You can identify sounds without seeing them because sound waves carry information to your ears. People who work in places where sound is very loud need to protect their hearing.

Properties of Sound Waves

- What properties explain the behavior of sound?
- Many behaviors of sound can be explained using a few properties—speed, intensity and loudness, and frequency and pitch.

Properties of Sound Waves

Sound waves are longitudinal waves—compressions and rarefactions that travel through a medium.

Properties of Sound Waves

Speed

It takes time for sound to travel from place to place.

The speed of sound varies in different media. In dry air at 20°C, the speed of sound is 342 meters per second.

Properties of Sound Waves

In general, sound waves travel fastest in solids, slower in liquids, and slowest in gases.

- Particles in a solid tend to be closer together than particles in a liquid or a gas.
- The speed of sound depends on many factors, including the density of the medium and how elastic the medium is.

Properties of Sound Waves

Speed of Sound	
Medium (at 1 atm)	**Speed (m/s)**
Dry air, 0°C	331
Dry air, 20°C	342
Fresh water, 0°C	1401
Fresh water, 30°C	1509
Salt water, 0°C	1449
Salt water, 30°C	1546
Lead, 25°C	1210
Cast iron, 25°C	4480
Aluminum, 25°C	5000
Borosilicate glass, 25°C	5170

Properties of Sound Waves

Intensity and Loudness

Intensity is the rate at which a wave's energy flows through a given area.

- Sound intensity depends on both the wave's amplitude and the distance from the sound source.
- The **decibel** (dB) is a unit that compares the intensity of different sounds.

Properties of Sound Waves

For every 10-decibel increase, the sound intensity increases tenfold.

- A 0-decibel sound can just barely be heard.
- A 20-decibel sound has 100 times more energy per second than a 0-decibel sound.
- A 30-decibel sound delivers 1000 times more energy per second than a 0-decibel sound.

Properties of Sound Waves

Lengthy exposure to sounds more intense than 90 decibels can cause hearing damage.

Sound Intensity Level	
Sound	**Intensity Level (decibels)**
Threshold of human hearing	0
Whisper	15–20
Normal conversation	40–50
Street noise	60–70
Inside a bus	90–100
Operating heavy machinery	80–120
Rock concert (in audience)	110–120
Threshold of pain	120
Jet plane (taking off)	120–160

Properties of Sound Waves

Loudness is a physical response to the intensity of sound, modified by physical factors.

- The loudness depends on sound intensity.
- Loudness also depends on factors such as the health of your ears and how your brain interprets sound waves.

Properties of Sound Waves

Frequency and Pitch

The frequency of a sound wave depends on how fast the source of the sound is vibrating.

The air in the tubing of brass instruments forms a standing wave. Longer tubing makes a standing wave with a longer wavelength and a lower frequency.

Properties of Sound Waves

The French horn can produce lower notes than the trumpet because it can make a longer tube for a standing wave.

French Horn

Trumpet

Properties of Sound Waves

Pitch is the frequency of a sound as you perceive it.

- High-frequency sounds have a high pitch, and low-frequency sounds have a low pitch.
- Pitch also depends on other factors such as your age and the health of your ears.

Ultrasound

- **How is ultrasound used?**
- **Ultrasound is used in a variety of applications, including sonar and ultrasound imaging.**

Ultrasound

Most people hear sounds between 20 hertz and 20,000 hertz.

- Infrasound is sound at frequencies lower than most people can hear.
- Ultrasound is sound at frequencies higher than most people hear.

