Ear examination
Sound wave:

**Sound**: it is the sensation produced when *longitudinal vibration* of the molecules in the external environment, i.e., alternate phase of condensation and rarefaction of the molecules, strike the tympanic membrane.

The speed of sound in air is about (344m/s) at 20°C at sea level. The speed of sound increases with:

1. Temperature.
2. Altitude.
3. Media: for example, the speed of the sound wave is (1450m/s) at 20°C in fresh water and is even greater in salt water.

**The characters of the sound:**

1. **Pitch of the sound (is correlated with the frequency).**
   - Frequency: is the number of waves per unit of time.
   - The greater the frequency, the higher the pitch.

2. **Frequency**: is the number of waves per unit of time.

3. **Heinrich Rudolf Hertz**: (هيرتز، 1857 - بون، 1894) هو فيزيائي ألماني أثبت بتجاربه وجود الأمواج الراديوية وبين أن خصائصها شبيهة بخصائص الأمواج الضوئية. وقد كان لتجاربه فضل كبير في اختراع التلغراف اللاسلكي.
2. Loudness of the sound (is correlated with the amplitude)

- The greater the amplitude, the louder the sound.

- The amplitude of a sound wave can be expressed in terms of the maximum pressure change at the eardrum, but a relative scale is more convenient. The **decibel scale** is such a scale.

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- The standard sound reference level adopted by the **Acoustical Society of America** corresponds to decibels at a pressure level of 0.000204 dyne/cm², a value that is just at auditory threshold for the average human. It is important to remember that the decibel scale is a log scale. Therefore, a value of zero deci-bel does not mean the absence of sound but a sound level of intensity equal to that slandered.

- The 0 to 140 decibel range from threshold pressure to a pressure that is potentially damaging to the organ of Corti actually represents a 10 million-folds variation in sound pressure. The ears can barely distinguish an approximately 1-decibel **change** in sound intensity.

- The sound frequencies audible to humans range from about 20 to a maximum of 20,000 cycle per second (Hz).

- In old age, this frequency range is usually shortened to 50 to 8000 cycles/sec or less.

- In other animals, notably bats and dogs, much higher frequency is audible.

- The Threshold of the human’s ear varies with the pitch of the sound, the greatest sensitivity being in the 1000 to 4000 Hz range.
The pitch of the average male voice in conversation is about 120 Hz and that of the average female voice about 250 Hz.

The number of pitches that can be distinguished by an average individual is about 2000, but trained musicians can improve on this figure considerably. **Pitch discrimination** is best in the 1000 to 3000 Hz range and is poor at high and low pitches.

**Masking:**

- It is common knowledge that the presence of one sound decreases an individual’s ability to hear other sounds. This phenomenon is known as masking.
- It is believed to be due to the relative or absolute refractoriness of previously stimulated auditory receptors and nerve fibers to other stimuli.
- The degree to which a given tone masks other tones is related to its pitch.

**Sound transmission:**

The ear converts sound waves in the external environment into action potentials in the auditory nerve. The waves are transformed by the eardrum and auditory ossicles into movements of the footplate of the stapes. These movements set up waves in the fluid of the inner ear. The action of the waves on the organ of Corti generates action potentials in the nerve fibers.
• Tympanic membrane:

In response to the pressure changes produced by sound wave on the external surface, the tympanic membrane moves in and out.

The membrane therefore functions as a resonator that reproduces the vibration of the sound source. It stops vibration almost immediately when the sound wave stops; i.e. it is very nearly critically damped.
Middle ear (Ossicular system):

The ossicles of the middle ear suspended by ligament in such a way the combined malleus and incus act as a single lever, having its fulcrum approximately at the border of the tympanic membrane.

The articulation of the incus with the stapes causes the stapes to push forward on the cochlear fluid every time the tympanic membrane and the handle of the malleus move and to pull backward on the fluid every time the malleus moves outward.

The ossicular lever system does not increase the movement distance of the stapes, as it commonly believed. Instead, the system actually reduces the distance but increase the force of movement about 1.3 times. In addition, the surface area of the tympanic membrane is about 55 mm², whereas the surface area of the stapes average 3.2 mm². This 17-fold difference times the 1.3-fold ratio of the lever system causes about 22 times as much pressure to be exerted on the fluid of the cochlea as is exerted by the sound wave against the tympanic membrane.

Because fluid has far greater inertia than air, it is easily understood that increased amounts of pressure are needed to cause vibration in the fluid. Therefore, the tympanic membrane and ossicular system provide impedance matching مطابمة المقاومة between the sound waves in air and the sound vibrations in the fluid of the cochlea.

Indeed, the impedance matching is about 50 to 75 percent of perfect for sound frequencies between 300 and 3000 cycles/sec, which allows utilization of most of the energy in the incoming sound waves.
Tympanic reflex (attenuation reflex):

Tympanic reflex occurs after a latent period of only 40 to 80 milliseconds to cause contraction of the **stapedius muscle** and, to a lesser extent, the **tensor tympani muscle**

Loud sounds initiate a reflex contraction of these muscles generally called the **tympanic reflex**

Stapedius muscle (pull stapes outward) ➤ prevent excessive movement of stapes

Tensor tympani (pull Malleus inward) ➤ pull tympanic membrane inward ➤ tense tympanic membrane.
The functions of tympanic reflex are:

1) To protect the cochlea from damaging vibrations caused by excessively loud sound. This attenuation reflex can reduce the intensity of lower-frequency sound transmission by 30 to 40 decibels, which is about the same difference as that between a loud voice and a whisper.

