

**Overview**

Tell students that this chapter will *not* focus on the physical tools of environmental science, such as microscopes or computers. This chapter discusses tools of the mind: the mental and conceptual tools that scientists use to explore and understand the environment. This chapter also explains the value of making informed, thoughtful decisions about the environment.

**Using the Figure** — GENERAL

Scientists have mounted cameras on the heads of Weddell seals to gather information about their habits. The resulting film has yielded something unexpected: observations of the Antarctic silverfish and the Antarctic toothfish, two ecologically important species. Ask students to consider how these videos might help scientists. (These videos might help scientists learn about the hunting habits of seals. They might also help scientists better understand feeding relationships.) **LS Logical**

**PRE-READING ACTIVITY**

Have pairs of students use their FoldNotes to study key terms from the chapter. Instruct one student to use the FoldNote to provide the key term, and have the other student give the definition. Have the student who provides the key term correct the other student's definition.

**VIDEO SELECT**

For information about videos related to this chapter, go to [go.hrw.com](http://go.hrw.com) and type in the keyword **HE8 TOOV**.

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**Chapter Correlations** *National Science Education Standards*

**ST 2c** Creativity, imagination, and a good knowledge base are all required in the work of science and engineering. (Section 1)

**SPSP 6d** Individuals and society must decide on proposals involving new research and the introduction of new technologies into society. Decisions involve assessment of alternatives, risks, costs, and benefits and consideration of who benefits and who suffers, who pays and gains, and what the risks are and who bears them. Students should understand the appropriateness and value of basic questions—"What can happen?"—"What are the odds?"—and "How do scientists and engineers know what will happen?" (Section 1, Section 2, Section 3)

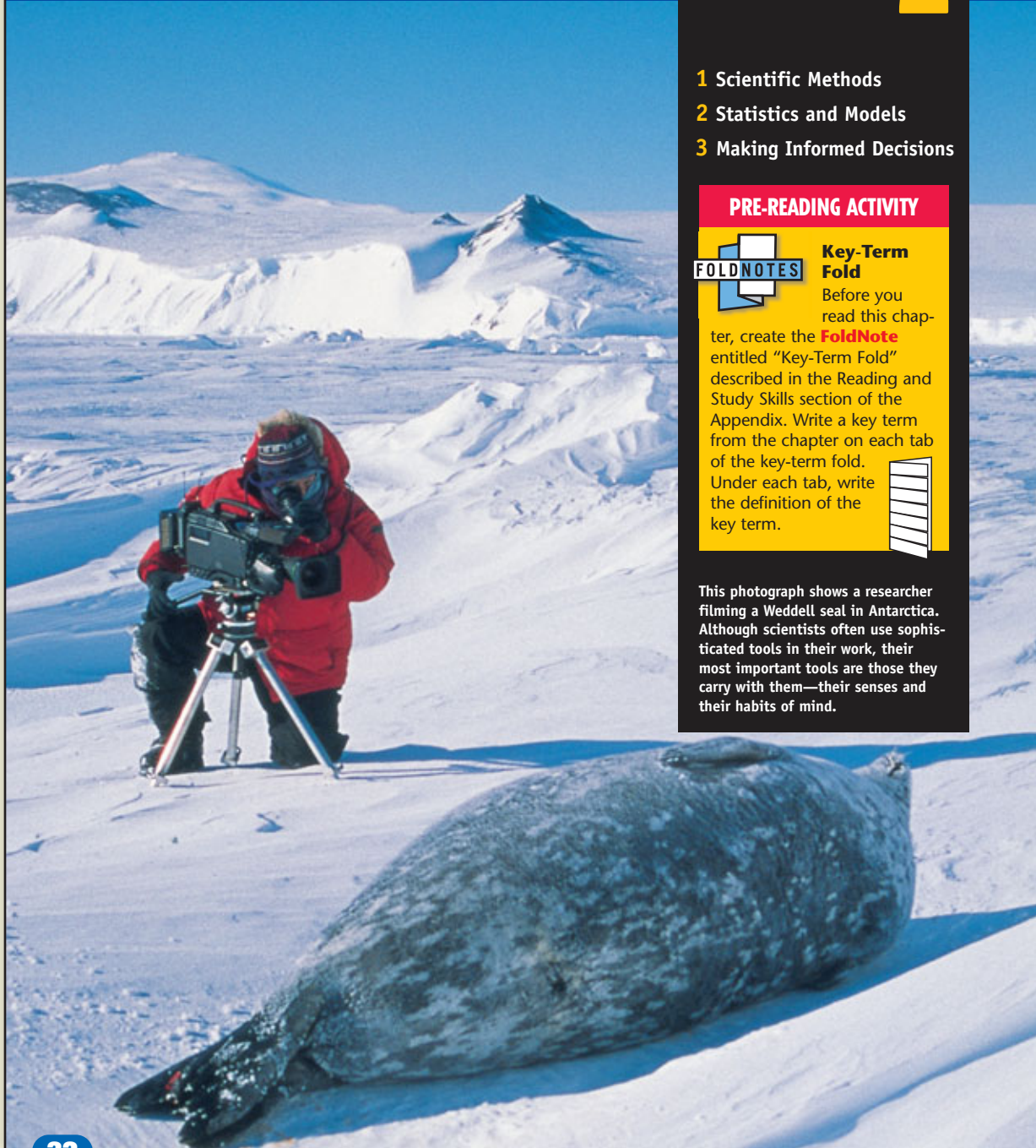
- 1 Scientific Methods
- 2 Statistics and Models
- 3 Making Informed Decisions

