Sound Waves

Prepared by Bruno Silva

Sound is a mechanical wave

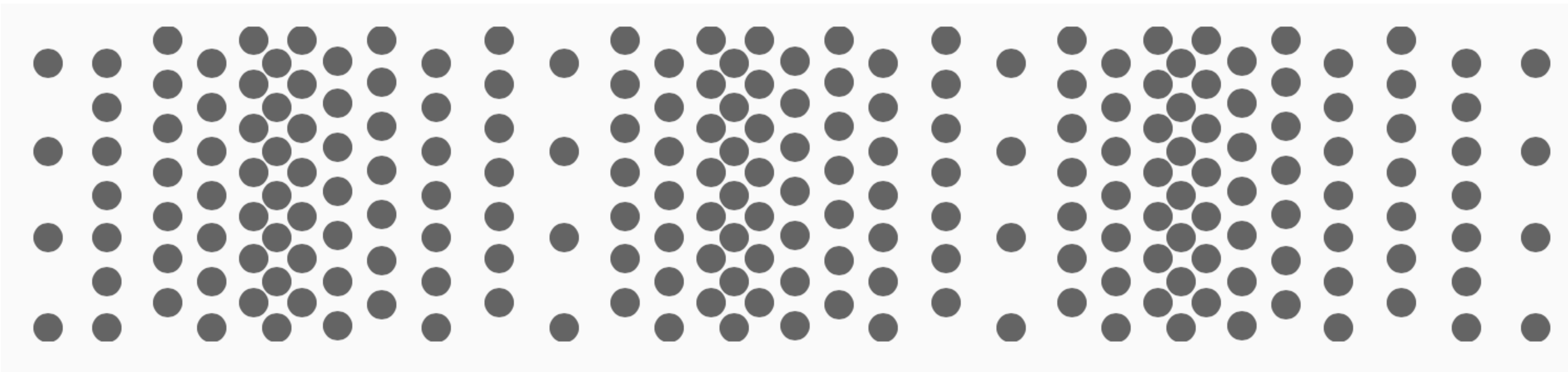
A sound wave is a pressure vibration caused by the movement of energy traveling through a medium e.g. air, as it propagates away from its source from one point (A) to another point (B)

Sound Waves are longitudinal waves that must pass through a medium such as air.
Echoes are reflections of sounds.

Properties of sound waves

When an object or substance vibrates, it produces sound. These sound waves can only travel through a solid, liquid or gas. They cannot travel through empty space.

As sound passes through the air, the air particles move left and right due to the energy of the sound wave passing through it. It's the vibrating air molecules that cause the human eardrum to vibrate, which the brain then interprets as sound.
Air molecules do not travel from the noise source to the ear. Each individual molecule only moves a small distance as it vibrates, which causes the adjacent molecules to vibrate in a rippling effect all the way to the ear.



Longitudinal sound wave showing compression (squeezing-high pressure) and rarefaction (spreading-low pressure) of air particles

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Longitudinal waves

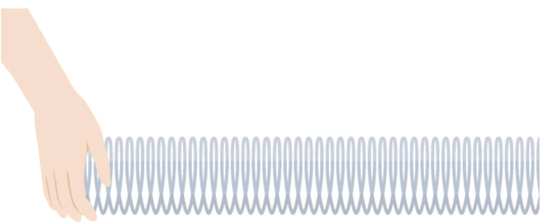
Sound waves are **<u>longitudinal waves</u>** and should not be confused with **transverse** waves.
Most waves are transverse including the light and the ripples we see on the water.

Transverse waves vibrate at 90 degrees to the direction of the wave such as water ripples or light. In contrast, longitudinal waves have vibrations along the same axis as the direction in which the wave is traveling. Think of the way a slinky behaves if two people are holding each end and one person quickly sends a number of vibrations down it.

