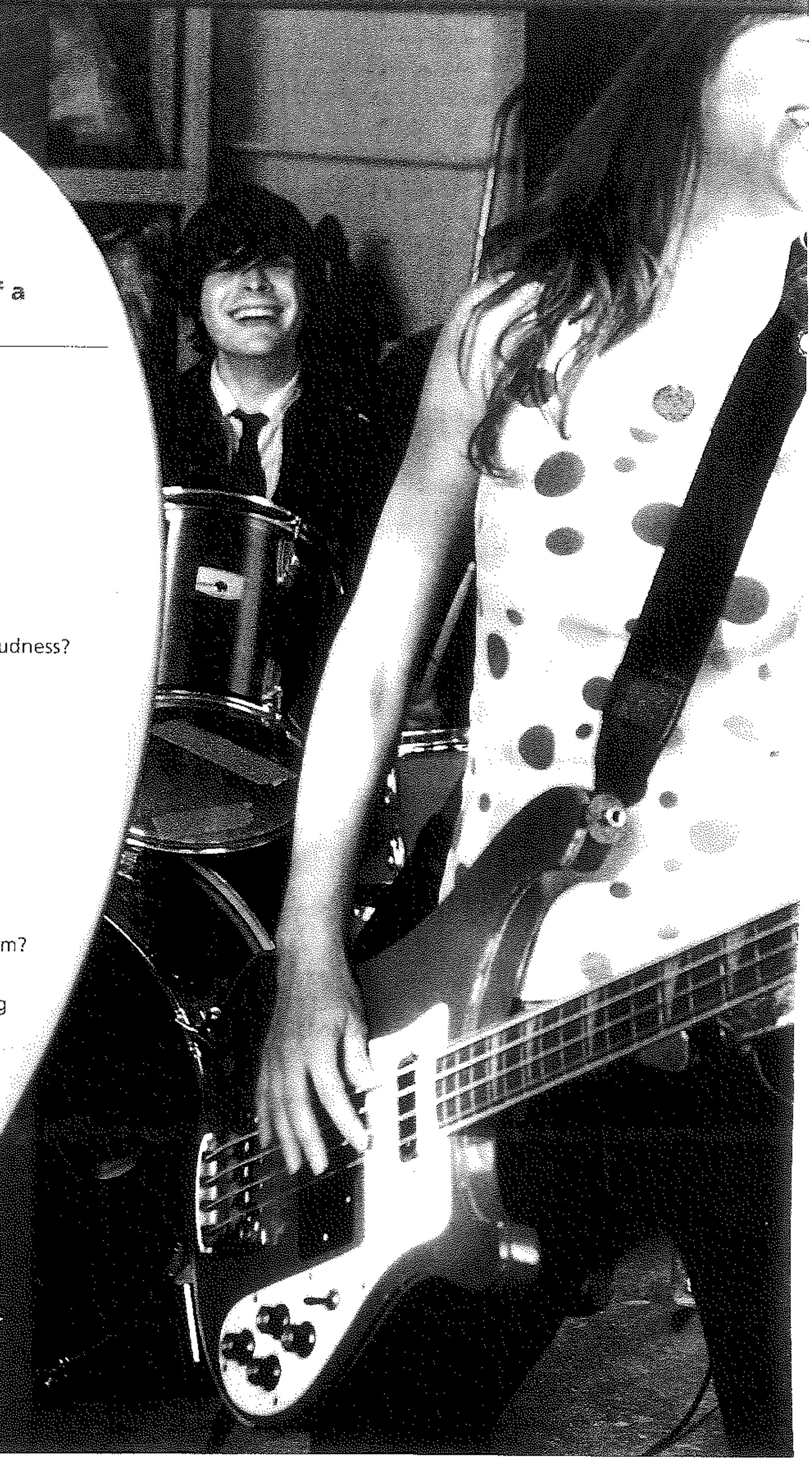
Chapter

# 16 Sound



## The BIG Idea
Energy and Waves

**What are the properties of a sound wave?**

### Chapter Preview

**1 The Nature of Sound**
- *Discover* What Is Sound?
- *Analyzing Data* Temperature and the Speed of Sound
- *At-Home Activity* Ear to the Sound

**2 Properties of Sound**
- *Discover* How Does Amplitude Affect Loudness?
- *Skills Activity* Predicting
- *Try This* Pipe Sounds
- *At-Home Activity* Hum Stopper

**3 Music**
- *Discover* How Can You Change Pitch?
- *Active Art* Musical Instruments
- *Design Your Own Lab* Changing Pitch

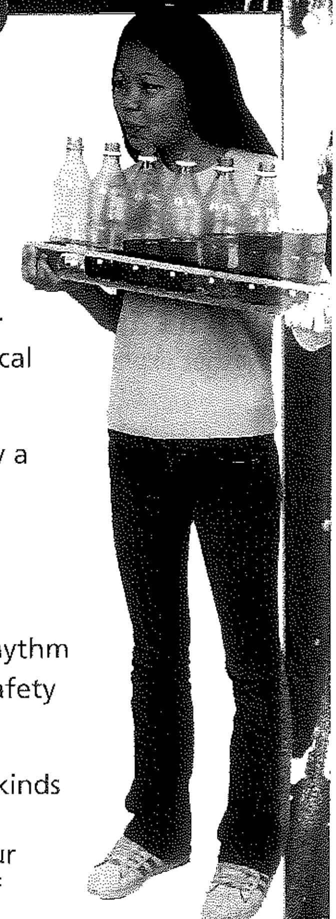
**4 How You Hear Sound**
- *Discover* Where Is the Sound Coming From?
- *Try This* Listen to This
- *Technology Lab* Design and Build Hearing Protectors
- *At-Home Activity* Sound Survey
- *Science and Society* Keeping It Quiet

**5 Using Sound**
- *Discover* How Can You Use Time to Measure Distance?
- *Skills Activity* Designing Experiments

As the band plays, a microphone picks ▶ up sound waves from the singers.

# Lab zone™ Chapter Project

## Music to Your Ears



In this chapter you will investigate the properties of sound. You will learn how sound is produced by different objects, including musical instruments. As you work through the chapter, you will gather enough knowledge to create a musical instrument of your own.

**Your Goal** To design, build, and play a simple musical instrument

Your musical instrument must
- be made of materials that are approved by your teacher
- be able to play a simple tune or rhythm
- be built and used following the safety guidelines in Appendix A

**Plan It!** Begin by discussing different kinds of instruments with your classmates. What instruments are common in your favorite type of music? Which type of instrument would you like to build? Make a list of materials you could use to build your instrument. Then, design and sketch your instrument. After your teacher approves your design, build your instrument and test it by playing a simple tune.

Section 1

# The Nature of Sound

## Reading Preview

### Key Concepts
- What is sound?
- How do sound waves interact?
- What factors affect the speed of sound?

### Key Terms
- echo • elasticity • density

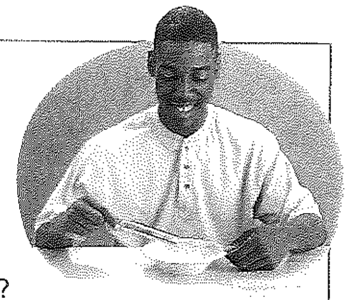
### Target Reading Skill
**Identifying Main Ideas** As you read the Interactions of Sound Waves section, write the main idea—the biggest or most important idea—in a graphic organizer like the one below. Then write three supporting details that further explain the main idea.

Main Idea

Sound waves interact . . .

Detail | Detail | Detail

## Lab zone Discover Activity



### What Is Sound?
1. Fill a bowl with water.
2. Tap a tuning fork against the sole of your shoe. Place the tip of one of the prongs in the water. What do you see?
3. Tap the tuning fork again. Predict what will happen when you hold it near your ear. What do you hear?

**Think It Over**

Observing How are your observations related to the sound you hear? What might change if you use a different tuning fork?

Here is an old riddle: If a tree falls in a forest and no one hears it, does the tree make a sound? To answer the riddle, you must decide what the word "sound" means. If sound is something that a person must hear, then the tree makes no sound. If sound can happen whether a person hears it or not, then the tree makes a sound.

## Sound Waves

To a scientist, a falling tree makes a sound whether someone hears it or not. When a tree crashes down, the energy with which it strikes the ground causes a disturbance. Particles in the ground and the air begin to vibrate, or move back and forth. The vibrations create a sound wave as the energy travels through the two mediums. **Sound is a disturbance that travels through a medium as a longitudinal wave.**

A falling tree ▶

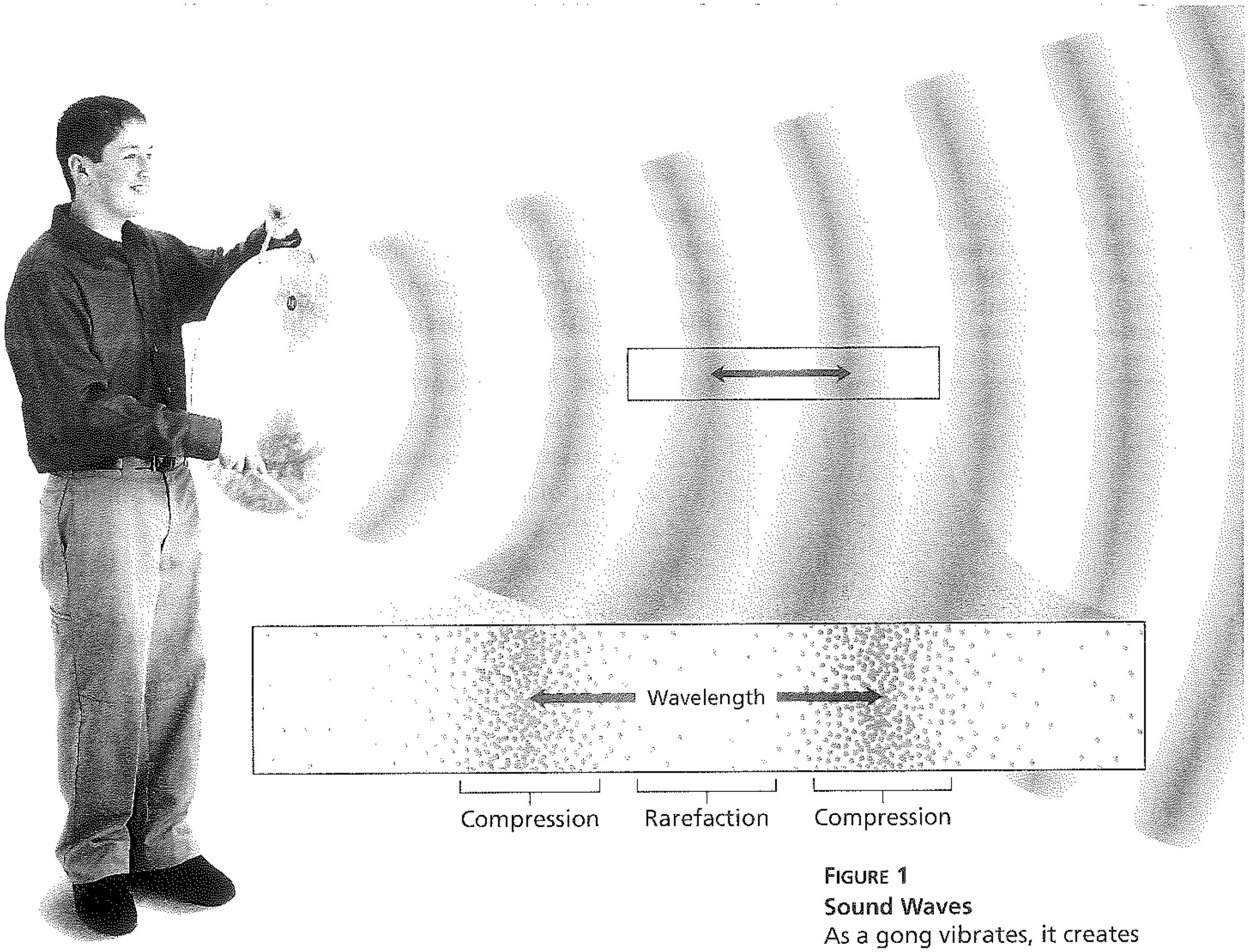



**FIGURE 1**
**Sound Waves**
As a gong vibrates, it creates sound waves that travel through the air. Observing *What do you observe about the spacing of particles in a compression?*

**Making Sound Waves** A sound wave begins with a vibration. Look at the metal gong shown in Figure 1. When the gong is struck, it vibrates rapidly. The vibrations disturb nearby air particles. Each time the gong moves to the right, it pushes air particles together, creating a compression. When the gong moves to the left, the air particles bounce back and spread out, creating a rarefaction. These compressions and rarefactions travel through the air as longitudinal waves.

**How Sound Travels** Like other mechanical waves, sound waves carry energy through a medium without moving the particles of the medium along. Each particle of the medium vibrates as the disturbance passes. When the disturbance reaches your ears, you hear the sound.

A common medium for sound is air. But sound can travel through solids and liquids, too. For example, when you knock on a solid wood door, the particles in the wood vibrate. The vibrations make sound waves that travel through the door. When the waves reach the other side of the door, they make sound waves in the air on the far side.

