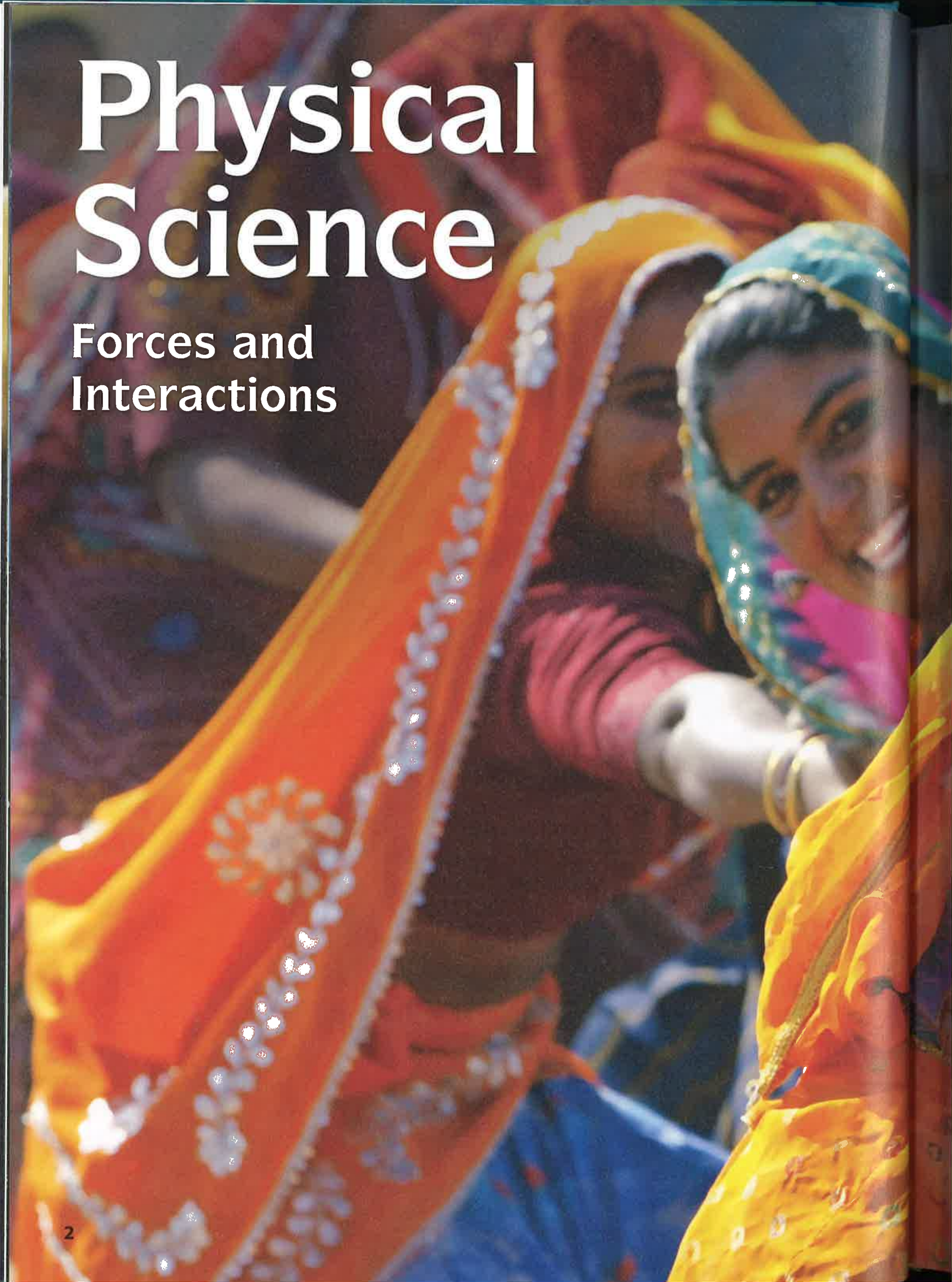
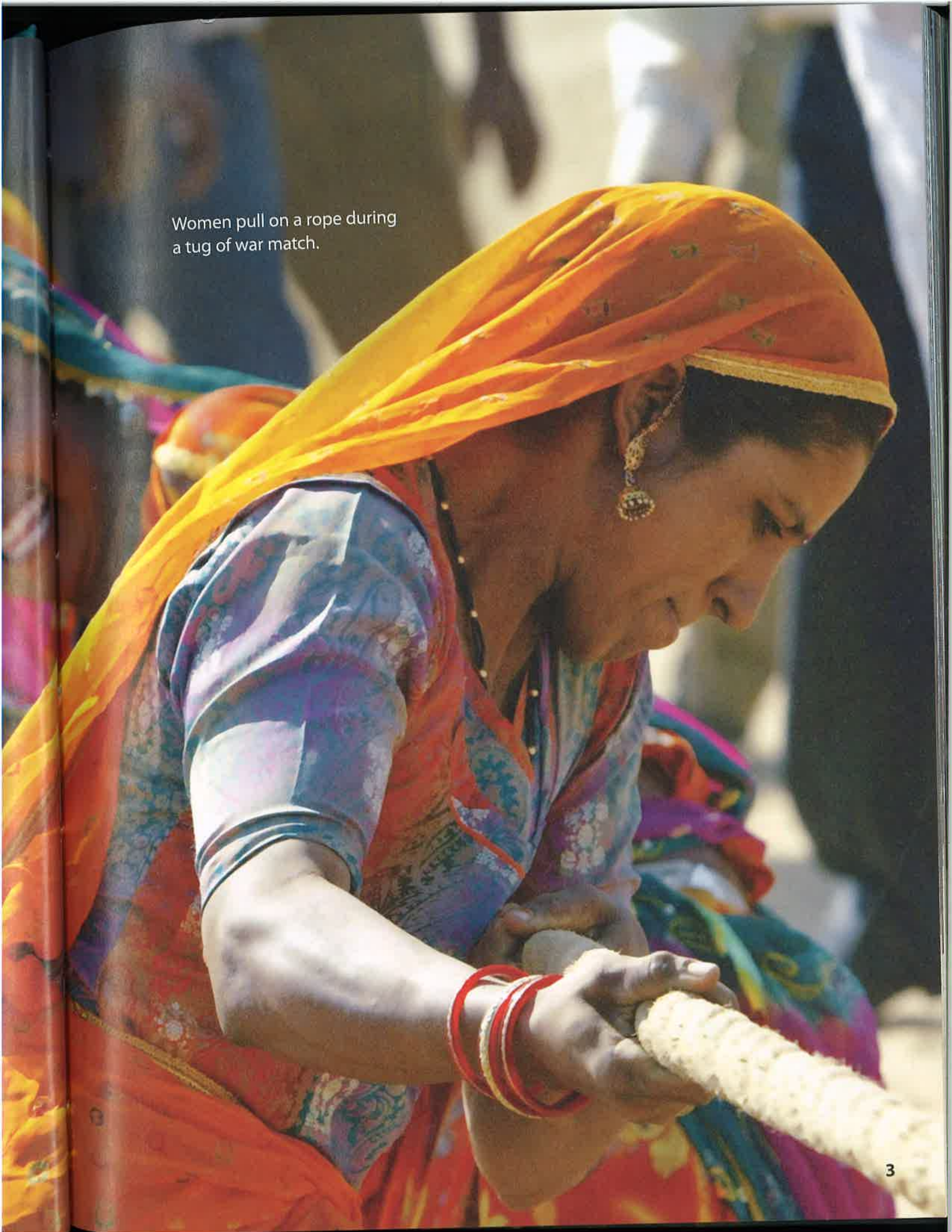
Physical Science

Forces and Interactions





Women pull on a rope during a tug of war match.

Pushes and Pulls

These athletes are in a race across dunes in the Sahara, a desert in North Africa. They use their strength to apply forces in the race. A **force** is a push or a pull. Every time a particular object is moved, a force is acting on it. You use forces when you push on the pedals of your bicycle or pull a door closed.

