Tishk International University

TISHK INTERNATIONAL UNIVERSITY
FACULTY OF APPLIED SCIENCE

Anesthesia Department

Sound and Ultrasound in medicine

Fall Semester
Course Name : Medical Physics
Stage : First
Prof. Dr. Fatiheea F Hassan
2026

Medical physics:-

1- Medical physics refers to two major areas:

A. First area is The applications of physics to the function of the human body in health and disease (the physics of physiology).

B- Second area of Medical physics

(The applications of physics in the practice of medicine)

b. The applications of physics in the practice of medicine. This includes such things as the physics of the stethoscope, the tapping of the chest (percussion), and the medical applications of lasers, ultrasound, radiation and so forth.

Introduction about Sound and Ultrasound

Sound is a form of mechanical energy that travels through a medium such as air, water, or body tissues in the form of waves. Unlike electromagnetic radiation, sound cannot travel in a vacuum because it requires particles to transfer energy from one place to another.

In medicine, sound waves are used mainly in diagnostic imaging and therapy. Ultrasound is a special type of sound wave with frequencies higher than the upper limit of human hearing.

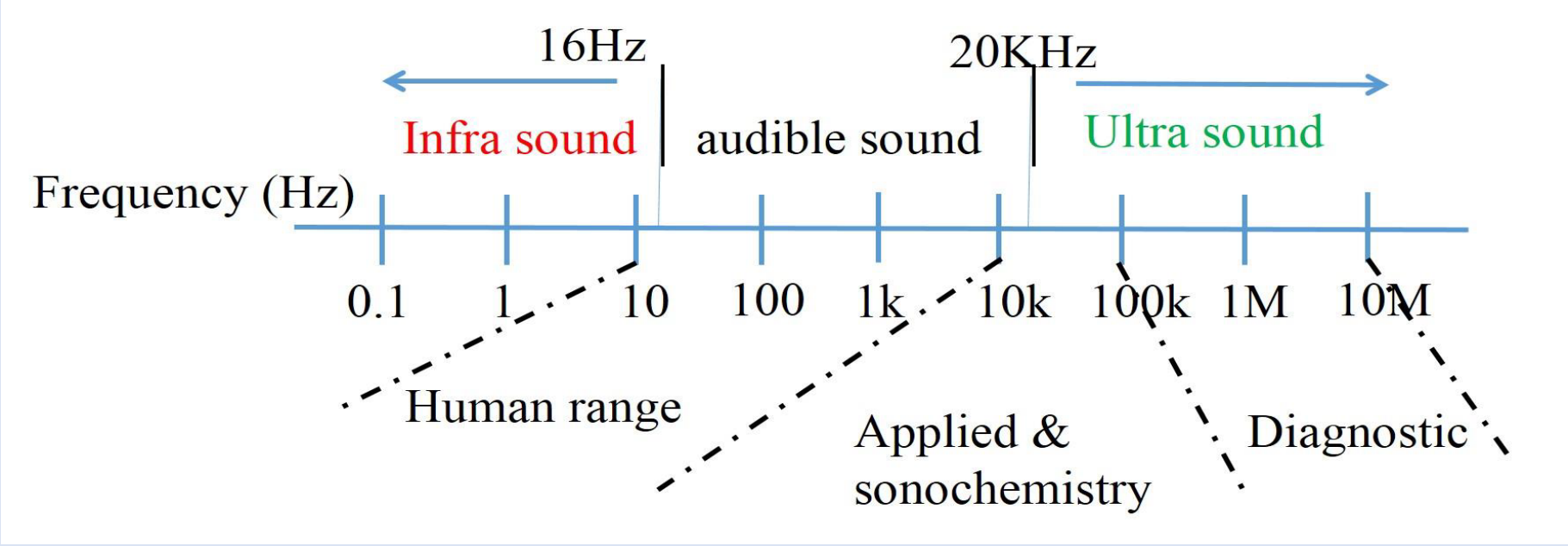
Human hearing ranges from **20 Hz to 20,000 Hz (20 kHz),** while ultrasound has frequencies **above 20 kHz**. Medical ultrasound commonly uses frequencies between **1 MHz and 20 MHz.**

Ultrasound is widely used because it is safe, non-invasive, relatively inexpensive, and does not use ionizing radiation.

Infra sound waves < 20Hz
(low frequency limit of human hearing).
Not audible.
Headaches and physiological disturbances. (Infrasound waves cause especial effect on human health that occurs with varying frequency and results in varying levels of disability)

Audible Sound
20 to 20,000Hz.
Audible sound by human.

