Lecture (7)

Medical Physics

Fourth Stage

Department of Physics

College of Science

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Medical Physics

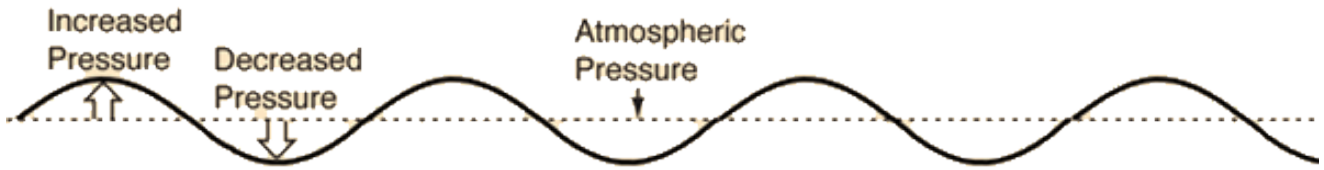
Physics of Hearing and ear

- Wave is a vibration of a partial in a medium. There are two types of wave:

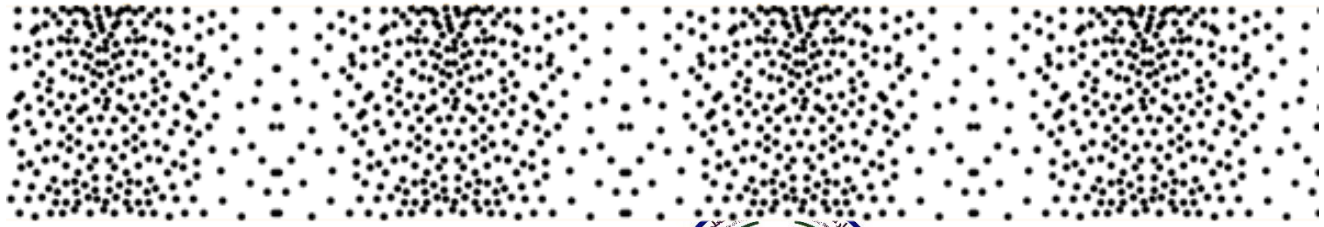
- Transvers wave (as in wire)
- Longitudinal wave (when the medium is air)

- Sound: is a mechanical disturbance produce in elastic medium that travels outwards with some definite velocity.

- Sound is a sensation received by ear. It is physical cause which is stimulate the auditory nerve to produce sensation of hearing.



- Sound waves are longitudinal waves:



- **General properties of sound**

- Amplitude - Frequency

- Wavelength - Phase Velocity $v = \sqrt{\frac{E}{\rho}}$

$where\ E\ is$ Young′s modulus

- **According to frequency, sound is classified into three category:**
- 1- Audible sound (20-20 kHz)
- 2- Ultrasound (>20 kHz)
- 3- Infrasound (<20 Hz)
- Ultrasound and Infrasound is called seismic wave, which is not detected by human ear.

- Table below showing variation in $v\ and\ \rho$

Medium	$\boldsymbol{\rho\ (kg/m^3)}$	**Velocity (m/s)**
Air	1.29	331
Water	$1*10^3$	1480
Brain	$1.02*10^3$	1560
Muscle	$1.04*10^3$	1640
Fat	$0.92*10^3$	1330
Bone	$1.9*10^3$	7680

- **There are two group of sound:**

1- Musical sound

2- Noise

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Function of ear as a hearing organ:

1- As a mechanical receptor

2- As a detector

3- As an analyzer

4- Monitoring action

5- Alerting organ

6- As a direction finder

7- As acoustic transducer

- **Quality of sound:** Characteristic which enables to distinguish between two tones of same pitch and frequency played on two different instrument.
- **Loudness:** is a magnitude of auditory sensation and it is degree of sensation. Loudness is directly proportional to intensity.
- **Pitch:** it is a characteristics of medical sound by which can be distinguish between sound of high frequency and low frequency. Note, voice of ladies and children high pitch and mosquito is also high pitch.

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Unit of intensity of sound:

$$bel = log \frac{Intensity\ of\ sound}{Intensity\ of\ standared\ sound}$$

$$bel = log \frac{I}{10^{-12}\ w/m^2}$$

$$Decibel\ (dB) = 0.1\ bel$$

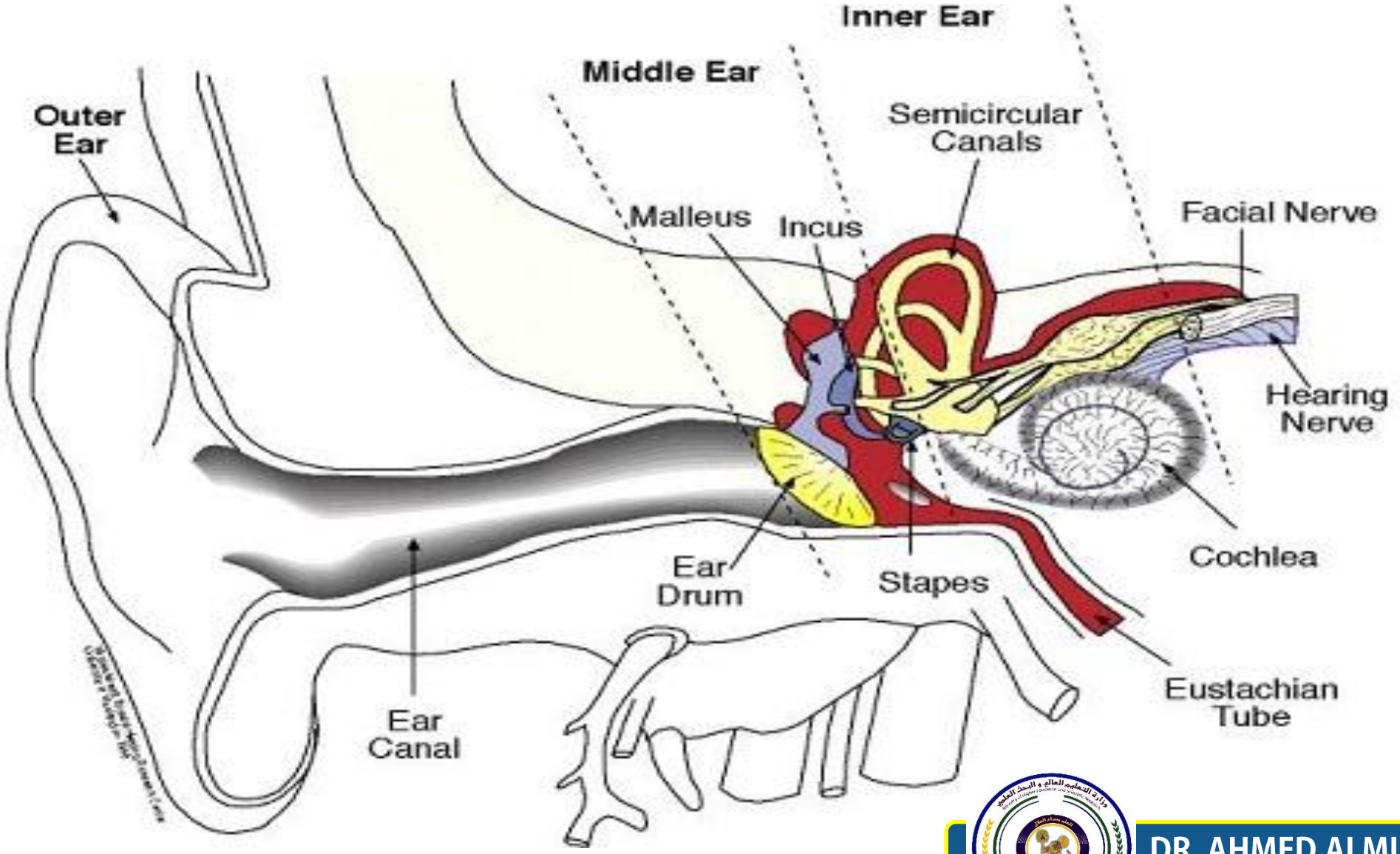
- **Intensity level in dB:**

$$dB = 10\ log \frac{I}{I_o}$$

Where: I intensity of given sound

I_o Intensity of standard sound $(10^{-12}\ w/m^2)$

Various Part of ear:



Cross section of ear

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1- Outer ear:

It consist of pinna and ear canal. It is called as external auditory canal. It is terminating at ear drum funneling of sound wave into canal (≈ 2.5 cm long). A man get (6 to 8) dB by cupping hands behind ear. In some animals, large ears are for loss of body heat.

Length of canal 2.5 cm

$$\lambda = 4\,l = 4 \times 2.5 = 10\ cm$$

$$n = \frac{v}{\lambda} = \frac{330 \times 10^2\ cm/sec}{10} = 3.3\ kHz$$

This shows that resonating frequency of ear drum is 3.3 kHz hence sensitivity is best at 3.3 kHz.

2- Middle ear:

Ossicles matches the impedance of sound waves at the ear drum to the liquid filled chambers of the inner ear.

Malleus, Incus and stapes are arranged to transmit vibrations from ear drum to inner ear. They transmit poorly vibration in the skull.

The ear is designed to reduce the sound waves by impedance matching.

Ossicles protect ear from large sound.

Eustachian tube equalizes pressure.

3- Inner ear:

It is best protected sense organ. It has small spired shaped, fluid filled structure known as cochlea. Ossicles communicate with cochlea via flexible membrane. Cochlea communicate with brain via auditory nerve. Auditory nerve provides information on frequency and intensity of sound wave. Cochlea divided into three chambers:

a) Oval window is on and off vestibular chamber

b) Middle chamber, cochlear chamber

c) Third chamber, Tympanic chamber

Vestibular and Tympanic chamber are inter connected at tip of spiral.

Hearing ability

For testing of hearing ability there is audiologist who checks our ear.

Method of testing hearing ability:

1- Sound proof testing room

2- Each ear tested separately

3- Test sound can be sent to either ear through comfortable headset

4- Subject gives signal when he hears sound

5- Selected frequency: 250 Hz to 8000 Hz

6- Each frequency operator raises and lowest volume until a consistent hearing threshold is obtained.