Athletes in this part of the race push and pull a team member in a special wheelchair.

NEXT GENERATION SCIENCE STANDARDS | DISCIPLINARY CORE IDEAS
PS2.A: Forces and Motion
Each force acts on one particular object and has both strength and a direction. (3-PS2-1)

Every force has a strength and a direction. In this desert race, team members in front pull the wheeled cart. Those behind it push the cart. All the team members are applying forces in the same forward direction. The cart moves in the direction of the forces.

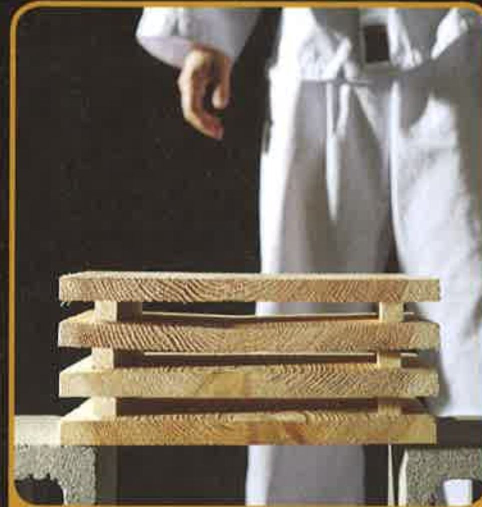
Wrap It Up!

My science notebook

1. **Define** What is a force?
2. **Relate** How does the direction of a push relate to the direction that the object moves?
3. **Infer** Suppose more team members pushed and pulled the cart. How might the force the people apply to the cart change?

Balanced Forces

The blackbelt studies four boards. The boards rest on two concrete blocks. When objects are in contact, they exert forces on each other. Gravity pulls down on the boards. The cement blocks push up on them. These **balanced forces** cancel each other out. The **net force,** or overall force, on the boards is zero.

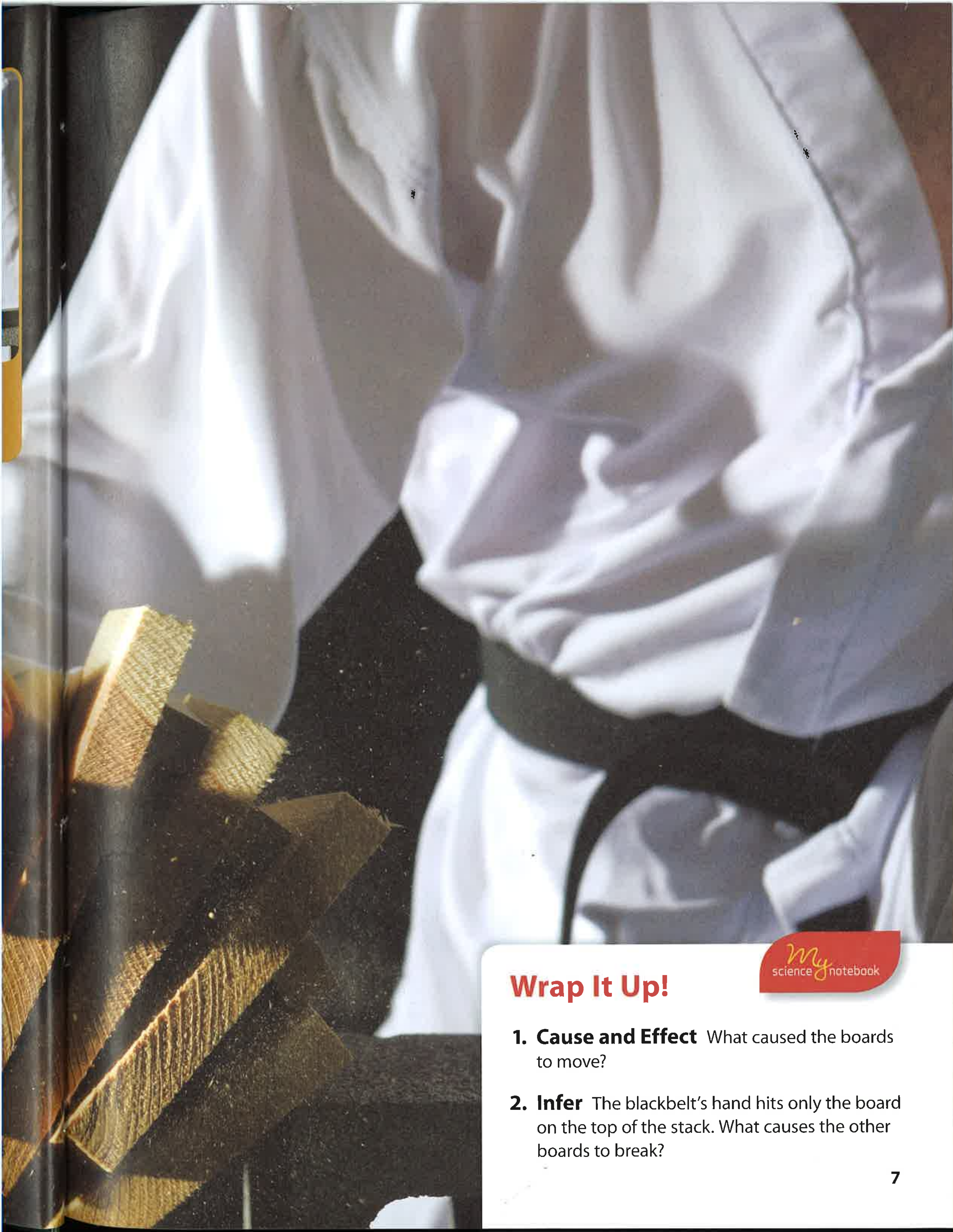


While forces acting on the boards are balanced, the boards do not move.

HYAH! The blackbelt hits the top board! The hand striking the board applies another force to it. The added downward force causes all the boards to move. The boards break and their pieces scatter.

When the blackbelt's hand strikes the top board, the forces acting on the board are no longer balanced.

NEXT GENERATION SCIENCE STANDARDS | DISCIPLINARY CORE IDEAS
PS2.A: Forces and Motion
Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (3-PS2-1)
PS2.B: Types of Interactions
Objects in contact exert forces on each other. (3-PS2-1)



Wrap It Up!

my science notebook

1. **Cause and Effect** What caused the boards to move?

2. **Infer** The blackbelt's hand hits only the board on the top of the stack. What causes the other boards to break?

Unbalanced Forces

A game of tug-of-war can be fun! Both team's members hold the rope tightly in their hands. The rope stays in one place as both teams pull with all their might. When the two teams pull in opposite directions with the same force, the net force is zero. The forces on the rope are balanced.

