NERVOUS SYSTEM BLOCK

9th Lectures

Physiology of Hearing

PHYSIOLOGY TEAM – 430

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- **General anatomy of the ear:**

1. External ear :
- Pinna (cartilaginous outer part of the ear) also named auricle.
- External auditory meatus
- Tympanic membrane (ear drum)

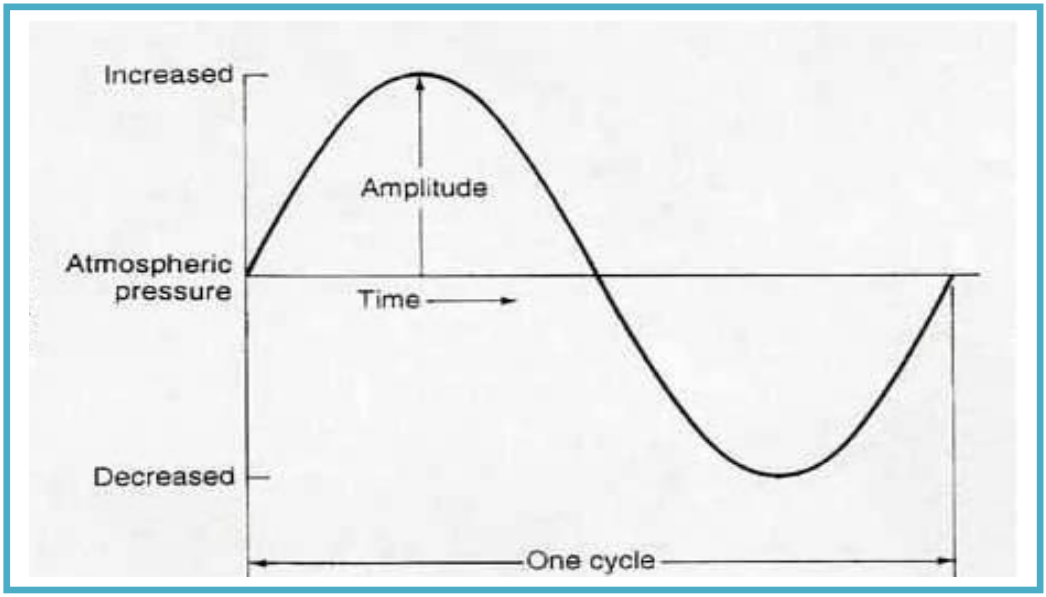
2. Middle ear: (air-filled cavity):
- Bones (auditory ossicles) :
  - Mallaus.
  - Incus.
  - Stapes.
- Muscles (tensor tympani – stapedius)
- Nerves

3. Internal ear:
- Bony and membranous labyrinth.

- **How is the sound produced ?**
  It is produced from alternate compression and rarefaction (الخلخله و الضغط)of air molecules by vibrating body.
  Stimulus : sound
  Alteration between compression and refraction of air molecule creates the sound waves.

- **Basic properties of sound waves:**

1- Amplitude: intensity
2- Frequency: pitch, tone
3- Quality (timbre): overtones



– **Amplitude (loudness):**

- (Low sound means low amplitude and vise versa)
- Measuring scale:

  1 decibel (dB) = 0.1 Bel

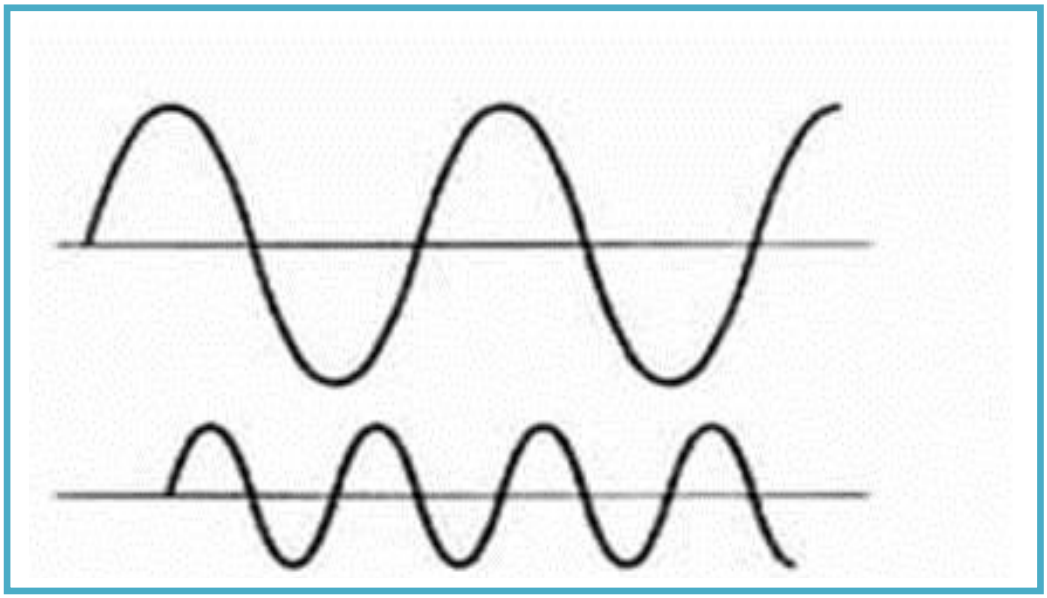
Its the unit to measure the sound as a whole wave
The threshold starts at 0 dB

