LESSON 5

Introduction to Forces

Having fun on a trampoline. What forces are at work?

Preparing for a dive. What forces are at work?

INTRODUCTION

Take a look at the photographs on this page. What forces are at work and what are they like? This is the first of several lessons in which you will investigate different forces. In this lesson, you will investigate two forces—the force of a rubber band and the force of gravity—and learn something about the nature of each. In Lessons 6 and 7, you will investigate the nature of friction and the forces that motors exert.

OBJECTIVES FOR THIS LESSON

Describe the nature of forces and how they act on objects.

Determine the relationship between elastic force and the stretch of a rubber band.

Measure the weight of objects with different masses.

Describe how mass and weight (force of gravity) are related.

Use data tables and graphs to interpret data.

Getting Started

1. In your science notebook, write what you know or think you know about forces. List some forces that are familiar to you.

2. Share your ideas about forces and your list of forces with the class.

3. In this lesson, you will use a spring scale to measure forces. Before using the spring scale, make sure it is set properly. When there is no force on the scale, it should register zero. Lay the spring scale on the table and make sure it registers zero. If it does not, your teacher will show you how to adjust the scale.

4. Examine the spring scale and write answers to the following questions in your science notebook:

   A. What happens to the reading on the scale when you pull horizontally on the scale?

   B. What are the units of measure for force on your scale?

   C. What is the maximum force that your scale can measure?

   D. How much force do the smaller marks along the scale represent?

MATERIALS FOR LESSON 5

For you

1 copy of Student Sheet 5.1: What Is the Elastic Force of the Rubber Band?

For you and your lab partner

1 pegboard assembly
1 0- to 10-N spring scale
1 large paper clip
1 rubber band
1 machine screw with wing nut
1 meterstick
5 large washers
1 piece of masking tape

Inquiry 5.1
Measuring Elastic Force

PROCEDURE

1. In this inquiry, you will investigate the elastic force needed to stretch a rubber band. To set up the experiment, use a wing nut to fasten a machine screw to a corner of the pegboard assembly. Lay the pegboard assembly on its back on the table with the base projecting over the table's edge, as shown in Figure 5.1. Tape the board down as shown.

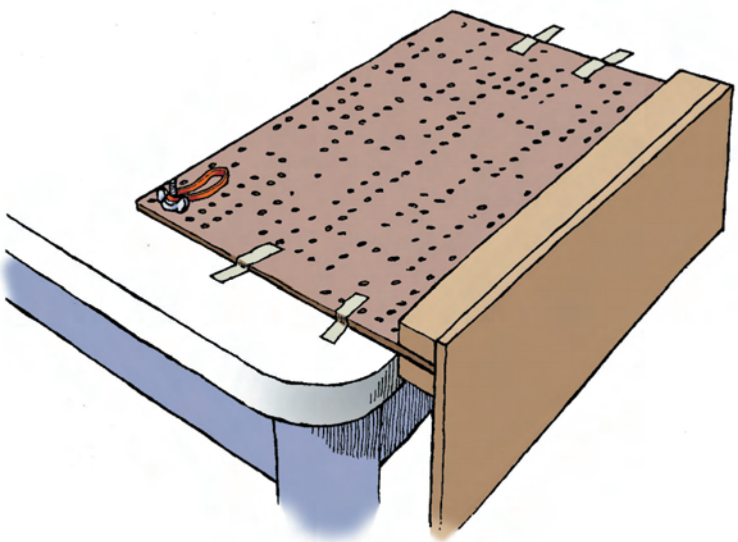


Figure 5.1 *Setup for pegboard assembly, machine screw, wing nut, and rubber band*

2. Put a rubber band around the screw. Leave enough room so that you can easily pull on the rubber band. With your finger, carefully stretch the rubber band far enough to feel the force of the pull (see Figure 5.2). When you stretch the rubber band, what do you feel and in what direction does the rubber band pull your finger?

