Advantages of ultrasound

- Ultrasound scanning is noninvasive (no needles or injections) and is usually painless.
- Ultrasound is widely available, easy-to-use and less expensive than other imaging methods.
- Ultrasound imaging uses non ionizing radiation.
- Ultrasound scanning gives a clear picture of soft tissues that do not show up well on x-ray images.
- Ultrasound causes no health problems and may be repeated as often as is necessary if medically indicated.
- There are no hazards for the patient and operator.

Disadvantages of ultrasound

- The major disadvantage is that the resolution of images is often limited.
- Bone absorbs ultrasound so that brain images are hard to get.
- Attenuation can reduce the resolution of the image.
- Sonography performs very poorly when there is a gas between the transducer and the organ of interest.
- Images of tissues on the far side of lungs are impossible to get.

Ex: Two identical machines are positioned the same distance from a worker. The intensity of sound delivered by each machine at the location of the worker is 2×10^{-7} W/m^2.

Find the sound level heard by the worker

(A) when one machine is operating

(B) when both machines are operating.

The difference in frequency (Δf) is called the **Doppler frequency shift** , **Doppler shift** or **Doppler frequency**.

The Doppler shift depends on:

- The emitted sound frequency (f_o).
- The observed sound frequency (f).
- The velocity of the sound wave (v)
- The velocity of the sound source (v_s)
- The velocity of the object (listener) (v_l).

Ex: A submarine (sub A) travels through water at a speed of 8 m/s, emitting a sonar wave at a frequency of 1400 Hz.

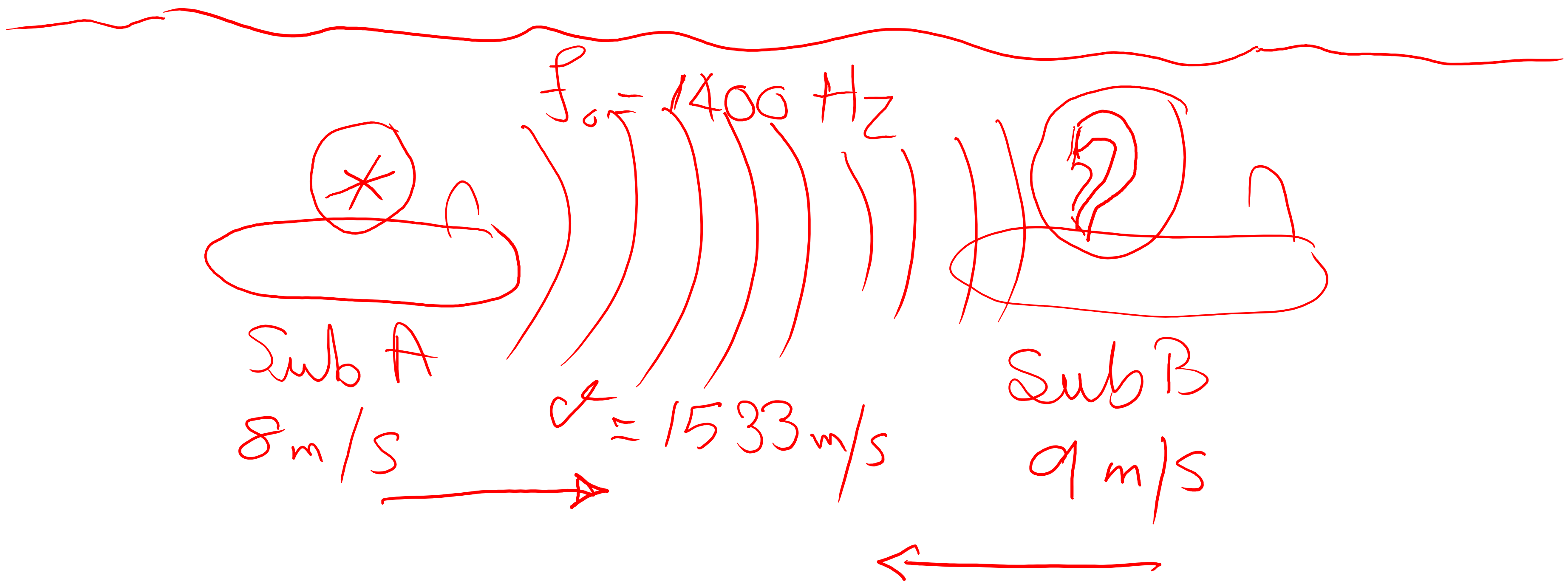
The speed of sound in the water is 1533 m/s.