Reading Checkpoint **What are three types of mediums that sound can travel through?**

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For: Links on sound
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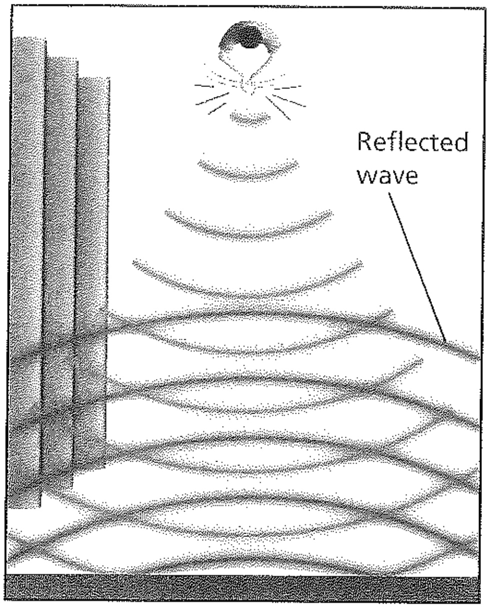
**FIGURE 2**
**Reflection of Sound**
Clapping your hands in a gym produces an echo when sound waves reflect off the wall.
Drawing Conclusions *What kind of material is the wall made of?*




## Interactions of Sound Waves

Sound waves interact with the surfaces they contact and with each other. **Sound waves reflect off objects, diffract through narrow openings and around barriers, and interfere with each other.**

**Reflection** Sound waves may reflect when they hit a surface. A reflected sound wave is called an **echo.** In general, the harder and smoother the surface, the stronger the reflection. Look at Figure 2. When you clap your hands in a gym, you hear an echo because the hard surfaces—wood, brick, and metal—reflect sound directly back at you. But you don't always hear an echo in a room. In many rooms, there are soft materials that absorb most of the sound that strikes them.

**Diffraction** Have you ever wondered why you can hear your friends talking in a classroom before you walk through the doorway? You hear them because sound waves do not always travel in a straight line. Figure 3 shows how sound waves can diffract through openings such as doorways.

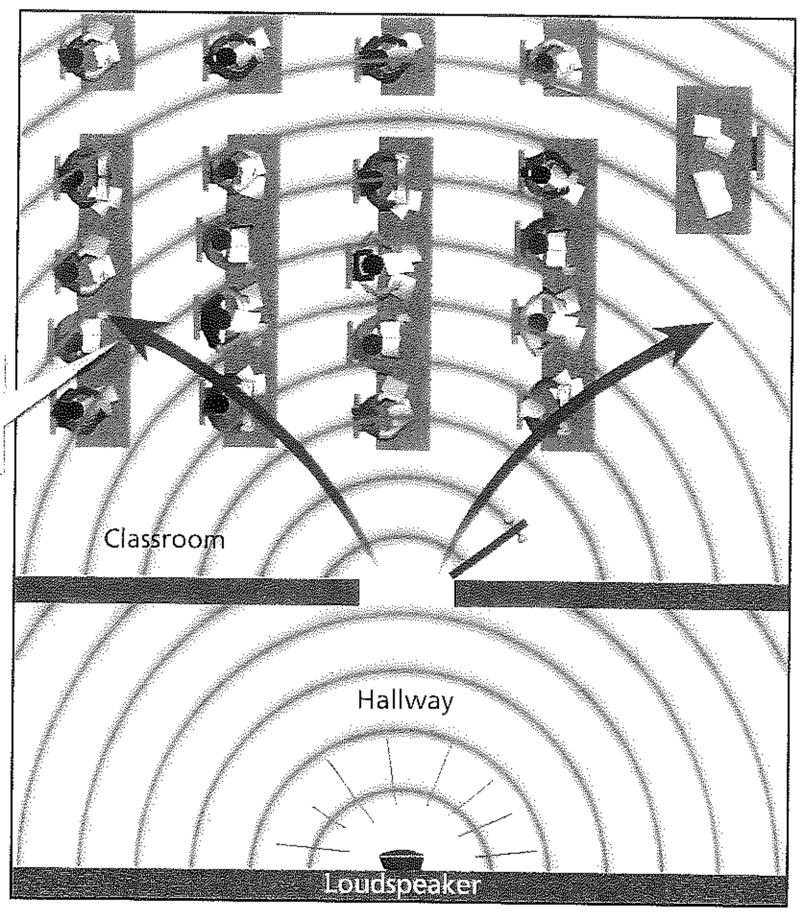



**FIGURE 3**
**Diffraction of Sound**
Sound waves can spread out after passing through a doorway, and can bend around a corner.

Sound waves can also diffract, or bend, around corners. This is why you can hear someone who is talking in the hallway before you come around the corner. The person's sound waves bend around the corner. Then they spread out so you can hear them even though you cannot see who is talking. Remember this the next time you want to tell a secret!

**Interference** Sound waves may meet and interact with each other. You may recall that this interaction is called interference. The interference that occurs when sound waves meet can be constructive or destructive. In Section 3, you will learn how interference affects the sound of musical instruments.

Reading Checkpoint **What are two ways that sound waves diffract?**

## The Speed of Sound

Have you ever wondered why the different sounds from musicians and singers at a concert all reach your ears at the same time? It happens because the sounds travel through air at the same speed. At room temperature, about 20°C, sound travels through air at about 343 m/s. This speed is much faster than most jet planes travel through the air!

The speed of sound is not always 343 m/s. Sound waves travel at different speeds in different mediums. Figure 4 shows the speed of sound in different mediums. **The speed of sound depends on the elasticity, density, and temperature of the medium the sound travels through.**

**Speed of Sound**

| Medium | Speed (m/s) |
|---|---|
| Gases | |
| Air (0°C) | 331 |
| Air (20°C) | 343 |
| Liquids (30°C) | |
| Fresh water | 1,509 |
| Salt water | 1,546 |
| Solids (25°C) | |
| Lead | 1,210 |
| Cast iron | 4,480 |
| Aluminum | 5,000 |
| Glass | 5,170 |

FIGURE 4
The speed of sound depends on the medium it travels through.

## Math Analyzing Data

### Temperature and the Speed of Sound

The speed of sound in dry air changes as the temperature changes. The graph shows data for the speed of sound in air at temperatures from –20°C to 30°C.

1. Reading Graphs What is the speed of sound in air at –10°C?
2. Interpreting Data Does the speed of sound increase or decrease as temperature increases?
3. Predicting What might be the speed of sound at 30°C?

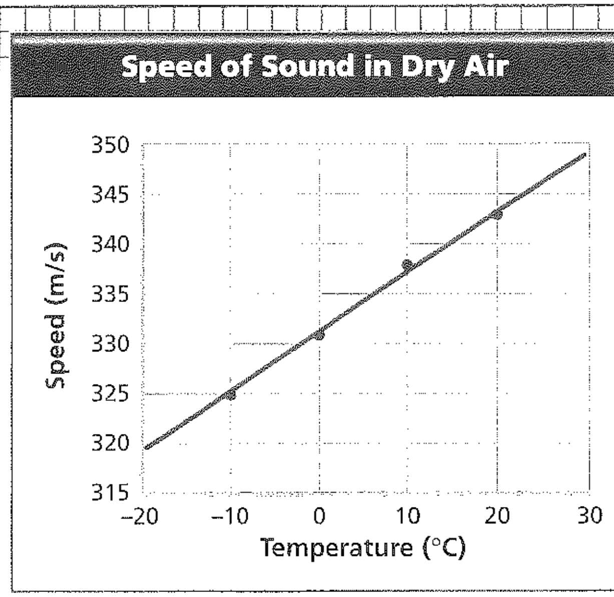
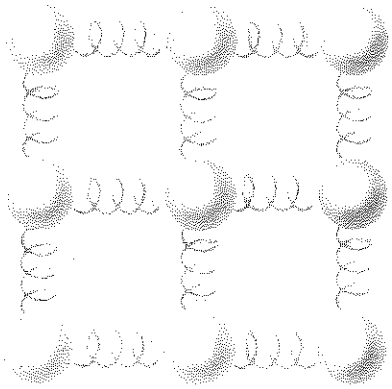


FIGURE 5
**Modeling Elasticity**
You can model elasticity by representing the particles in a medium as being held together by springs.



**Elasticity** If you stretch a rubber band and then let it go, it returns to its original shape. However, when you stretch modeling clay and then let it go, it stays stretched. Rubber bands are more elastic than modeling clay. **Elasticity** is the ability of a material to bounce back after being disturbed.

The elasticity of a medium depends on how well the medium's particles bounce back after being disturbed. To understand this idea, look at Figure 5. In this model, the particles of a medium are linked by springs. If one particle is disturbed, it is pulled back to its original position. In an elastic medium, such as a rubber band, the particles bounce back quickly. But in a less elastic medium, the particles bounce back slowly.

The more elastic a medium, the faster sound travels in it. Sounds can travel well in solids, which are usually more elastic than liquids or gases. The particles of a solid do not move very far, so they bounce back and forth quickly as the compressions and rarefactions of the sound waves pass by. Most liquids are not very elastic. Sound does not travel as well in liquids as it does in solids. Gases generally are not very elastic. Sound travels slowly in gases.

**Density** The speed of sound also depends on the density of a medium. **Density** is how much matter, or mass, there is in a given amount of space, or volume. The denser the medium, the more mass it has in a given volume. Figure 6 shows two cubes that have the same volume. The brass cube is denser because it has more mass in a given volume.

In materials in the same state of matter—solid, liquid, or gas—sound travels more slowly in denser mediums. The particles of a dense material do not move as quickly as those of a less dense material. Sound travels more slowly in dense metals, such as lead or silver, than in iron or steel.

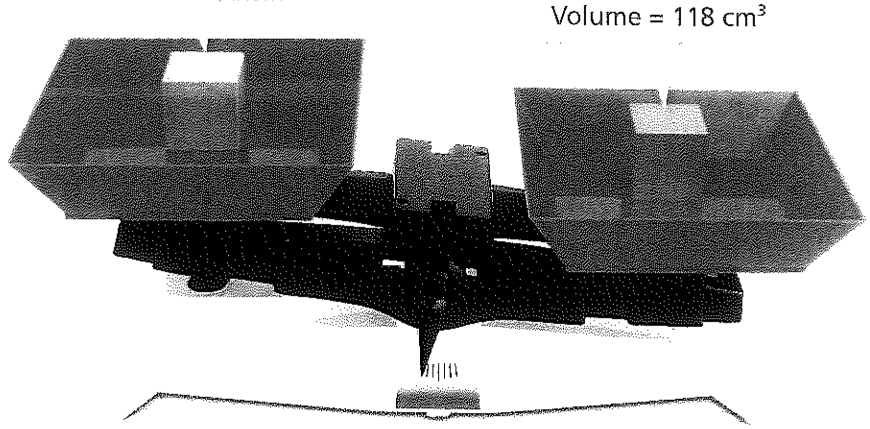



FIGURE 6
**Comparing Density**
The volumes of these cubes are the same, but the brass cube has more mass.
Interpreting Photographs *Which cube has a greater density: brass or aluminum?*

**Temperature** In a given medium, sound travels more slowly at lower temperatures than at higher temperatures. Why? At a low temperature, the particles of a medium move more slowly than at a high temperature. So, they are more difficult to move, and return to their original positions more slowly. For example, at 20°C, the speed of sound in air is about 343 m/s. But at 0°C, the speed of sound is about 330 m/s.

At higher altitudes, the air is colder than at lower altitudes, so sound travels more slowly at higher altitudes. On October 14, 1947, Captain Charles E. "Chuck" Yeager of the United States Air Force used this knowledge to fly faster than the speed of sound.

To fly faster than the speed of sound, Captain Yeager flew his plane to an altitude of more than 12,000 meters. Here, the air temperature was –59°C. The speed of sound at this temperature is only about 293 m/s. At 12,000 meters, Captain Yeager accelerated his plane to a record-breaking 312 m/s. By doing this, he became the first person to "break the sound barrier."


FIGURE 7
**Breaking the Sound Barrier**
On October 14, 1947, Captain Chuck Yeager became the first person to fly a plane faster than the speed of sound.

Reading Checkpoint **How does temperature affect the speed of sound?**

## Section 1 Assessment

**Target Reading Skill** Identifying Main Ideas Use your graphic organizer to help you answer Question 2 below.

### Reviewing Key Concepts

1. a. Reviewing What is sound?
   b. Explaining How is a sound wave produced?
   c. Sequencing Explain how a ringing telephone can be heard through a closed door.
2. a. Listing What are three ways that sound waves can interact?
   b. Applying Concepts Explain why you can hear a teacher through the closed door of a classroom.
   c. Inferring At a scenic overlook, you can hear an echo only if you shout in one particular direction. Explain why.
3. a. Identifying What property describes how a material bounces back after being disturbed?
   b. Summarizing What three properties of a medium affect the speed of sound?
   c. Developing Hypotheses Steel is denser than plastic, yet sound travels faster in steel than in plastic. Develop a hypothesis to explain why.

**Lab zone At-Home Activity**

Ear to the Sound Find a long metal fence or water pipe. **CAUTION:** *Beware of sharp edges and rust.* Put one ear to one end of the pipe while a family member taps on the other end. In which ear do you hear the sound first? Explain your answer to your family members. What accounts for the difference?

Section 2

# Properties of Sound

## Reading Preview

### Key Concepts

- What factors affect the loudness of a sound?
- What does the pitch of a sound depend on?
- What causes the Doppler effect?

### Key Terms

- loudness
- intensity
- decibel (dB)
- pitch
- ultrasound
- infrasound
- larynx
- Doppler effect

### Target Reading Skill

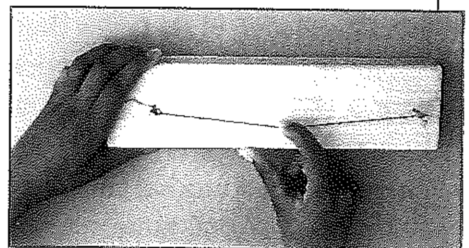
**Outlining** An outline shows the relationship between main ideas and supporting ideas. As you read, make an outline about the properties of sound. Use the red headings for the main ideas and the blue headings for the supporting ideas.

| Properties of Sound |
|---|
| I. Loudness |
| A. Energy of a sound source |
| B. |
| C. |
| II. Pitch |
| A. |

## Lab zone Discover Activity

### How Does Amplitude Affect Loudness?

1. Your teacher will give you a wooden board with two nails in it. Attach a guitar string to the nails by wrapping each end tightly around a nail and tying a knot.
2. Hold the string near the middle. Pull it about 1 cm to one side. This distance is the amplitude of vibration. Let it go. How far does the string move to the other side? Describe the sound you hear.