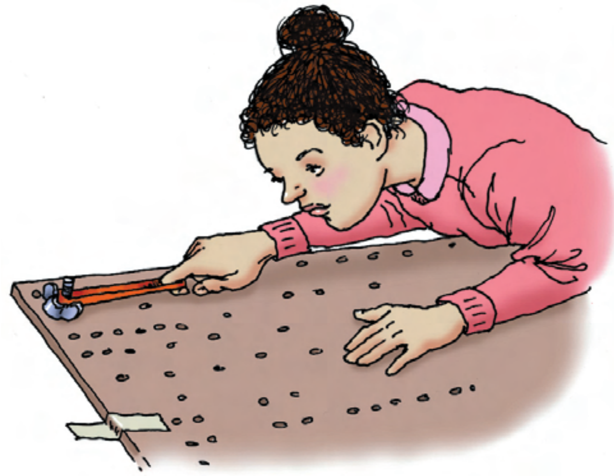


Figure 5.2 *With your finger, pull and stretch the rubber band.*

3. Pull a little harder on the rubber band. Now what happens to it? Record your observations in your science notebook.

4. Hook the free end of the rubber band to the spring scale. It should be straight but not stretched, as shown in Figure 5.3.

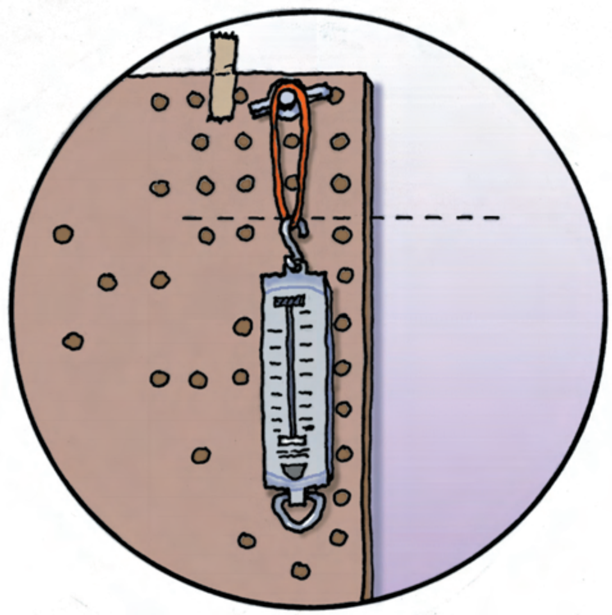


Figure 5.3 *The rubber band with the spring scale attached*

5. Tape the meterstick to the table so the zero mark on the meterstick is even with the end of the rubber band hooked to the spring scale (see Figure 5.4).

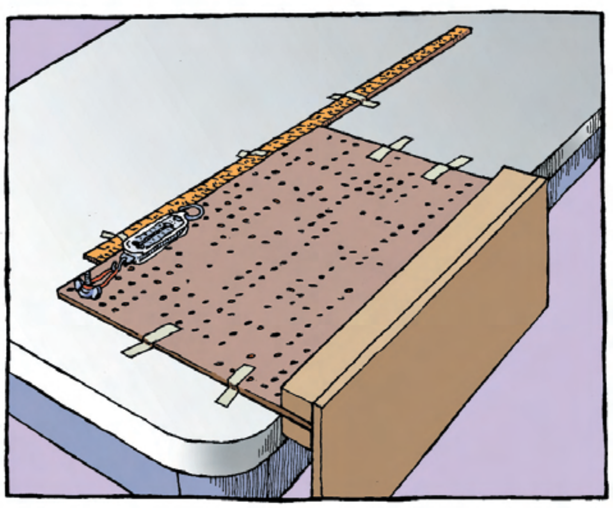


Figure 5.4 *Pegboard and rubber band set up with the meterstick*

6. Pull slowly on the spring scale until the rubber band is stretched 2.0 cm. Record the spring scale's force reading in Table 1 on Student Sheet 5.1: What Is the Elastic Force of the Rubber Band?

7. Stretch the rubber band another 2.0 cm and record the force. Repeat this process for each 2.0-cm interval shown in the data table. Each time you stretch the rubber band, record the force on the spring scale.

8. Look at the measurements in your data table and answer Question 1 on Student Sheet 5.1: What happens to the force required to stretch the rubber band when the stretching distance is doubled? Review at least three instances of doubling the distance.

9. Use the data you collected to make a graph. Remember to plot the dependent variable versus the independent variable. Make sure both axes are uniformly scaled and properly labeled. Give your graph a title.

