Sound and Light

Sound

Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.		
Before	**Statement**	**After**
	1. Vibrating objects make sound waves.	
	2. Human ears are sensitive to more sound frequencies than any other animal's ears.	

Key Concepts

- How are sound waves produced?
- Why does the speed of sound waves vary in different materials?
- How do your ears enable you to hear sounds?

Read to Learn

What is sound?

Have you ever walked down a busy city street and noticed all the sounds? They all have one thing in common. The sounds travel from one place to another as sound waves. *A* **sound wave** *is a longitudinal wave that can travel only through matter.* Sound waves can travel through solids, liquids, and gases. The sounds you hear now are traveling through air—a mixture of solids and gases.

You might have dived under water and heard someone call you. Those sound waves traveled through a liquid. Sound waves travel through a solid when you knock on a door. Your knock makes the door vibrate. Vibrating objects produce sound waves.

Mark the Text

Identify Main Ideas As you read, underline the main ideas under each heading. After you finish reading, review the main ideas that you underlined.

REVIEW VOCABULARY

longitudinal wave
a wave in which particles in a material move along the same direction that the wave travels

Vibrations and Sound

Some objects, such as doors or drums, vibrate when you hit them. When you hit a drum, the drumhead moves up and down, or vibrates. These vibrations produce sound waves by moving molecules in air.

Compressions and Rarefactions

As the drumhead moves up, it pushes the molecules in the air above it closer together. The region where molecules are closer together is a compression.

Visual Check

1. Point Out Highlight the air molecules above each drumhead that are part of the compression.

Key Concept Check

2. Explain How do vibrating objects produce sound waves?

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Visual Check

3. Specify How is the wavelength of a sound wave measured?

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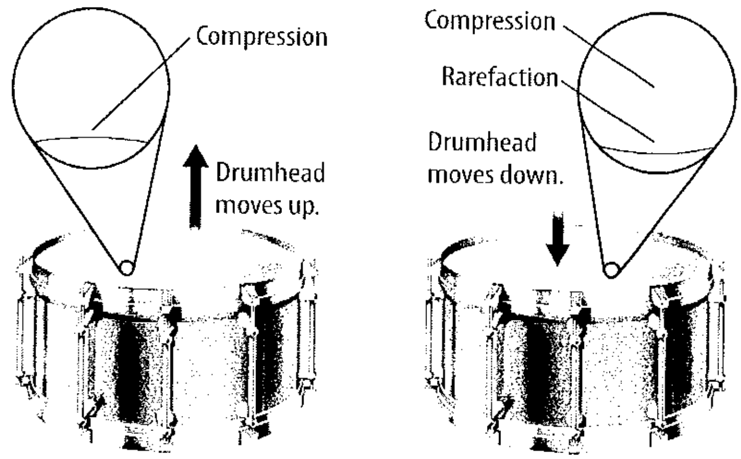


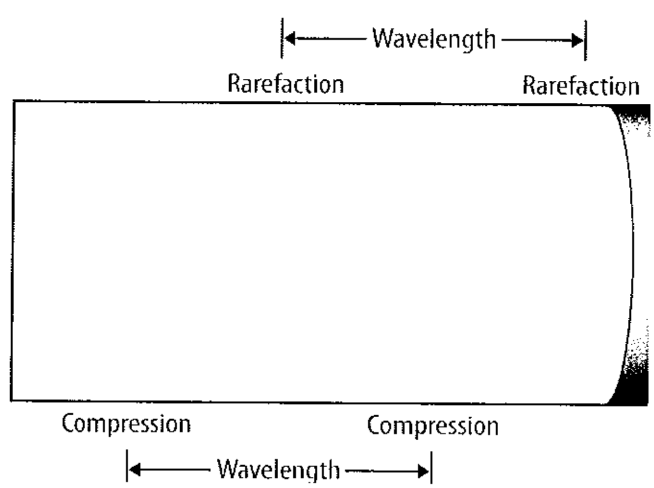
When the drumhead moves down, it makes a rarefaction. This is a region where the molecules in the air are farther apart. As the drumhead vibrates up and down, it produces a series of compressions and rarefactions, as shown in the figure above, that travels away from the drumhead. This series of compressions and rarefactions is a sound wave.