A second submarine (sub B) is moving at 9 m/s and is located such that both submarines are traveling directly toward one another.

(A) What frequency is detected by an observer riding on sub B as the subs approach (move towards) each other?

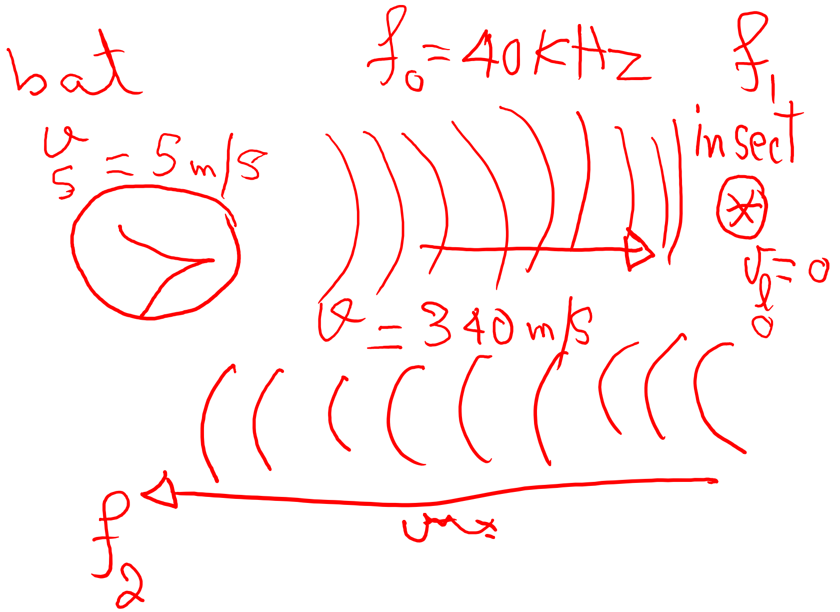
(B) The subs barely miss each other and pass (move Away) .
What frequency is detected by the observer riding on sub B as the subs recede (move Away) from each other?

$$f = f_o \frac{v \pm v_l}{v \pm v_s}$$



$f_o = 1400$ Hz
Sub A
8 m/s
$c = 1533$ m/s
Sub B
9 m/s

EX: A bat, moving at 5 m/s, is chasing a flying insect.
If the bat emits a 40-kHz chirp.
What is the frequency hat bat receives back. Suppose that the we neglect insect speed. (Take the speed of sound in air to be $v = 340$ m/s.)



$$f = f_o \frac{v \pm v_l}{v \pm v_s}$$

$$f_1 = f_0 \frac{v + 0}{v - v_s} =$$

$$f_2 = f_1 \frac{v + v_s}{v - 0}$$

when the sound is reflected the bat is listner and insect is sourc of sound

Ex: Ultrasound of 100 kHz was used to measure the average velocity of blood flow in Aorta. If the sound velocity in blood is 1500 m/s, the Doppler frequency shift was 20 Hz. If the incident angle of sound wave is 10^o on the direction of blood flow.

Calculate the average velocity of blood flow in Aorta.

