

Al-Mustaqbal University

College of Science

Medical physics Department

Medical Physics II

Second Semester

3<sup>rd</sup> stage



# Lesson 3

# Physics of the ear and hearing

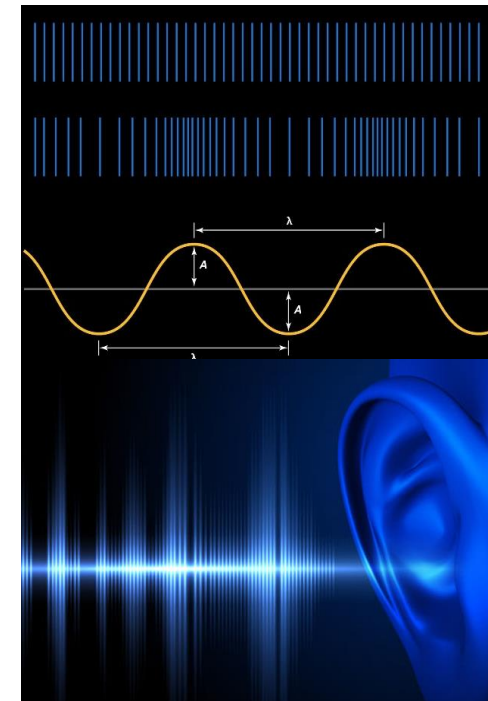
Prof. Dr. Hikmat Adnan

## Soundwaves

A sound wave is the pattern of disturbance caused by the energy travelling away from the source of the sound. Sound waves are longitudinal waves; this means that the propagation of vibration of particles is parallel to the energy wave propagation direction. When the atoms are set in vibration they move back and forth. This continuous back and forth motion results in a high-pressure and a low-pressure region in the medium. These regions are transported to the surrounding medium resulting in the sound waves travelling from one medium to another.

Medium	Speed of sound
Water	1481 m/s
Air	343.2 m/s
Copper	4600 m/s
Hydrogen	1270 m/s
Glass	4540 m/s

The lower the **frequency**, the fewer the oscillations. High frequencies produce more oscillations. The units of frequency are called hertz (Hz). Humans can hear sounds between 20 Hz and 20,000 Hz. Frequencies above 20,000 Hz are known as ultrasound.



## Hearing system

We can hear a range of sound intensities of over a million million ( $10^{12}$ ), or 100 times greater than the range of light intensities the eye can handle.

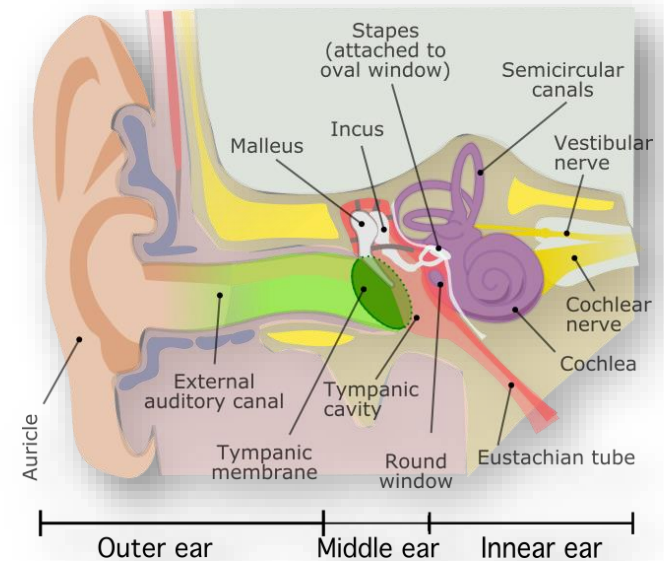
The sense of hearing involves

- (1) The mechanical system that stimulates the **hair cells** in the **cochlea**.
- (2) The **sensors** that produce the action potentials in the nerves.
- (3) The **cortex**, the part of the brain that interprets the signals.