**PRE-READING ACTIVITY****Key-Term Fold**

Before you read this chapter, create the **FoldNote** entitled "Key-Term Fold" described in the Reading and Study Skills section of the Appendix. Write a key term from the chapter on each tab of the key-term fold. Under each tab, write the definition of the key term.



This photograph shows a researcher filming a Weddell seal in Antarctica. Although scientists often use sophisticated tools in their work, their most important tools are those they carry with them—their senses and their habits of mind.



**Focus**

**Overview**

**Before beginning this section, review with your students the Objectives in the Student Edition.**

The section focuses on the experimental method, but it also explains the value of the correlation method for use when experiments are impossible or unethical. Students learn about scientific habits of mind, including curiosity, skepticism, intellectual honesty, and imagination.

**Bellringer**

Ask students, “Why might the scientists be measuring the wolf’s tail in **Figure 1**? Once they make the measurement, how might they use it?” (The scientists might be measuring the tail to record characteristics of the members of a wolf pack. The scientists could use this information to study how the pack changes over time.) **LS Logical**

**Motivate**

**Identifying Preconceptions** — **BASIC**

**Scientific Methods** An experiment may grow out of an observation, but a scientist does not necessarily know beforehand what he or she is going to observe. For example, if a scientist goes to a stream to make observations about the population trends of a type of frog, she might discover that another frog species is missing from a lake and decide to investigate that species instead. Ask students, “Where would the scientist go from there?” (Much like a reporter, a scientist observes and follows observations to seek out a story. The scientist might try to find out if the frogs have disappeared from other bodies of water in the surrounding area. The scientist will look for explanations that he or she can test.) **LS Logical**

The word *science* comes from the Latin verb *scire*, meaning “to know.” Indeed, science is full of amazing facts and ideas about how nature works. But science is not just something you know; it is also something you do. This chapter explores how science is done and examines the tools scientists use.

**The Experimental Method**

You have probably heard the phrase, “Today scientists discovered...” How do scientists make these discoveries? Scientists make most of their discoveries using the *experimental method*. This method consists of a series of steps that scientists worldwide use to identify and answer questions. The first step is observing.

