SECTION 2

What Is a Force?

You have probably heard the word force *in everyday conversation. People say things such as "That storm had a lot of force" or "Our football team is a force to be reckoned with." But what, exactly, is a force?*

In science, a **force** is simply a push or a pull. All forces have both size and direction. A force can change the acceleration of an object. This acceleration can be a change in the speed or direction of the object. In fact, any time you see a change in an object's motion, you can be sure that the change in motion was created by a force. Scientists express force using a unit called the **newton** (N).

READING WARM-UP

Objectives

- Describe forces, and explain how forces act on objects.
- Determine the net force when more than one force is acting on an object.
- Compare balanced and unbalanced forces.
- Describe ways that unbalanced forces cause changes in motion.

Terms to Learn

force
newton
net force

READING STRATEGY

Reading Organizer As you read this section, make a table comparing balanced forces and unbalanced forces.

Forces Acting on Objects

All forces act on objects. For any push to occur, something has to receive the push. You can't push nothing! The same is true for any pull. When doing schoolwork, you use your fingers to pull open books or to push the buttons on a computer keyboard. In these examples, your fingers are exerting forces on the books and the keys. So, the forces act on the books and keys. Another example of a force acting on an object is shown in **Figure 1.**

However, just because a force acts on an object doesn't mean that motion will occur. For example, you are probably sitting on a chair. But the force you are exerting on the chair does not cause the chair to move. The chair doesn't move because the floor is also exerting a force on the chair.

Figure 1 *The bulldozer is exerting a force on the pile of soil. But the pile of soil also exerts a force by just sitting on the ground!*

Unseen Sources and Receivers of Forces

It is not always easy to tell what is exerting a force or what is receiving a force, as shown in **Figure 2.** You cannot see what exerts the force that pulls magnets to refrigerators. And you cannot see that the air around you is held near Earth's surface by a force called *gravity*.

Figure 2 *Something that you cannot see exerts a force that makes this cat's fur stand up.*

Determining Net Force

Usually, more than one force is acting on an object. The **net force** is the combination all of the forces acting on an object. So, how do you determine the net force? The answer depends on the directions of the forces.

Forces in the Same Direction

Suppose the music teacher asks you and a friend to move a piano. You pull on one end and your friend pushes on the other end, as shown in **Figure 3.** The forces you and your friend exert on the piano act in the same direction. The two forces are added to determine the net force because the forces act in the same direction. In this case, the net force is 45 N. This net force is large enough to move the piano—if it is on wheels, that is!

Reading Check **How do you determine the net force on an object if all forces act in the same direction?** (*See the Appendix for answers to Reading Checks.*)

force a push or a pull exerted on an object in order to change the motion of the object; force has size and direction

newton the SI unit for force (symbol, N)

