Section 17.1

1 FOCUS

Objectives

17.1.1 **Define** mechanical waves and **relate** waves to energy.
17.1.2 **Describe** transverse, longitudinal, and surface waves and **discuss** how they are produced.
17.1.3 **Identify** examples of transverse and longitudinal waves.
17.1.4 **Analyze** the motion of a medium as each kind of mechanical wave passes through it.

Reading Focus

Build Vocabulary L2

Paraphrase This section contains several words that may not be familiar to students: *medium*, *crest*, *trough*, *transverse*, *longitudinal*, *compression*, and *rarefaction*. Have students paraphrase these words using words they know. For example, they might construct a sentence such as, "In other words, a *medium* is the stuff carrying the wave."

Reading Strategy L2

a. Troughs **b.** Rest position; Longitudinal Wave: Compressions, Rarefactions, Rest position, Direction; Surface Wave: Circular motion that returns to same position, Direction of wave

2 INSTRUCT

What Are Mechanical Waves?

Build Science Skills L2

Inferring Have students look at Figure 1. Ask, **What happens to the swimmers in the pool as a wave passes?** *(The swimmers move up and down and back and forth.)* **What kind of energy do the swimmers have as they bob up and down?** *(Kinetic)* **From where do they get this energy?** *(From the wave)*
Logical, Visual

17.1 Mechanical Waves

Reading Focus

Key Concepts

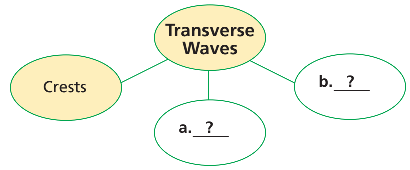
- What causes mechanical waves?
- What are the three main types of mechanical waves?

Vocabulary

- mechanical wave
- medium
- crest
- trough
- transverse wave
- compression
- rarefaction
- longitudinal wave
- surface wave

Reading Strategy

Previewing Copy the web diagram below. Use Figure 2 to complete the diagram. Then use Figures 3 and 4 to make similar diagrams for longitudinal waves and surface waves.



Have you ever gone to a wave pool at an amusement park? You can hear the laughter and screams as wave after wave passes by, giving the people a wild ride. It's obvious that waves are moving through the water, but you may not realize that the screams and laughter are also carried by waves. In this chapter, you will learn about the different kinds of mechanical waves, including sound waves.

What Are Mechanical Waves?

A **mechanical wave** is a disturbance in matter that carries energy from one place to another. Recall that energy is the ability to do work. In a wave pool, each wave carries energy across the pool. You can see the effects of a wave's energy when the wave lifts people in the water.

Figure 1 In a wave pool, the waves carry energy across the pool.

Mechanical waves require matter to travel through. The material through which a wave travels is called a **medium.** Solids, liquids, and gases all can act as mediums. In a wave pool, waves travel along the surface of the water. Water is the medium. Waves travel through a rope when you shake one end of it. In that case, the medium is the rope.

A mechanical wave is created when a source of energy causes a vibration to travel through a medium. A vibration is a repeating back-and-forth motion. When you shake a rope, you add energy at one end. The wave that results is a vibration that carries energy along the rope.

Section Resources

Print
- ***Reading and Study Workbook With Math Support,*** Section 17.1
- ***Transparencies,*** Chapter Pretest and Section 17.1

Technology
- ***Interactive Textbook,*** Section 17.1
- ***Presentation Pro CD-ROM,*** Chapter Pretest and Section 17.1
- ***Go Online,*** NSTA SciLinks, Vibrations and waves

Types of Mechanical Waves

Mechanical waves are classified by the way they move through a medium. **The three main types of mechanical waves are transverse waves, longitudinal waves, and surface waves.**

Transverse Waves When you shake one end of a rope up and down, the vibration causes a wave. Figure 2 shows a wave in a rope at three points in time. Before the wave starts, every point on the rope is in its rest position, represented by the dashed line. The highest point of the wave above the rest position is the **crest.** The lowest point below the rest position is the **trough** (TRAWF). You can see from the ribbon attached to the rope that crests and troughs are not fixed points on a wave. In Figure 2A, the ribbon is at a crest. In Figure 2C, the ribbon is at a trough. The motion of a single point on the rope is like the motion of a yo-yo. The point vibrates up and down between a maximum and minimum height.

Notice that the wave carries energy from left to right, in a direction perpendicular to the up-and-down motion of the rope. This is a transverse wave. A **transverse wave** is a wave that causes the medium to vibrate at right angles to the direction in which the wave travels.

Have you ever shaken crumbs off a picnic blanket? This is another example of a transverse wave. Shaking one end of the blanket up and down sends a transverse wave through the blanket. The up and down motion of the blanket helps to shake off the crumbs.