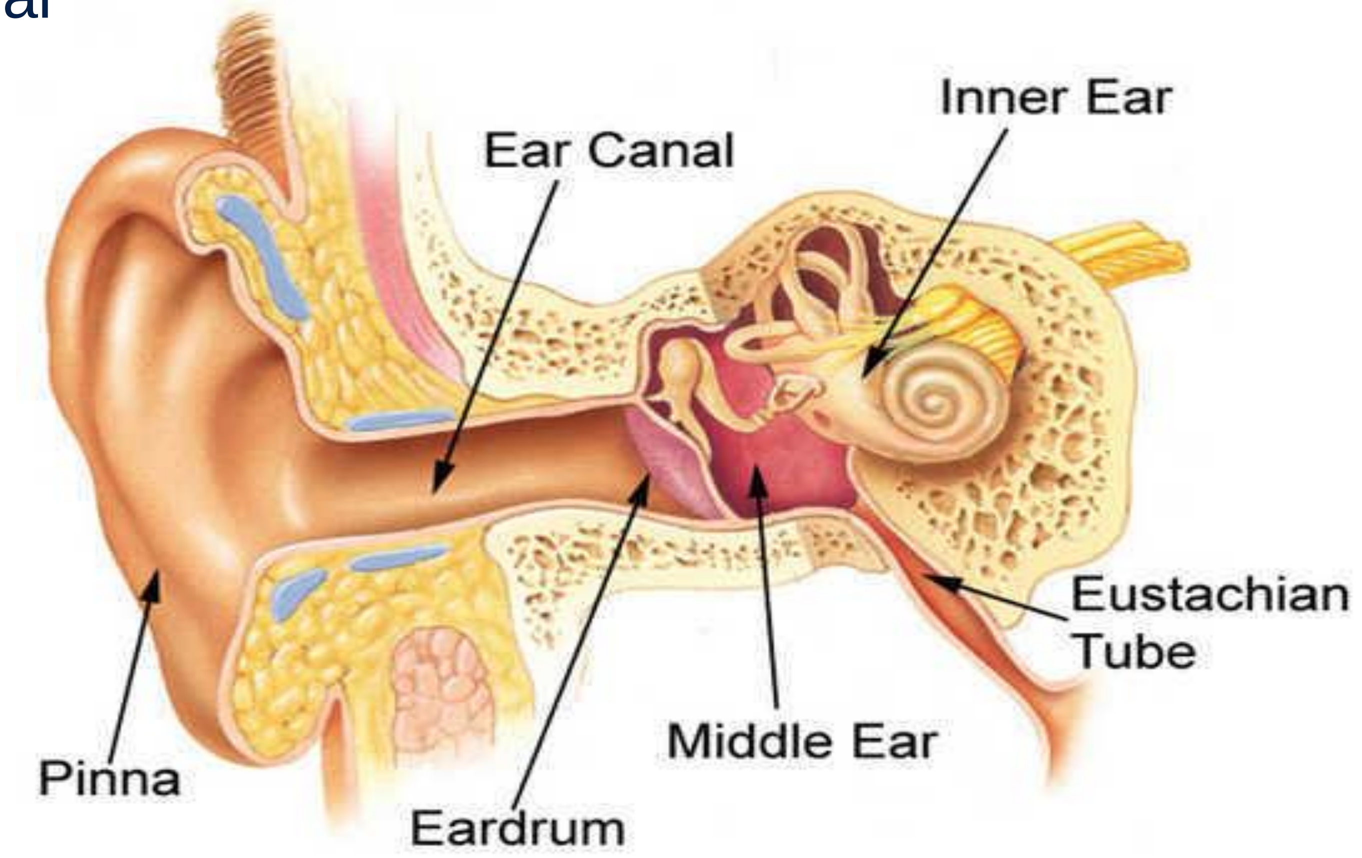
$$\Delta f = \frac{2 f_o}{v} v_l \cos\theta$$

Ex: If the sound speed in bone is 4100 m/s (ρ_{bone} = 1912 kg/m^3), Calculate the acoustic bone impedance.

Ear and How it Works

The ear has three main parts:

1. Outer ear (including the external auditory canal)
2. Middle ear
3. Inner ear



The ear is the organ of hearing and balance in mammals.