**Observing** Science usually begins with observation. Someone notices, or observes, something and begins to ask questions. An **observation** is a piece of information we gather using our senses—our sight, hearing, smell, and touch. To extend their senses, scientists often use tools such as rulers, microscopes, and even satellites. For example, a ruler provides our eyes with a standard way to compare the lengths of different objects. The scientists in **Figure 1** are observing the tail length of a tranquilized wolf with the help of a tape measure. Observations can take many forms, including descriptions, drawings, photographs, and measurements.

Students at Keene High School in New Hampshire have observed that dwarf wedge mussels are disappearing from the Ashuelot River, which is located near their school. The students have also observed that the river is polluted. These observations prompted the students to take the next step in the experimental method—forming hypotheses.



**Objectives**

- ▶ List and describe the steps of the experimental method.
- ▶ Describe why a good hypothesis is not simply a guess.
- ▶ Describe the two essential parts of a good experiment.
- ▶ Describe how scientists study subjects in which experiments are not possible.
- ▶ Explain the importance of curiosity and imagination in science.

**Key Terms**

- observation
- hypothesis
- prediction
- experiment
- variable
- experimental group
- control group
- data
- correlation

**Figure 1** ▶ These scientists are measuring the tail of a tranquilized wolf. What questions could these observations help the scientists answer?

**MISCONCEPTION ALERT**

**What is an Observation?** Ask students to define *observation* and give examples. Many students may assume that observations include only phenomena they can see. In fact, observations are made using all the senses. Point out that many scientific observations must be made indirectly, as when studying Earth’s deep interior or studying magma chambers inside volcanoes. Observations can also be made remotely using robots or satellites.

**Chapter Resource File**

- Lesson Plan
- Active Reading **BASIC**
- Section Quiz **GENERAL**

**Transparencies**

TT Bellringer

## Teach

### QuickLAB

#### Skills Acquired

- Predicting
- Interpreting

#### Answers

1. Answers may vary. Students should observe that fine-grained soils are more likely to wash away.
2. Answers may vary.

### MISCONCEPTION ALERT

#### Hypotheses Vs. Predictions

Many people confuse hypotheses with predictions. Explain that a hypothesis is a general statement that offers an explanation of a problem that has been observed. Hypotheses can be supported or contradicted by experimentation. Point out that a prediction is based on a hypothesis. A prediction is meant to describe what will happen in a specific situation, such as during an experiment, if the hypothesis turns out to be right. Reinforce this distinction by having students form hypotheses and then make predictions based on their hypotheses.

#### Answer to Reading Check

A hypothesis is a testable idea or explanation that leads to a scientific investigation. A prediction is a logical statement about what will happen if the hypothesis is correct.

### QuickLAB

#### Hypothesizing and Predicting

##### Procedure

1. Place a **baking tray** on a table, and place a **thin book** under one end of the tray.
2. Place **potting soil**, **sand**, and **schoolyard dirt** in three piles at the high end of the baking tray.
3. Use a **toothpick** to poke several holes in a **paper cup**.
4. Write down a hypothesis to explain why soil gets washed away when it rains.
5. Based on your hypothesis, predict which of the three soils will wash away most easily.
6. Pour **water** into the cup, and slowly sprinkle water on the piles.

##### Analysis

1. What happened to the different soils?
2. Revise your hypothesis, if necessary, based on your experiment.

**Hypothesizing and Predicting** Observations give us answers to questions, but observations almost always lead to more questions. To answer a specific question, a scientist may form a hypothesis. A **hypothesis** (hie PAHTH uh sis) is a testable idea or explanation that leads to a scientific investigation. A hypothesis is more than a guess. A good hypothesis follows from what you already know and can be tested.