NEXT GENERATION SCIENCE STANDARDS | DISCIPLINARY CORE IDEAS

PS2.A: Forces and Motion

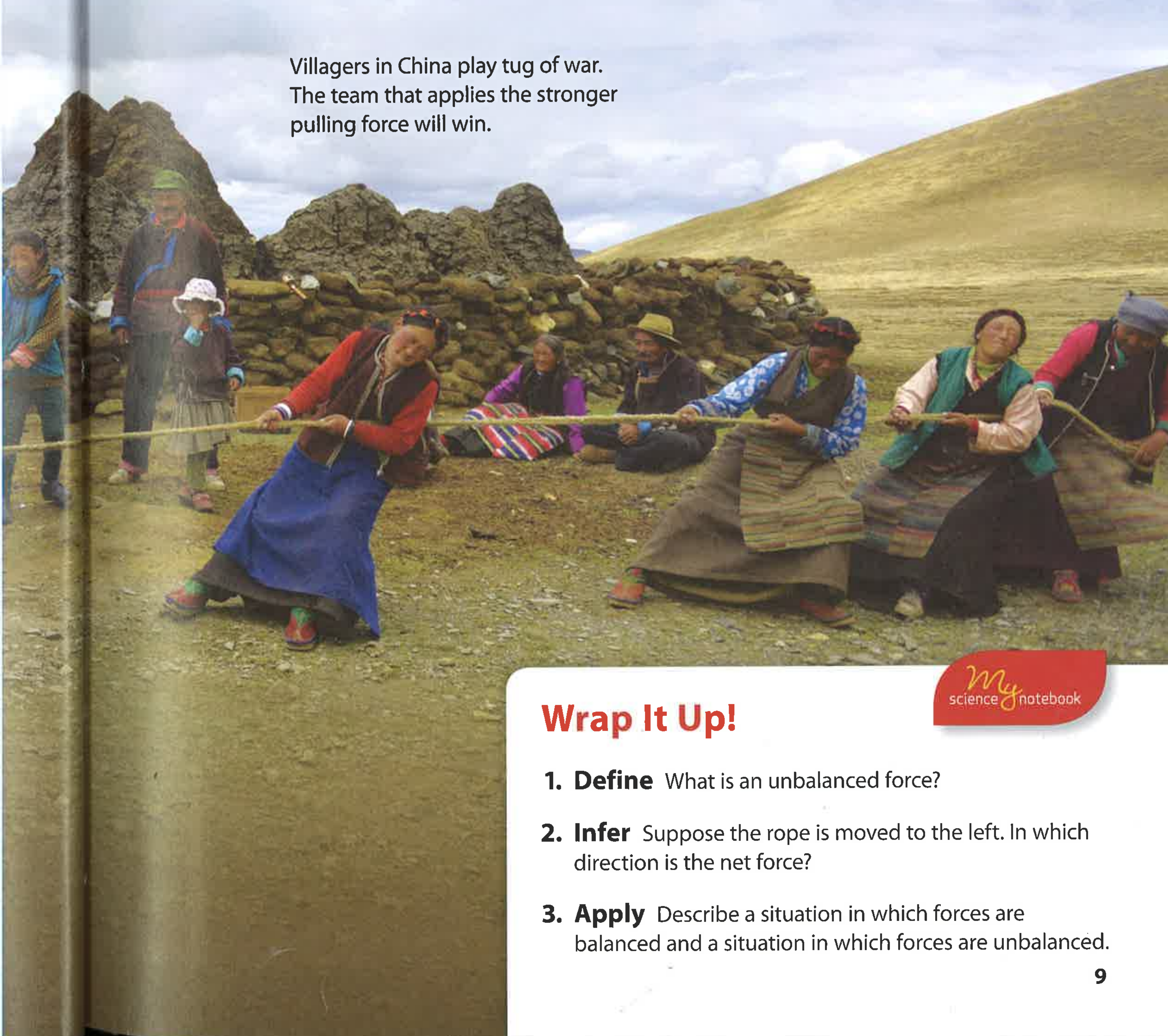
Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (3-PS2-1)

PS2.B: Types of Interactions

Objects in contact exert forces on each other. (3-PS2-1)

Now the women on the right pull with more force than the men on the left. The rope is moved to the right, the direction in which the women are pulling. The forces on the rope are unbalanced. **Unbalanced forces** cause an object to move.

When forces are unbalanced, they no longer add up to zero. In this case, the net force is to the right, and the rope is moved to the right.



Villagers in China play tug of war. The team that applies the stronger pulling force will win.

My science notebook

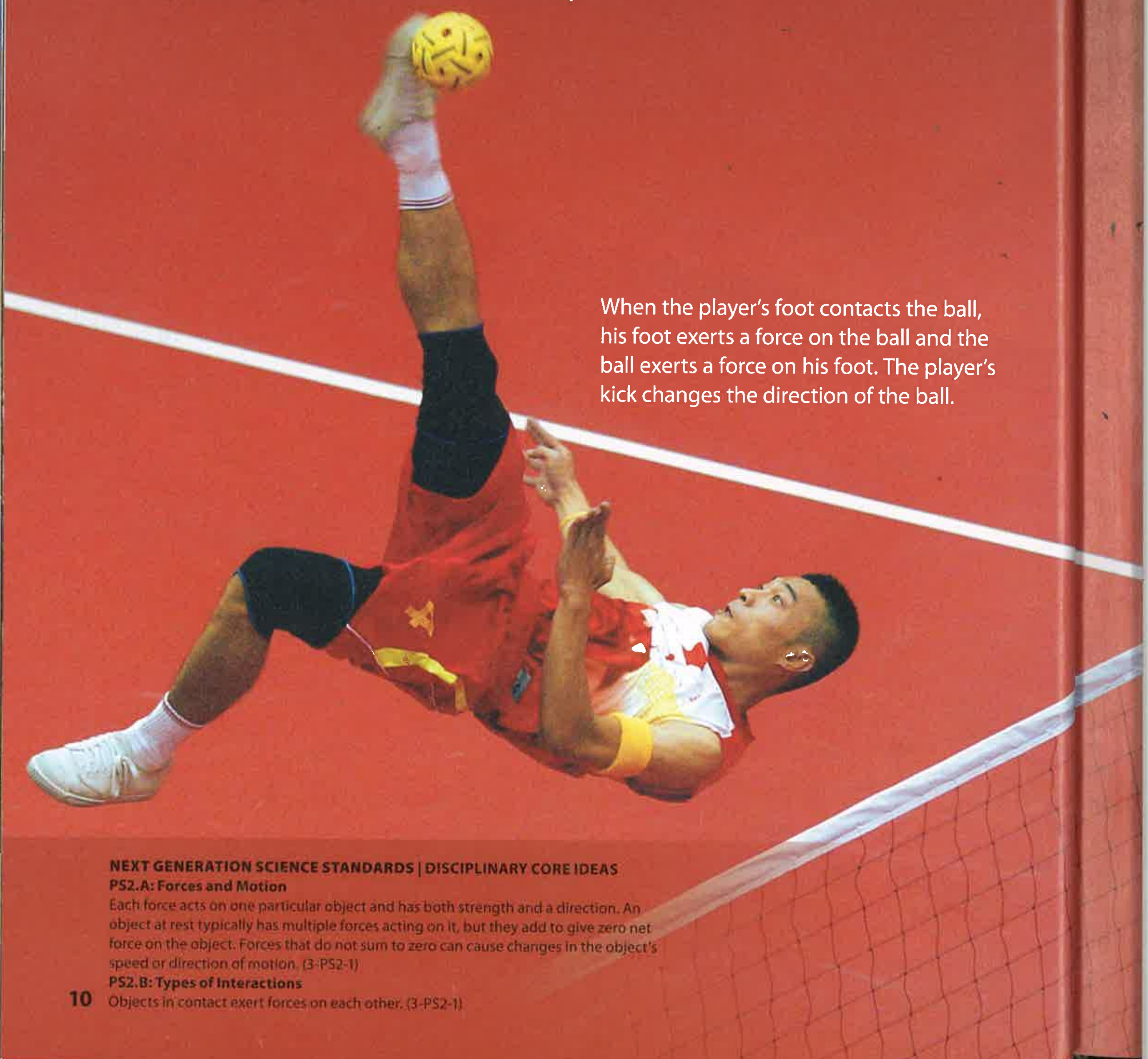
Wrap It Up!

1. **Define** What is an unbalanced force?
2. **Infer** Suppose the rope is moved to the left. In which direction is the net force?
3. **Apply** Describe a situation in which forces are balanced and a situation in which forces are unbalanced.

Changing Direction

Athletes use forces in games of all types. This photo shows a type of kick volleyball called sepak takraw that is often played in Southeast Asia.

A skilled player can control every motion of the ball. The player uses forces to start the ball moving, changing it's direction and speed.



When the player's foot contacts the ball, his foot exerts a force on the ball and the ball exerts a force on his foot. The player's kick changes the direction of the ball.

