1.32 Sound Waves

- Define sound.
- Describe sound waves and how they are generated.
- Identify media through which sound waves can travel.

Crack! Crash! Thud! That's what you'd hear if you were in the forest when this old tree cracked and came crashing down to the ground. But what if there was nobody there to hear the tree fall? Would it still make these sounds? This is an old riddle. To answer the riddle correctly, you need to know the scientific definition of sound.

Defining Sound

In science, **sound** is defined as the transfer of energy from a vibrating object in waves that travel through matter. Most people commonly use the term sound to mean what they hear when sound waves enter their ears. The tree above generated sound waves when it fell to the ground, so it made sound according to the scientific definition. But the sound wasn't detected by a person's ears if there was nobody in the forest. So the answer to the riddle is both yes and no!

How Sound Waves Begin

All sound waves begin with vibrating matter. Look at the first guitar string on the left in the **Figure** 1.68. Plucking the string makes it vibrate. The diagram below the figure shows the wave generated by the vibrating string. The moving string repeatedly pushes against the air particles next to it, which causes the air particles to vibrate. The vibrations spread through the air in all directions away from the guitar string as longitudinal waves. In longitudinal waves, particles of the medium vibrate back and forth parallel to the direction that the waves travel. You can see an

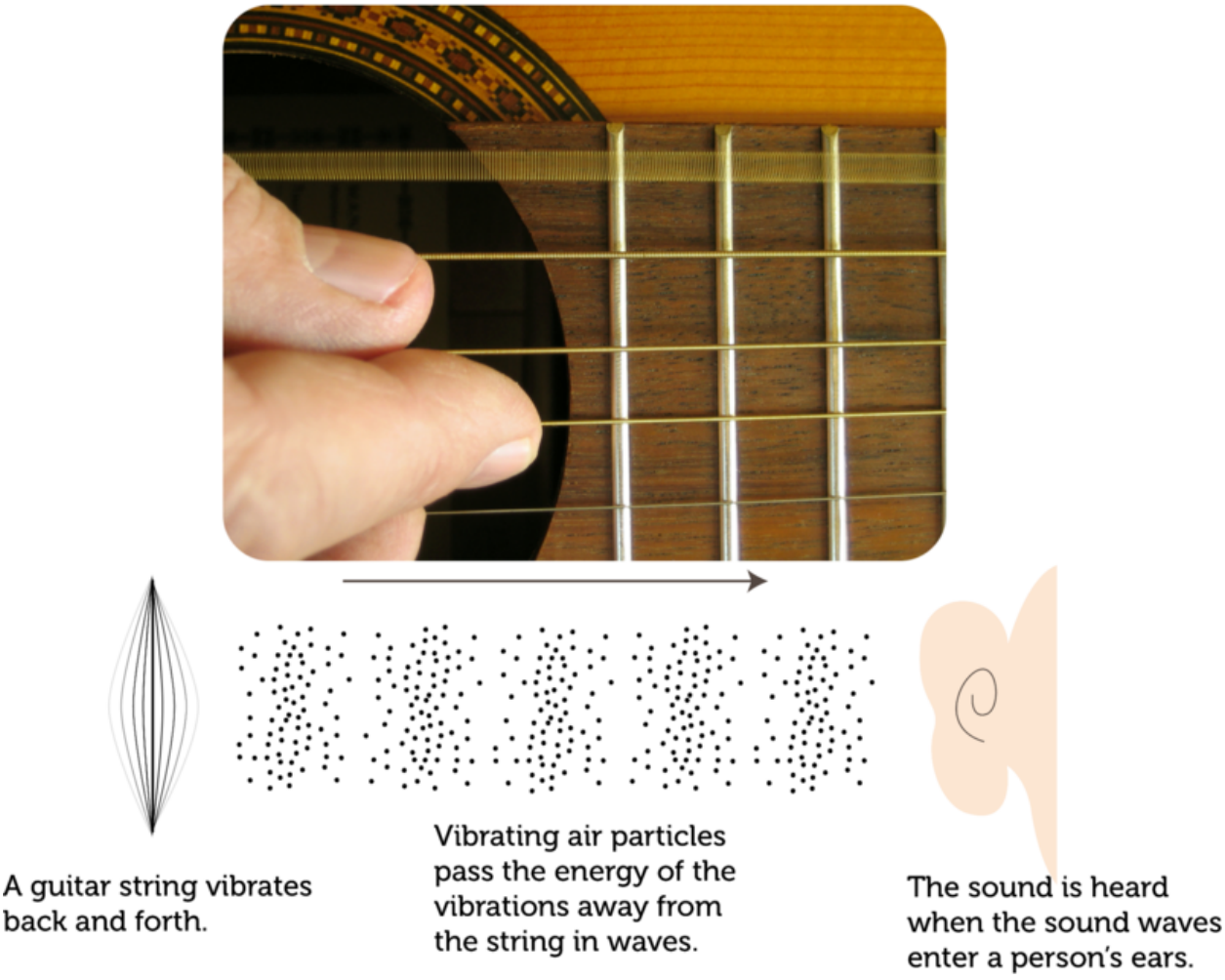

FIGURE 1.68

animation of sound waves traveling through air at this URL: http://www.mediacollege.com/audio/01/sound-waves.html

Q: If there were no air particles to carry the vibrations away from the guitar string, how would sound reach the ear?

A: It wouldn't unless the vibrations were carried by another medium. Sound waves are mechanical waves, so they can travel only though matter and not through empty space.

