound waves vibrate the tympanic membrane | Tympanic membrane moves the handle of malleus | Incus move | Stapes move in & out of the membrane covering 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: In Girls slide only

1. The surface area of the oval window is smaller than that of the tympanic membrane. Therefore, the sound wave pressure is concentrated on a smaller area. The ratio is 17:1

2. The lever action of the ossicles, caused by the fact that the long process of the incus is shorter than that of the manubrium, increases the force of the incoming sound waves 1.3 times .

3. The total increase: 17 X 1.3 = 22 times

# 3) Inner ear:

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

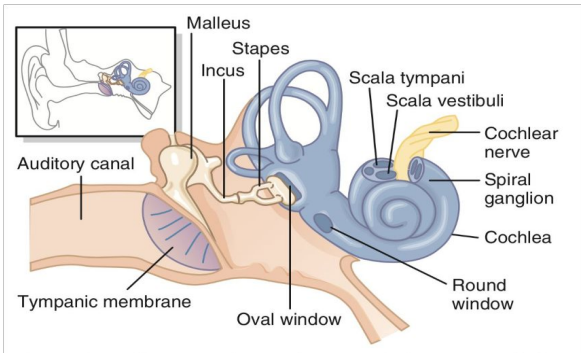



**Figure 53-1.** The tympanic membrane, ossicular system of the middle ear, and inner ear.

## - Cochlea:

- ❖ It is a system of three coiled tubes through its length
- ❖ The basilar membrane and the reissner's (vestibular)

**membrane Divide it into three canals:**
Scala Vestibuli , Scala Tympani, 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 |

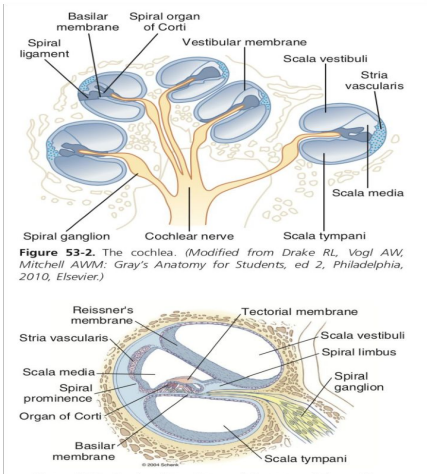



**Figure 53-2.** The cochlea. *(Modified from Drake RL, Vogl AW, Mitchell AWM: Gray's Anatomy for Students, ed 2, Philadelphia, 2010, Elsevier.)*




**Figure 53-3.** Section through one of the turns of the cochlea.

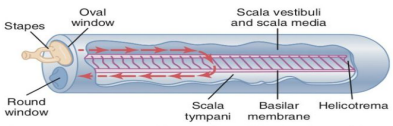
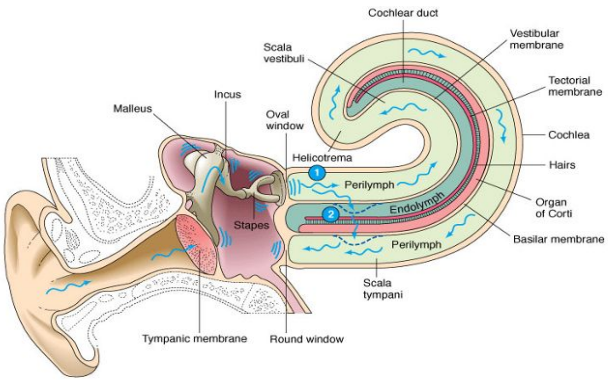
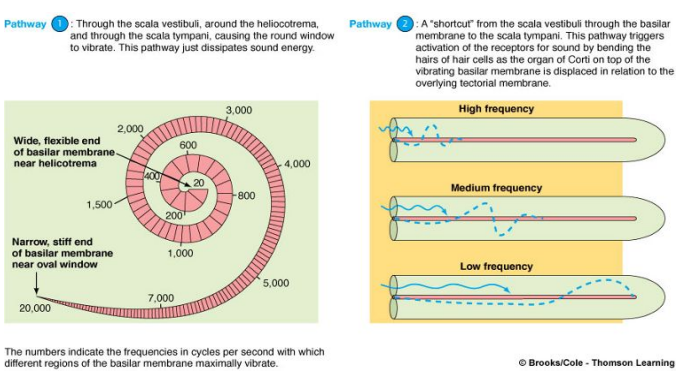



**Figure 53-4.** Movement of fluid in the cochlea after forward thrust of the stapes.



# Organ of corti

1. Located (resting) on the basilar membrane within the cochlea.
   Extending 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.

