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 ▶

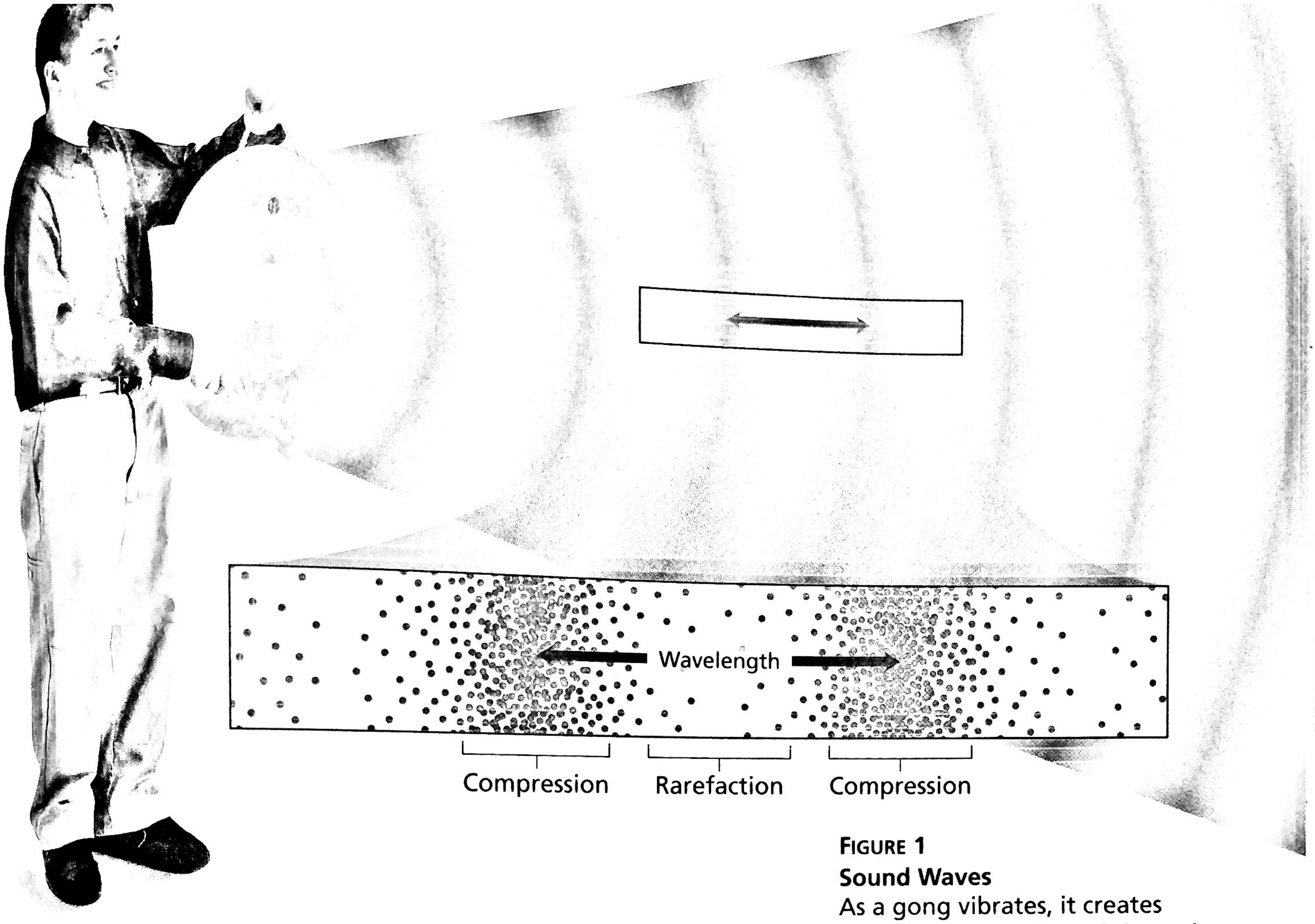

FIGURE 1
Sound Waves
As a gong vibrates, it creates sound waves that travel through the air. **Observing** *What do you observe about the spacing of particles in a compression?*