The vibrating drumhead causes molecules in the air to move closer together and then farther apart. The molecules move back and forth in the same direction that the sound wave travels. As a result, a sound wave is a longitudinal wave.

Wavelength and Frequency

Wavelength is the distance between a point on a wave and the nearest point just like it. The figure below shows that the wavelength is the distance between one compression and the next compression or the distance between a rarefaction and the next rarefaction.

The frequency of a sound wave is the number of wavelengths that pass a given point in one second. The faster an object vibrates, the higher the frequency of the sound wave it produces. Frequency is measured in hertz (Hz).



Speeds of Sound Waves

Sound waves traveling through air cause most of the sounds you hear every day. Recall that sound waves can also travel through liquids and solids. Like all types of waves, the speed of a sound wave depends on the material in which it travels.

The Speed of Sound Waves in Different Materials

Gases (0°C)		Liquids (25°C)		Solids	
Material	**Speed (m/s)**	**Material**	**Speed (m/s)**	**Material**	**Speed (m/s)**
Carbon dioxide	259	Ethanol	1,207	Brick	3,480
Dry air	331	Mercury	1,450	Ice	3,850
Water vapor	405	Water	1,500	Aluminum	6,420
Helium	965	Glycerine	1,904	Diamond	17,500

Sound in Gases, Liquids, and Solids

Sound waves travel at different speeds in different materials. The table above lists the speed of sound waves in different materials. The more dense the material is, the faster a sound wave can move through it. Solids and liquids are usually more dense than gases. Sound waves move fastest through solids and slowest through gases.

A sound wave's speed also depends on the strength of the forces between the particles—atoms or molecules—in the material. The stronger these forces, the faster a sound wave can move through the material.

These forces are usually strongest in solids and weakest in gases. Overall, sound waves usually travel faster in solids than in liquids or gases. ✓

Temperature and Sound Waves

The temperature of a material also affects the speed of a sound wave. The speed of a sound wave in a material increases as the temperature of the material increases.

For example, the speed of a sound wave in dry air increases from 331 m/s to 343 m/s as the air temperature increases from 0°C to 20°C. Therefore, sound waves in air travel faster on a warm, summer day than on a cold, winter day.

Math Skills

Speed (s) is equal to the distance (d) something trave divided by the time (t) it take to cover that distance:

$$s = \frac{d}{t}$$

You can use this equation tc calculate the speed of soun waves. For example, if a sour wave travels a distance of 662 meters in 2 seconds in air, its speed is:

$$s = \frac{d}{t} = \frac{662\ \text{m}}{2\ \text{s}} = 331\ \text{m/s}$$

4. Use a Simple Equation How fast is a sound wave traveling if it travels 5,000 m in 5 s?

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Interpreting a Table

5. Compare Through which material do sound waves move fastest? (Circle the correct answer.)

a. dry air

b. water

c. ice

✓ Key Concept Chec

6. Explain Why is the speed of sound waves faste in solids than in liquids or gases?

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Visual Check
7. Identify In which part of the ear is the cochlea located?

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Think it Over
8. Analyze Bat-eared foxes have very large outer ears. How do large outer ears benefit these foxes?

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Key Concept Check
9. Describe What is the function of each of the three parts of the ear?

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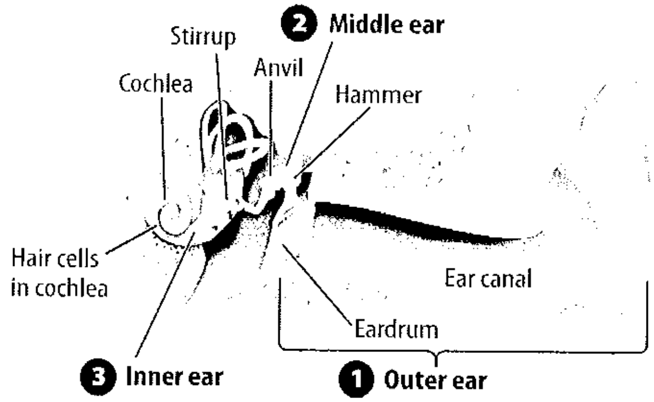


The Human Ear

When you think about your ears, you probably think only about the structure on each side of your head. However, the human ear has three parts—the outer ear, the middle ear, and the inner ear. These parts collect and amplify sound waves and convert the waves into nerve signals. The parts of the ear are shown in the figure above.