net force the combination of all of the forces acting on an object

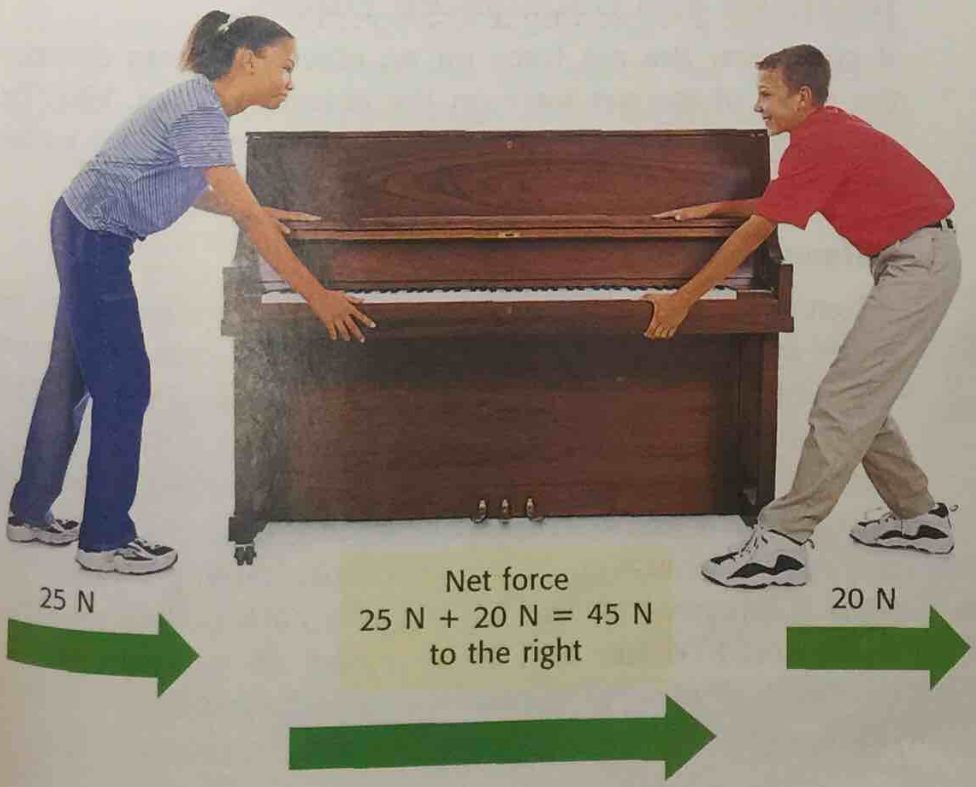

Figure 3 *When forces act in the same direction, you add the forces to determine the net force. The net force will be in the same direction as the individual forces.*

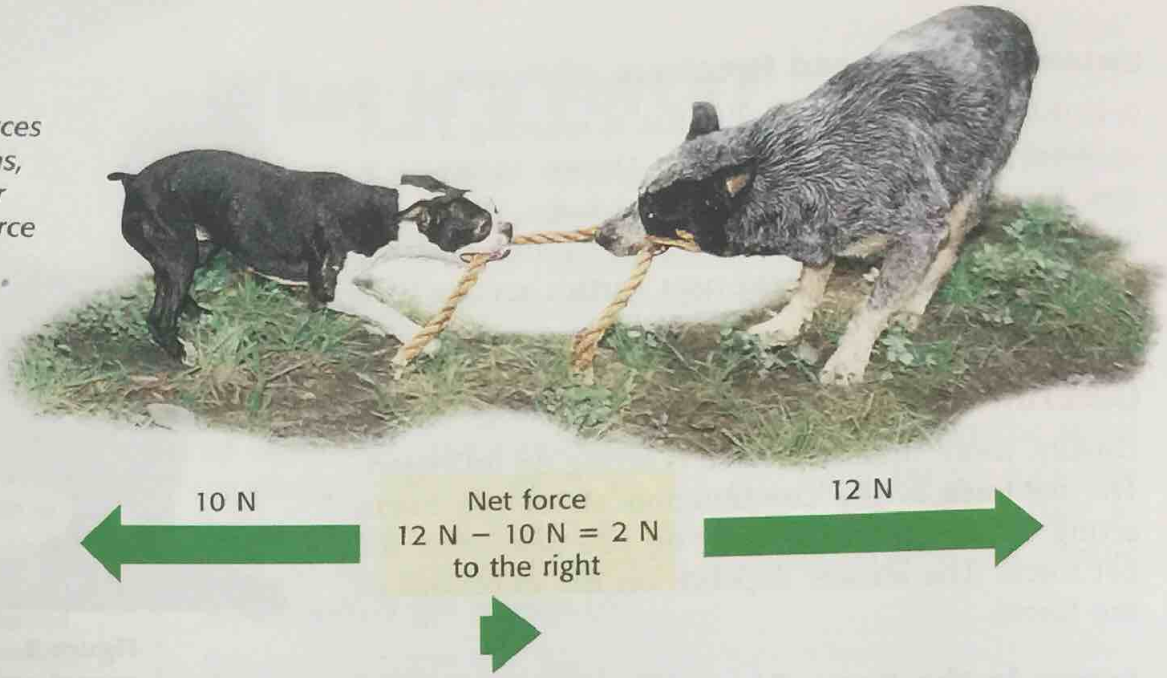

Figure 4 *When two forces act in opposite directions, you subtract the smaller force from the larger force to determine the net force. The net force will be in the same direction as the larger force.*

Forces in Different Directions

Look at the two dogs playing tug of war in **Figure 4.** Each dog is exerting a force on the rope. But the forces are in opposite directions. Which dog will win the tug of war?