NEXT GENERATION SCIENCE STANDARDS | DISCIPLINARY CORE IDEAS

PS2.A: Forces and Motion

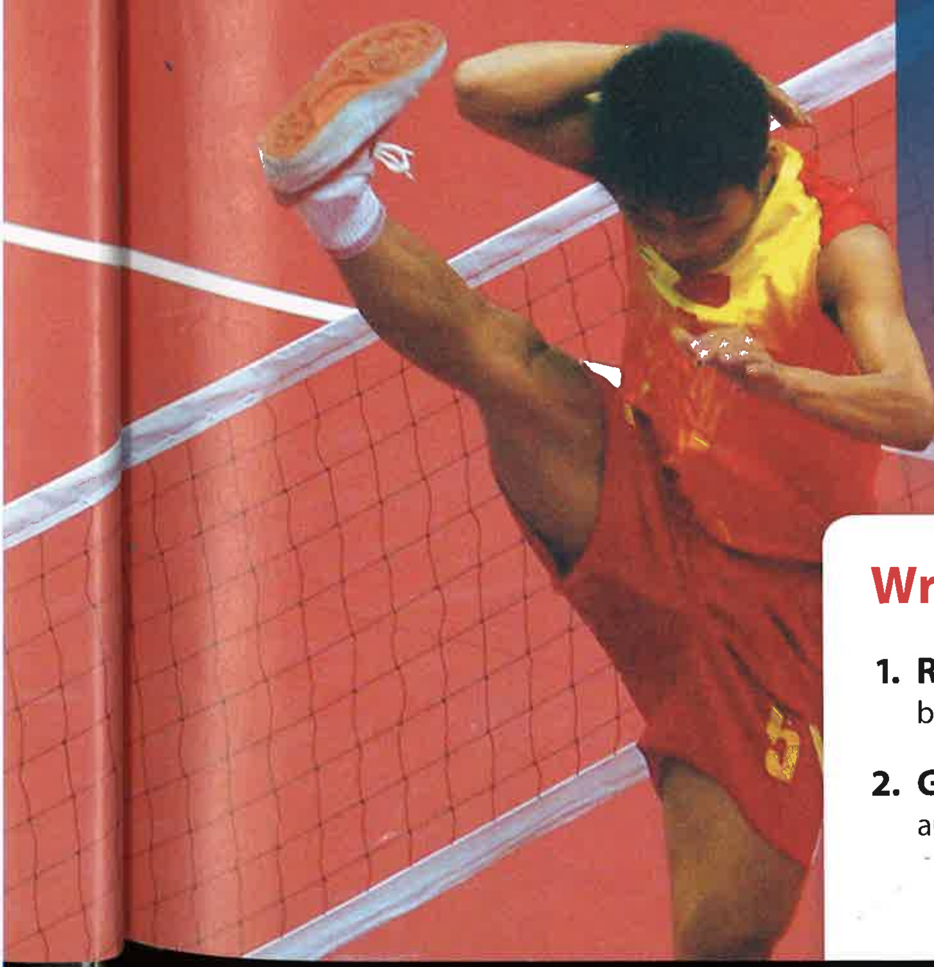
Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (3-PS2-1)

PS2.B: Types of Interactions

Objects in contact exert forces on each other. (3-PS2-1)

A strong force will cause the ball to move faster than a weak force. He uses just the right force in the right direction to move the ball over the net.

Think of the force you would need to move this ball over the net. Would you need a push or a pull? How strong of a force would you need? In which direction would you apply the force?



SCIENCE in a SNAP

Change of Motion

1 Apply a gentle force to a ball by tapping it with a pencil. How did you change its motion?

2 How else can you change the motion of the ball? Use the pencil to change the motion of a ball in different ways. Can you make the ball move faster? Slower? To the left or right? Can you make it stop?

Wrap It Up!

my science notebook

1. **Recall** Are the forces on the ball in the photo balanced or unbalanced? How do you know?
2. **Generalize** In what ways can forces change an object's motion?

NATIONAL GEOGRAPHIC LEARNING | **Think Like a Scientist**

Plan and Conduct an Investigation

Like these players, you can use forces to change the motion of an object. Your object will be a cotton ball. The force will be the push of air as you blow through a straw. How the cotton ball moves is up to you!

1. Ask a question.

How can you use balanced and unbalanced forces to move a cotton ball through an obstacle course?

2. Plan and conduct an investigation.

Try blowing through the straw on the cotton ball to get a feel for how it moves. Now for the challenge—you must use balanced and unbalanced forces to move your cotton ball in at least three of the following ways:

- around a corner
- through a tube
- forward 10 centimeters and then stop
- up or down a ramp
- stay still while air is blown on it

Look at the materials available. What will you use to build your course? Draw a picture of your course and list your materials. Identify the three ways your cotton ball will move. Then build and test your course. Record your observations.

3. Analyze results and revise.

Review your observations. Check off each way the cotton ball moved. Did the cotton ball move the way you wanted it to? How can your course be improved? Change your course and test it again. Remember to record both your changes and your results.

NEXT GENERATION SCIENCE STANDARDS | PERFORMANCE EXPECTATION

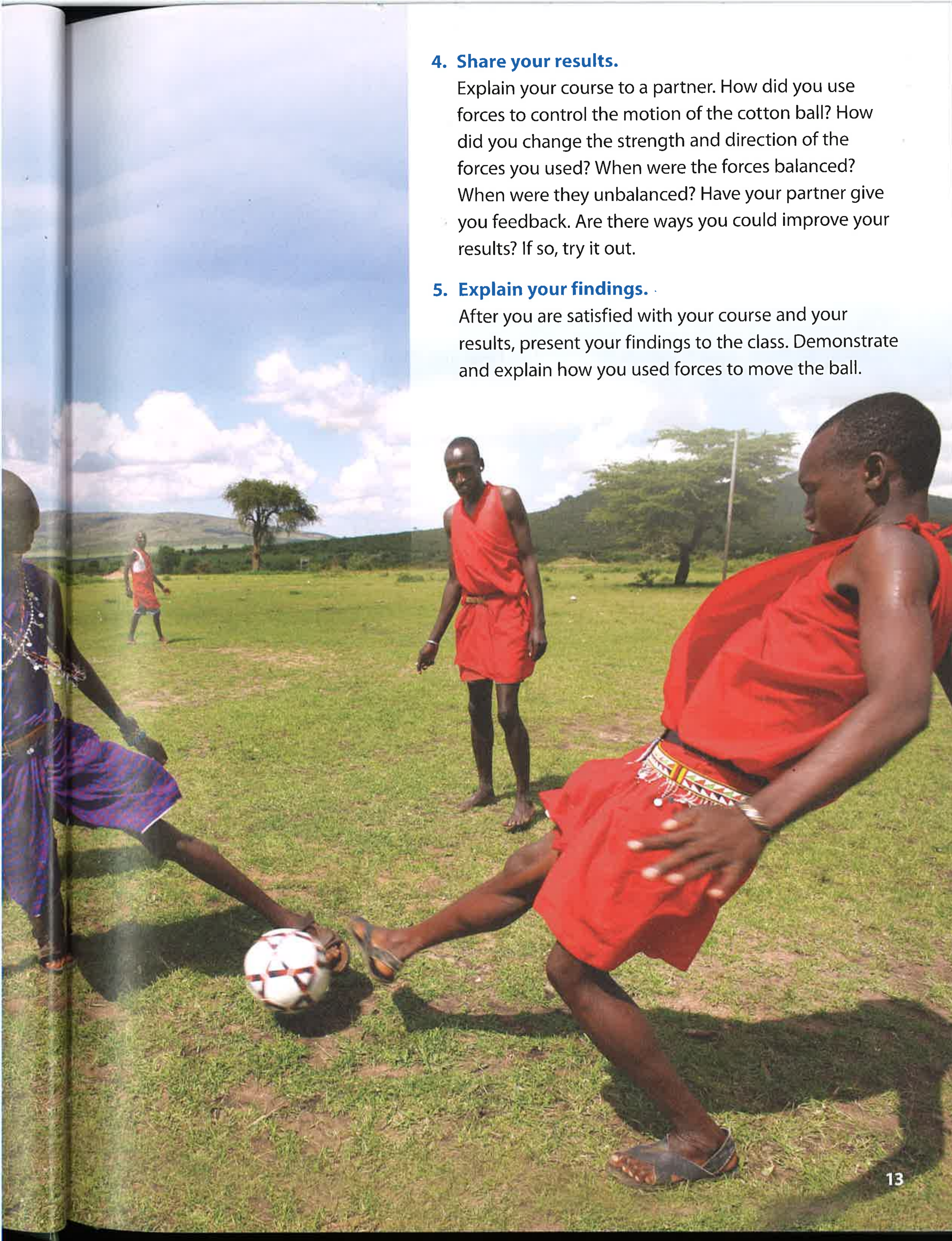
3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

4. **Share your results.**

Explain your course to a partner. How did you use forces to control the motion of the cotton ball? How did you change the strength and direction of the forces you used? When were the forces balanced? When were they unbalanced? Have your partner give you feedback. Are there ways you could improve your results? If so, try it out.