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?**

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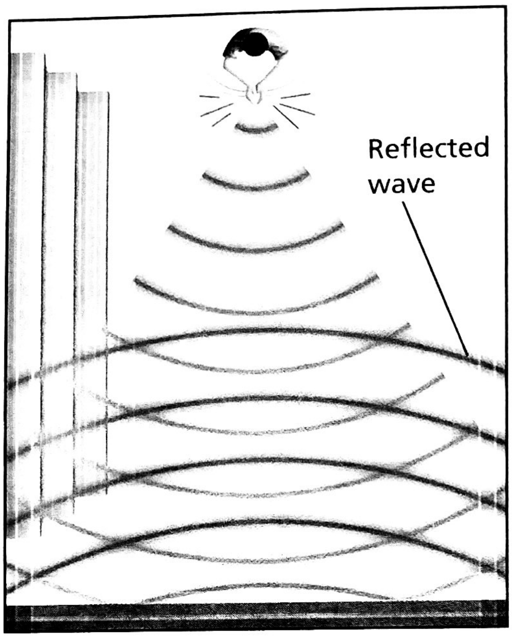
FIGURE 2
Reflection of Sound
Clapping your hands in a gym produces an echo when sound waves reflect off the wall.
Drawing Conclusions *What kind of material is the wall made of?*



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.