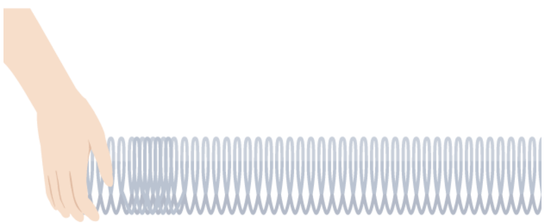
Similar to the slinky wave described above, a sound wave carries a disturbance (vibration) from one location (point) to another. For the most part the medium through which it travels is air, although sound waves can just as readily travel though water or metal materials.

Longitudinal waves referes to the vibrations in the same direction as the direction of travel.

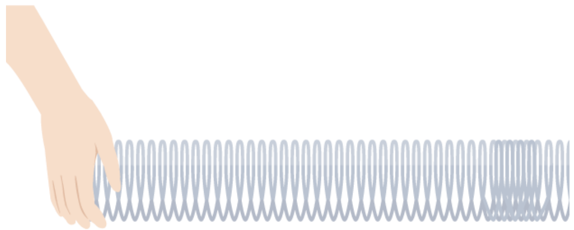
The pictures below shows how you can model longitudinal waves using a long spring:



Stretch the spring and hold at each end



Shake your hand forward



The compressed area of the spring travels along its length

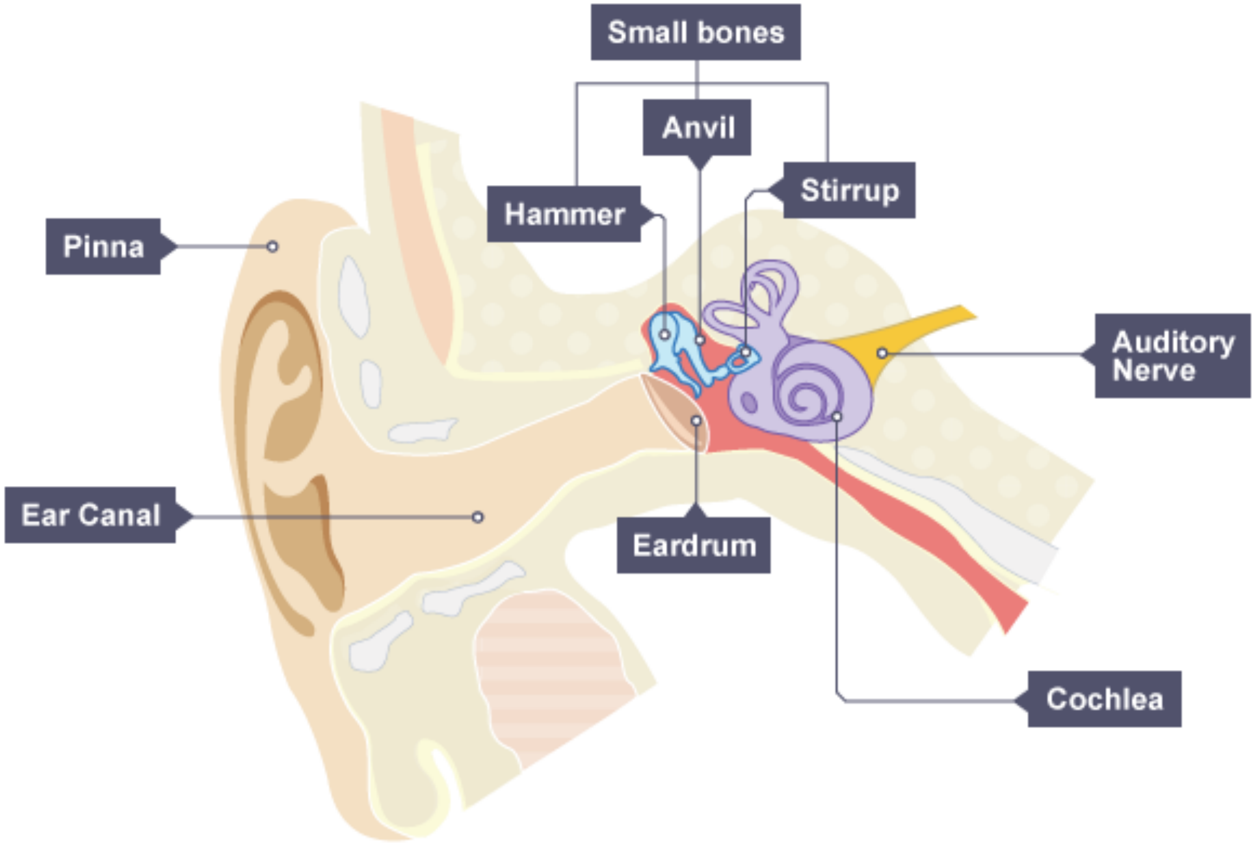
Reflections

Sound waves can **<u>reflect</u>** off surfaces. We hear sound reflections as **<u>echoes</u>**. Hard, smooth surfaces are particularly good at reflecting sound. This is why empty rooms produce lots of echoes.
Soft, rough surfaces are good at absorbing sound. This is why rooms with carpets and curtains do not usually produce lots of echoes.

Detecting sound

Ears

We can detect sound using our ears. An ear has an eardrum inside, connected to three small bones. The vibrations in the air make the eardrum vibrate, and these vibrations are passed through the three small bones (called ossicles) to a spiral structure called the cochlea. Signals are passed from the cochlea to the brain through the auditory nerve, and our brain interprets these signals as sound.



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Sound Waves
Mechanical vs Electromagnetic

Characteristics of Electromagnetic Waves

- Electromagnetic waves have both electric and a magnetic nature
- Electromagnetic waves are capable of traveling through a vacuum
- Electromagnetic waves do not require a medium to transport their energy

Characteristics of Mechanical Waves

- Mechanical waves do require a medium in order to transport their energy from one location to another
- Mechanical waves are unable to travel through a vacuum. Because mechanical waves depend upon particle interaction as a means for transporting their energy