Because the forces are in opposite directions, the net force on the rope is found by subtracting the smaller force from the larger one. In this case, the net force is 2 N in the direction of the dog on the right. Give that dog a dog biscuit!

Reading Check **What is the net force on an object when you combine a force of 7 N north with a force of 5 N south?**

Balanced and Unbalanced Forces

If you know the net force on an object, you can determine the effect of the net force on the object's motion. Why? The net force tells you whether the forces on the object are balanced or unbalanced.

Balanced Forces

When the forces on an object produce a net force of 0 N, the forces are *balanced*. Balanced forces will not cause a change in the motion of a moving object. And balanced forces do not cause a nonmoving object to start moving.

Many objects around you have only balanced forces acting on them. For example, a light hanging from the ceiling does not move because the force of gravity pulling down on the light is balanced by the force of the cord pulling upward. A bird's nest in a tree and a hat resting on your head are also examples of objects that have only balanced forces acting on them. **Figure 5** shows another example of balanced forces.

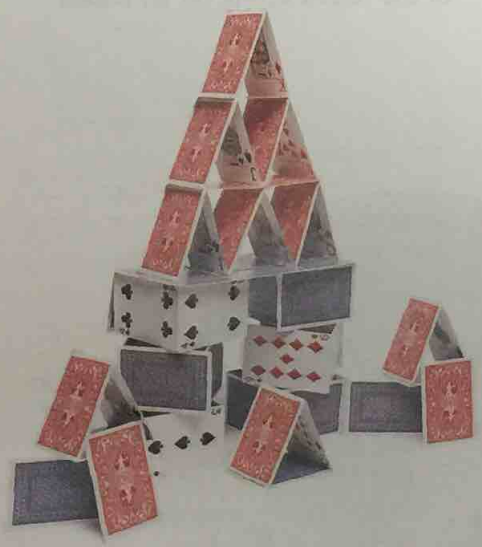

Figure 5 *Because all the forces on this house of cards are balanced, none of the cards move.*

Unbalanced Forces

When the net force on an object is not 0 N, the forces on the object are *unbalanced*. Unbalanced forces produce a change in motion, such as a change in speed or a change in direction. Unbalanced forces are necessary to cause a nonmoving object to start moving.

Unbalanced forces are also necessary to change the motion of moving objects. For example, consider the soccer game shown in **Figure 6.** The soccer ball is already moving when it is passed from one player to another. When the ball reaches another player, that player exerts an unbalanced force—a kick—on the ball. After the kick, the ball moves in a new direction and has a new speed.

An object can continue to move when the unbalanced forces are removed. For example, when it is kicked, a soccer ball receives an unbalanced force. The ball continues to roll on the ground long after the force of the kick has ended.

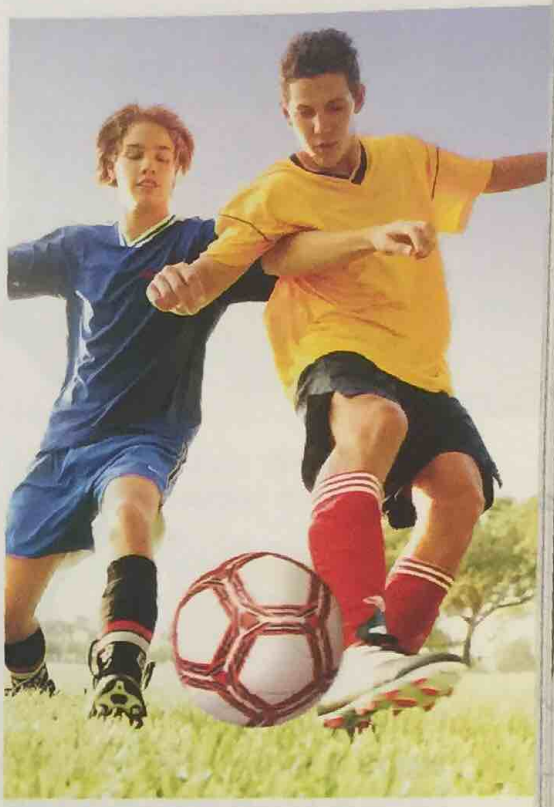

Figure 6 *The soccer ball moves because the players exert an unbalanced force on the ball each time they kick it.*

