Section 1

The Nature of Sound

Objectives

After this lesson, students will be able to

O.2.1.1 Define sound and explain what causes sound and how it travels.

O.2.1.2 Describe how sound waves interact.

O.2.1.3 Identify factors that affect the speed of sound.

Target Reading Skill

Identifying Main Ideas Explain that identifying main ideas and details helps students sort the facts from the information into groups. Each group can have a main topic, subtopics, and details.

Answers

Sample graphic organizer:

Main Idea: Sound waves interact with objects and with other sound waves.

Detail: Reflection occurs when sound waves strike a surface.

Detail: Sound waves can diffract around corners and through openings.

Detail: The interference of sound waves can be constructive or destructive.

All in One **Teaching Resources**

- Transparency O15

Preteach

Build Background Knowledge L2

Making Sound Waves

Direct students to make a sound using just their hands. *(Students can clap their hands, tap their desk, or snap their fingers.)* Ask: **What caused the sound that you made?** *(The impact created by the hands or fingers caused the sound. Some students may say the impact caused the air to vibrate, thereby producing sound waves.)* Tell students they will learn about sound and sound waves in this section.

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 ▶

Lab zone Discover Activity

Skills Focus Observing L1

Materials bowl, water, tuning fork

Time 10 minutes

Tips Lower-frequency tuning forks make waves that are easier to see. Point out the prongs of the tuning fork if students are unsure which parts they are.

Expected Outcome Students will see tiny ripples when the prong is dipped in the water. When they hold the tuning fork up to their ear, they will hear the tuning fork hum.

Think It Over Ripples are caused by vibrations of the tuning fork, which also produce the sound students hear. Different tuning forks may produce waves with different characteristics.

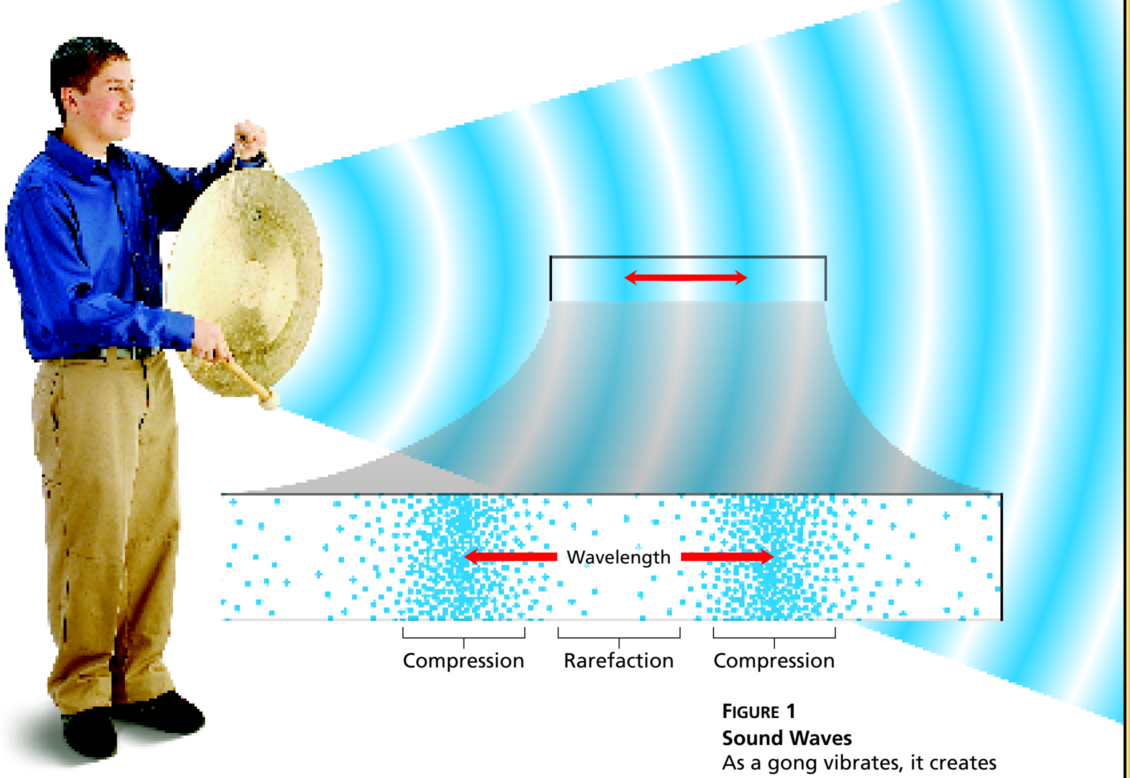


FIGURE 1
Sound Waves
As a gong vibrates, it creates sound waves that travel through the air. **Observing** *What do you observe about the spacing of particles in a compression?*