3. Repeat Step 2 four more times. Each time, pull the string back a greater distance. Describe how the sound changes each time.

**Think It Over**

Forming Operational Definitions How would you define the amplitude of the vibration? What effect did changing the amplitude have on the sound?

Suppose that you and a friend are talking on a sidewalk and a noisy truck pulls up next to you and stops, leaving its motor running. What would you do? You might talk louder, almost shout, so your friend can hear you. You might lean closer and speak into your friend's ear so you don't have to raise your voice. Or you might walk away from the noisy truck so it's not as loud.

## Loudness

Loudness is an important property of sound. **Loudness** describes your perception of the energy of a sound. In other words, loudness describes what you hear. You probably already know a lot about loudness. For example, you know that your voice is much louder when you shout than when you speak softly. The closer you are to a sound, the louder it is. Also, a whisper in your ear can be just as loud as a shout from a block away. **The loudness of a sound depends on two factors: the amount of energy it takes to make the sound and the distance from the source of the sound.**

**Energy of a Sound Source** In general, the greater the energy used to make a sound, the louder the sound. If you did the Discover activity, you may have noticed this. The more energy you used to pull the guitar string back, the louder the sound when you let the string go. This happened because the more energy you used to pull the string, the greater the amplitude of the string's vibration. A string vibrating with a large amplitude produces a sound wave with a large amplitude. Recall that the greater the amplitude of a wave, the more energy the wave has. So, the larger the amplitude of the sound wave, the more energy it has and the louder it sounds.

**Distance From a Sound Source** If your friend is speaking in a normal voice and you lean in closer, your friend's voice sounds louder. Loudness increases the closer you are to a sound source. But why?

Imagine ripples spreading out in circles after you toss a pebble into a pond. In a similar way, a sound wave spreads out from its source. Close to the sound source, the sound wave covers a small area, as you can see in Figure 8. As the wave travels away from its source, it covers more area. The total energy of the wave, however, stays the same whether it is close to the source or far from it. Therefore, the closer the sound wave is to its source, the more energy it has in a given area. The amount of energy a sound wave carries per second through a unit area is its **intensity.** A sound wave of greater intensity sounds louder. As you move away from a sound source, loudness decreases because the intensity decreases.

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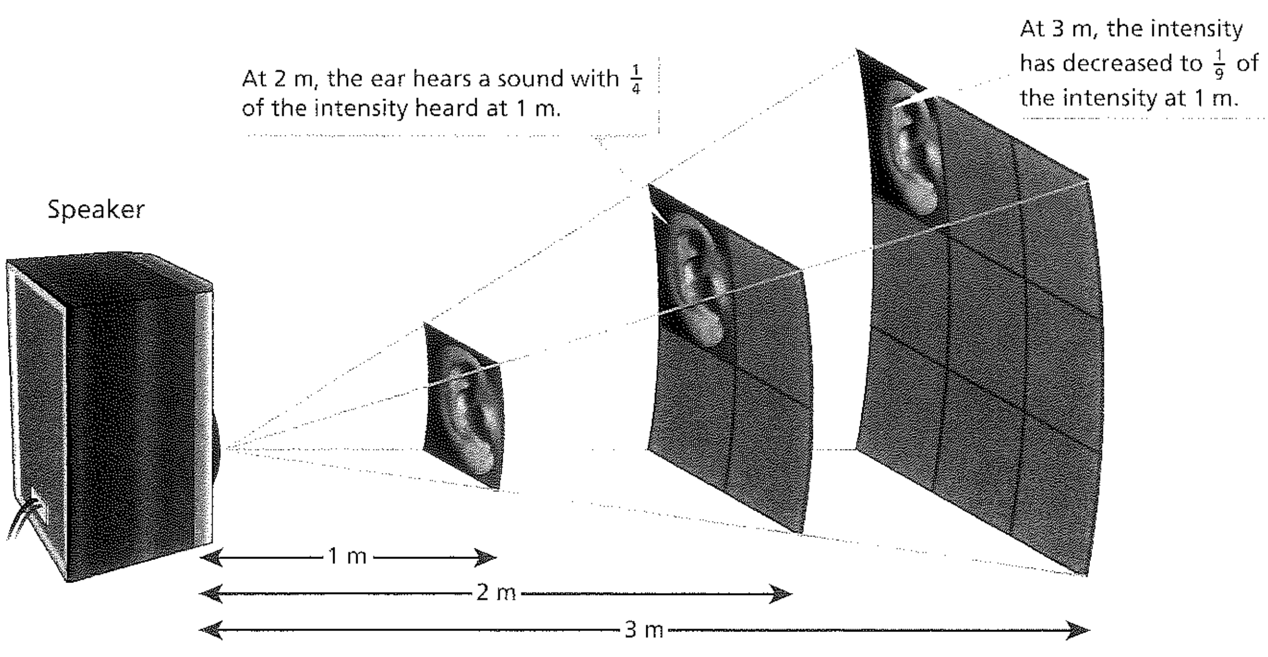
FIGURE 8
## Intensity and Distance
Because sound waves spread out, intensity decreases with distance from the source.
**Interpreting Diagrams** *How does the intensity at 3 meters compare to the intensity at 2 meters?*



| Measuring Loudness | |
|---|---|
| Sound | Loudness (dB) |
| Rustling leaves | 10 |
| Whisper | 15–20 |
| Very soft music | 20–30 |
| Normal conversation | 40–50 |
| Heavy street traffic | 60–70 |
| Loud music | 90–100 |
| Rock concert | 110–120 |
| Jackhammer | 120 |
| Jet plane at takeoff | 120–160 |

**FIGURE 9**
Some sounds are so soft that you can barely hear them. Others are so loud that they can damage your ears. Interpreting Data *Which sounds louder, a rock concert or a jet plane at takeoff?*

**Measuring Loudness** The loudness of different sounds is compared using a unit called the **decibel (dB).** Figure 9 shows the loudness of some familiar sounds. The loudness of a sound you can barely hear is about 0 dB. Each 10-dB increase in loudness represents a tenfold increase in the intensity of the sound. For example, soft music at 30 dB sounds ten times louder than a 20-dB whisper. The 30-dB music is 100 times louder than the 10-dB sound of rustling leaves. Sounds louder than 100 dB can cause damage to your ears, especially if you listen to those sounds for long periods of time.

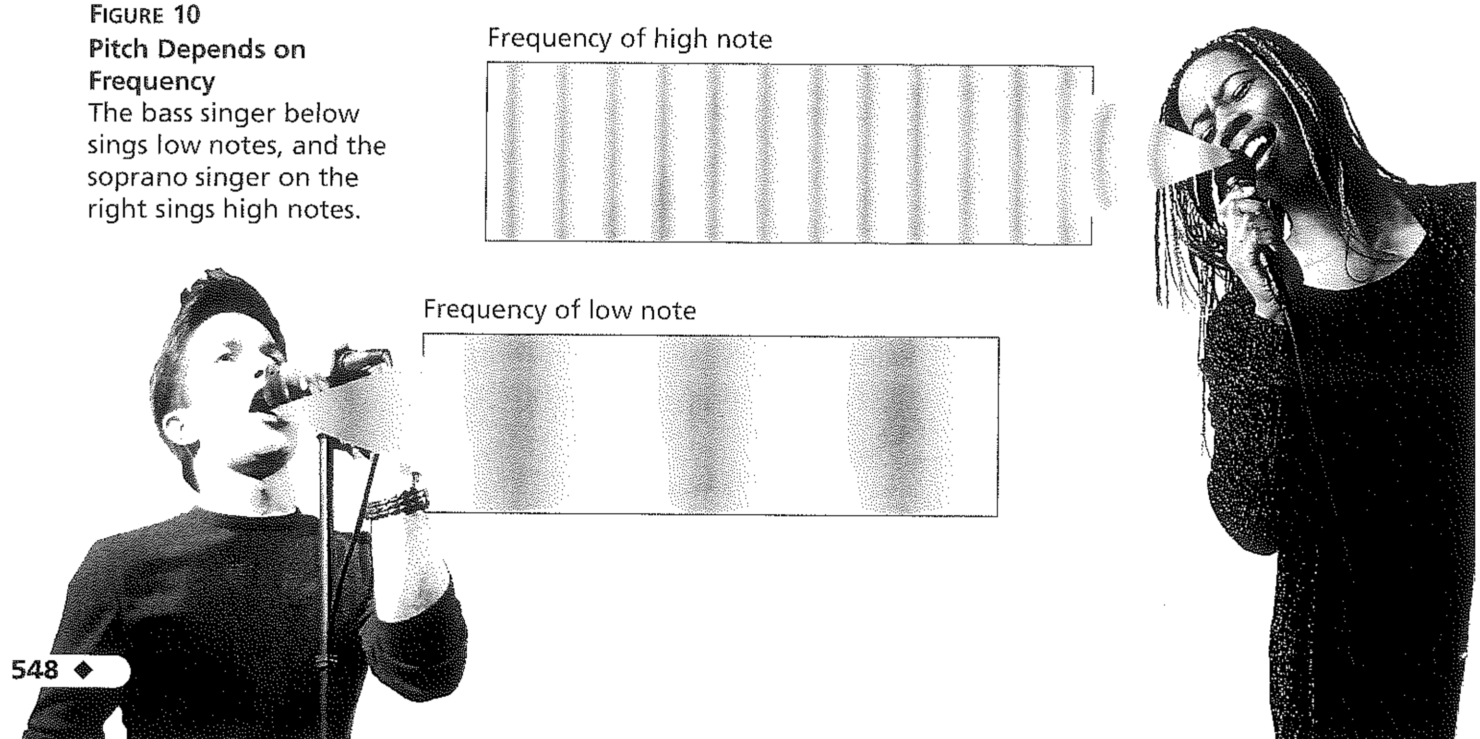
Reading Checkpoint **What is a decibel?**

## Pitch

Pitch is another property of sound you may already know a lot about. Have you ever described someone's voice as "high-pitched" or "low-pitched?" The **pitch** of a sound is a description of how high or low the sound seems to a person. **The pitch of a sound that you hear depends on the frequency of the sound wave.**

**Pitch and Frequency** Sound waves with a high frequency have a high pitch. Sound waves with a low frequency have a low pitch. Frequency is measured in hertz (Hz). For example, a frequency of 50 Hz means 50 vibrations per second. Look at Figure 10. A bass singer can produce frequencies lower than 80 Hz. A trained soprano voice can produce frequencies higher than 1,000 Hz.

**FIGURE 10**
**Pitch Depends on Frequency**
The bass singer below sings low notes, and the soprano singer on the right sings high notes.



Most people can hear sounds with frequencies between 20 Hz and 20,000 Hz. Sound waves with frequencies above the normal human range of hearing are called **ultrasound.** The prefix *ultra-* means "beyond." Sounds with frequencies below the human range of hearing are called **infrasound.** The prefix *infra-* means "below." People cannot hear either ultrasound waves or infrasound waves.

**Changing Pitch** Pitch is an important property of music because music usually uses specific pitches called notes. To sing or play a musical instrument, you must change pitch often.

When you sing, you change pitch using your vocal cords. Your vocal cords are located in your voice box, or **larynx,** as shown in Figure 11. When you speak or sing, air from your lungs is forced up the trachea, or windpipe. Air then rushes past your vocal cords, making them vibrate. This produces sound waves. Your vocal cords are able to vibrate more than 1,000 times per second!

To sing different notes, you use muscles in your throat to stretch and relax your vocal cords. When your vocal cords stretch, they vibrate more quickly as the air rushes by them. This creates higher-frequency sound waves that have higher pitches. When your vocal cords relax, lower-frequency sound waves with lower pitches are produced.

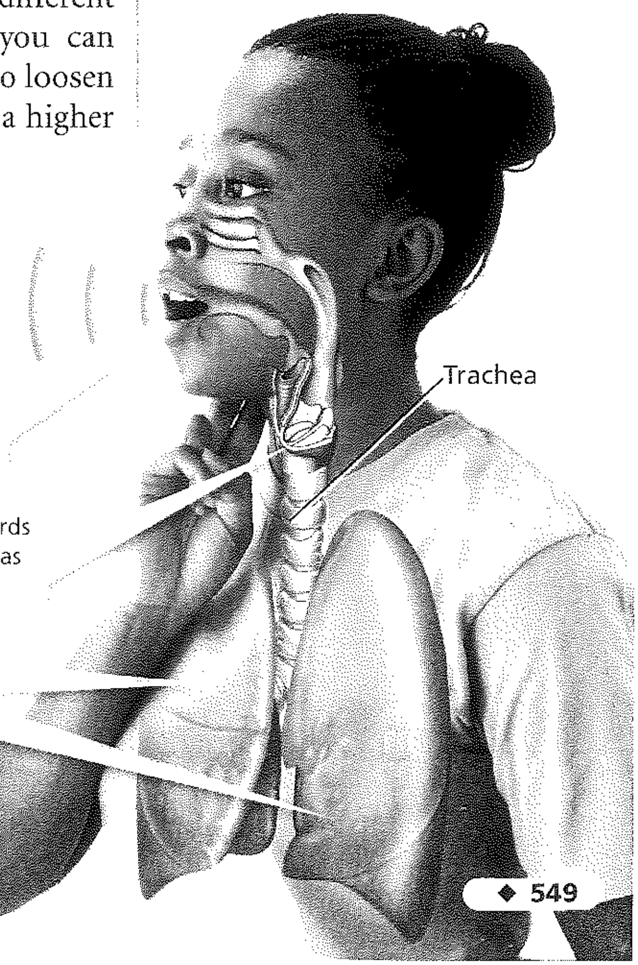
With musical instruments, you change pitch in different ways depending on the instrument. For example, you can change the pitch of a guitar string by turning a knob to loosen or tighten the string. A tighter guitar string produces a higher frequency, which you hear as a note with higher pitch.