- Mechanical waves, do not transmit when sent through tunnels, underwater, and all other examples of vacuous structures.

Sound Waves
Longitudinal

As stated previously, sound is a mechanical wave. It is created by a vibrating motion that travels through a conductive (non-vacuous) medium. Sound results from the longitudinal motion of the particles of the medium through which the mechanical sound wave travels.

When the sound wave move from left to right through air, this causes the displacement of air particles as the energy of the sound wave passes. The motion of the particles exists in both parallel and non-parallel forms to the direction in which energy is being transported. Hence, this is the what characterizes sound as a Longitudinal Wave.

Sound is a combination of pressure variances. Due to the longitudinal motion of the air particles, there are pockets where the air particles are pressed together (compressions) and other regions where the air particles are spread apart (rarefactions, or rarifications). The compressions are regions in which high air pressure has clustered (condensation) whereas rarefactions are regions comprised of low air pressure (dilation).

Longitudinal Sound Wave

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Sound Waves
Measurement Methods

Waves can be measured in a range of different ways: by their **amplitude**, **wavelength**, **frequency**, **speed**, and, at times, their **phase**.

Amplitude is a metric method associated with hearing. It is commonly grouped with intensity, loudness, and (or) volume.
Is the maximum height of the wave from its resting position - the greater the amplitude, the louder the sound.

The **wavelength** is easy enough to detect during one complete wave cycle, meaning the distance a disturbance travels through the medium in one complete wave cycle.
In other words, is the distance between the crests (tops) of two waves next to each other (or any other two identical point on waves next to each other).