Go Online NSTA SCILINKS

For: Links on vibrations and waves
Visit: www.SciLinks.org
Web Code: ccn-2171

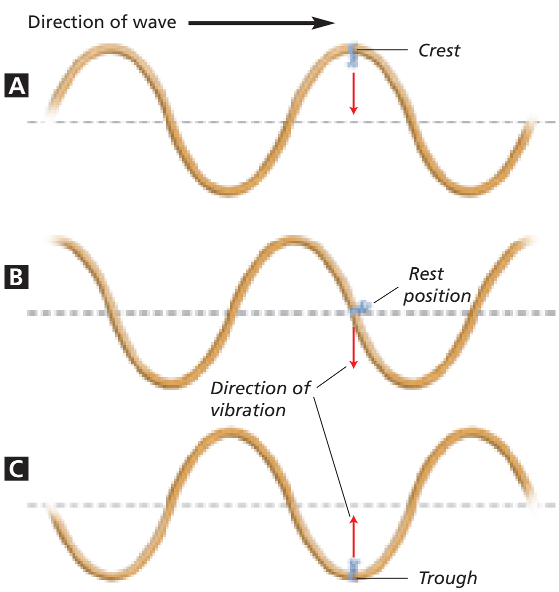


Figure 2 A transverse wave causes the medium to vibrate in a direction perpendicular to the direction in which the wave travels. In the wave shown here, each point on the rope vibrates up and down between a maximum and minimum height. **A** The ribbon is at a crest. **B** The ribbon is at the rest position. **C** The ribbon is at a trough. **Comparing and Contrasting** ***How does the direction of the wave compare with the direction in which the ribbon moves?***

Teacher Demo

Wave Dance

L2

Purpose Students will simulate transverse and longitudinal waves.

Materials 10 chairs, 10 students, space to move around

Class Time 20 minutes

Procedure Prepare students for the demonstration ahead of time. To simulate a transverse wave, students will do a wave like the one fans do at a football or baseball game. Place the chairs in a line and have each student sit in a chair. Each student rises when the student in front of him or her is fully standing. To simulate a longitudinal wave, have students stand in a line, arm-length apart. The first student steps forward and back, then taps the next student. When each student feels a tap, he or she takes a step forward and then a step back. These steps can be repeated as a dance.

Expected Outcome Students will recognize that waves occur when a disturbance moves through a medium, and students will distinguish between two different kinds of disturbance.
Kinesthetic, Visual

Types of Mechanical Waves

Use Visuals

L1

Figure 2 Have students examine the position of the ribbon in Figure 2A and Figure 2B. Ask, **How has the ribbon moved?** *(It has moved down. There is no left-to-right motion.)* **How does this compare to the direction of the wave?** *(Perpendicular)*
Visual

Go Online NSTA SCILINKS

Download a worksheet on vibrations and waves for students to complete, and find additional teacher support from NSTA SciLinks.

Customize for English Language Learners

Simplify the Presentation
In English, one word may have several different meanings. For that reason, students who are learning English may have additional difficulty grasping the scientific meanings of such words. Identify the multiple-meaning words in this section, such as *wave, matter,* and *medium.* Discuss with students the different meanings of each word and then explain which meaning is used in this section.

Answer to . . .

Figure 2 *The movement of the ribbon is up and down, which is perpendicular to the direction of the wave.*

Quick Lab

Observing Waves in a Medium

L2

Objective
After completing this activity, students will be able to
- describe a mechanical wave as a passage of energy through a medium, with no net movement of the medium.

Address Misconceptions

This lab can dispel the misconception that waves are parts of the medium that travel with the wave.

Skills Focus **Inferring**

Prep Time 15 minutes

Materials large, clear container; food coloring; ruler; droppers (optional)

Advance Prep Dilute food coloring with water. Use droppers to drop colored water into the container.

Class Time 15 minutes

Safety Students should wear a laboratory apron to avoid stains.

Teaching Tips
- Instruct students to observe the wave and the drop from the side.

Expected Outcome The drop of food coloring sits on the bottom of the container as the water wave moves back and forth. Some small currents disturb the food coloring.

Analyze and Conclude
1. The wave moved. The food coloring stayed in place on the bottom.
2. Students may hypothesize that water at the bottom is not disturbed by a surface wave, or that the disturbance depends on the depth of the water.
Visual, Logical

For Enrichment

L3

Float bits of cork on the water. Generate waves and observe the motion of the cork bits. Students should observe up-and-down motion and also side-to-side motion of the cork bits. Students should vary the depths of the water to see if this affects the results.
Visual

Quick Lab

Observing Waves in a Medium

Procedure

1. Fill a large, clear, square or rectangular container halfway with water. Add a drop of food coloring in the center of the container.
2. At the side of the container, submerge a ruler lengthwise. Move the ruler up and down to make waves.
3. Observe and record how the waves and the food coloring move.