Reading Checkpoint **Where are your vocal cords located?**

**Lab zone Skills Activity**

### Predicting

1. Flatten one end of a drinking straw and cut the end to form a point.
2. Blow through the straw. Describe what you hear.
3. Predict what changes you would hear if you shortened the straw by cutting off some of the straight end. Test your prediction by making two new straws of different lengths.




**Sound** Sound waves produced by the vibrating vocal cords come out through the mouth.

**Vocal Cords** The vocal cords inside the larynx vibrate as air rushes past them.

**Lungs** Air from the lungs rushes up the trachea.

**FIGURE 11**
**The Human Voice**
When a person speaks or sings, the vocal cords vibrate. The vibrations produce sound waves in the air.

## Lab zone Try This Activity

### Pipe Sounds

1. Find an open space without objects or people nearby.
2. Hold the end of a flexible plastic tube firmly (a vacuum cleaner hose works well). Swing the tube in a circle over your head to produce a sound.
3. Keeping the speed steady, listen to the sound. Have a partner stand at a safe distance and listen at the same time.

**Observing** Describe the sound you heard. How is it different from the sound your partner heard? Explain the difference.

# The Doppler Effect

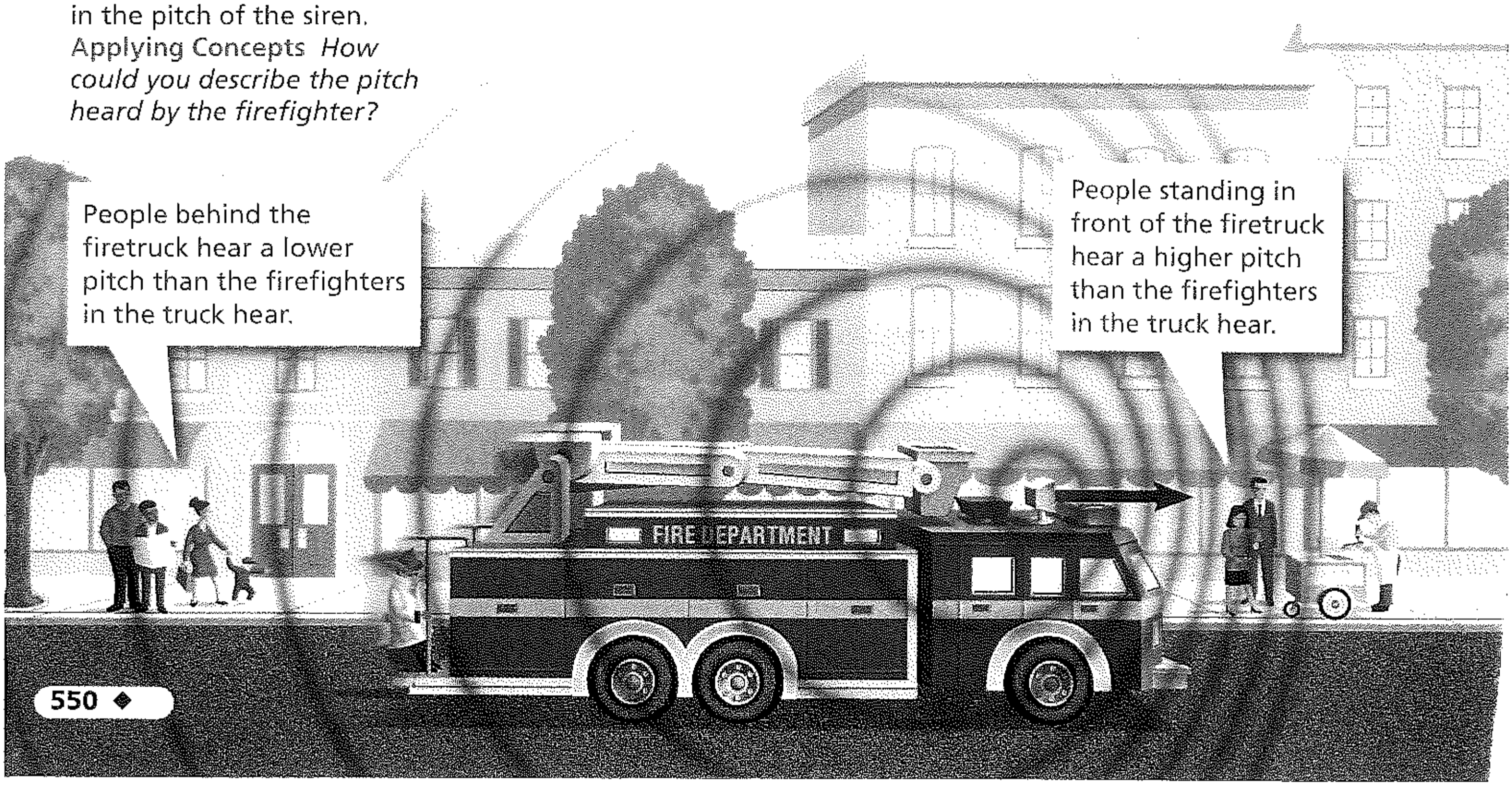
If you listen carefully to the siren of a firetruck on its way to a fire, you will notice something surprising. As the truck goes by you, the pitch of the siren drops. But the pitch of the siren stays constant for the firefighters in the truck. The siren's pitch changes only if it is moving toward or away from a listener.

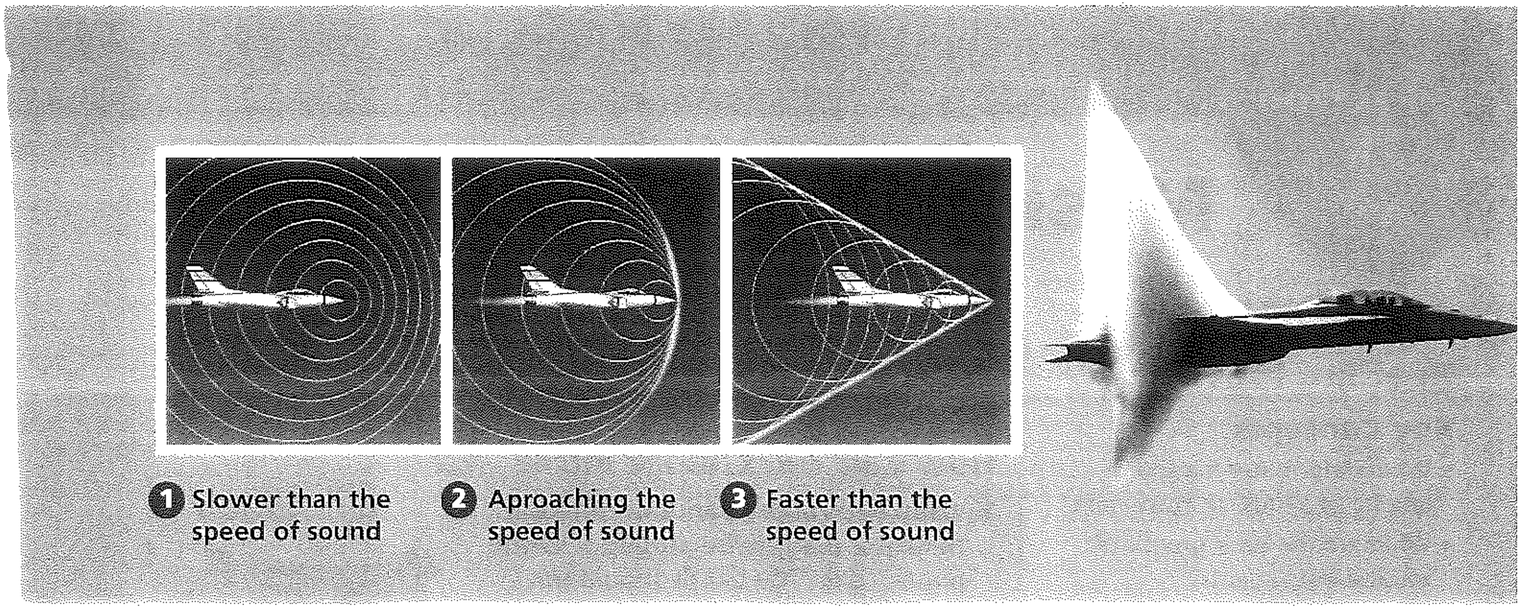
The change in frequency of a wave as its source moves in relation to an observer is called the **Doppler effect.** If the waves are sound waves, the change in frequency is heard as a change in pitch. The Doppler effect is named after the Austrian scientist Christian Doppler (1803–1853).

**What Causes the Doppler Effect?** Figure 12 shows how sound waves from a moving source behave. When the source moves toward a listener, the frequency of the waves is higher than it would be if the source were stationary. **When a sound source moves, the frequency of the waves changes because the motion of the source adds to the motion of the waves.**

To understand why the frequency changes, imagine that you are standing still and throwing tennis balls at a wall in front of you. If you throw one ball each second the balls hit the wall at a rate of one per second. Now suppose you walk toward the wall while still throwing one ball per second. Because each ball has a shorter distance to travel than the one before, each takes less time to get there. The balls hit the wall more often than one per second, so the frequency is higher. On the other hand, if you throw balls at the wall as you back away, each ball has farther to travel and the frequency is lower.

FIGURE 12
**The Doppler Effect**
As the firetruck speeds by, the observers hear a change in the pitch of the siren.
**Applying Concepts** *How could you describe the pitch heard by the firefighter?*






**What Causes Shock Waves?** At high speed, the Doppler effect can be spectacular. Look at Figure 13. When the plane travels almost as fast as the speed of sound, the sound waves pile up in front of the plane. This pile-up is the "sound barrier." As the plane flies faster than the speed of sound, it moves through the barrier. A shock wave forms as the sound waves overlap. The shock wave releases a huge amount of energy. People nearby hear a loud noise called a sonic boom when the shock wave passes by them.

FIGURE 13
**Breaking the Sound Barrier**
When a plane goes faster than the speed of sound, a shock wave is produced. The photo on the right shows how sudden changes in pressure at this speed can cause a small cloud to form.

Reading Checkpoint **What is a shock wave?**

## Section 2 Assessment

**Target Reading Skill** Outlining Use the information in your outline about the properties of sound to help you answer the questions below.

### Reviewing Key Concepts

1. a. Identifying What two factors affect the loudness of a sound?
   b. Applying Concepts Why does moving away from a radio affect the loudness you hear?
   c. Calculating A band plays music at 60 dB and then changes to a rock song at 80 dB. How many times louder is the rock song?
2. a. Reviewing What determines the pitch of a sound?
   b. Comparing and Contrasting How are high-pitch sounds different from low-pitch sounds?
   c. Explaining How do your vocal cords produce different pitches?
3. a. Summarizing What is the Doppler effect?
   b. Relating Cause and Effect What causes the Doppler effect?
   c. Predicting Would you hear a change in pitch if you are on a moving train and the train's whistle blows? Explain.

### Lab zone At-Home Activity

Hum Stopper When listening to a cat's heart, a veterinarian will cover the cat's nostrils to keep the cat from purring. At home, ask family members to hum with their lips closed. Then ask them to cover both of their nostrils while humming. Use Figure 11 to explain what happened.

Section 3

# Music

## Reading Preview

### Key Concepts

- What determines the sound quality of a musical instrument?
- What are the basic groups of musical instruments?
- How is acoustics used in concert hall design?

### Key Terms

- music
- fundamental tone
- overtone
- acoustics
- reverberation

### Target Reading Skill

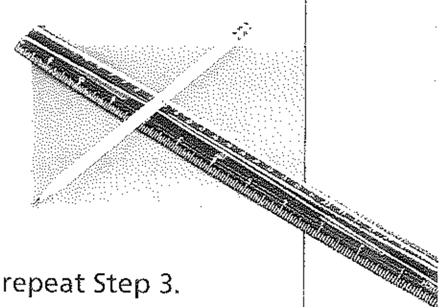
**Previewing Visuals** When you preview, you look ahead at the material to be read. Preview Figure 15. Then write two questions that you have about the diagrams in a graphic organizer like the one below. As you read, answer your questions.

**Musical Instruments**

| | |
|---|---|
| Q. | How is pitch changed in each type of instrument? |
| A. | |
| Q. | |

## Lab zone Discover Activity

### How Can You Change Pitch?



1. Wrap two rubber bands of different thickness lengthwise around a 30-cm plastic ruler. The bands should not touch each other.
2. Place a pencil under the bands at the 10-cm mark.
3. Pluck each band. How are the sounds different?
4. Move the pencil to the 15-cm mark and repeat Step 3.

**Think It Over**

Drawing Conclusions Why are the sounds you made in Step 4 different from the sounds in Step 3?

You are late. When you arrive at your orchestra rehearsal, your friends are already tuning up. With all the instruments playing different notes, it sounds like noise! You quickly pull out your instrument and take your seat. Then the music starts, and everything changes. What makes noise and music different? The answer is in the way sound waves combine.

Orchestra rehearsal ▶

## Sound Quality

Most people agree on what is or is not music. **Music** is a set of notes that combine in patterns that are pleasing. Noise, on the other hand, has no pleasing patterns. When you describe a sound as pleasant or unpleasant, you are describing sound quality. The sound quality of music depends on the instruments making the music. **The sound quality of musical instruments results from blending a fundamental tone with its overtones. Resonance also plays a role in the sound quality.**

**Fundamental Tones and Overtones** You may recall that standing waves occur when waves with just the right frequency interfere as they reflect back and forth. Standing waves occur in musical instruments when they are played. In a guitar, for example, standing waves occur in a vibrating string. In a trumpet, standing waves occur in a column of vibrating air.