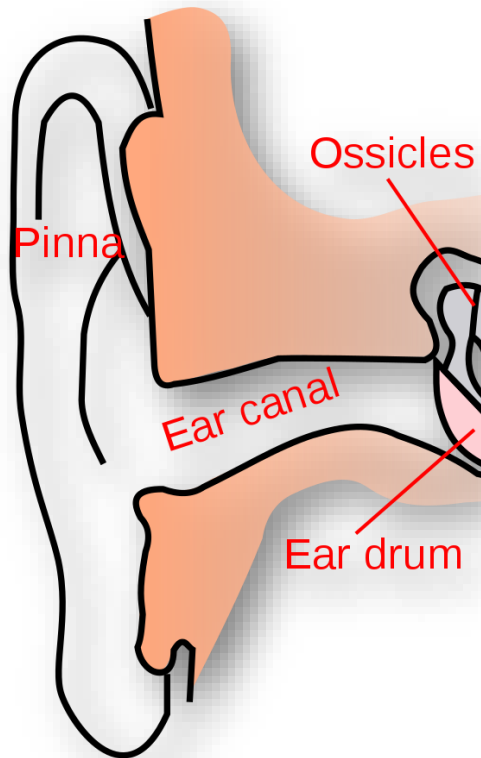
**Deafness** or hearing loss results if any of these parts malfunctions.

The ear is divided into three areas;

- (1) **The outer ear**; consists of the ear canal which terminates at the eardrum.
- (2) **The middle ear**; includes the three small bones (**ossicles**).
- (3) **The inner ear**; consists of the fluid-filled, spiral-shaped cochlea containing the organ of **corti**.



## (I) The Outer Ear



The outer ear is the external part of the ear; its function is to collect sound waves and to direct them into the ear. Important parts of the outer ear are;

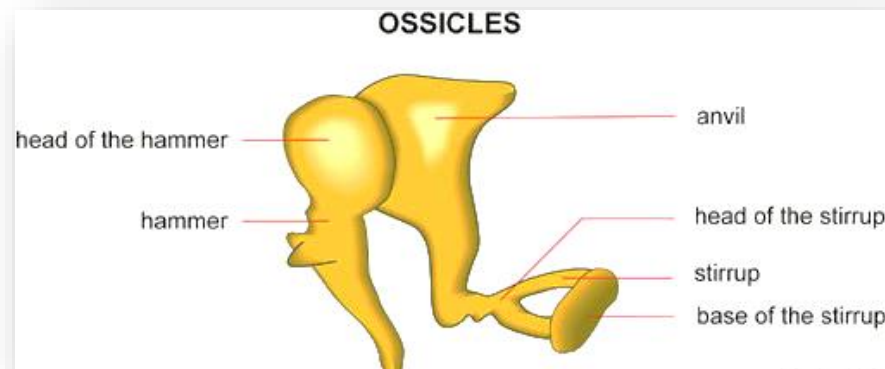
- Pinna, the ear canal. Its 2.5 cm long and the diameter of a pencil
- Eardrum (0.1 mm thick)

The pinna is the visible part of the ear. It acts as a funnel to direct sound further inside the ear without loss. The ear canal is located right after the pinna to transmit the sound to the eardrum. It is a very sensitive part of the ear that vibrates due to the pressure of sound waves.

## (2) The Middle Ear

The middle ear is the part that connects the inner and outer parts of the ear. It consists of;

- **The hammer**
- **The anvil**
- **The stirrup**
- **The round window**
- **The Eustachian tube (auditory tube)**



*The hammer, anvil, and stapes* are three bones inside the middle ear that sound passes through to reach the round window .

*The round window* is a membrane that covers the cochlea. Its function is to amplify the sound waves before they enter the inner ear. The pressure suddenly increases as the sound waves enter a relatively small space.

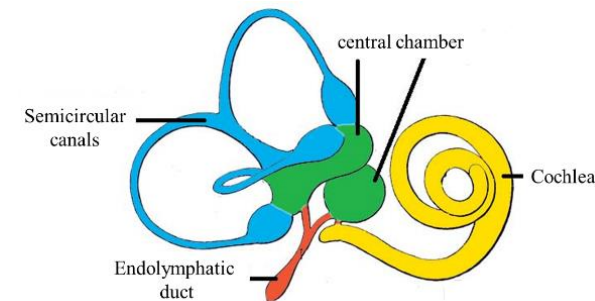
*The Eustachian tube*'s function is to equalize the air pressure on both sides of the eardrum to avoid pressure buildup. The tube opens during swallowing which equalizes the air pressure inside and outside the ear.

### (3) The Inner Ear

The inner ear is located near the middle ear, and under the temporal bone of the brain that protects structures and nerves of the ear. It consists of two different networks of passages (the membranous and the bony labyrinths).

The bony labyrinth is a hollow cavity located at the temporal bone of the skull with multiple passages that consist of three main parts:

- **The cochlea .**
- **The three semicircular canals.**
- **The central chamber called the vestibular system.**



The cochlea is responsible for hearing

Cochlea is made of a bone that is structured similar to a snail, about 9mm x 5mm, it is divided into two sections by a membrane. These chambers are filled with fluid, which vibrates when sound passes through.