- 0 dB sound intensity at a pressure of: 0.000204 dynes/cm^2

Sound	Rating (dB)
Absolute silence	0
Whisper	10
Automobile – 30 ft	60
Conversation – 3 ft	70
Loud radio	80
Pneumatic hammer – 3 ft (drill)	120
Jet aircraft takeoff	+15

– **(Automobile – 30 ft: means the sound of the automobile (ex. Car) with the distance of 30 ft)**

– **Sounds > 80 dB are considered as sound pollution**



– **Frequency :**

- number of cycles/seconds (hertz, hz)(اختلاف مخارج الحروف)

Human ear can detect sound waves with frequencies between 20-20000 cycle/sec

- **Mechanism of hearing:**

- **External ear:**

Functions :

1. Detection (localization) & collection of sound waves.
2. Concentration of sound waves in the external auditory meatus
3. Protections (ear wax)

- **Tympanic membrane:**

- Resonator: Vibrates at the same frequency as the sound waves
- Critical damping:
  means that the tympanic membrane stops vibrating once the stimulus has stopped)

- **Middle ear:**

Functions:

1. **Transmission of sound to the inner ear**

The pathway of transmission:

Vibrations are collected by the auricle > external auditory meatus > tympanic membrane vibrates > movement of handle of malleus > ancous > stapes > oval window > pressure to the cochlea > stimulation of hair cells in organ of corti > stimulation of auditory nerve.

2. **Amplification of sound (x22 times)**

A. Concentration of force: Due to the size of the tympanic membrane, which is 17 times greater than the oval window (Amplification due to difference in area size).

- Area of drum: 55 mm^2
- Area of oval window: 2.5 mm^2

B. Leverage (Lever system) (الترس): The force increases about 1.3 fold when it moves from big objects to smaller ones (the ossicles).

Amplification due to difference in areas is x17 times
Total amplification of sound is 1.3X17 = 22 times

So the amplification of sound is due to the size difference between the tympanic membrane and the oval window (17 times) plus the lever system of the ossicles (1.3 times) and their multiplication is equal to the total amplification, which is 22 times

3. **Protection from laud continuous noise.**

– The tympanic reflex:

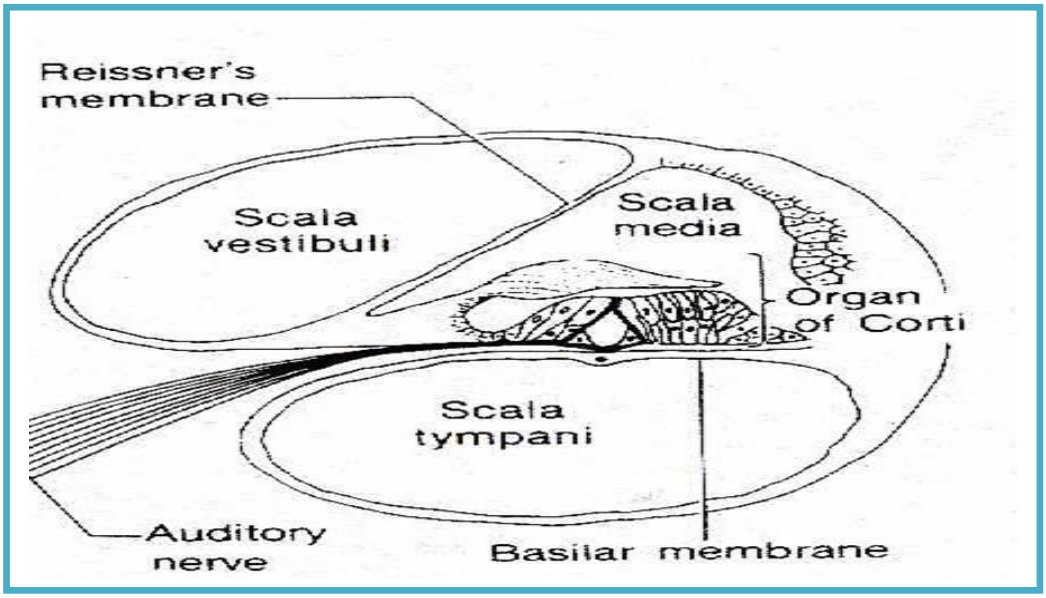
1- It is the contraction of the 2 muscles (tensor tempani contractes to tense the tympanic membrane > less vibrates transmitted & contraction of stapedius) in response to a very loud sound (70 db) and the main function of this reflex is to protect the inner ear.
2- Latent period of tympanic reflex: 30-130 msec
Sudden noise doesn't stimulate this reflex. It has to be continuous for at least 40-80 msec.