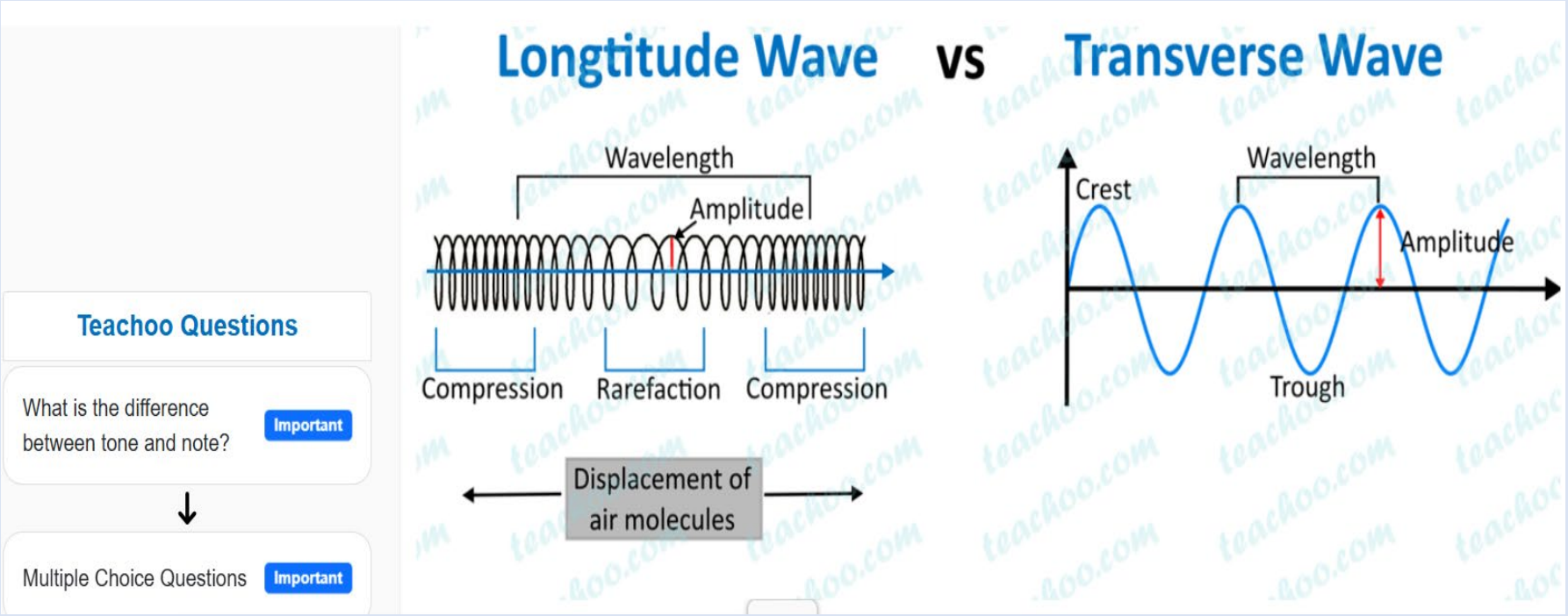
Ultrasound waves: >20KHz
Not audible.
Medical imaging for diagnosis, treatment and doppler.
Average speed of ultrasound in body is 1540m/sec.



1. Basic Properties of Sound

Sound waves are **longitudinal waves**. In longitudinal waves, particles of the medium vibrate back and forth in the same direction as the wave travels.

Longitudinal waves feature particle displacement parallel to energy transfer, creating compressions/rarefactions, while transverse waves vibrate perpendicular to energy transfer, forming crests/troughs.



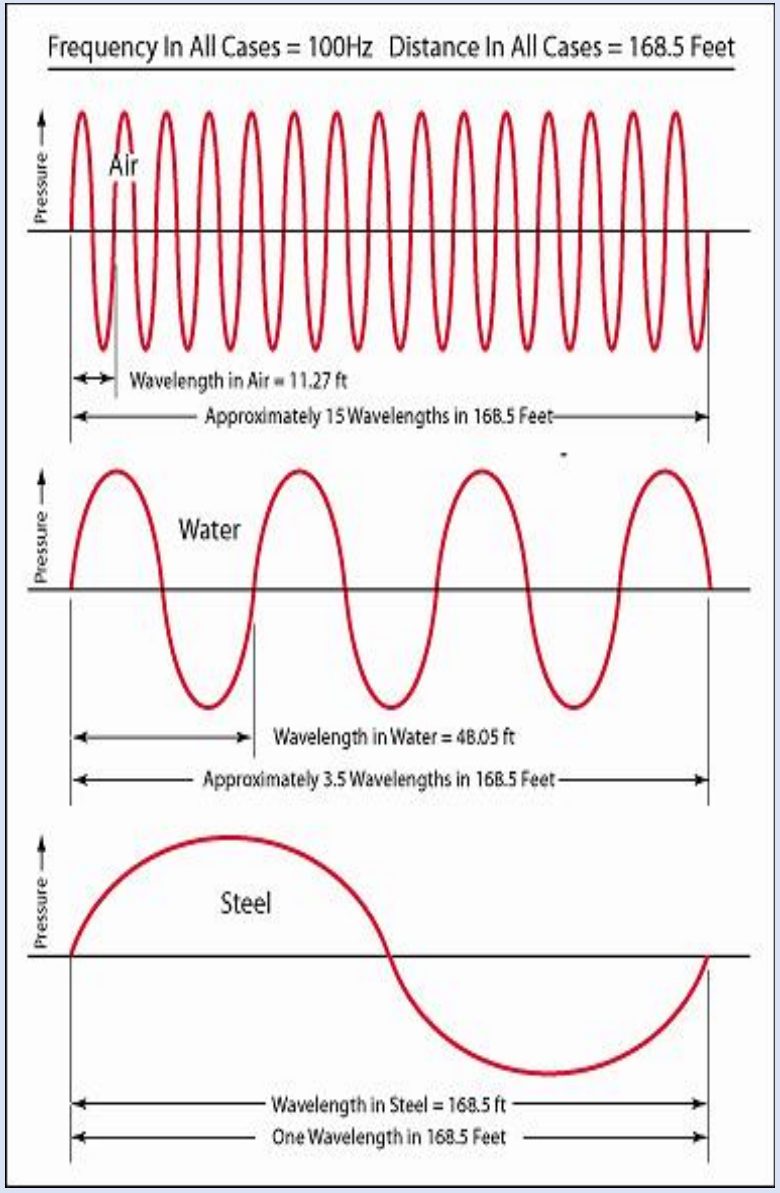
Main Characteristics of Sound

1.Frequency (f)

- Frequency is the number of vibrations or cycles per second.
- It is measured in Hertz (Hz).
- Higher frequency means better image resolution but less penetration.
- Lower frequency means deeper penetration but lower image detail.

2.Wavelength (λ)

- Wavelength is the distance between two consecutive compressions or rarefactions.
- Shorter wavelength produces better image resolution.



3. Velocity (v)

- Velocity is the speed at which sound travels through a medium.
- Sound travels at different speeds in different materials.
- In soft tissue, the average speed of sound is approximately 1540 m/s.

4. Amplitude

- Amplitude refers to the strength or height of the sound wave.
- Greater amplitude means greater intensity.

5. Intensity

- Intensity is the amount of energy carried by the sound wave.
- Stronger echoes create brighter images.