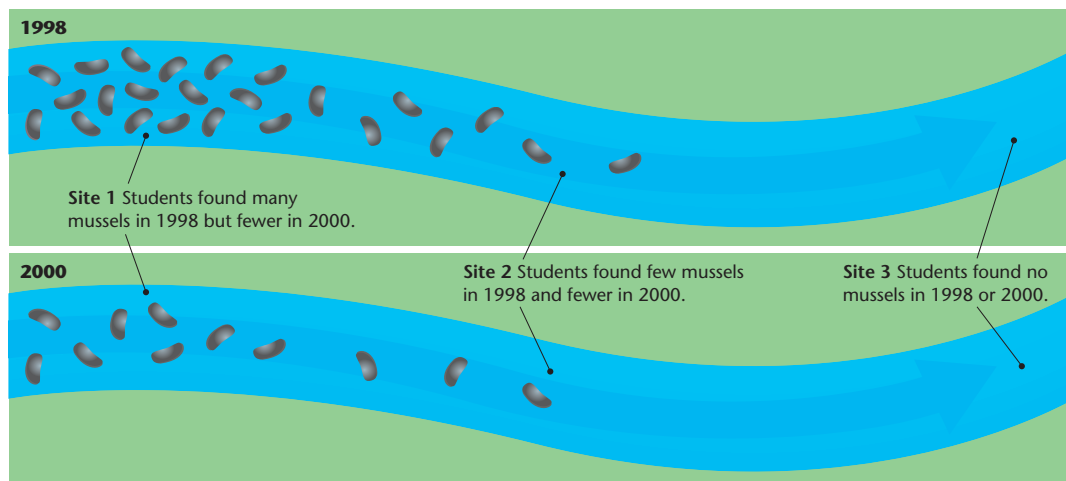
The Keene High School students observed two trends: that the number of dwarf wedge mussels on the Ashuelot River is declining over time and that the number of dwarf wedge mussels decreases at sites downstream from the first study site. These trends are illustrated in **Figure 2**. Students tested the water in three places and found that the farther downstream they went, the more phosphate the water had. Phosphates are chemicals in many fertilizers.

Armed with their observations, the students might make the following hypothesis: *phosphate fertilizer from a lawn is washing into the river and killing dwarf wedge mussels*. To test their hypothesis, the students make a **prediction**, a logical statement about what will happen if the hypothesis is correct. The students might make the following prediction: *mussels will die when exposed to high levels of phosphate in their water*.

It is important that the students' hypothesis—high levels of phosphate are killing the mussels—can be disproved. If students successfully raised mussels in water that has high phosphate levels, their hypothesis would be incorrect. Every time a hypothesis is disproved, the number of possible explanations for an observation is reduced. By eliminating possible explanations a scientist can zero in on the best explanation with more confidence.

**Reading Check** What is the difference between a hypothesis and a prediction? (See the Appendix for answers to Reading Checks.)

**Figure 2** ▶ The diagram below shows the trends observed by the students at Keene High School. Site 1 is upstream. Site 3 is downstream.



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### MISCONCEPTION ALERT

**Laws and Theories** Many students believe that if a theory is accepted by enough people for a long enough period of time, the theory will “grow up” to be a law. Emphasize that laws and theories are both accepted, but that they serve different functions. A law, such as the law of gravity, is a concise statement of fact that is accepted as true and universal. Theories, such as the theory of evolution by natural selection, are statements that are products of many scientific observations and may encompass numerous hypotheses or laws. Like

a law, a theory is accepted as true, but theories are much more complex. A law can be compared to a rubber ball. When dropped under constant conditions, the ball will always bounce exactly as predicted. Bouncing is the only action the ball performs. On the other hand, a theory can be compared to the operation of a car. A car has many components, all performing different tasks and working in unison. A part of the car may be improved, such as the brakes or air bags, but the general function of the car remains constant.

**Experimenting** The questions that arise from observations often cannot be answered by making more observations. In this situation scientists usually perform one or more experiments. An **experiment** is a procedure designed to test a hypothesis under controlled conditions.

Experiments should be designed to pinpoint cause-and-effect relationships. For this reason, good experiments have two essential characteristics: a single variable is tested, and a control is used. The **variable** (VER ee uh buhl) is the factor of interest, which, in our example, would be the level of phosphate in the water. To test for one variable, scientists usually study two groups or situations at a time. The variable being studied is the only difference between the groups. The group that receives the experimental treatment is called the **experimental group**. In our example, the experimental group would be those mussels that receive phosphate in their water. The group that does not receive the experimental treatment is called the **control group**. In our example, the control group would be those mussels that do not have phosphate added to their water. If the mussels in the control group thrive while most of those in the experimental group die, the experiment's results support the hypothesis that phosphates from fertilizer are killing the mussels.



