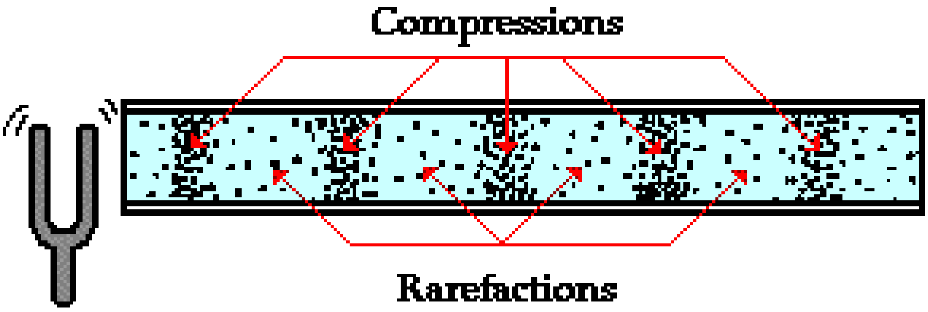
# L24 SOUND IN MEDICINE

## Generanl properties of sound

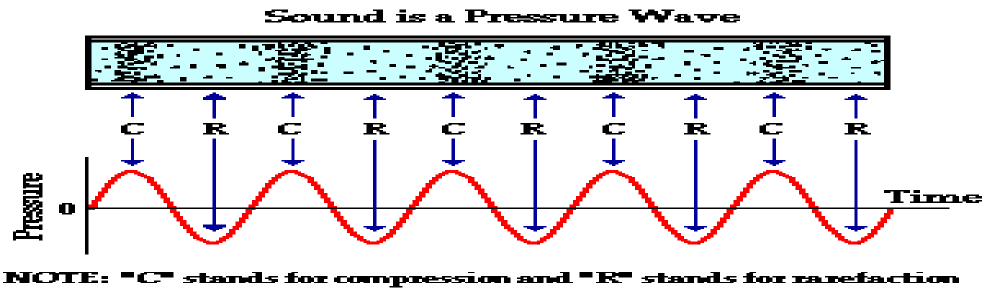
Sound is a wave, i.e. traveling variations of some quantity (pressure). It involves mechanical motion in the medium through which it travels. Pressure variations cause particles of the medium to vibrate due to increase and decrease of density.

∴ A sound wave is a mechanical disturbance in a gas, liquid, or solid that travels outward from the source with some definite velocity.

- The vibrations cause local increases and decreases in pressure relative to atmospheric pressure
- These pressure increases, called compressions, and decreases, called rarefactions
- A **compression** is a region in a longitudinal wave where the particles are closest together
- A **rarefaction** is a region in a longitudinal wave where the particles are furthest apart.




Since a sound wave consists of a repeating pattern of high-pressure and low-pressure regions moving through a medium, it is sometimes referred to as a pressure wave.




## Frequency and Period

**Frequency:** How many cycles occur in one second, measured in Hertz. (1 Hz = 1/s). Human hearing: 20 Hz to 20 000 Hz, or 20 KHz. Ultrasound: beyond 20 KHz. Frequency is important in ultrasound because of its impact on resolution and penetration of sonographic images.

**Period:** Time that takes for one cycle to occur. Inverse of frequency ? if frequency increases period decreases. For example, the period for 5 MHz (5 million Hertz) ultrasound is 1 / 5, 000, 000 = 0.0000002 = 0.2 µs. 1 µs is 1 millionth of a second (0.000001 s). Period is an important concept for pulsed ultrasound.

## Sound : Wavelength and Speed of Propagation

**Wavelength: Length of space over which one cycle occurs. It is usually expressed in millimeters. One millimeter, 1 mm, is one thousandth of a meter (0.001 m). Wavelength is important when considering resolution of images.**

**Propagation Speed: Speed at which a wave moves through a medium. Measured in meters per second, or millimeters / microsecond.**

**Wavelength depends on the frequency and propagation speed:**

**Wavelength (mm) = Propagation Speed (mm/microsecond) / Frequency(MHz)**

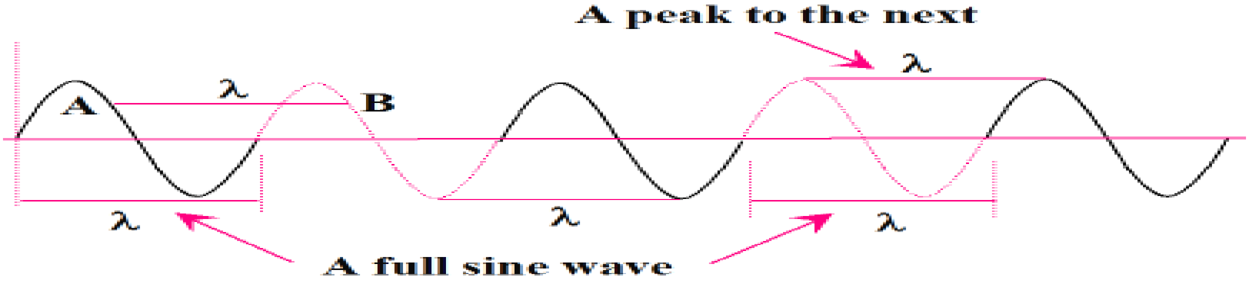
**Previous relationship says that if frequency increases wavelength decreases.**