In this figure, two sound waves of different intensities.
The louder sound wave has a bigger amplitude. Bigger amplitude means the air particles move back and forth more.

<u>In sound waves:</u>

Strong compressions = air particles are pushed very close together.

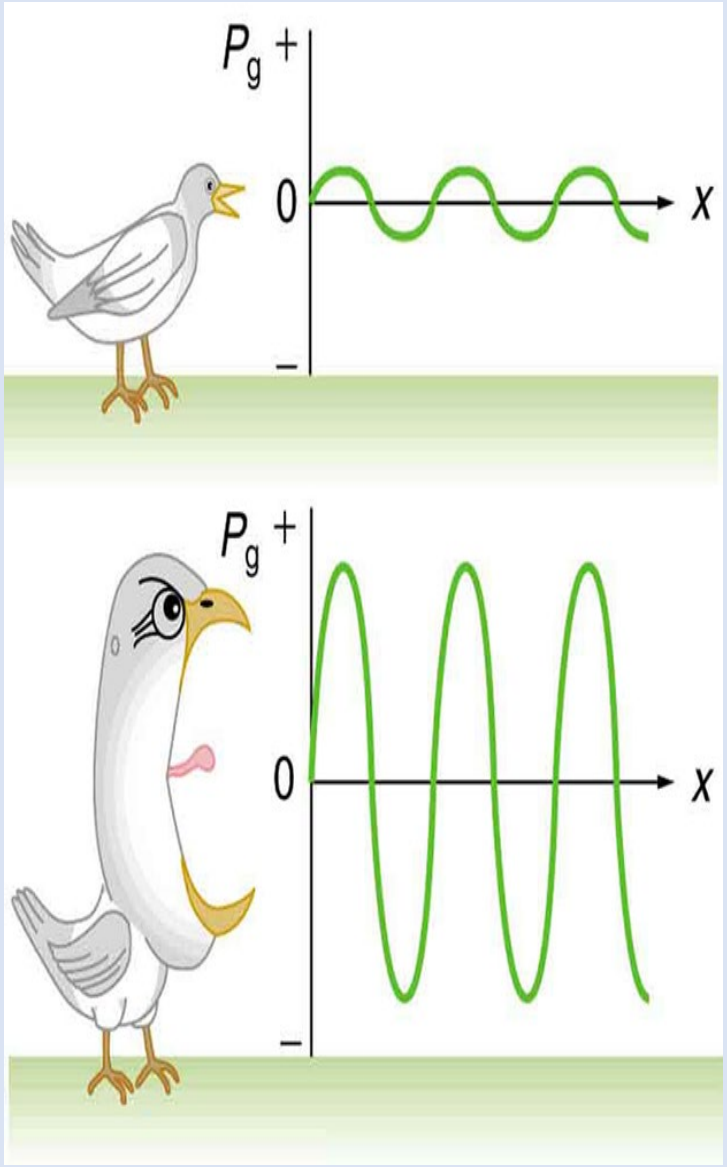
Strong rarefactions = air particles are spread farther apart.

<u>So, a louder sound has:</u>

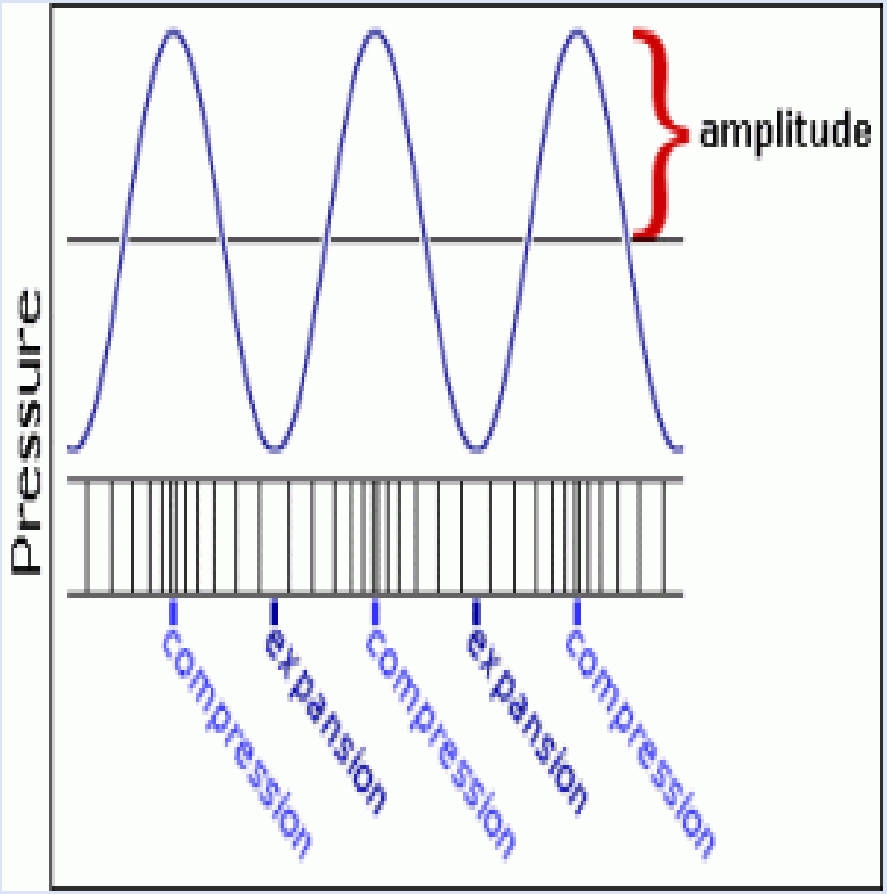
Bigger compressions

Bigger rarefactions

Higher pressure changes in the air



A longitudinal sound wave travels through a medium as repeating regions of compression and rarefaction.
Compression: particles are close together, creating high pressure.
Rarefaction: particles are spread apart, creating low pressure.
The wavelength is the distance from one compression to the next compression, or from one rarefaction to the next rarefaction.
The amplitude is the maximum distance that particles move away from their normal position.