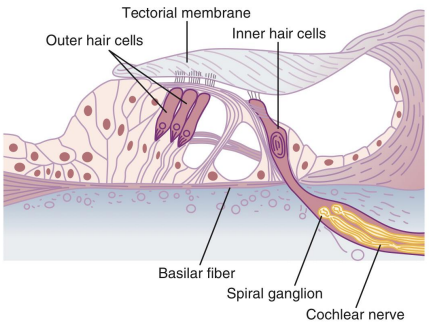



**Figure 53-7.** The organ of Corti, showing especially the hair cells and the tectorial membrane pressing against the projecting hairs.

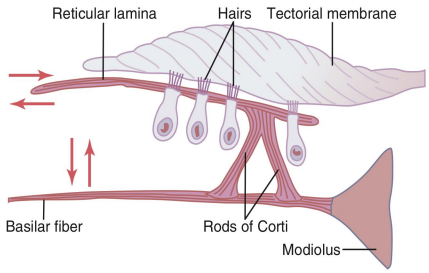
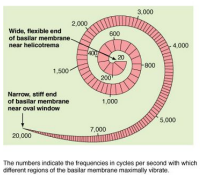



**Figure 53-8.** Stimulation of the hair cells by to-and-fro movement of the hairs projecting into the gel coating of the tectorial membrane.

5. Each frequency will be received by special area in the cochlea. In Girls slide only **but very important**
   - ❖ High frequency sound wave is likely to stimulate the organ of corti in the base of cochlea.
   - ❖ Lower frequency sound waves stimulates the area on the apex.

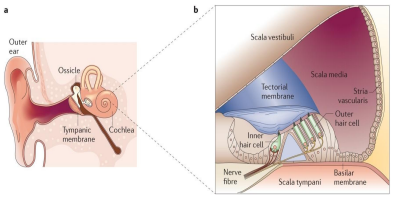


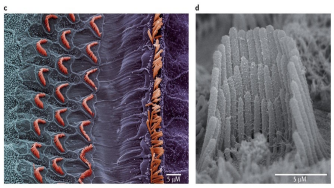

The numbers indicate the frequencies in cycles per second with which different regions of the basilar membrane maximally vibrate.

## Hair cells (Stereocilia) Arrangement and function

### Inner hair cells

**Arrangement**
Extending from the top, One row of inner hair cells (not attached to tectorial membrane).




**Function**
- ❖ Striocellia not embedded in tectorial membrane. but bent by fluid movement under the tectorial membrane.
- ❖ They are primary receptors for sound, transducing fluid movement in cochlea into action potential in the auditory nerve

### Outer hair cells

**Arrangement**
Extending from the top, Three rows of outer hair cells (attached to the reticular lamina or tectorial membrane).

**Function** In Girls slide only
embedded in the tectorial membrane
- ❖ Large number, but stimulate only small fraction of nerve fibres in the cochlear nerve
- ❖ 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

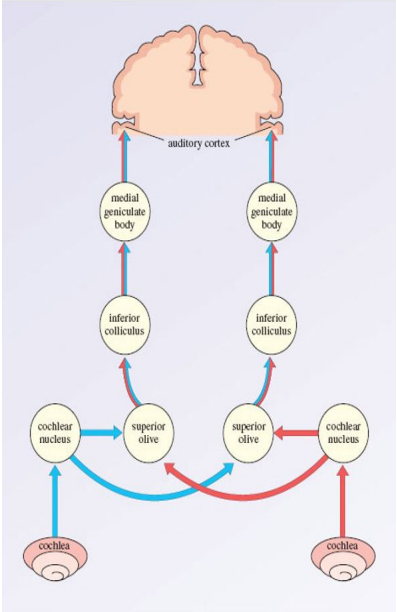
# Receptors & Endocochlear potentials

L8

| | |
|---|---|
| 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<br>→(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, then interpretation occurs in the auditory association areas (wernicke's area)