2) To mask low-frequency sounds in loud environments. This usually removes a major share of the background noise and allows a person to concentration on sounds above 1000 cycle per second, where most of the pertinent information in voice communication is transmitted.

3) To decrease a person’s hearing sensitivity to his or her own speech. This effect is activated by collateral signals transmitted to these muscles at the same time that the brain activates the voice mechanism.

Deafness:
It is a condition wherein the ability to detect certain frequencies of sound is completely or partially impaired.

Hearing impairments are categorized by: their type, by their severity, by the age of onset and by the site.

1. By their types:
A. Conductive hearing loss
A conductive hearing impairment is an impairment resulting from dysfunction in any of the mechanisms that normally conduct sound waves through the outer ear (external ear), the eardrum or the bones of the middle ear.

The abnormality reduces the effective intensity of the air-conducted signal reaching the cochlea, but it does not affect the bone-conducted signal that does not pass through the outer or middle ear.

Examples of abnormalities include ① occlusion of the external auditory canal by cerumen (ear wax) or a mass, ② middle ear infection and/or fluid, ③ perforation of the tympanic membrane, or ④ ossicular abnormalities.
B. Sensori-neural hearing loss
A sensori-neural hearing impairment is one resulting from dysfunction in:
1. Sensory: Sensory the inner ear, especially the cochlea where sound vibrations are converted into neural signals
2. Neural: either ① Neural auditory nerve (vestibule-cochlear N: VIII Cranial) ② the brain.

C. Mixed
Mixed hearing loss has conductive and sensori-neural components.

2. By severity:
The severity of a hearing impairment is ranked according to the additional intensity above a nominal threshold that a sound must be before being detected by an individual; it is (measured in decibels of hearing loss, or dB).

Hearing impairment may be ranked as mild, moderate, moderately severe, severe or profound as defined below:

A. Mild:
For adults: between 26 and 40 dB HL.
For children: between 20 and 40 dB HL
B. Moderate: between 41 and 55 dB HL
C. Moderately severe: between 56 and 70 dB HL
D. Severe: between 71 and 90 dB HL
E. Profound: 91 dB HL or greater
3. By age:
The age at which hearing loss occurs is crucial for the acquisition of a spoken language.
A. Pre-lingual deafness
Pre-lingual deafness is hearing impairment that is sustained prior to the acquisition of a spoken language.
B. Post-lingual deafness
Post-lingual deafness is hearing impairment that is sustained after the acquisition of a spoken language.

4. By the site:
A. Unilateral hearing impairment:
People with unilateral hearing impairment have impairment in only one ear.
B. Bilateral hearing impairment:
People with bilateral hearing impairment have impairment in both ears.

How to detect hearing loss?
I. Using tuning fork:
A. Rinne's test:

Compares air conduction with bone conduction normally air conduction > bone conduction (Rinne positive test)
• BC > AC = conductive hearing loss
• AC > BC but impaired = sensori-neural hearing loss
B. Weber’s Test
Interpretation of Results:
Normal Response: sound is heard equally at both ears.
Sensori-neural Hearing Loss: loudest sound in unaffected ear. This is because the affected ear is less effective at picking up sound even if it is transmitted directly by conduction into the inn ear.
Conductive Hearing Loss: Loudest sound in affected ear (hears vibrations only). This is because the conduction problem masks the ambient ambient noise of the room, whilst the well-functioning inn ear picks the sound up via the bones of the skull causing it to be perceived as a louder sound than in the unaffected ear.
2. Audiometry (Pure Tone Audiometry):
An audiogram is the best test for hearing.

Air conduction is measured by placing earphones over both ears. Each ear is tested individually to determine its hearing threshold (pitches) at 250, 500, 1000, 2000, 4000, 6000, and 8000 cps or Hertz (Hz). The numbers running from left to right across the top of the graph. They run from low to high, from left to right.

Hearing is measured in decibels (dB), which is a logarithmic scale from -10 to 120 dB. The hearing threshold is defined as the quietest sound heard by the person when being tested. The numbers running from the top to the bottom of the graph indicate loudness levels. Numbers closer to the top relate to soft sounds (like a pin dropping) while numbers at the bottom refer to much louder sounds (like a plane flying overhead).

A normally hearing person would expect to have a threshold of 20dB or better and this represents no hearing loss on the audiogram. The everyday 6dB increase measured represents a doubling of sound pressure level. To the human ear (perceptually), every 10dB increases sounds twice as loud. For example, 20 dB sounds twice as loud as 10dB but 40dB sounds twice as loud as 30dB and 8 times as loud as 10dB (i.e. 10 to 20 to 30 to 40 is $2 \times 2 \times 2 = 8$ times as loud).

It is important to note that hearing is NOT measured in percentages.
An audiometer is a special instrument that is used to measure the acuity of hearing.

Hearing loss audiometry includes quantitative testing for a hearing deficit. An audiometer is used to measure and record thresholds of hearing by air conduction and bone conduction tests. The test results determine if hearing loss is conductive, sensorineural, or a combination of both. Hearing loss audiometry includes quantitative testing for a hearing deficit.