Introduction about Ultrasound

Ultrasound is a form of mechanical energy that travels in waves through a medium. In medicine, ultrasound refers to sound waves with frequencies **greater than 20,000 Hz**, which is above the range of human hearing.

Medical ultrasound commonly uses frequencies between **1 and 20 MHz.**

Ultrasound is widely used in medicine because it is non-invasive, does not use ionizing radiation, provides real-time imaging, and is relatively inexpensive compared with other imaging methods.

Principles of Ultrasound

Ultrasound waves are longitudinal waves. They travel through tissues as alternating compressions and rarefactions.

The speed of ultrasound depends on the medium through which it travels.

Typical speed of sound in soft tissue:

- Approximately 1540 m/s

The relationship between speed, frequency, and wavelength is:

$$V = \lambda f$$

Where:

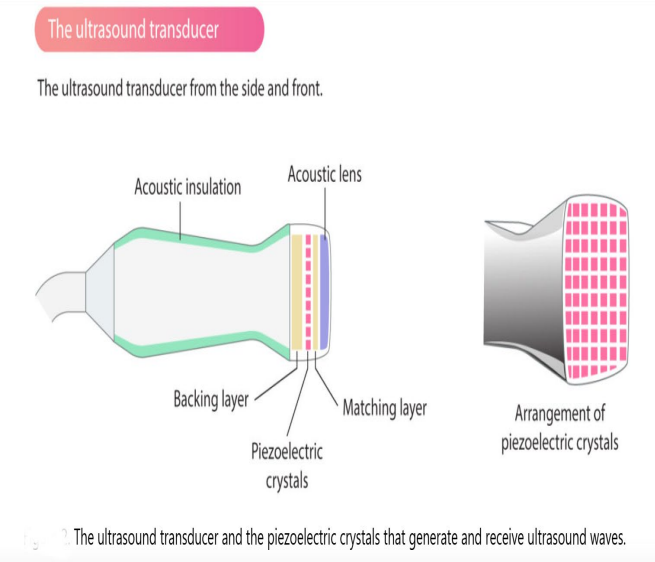
- v = wave speed
- f = frequency
- λ = wavelength

Higher-frequency ultrasound provides better image resolution but has less penetration into tissue. Lower-frequency ultrasound penetrates deeper but produces lower image resolution.

Production of Ultrasound

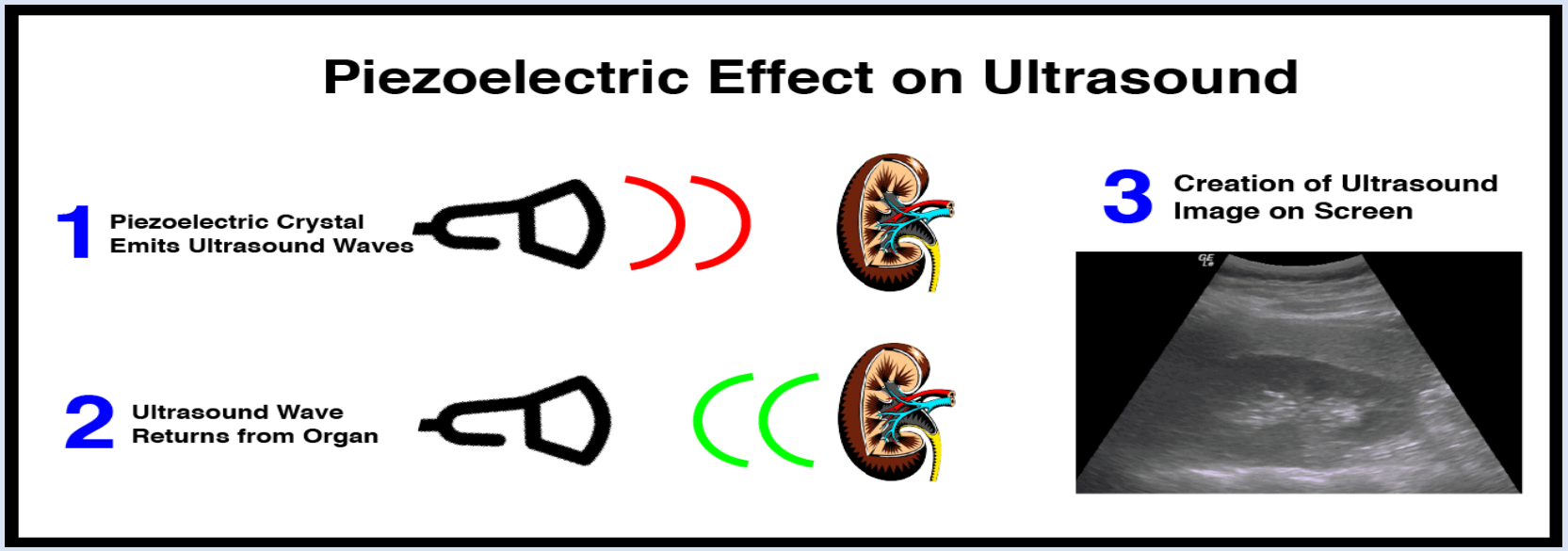
Ultrasound waves are produced by the piezoelectric effect.

Certain crystals, such as quartz or lead zirconate titanate (PZT), change shape when an electric current is applied. This produces sound waves. The same crystal can also receive returning echoes and convert them back into electrical signals.