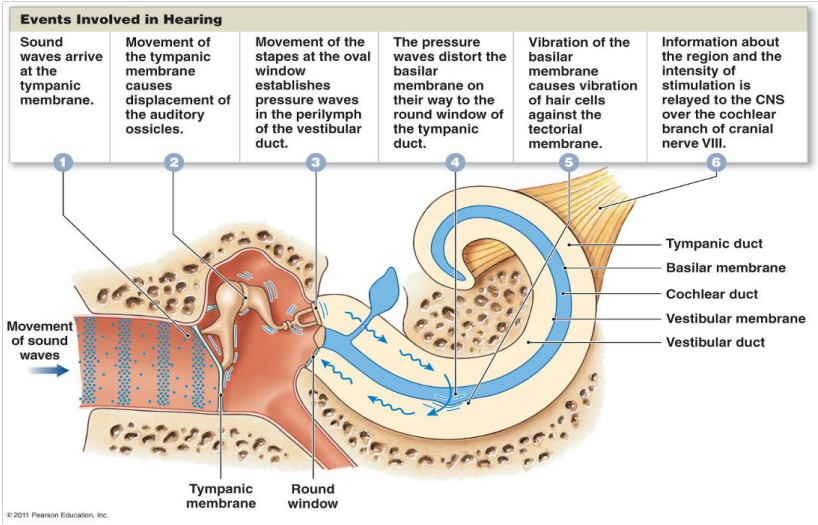

- There is a bilateral cortical connection of auditory area
- Damage to one side only slightly reduces hearing
- Destruction of both primary auditory cortices greatly reduces sensitivity for hearing.
- Destruction of one side slightly reduces hearing in the opposite ear;
- It does not cause deafness 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.
- **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

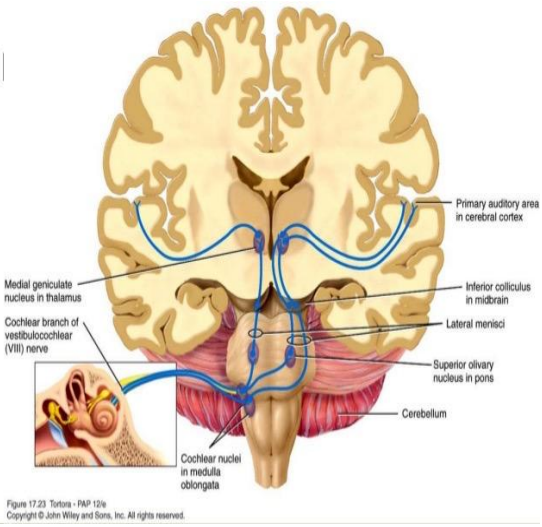
Boys slide only

# General mechanism of hearing

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:** Hair movements in the cochleae
7. **Auditory nerve stimulation**

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




## 1 Sound localization Girls slide only

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

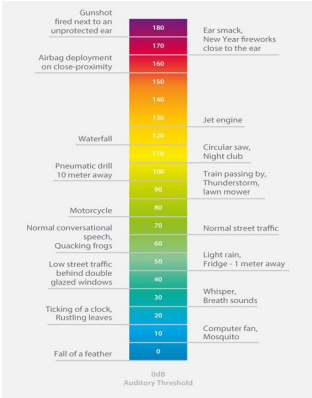
## 2 Masking Effect

Produced by organ of corti

- 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
- Presence of one sound decreases an individual's ability to hear other sounds. This phenomenon is known as **masking**