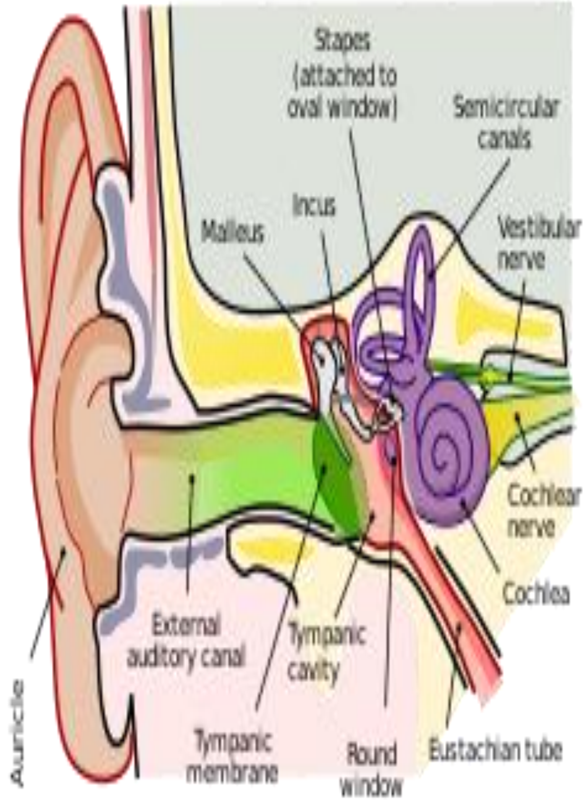
In mammals, the ear is usually described as having three **parts—the outer ear, the middle ear and the inner ear.**

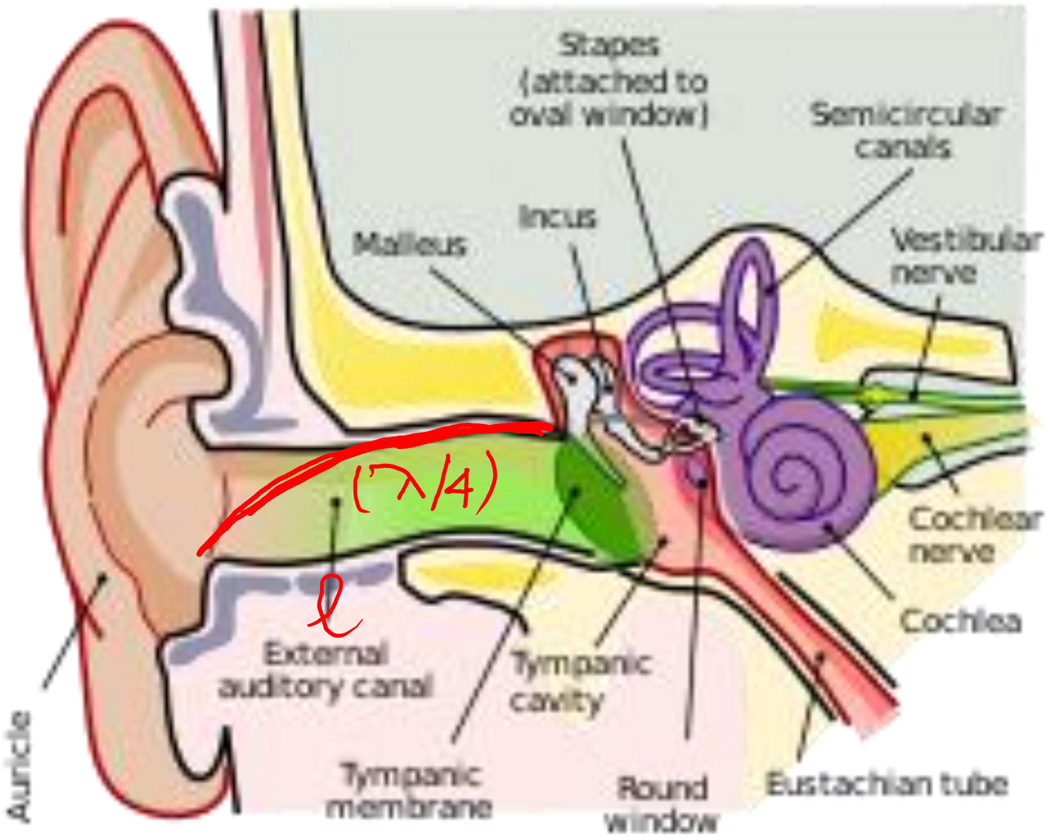
- The outer ear consists of the pinna and the ear canal.
- The middle ear includes the tympanic cavity and the three ossicles.
- The inner ear contains structures which are key to several senses and the cochlea, which enables hearing.