10. Use your graph to answer Questions 2, 3, and 4 on the student sheet: What does your graph tell you about the relationship between the force needed to stretch the rubber band and the distance it stretches? Did the force needed to stretch the rubber band increase by the same amount each time you stretched the rubber band another 2.0 cm? Is the answer visible in the graph? Can you predict the force needed to stretch the rubber band to 40.0 cm? Why or why not?

11. Discuss your findings with the class.

THE DIFFERENCE BETWEEN MASS AND WEIGHT

How much do you weigh? What is your mass? Many people think that these two questions are asking the same thing. But that's not true. Weight and mass are different. Although many people know what their weight is, few know their mass.

Weight is a measure of the force of gravity pulling on a body. If you weigh 400 newtons (90 pounds), then gravity pulls your body down toward the earth with a force of 400 newtons. You can measure your weight by standing on a bathroom scale. When you stand on the scale, your body's weight compresses the spring in the scale. The amount the spring is compressed is proportional to your body's weight. If you went to the moon, you would weigh less because the force of gravity on the moon's surface is not as strong as the force of gravity on the surface of the earth. In fact, on the moon, you would weigh only one-sixth as much as on the earth.

Now what about your mass? Mass is a measure of how much matter is in your body. The mass of a person who weights 400 newtons on the earth is about 40 kilograms. Mass is measured differently from weight. Mass is measured in kilograms. You can measure your mass by sitting on a balance. You sit on one side of the balance and put objects whose masses are known on the other side. When the sum of the known masses equals your mass, the system balances. Suppose you went to the moon. Would your mass change? The answer is no—the matter in your body would be the same as it is on the earth. If you do not add to or take away any matter from your body, your mass stays the same, no matter where you are.

Inquiry 5.2
Measuring Gravitational Force

PROCEDURE

1. In this inquiry, you will investigate the force of gravity on various objects. Before beginning, read about the difference between "mass" and "weight."

2. Your teacher will give you some objects with different masses to study. Pick up each object and describe its weight. List the objects in order, from heaviest to lightest. Which objects are heaviest? Record the list in your science notebook. Discuss your list with the class.

3. Think about the statement "Different objects have different weights." Develop a hypothesis about the relationship between weight and mass.

4. With the rest of the class, develop a plan that uses spring scales and washers to investigate the relationship between the weight of an object and its mass. Record the procedure in your science notebook.

5. Work with your partner to carry out your procedure. Remember to do the following:

   A. Make a table in your notebook to record your data.

   B. Describe how you will measure mass.

   C. Develop a plan to analyze your data.

   D. Hold the scale vertically, and make sure it registers zero when nothing is hanging on the hook.

6. After collecting and analyzing your data, compare your results with the results of other groups and discuss them with the class.

7. In your notebook, summarize what you learned about weight in this inquiry. Give evidence to support your conclusion.

REFLECTING ON WHAT YOU'VE DONE

1. In your notebook, write the answers to the questions in Steps 2 through 6 below. Discuss your answers with the class.

2. *Use the results of your experiment with the rubber band to answer the following questions:*

   A. You want to pull a cart along the floor. How would you use the rubber band to do this?

   B. Suppose you want to apply a force twice as big as the one you would use for Question 2A. What would you do to the rubber band to produce twice as much force?

3. *Use the results of your weight experiment to answer the following questions:*

   A. What is the mass of a single washer?

   B. What is the weight of a single washer?

   C. When you added more washers (mass) to the spring scale, what did the spring do?

   D. What do you call the force that makes objects have weight?

   E. In what direction does this force pull on the washers?

4. *From your observations, explain why different objects have different weights. What do you think determines the weight of an object? Support your answer with data.*

5. *In this inquiry you examined forces that pull on objects. Give an example of another way to exert a force on an object.*

6. *In your science notebook, define "force."*

BUNGEE JUMPING: The Forces Are With You


CORBIS/PAUL A. SOUDERS

A bungee jumper takes the plunge off a bridge over the Nanaimo River in Canada. Gravity and elastic force work together in this thrilling sport.

Bungee jumping isn't for wimps! You leap from a bridge or high platform and drop like a rock for hundreds of feet. And just when you're thinking that you'll never stop falling, you do. You stop just short of hitting the ground. What saved you? You may think it's the thin elastic cord around your ankles. You just experienced two powerful forces—gravity and elastic force.

Real Swingers!