1. The Outer Ear

The outer ear collects sound waves. The structure on each side of your head and the ear canal are included in the outer ear. The visible part of the outer ear collects sound waves and funnels them into the ear canal. The ear canal channels sound waves into the middle ear.

2. The Middle Ear

The middle ear amplifies, or strengthens, sound waves. As shown in the figure above, the middle ear includes the eardrum and three tiny bones—the hammer, the anvil, and the stirrup. The eardrum is a thin membrane that stretches across the ear canal. When a sound wave hits the eardrum, it causes the eardrum to vibrate. The vibrations travel to the three tiny bones, which amplify the sound wave.

3. The Inner Ear

The inner ear converts, or changes, vibrations into nerve signals that travel to the brain. The inner ear has a small chamber called the cochlea (KOH klee uh). The cochles is filled with fluid. Tiny hairlike cells line the inside of the cochlea. These cells are sensitive to vibrations. As a sound wave passes into the cochlea, it causes some hair cells to vibrate. The movements of these cells produce nerve signals that travel to the brain. ✓

Frequencies and the Human Ear

Recall that frequency—vibrations per second—is measured in hertz (Hz). The table shows that humans hear sounds with frequencies between about 20 Hz and 20,000 Hz. Some mammals can hear sounds with frequencies greater than 100,000 Hz.

Frequencies Different Mammals Can Hear

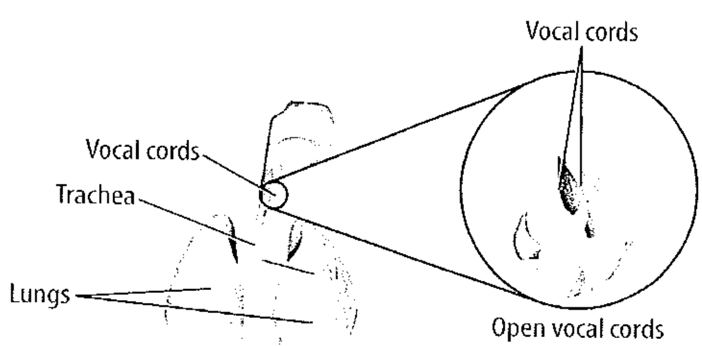
Creature	Frequency Range (Hz)
Human	20–20,000
Dog	67–45,000
Cat	45–64,000
Bat	2,000–110,000
Beluga whale	1,000–123,000
Porpoise	75–150,000

Sound and Pitch

If you pluck a guitar string, you hear a note. A thick guitar string makes a low note. A thin guitar string makes a higher note. The sound a thick string makes has a lower pitch than the sound a thin string makes. *The* **pitch** *of a sound is the perception of how high or low a sound seems.* A sound wave with a higher frequency has a higher pitch. A sound wave with a lower frequency has a lower pitch.

You use your vocal cords to make sounds of different pitches. As shown below, vocal cords are two membranes in your neck above your windpipe, or trachea (TRAY kee uh). When you speak, you force air from your lungs through the space between the vocal cords. Your vocal cords then vibrate, making sound waves that people hear. This is your voice.

You change the pitch of your voice by using the muscles connected to your vocal cords. When these muscles contract, they pull on your vocal cords. This stretches the vocal cords, and they become longer and thinner. The pitch of your voice is then higher, just as a thinner guitar string produces a higher pitch. When these muscles relax, the vocal cords become shorter and thicker, and the pitch of your voice is lower.



Interpreting a Table

10. Compare Which mammals listed in the table can hear a sound with a frequency of 55 Hz?

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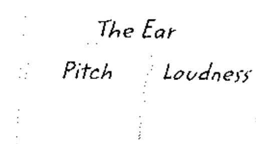
FOLDABLES

Make a two-tab concept-ma book to organize informatio about pitch and loudness.



Visual Check

11. Select Highlight the structure that controls the pitch of the human voice.

Low-amplitude sound wave **High-amplitude sound wave**

Visual Check

12. Contrast How do distances between particles differ in high- and low-amplitude sound waves?

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Visual Check

13. Calculate What is the difference in decibels between a vacuum cleaner and a jet plane taking off?

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Sound and Loudness

Loudness is the human sensation of how much energy a sound wave carries. Sound waves made by a shout carry more energy than sound waves made by a whisper. Because a shout carries more energy, it sounds louder than a whisper.