From the pinna, the sound waves move into the ear canal (also known as the *external acoustic meatus*) a simple tube running through to the middle ear.

This tube leads inward from the bottom of the auricula and conducts the vibrations to the tympanic cavity and amplifies frequencies in the range 3 kHz to 5 kHz.

The ear canal stretches for about 1 inch (2.5 cm) long and its diameter is about 8 mm.



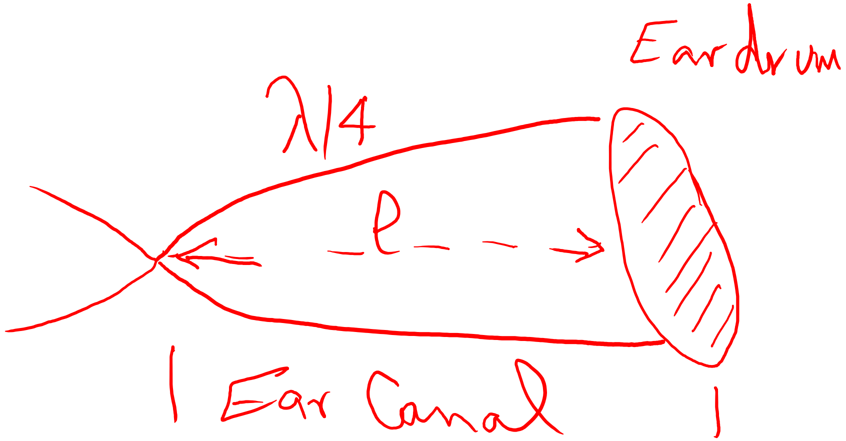


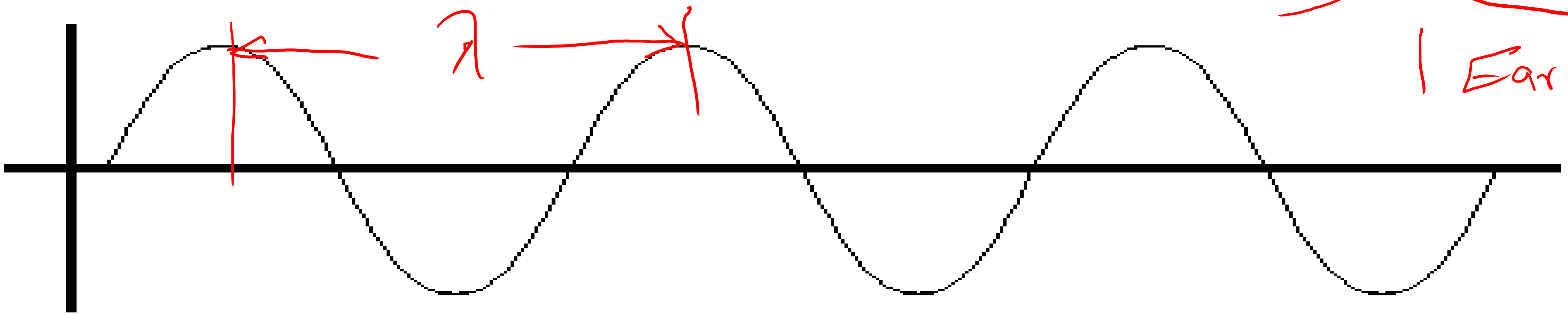
$$l = \frac{1}{4}\lambda$$

Ear Canal length

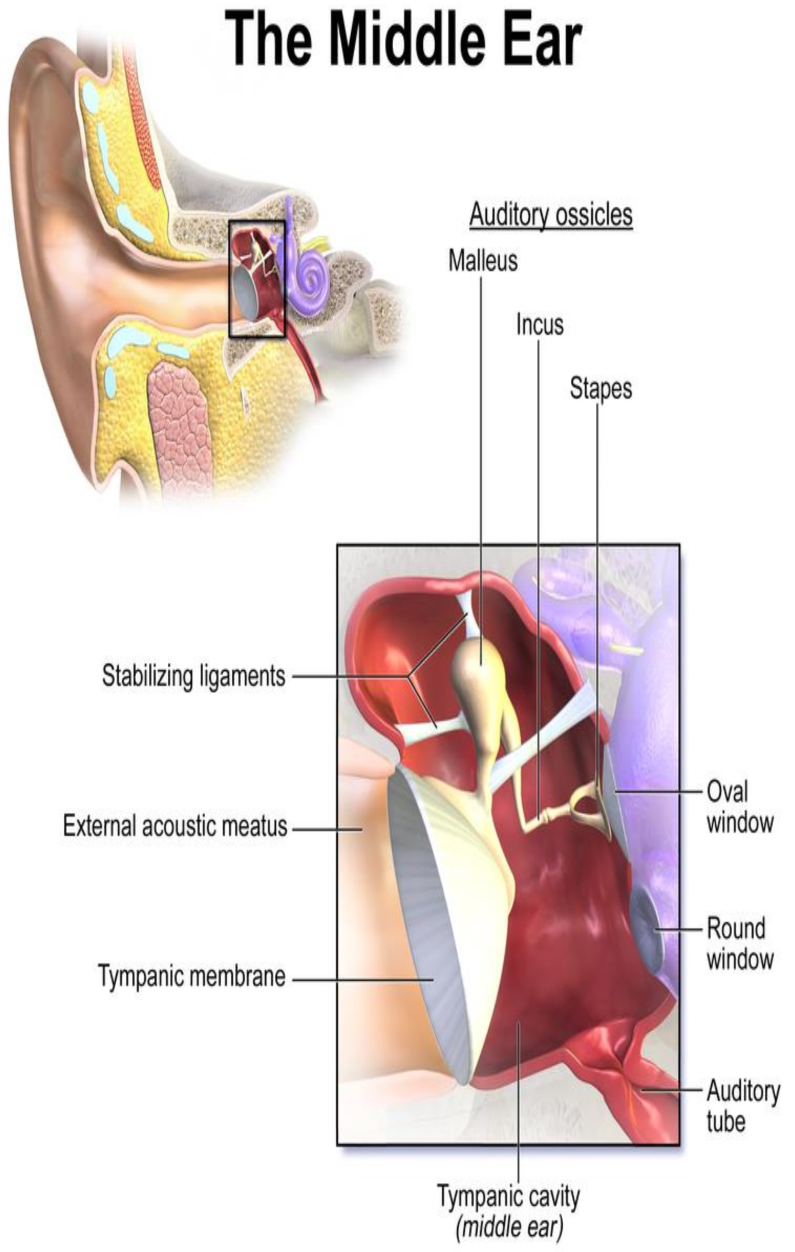
$$v = \lambda . f$$

$$f = \frac{v}{\lambda} = \frac{340}{4l} = \frac{340}{4x2.5x10^{-2}} = = 3400 \text{ Hz}$$





- The middle ear lies between the outer ear and the inner ear. It consists of an air-filled cavity called the tympanic cavity and includes the three ossicles and their attaching ligaments; the auditory tube; and the round and oval windows.
- The ossicles are three small bones that function together to receive, amplify, and transmit the sound from the eardrum to the inner ear. The ossicles are the malleus (hammer), incus (anvil), and the stapes (stirrup).
- The stapes is the smallest named bone in the body.