You might think that bungee jumping is as new as the closest amusement park, but actually it's been around for centuries. In a village called Bunlap on Pentecost Island in the South Pacific Ocean, it is an annual ritual. The islanders call it land diving.

Each year at harvest time, the men of the vil-

CORBIS/ALBRECHT G. SCHAEFER

Both men and boys on Pentecost Island participate in land diving. They tie bungee cords made from springy liana vines around their ankles and leap from the top of towers 25 meters high.

lage erect towers made of tree trunks, branches, and vines. These towers are 15 to 25 meters high. Then each man selects some of the same vines to make his own bungee cord. One after another, the men and older boys take their homemade bun-gee cords and climb the tower. The younger jumpers climb only part of the way, but the older men go to the very top. Before the jump, friends tie a vine to each of the jumper's legs. They anchor the other end to the tower.

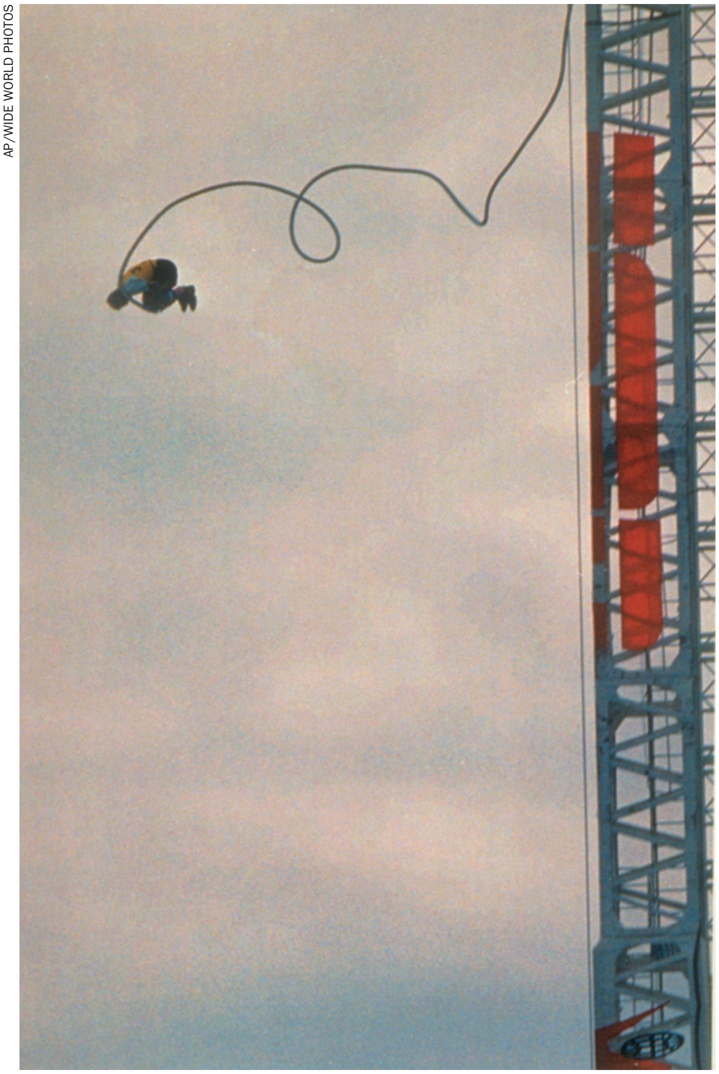
The jumper takes his position. Below, the villagers sing and dance. He raises his arm, and the crowd becomes silent. The jumper plunges to earth. If all goes as planned, the springy, elastic vines break his fall just before he reaches the ground. Fellow members of the tribe rush to untie the vines and begin to dance in his honor.

Jumping Across Continents

Bungee jumping became popular in the western world in 1979, when members of the Dangerous Sports Club at Oxford University, who had read about the land divers of Pentecost Island, leaped from the 75-meter-high Clifton Bridge in the city of Bristol, England. Because it was an important occasion, they were all wearing tuxedos and top hats! Later, these men traveled around the world. They leaped from the Golden Gate Bridge in California and the Royal Gorge in Colorado.

As soon as people heard of this thrilling new sport, many wanted to try it for themselves.

AP/WIDE WORLD PHOTOS



A diver takes the plunge at an amusement-park bungee-jump ride.