Piezoelectric Effect

- Electrical energy → mechanical vibration → ultrasound wave
- Returning echoes → electrical signals → image formation



Interaction of Ultrasound with Tissue

When ultrasound travels through the body, several interactions can occur:

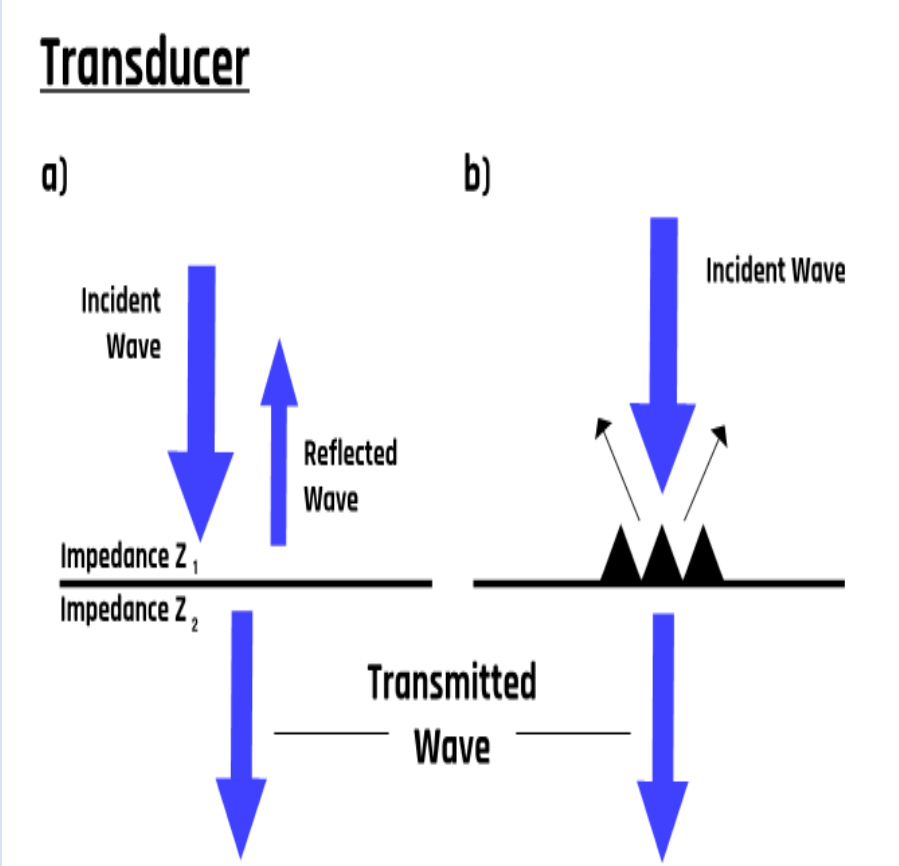
1. Reflection

Reflection occurs when ultrasound waves strike a boundary between two tissues with different acoustic impedances.

Examples:

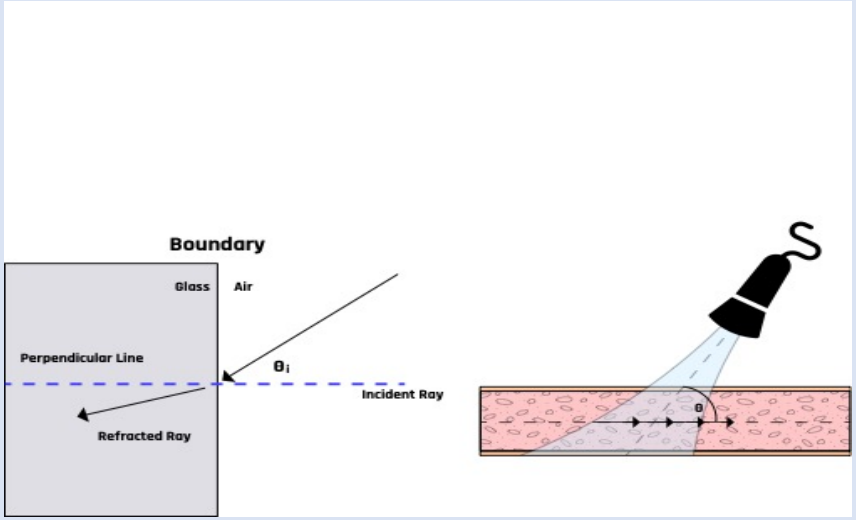
- **Soft tissue and bone**
- **Soft tissue and air**

The reflected sound waves return to the transducer and form the image.



2. Refraction

Refraction occurs when the ultrasound beam changes direction as it passes from one tissue to another.



3. Scattering

Scattering occurs when ultrasound strikes small or irregular structures.

4. Absorption

Some ultrasound energy is absorbed by tissues and converted into heat.

Acoustic Impedance

Acoustic impedance determines how much sound is reflected at a tissue boundary.

It is defined as:

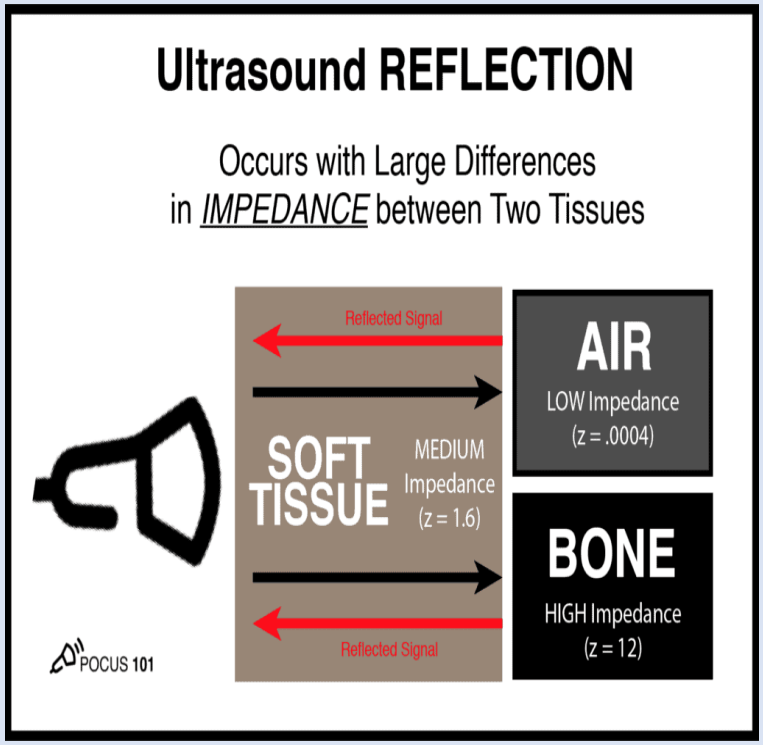
$Z = \rho c$

Where:-

Z = acoustic impedance

ρ = density of the medium

c = speed of sound in the medium



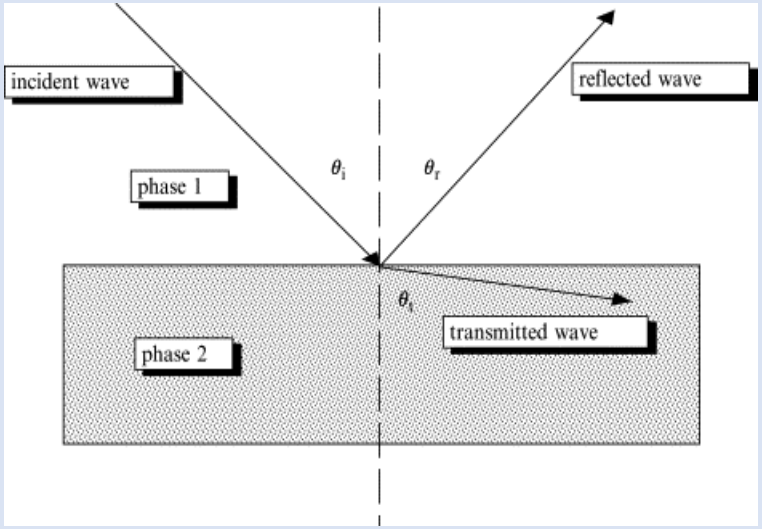
Large differences in acoustic impedance cause strong reflections.

For example:

Soft tissue to bone produces a strong reflection.

Soft tissue to air also produces a strong reflection.

This is why gel is used between the transducer and the skin. The gel removes air and improves transmission of sound waves.



Ultrasound Transducer

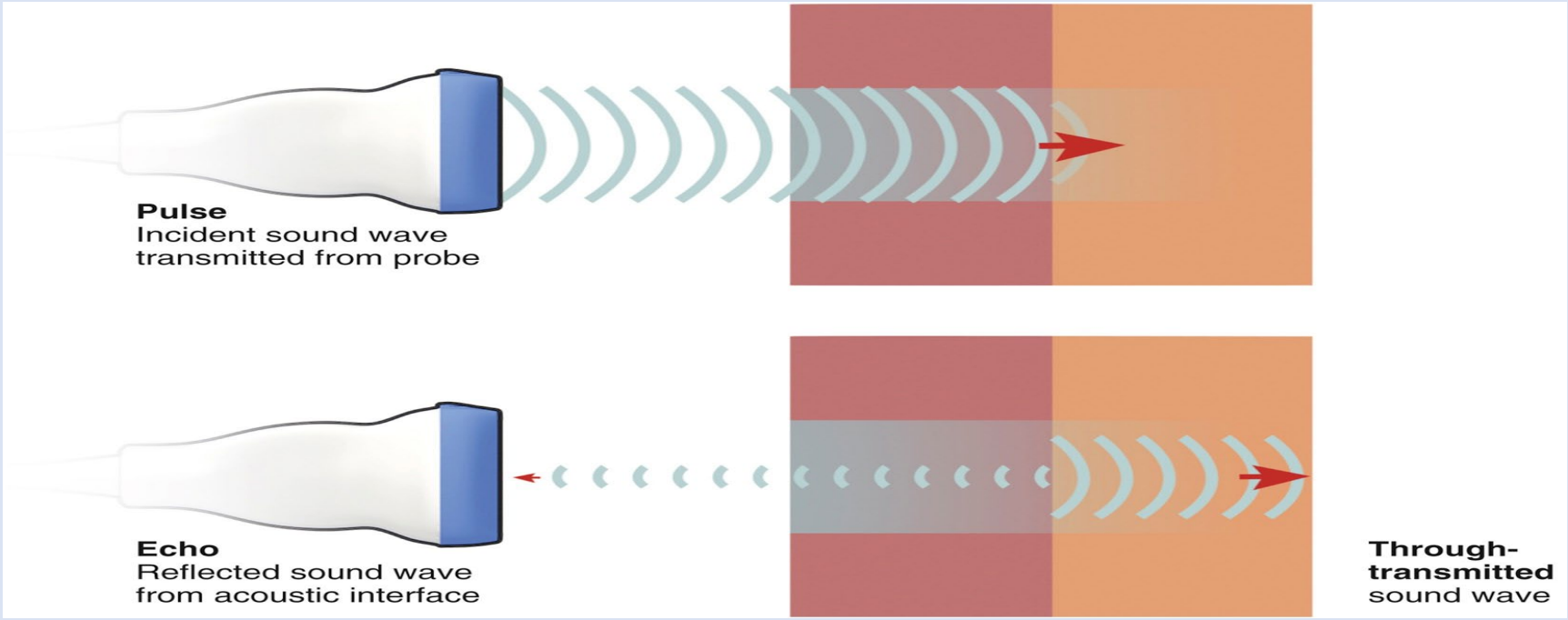
The transducer is the device placed on the patient's body.

Functions of the transducer:

1.Produces ultrasound waves

2.Receives reflected echoes

3.Converts echoes into electrical signals



Medical Uses of Ultrasound

Ultrasound is widely used in many medical specialties.