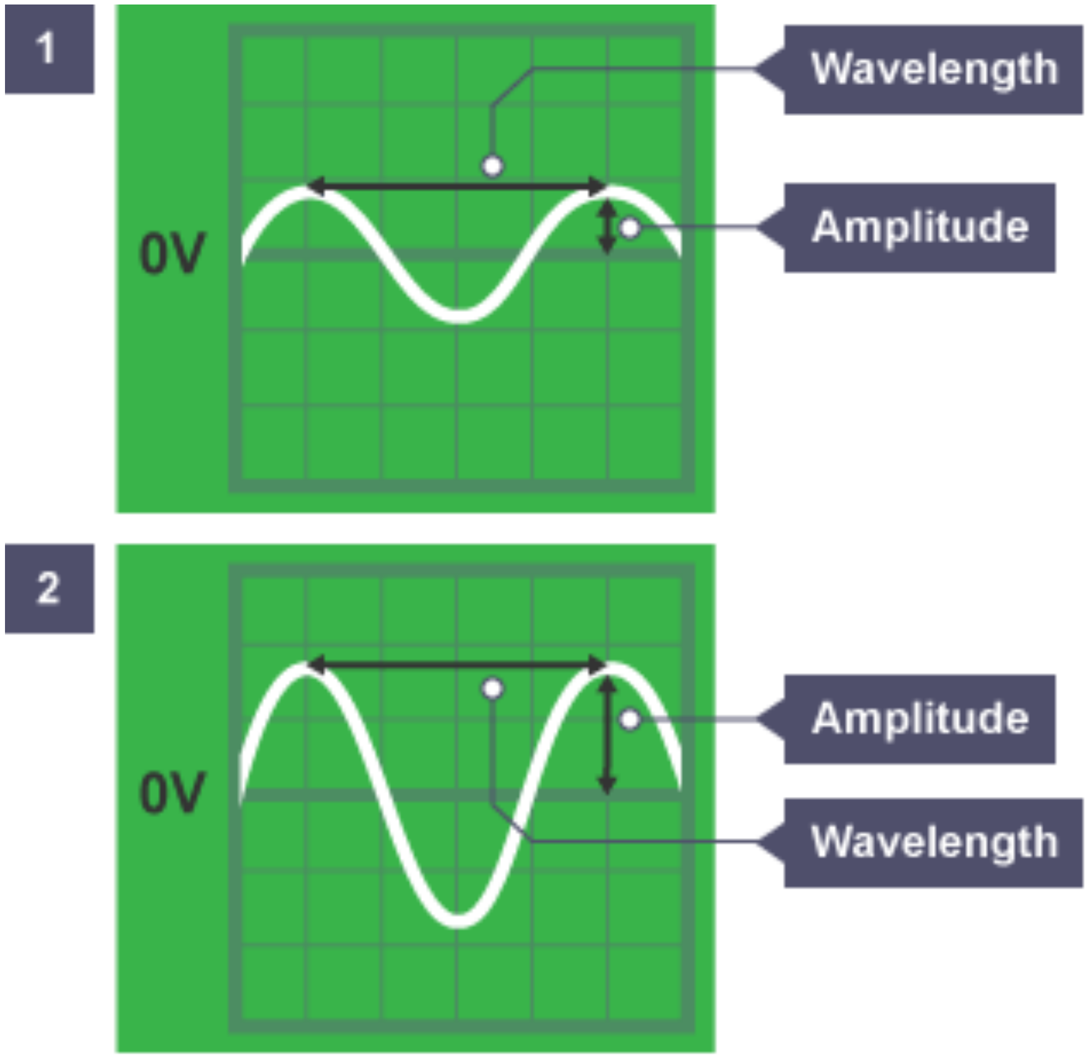
Once every wave cycle, a wave will repeat its pattern. For this reason, the wavelength is sometimes referred to as the length of the repeating pattern or the length of one complete cycle.

Because longitudinal waves are comprised of repeating patterns of compressions and rarefactions, their wavelengths can commonly be measured as the distance from one compression to the next compression, or the distance from one rarefaction to the next rarefaction.