Soon they were lining up at amusement parks and paying for the privilege of taking a death-defying leap.

There's Science Behind It

Suppose you want to make a jump. How would you convince your mom or dad that it's really not dangerous?

You'd tell them that when you're bungee jumping, the forces are with you—the force of gravity and elastic force, that is.

Let's take an imaginary jump and see what happens.

First, the operator hooks you up to a bungee cord—a stretchy, elastic material. After a few instructions, you're ready to leap. You close your eyes and step off into thin air. You immediately feel the pull of gravity.

You open your eyes. The ground is rushing toward you like a railroad train. As you near the ground, the bungee cord stretches like a gigantic rubber band. The more the cord stretches, the stronger its force becomes.

Finally, you reach the point where the upward pull of the cord is greater than the downward pull of gravity. You feel an upward pull ("Thank

HOOKE AND NEWTON:
Geniuses at Work

Cooperation pays off in science, but competition also has its rewards. Two of the leading scientists of 17th-century England, Sir Isaac Newton and Robert Hooke, were rivals almost all their lives. Each made important contributions to physics. Robert Hooke discovered the nature of elastic force, and Sir Isaac Newton investigated light. The nature of gravity was a subject that fascinated both men, but they also had many other scientific interests.

Hooke studied his world in many ways—through a telescope as well as through a microscope. With the microscope, which he built himself, Hooke looked at fish scales, feathers, and cork. He noted that these objects, viewed under magnification, were made up of tiny compartments. He named these compartments “cells.” Hooke published a book entitled *Micrographica* that contained many beautiful drawings of the things he’d seen with his microscope.

Hooke’s investigations of forces resulted in Hooke’s Law, which states that the force a spring exerts depends on how far it is stretched.