Amplitude and Energy

The amplitude of a wave depends on the amount of energy the wave carries. The more energy the wave has, the greater the amplitude.

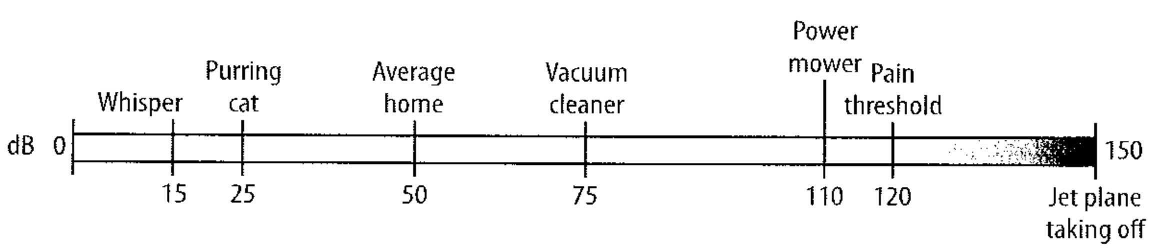
The figure above shows the difference between a high-amplitude sound wave and a low-amplitude sound wave. High-amplitude sound waves have particles that are closer together in the compressions and farther apart in the rarefactions.

The Decibel Scale

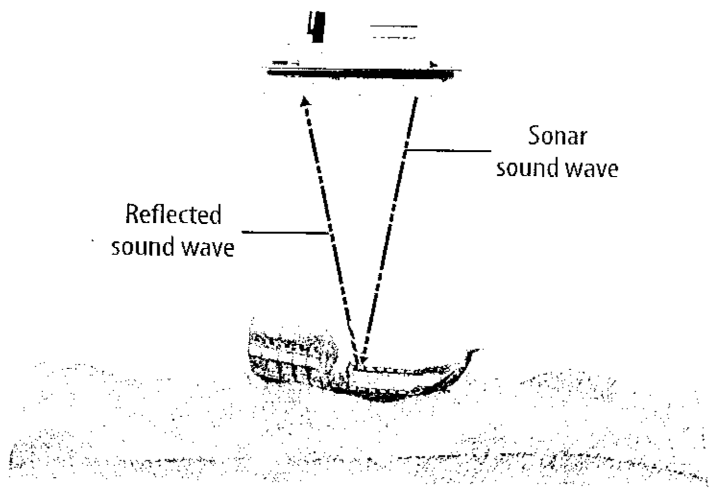
The decibel scale is one way to compare the loudness of sounds. The figure below shows the decibel measurements for some sounds.

The softest sound a person can hear is about 0 decibels (dB). Normal conversation is about 50 dB. A sound wave that is 10 dB higher than another sound wave carries ten times more energy. However, people hear the higher-energy sound wave as being only twice as loud.

The Decibel Scale



Sonar System



Using Sound Waves

If you have ever shouted in a cave or a big, empty room, you might have heard an echo of your voice. *An* **echo** *is a reflected sound wave.* You probably can't tell how far away a wall is by hearing an echo. However, sonar systems and some animals use reflected sound waves to determine how far away objects are.

Sonar and Echolocation

Sonar systems use reflected sound waves to locate objects under water, as shown in the figure above. The sonar system sends a sound wave that reflects off an underwater object. The sonar system calculates the distance to the object by measuring the time difference between when the sound leaves the ship and when the sound returns to the ship. Sonar is used to map the ocean floor and to detect submarines, schools of fish, and other objects under water.

Some animals use echolocation to hunt or to find their way. Echolocation is a type of sonar. Bats and dolphins make high-pitched sounds and interpret the echoes reflected from objects. Echolocation makes it possible for bats and dolphins to locate prey and detect objects.

Ultrasound

Ultrasound scanners use high-frequency sound waves to make images of internal body parts. The sound waves reflect from structures within the body. The scanner analyzes the reflected waves and produces images, called sonograms, of body structures. The images can help doctors diagnose disease or other medical conditions.

Visual Check

14. Identify What is the echo in the figure at the left?

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Reading Check

15. Explain How do sonar systems use sound waves?

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Think it Over

16. Apply When a bat flies in darkness, why is it able to avoid objects in its path?

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