A Ticking Clock

The fact that sound cannot travel through empty space was first demonstrated in the 1600s by a scientist named Robert Boyle. Boyle placed a ticking clock in a sealed glass jar. The clock could be heard ticking through the air and glass of the jar. Then Boyle pumped the air out of the jar. The clock was still ticking, but the ticking sound could no longer be heard. That's because the sound couldn't travel away from the clock without air particles to pass the sound energy along. You can see an online demonstration of the same experiment—with a modern twist—at this URL: http://www.youtube.com/watch?v=b0JQt4u6-XI

Sound Waves and Matter

Most of the sounds we hear reach our ears through the air, but sounds can also travel through liquids and solids. If you swim underwater—or even submerge your ears in bathwater—any sounds you hear have traveled to your ears through the water. Some solids, including glass and metals, are very good at transmitting sounds. Foam rubber and heavy fabrics, on the other hand, tend to muffle sounds. They absorb rather than pass on the sound energy.

Q: How can you tell that sounds travel through solids?

A: One way is that you can hear loud outdoor sounds such as sirens through closed windows and doors. You can also hear sounds through the inside walls of a house. For example, if you put your ear against a wall, you may be able to eavesdrop on a conversation in the next room—not that you would, of course.

Summary

- In science, sound is defined as the transfer of energy from a vibrating object in waves that travel through matter.
- All sound waves begin with vibrating matter. The vibrations generate longitudinal waves that travel through matter in all directions.
- Most sounds we hear travel through air, but sounds can also travel through liquids and solids.

Vocabulary

- **sound**: Transfer of energy from a vibrating object in longitudinal waves that travel through matter.

Practice

Watch the video "How Sound Waves Travel" at the following URL. Then explain how sound waves begin and how they travel, using the human voice as an example. http://www.youtube.com/watch?v=_vYYqRVi8vY

Review

1. How is sound defined in science? How does this definition differ from the common meaning of the word?
2. Hitting a drum, as shown in the **Figure** 1.69, generates sound waves. Create a diagram to show how the sound waves begin and how they reach a person's ears.

3. How do you think earplugs work?

FIGURE 1.69

1.33 Speed of Sound

- Give the speed of sound in dry air at 20 °C.
- Describe variation in the speed of sound in different media.
- Explain the effect of temperature on the speed of sound.

Has this ever happened to you? You see a flash of lightning on the horizon, but several seconds pass before you hear the rumble of thunder. The reason? The speed of light is much faster than the speed of sound.

What Is the Speed of Sound?

The **speed of sound** is the distance that sound waves travel in a given amount of time. You'll often see the speed of sound given as 343 meters per second. But that's just the speed of sound under a certain set of conditions, specifically, through dry air at 20 °C. The speed of sound may be very different through other matter or at other temperatures.

Speed of Sound in Different Media

Sound waves are mechanical waves, and mechanical waves can only travel through matter. The matter through which the waves travel is called the medium (plural, media). The **Table** 1.3 gives the speed of sound in several different media. Generally, sound waves travel most quickly through solids, followed by liquids, and then by gases. Particles of matter are closest together in solids and farthest apart in gases. When particles are closer together, they can more quickly pass the energy of vibrations to nearby particles. You can explore the speed of sound in different media at this URL:

http://www.ltscotland.org.uk/resources/s/sound/speedofsound.asp?strReferringChannel=resources&strReferringPageID=tcm:4-248291-64

TABLE 1.3: speed of sound

Medium (20 °C)	Speed of Sound Waves (m/s)
Dry Air	343
Water	1437
Wood	3850
Glass	4540
Aluminum	6320

Q: The table gives the speed of sound in dry air. Do you think that sound travels more or less quickly through air that contains water vapor? (Hint: Compare the speed of sound in water and air in the table.)

A: Sound travels at a higher speed through water than air, so it travels more quickly through air that contains water vapor than it does through dry air.

Temperature and Speed of Sound

The speed of sound also depends on the temperature of the medium. For a given medium, sound has a slower speed at lower temperatures. You can compare the speed of sound in dry air at different temperatures in the following **Table** 1.4. At a lower temperature, particles of the medium are moving more slowly, so it takes them longer to transfer the energy of the sound waves.

TABLE 1.4: speed of sound

Temperature of Air	Speed of Sound Waves (m/s)
0 °C	331
20 °C	343
100 °C	386

Q: What do you think the speed of sound might be in dry air at a temperature of -20 °C?

A: For each 1 degree Celsius that temperature decreases, the speed of sound decreases by 0.6 m/s. So sound travels through dry, -20 °C air at a speed of 319 m/s.

Summary

- The speed of sound is the distance that sound waves travel in a given amount of time. The speed of sound in dry air at 20 °C is 343 meters per second.
- Generally, sound waves travel most quickly through solids, followed by liquids, and then by gases.
- For a given medium, sound waves travel more slowly at lower temperatures.

Vocabulary

- **speed of sound**: Speed at which sound waves travel, which is 343 m/s in dry air at 20 °C.

Practice

At the following URL, read about the speed of sound in different materials. Be sure to play the animation. Then answer the questions below. http://www.ndt-ed.org/EducationResources/HighSchool/Sound/speedinmaterials.htm

1. Describe what you hear when you play the animation. Explain your observations.

2. Name two properties of materials that affect the speed of sound waves. How do they affect the speed of sound?
3. Explain why sound waves moves more quickly through warmer air than cooler air.

Review

1. What is the speed of sound in dry air at 20 °C?
2. Describe variation in the speed of sound through various media.
3. Explain how temperature affects the speed of sound.