**Propagation speed depends on the medium. In soft tissue it averages 1540 m/s, or 1.54 mm/μs.**

- **The relationship between the frequency of vibration f , the wavelength λ, and velocity V of the sound wave is**

$$V = \lambda f$$

**The velocity of the sound differs from the medium to medium because of the freedom of motion of the molecules in the medium, that is their stuffiness elasticity, or compressibility**




**Density and stiffness determine propagation speed. Density is the concentration of matter (mass per unit volume: $kg/m^3$ ). Hardness is the resistance of a material to compression (inverse of compressibility). Hardness is usually dominant factor on propagation speed:**

**Gas --> low propagation speed**

**Liquid -->higher propagation speed**

**Solid -->highest propagation speed.**

## The Nature of Sound

- **Speed**
- **Pitch**
- **Intensity**

**Sound waves are created from some source that is vibrating. The vibrating source creates longitudinal waves in some medium that are detected by our ear or by an instrument.**

## Speed

**The speed of sound is the distance travelled per unit time by a sound wave as it propagates through an elastic medium. At 20 °C (68 °F), the speed of sound in air is about 343 meters per second**

**The speed of the sound wave will depend on the properties of the medium in which the sound is traveling.**

1. **Elastic Properties ( the bulk modulus )**

**The speed of sound is different for different types of solids, liquids, and gases. One of the reasons for this is that the elastic properties are different for different materials. Elastic properties relate to the tendency of a material to maintain its shape and not deform when a force is applied to it. A material such as steel will experience a smaller deformation than rubber when a force is applied to the materials. Steel is a rigid material while rubber deforms easily and is a more flexible material.**

**At the particle level, a rigid material is characterized by atoms and/or molecules with strong forces of attraction for each other. These forces can be thought of as springs that control how quickly the particles return to their original positions. Particles that return to their resting position quickly are ready to move again more quickly, and thus they can vibrate at higher speeds. Therefore, sound can travel faster through mediums with higher elastic properties (like steel) than it can through solids like rubber, which have lower elastic properties.**

**The phase of matter has a large impact upon the elastic properties of a medium. In general, the bond strength between particles is strongest in solid materials and is weakest in the gaseous state. As a result, sound waves travel faster in solids than in liquids, and faster in liquids than in gasses. While the density of a medium also affects the speed of sound, the elastic properties have a greater influence on the wave speed.**


2. **The density**

**The density of a medium is affects the speed of sound. Density describes the mass of a substance per volume. A substance that is denser per volume has more mass per volume. Usually, larger molecules have more mass. If a material is denser because its molecules are larger, it will transmit sound slower. Sound waves made up of kinetic energy. It takes more energy to make large molecules vibrate than it does to make smaller molecules vibrate. Thus, sound will travel at a slower rate in the denser object if they have the same elastic properties.**

**(Sound travels at 343 m/s in air; it travels at 1,480 m/s in water (4.3 times as fast as in air); and at 5,120 m/s in iron (about 15 times as fast as in air)).**

## Temperature and the speed of sound

**Temperature is also a condition that affects the speed of sound. Heat, like sound, is a form of kinetic energy. Molecules at higher temperatures have more energy, thus they can vibrate faster. Since the molecules vibrate faster, sound waves can travel more quickly. The speed of sound in room temperature air is 346 meters per second. This is faster than 331 meters per second, which is the speed of sound in air at freezing temperatures(0° C).**

**We can determine the approximate speed of sound in air at different temperatures from the equation,**

$$V=(331 + 0.60T) \text{ m/s}$$

**Where *T:* is the temperature in Celsius.**

**Humidity has a small but measurable effect on the speed of sound (causing it to increase by about 0.1%–0.6%), because oxygen and nitrogen molecules of the air are replaced by lighter molecules of water. This is a simple mixing effect.**

**Problem:** **A camera focuses using ultrasound. If it focuses precisely at 20° C, how far off (%) will it be at 0° C?**

**We use $d = vt$**

$$v_0 = 331 \text{ m/s}$$

$$v_{20} = (331 + 0.60(20°\text{C})) \text{ m/s} = 343 \text{ m/s}$$

$$100\% * (343-331) *t/343*t = 3.50\% \text{ off}$$

**Pitch : is a physiological amount depends on the frequency, pitch property relating to sense sound and are able to distinguish sounds in terms of sharpness or cruelty.**

**The man's voice is thicker than women's voices and the sound of the drums is thicker than the bells. If a sharp sound high degree said though thick, low grade**

**The pitch refers to whether the sound is a high or low**

**Pitch is a perceptual property of sounds that allows their ordering on a frequency-related scale , or more commonly, pitch is the quality that makes it possible to judge sounds as "higher" and "lower" in the sense associated with musical melodies. Pitch can be determined only in sounds that have a frequency that is clear and stable enough to distinguish from noise. Pitch is a major auditory attribute of musical tones, along with duration, loudness, and timbre.**

**Note.**

**High frequencies create high pitches and low frequencies produce low pitches.**

**The human ear can hear the audible waves of frequencies between about 20Hz and 20,000Hz.**