- **Inner ear:**

  - Bony structure lined by membrane (fluid filled cavity)
  - There are two membranes inside the inner ear (Basilar membrane and Vestibular "Reissner's" membrane) and the main function of these membranes are the division of the cochlea into three chambers (Scala Vestibuli, Scala Tympani and Scala Media)
  - Scala tympani and vestibule are both filled with the perilymph while the scala media is filled with the endolymph.

  - The main components of the Cochlea are:

1- The organ of corti
2- Auditory "vestibulocochlear" nerve
3- Basilar membrane



	endolymph	Perilymph
K+ (mmol/l)	144.8	4.8
Na+ (mmol/l)	15.8	150.5
Cl+ (mmol/l)	107.1	121.5
Protein (mg/dl)	15	50.0

The endolymph has the property of the intracellular fluid (depolarized) high K and low Na.While the perilymph has the property of the extracellular fluid (hyperpolarized) high Na and low K.

- **Organ of Corti:**

  Collection of cells located in the basilar membrane in scala media
  It contains:

  1- One row of inner hair cells
  2- Three rows of outer hair cells
  3- tectorial membrane: one sided free moving membrane attached with the outer hair cells only.

- **Auditory receptors:**

  Receptors are hair cells (have stereocilia not embedded into the tectorial membrane) and they have two types:

  1- Inner hair cells: single row (n=3500)
  2- Outer hair cells: three row (n=20,000)

- 90-95% of auditory nerve fibers innervate inner hair cells & 5-10 innervates the outer hair cells

- **Functions of inner hair cells:**

– Primary receptors for sound.
– Hairs are bent by fluid movement under the tectorial membrane
– i.e. transducing fluid movement into action potentials in the auditory nerve.

- **Functions of outer hair cells:**

– They are supplied by efferent cholinergic fibers from superior olivary complex.
– Large number, but stimulate only small fraction of nerve fibers in the cochlear nerve
– If damaged they cause significant loss of hearing (they control the sensitivity of inner hair cells to particular sound frequency.
– Contractile >> Tension in basilar membrane.

Each hair cell is stimulated by particular type of frequencies

- **Sound transmission in the middle and inner ears:**
  The bony wall is rigid and the membranes are flexible >> peaks of waves will enter the scala vestibuli >> basilar membrane depression >> bending of hair cells >> generation of action potential

- **The central auditory pathways:**

  This pathway begins in the organ of corti and ends in the primary auditory cortex (area 41& 42 of superior temporal gyrus in the temporal lobe of the brain)

  Fibers end in the auditory area (anterior end of the superior temporal gyrus) > where it is heard.

  Interpretation occurs in the auditory association areas (posterior end of the superior temporal gyrus) (wernikes area)

  Because there is a bilateral cortical connection of auditory area, damage to one side only slightly reduces hearing.

- **Sound localization :**

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

- **Masking effect:**

> Noise pollution is an environmental hazard.
>
> Exposure to sound intensity above 80dB may damage outer hair cells

– Presence of background noise affect the ability to hear another sound, due to some receptors are in refractory period (they are occupied by other sound)
– Masking is more clear if two sound are having the same frequencies

- **Conduction of sound waves:**

1-Air conduction (main pathway of hearing in humans):

Normal situation of hearing, sound travel in air causes vibration of Tympanic membrane, transmitted by ossicles to the oval window

2-Bone conduction

Sound waves cause vibration of skull bones which directly transmit the sound vibration to the cochlea (eg when placing tuning fork on the head or mastoid process)

In some animals this is the main pathway of hearing.

- **Tests of hearing:**

– Audiometer
– Weber test
– Rinnes test