5. **Explain your findings.**

After you are satisfied with your course and your results, present your findings to the class. Demonstrate and explain how you used forces to move the ball.

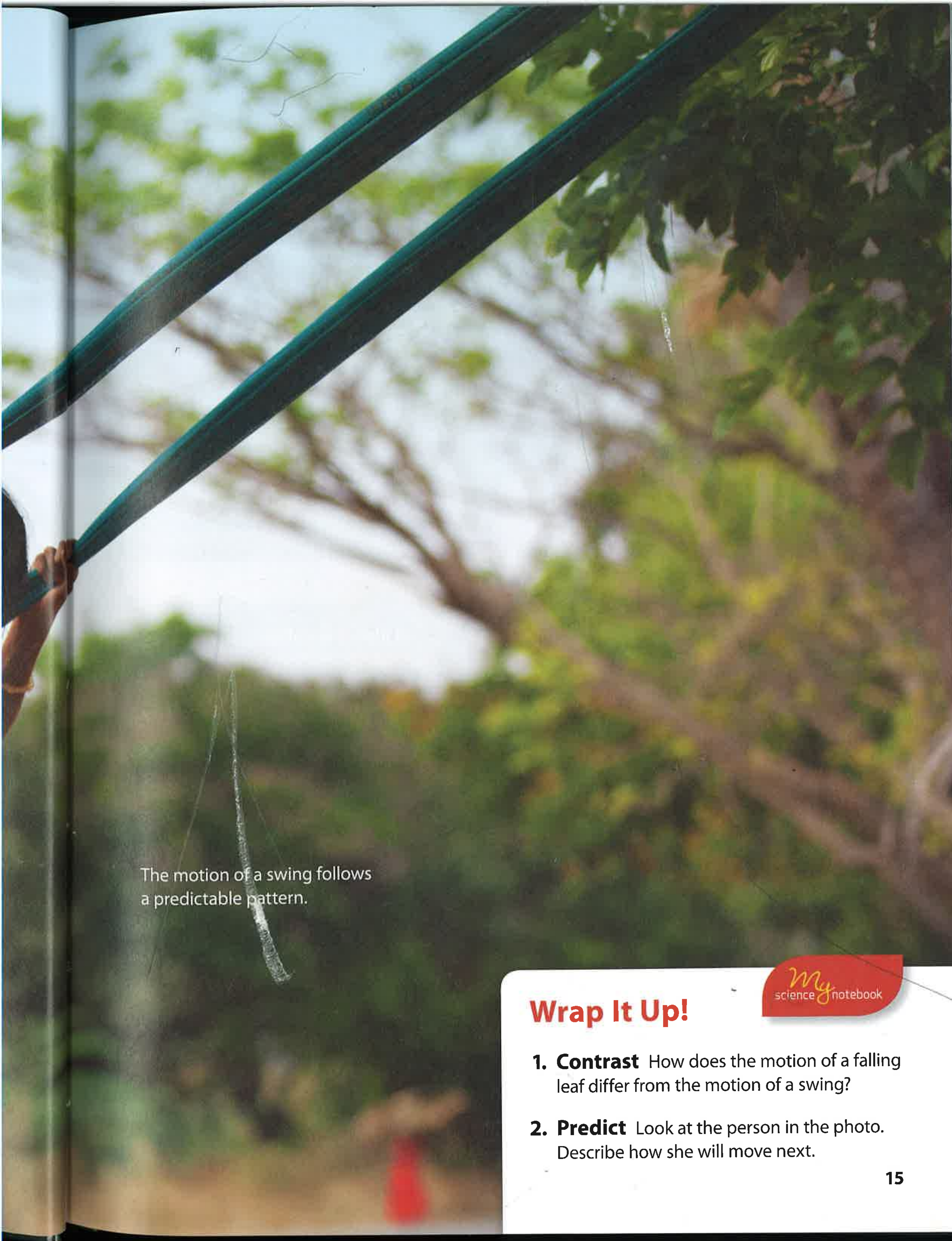


Patterns of Motion

Some motion is hard to predict. For instance, it is hard to know exactly where a leaf blowing in the wind might land. But some motion follows a pattern.

When motion follows a pattern, it is easier to predict future motion. **Regular motion** has a pattern of repeating over and over. A swing has regular motion. Swings move back and forth, over and over.

NEXT GENERATION SCIENCE STANDARDS | DISCIPLINARY CORE IDEAS
PS2.A: Forces and Motion
The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (3-PS2-2)



The motion of a swing follows a predictable pattern.

my science notebook

Wrap It Up!

1. **Contrast** How does the motion of a falling leaf differ from the motion of a swing?
2. **Predict** Look at the person in the photo. Describe how she will move next.

Investigate

Motion

? How can you predict a marble's motion?

Some objects' motion can be observed and measured. When you observe a pattern, you can predict what will likely happen next. In this investigation, you will observe and predict the motion of a marble.

Materials

foam tube

tape

marble

meterstick

When the skateboarder rolls up one side of the halfpipe, what happens next?

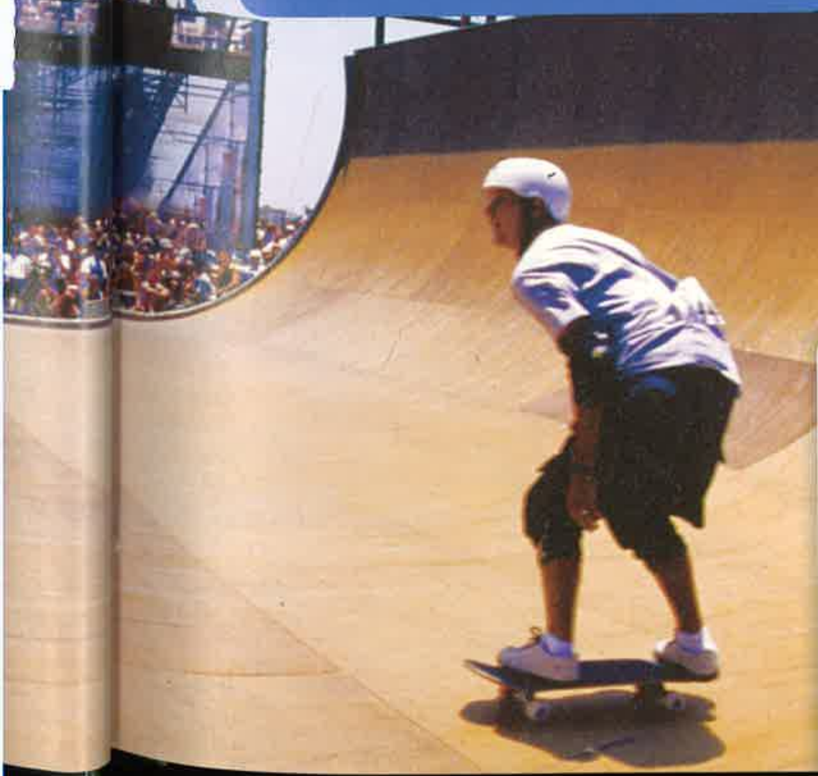
NEXT GENERATION SCIENCE STANDARDS | DISCIPLINARY CORE IDEAS
PS2.A: Forces and Motion
The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it. (3-PS2-2)

1 Set up two chairs as shown. Tape each end of the ramp to the back of a chair. The tube should touch the floor in between the chairs. Use the meterstick to measure the height of the ramp. Record the measurement in your notebook. Place the marble at the top of the ramp.