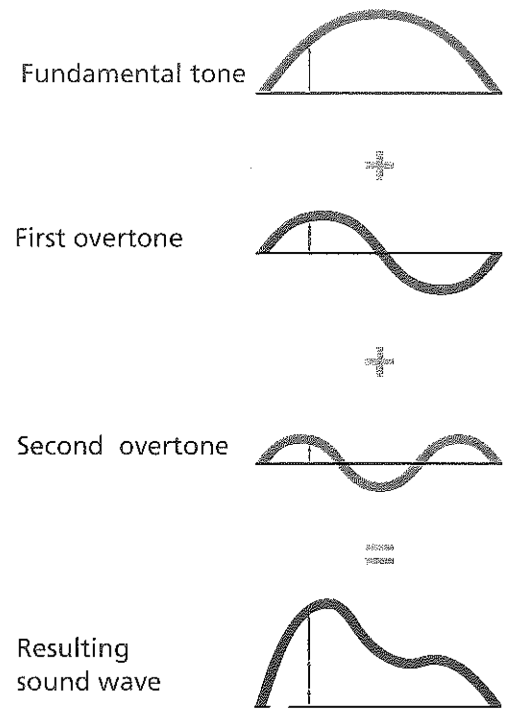
A standing wave can occur only at specific frequencies that are called natural frequencies. Every object has its own natural frequencies. The lowest natural frequency of an object is called the **fundamental tone.** The object's higher natural frequencies are called **overtones.** Overtones have frequencies that are two, three, or more times the frequency of the fundamental tone. Look at Figure 14 to see how the natural frequencies of a guitar string add together to produce a unique sound.

The fundamental tone determines what note you hear. For example, when a guitar and a trumpet play middle C, they both produce waves with a frequency of 262 Hz. But each instrument produces different overtones, so the blending of the fundamental tones and overtones produces different sound qualities.

**Resonance** Resonance affects the sound quality of a musical instrument by increasing the loudness of certain overtones. Recall that resonance occurs when one object causes a nearby object to vibrate at a natural frequency. A musical instrument is designed so that a part of it will resonate with the overtones it produces. In a guitar, for example, the vibrating strings cause the guitar's hollow body to resonate. The shape and material of the guitar determine which overtones are loudest.

**Reading Checkpoint** **What are overtones?**

**FIGURE 14**
**Sound Quality**
A guitar string can resonate at several frequencies that combine to produce a unique sound quality. Interpreting Diagrams *What determines the resulting wave?*




The resulting sound wave is the sum of the fundamental tone and the overtones.

Go Online
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**For:** Musical Instruments activity
**Visit:** PHSchool.com
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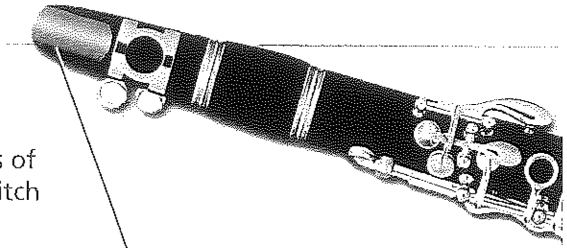
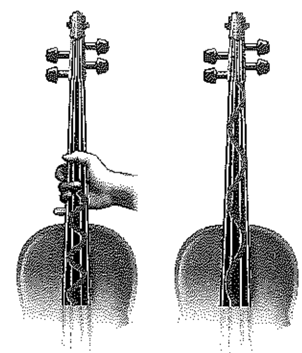
FIGURE 15
**Musical Instruments**
A musician controls the vibrations of a musical instrument to change pitch and loudness. Classifying *How would you classify a tuba, a tambourine, and a banjo?*



**Wind Instrument: Clarinet**
**Loudness** is controlled by how hard the musician blows.

**Stringed Instrument: Violin**
**Loudness** is increased by the musician pressing the bow harder against the strings.

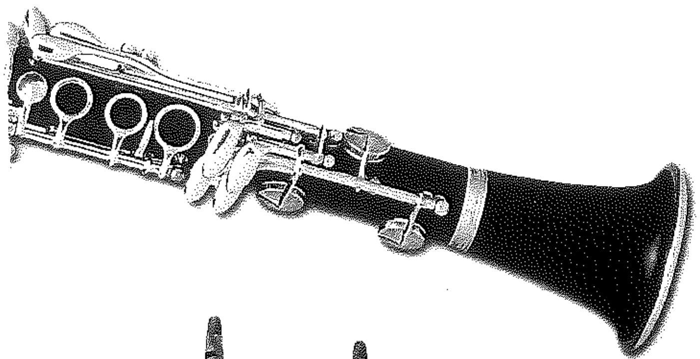
**Pitch** depends on the length and thickness of the strings, the material they are made of, and how tightly the strings are stretched. A short string produces a high pitch, and a longer string produces a lower pitch.

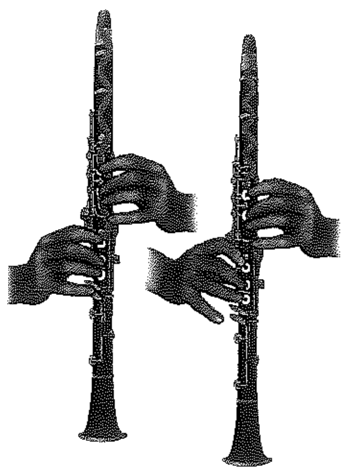


## Groups of Musical Instruments

How does a musician control the sounds produced by a musical instrument? To control pitch, the musician changes the fundamental tones produced by the instrument. To control loudness, the musician changes the energy of the vibrations. The way that pitch and loudness are controlled varies among the groups of instruments, as shown in Figure 15. **There are three basic groups of musical instruments: stringed instruments, wind instruments, and percussion instruments.**

**Stringed Instruments** The guitar and the violin are stringed instruments. The strings of these instruments produce sound by vibrating when they are strummed or rubbed with a bow. Their loudness is increased by resonance when the instrument's hollow body vibrates as the strings vibrate. The pitch of each string depends on four factors: its length and thickness, the material it is made from, and how tightly it is stretched. An instrument with long strings, such as a cello, produces lower notes than an instrument with short strings, such as a violin.



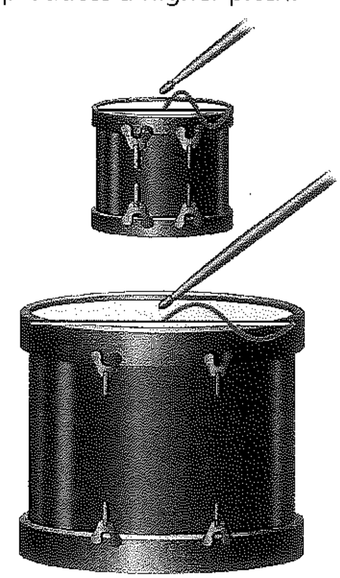


**Pitch** depends on the length of the air column, which can be changed by covering different holes. A short air column produces a high pitch, and a longer column produces a lower pitch.

**Percussion Instrument: Drum**

**Loudness** is controlled by how hard the musician strikes the drum.

**Pitch** depends on the size of the drum head, the material, and the tension in the drum head. A smaller drum produces a higher pitch.



**Wind Instruments** Wind instruments include brass instruments, such as trumpets, and woodwind instruments, such as clarinets. Brass instruments produce sound when a musician's lips vibrate against the mouthpiece, causing the air column in the instrument to vibrate. Woodwinds usually contain a thin, flexible strip of material called a reed. A woodwind produces sound when the reed vibrates, causing the instrument's air column to vibrate. In wind instruments, the length of the vibrating air column determines the note that you hear. A tuba, which has a long air column, produces lower notes than a flute, which has a short air column.

**Percussion Instruments** Percussion instruments include drums, bells, cymbals, and xylophones. These instruments vibrate when struck. The pitch of a drum depends on its size, the material it is made of, and the tension in the drumhead. A large drum produces lower pitches than a small drum.

**Reading Checkpoint** **What are four examples of percussion instruments?**

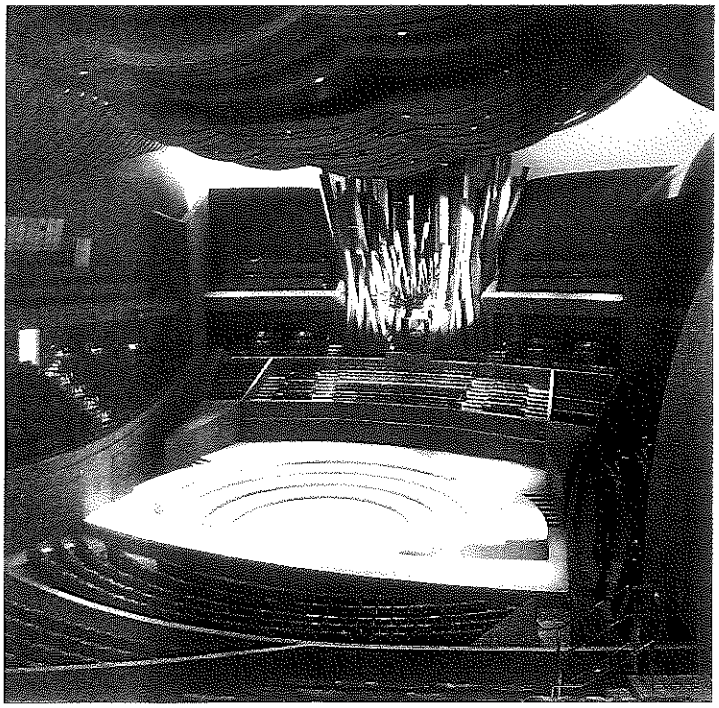


FIGURE 16
**Concert Hall Acoustics**
Surfaces in concert halls are designed with a variety of materials and shapes.
*Inferring What might be the purpose of the curved panels near the ceiling?*

## Acoustics

Your surroundings affect the musical sounds that you hear at a concert. To understand this, compare the sound of your voice in different places—in class, outdoors, or in a gym. The differences you hear are due to the different ways that sounds interact. **Acoustics** is the study of how sounds interact with each other and the environment.

Sound waves can interfere with each other. Constructive interference may distort sound, while destructive interference can produce "dead spots" where loudness is reduced. Sound waves interact with the environment, also. For example, if you clap your hands in a gym, you hear echoes after you clap because sound waves reflect back and forth off the hard surfaces. This is **reverberation,** in which the echoes of a sound are heard after the sound source stops producing sound waves. The sound from a handclap can take more than a second to die out in a gym.

**Acoustics is used in the design of concert halls to control reverberation and interference.** Curved hard surfaces are used to direct sound waves to different parts of the concert hall. Soft surfaces absorb sound waves, reducing reverberation. But some reverberation is desirable. With too little reverberation, instruments would sound thin and distant. With too much reverberation, reflected waves interfere and individual notes become hard to pick out.

## Section 3 Assessment

**Target Reading Skill** Previewing Visuals Refer to your questions and answers about Figure 15 to help you answer Question 2 below.

### Reviewing Key Concepts

1. a. Describing How do overtones affect the sound quality of a musical instrument?
   b. Explaining How does resonance affect the sound quality of a musical instrument?
2. a. Listing What are the three groups of musical instruments?
   b. Summarizing How is pitch controlled in each group of musical instruments?
   c. Comparing and Contrasting How is loudness increased in a drum and in a guitar?
3. a. Defining What is acoustics?
   b. Relating Cause and Effect How is acoustics used in the design of concert halls?
   c. Making Judgments Why is some reverberation desirable in a concert hall?

### Writing in Science

**Explanation** A friend e-mails you and asks how your new guitar produces music. Write an e-mail that answers your friend's question. Be sure to explain how you can change pitch, and why the guitar has a hollow body.

# Changing Pitch

## Problem

When you blow across the mouth of a bottle, you can play a "note." What determines the pitch you hear?

## Skills Focus

controlling variables, designing experiments

## Suggested Materials

- 1-L soda bottle
- 2-L soda bottle
- 250-mL graduated cylinder
- metric ruler
- straw
- water

## Design a Plan

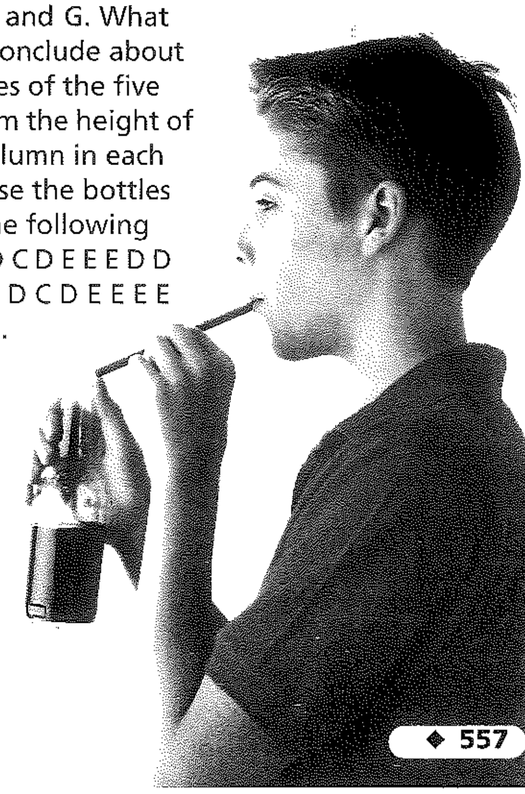
1. Practice making a sound by using a straw to blow across the mouth of a 1-L bottle. Then blow across the mouth of a 2-L bottle in the same way. Compare the pitches. Record your observations in your notebook.
2. Add 250 mL of water to both the 1-L bottle and the 2-L bottle. Blow across the mouth of each bottle and compare the pitches. Record your observations in your notebook.
3. Analyze your observations from Steps 1 and 2 to predict what may have affected the pitches. For example, measure the height of the air column, and calculate the volume of air in each bottle. (*Hint:* Subtract the volume of water in the bottle from the total volume of the bottle.)
4. Develop a hypothesis about what determines the pitch of the sound produced by blowing across the mouth of a bottle. Record your hypothesis in your notebook.
5. Design an experiment to test your hypothesis. Create a data table to record information about the variables. Write your plan. (*Hint:* You can change the height of the air column in a bottle by changing the amount of water in the bottle.)
6. After receiving your teacher's approval of your plan, conduct your experiment and record the results in your notebook.