Balanced and Unbalanced Forces in Action

Balanced and unbalanced forces and the interactions between them are important in all parts of your life. Balanced and unbalanced forces help you enjoy your free time, play sports, travel, and move your body.

Forces in Recreation

How do you spend your free time? Perhaps you play board games, read, or ride a skateboard. Forces are important in all these recreational activities. Your game piece stays on a game board because all of the forces on it are balanced. But you exert unbalanced forces to lift and roll the dice. Balanced forces keep your book open so that you can read it. But unbalanced forces are needed to turn the pages. Balanced and unbalanced forces are also important for the skateboarder in **Figure 7.**

Figure 7 *A skateboarder stays on his skateboard when the forces on him are balanced. But unbalanced forces let him have fun going down a ramp.*

Figure 8 *All the forces on this skater are balanced as she glides across the ice. But an unbalanced force was needed for her to start moving.*

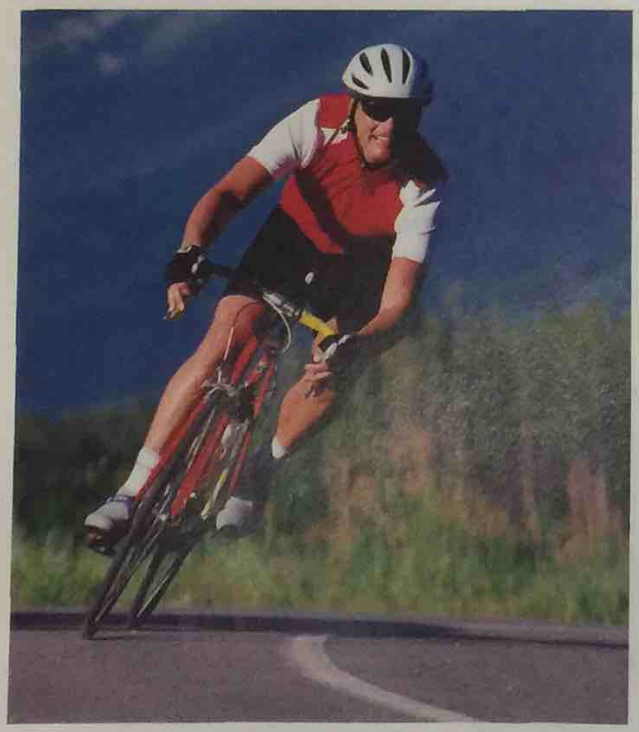

Figure 9 *Balanced forces keep a cyclist on his bicycle, but unbalanced forces are needed for him to turn corners or accelerate.*

Forces in Sports

Athletes use balanced and unbalanced forces all the time—even if they don't realize it. The figure skater in **Figure 8** probably doesn't know that balanced forces are helping her look graceful on the ice.

Now, think about what has to happen for a football placekicker to kick a field goal. First, the center exerts an unbalanced force on the football to snap the ball to the holder. Next, the holder makes sure that all the forces on ball are balanced as he or she holds the ball steady for the kicker. The kicker then exerts an unbalanced force on the ball to send it sailing through the goal posts.

A swimmer also uses balanced and unbalanced forces. The upward and downward forces on a swimmer have to be balanced so that the swimmer will stay afloat. If they weren't balanced, the swimmer would sink! To move forward, a swimmer pushes on the water with his or her arms and legs. These pushes create unbalanced forces that move the swimmer forward.

Forces in Transportation

The purpose of transportation is to move. And you already know that unbalanced forces are needed to start motion. The engines in cars, buses, and trains exert forces that turn their wheels to move forward or backward. Propellers on motorboats exert forces on the water to move the boat, and wind exerts forces on a sail to move a sailboat forward.