2 Let the marble go. Observe how far the marble moves up the other side of the ramp. Put your finger in that spot and have a partner measure the height. Repeat your test three times. Record your observations.

3 Choose a different height to drop the marble from. Predict how far the marble will move up the other side of the ramp. Release the marble. Repeat three times and record your observations.

4 Repeat step 3 from two different heights.



Wrap It Up!

1. **Predict** Did your results support your predictions? Explain.
2. **Interpret** What pattern do you notice in your data?

Make Observations

A trapeze is like a playground swing. The trapeze artist uses the pattern of the trapeze's swinging motion to plan and perform tricks. You can observe and predict the motion of a swinging object, too.

1. **Ask a question.**
   How can you use your observations to predict the future motion of a swinging object?

2. **Plan and conduct an investigation.**
   Tie a metal washer to one end of a string. Tape the free end of the string to the edge of a table. The washer should be close to the floor but not touching it. You have made a pendulum!

   Swing the pendulum to see how it moves.

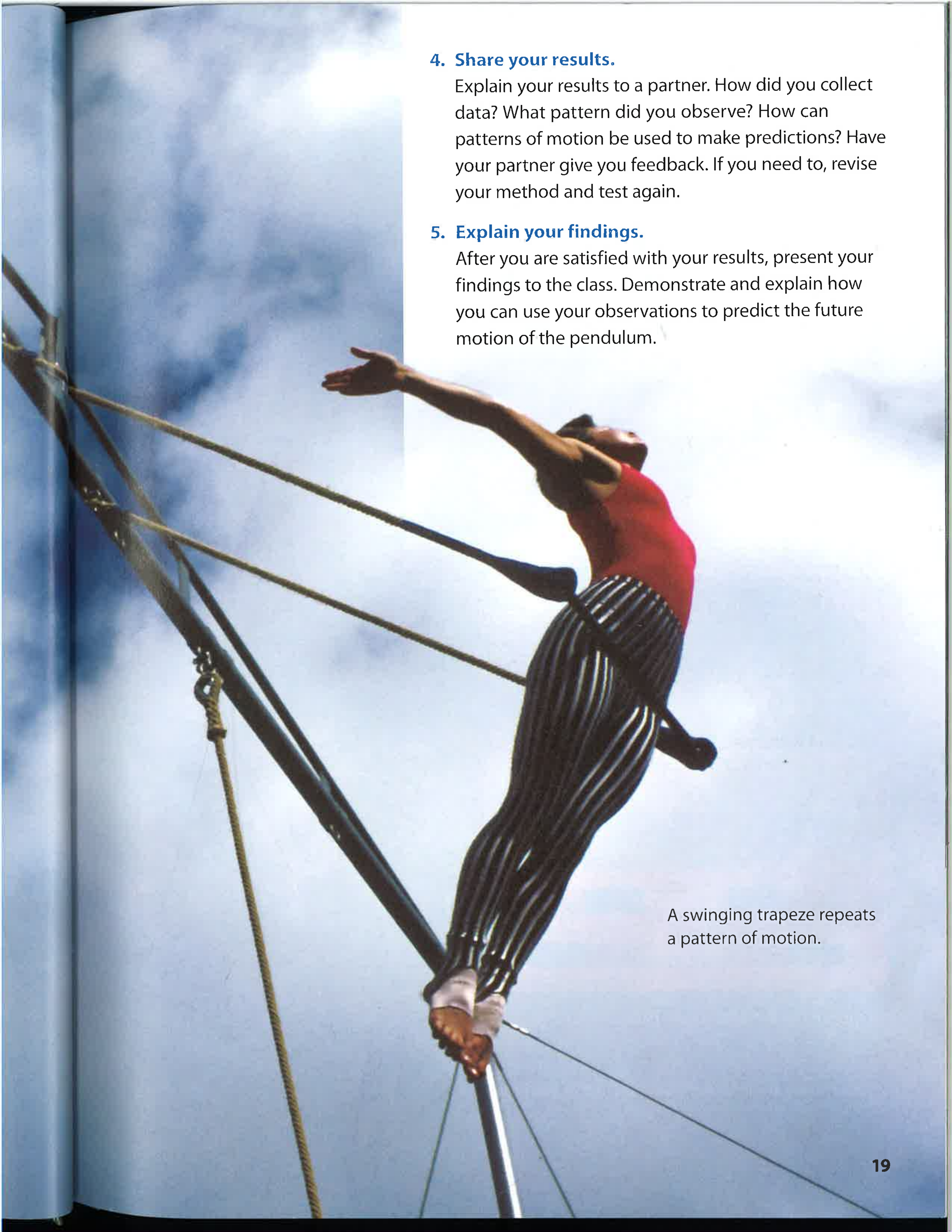
   Plan an investigation to determine how you can make the pendulum move faster, higher, or longer. After you carry out your investigation, your goal will be to predict how a pendulum will move without testing it! Record your plan in diagrams or in words. Predict what you think will happen when you make each change. Then carry out your plan. Record your observations as you carry out each test.

3. **Analyze and interpret data.**
   Examine your data. What were your results? Can you use your data to predict the future motion of the pendulum? Are there things you could do differently to improve your results? Revise your plan and retest. Record your observations.

NEXT GENERATION SCIENCE STANDARDS | PERFORMANCE EXPECTATION
3-PS2-2. Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

4. **Share your results.**
   Explain your results to a partner. How did you collect data? What pattern did you observe? How can patterns of motion be used to make predictions? Have your partner give you feedback. If you need to, revise your method and test again.

5. **Explain your findings.**
   After you are satisfied with your results, present your findings to the class. Demonstrate and explain how you can use your observations to predict the future motion of the pendulum.

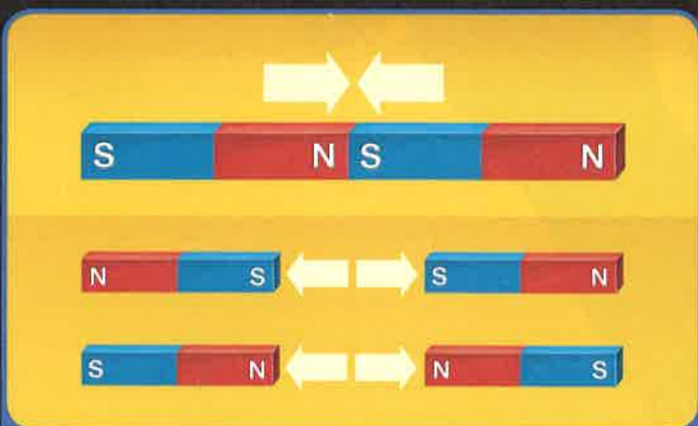


A swinging trapeze repeats a pattern of motion.

Magnets

Have you ever dipped a magnet into a pile of paper clips? If you have, you saw that the paper clips stuck to the magnet. That's because **magnets** pull on certain kinds of metals. Magnets also pull on, or **attract,** other magnets. The pull a magnet exerts is called **magnetic force.** A magnet doesn't have to touch a paper clip to exert a magnetic force on it. The magnet just has to be close enough to the clip for the magnetic force to affect it.

The places on a magnet where the pull is strongest are called **poles.** There are two kinds of poles—north (N) and south (S). The north pole of one magnet attracts the south pole of another magnet. Two north poles or two south poles **repel,** or push each other apart.



Opposite poles attract. Like poles repel.

The magnetic force of this magnet is strong enough to keep these objects from falling.