## Analyze and Conclude

1. **Observing** Describe the pitch of the sound produced by each bottle in Steps 1 and 2.
2. **Designing Experiments** Did your experiment support your hypothesis? Explain.
3. **Controlling Variables** Identify the manipulated and responding variables in your experiment.
4. **Inferring** If you had a 1-L bottle that contained 250 mL of water, what would you do to produce a higher-pitched sound?
5. **Drawing Conclusions** What is the relationship between the height of the air column and the pitch of the sound produced by blowing across the mouth of a bottle?
6. **Communicating** Based on your results, describe how you could use a set of bottles as a musical instrument.

## More to Explore

Use a set of tuning forks or a pitch pipe to "tune" five bottles to match the notes C, D, E, F, and G. What can you conclude about the pitches of the five notes from the height of the air column in each bottle? Use the bottles to play the following notes: E D C D E E E D D D E G G E D C D E E E E D D E D C.



Section 4

Integrating Life Science

# How You Hear Sound

## Reading Preview

### Key Concepts

- What is the function of each section of the ear?
- What causes hearing loss?

### Key Terms

- ear canal
- eardrum
- cochlea

### Target Reading Skill

**Sequencing** A sequence is the order in which the steps in a process occur. As you read, make a flowchart that shows how you hear sound. Put the steps of the process in separate boxes in the order in which they occur.

**How You Hear Sound**

The outer ear funnels sound waves into the ear canal.

↓

Sound waves make the eardrum vibrate.

↓

## Lab zone Discover Activity

### Where Is the Sound Coming From?

1. Ask your partner to sit on a chair, with eyes closed.
2. Clap your hands near your partner's left ear. Ask your partner what direction the sound came from. Record the answer.
3. Now clap near your partner's right ear. Again, ask your partner what direction the sound came from and record the answer. Continue clapping in different locations around your partner's head and face. How well did your partner identify the directions the sounds came from?
4. Switch places with your partner and repeat Steps 1–3.

**Think It Over**

Observing From which locations are claps easily identified? For which locations are claps impossible to identify? Is there a pattern? If so, suggest an explanation for the pattern.

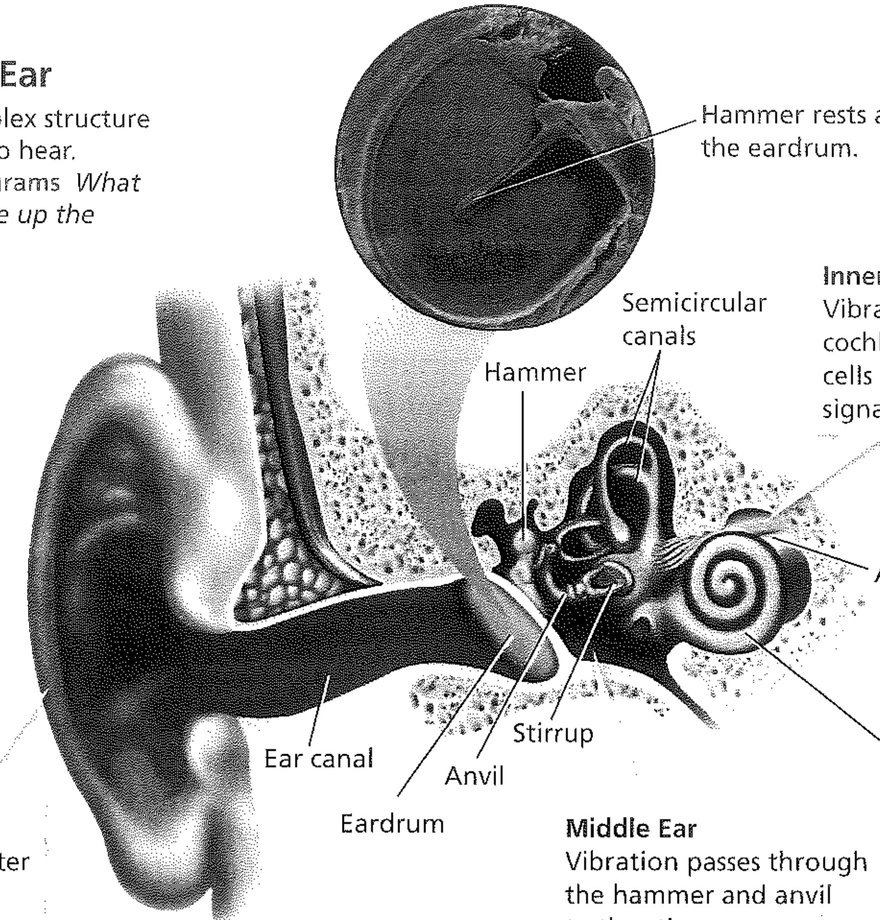
The house is quiet. You are sound asleep. All of a sudden, your alarm clock goes off. Startled, you jump up out of bed. Your ears detected the sound waves produced by the alarm clock. But how exactly did your brain receive the information?

## The Human Ear

The function of your ear is to gather sound waves and send, or transmit, information about sound to your brain. Your ear has three main sections: the outer ear, the middle ear, and the inner ear. Each section has a different function. **The outer ear funnels sound waves, the middle ear transmits the waves inward, and the inner ear converts sound waves into a form that travels to your brain.**

**Outer Ear** Look at Figure 17. The first section of your ear is the outer ear. The outermost part of your outer ear looks and acts like a funnel. It collects sound waves and directs them into a narrow region called the **ear canal.** Your ear canal is a few centimeters long and ends at the eardrum. The **eardrum** is a small, tightly stretched, drumlike membrane. The sound waves make your eardrum vibrate, just as a drum vibrates when you strike it.

FIGURE 17
## The Human Ear
The ear is a complex structure that allows you to hear.
**Interpreting Diagrams** *What three bones make up the middle ear?*




**Middle Ear** Behind the eardrum is the middle ear. The middle ear contains the three smallest bones in your body—the hammer, the anvil, and the stirrup. The hammer is attached to the eardrum, so when the eardrum vibrates, the hammer does too. The hammer then transmits vibrations first to the anvil and then to the stirrup.

**Inner Ear** A membrane separates the middle ear from the inner ear, the third section of the ear. When the stirrup vibrates against this membrane, the vibrations pass into the cochlea. The **cochlea** (KAHK lee uh) is a fluid-filled cavity shaped like a snail shell. The cochlea contains more than 10,000 tiny structures called hair cells. These hair cells have hairlike projections that float in the fluid of the cochlea. When vibrations move through the fluid, the hair cells move, causing messages to be sent to the brain through the auditory nerve. The brain processes these messages and tells you that you've heard sound.

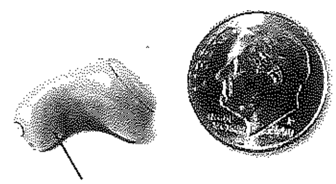
**Reading Checkpoint** What are the three main sections of the ear?

**Lab zone Try This Activity**

### Listen to This
1. Tie two strings to the handle of a metal spoon. Each string should be about 40 cm long.
2. Hold the loose end of each string in each hand. Bump the spoon against a desk or other hard solid object. Listen to the sound.
3. Now wrap the ends of the string around your fingers. Put your index fingers against your ears and bump the spoon again. How is the sound different?

**Inferring** What can you infer about how sound travels to your ears?

FIGURE 18
**A Modern Hearing Aid**
Some hearing aids are about the size of a dime. Inferring *What are some benefits and drawbacks of tiny hearing aids?*




## Hearing Loss

When hearing loss occurs, a person may have difficulty hearing soft sounds or high-pitched sounds. **There are many causes of hearing loss, including injury, infection, exposure to loud sounds, and aging.**

**Causes of Hearing Loss** Hearing loss can occur suddenly if the eardrum is damaged or punctured. (Imagine trying to play a torn drum!) For this reason, it is dangerous to put objects into your ear, even to clean it. Infections also can damage the delicate inner ear, causing permanent hearing loss.

Extended exposure to loud sounds can damage hair cells in the ear. The damaged cells will no longer send signals to the brain. You can prevent this type of hearing loss by wearing hearing protection when you are around loud sounds.

The most common type of hearing loss occurs gradually. As a person gets older, some hair cells in the cochlea die and are not replaced. People with this kind of hearing loss often have difficulty hearing high-frequency sounds.

**Hearing Aids** For some types of hearing loss, hearing aids can restore some ability to hear. Hearing aids amplify sounds entering the ear. Some are so tiny that they can fit invisibly in the ear canal. Others can amplify specific frequencies that a person has lost the ability to hear.

Reading Checkpoint **What happens when a hearing loss occurs?**

## Section 4 Assessment

**Target Reading Skill** Sequencing Refer to your flowchart about hearing as you answer Question 1.

### Reviewing Key Concepts

1. a. Identifying What is the function of each section of your ear?
   b. Interpreting Diagrams Look at Figure 17. What happens to a sound wave as it enters your ear canal?
   c. Relating Cause and Effect How are sound waves transmitted through the middle ear?
2. a. Listing What are four causes of hearing loss?
   b. Explaining How can loud sounds lead to hearing loss?
   c. Making Judgments Should people at a rock concert wear earplugs? Why or why not?

**Lab zone At-Home Activity**

Sound Survey Ask family members to survey the sounds they hear in a day. Ask them to rate the sounds as quiet, normal, loud, or painful. Then rate each sound as pleasant, neutral, or annoying. For each sound record the source, location, time of day, and time exposed to the sound. How are the ratings similar? How are they different?

Lab zone **Technology Lab**

• Tech & Design •

# Design and Build Hearing Protectors

## Problem

Can you design and build hearing protectors that block some sound from reaching your ears?

## Design Skills

designing a solution, evaluating the design

## Suggested Materials

- sound source (radio, tape player, or CD player)
- soundproofing materials
- tape measure
- scissors
- string
- pencil
- different types of headgear
- glue

## Procedure

### PART 1 Research and Investigate

1. Copy the data table on a separate sheet of paper.
2. Select a soundproofing material.
3. Stand quietly at the back of the room. Your teacher will adjust the loudness of a sound source until you are just able to hear it. Ask your partner to measure and record your distance from the sound source. Record the measurement in your data table.
4. Cover both ears with the soundproofing material. **CAUTION:** *Do not insert any material into your ears.* Move slowly forward until you can just hear the sound source again. Stop. Then have your partner measure your distance from the sound source. Record the measurement in your data table.
5. Repeat Steps 2–4 using three other materials.

Data Table

| Soundproofing Material | Distance From Sound Source (m) |
|---|---|
| No material | |
| Material 1 | |
| Material 2 | |
| Material 3 | |
| Material 4 | |
| | |

### PART 2 Design and Build

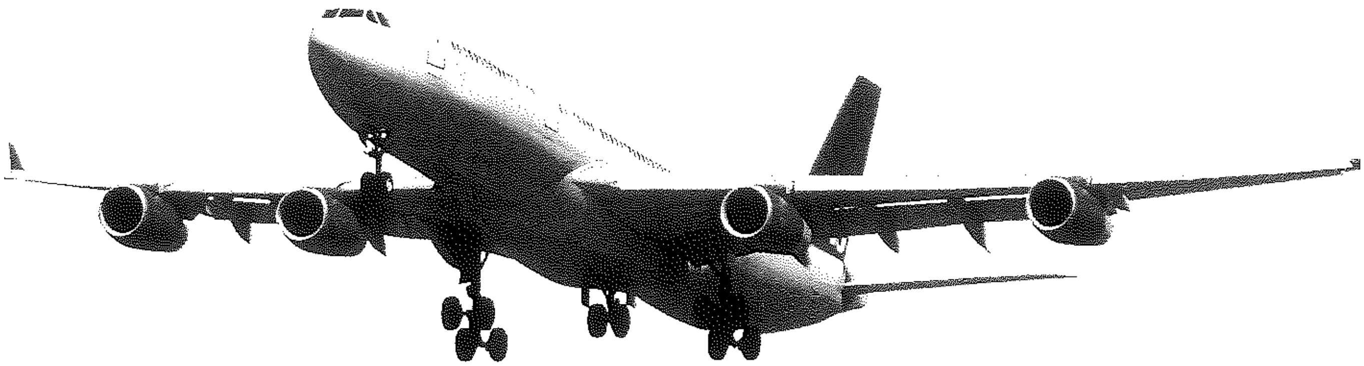
6. Based on what you learned in Part 1, design and build hearing protectors. Your device should
   - keep you from hearing a pencil dropped on a table at a distance of 5 meters
   - fit comfortably on your head without needing to be held in place
   - be made of materials approved by your teacher
7. Sketch your design and list the materials you will use. After your teacher approves your design, build your hearing protectors.

## Analyze and Conclude

1. Designing a Solution What did you learn about soundproofing materials in Part 1 that helped you design your device?
2. Evaluating the Design Test your hearing protectors. Did your device meet all of the goals stated in Step 6? Explain.
3. Troubleshooting As you designed, built, and tested your hearing protectors, what problems did you encounter? How did you solve them?