## CASE STUDY

### The Experimental Method In Action at Keene High School



Keene High School students collected mussels (nonendangered relatives of the dwarf wedge mussel) and placed equal numbers of them in two aquariums. They ensured that the conditions in the aquariums were identical—same water temperature, food, hours of light, and so on. The students added a measured amount of phosphate to the aquarium of the experimental group. They added nothing to the aquarium of the control group.

A key to the success of an experiment is changing only one variable

► **Keene High School** students are conducting an experiment to study the effect of phosphate levels on the growth rates of freshwater mussels.

and having a control group. What would happen if the aquarium in which most of the mussels died had phosphate in the water and was also warmer? The students would not know if the phosphate or the higher temperature killed the mussels.

Another key to experimenting in science is *replication*, or recreating the experimental conditions to make sure the results are consistent. In this case, using six aquariums—three control and three experimental—

would help ensure that the results are not simply due to chance.

#### CRITICAL THINKING

- 1. Applying Ideas** Why did the students ensure that the conditions in both aquariums were identical?
- 2. Evaluating Hypothesis** How would you change the hypothesis if mussels died in both aquariums?

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#### Notable Quotes

GENERAL

“If I have seen further than others, it is because I have stood on the shoulders of giants.”

—Isaac Newton

Much like the upper levels of a building depend on the lower levels for structure, discoveries are often possible only because of earlier scientific findings. Ask students to research Newton's three laws of motion and describe how Newton based his work on that of others. **LS Logical**

#### SKILL BUILDER

BASIC

**Writing Skills** Have students find something of interest to them in the classroom, such as a model, a fish tank, or a globe, and write down as many observations about the object as they can in 5 minutes. Then have students switch objects with a partner and repeat the exercise. Have them compare observations and write a short summary of what they learned from this experience in their *EcoLog*. **LS Intrapersonal**

English Language Learners

#### Activity

BASIC

**Park it Right Here** Use the following demonstration to introduce scientific methods in a fun, dramatic way. Ask students to name some national parks. No matter what park is mentioned, write “Yellowstone” on a separate piece of paper each time a park is called out. Crumple each paper into a ball, and toss it into a clean wastebasket. After doing this several times, ask a student to pick one of the crumpled balls. Have the student open the paper and concentrate on the park name without saying it aloud. Look like you are concentrating really hard, then amaze them with your mind-reading abilities. When students ask how you did it, ask them to form hypotheses and predictions about what happened. Ask them how they could test their predictions. Explain that this is how science works. People observe something strange, they try to explain their observations, they test their explanations, and they weed out incorrect explanations until they are left with the most likely one. **LS Logical**

#### CASE STUDY

**The Experimental Method In Action** If students have trouble identifying the hypothesis, tell them that the Keene High School students hypothesized that phosphates were killing the mussels.

#### Answers to Critical Thinking

1. Students ensured that the conditions in the aquariums were identical so that they could test one variable.
2. Answers may vary. Students may suggest testing other variables.

## Teach, continued

### Group Activity — ADVANCED

**The Metric Game** Point out that most of the measurements in this book use SI units. Understanding the metric system is an essential component of scientific literacy. Divide students into teams and have each team send a representative to the board. Select an item in the room (such as a book, the board, or water in a glass) and provide a metric unit with which to measure the item. Have each team estimate the measurement of the item. After measuring the item, the team with the closest estimate is awarded one point. Allow students to take turns measuring the items so that students become familiar with the meter stick, balance, graduated cylinder, and other measuring tools. Repeat this exercise throughout the year. **LS Visual**

### MISCONCEPTION ALERT

#### Information on the Internet

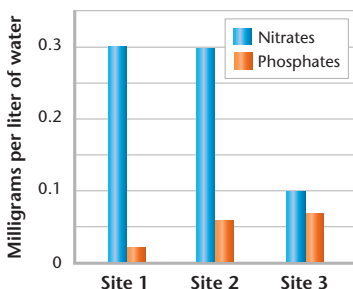
The Internet is an increasingly important means not only for disseminating scientific results and studies but also for linking relevant studies together. The Internet also offers a lot of misinformation and bias. As a class, brainstorm a list of environmental science keywords. Then have students use the keywords to find examples of both unbiased and biased information on the Internet.