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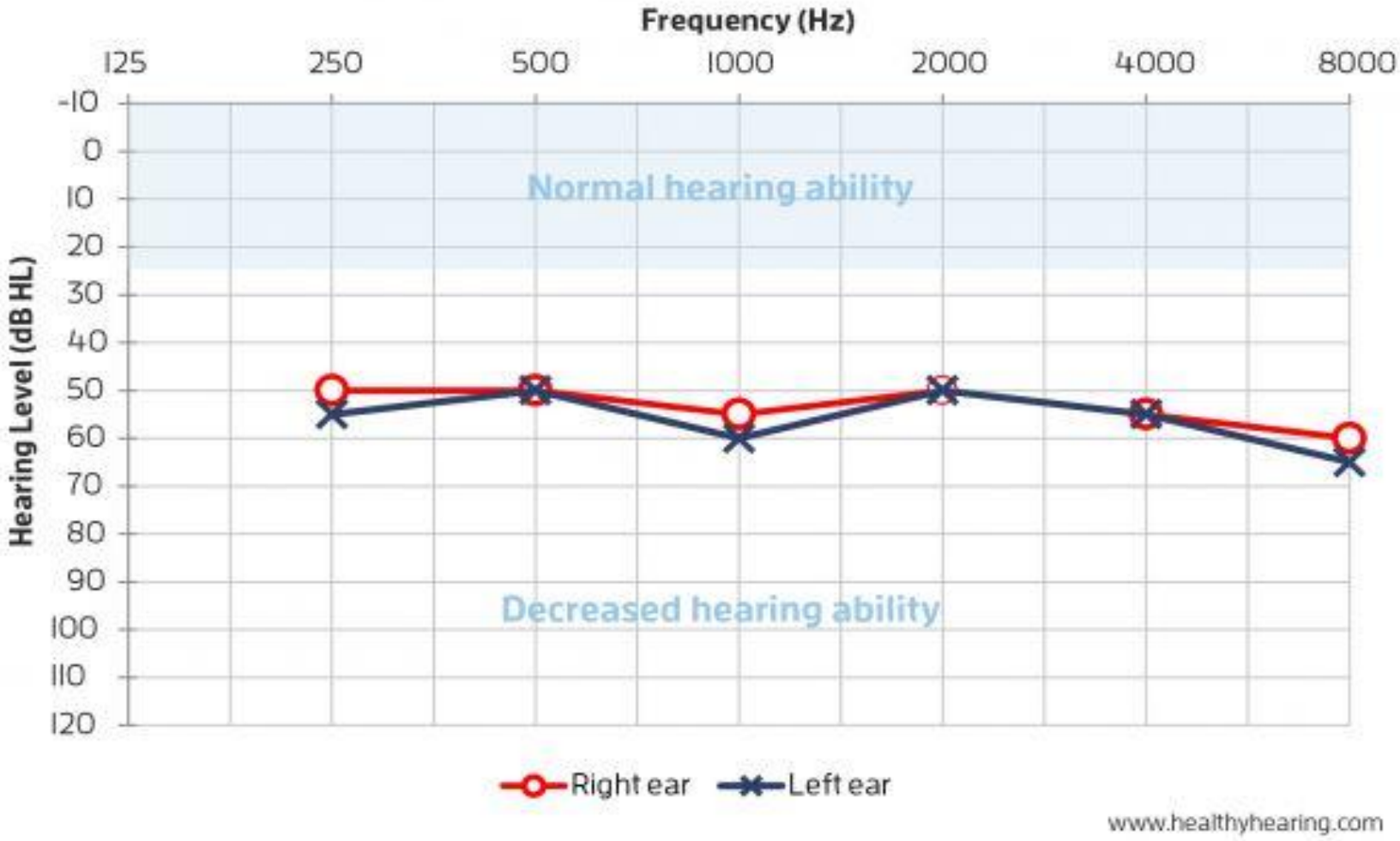

Figure typical hearing ability test

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Hearing Aids

Hearing aids are used to improve your hearing ability. There are two types of hearing loss:

1- Conduction hearing loss: sound vibration do not reach inner ear.

Conduction hearing loss maybe temporary due to plug of wax blockage between ear drum and fluid in middle ear. This can be corrected by stape operation.

If conduction hearing loss is not curable, hearing aids are used.

2- Nerve hearing loss: Sound reaches inner ear but no nerve signals are sent to brain.

- For nerve hearing loss no cure or ids present.

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Types of Hearing Aids

1- Simplest hearing aid: To cup hand behind ear reflects 6-8 dB of additional sound.

2- Ear trumpet: it is artificial hearing aids. Lower hearing threshold by (10-15) dB and it is not common. It is funnel to concentrates the energy at the ear.

3- Electronic hearing aid: Electronic hearing aids like PAs. Possible to obtain amplification of 90 dB. Hearing aid compensate hearing loss only. Abrupt hearing loss above 3000 Hz cannot be completely corrected.

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