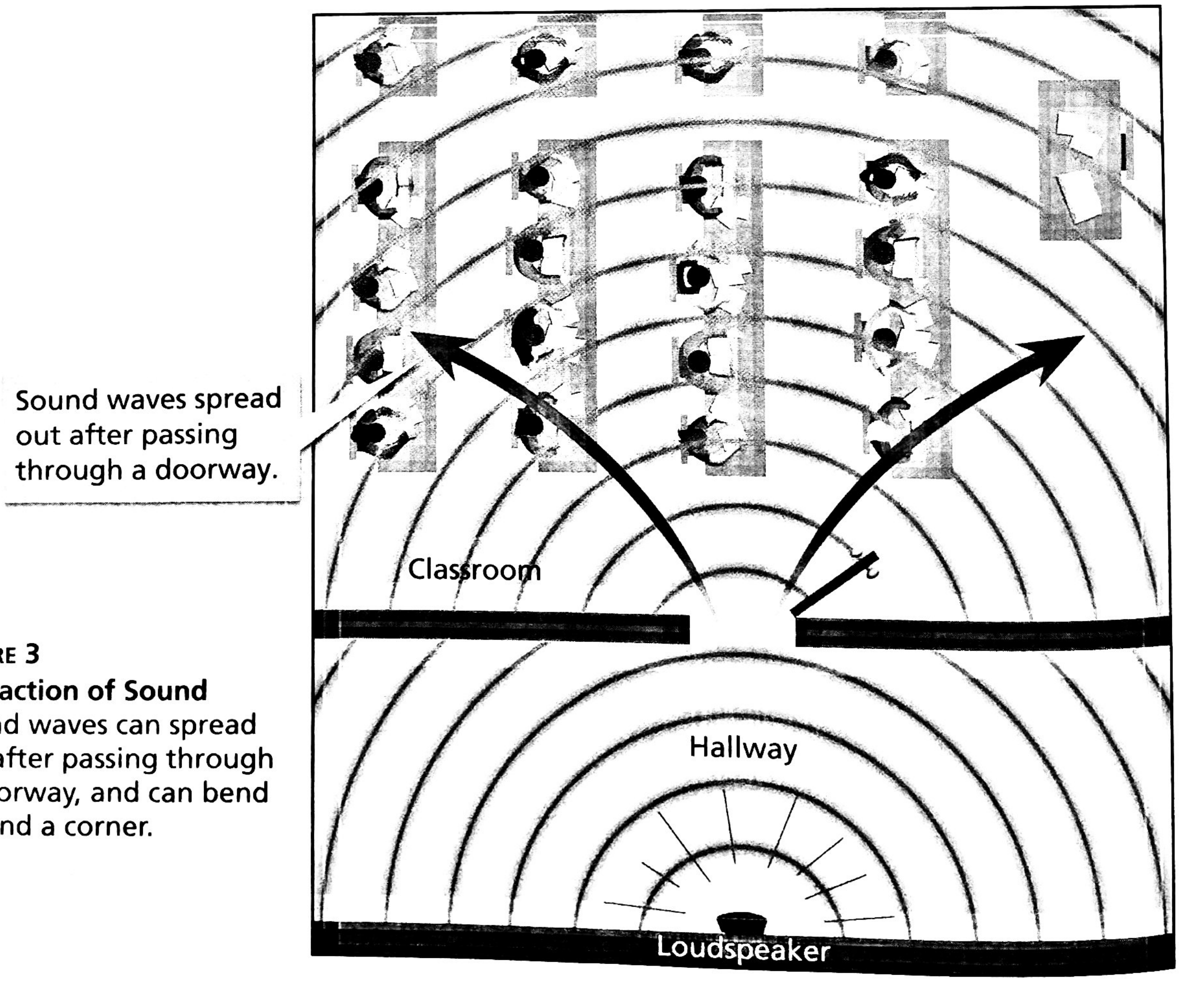


FIGURE 3
Diffraction of Sound
Sound waves can spread out after passing through a doorway, and can bend around a corner.

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?

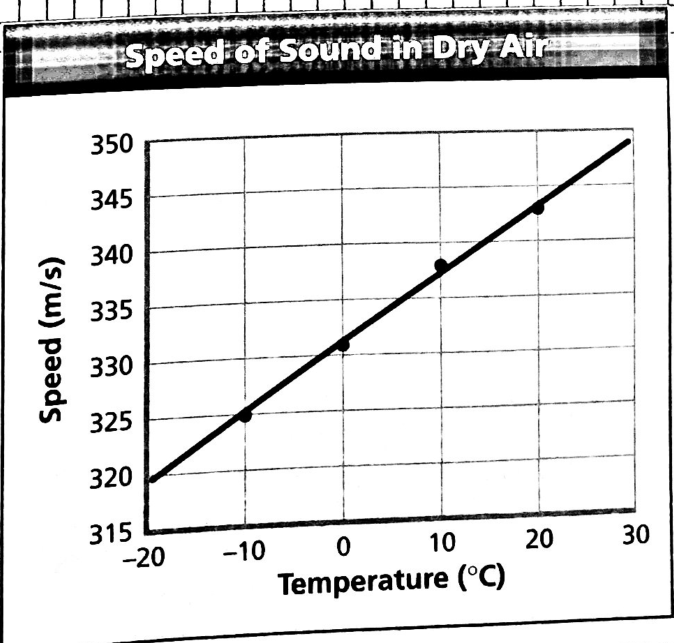
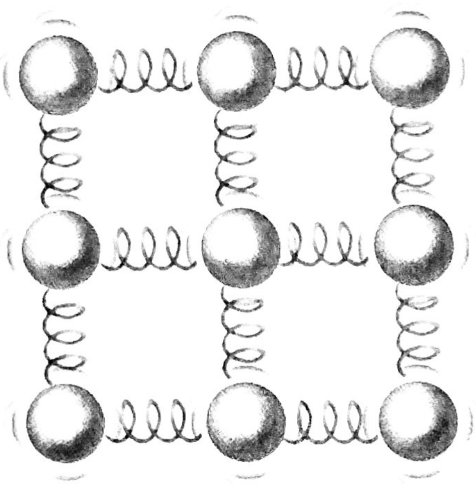


FIGURE 5
Modeling Elasticity
You can model elasticity by representing the particles in a medium as being held together by springs.



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.