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?**

Go Online SCILINKS NSTA
For: Links on sound
Visit: www.SciLinks.org
Web Code: scn-1521

Differentiated Instruction

English Learners/Beginning L1
Comprehension: Key Concepts On the board, write the definition of sound, and underline *disturbance* and *medium*. Say that all sounds involve a disturbance and a medium. Help students identify the disturbance and medium for common sounds. **learning modality: visual**

English Learners/Intermediate L2
Comprehension: Ask Questions Check students' comprehension and reinforce basic concepts. Ask: **What begins a sound wave?** *(A disturbance, or vibration)* **What type of wave is a sound wave?** *(Longitudinal)* **What does a sound wave need in order to travel?** *(A medium)* **learning modality: verbal**

Instruct

Sound Waves

Teach Key Concepts L2
Making Sound

Focus Tell students that all sound waves begin with a vibration.

Teach Ask: **What are some sounds and how do they begin?** *(Sample answer: A drumbeat begins with a vibrating drumhead. A guitar sound begins with a vibrating string.)*

Apply Ask: **In what direction do air particles move when they vibrate in a sound wave?** *(Parallel to the direction of the wave)* **learning modality: verbal**

Lab zone Teacher Demo L2

Observing Sound Vibrations

Focus Help students visualize how sound waves move air particles.

Teach Sprinkle sand on a drumhead. Ask: **What do you observe when the drumhead is tapped?** *(The sand vibrates)*

Apply Ask: **How are air molecules near the drumhead similar to the sand particles?** *(They move when the drumhead is tapped.)*

Go Online SCILINKS NSTA
For: Links on sound
Visit: www.SciLinks.org
Web Code: scn-1521
Download a worksheet that will guide students' review of Internet resources on sound.

All in One **Teaching Resources**
- Transparency O16

Independent Practice L2

All in One **Teaching Resources**
- *Guided Reading and Study Worksheet: The Nature of Sound*

Student Edition on Audio CD

Monitor Progress L2

Answers

Figure 1 The particles are spaced closely.

Reading Checkpoint Gases, liquids, and solids

Interactions of Sound Waves

Teach Key Concepts L2

Reflection of Sound Waves

Focus Introduce sound wave interactions with the familiar example of reflection of sound waves and echoes.

Teach Remind students that mechanical waves are reflected from surfaces they cannot pass through. Help students apply what they already know about reflection to sound. Ask: **What are examples of surfaces that readily reflect sound waves?** *(Sample answer: Rock walls, walls of high-rise buildings)* **How does reflection of sound waves affect the sound that you hear?** *(It causes echoes.)*

Apply Ask: **What are some everyday examples of reflected sound waves?** *(Any type of echo, such a shouts in a gym or thunder in the mountains)* **learning modality: verbal**

All in One **Teaching Resources**

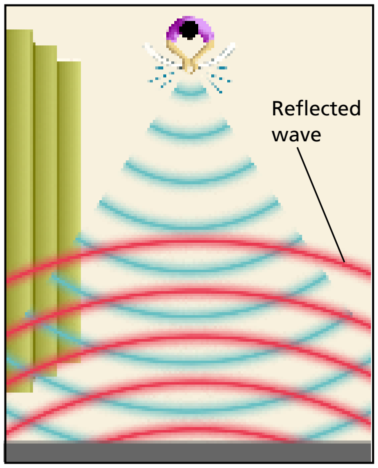
Transparencies O17, O18

Help Students Read L1

Making Inferences Refer to the Content Refresher in this chapter, which provides guidelines for using the Making Inferences strategy.

Help students infer interactions of sound waves. Ask: **Based on your knowledge of waves, what happens to sound waves that strike a barrier they cannot pass through?** *(They bounce back, or reflect.)* **What happens to sound waves near the edge of a barrier or at a hole in a barrier?** *(They bend.)* **What happens when sound waves meet?** *(They can interfere constructively or destructively.)*

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.