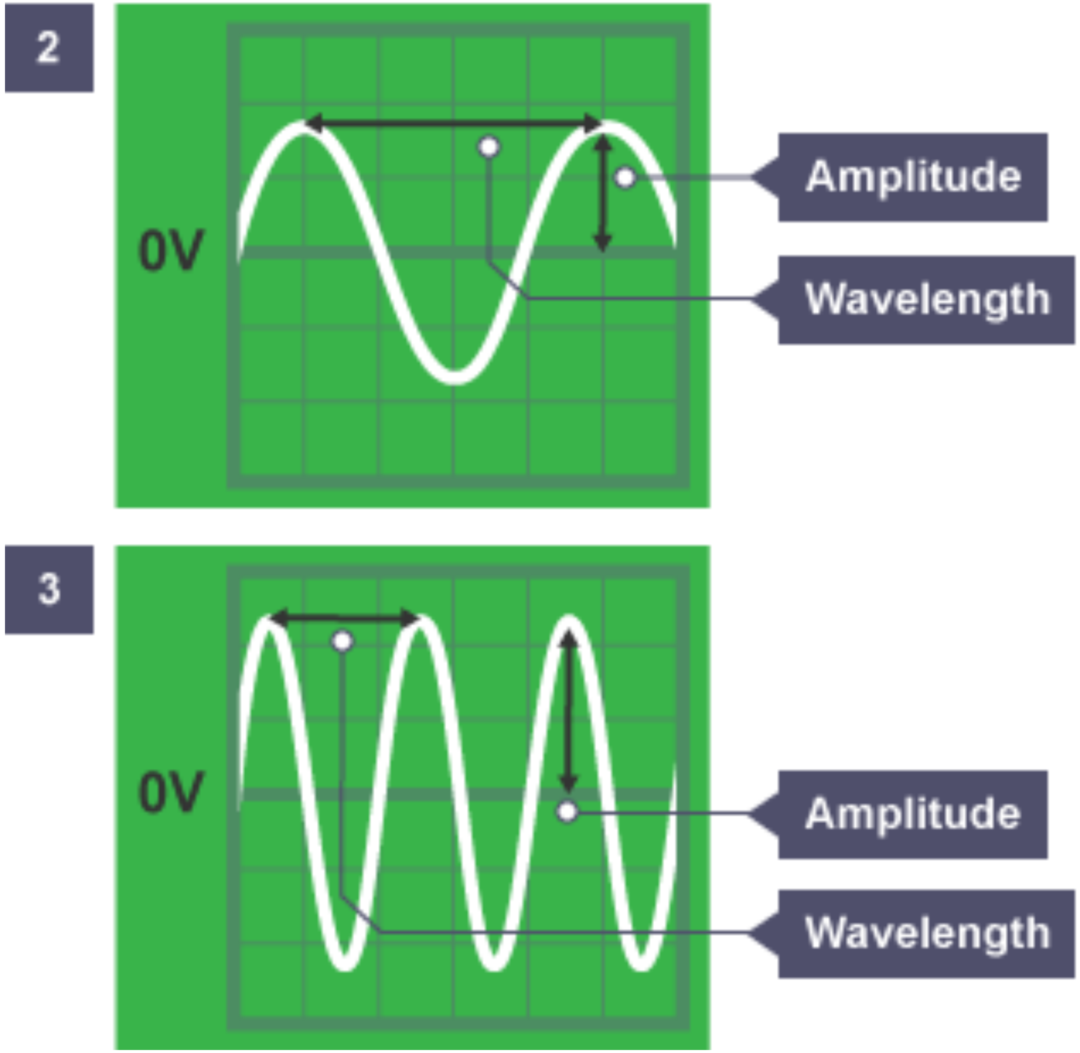
The **frequency** is the number of waves per second – the higher the frequency, the closer together the waves are and the higher the **pitch.**

Lastly, the **speed** of sound depends upon the type of medium and its state. It is generally affected by two things: elasticity (ease with which molecules move or degree to which molecules move away from their neutral position when disturbed) and inertia (the denser the air or medium, the more inertia the sound wave has).