Ultrasound

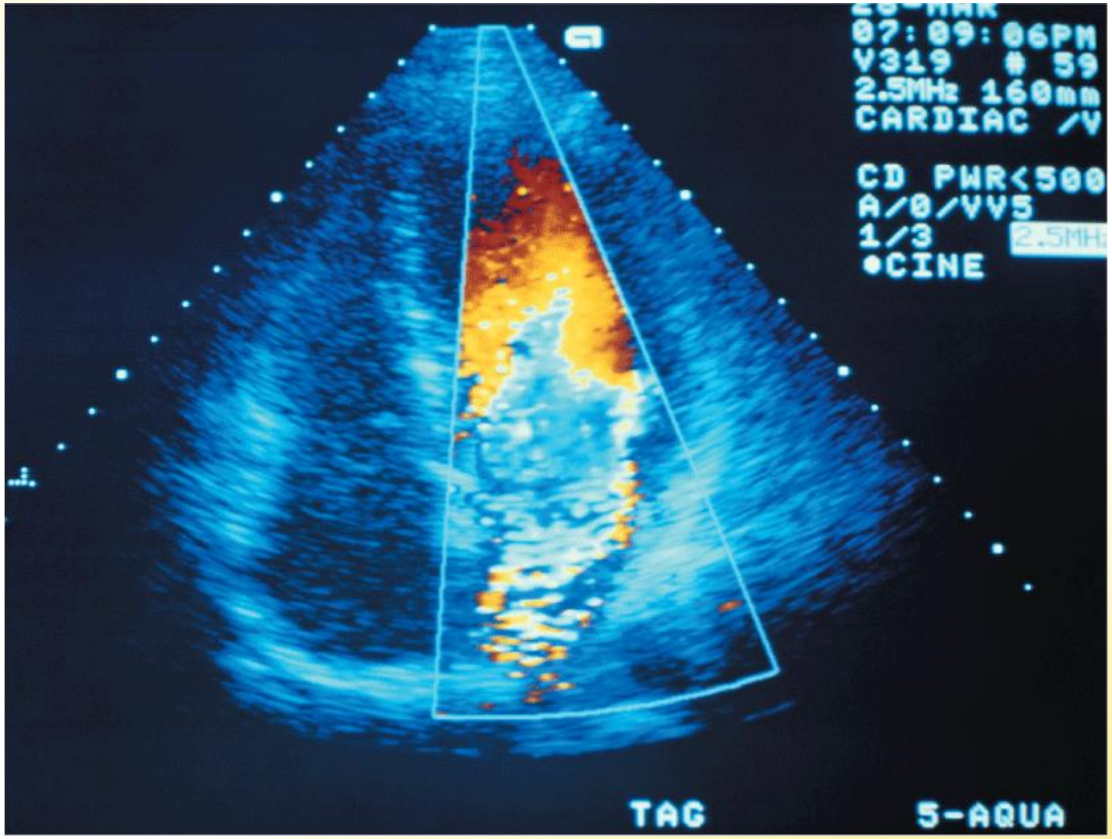
Sonar is a technique for determining the distance to an object under water.

Ultrasound imaging is an important medical technique. Computer software uses reflected pulses of ultrasound to make a detailed map of structures and organs inside the body.

Ultrasound

Ultrasound can be used to make images of the heart.

DOK Question: Hypothesize how this picture is made.



The Doppler Effect

How does frequency of sound change for a moving source?

As a source of sound approaches, an observer hears a higher frequency. When the sound source moves away, the observer hears a lower frequency.

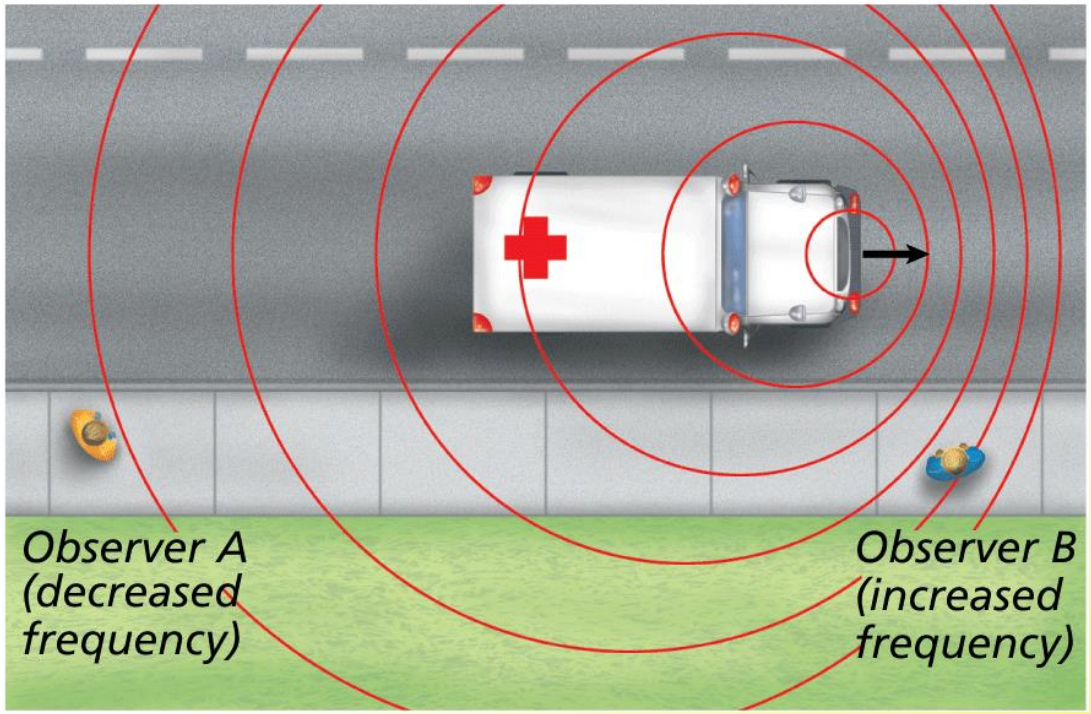
The Doppler Effect

The **Doppler effect** is a change in sound frequency caused by motion of the sound source, motion of the listener, or both.