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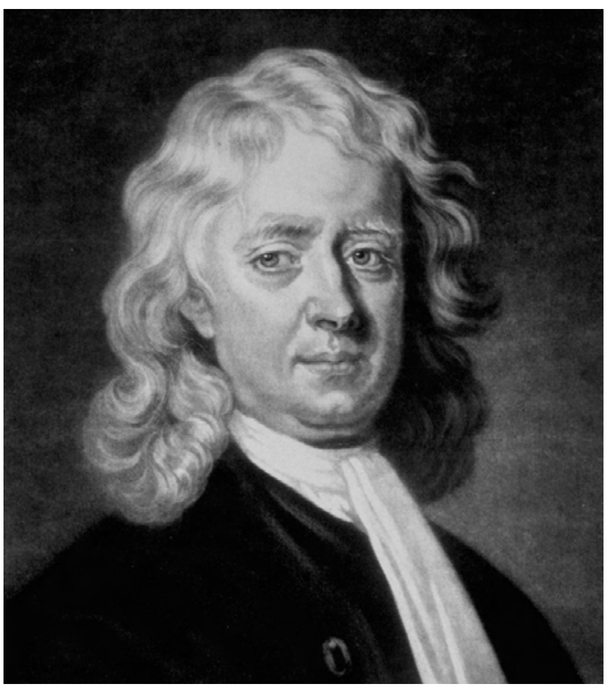
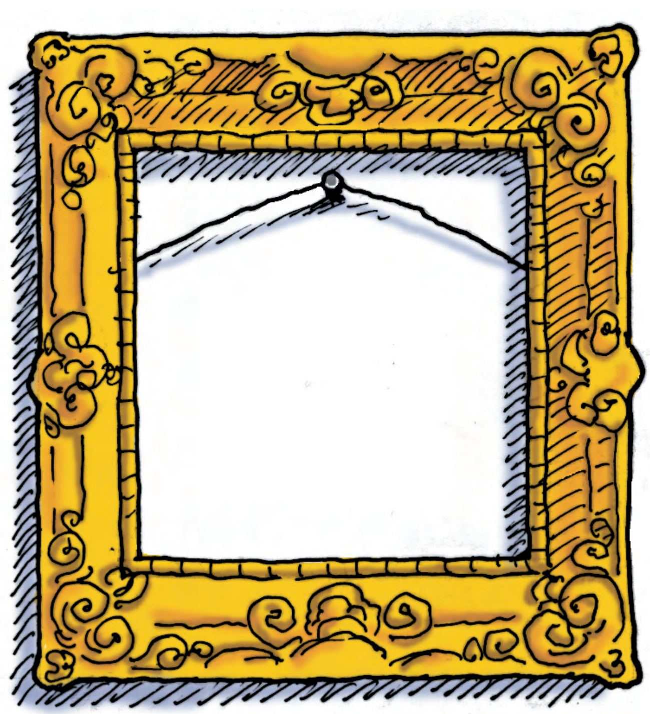
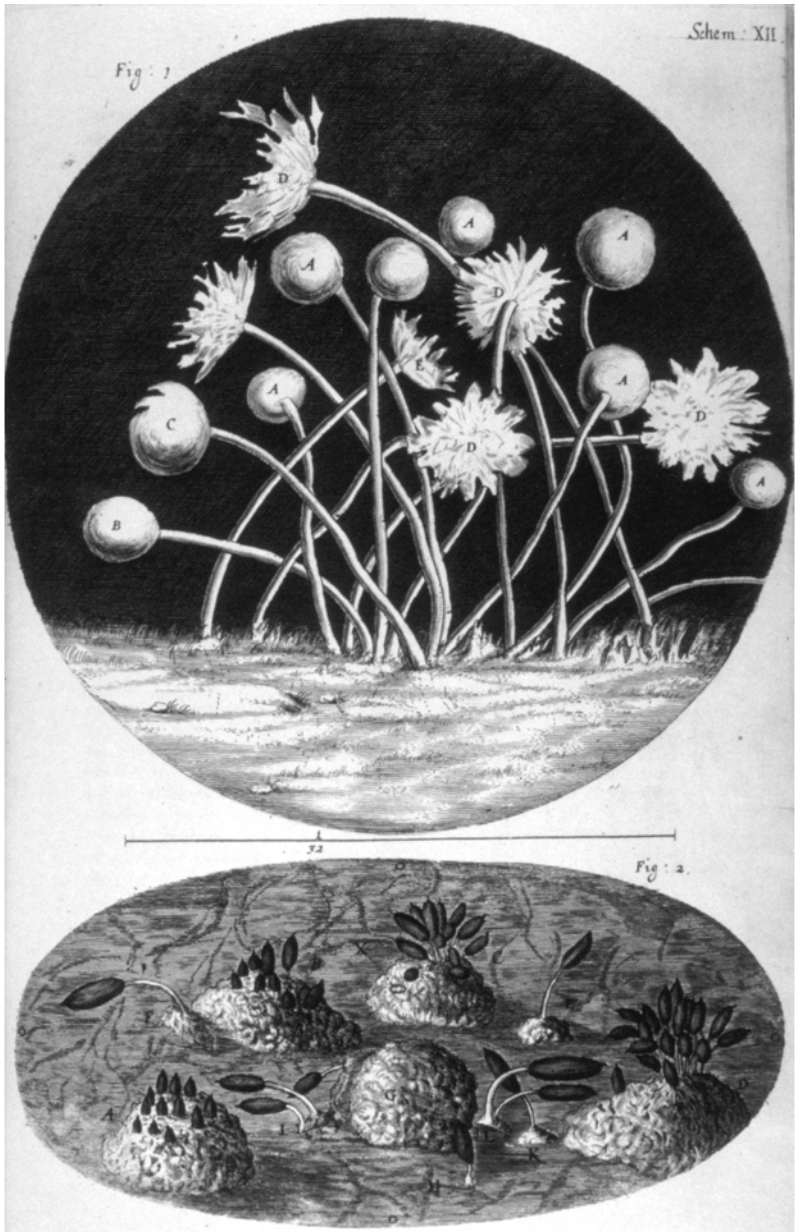


Sir Isaac Newton



Although Hooke made many fine drawings of things he saw, no known portrait of him exists.



These may look like flowers in a field, but they are actually mold spores as seen through Hooke's microscope.

Under the Apple Tree

Meanwhile, unknown to Hooke, Isaac Newton had an unexpected opportunity to work on the problem of gravity. Newton, who was a college professor, had some free time when the bubonic plague caused universities across England to close. In 1666, he returned to the farm where he had grown up.

One day he was sitting outside under a tree, thinking serious thoughts—in this case, about why the moon orbits the earth. Suddenly, an apple plopped to the ground.