Obstetrics and Gynecology

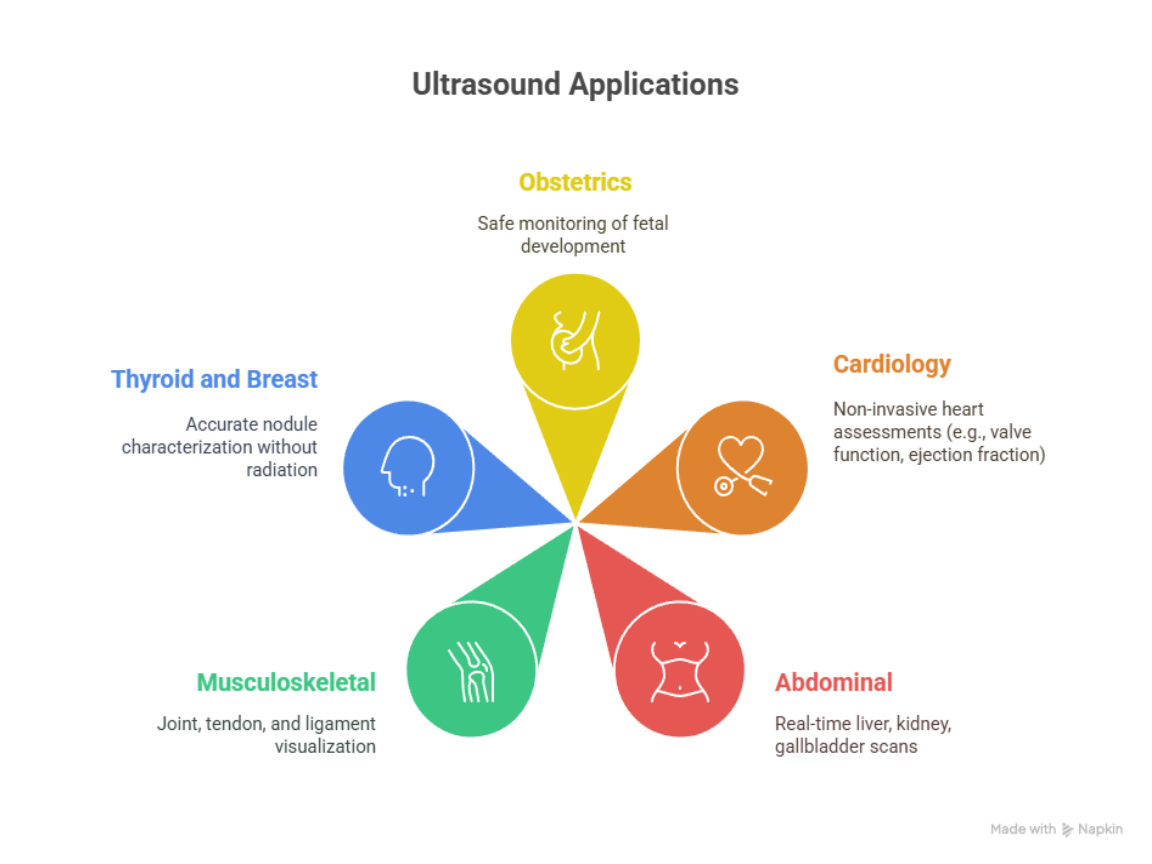
Cardiology

Abdominal Imaging

Vascular Imaging

Musculoskeletal Imaging

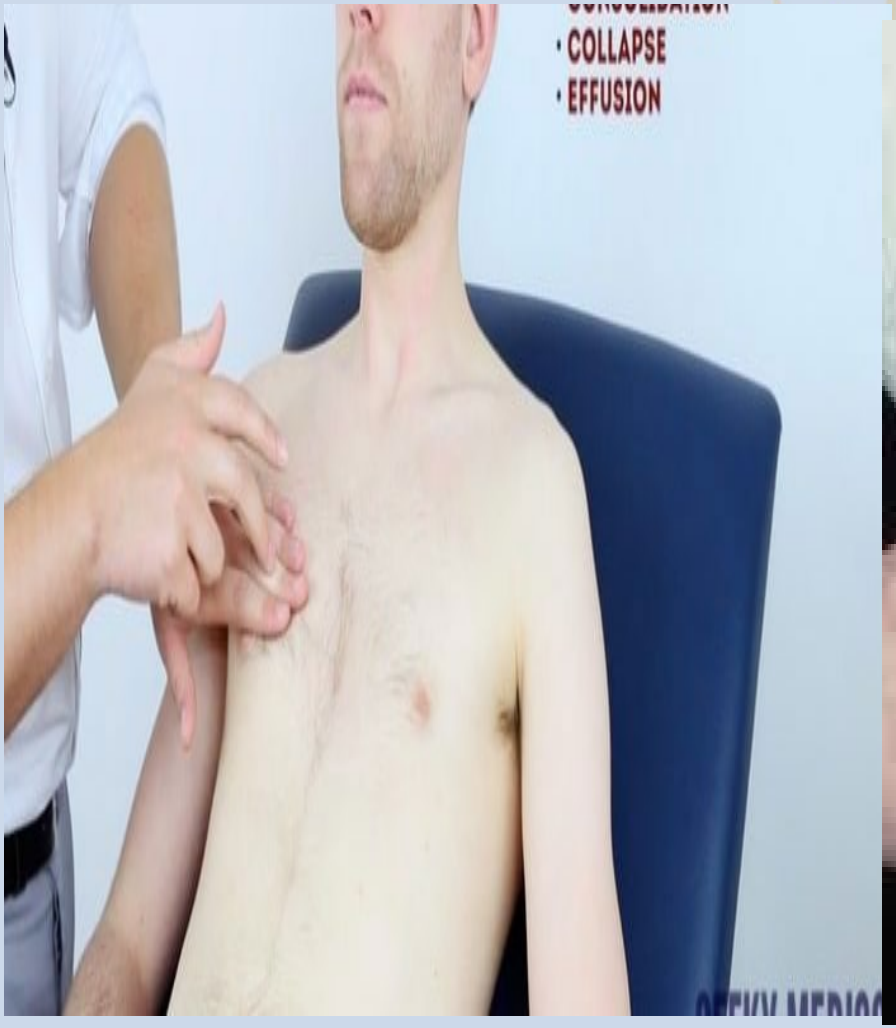
Emergency Medicine



Advantages of Ultrasound

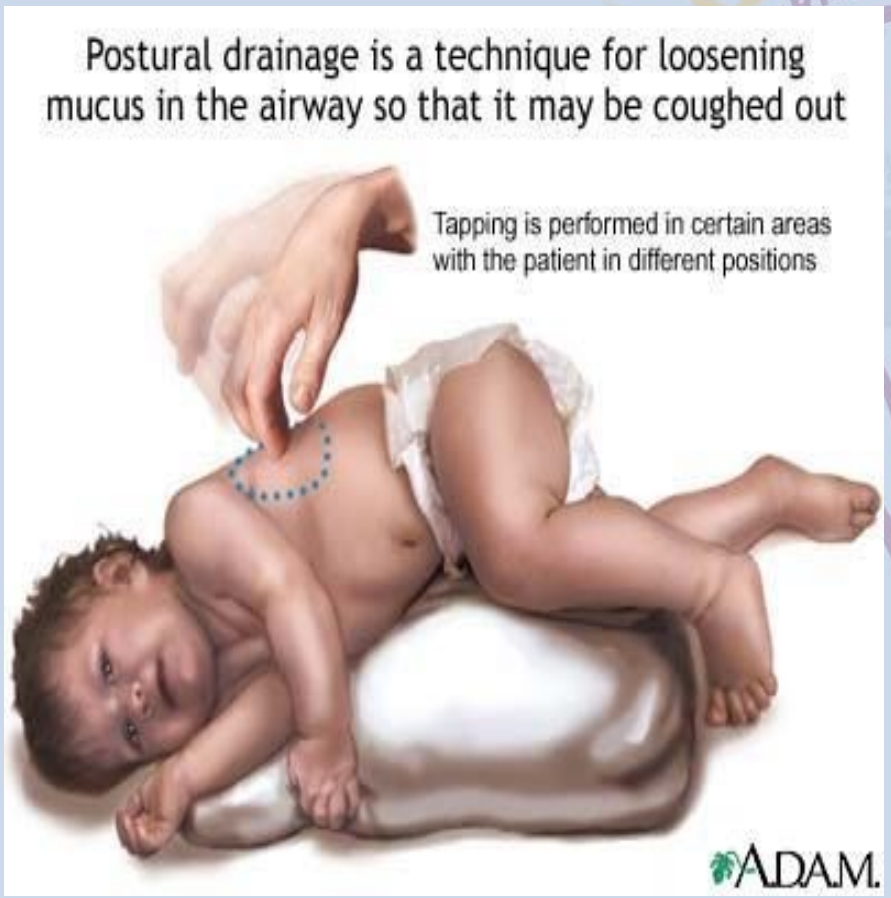
- No ionizing radiation
- Safe for pregnant women
- Real-time imaging
- Portable equipment
- Relatively low cost
- Useful for soft tissue imaging

The tapping of the chest (percussion)



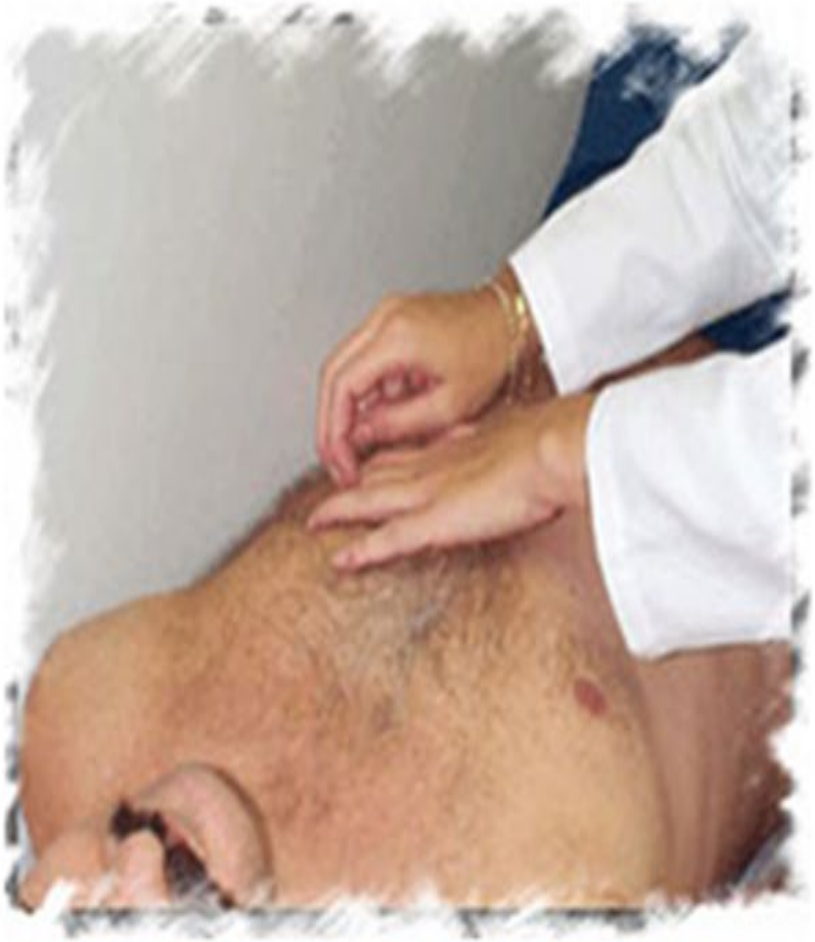
The physics of percussion -

1- **Percussion** is often a beneficial manual technique to help in the removal of secretions in a number of respiratory conditions. It is performed with the aim of loosening thick, sticky or retained secretions from the chest wall



Percussion is often a beneficial …….to help in the removal of secretions in a number of respiratory conditions

a. last technique
b. Modern technique
c. manual technique
d. Old manual technique



2- **Percussion** is an assessment technique which produces sounds by the examiner tapping on the patient's chest wall. So tapping on the chest wall produces sounds based on the amount of air in the lungs.

Percussion sets the chest wall and underlying tissues into motion, producing audible sounds and palpable vibrations. Percussion helps to determine whether the underlying tissues are filled with air, fluid, or solid material.

Percussion is an assessment technique which produces sounds by the examiner tapping on the patient's……...

a. chest wall
b. Heart wall
c. Head bone
d. Liver wall

THANKS....