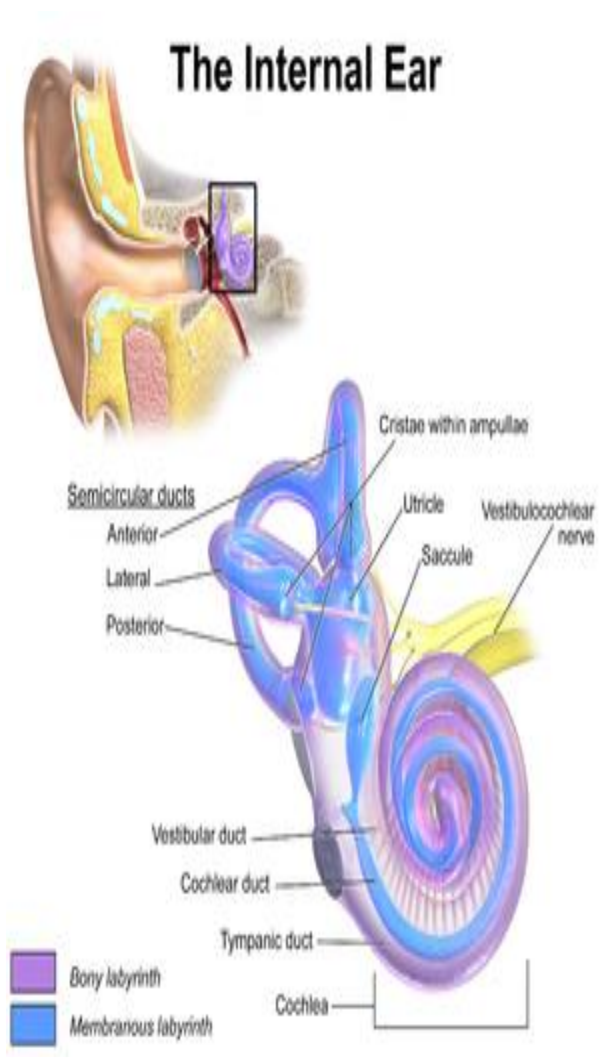


- The three ossicles transmit sound from the outer ear to the inner ear. The malleus receives vibrations from sound pressure on the eardrum, where it is connected at its longest part (the manubrium or handle) by a ligament. It transmits vibrations to the incus, which in turn transmits the vibrations to the small stapes bone. The wide base of the stapes rests on the oval window. As the stapes vibrates, vibrations are transmitted through the oval window, causing movement of fluid within the cochlea.

Inner ear

The inner ear structurally begins at the oval window, which receives vibrations from the incus of the middle ear. Vibrations are transmitted into the inner ear into a fluid.

The cochlea consists of three fluid-filled spaces. Transduction mechanical changes into electrical stimuli are present in the organ of Corti in the cochlea.



A **hearing test** is **performed** in a sound proof room.
You will wear headphones or earplugs connected to a device that sends sounds of different volumes (**Y**) and pitches (**f**) to one ear at a time.
You will be asked to respond by raising your hand or pressing a button each time you hear a sound.

With moderate hearing loss, you have difficulty hearing sounds quieter than 40 decibels to 50 decibels (dB).

$$\mathbf{I} = \frac{1}{2} Z Y^2 (2\pi f)^2$$

$$S.L = \beta = 10 \log_{10} (I / I_o) \text{ --------- } (dB)$$

Example sound	Sound Intensity I (W/m^2)	Intensity Ratio (I/I_o)	Intensity Level (dB)
Loud rock concert	1	10^{12}	120
Underground train	10^{-2}	10^{10}	100
Shouting person	10^{-4}	10^{8}	80
Normal conversation	10^{-6}	10^{6}	60
Quiet room	10^{-8}	10^{4}	40
Rustling leaves	10^{-10}	10^{2}	20
Reference level (Io)	10^{-12}	1	0