Due to the vibrations, the small hairs called **stereocilia** that are located in that area also vibrate, sending electrical impulses or sound signals to the brain.

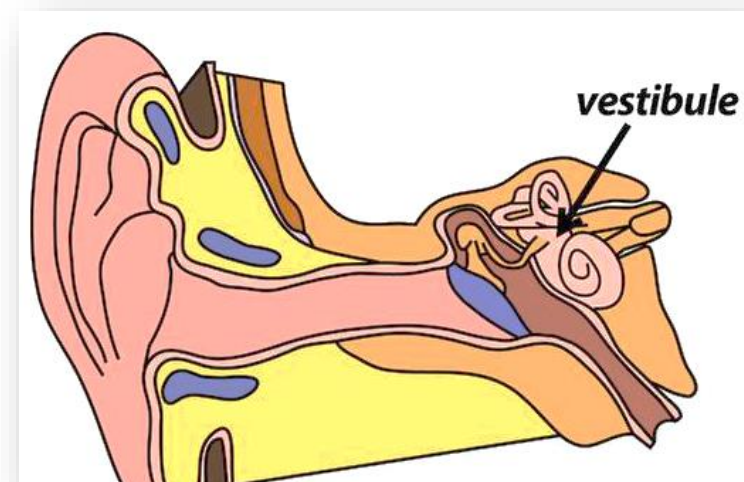
*The semicircular canals* are responsible for balance. They are located above the cochlea and are connected by the vestibular system. There are three such canals, which help the brain to identify the direction of motion of the head. Like the cochlea, these canals are also filled with fluid and tiny hairs that sense the motion of the fluid. These include the **horizontal**, **superior**, and **posterior semicircular canals**.

*The vestibular system* is the central part of the bony labyrinth. It is separated from the middle part of the ear and communicates with the cochlea and semicircular canals. It is able to detect changes in height, rotation, and linear movement.

It can sense when the body is standing, upside down, or rotating. There are three main compartments in the vestibular systems:

(1) **Cochlear duct**, (2) **semicircular ducts**, and (3) **utricle and saccule**.

Each type of movement is sensed from a specific structure. The semicircular canal detects rotational motion while the saccule and utricle sense vertical and horizontal motion.



## The balance system

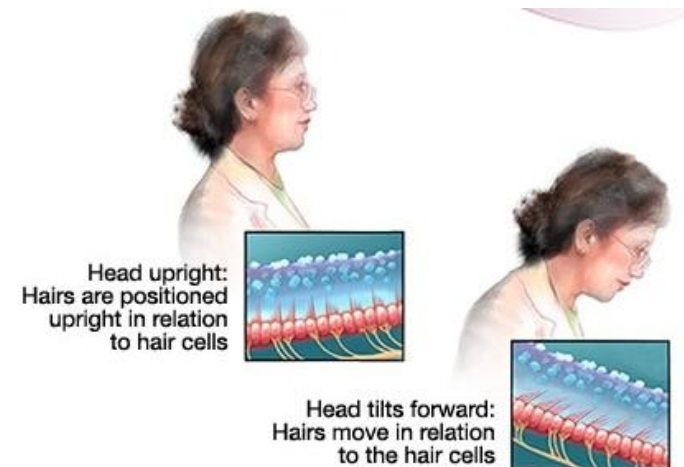
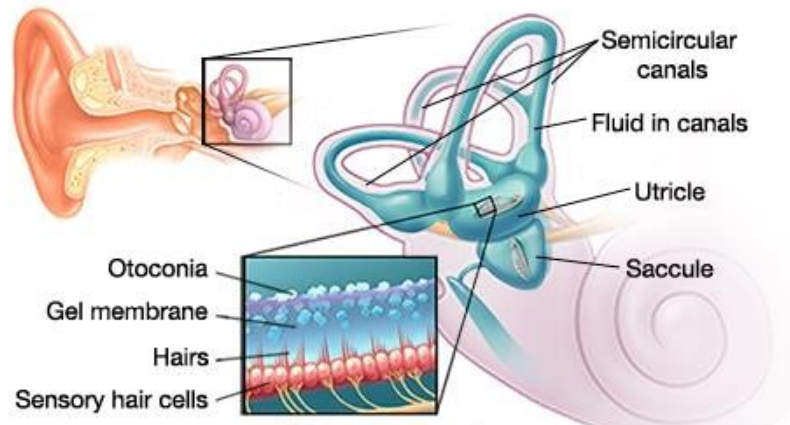
The balance system sends continuous electrical impulses to the brain.