Analyze and Conclude

1. **Comparing and Contrasting** Compare the movement of the waves with the movement of the food coloring.
2. **Formulating Hypotheses** Generate one or more hypotheses to explain the observed motion of the food coloring.

Longitudinal Waves Figure 3 shows a wave in a spring toy at two points in time. To start the wave, add energy to the spring by pushing and pulling the end of the spring. The wave carries energy along the spring from left to right. You can see in Figure 3A that when the wave starts, some of the coils are closer together than they would be in the rest position. An area where the particles in a medium are spaced close together is called a **compression** (kum PRESH un). As the compression moves to the right in Figure 3B, coils behind it are spread out more than they were in the rest position. An area where the particles in a medium are spread out is called a **rarefaction** (rehr uh FAK shun).

Look at the ribbon tied to one of the coils. The ribbon is first in a compression and then in a rarefaction. However, the ribbon and the coil it is tied to do not move along the spring. As compressions and rarefactions travel along the spring toward the right, each coil vibrates back and forth around its rest position. In this wave, the vibration is a back-and-forth motion of the coil that is parallel to, or in the same direction as, the direction in which the wave moves. This is a longitudinal wave. A **longitudinal wave** (lawn juh TOO duh nul) is a wave in which the vibration of the medium is parallel to the direction the wave travels.

Waves in springs are not the only kind of longitudinal waves. P waves (originally called primary waves) are longitudinal waves produced by earthquakes. Because P waves can travel through Earth, scientists can use these waves to map Earth's unseen interior.

Reading Checkpoint *What are compressions and rarefactions?*

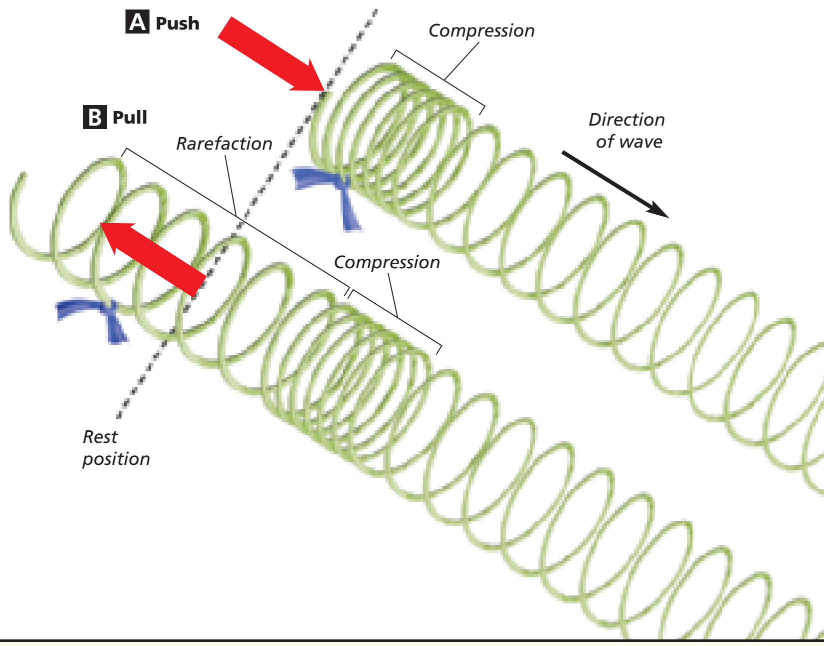


Figure 3 A longitudinal wave causes the medium to vibrate in a direction parallel to the direction in which the wave travels. Each point on the spring vibrates back and forth about its rest position. **A** When the end of the spring is pushed, a compression starts to move along the spring. **B** When the end of the spring is pulled, a rarefaction follows the compression along the spring.

Facts and Figures

Surfing Surfing originated in Polynesia and was developed in Hawaii. Native Hawaiians rode long, heavy, carved wooden surfboards. Surfing is possible because of the properties of waves as they enter shallower water. The speed of a wave in shallow water depends on the depth of the water. As a wave approaches the shore, it slows down. In shallow water with a sloping bottom, the front portion of the wave is in shallower water and moving slower than the rear portion, so the back of the wave catches up with the front. This causes the wave to "break." Surfers ride the breaking wave as the surfboard slides down the steep front of the wave. Modern surfboards are made from a foam core covered with plastic resin. These lighter and smaller surfboards are much easier to handle than the heavy wooden boards used by early Hawaiians.

Surface Waves If you ask people to describe waves, most likely they will describe ocean waves before they think of the waves that travel in a rope or a spring. Ocean waves are the most familiar kind of surface waves. A **surface wave** is a wave that travels along a surface separating two media.