The Doppler Effect

Observer A hears a lower-pitch sound than observer B because the wave fronts are farther apart for observer A.

DOK Question: Hypothesize how this picture explains the Doppler Effect.



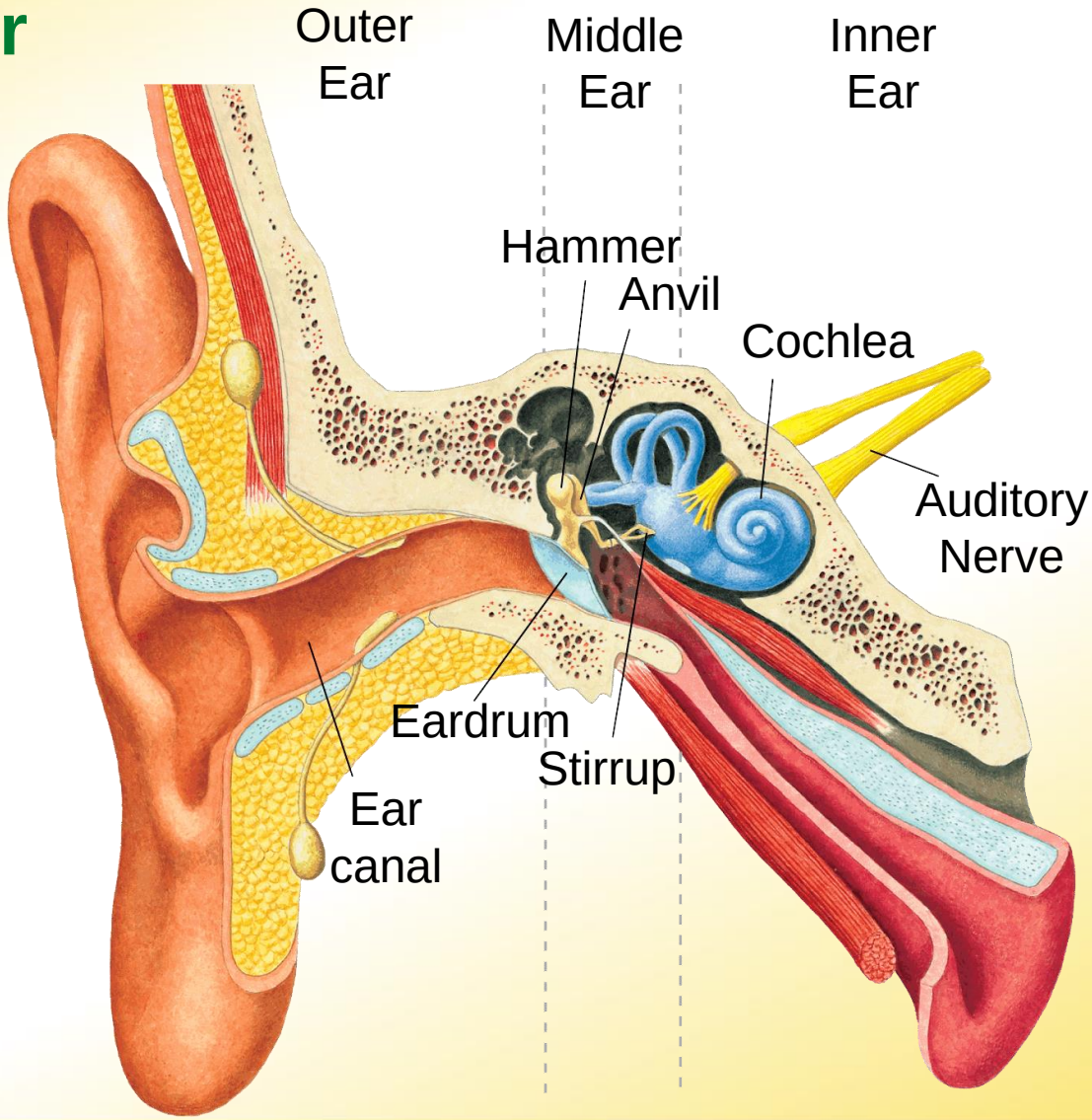
Hearing and the Ear

What are the functions of the three main regions of the ear?