Inertia is the resistance of any physical object to any change in its velocity. This includes changes to the object's speed, or direction of motion



Diagrams 1 and 2 show two sounds with the same wavelength and frequency, so they will have the same pitch. The sound in diagram 2 has a greater amplitude than the one in diagram 1, so it will be louder.



Diagrams 2 and 3 show two sounds with a different wavelength and frequency. The sound in diagram 3 has a higher frequency than the one in diagram 2, so its pitch will be higher.

Sound through different materials

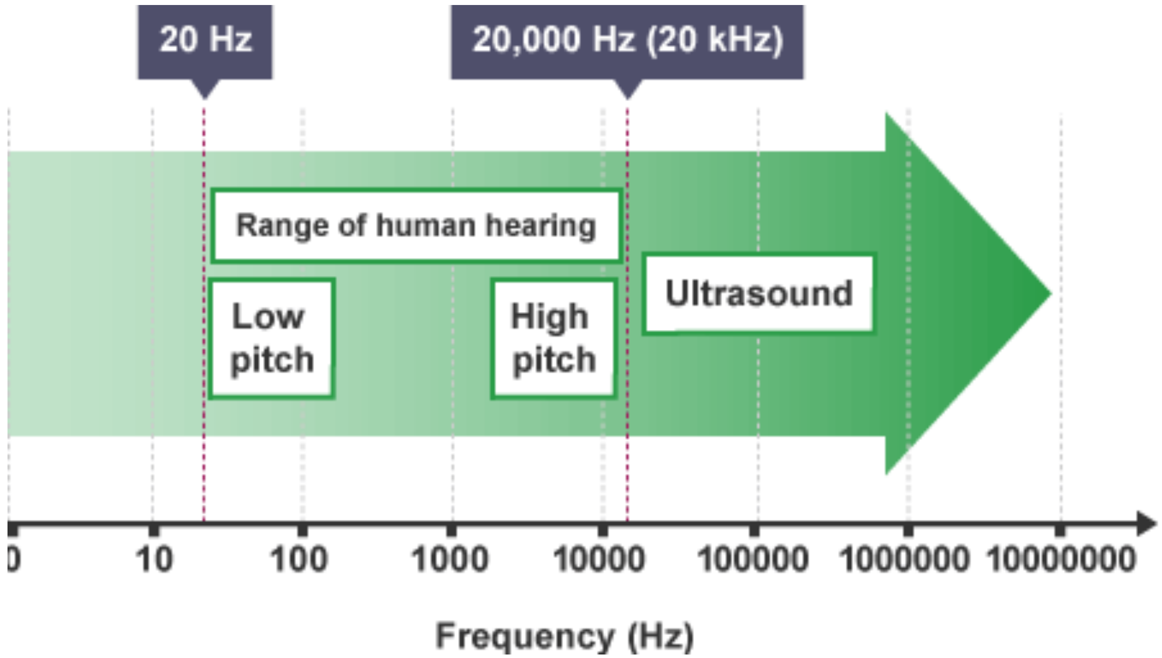
Sound travels faster through liquids and solids than it does through air and other gases. The table gives some examples.

Substance	Speed of sound
Air	343 m/s
Water	1493 m/s
Steel	5130 m/s

This is because the particles of gases are further apart than liquids and finally solids. Sound waves move more slowly when particles are further apart.