## Communicate

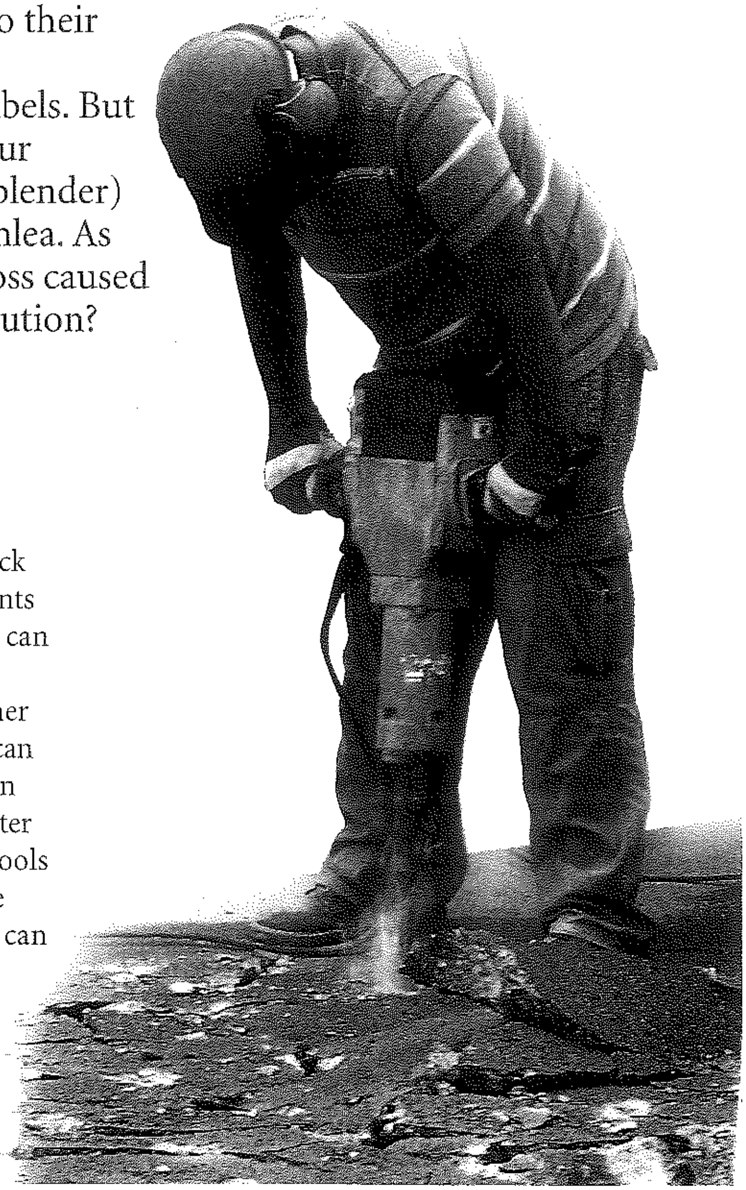
A construction company is considering buying your hearing protectors. Write a summary of your test results to convince the company that the device meets the design goals stated in Step 6.



# Keeping It Quiet...

A construction worker uses a jackhammer; a woman waits in a noisy airport; a spectator watches a car race. All three experience noise pollution. In the United States alone, 40 million people face danger to their health from noise pollution.

People start to feel pain at about 120 decibels. But noise that "doesn't hurt" can still damage your hearing. Exposure to 85 decibels (a kitchen blender) can slowly damage the hair cells in your cochlea. As many as 9 million Americans have hearing loss caused by noise. What can be done about noise pollution?



## The Issues

### What Can Individuals Do?

Some work conditions are noisier than others. Construction workers, airport employees, and truck drivers are all at risk. Workers in noisy environments can help themselves by using ear protectors, which can reduce noise levels by 35 decibels.

Many leisure activities also pose a risk. A listener at a rock concert or someone riding a motorbike can prevent damage by using ear protectors. People can also reduce noise at the source. They can buy quieter machines and avoid using lawnmowers or power tools at quiet times of the day. Simply turning down the volume on headphones for radios and CD players can help prevent hearing loss in young people.

## What Can Communities Do?

Transportation—planes, trains, trucks, and cars—is the largest source of noise pollution. About 15 million Americans live near airports or under airplane flight paths. Careful planning to locate airports away from dense populations can reduce noise. Cities can also prohibit late-night flights.

Many communities have laws against noise that exceeds a certain decibel level, but these laws are hard to enforce. In some cities, "noise police" can give fines to people who use noisy equipment.

## What Can the Government Do?

A National Office of Noise Abatement and Control was set up in the 1970s. It required labels on power tools to tell how much noise they made. But in 1982, this office lost its funding. In 1997, lawmakers proposed The Quiet Communities Act to bring the office back and set limits to many types of noise. But critics say that national laws have little effect. They want the federal government to encourage—and pay for—research into making quieter vehicles and machines.

## You Decide

1. **Identify the Problem**
   In your own words, describe the issues of noise pollution.
2. **Analyze the Options**
   List as many methods as you can for dealing with noise. How would each method reduce noise or protect people from noise?
3. **Find a Solution**
   Choose one method for reducing noise in your community. Make a poster to convince people to support your proposal.

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PHSchool.com
**For:** More on noise pollution
**Visit:** PHSchool.com
**Web Code:** cgh-5020

Section

# 5 Using Sound

## Reading Preview

### Key Concepts

- Why do some animals use echolocation?
- What are ultrasound technologies used for?

### Key Terms

- echolocation
- sonar
- sonogram

### Target Reading Skill

**Comparing and Contrasting** As you read, compare and contrast echolocation and sonar by completing a table like the one below.

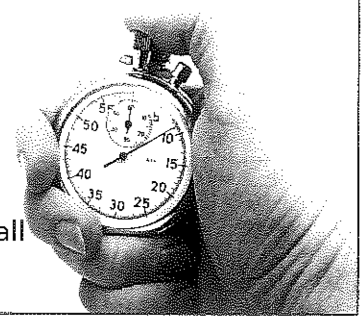
**Using Sound**

| Feature | Echolocation | Sonar |
|---|---|---|
| Type of wave | Ultrasound | |
| Medium(s) | | Water |
| Purposes | | |

## Lab zone Discover Activity

### How Can You Use Time to Measure Distance?

1. Measure a distance 3 meters from a wall and mark the spot with a piece of masking tape.
2. Roll a soft ball in a straight line from that spot toward the wall. What happens to the ball?
3. Roll the ball again. Try to roll the ball at the same speed each time. Have a classmate use a stopwatch to record the time it takes for the ball to leave your hand, reflect off the wall, and then return to you.
4. Now move 6 meters away from the wall. Mark the spot with tape. Repeat Steps 2 and 3.
5. Compare the time for both distances.



**Think It Over**

Inferring What does the difference in time tell you about the distance the ball has traveled?

A dog trainer stands quietly, watching the dog a short distance away. To get the dog's attention, the trainer blows into a small whistle. You don't hear a thing. But the dog stops, cocks an ear, and then comes running toward the trainer. Dogs can hear ultrasound frequencies up to about 45,000 Hz, well above the upper limit for humans. Other animals, such as cats and mice, can also hear ultrasound frequencies.

Some types of animals not only hear ultrasound, but also produce ultrasound waves. They use ultrasound waves to "see in the dark."

◀ **Dog hearing an ultrasound whistle**

## Echolocation

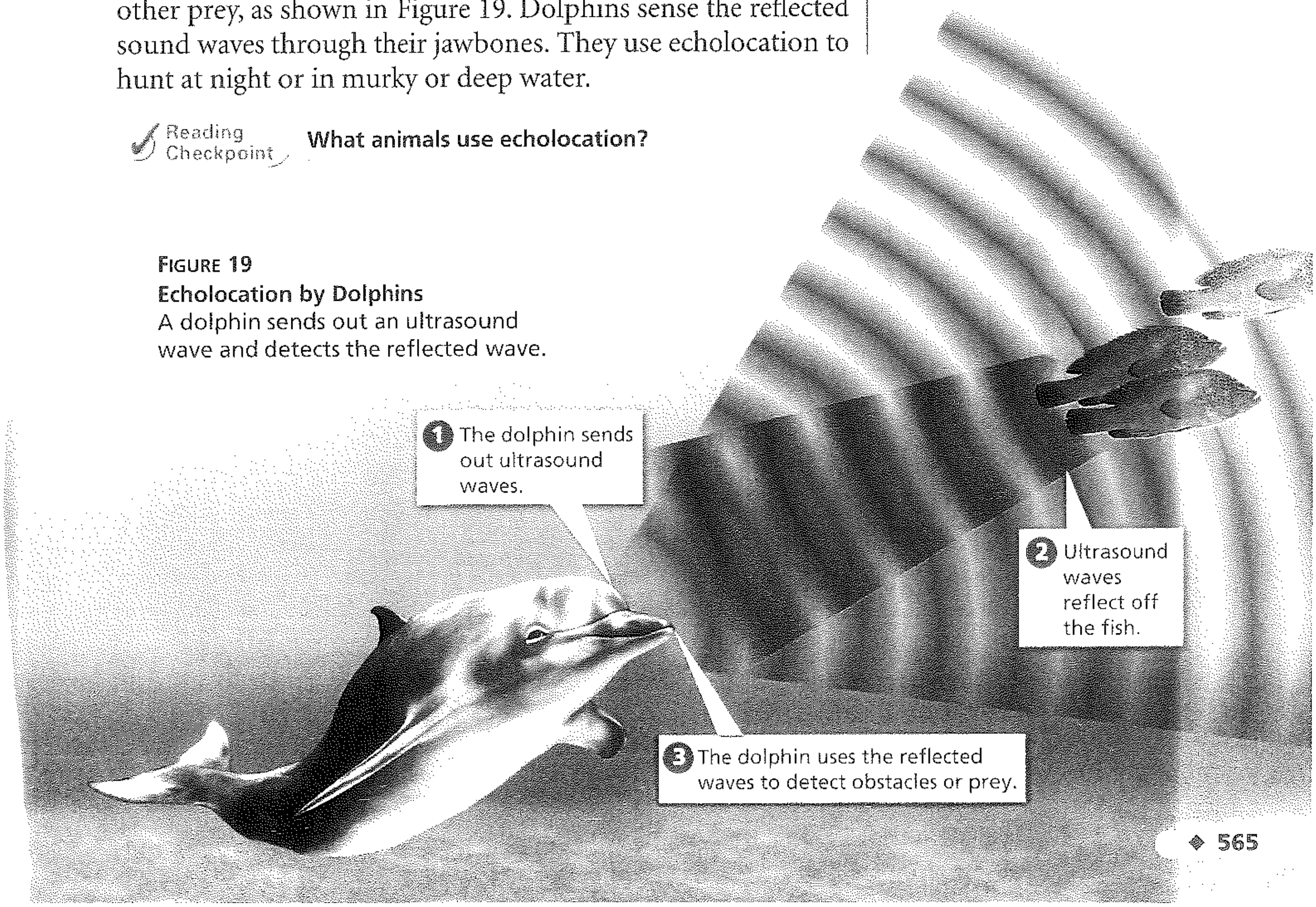
Imagine trying to walk around in a totally dark room. You would probably bump into objects every few steps. Unlike you, bats find it easy to move around in dark places. This is because they use echolocation. **Echolocation** (ek oh loh KAY shun) is the use of reflected sound waves to determine distances or to locate objects. **Some animals, including bats and dolphins, use echolocation to navigate and to find food.**

**Bats** Bats use ultrasound waves with frequencies up to 100,000 Hz to move around and hunt. As a bat flies, it sends out short pulses of ultrasound waves—as many as 200 pulses per second! The waves reflect off objects and return to the bat's ears. The time it takes for the sound waves to return tells the bat how far it is from obstacles or prey. The bat uses the reflected sound waves to build up a "picture" of what lies ahead.

**Dolphins, Porpoises, and Whales** Dolphins, porpoises, and some whales must often hunt in darkness. Like bats, these animals use echolocation. For example, dolphins send out ultrasound waves with frequencies up to 150,000 Hz. The sound waves travel through the water and bounce off fish or other prey, as shown in Figure 19. Dolphins sense the reflected sound waves through their jawbones. They use echolocation to hunt at night or in murky or deep water.

Reading Checkpoint **What animals use echolocation?**

**FIGURE 19**
**Echolocation by Dolphins**
A dolphin sends out an ultrasound wave and detects the reflected wave.



## Lab zone Skills Activity

### Designing Experiments

1. Stand a square piece of cardboard on a table. Prop it up with a book.
2. Lay two cardboard tubes flat on the table. The tubes should be angled to make a V shape, with the point of the V near the cardboard square. Leave a gap of about 6 cm between the cardboard square and the ends of the tubes.
3. Place a ticking watch in one tube. Put your ear near the open end of the second tube. Cover your free ear with your hand. What do you hear?
4. Design an experiment to determine how well sound reflects off different materials.

# Ultrasound Technologies

People cannot send out pulses of ultrasound to help them move around in the dark. But people sometimes need to explore places they cannot easily reach, such as deep underwater or inside the human body. **Ultrasound technologies such as sonar and ultrasound imaging are used to observe things that cannot be seen directly.**

**Sonar** A system that uses reflected sound waves to detect and locate objects underwater is called **sonar**. The word *sonar* comes from the initial letters of **so**und **n**avigation **a**nd **r**anging. *Navigation* means finding your way around on the ocean (or in the air), and *ranging* means finding the distance between objects. Today, sonar is used to determine the depth of water, to map the ocean floor, and to locate sunken ships, schools of fish, and other objects in the ocean.

A sonar device sends a burst of ultrasound waves that travel through the water. When the sound waves strike an object or the ocean floor, they reflect as shown in Figure 20. The sonar device detects the reflected waves.

The farther a sound wave travels before bouncing off an object, the longer it takes to return to the sonar device. A computer in the sonar device measures the time it takes for the sound waves to go out and return. Then, it multiplies this time by the speed of sound in water. The result is the total distance the sound waves traveled. The total distance is divided by two to find how far away the object is. You must divide by two because the sound waves travel out and back.