Leaning or moving the head causes the fluid in the semi-circular canals to shift which affects the electrical impulses to the brain accordingly.

The brain uses the signals to make any adjustments necessary for the body to maintain balance.

*Most balance problems are caused by issues in your inner ear.*

You may feel vertigo, dizziness, nausea, or unsteady on your feet.

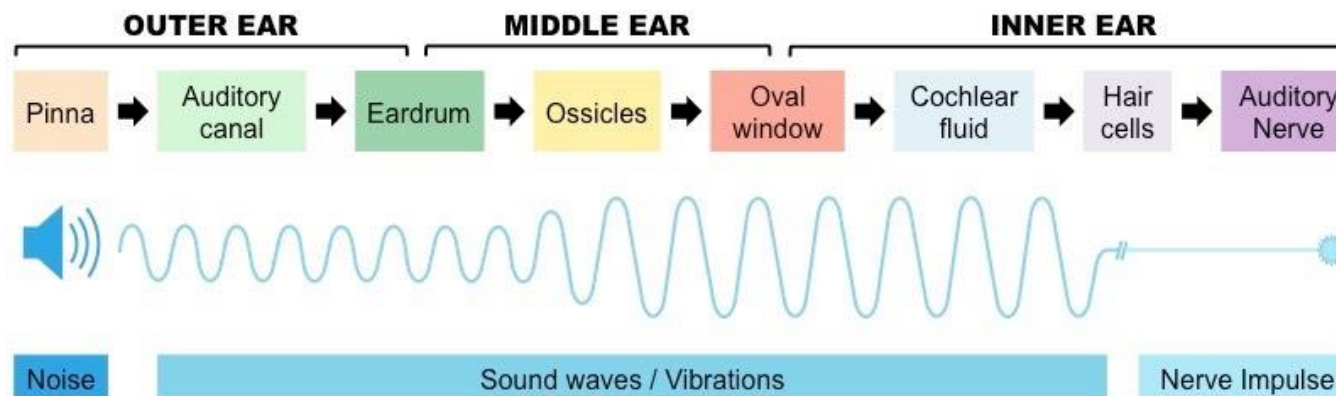




## The path of sound

There are several steps that have to happen from outer ear to inner ear for a person to hear a sound:

1. The outer ear acts like a funnel that sends sounds into your ear canal from the outside world.
2. The sound waves travel down the ear canal to your eardrum in the middle ear.
3. Sound waves make your eardrum vibrate and move the 3 tiny bones in your middle ear.
4. The movement from the middle ear leads to pressure waves that make the fluid inside the cochlea move.
5. The movement of fluid in your inner ear makes the tiny hairs in the cochlea bend and move.
6. The “dancing” hairs in the cochlea convert the movement from sound waves into electrical signals.
7. The electrical signals are sent to the brain through the hearing (auditory) nerves.



## Problem of hearing

The most common issue with ears is the loss of hearing. This happens naturally with age.

A child has a spectrum of hearing that goes from 20 Hz to 20 KHz.

An adult won't hear sounds above approximately 15 KHz.

After aging, loud sounds are the leading cause of hearing loss. These can cause damage with exposure over time.

The threshold of pain begins at 130 dB. Damage occurs immediately when the sound pressure is 140 dB or more.

Another malfunction of hearing is tinnitus. This is described as hearing sounds such as ringing or hissing where there is no cause for the sound. Tinnitus can be caused by exposure to loud noises.



## Exercises

**1 Humans can hear sounds between;**

- (a) 10 – 1000 Hz (b) 10 – 1000 Hz (c) 20 – 2000 Hz (d) 1 – 10000 Hz (e) 20 – 20000 Hz

**2 Ossicles are three small bones in the;**

- (a) Middle ear (b) Outer ear (c) Inner ear (d) Cortex (e) Retina

**3 The outer ear is the external part of the ear; its function is to -----**

- (a) collect sound waves (b) Maintain balance (c) Sense the sound (d) Convert vibrations (e) Focusing the light

**4 -----that are located in the inner ear, vibrate and sending electrical impulses or sound signals to the brain.**

- (a) vestibular system (b) Stereocilia (c) Pinna (d) Sound canal (e) None of them

**5 -----is the central part of the bony labyrinth. It is able to detect changes in height, rotation, and linear movement.**

- (a) The semicircular canals (b) The cochlea (c) The vestibular system (d) Ossicles (e) Cornea