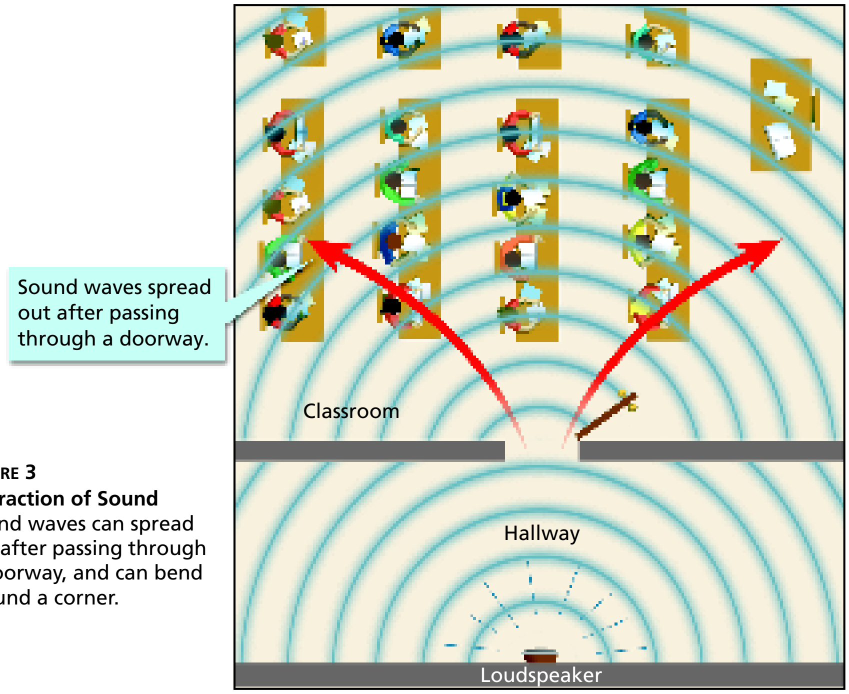


FIGURE 3
Diffraction of Sound
Sound waves can spread out after passing through a doorway, and can bend around a corner.

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. Recall from Chapter 1 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.

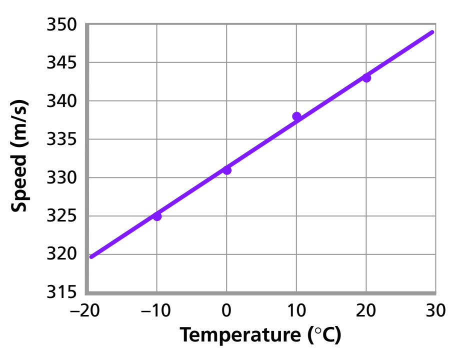
Math Analyzing Data

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 –10°C to 20°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?

Speed of Sound in Dry Air



The Speed of Sound

Teach Key Concepts L2

Putting the Speed of Sound in Context

Focus State that sound travels faster than a jet plane at take off but not as fast as light.

Teach Ask: **Can you think of a situation in which you saw a distant action before you heard it?** *(Sample answer: Seeing the smoke from a starting gun before hearing the gun fire at the start of a race; seeing fireworks before hearing them.)* Explain that each action is seen before the sound is heard because sound travels more slowly than light.

Apply Ask: **Why do you usually hear thunder after you see lightning?** *(Because sound travels more slowly than light)* **learning modality: verbal**

Math Analyzing Data

Math Skill Making and interpreting graphs

Focus Tell students that the speed of sound through dry air depends on the temperature of the air.

Teach Call students' attention to the graph. Explain that a line graph is one way to show the relationship between two variables, such as air temperature and speed of sound. Ask: **Which variable does each axis represent?** *(The x-axis represents air temperature, and the y-axis represents the speed of sound.)*

Answers
1. The speed at –10°C is 325 m/s.
2. The speed of sound increases as air temperature increases.
3. At 30°, the speed of sound might be 349 m/s.

Differentiated Instruction

Special Needs L1

Feeling Sound Waves Give students a chance to feel sound waves traveling through a solid object. Have students place their hands on a guitar or piano as the instrument is played. The harder it is played, the more easily the vibrations can be felt. Explain to students that the vibrations they feel are sound waves that travel through a solid. **learning modality: kinesthetic**

Gifted and Talented L3

Properties of Sound Waves Have students research values for the speed, frequency, and wavelength of sound waves through different mediums. Then, have them draw graphs to show how the variables change and also how the three variables are related to one another. Invite students to share their graphs with the class. **learning modality: logical/mathematical**

Monitor Progress L2

Oral Presentation Call on students to identify factors that affect the speed of sound.

Answers

Figure 2 The wall is made of hard, smooth material that reflects sound waves.

Reading Checkpoint Two ways sound waves diffract are through openings and around barriers.

Help Students Read L1

Vocabulary: Word/Part Analysis The term *elasticity* may be unfamiliar to students. Tell them that the word is a noun containing the adjective *elastic*. Explain that adding *-ity* to some adjectives changes them to nouns. Give students another example, such as scarce/scarcity. Say that scarce means "rare" or "few in number," and scarcity means "the state or condition of being rare or few in number." Ask: **If elastic means "springy," what does elasticity mean?** *(The state or condition of being springy)* Explain that elastic materials have the ability to bounce back after being disturbed.