But balanced forces are also important in transportation. For example, the cyclist in **Figure 9** doesn't fall off his bicycle because the forces on him are balanced. Also, airplanes stay at their cruising altitude only when the downward force of gravity is balanced with an upward force called *lift*. Lift is created as an airplane moves through the air. The shape of an airplane's wings helps create lift, so a pilot can change the amount of lift by moving the flaps on the wings. If the pilot of the plane wants to land the plane, he or she has to decrease lift so that the force of gravity is greater than the lift. When this happens, gravity and lift are no longer balanced and the plane starts moving downward.

Reading Check **What two forces must be balanced so that a plane can fly at a certain altitude?**

Forces in the Human Body

Nod your head. Now, hold it still. You've just experienced unbalanced and balanced forces on your body. To move any part of your body, your muscles have to exert unbalanced forces. For example, your muscles have to exert a force on your arm if you want to raise your hand in class. To hold any part of your body still, the forces on it have to be balanced, as shown in **Figure 10.** But unbalanced forces are always acting in your body even when you are completely still. For example, your blood flows through your body because the muscles of the heart exert unbalanced forces to keep the heart beating.

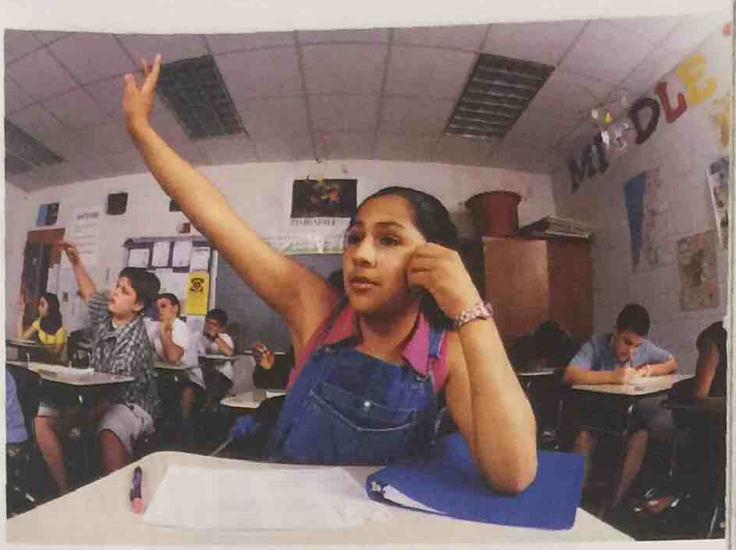

Figure 10 *To keep her hand up, this girl's muscles have to continue exerting a force to balance the force of gravity.*

SECTION Review

Summary

- A force is a push or a pull. Forces have size and direction and are expressed in newtons.
- Force is always exerted by one object on another object.
- Net force is determined by combining forces. Forces in the same direction are added. Forces in opposite directions are subtracted.
- Balanced forces produce no change in motion. Unbalanced forces produce a change in motion.
- Interactions of balanced and unbalanced forces are useful in recreation, sports, transportation, and the human body.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *force* and *net force*.

Understanding Key Ideas

2. Which of the following may happen when an object receives unbalanced forces?
   - **a.** The object changes direction.
   - **b.** The object changes speed.
   - **c.** The object starts to move.
   - **d.** All of the above
3. Explain the difference between balanced and unbalanced forces.
4. Give an example of an unbalanced force causing a change in motion.
5. Give an example of an object that has balanced forces acting on it.
6. Explain the meaning of the phrase "Forces act on objects."

Math Skills

7. A boy pulls a wagon with a force of 6 N east as another boy pushes it with a force of 4 N east. What is the net force?

Critical Thinking

8. **Making Inferences** When finding net force, why must you know the directions of the forces acting on an object?
9. **Applying Concepts** List three forces that you exert when riding a bicycle.
10. **Analyzing Processes** Think about an activity that you do in your free time. Analyze the interactions of balanced and unbalanced forces needed to do that activity.
11. **Applying Concepts** How does the interaction of balanced and unbalanced forces help you get from your home to school?