**Figure 3** ▶ This scientist is analyzing his data with the help of a computer.

**Table 1** ▼

Pollutant Concentrations (mg/L)		
Site	Nitrates	Phosphates
1	0.3	0.02
2	0.3	0.06
3	0.1	0.07



**Figure 4** ▶ This graph and the table above it compare the concentrations of phosphates and nitrates in the Ashuelot River in 2000. Site 1 is upstream of Sites 2 and 3.

**Organizing and Analyzing Data** Keeping careful and accurate records is extremely important in science. A scientist cannot rely on sloppy observations or incomplete records. The information that a scientist gathers during an experiment, which is often in numeric form, is called **data**.

Organizing data into tables and graphic illustrations helps scientists analyze the data and explain the data clearly to others. The scientist in **Figure 3** is analyzing data on pesticides in food. Graphs are often used by scientists to display relationships or trends in the data. Graphs are especially useful for illustrating conclusions drawn from an experiment.

One common type of graph is called a *bar graph*. Bar graphs are useful for com-

paring the data for several things in one graph. **Figure 4** shows the data in **Table 1** in the form of a bar graph. Look at the data for Site 3 in the bar graph. The data show that the concentration of phosphates is higher at Site 3 than at Sites 1 and 2, and the concentration of nitrates is lower than at Sites 1 and 2.

**Drawing Conclusions** Scientists determine the results of their experiment by analyzing their data and comparing the outcome of their experiment with their prediction. Ideally, this comparison provides scientists with an obvious conclusion. But often the conclusion is not obvious. For example, in the mussel experiment, what if three mussels died in the control tank and five died in the experimental tank? The students could not be certain that phosphate is killing the mussels. Scientists often use mathematical tools to help them determine whether such differences are meaningful or are just a coincidence. Scientists also repeat their experiments.

**Repeating Experiments** Although the results from a single experiment may seem conclusive, scientists look for a large amount of supporting evidence before they accept a hypothesis. The more often an experiment can be repeated with the same results, in different places and by different people, the more sure scientists become about the reliability of their conclusions.

**Communicating Results** Scientists publish their results to share what they have learned with other scientists. When scientists think their results are important, they usually publish their findings as a scientific article. A scientific article includes the question the scientist explored, reasons why the question is important, background information, a precise description of how the work was done, the data that were collected, and the scientist's interpretation of the data.

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### Notable Quotes

ADVANCED

“There are two possible outcomes: If the result confirms the hypothesis, then you’ve made a measurement. If the result is contrary to the hypothesis, then you’ve made a discovery.”

—Enrico Fermi

Ask students to explain the following quote in relation to scientific methods and the formation of a hypothesis.