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**For:** More on sonar
**Visit:** PHSchool.com
**Web Code:** cgd-5025

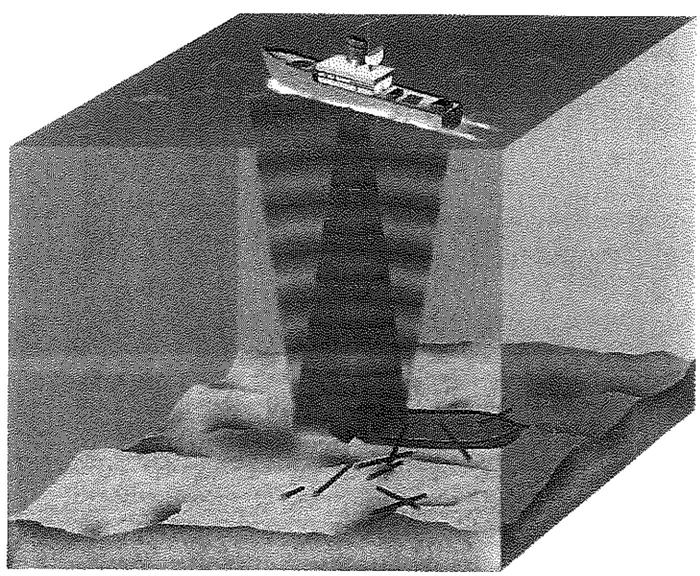


FIGURE 20
**Using Sonar**
A sonar device sends out ultrasound waves and then detects the reflected waves. **Interpreting Diagrams** *What happens to the reflected sound waves?*

**Ultrasound Imaging** Doctors use ultrasound imaging to look inside the human body. Ultrasound imaging devices send ultrasound waves into the body and detect the reflected sound waves. Different parts of the body, such as bones, muscles, the liver, or the heart, reflect sound differently. The device uses the reflected ultrasound waves to create a picture called a **sonogram.** A doctor can use sonograms to diagnose and treat many medical conditions.

Ultrasound imaging is used to examine developing babies before they are born. A technician or doctor holds a small probe on a pregnant woman's abdomen. The probe sends out very high frequency ultrasound waves (about 4 million Hz). By analyzing the reflected sound waves, the device builds up a sonogram. The sonogram can show the position of the baby. Sonograms can also show if more than one baby will be born. In addition to a still picture, ultrasound imaging can produce a video of a developing baby.

Reading Checkpoint — What is a sonogram?

FIGURE 21
**Ultrasound in Medicine**
An ultrasound imaging device uses reflected ultrasound waves to build up a picture of a developing baby.

◀ **Sonogram**

# Section 5 Assessment

## Target Reading Skill

Comparing and Contrasting Use your table about echolocation and sonar to help you answer the questions below.

## Reviewing Key Concepts

1. a. Defining What is echolocation?
   b. Summarizing Why do bats and dolphins use echolocation?
   c. Interpreting Diagrams Look at Figure 19. Why would a dolphin need to continue sending out sound waves as it nears its prey?
2. a. Reviewing Why do people use ultrasound technologies?
   b. Drawing Conclusions A sonar device can show the size of a fish but not the type of fish. Explain why.
   c. Comparing and Contrasting How is sonar similar to ultrasound imaging used in medicine? How is it different?

## Writing in Science

**Advertisement** Write a short advertisement for a depth finder used on fishing boats. Describe how the depth finder can determine the depth and direction of fish in the area. Include a diagram to show how the depth finder works.

Chapter 16

# Study Guide

The BIG Idea

**Energy and Waves** Sound is a longitudinal wave that transports the energy of vibrations through a medium. The properties of sound include speed, loudness, and pitch.

## 1 The Nature of Sound

Key Concepts

- Sound is a disturbance that travels through a medium as a longitudinal wave.
- Sound waves reflect off objects, diffract through narrow openings and around barriers, and interfere with each other.
- The speed of sound depends on the elasticity, density, and temperature of the medium the sound travels through.

Key Terms

echo  elasticity  density

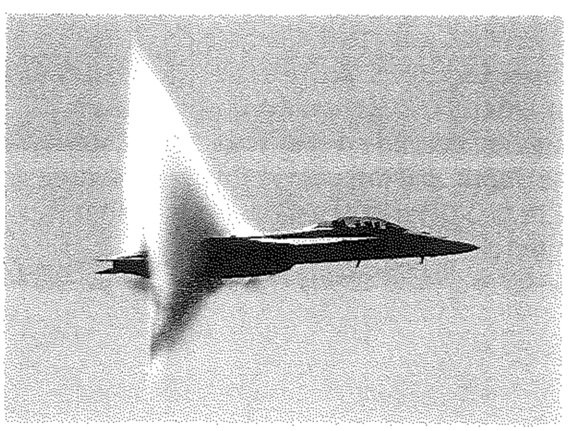
## 2 Properties of Sound

Key Concepts

- The loudness of a sound depends on two factors: the amount of energy it takes to make the sound and the distance from the source of the sound.
- The pitch of a sound that you hear depends on the frequency of the sound wave.
- When a sound source moves, the frequency of the waves changes because the motion of the source adds to the motion of the waves.

Key Terms

loudness
intensity
decibel (dB)
pitch
ultrasound
infrasound
larynx
Doppler effect



## 3 Music

Key Concepts

- Sound quality results from the blending of a fundamental tone with its overtones. Resonance also plays a role in sound quality.
- There are three basic groups of musical instruments: stringed instruments, wind instruments, and percussion instruments.
- Acoustics is used in the design of concert halls to control reverberation and interference.

Key Terms

music
fundamental tone
overtone
acoustics
reverberation

## 4 How You Hear Sound

Key Concepts

- The outer ear funnels sound waves, the middle ear transmits the waves inward, and the inner ear converts sound waves into a form that travels to your brain.
- There are many causes of hearing loss, including injury, infection, exposure to loud sounds, and aging.

Key Terms

ear canal  eardrum  cochlea

## 5 Using Sound

Key Concepts

- Some animals, including bats and dolphins, use echolocation to navigate and to find food.
- Ultrasound technologies such as sonar and ultrasound imaging are used to observe things that cannot be seen directly.

Key Terms

echolocation  sonar  sonogram

# Review and Assessment

Go Online
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Visit: PHSchool.com
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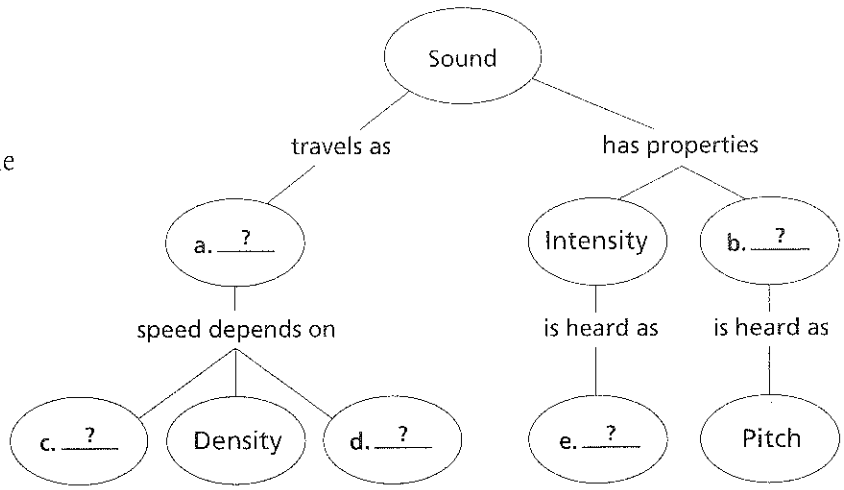
## Organizing Information

**Concept Mapping** Copy the concept map about sound onto a separate sheet of paper. Then complete it and add a title. (For more on Concept Mapping, see the Skills Handbook.)




## Reviewing Key Terms

**Choose the letter of the best answer.**

1. The ability of a medium to bounce back after being disturbed is called
   a. echolocation. b. elasticity.
   c. density. d. interference.
2. Which property of sound describes your perception of the energy of a sound?
   a. loudness
   b. intensity
   c. pitch
   d. wave speed
3. The lowest natural frequency of a sound is
   a. a standing wave.
   b. an overtone.
   c. an echo.
   d. the fundamental tone.
4. In the ear, a fluid-filled cavity that is shaped like a snail shell is the
   a. ear canal. b. eardrum.
   c. cochlea. d. larynx.
5. A system of using reflected sound waves to detect and locate objects underwater is called
   a. sonar. b. acoustics.
   c. echolocation. d. reverberation.

**If the statement is true, write *true*. If it is false, change the underlined word or words to make the statement true.**

6. <u>Intensity</u> is mass per unit volume.
7. <u>Loudness</u> is how the ear perceives frequency.
8. <u>Music</u> is a set of notes that are pleasing.
9. The <u>ear canal</u> is a small, drumlike membrane.
10. A <u>sonogram</u> is a picture made using reflected ultrasound waves.

## Writing in Science

**Firsthand Account** Imagine that you are a dolphin researcher. Write a letter to a friend describing your latest research. Be sure to include information about how dolphins use their sonar.

# Review and Assessment

## Checking Concepts

11. When a gong vibrates, the air particles next to the gong do not reach your ears, yet you hear the sound of the gong. Explain.
12. Explain when a whisper would sound louder than a shout.
13. Why do you hear friends talking in the hallway even though you cannot see them around a corner?
14. As a car drives past you, the driver keeps a hand pressing on the horn. Describe what you hear as the car approaches and after it has passed by.
15. The same note is played on a flute and a cello. Why is there a difference in the sound?
16. How can a sound continue to be heard after a sound source stops making the sound?
17. How can loud noises damage your hearing?
18. How are ultrasound waves used in medicine?

## Thinking Critically

19. **Comparing and Contrasting** How do sound waves behave like waves in a spring toy? How are they different?
20. **Inferring** Thunder and lightning happen at the same time. Explain why you see the lightning before you hear the thunder.
21. **Predicting** Look at the table below. Which material would you use in hearing protectors to reduce the transmission of sound waves? Explain your answer.

| Substance | Speed (m/s) |
|---|---|
| Rubber | 60 |
| Plastic | 1,800 |
| Gold | 3,240 |
| Brick | 3,650 |
| Steel | 5,200 |

22. **Classifying** Classify the following instruments into three groups: a guitar, a tuba, a bell, a clarinet, a drum, and a harp.

## Applying Skills

**Use the data in the table below to answer Questions 23–25.**

*The table shows the range of frequencies produced and heard by various animals.*

| Animal | Highest Frequency Heard (Hz) | Highest Frequency Produced (Hz) |
|---|---|---|
| Human | 20,000 | 1,100 |
| Dog | 50,000 | 1,800 |
| Cat | 65,000 | 1,500 |
| Bat | 120,000 | 120,000 |
| Porpoise | 150,000 | 120,000 |

23. **Interpreting Data** Can you hear the ultrasound waves that a bat uses for echolocation? Why or why not?
24. **Graphing** Draw a bar graph to compare the highest frequencies heard and the highest frequencies produced by the animals.
25. **Calculating** If the speed of sound in air is 343 m/s, what is the shortest wavelength of sound that humans can hear? (*Hint:* Wavelength = Speed ÷ Frequency)

## Lab zone Chapter Project

**Performance Assessment** Present your musical instrument to your class. Explain how it was built and how you solved any design problems. Then demonstrate how you can change the pitch or loudness of your instrument. Brainstorm with the class methods for improving the design of the instrument. How is your instrument similar to or different from instruments your classmates built?

# Standardized Test Prep

## Test-Taking Tip

**Interpreting Graphs**

If you are asked to interpret a bar graph, look at the labels of the horizontal and vertical axes. The labels tell you what variables are being compared. A bar graph is used to show data in several categories that are not related. The graph on this page compares the loudness of four common sounds. In this graph, the sounds that are being compared are otherwise unrelated to each other. Study the graph and answer the sample question below.

***Sample Question***

Which sounds are likely to cause hearing damage?

**A** noise from a classroom
**B** noise from loud thunder or jet engines
**C** noise from street traffic or thunder
**D** none of the sounds shown on the graph

***Answer***

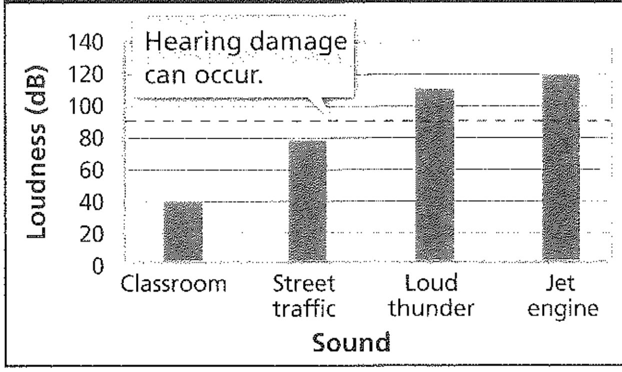
**B** is correct because both sounds are louder than 100 dB. You can eliminate **A** and **C** because they include a sound softer than 100 dB. **D** is incorrect because two sounds are louder than 100 dB.

**Choose the letter of the best answer.**

1. Bats and dolphins use echolocation to determine distances and find prey. What characteristic of sound waves is most important for echolocation?
   **A** Sound waves reflect when they hit a surface.
   **B** Sound waves spread out from a source.
   **C** Sound waves diffract around a corner.
   **D** Sound waves interfere when they overlap.

2. A scientist is doing research with 110-dB sound waves. What piece of safety equipment must she wear in the lab?
   **F** goggles
   **G** gloves
   **H** lab apron
   **J** hearing protectors

**Comparing Loudness**




3. Use the graph above to determine how much more intense the sound of a jet engine is than the sound of loud thunder.
   **A** ten times more intense
   **B** two times more intense
   **C** four times more intense
   **D** Both sounds are about the same intensity.

4. An experiment was conducted in which two containers held solids *A* and *B* at the same temperature. The speed of a sound wave traveling through solid *A* was greater than its speed through solid *B*. What can you conclude from this experiment?
   **F** Solid *A* is denser than solid *B*.
   **G** Solid *A* is less dense than solid *B*.
   **H** Solid *A* is more elastic than solid *B*.
   **J** Solid *A* is less dense than solid *B* or solid *A* is more elastic than solid *B*.

5. After a new concert hall is built, it is found that the acoustics are poor because of reverberation. How can the acoustics be improved?
   **A** Add metal seats to the hall.
   **B** Remove the drapes covering the windows.
   **C** Cover the wooden floor with carpeting.
   **D** Install a wooden backdrop behind the stage.

## Constructed Response

6. You drop a book onto the floor in the bedroom of your apartment. Your neighbor downstairs hears the sound. Describe how the sound travels to your neighbor's ears. What mediums do the sound waves have to travel through?