Ultrasound

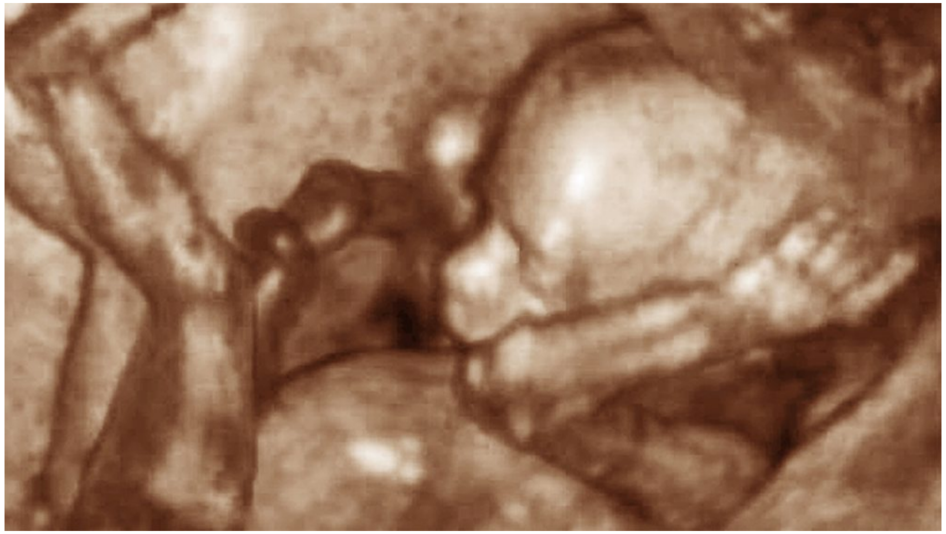
The frequency of sound waves is measured in hertz, which has the symbol Hz. The bigger the number, the greater the frequency and the higher the pitch of the sound. Human beings can generally hear sounds as low as 20 Hz and as high as 20,000 Hz (20 kHz).



The normal range of human hearing and ultrasound

High pitched

Sound with a frequency of more than 20,000 Hz is called **ultrasound**. It is too high pitched for humans to hear, but other animals (such as dogs, cats and bats) can hear ultrasound.
Ultrasound has many applications in medicine, including ultrasound scans to check on the health of unborn babies



An ultrasound image of an unborn baby

Sound and ultrasound are pressure waves that transfer energy from place to place. Ultrasound can be used to clean jewelry. The jewelry is placed in an ultrasonic bath, where the rapid vibrations shake the dirt loose. Ultrasound can also be used for physiotherapy. Its energy is absorbed by soft tissue in the body, bringing relief from sprains and arthritis (painful joints).

Summary

- Sounds are produced by **vibrations**.
- Sound travels as **waves**, which are vibrating particles.
- Sound waves are **reflected** by surfaces.
- **How is sound produced?**
  Ex: When you bang a drum its skin vibrates. The harder you bang, the bigger the vibrations.
  The vibrating drum skin causes nearby **air particles** to vibrate,
  which in turn causes other nearby air particles to vibrate.
  These vibrating particles make up a **sound wave**.
- **How does sound travel?**
  Sound waves travel at **343 m/s** through the **air** and **faster** through **liquids and solids**.
  The waves transfer energy from the source of the sound, e.g. a drum, to its surroundings.
  Your **ear** detects sound waves when vibrating air particles cause your **ear drum to vibrate**.
  The bigger the vibrations the louder the sound.

- **Reflection of sound**
  Surfaces reflect sound waves:
  Hard surfaces reflect sound **well**, making **echoes**.
  Soft surfaces, like curtains and carpets, reflect **very little** sound.
  They **absorb** the sound instead, so there are no echoes.

- A sound wave is not a transverse wave with crests and troughs (depressions), but rather a longitudinal wave with compressions and rarefactions.

- These regions of high pressure and low pressure, known respectively as ***compressions*** and ***rarefactions***, are established as the result of the vibrations of the sound source.

- Sound waves can be measured according to several different paradigms: **amplitude**, **wavelength**, **frequency**, **speed**, and, at times, **phase**.
  <u>Each of these is associated with certain characteristics:</u>
  - Loudness and pitch with amplitude
  - Rarefactions and compressions with frequency
  - Distance with wavelength
  - Elasticity and inertia with speed