The outer ear gathers and focuses sound into the middle ear, which receives and amplifies the vibrations. The inner ear uses nerve endings to sense vibrations and send signals to the brain.

Hearing and the Ear

Your ear is a complex system that consists of three main regions—the outer ear, the middle ear, and the inner ear.



Hearing and the Ear

Outer Ear

- The part of the ear you can see funnels sound waves down the ear canal, a tunnel about 2.5 cm long.
- Sound waves strike the eardrum, a tightly stretched membrane between the outer and middle ear.
- The eardrum vibrates at the same frequency as the sound waves striking it.

Hearing and the Ear

Middle Ear

The middle ear contains three tiny bones—the hammer, the anvil, and the stirrup. The three bones act as a lever system to amplify the motion of the eardrum.

- When the eardrum vibrates, the hammer vibrates at the same frequency.
- The hammer strikes the anvil.
- The anvil moves the stirrup back and forth.

Hearing and the Ear

Inner Ear

Vibrations from the stirrup travel into the cochlea, a spiral-shaped canal filled with fluid.

- The inside of the cochlea is lined with thousands of nerve cells with tiny hair-like projections.
- As the fluid in the cochlea vibrates, the projections sway back and forth and send electrical impulses to the brain.

How Sound Is Reproduced

How is sound recorded?

Sound is recorded by converting sound waves into electronic signals that can be processed and stored. Sound is reproduced by converting electronic signals back into sound waves.

How Sound Is Reproduced

When a singer sings into a microphone, sound waves from the singer's voice vibrate a membrane inside the microphone.

- The membrane causes a magnet to vibrate.
- The vibration produces an electronic signal in the microphone wires.
- The energy of sound waves has been converted into an electronic signal that can be processed and stored.

How Sound Is Reproduced

In a speaker, an electronic signal causes a magnet to vibrate.

- The magnet is attached to a membrane.
- The vibrating membrane sends sound waves through the air.

Music

- How do musical instruments vary pitch?
- Most musical instruments vary pitch by changing the frequency of standing waves.

Music

Musical instruments can produce a wide variety of sounds.

- In a wind instrument, holes are closed using fingers or valves to change the length of the standing sound wave.
- For some stringed instruments, musicians change the length of the strings by pressing down with their fingers.
- Other instruments use a fixed set of strings of different lengths.

Music

Resonance is the response of a standing wave to another wave of the same frequency. Musical instruments often use resonance to amplify sound.

- One wave can “push” another wave to a higher amplitude.
- Resonance can produce a dramatic increase in amplitude.

Music

Sound-absorbing tiles in this auditorium reduce unwanted reflections. The curved reflecting panels above the stage help gather and direct sound waves toward the audience.

Assessment Questions

1. The intensity of sound waves is measured in units of
   a. hertz (Hz).
   b. decibels (dB).
   c. joules (J).
   d. meters (m).

Assessment Questions

1. The intensity of sound waves is measured in units of
   a. hertz (Hz).
   b. decibels (dB).
   c. joules (J).
   d. meters (m).

   ANS: B

Assessment Questions

2. Most musical instruments vary pitch by
   a. changing the amplitude of sound waves.
   b. reflecting sound from surfaces in a room.
   c. changing the frequency of a standing wave.
   d. using the Doppler effect.

Assessment Questions

2. Most musical instruments vary pitch by
   a. changing the amplitude of sound waves.
   b. reflecting sound from surfaces in a room.
   c. changing the frequency of a standing wave.
   d. using the Doppler effect.

   ANS: C

Assessment Questions

3. The Doppler effect is
   a. a change in sound frequency caused by motion of the sound source relative to the listener.
   b. used in a variety of applications including sonar and ultrasound imaging.
   c. a technique for determining the distance to an object under water.
   d. the rate at which a wave's energy flows through a given area.

Assessment Questions

3. The Doppler effect is
   a. a change in sound frequency caused by motion of the sound source relative to the listener.
   b. used in a variety of applications including sonar and ultrasound imaging.
   c. a technique for determining the distance to an object under water.
   d. the rate at which a wave's energy flows through a given area.

   ANS: A

Assessment Questions

4. What part of the human ear acts as an amplifier to increase the motion of the eardrum?
   a. ear canal
   b. middle ear
   c. inner ear
   d. auditory nerve

Assessment Questions

4. What part of the human ear acts as an amplifier to increase the motion of the eardrum?
   a. ear canal
   b. middle ear
   c. inner ear
   d. auditory nerve

   ANS: B