# 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




## 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

- Impairment of sound transmission through external or middle ear **due to:**
  - Wax
  - Repeated infection
  - 
  - Perforated drum
  - 
  - Destruction of ossicles
  - 
  - Osteosclerosis (pathological fixation of stapes on the oval window)
- All sound frequencies are equally affected
- Bone conduction is better than air conduction

### Perceptive deafness

- Due to congenital or damage to cochlea or auditory nerve pathway **due to:**
  - Toxins (antibiotics, gentamicin)
  - Inflammation
  - Vascular **(**Hemorrhagic **or** ischemic**)**
  - Tumour
- Both air and bone conduction are affected

# Test of hearing

Girls Dr: not important for MCQ

In the Girls slides

**1**

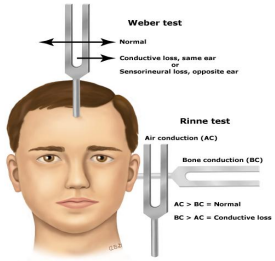
**Audiometer**

a machine used for evaluating hearing acuity.

**2**

**Weber Test**

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




**3**

**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

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

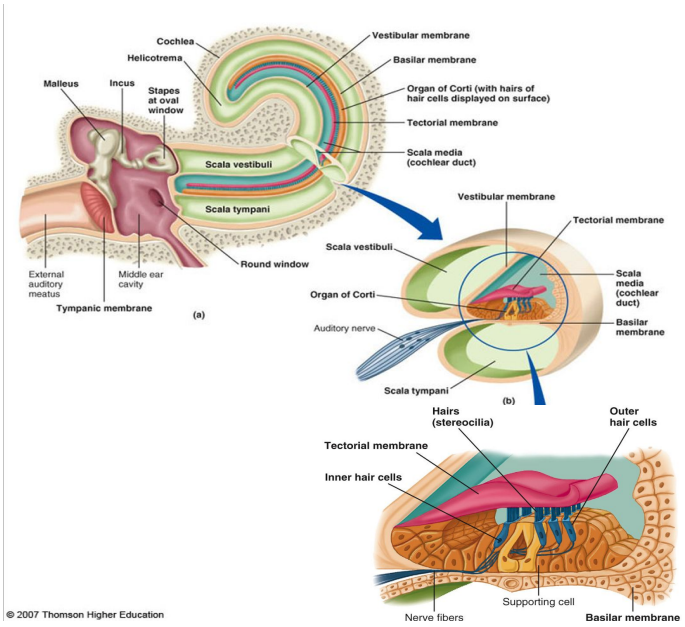
In the boys slides

Common tests with a tuning fork to distinguish between nerve and conduction deafness.

| | 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 normal 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) |
| **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 |