NEXT GENERATION SCIENCE STANDARDS | DISCIPLINARY CORE IDEAS
PS2.B: Types of Interactions
Electric and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. (3-PS2-3), (3-PS2-4)

The magnet does not have to touch the paper clip to attract it.

The pieces that make up this sculpture are magnets. Magnetic force holds the sculpture together.

Wrap It Up!

1. **Define** What does *attract* mean? What does *repel* mean?
2. **Contrast** How is the force applied in the kick of a soccer ball different from the force a magnet exerts on a paper clip?
3. **Explain** Tell what the phrase "opposites attract" means about magnets.

Investigate

Magnetic Force

How do magnets exert force?

Some magnets can pull harder than others. Remember, every force has a strength and direction. The strength and direction of a magnet's force can depend on the magnet's size, materials the magnet is made of, how far away the magnet is, and how the magnet is turned. In this investigation, you'll explore magnetic forces.

Materials

ruler	2 bar magnets
	
paper clips	1 small bar magnet
	

NEXT GENERATION SCIENCE STANDARDS | DISCIPLINARY CORE IDEAS
PS2.B: Types of Interactions
Electric and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. (3-PS2-3), (3-PS2-4)

My science notebook

1 Place the 2 large bar magnets 10 cm apart with their north poles facing each other. Slowly push the magnet on the right toward the magnet on the left. Record your observations.

2 Repeat step 1 with a north pole facing a south pole and then again with a south pole facing a south pole. Record your observations.

3 Arrange a paper clip and one of the large bar magnets along the ruler as shown. Predict how close the magnet will get before the magnetic force affects the clip. Record your prediction, and then carry out your test. Record your observations.

4 Slowly move the north pole of 1 large bar magnet near the paper clips. Repeat with the south pole. Record your observations. Repeat using the smaller bar magnet. Record your observations.

Magnets attracts shavings of magnetic metal.

Wrap It Up!

My science notebook

1. **Describe** Identify evidence from your investigation that magnets can exert forces without touching.
2. **Compare and Contrast** How are the large and small magnets alike? How are they different?
3. **Cause and Effect** What would happen if you brought the north pole of a bar magnet toward the north pole of another magnet that was attached to a toy car?

Investigate

Electromagnets

? How can you test the strength of an electromagnet?

Some magnets use electricity to produce a very strong magnetic force. These magnets are called electromagnets. Electromagnets are handy at scrap yards because they are very strong, and they can be turned on and off. In this investigation, you'll build and test an electromagnet.

Materials

bolt

wire

battery

battery holder

paper clips

NEXT GENERATION SCIENCE STANDARDS | DISCIPLINARY CORE IDEAS
PS2.B: Types of Interactions
Electric and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. (3-PS2-3), (3-PS2-4)

1 Leave about 10 cm of wire loose at one end and wrap the wire around the bolt 15 times. Try not to overlap the wire as you wrap it around the bolt.

2 Attach each end of the wire to the battery holder by connecting it to the metal pieces on each side. Place the battery in the holder.

My science notebook

3 Test your electromagnet. Bring the end of the bolt near a pile of paper clips. Count the number of paper clips the electromagnet can hold. Record your observations.

4 Remove the battery. Predict what will happen if you wrap the wire around the bolt 25 times. Try it! Record your observations. Repeat with 35 wraps.

Electromagnets can be very powerful.

Wrap It Up!

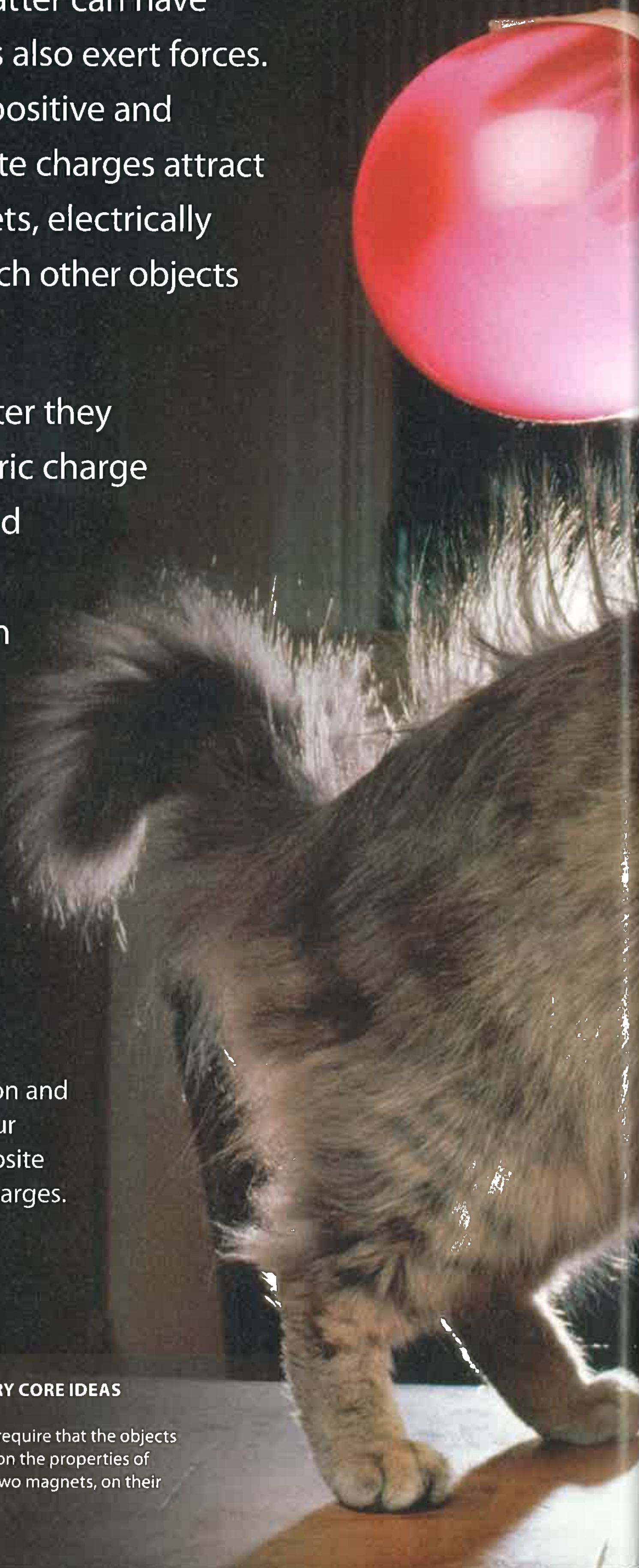
My science notebook

1. **Explain** How did you measure the strength of the electromagnet's force? When was it weakest? Strongest?
2. **Generalize** Can an electromagnet exert a force without touching an object? Explain.
3. **Cause and Effect** What might happen if you had a longer bolt and wrapped the wire around 50 times?

Electric Forces

The tiny particles that make up matter can have an electric charge. Electric charges also exert forces. There are two kinds of charges—positive and negative. In electric forces, opposite charges attract and like charges repel. Like magnets, electrically charged objects don't have to touch other objects to act on them.

Some objects become charged after they contact certain materials. An electric charge that builds up on an object is called **static electricity.** You might have experienced static electricity when taking off a shirt made your hair crackle and stand on end!



The balloon and the cat's fur have opposite electric charges.

NEXT GENERATION SCIENCE STANDARDS | DISCIPLINARY CORE IDEAS
PS2.B: Types of Interactions
Electric and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. (3-PS2-3), (3-PS2-4)

SCIENCE in a SNAP

Effects of Electric Charge

1 Cut tissue paper into small pieces. Put the pieces in a pile.

2 Move a balloon toward the pieces of tissue paper. Record your observations.

3 Rub one side of the balloon with a wool cloth. Predict what will happen when you move the rubbed balloon toward the tissue paper. Then try it!

Wrap It Up!

My science notebook

1. **Compare** How are the forces exerted by electric charges similar to the forces exerted by magnets?
2. **Identify** Where have you seen the effects of static electricity at home or at school?