The ocean wave in Figure 4 travels at the surface between water and air. The floating fishing bobber helps to visualize the motion of the medium as the wave carries energy from left to right. When a crest passes the bobber, the bobber moves up. When a trough passes, the bobber moves down. This up-and-down motion, like the motion of a transverse wave, is perpendicular to the direction in which the wave travels. But the bobber also is pushed back and forth by the surface wave. This back-and-forth motion, like the motion of a longitudinal wave, is parallel to the direction in which the wave travels. When these two motions combine in deep water, the bobber moves in a circle.

If you watched the bobber for ten minutes, it would not move closer to shore. Most waves do not transport matter from one place to another. But when ocean waves approach the shore, they behave differently. Perhaps you have seen seaweed washed ashore by breaking waves. As a wave enters shallow water, it topples over on itself because friction with the shore slows down the bottom of the wave. The top of the wave continues forward at its original speed. As a result, the wave carries the medium, along with anything floating in it, toward the shore.

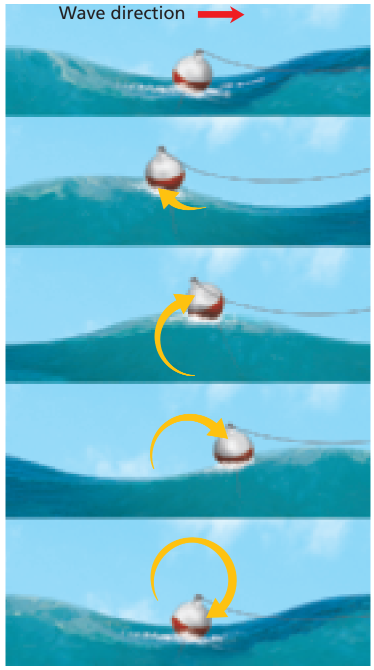


Figure 4 As the ocean wave moves to the right, the bobber moves in a circle, returning to its original position. **Making Generalizations** *If these were breaking waves near the shore, what would happen to the bobber over time?*

Section 17.1 Assessment

Reviewing Concepts

1. Describe how mechanical waves are produced.
2. List the three main types of mechanical waves.
3. For each type of wave, compare the vibration of the medium to the direction of the wave.
4. Name one example of each type of wave.

Critical Thinking

5. **Comparing and Contrasting** How are transverse and longitudinal waves similar? How are they different?
6. **Applying Concepts** A spring hangs from the ceiling. Describe how a single coil moves as a longitudinal wave passes through the spring.
7. **Interpreting Diagrams** In Figure 4, why is the first position of the bobber the same as the fifth position of the bobber?

Connecting Concepts

Energy Review potential and kinetic energy in Section 15.1. Then, describe the energy changes in a single coil of a spring as longitudinal waves pass through it.

Build Reading Literacy L1

Summarize Refer to page **598D** in **Chapter 20**, which provides the guidelines for summarizing.

Have students construct a table to summarize what they have learned about mechanical waves. The rows could be labeled with the kind of wave and the columns could be labeled with the wave properties.
Logical

3 ASSESS

Evaluate Understanding L2

Have students write a paragraph summarizing the content of this section.

Reteach L1

Use Figures 2 and 3 to summarize the similarities and differences between transverse and longitudinal waves.

Connecting Concepts

The coil gains elastic potential energy and has the least kinetic energy when it is in a compression. In a rarefaction, the coil is moving fastest, has its greatest kinetic energy, and its elastic potential energy is at a minimum.

Interactive Textbook If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 17.1.

Answer to . . .

Figure 4 *The bobber would be pushed to shore by breaking waves.*

Reading Checkpoint *Compressions are areas where particles in a medium are spaced close together. Rarefactions are areas where particles in a medium are spread out.*

Section 17.1 Assessment

1. Mechanical waves are formed when a source of energy causes a vibration to travel through a medium.
2. Transverse, longitudinal, and surface waves
3. Transverse wave: medium vibrates perpendicular to the direction the wave travels; Longitudinal wave: medium vibrates parallel to the direction the wave travels; Surface wave: medium vibrates both perpendicular and parallel to wave direction (circular motion)
4. Transverse wave: shaking the end of a rope up and down; Longitudinal wave: compressions and rarefactions moving through a spring; Surface wave: deep water wave in an ocean
5. Both kinds of waves carry energy through a medium without transferring matter. In transverse waves, the medium vibrates perpendicular to the direction in which the wave travels, while in longitudinal waves, the medium vibrates parallel to the direction in which the wave travels.
6. The coil will move up and down about its rest position as compressions and rarefactions pass through.
7. The bobber has moved in a full circle that returns it back to its starting position (because one complete surface wave has passed through the bobber's position).