# Picture from the lecture

## Inner ear Slide 6 , 7




## Noise pollution Slide 10


## The Central Auditory pathway Slide 8

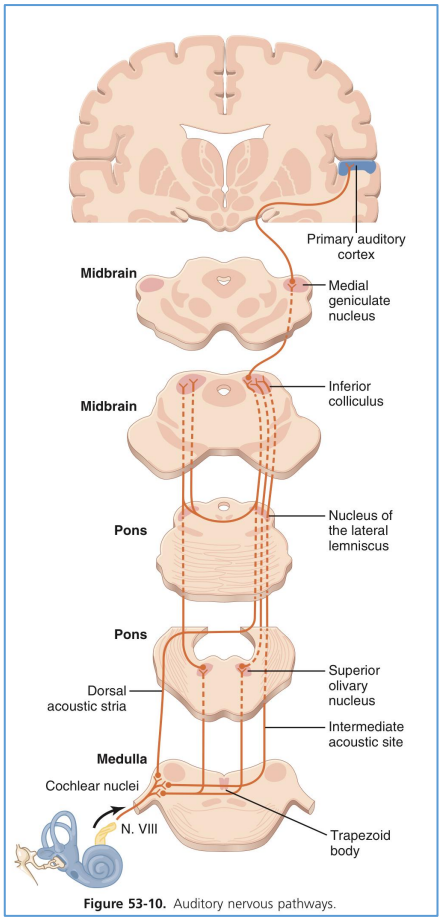
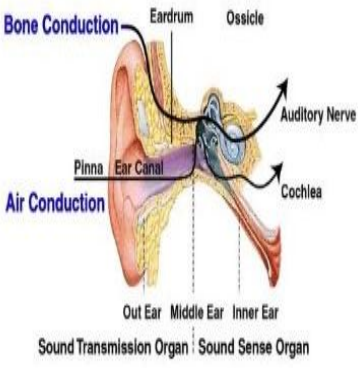
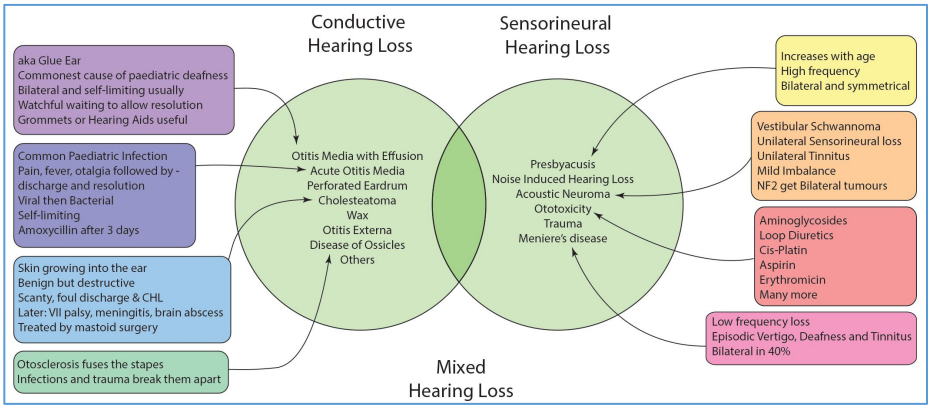



**Figure 53-10.** Auditory nervous pathways.

## Conducting of sound waves Slide 10




## Deafness Slide 10



# MCQ & SAQ:



**Q1: The quality of sound depends on:**

A. No.of cycle/sec
B. Overtone
C. Amplitude
D. Pitch

**Q2: Sound is produced from alternate compression and rarefaction by vibrating body.**

A.True
B. False
C.
D.

**Q3: The total increase of middle ear magnifying:**

A.20
B. 21
C. 22
D. 23

**Q4: Perspective Deafness could be due to one of the following reasons?**

A.Excessive ear wax
B.Osteosclerosis
C.Tumors
D.Perforated drum

**Q5: Which of the following sound intensities could be considered as noise?**

A.95 dB
B.60 dB
C.50 dB
D.20 dB

**Q6: Where does the central auditory pathway start at?**

A. wernicke's area
B. Superior temporal gyrus
C. Area 41 & 42 of the primary cortex
D. Organ of corti

answer key:
1: B
2: A
3: C
4: C
5: A
6: D

**1- What is the part of ear?**

**2- What is the function of external ear?**

**3-How are the hair cell arranged within the cochleae?**

**4-Briefly describe the masking effect**

**A1:External ear,middle ear,internal ear**

**A2:Collect sound,sound localization,protection,alter amplitude,wax**

**A3: 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)**

**A4: Presence of one sound decreases an individual's ability to hear other sounds.**

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- Abdullah Alhumimidi.
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- Abdulrahman Barashid.
- Abdulrhman Alsuhaibany.
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- Aljoharah Albnyan.
- Aljoud Algazlan.
- Almaha Alshathri.
- Arwa Al-Qahtani.
- Bader Alrayes.
- Bassam Alasmari.
- Bushra Alotaibi.
- Faisal Jazzar.
- Feras Alqaidi.
- Ghaida Alassiry.
- Ghaida Alshehri.
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- Norah Aldakhil.
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- Noura Alshathri.
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- Raed Alnutaifi.
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- Reem Alqahtani.
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- Saud Alhasani.
- Shaden Alobaid.
- Shahd Almezel.
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