Investigate

Electric Forces

? How can you observe the effects of electric forces?

You've investigated how magnetic forces interact. Now you can investigate the interaction of electric forces.

Materials

2 balloons	2 strings
	
tape	**wool cloth**
	

The foam packing pieces are not sticky like tape. It is static electricity that makes them cling to the woman's hands.

NEXT GENERATION SCIENCE STANDARDS | DISCIPLINARY CORE IDEAS
PS2.B: Types of Interactions
Electric and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. (3-PS2-3), (3-PS2-4)

1 Tie a piece of string to each balloon. Tape the ends of both balloon strings to the edge of a table. Allow the balloons to hang freely, about 5 cm apart.

my science notebook

2 Move the balloons toward each other, and then let them go. Record your observations.

3 Place one balloon on the table. Rub the balloon with the wool cloth. Be sure to rub all parts of the balloon. Predict what will happen when the balloons again hang freely. Then try it. Record your predictions and observations.

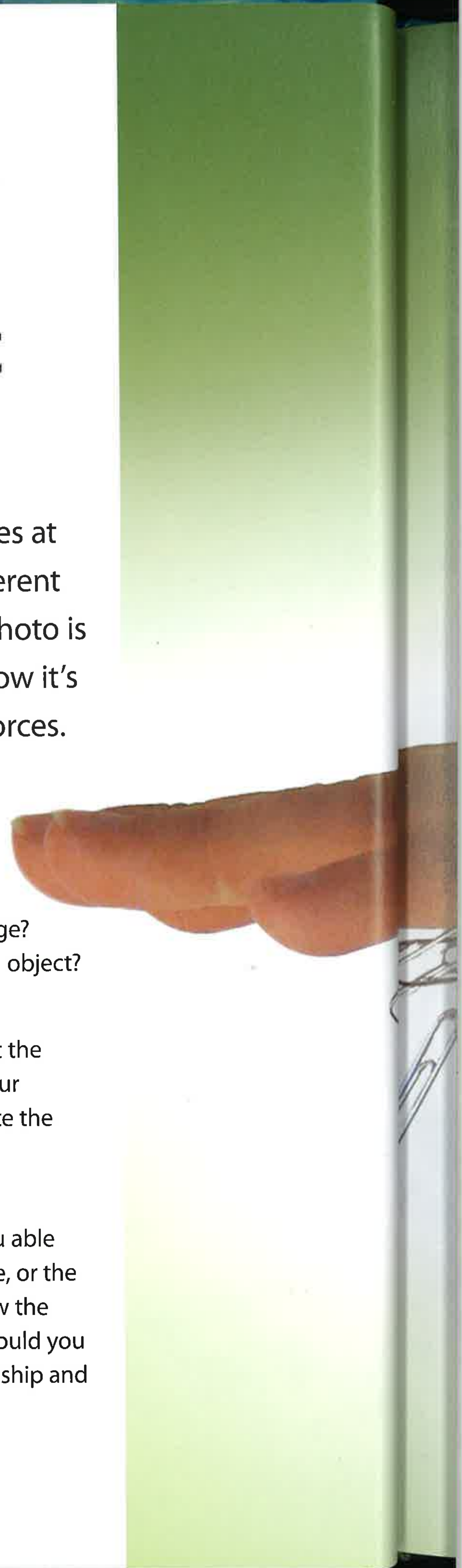
4 Now rub both balloons with the wool cloth. Be sure to rub all parts of the balloons. Predict what will happen when the balloons again hang freely. Then try it. Record your predictions and observations.

Wrap It Up!

my science notebook

1. **Explain** Why did you observe the hanging balloons before you rubbed them?
2. **Describe** In steps 3 and 4, what happened when the balloons were hanging freely? What did you do to cause this difference?
3. **Infer** What can you infer about the charges on the balloons in step 3? In step 4?

Determine Cause and Effect Relationships



You have observed magnetic and electric forces at work. You have also seen that forces have different strengths and directions. The magnet in the photo is so strong it can exert force through a hand! Now it's your turn to investigate magnetic or electric forces.

1. **Ask a question.**
   Choose one of these questions to test:
   - How can I measure the strength of a magnet?
   - How can I determine the direction of a magnet's force?
   - How can I measure the strength of a static electric charge?
   - How can I determine the direction of force of a charged object?

2. **Plan and conduct an investigation.**
   Copy the question you chose into your notebook. Look at the materials available to you. Plan an investigation to test your question. List and gather the materials you will need. Write the steps of your investigation. Then carry them out.

3. **Analyze and interpret data.**
   Examine your data. What did your results show? Were you able to measure the strength of a magnet or an electric charge, or the direction of a magnet's force? Did your investigation show the relationship between a cause and its effect? If not, how could you change your investigation so that it shows such a relationship and answers your question?

NEXT GENERATION SCIENCE STANDARDS | PERFORMANCE EXPECTATION
3-PS2-3. Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.

4. **Share your results.**
   Explain your results to a partner. How did you collect data? What cause-and-effect relationship did you observe?

5. **Explain your findings.**
   After you are satisfied with your results, present your findings to the class. Demonstrate and explain how you can use your investigation to show a cause-and-effect relationship.

Don't worry, this doesn't hurt!

NATIONAL GEOGRAPHIC LEARNING | **Think Like an Engineer**

Define and Solve a Design Problem

This ball contains a sensor that detects a magnetic field at the opening of the goal.

Magnets have many practical uses. Magnets inside a refrigerator door hold the door shut. Magnetic screwdrivers keep metal screws from falling. Magnets can hold name tags on shirts without any sharp pins. Now it's your turn to be the engineer and design a new use for magnets.

1. **Ask a question.**
   How can you use magnets to solve a problem?

2. **Plan and carry out an investigation.**
   Think of a problem that can be solved using magnets. For example, could you use magnets to keep a mailbox shut? Could you use magnets to keep two toy cars on a track from crashing together? Write the problem in your notebook. Look at the materials your teacher provides. You may only use these materials to solve the problem. How could you use them to make a prototype of your design solution? Draw a picture of your prototype. How will you test your prototype? How will you determine whether or not your prototype works? Write your plans for building and testing your prototype in your science notebook.

3. **Analyze and interpret data.**
   Make and test your prototype. Does your solution work the way you want it to? How do you know? Can you make your prototype easier to use? Less expensive to make? Less complicated? Make changes and test again.

NEXT GENERATION SCIENCE STANDARDS | PERFORMANCE EXPECTATION
3-PS2-4. Define a simple design problem that can be solved by applying scientific ideas about magnets.
3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

4. **Construct an explanation from evidence.**
   Explain your prototype to a partner. How does it use magnetic forces to solve a problem? Does it use magnets to attract or repel an object?

5. **Communicate information.**
   Share your results with the class. Now write and investigate your own question.

When the ball crosses the magnetic field, it sends a signal to the referee's watch. Goal!

Roller Coaster Designer

As pushes and pulls move roller coasters, work is being done. But it is fun work! Roller coaster designer Cynthia Emerick takes advantage of different forces to design roller coasters that are thrilling to ride.

NGL Science What is your job?

Cynthia Emerick I oversee the design and installation of roller coasters. I figure out how to do it in a way that's safe and not too expensive. My team and I solve engineering problems every day.

NGL Science What did you do in school to learn how to do your job?

Cynthia Emerick I always found math and science interesting. In college, I learned about materials and how to put them together to make things. I also learned about what happens when materials break down. That helps me understand how to make rides safe.

Roller coasters use motors to move the riders to the top of the first hill. From there, gravity takes over. Forces move roller coasters in all directions.

NEXT GENERATION SCIENCE STANDARDS | CONNECTIONS TO NATURE OF SCIENCE
Scientific Investigations Use a Variety of Methods
Science investigations use a variety of methods, tools, and techniques.

Cynthia Emerick studied material science and engineering to become a roller coaster designer. She works with teams of people over many months to solve the problems of making rides both thrilling and safe.