Lab zone Teacher Demo L1

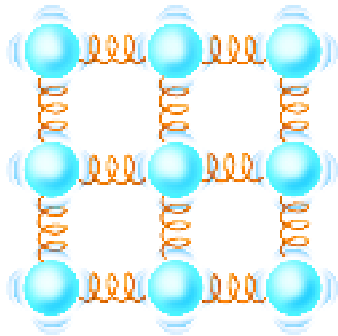
Demonstrating Density

Focus Remind students that the speed of sound waves depends in part on the density of the medium and that density is mass divided by volume.

Teach Demonstrate the concept of density with a slice of bread. Squeeze the bread into a ball that is smaller in size than the original slice. Point out that the same amount of bread is in the ball, but it now takes up less space. Ask: **Did the mass of the bread change?** *(No)* **Did the volume change?** *(Yes, the bread got smaller.)*

Apply Ask: **How did the density of the bread change?** *(It increased.)*

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.

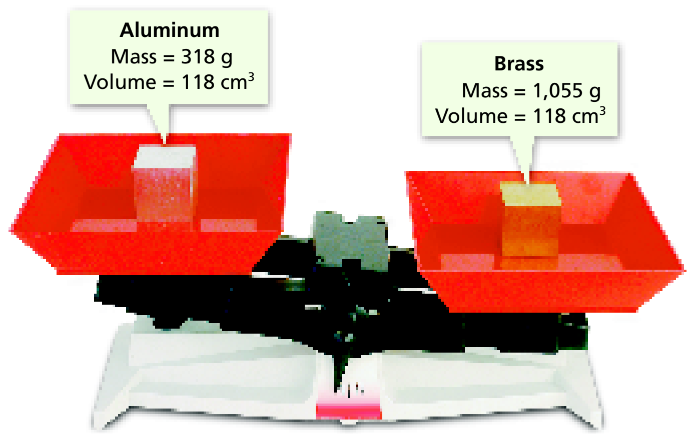


FIGURE 6
Comparing Density
The volumes of these cubes are the same, but the brass cube has more mass.
Interpreting Photographs *Which cube has a greater density: brass or aluminum?*

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 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."

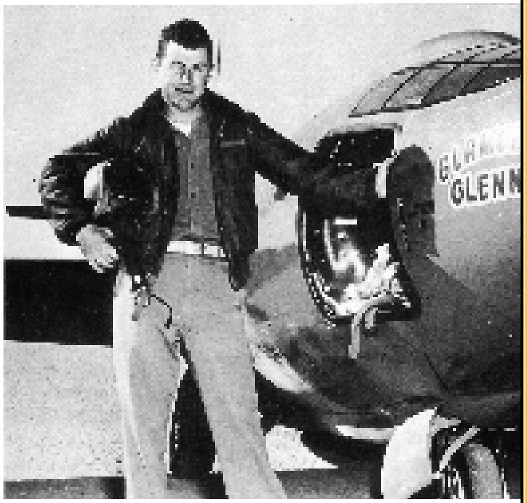


FIGURE 7
Breaking the Sound Barrier
On October 14, 1947, Captain Chuck Yeager became the first person to fly a plane faster than the speed of sound.

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?

Lab zone At-Home Activity

Ear to the Sound L2 The effect will be most noticeable if the pipe is at least 25 m long. Students will hear the sound first through the ear closest to the pipe and a little later through the other ear. Students might explain the outcome by saying that sound travels faster through metal than air because metal is much more elastic than air.

Monitor Progress L2

Answers
Figure 6 The brass cube has a greater density.

Reading Checkpoint The greater the temperature of a medium, the faster sound travels through it.

Assess

Reviewing Key Concepts

1. a. Sound is a disturbance that travels through a medium as a longitudinal wave. **b.** A sound wave begins with a vibration. The vibration disturbs nearby air particles, forming compressions and rarefactions that travel as a sound wave. **c.** The ring causes nearby air particles to vibrate. Vibrating air particles strike the closed door causing particles in the door to vibrate. The vibrations of the door particles start air particles vibrating on the other side of the door. These vibrations reach your ears.
2. a. Reflection, diffraction, and interference **b.** Sound waves from the teacher strike the door. Some of the sound waves are reflected, but some pass through the door and through the air on the other side to your ear. **c.** It may be that there is a hard flat surface in that particular direction, and sound waves from your shout are reflected from the surface back to you.
3. a. Elasticity **b.** Elasticity, density, and temperature **c.** Steel is more elastic than plastic, and the faster speed due to its greater elasticity more than compensates for the slower speed due its greater density.

Reteach L1

Read each of the boldface sentences, leaving an important term blank in each sentence. Call on students to fill in the blanks.

Performance Assessment L2

Drawing Have students make a drawing to show how a sound wave changes as it passes through an opening in a barrier.

All in One Teaching Resources
- Section Summary: *The Nature of Sound*
- Review and Reinforcement: *The Nature of Sound*
- Enrich: *The Nature of Sound*