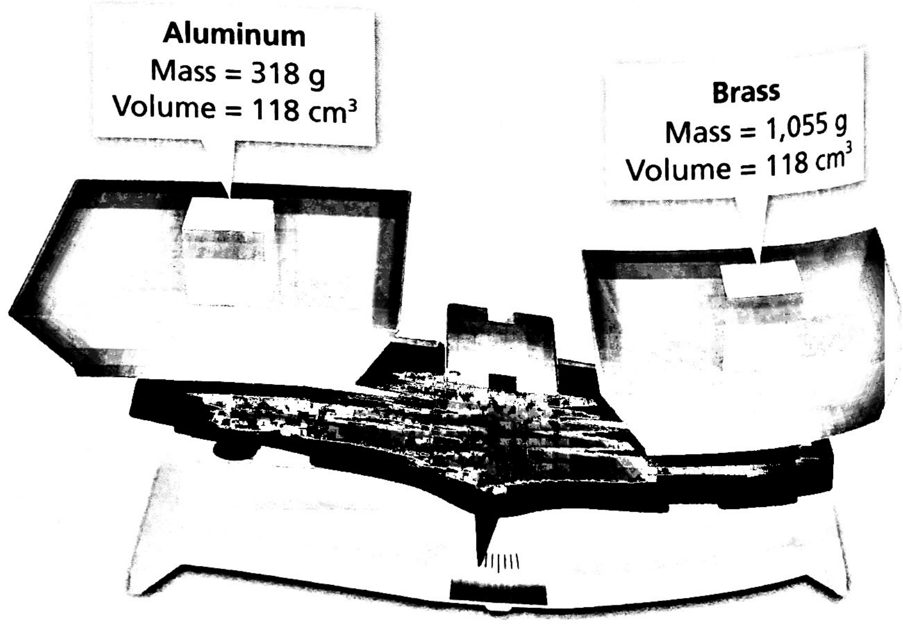


FIGURE 6
Comparing Density
The volumes of these cubes are the same, but the brass cube has more mass.
Interpreting Photographs *Which cube has a greater density: brass or aluminum?*

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."

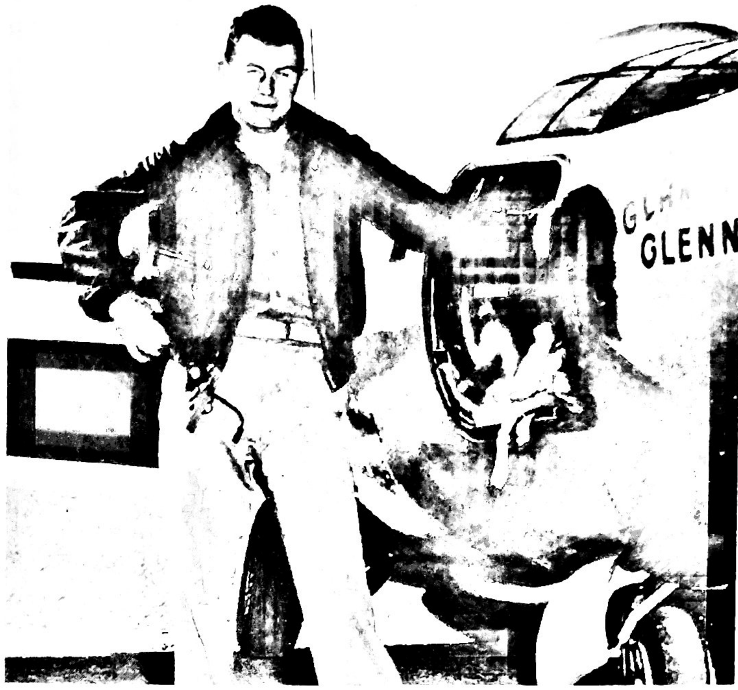


FIGURE 7
Breaking the Sound Barrier
On October 14, 1947, Captain Chuck Yeager became the first person to fly a plane faster than the speed of sound.

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?