Newton's eyes lit up. A hypothesis! Perhaps gravity, the force that pulled the apple to the ground, was the same force that keeps the moon and the planets in orbit. In other words, the same force that had long been known to operate on the earth was holding the solar system together. Earth and the heavens might operate according to the same physical principles! He did some mathematical calculations and became convinced that his hypothesis was correct: Gravity holds the moon in its orbit as it revolves around the earth.

But Newton did not publish his findings. Time passed.

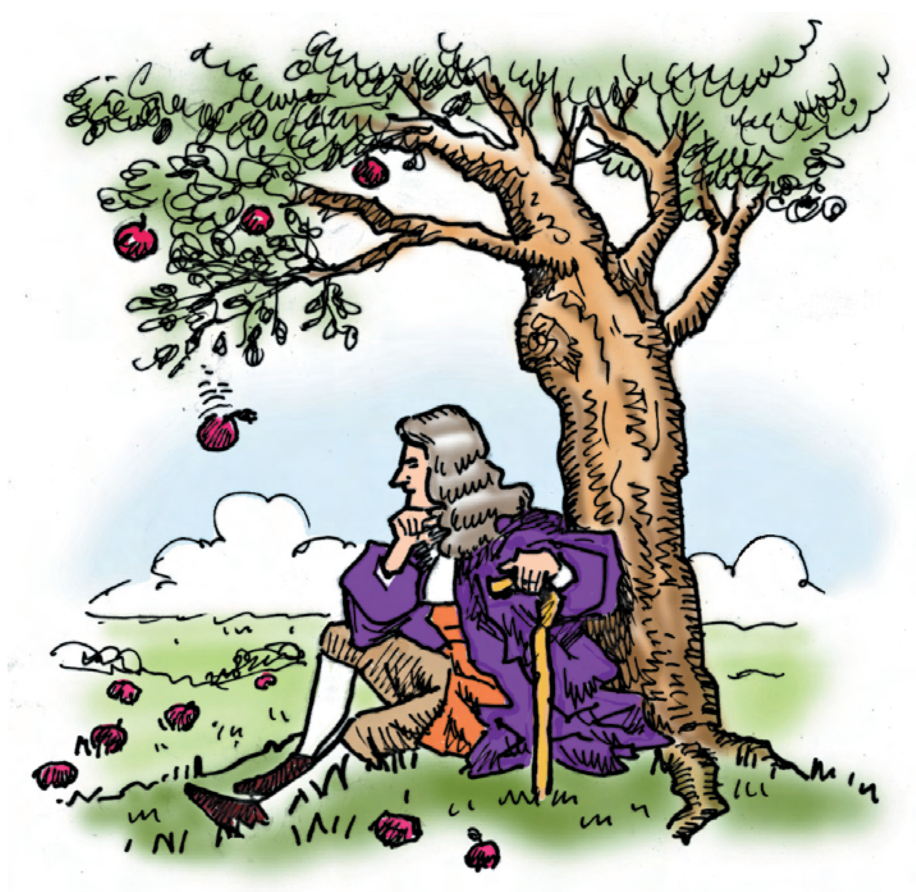
Twenty years later, other scientists were still trying to understand the force of gravity and explain what keeps the planets in their orbits. Among them was Hooke. By this time Hooke and Newton, both famous for other discoveries, were also well known because of the rivalry that had grown up between them. Hooke had publicly criticized some of Newton's theories about light.

A third scientist, Edmund Halley, was a friend of both men. Probably feeling very proud of himself, Halley asked Newton whether he understood how gravity keeps an object in orbit. "Of course," Newton probably replied, "I figured it out 20 years ago."

"Well," Halley might have responded, "you'd better watch out, because Robert Hooke is pretty close to figuring it out, too."

Newton decided it was time to publish his findings on gravity. The result was a book that would become famous around the world: *Mathematical Principles of Natural Philosophy*. In it, he described how gravity works and demonstrated that objects on earth operate under the same principles as objects in space. The book also contains Newton's three laws of motion.

Sir Isaac may have beat Hooke in figuring out how gravity works, but both men made important discoveries and wrote books that have influenced science for centuries. Many people regard them as two of the greatest scientists of the 17th century. □



An apple falling from a tree inspired Newton to solve the mystery of how gravity works.