**LS Verbal**

### LANGUAGE ARTS

CONNECTION

GENERAL

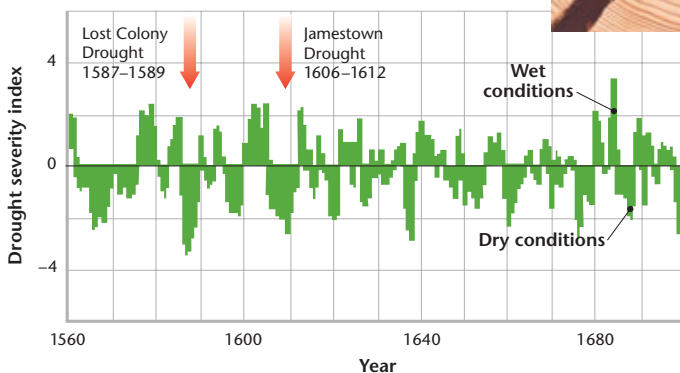
**Never Cry Wolf** Students may not be familiar with naturalist Farley Mowat’s novel *Never Cry Wolf*. In this book, the Canadian government sent Mowat out to investigate wolves. Their hypothesis was that the growing wolf population threatened people and caribou. Mowat’s data did not confirm the hypothesis. In fact, the wolves were helping to maintain a healthy caribou population. Ask students to read *Never Cry Wolf*, or watch the movie, and identify different aspects of the scientific method in Mowat’s research. **LS Logical**

## The Correlation Method

Whenever possible, scientists study questions by using experiments. But many questions cannot be studied experimentally. The question “What was Earth’s climate like 60 million years ago?” cannot be studied by performing an experiment because the scientists are 60 million years too late. “Does smoking cause lung cancer in humans?” cannot be studied experimentally because doing experiments that might injure people would be unethical.

When using experiments to answer questions is impossible or unethical, scientists test predictions by examining **correlations**, or associations between two or more events. For example, scientists know that the relative width of a ring on a tree trunk is a good indicator of the amount of rainfall the tree received in a given year. Trees produce wide rings in rainy years and narrow rings in dry years. Scientists have used this knowledge to investigate why the first European settlers at Roanoke Island, Virginia (often called the Lost Colony) disappeared and why most of the first settlers at Jamestown, Virginia, died. As shown in **Figure 5**, the rings of older trees on the Virginia coast indicate that the Lost Colony and the Jamestown Colony were founded during two of the worst droughts the coast had experienced in centuries. The scientists concluded that the settlers may have starved because the famine made it hard to grow food.

Although correlation studies are useful, correlations do not necessarily prove cause-and-effect relationships between two variables. For example, the correlation between increasing phosphate levels and a declining mussel population on the Ashuelot River does not prove that phosphates harm mussels. Scientists become more sure about their conclusions if they find the same correlation in different places and as they eliminate other possible explanations.



Source: *Science*.

## Connection to Geology

**Coral Correlation** Some geologists use an interesting correlation to study records of past climates. Certain species of coral put down layers of skeleton every year and can live for 300 years. Coral skeletons contain the elements strontium, Sr, and calcium, Ca. In some corals, the ratio of these elements in a layer of skeleton correlates with local sea surface temperature at the time that the layer forms. The correlation between the Sr to Ca ratio and the sea temperature provides scientists with one record of how Earth’s climate has changed over the centuries.

## Using the Figure — GENERAL

**Drought in Jamestown** The drought severity index for the Jamestown area from 1560 until 1700 is shown in **Figure 5**. Ask students to look for and discuss patterns in the data. Ask, “What does the data show about the ‘average’ rainfall in the Jamestown area? What conclusions can you draw about the role of rainfall variability on the history of human settlements and civilizations?” (The data shows that the rainfall in any given year is likely to vary, often widely, from the average. Variability in rainfall could have contributed significantly to the fates of human settlements and civilizations.)

**LS Visual**

## Internet Activity — ADVANCED

### Dendrochronology Tutorials

Dendrochronologists are scientists who study tree rings. Because trees have annual growth cycles, scientists can determine a tree’s history by taking tree ring samples. A thick ring indicates that conditions were favorable for tree growth and a thin ring can reveal environmental stresses such as drought. Dendrochronologists analyze tree-ring data from around the world to establish a record of the Earth’s climate. There are several dendrochronology tutorials and activities available on the Internet. Have students find the best ones and share them with the class.

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## BRAIN FOOD



**Phenology in Alaska** In an attempt to study climate change, scientists have utilized the records from a yearly betting pool in Nenana, Alaska. For most of the past century, area residents bet yearly on when the ice of the Nenana River would crack, signaling the start of the spring thaw. Participants pay a few dollars to enter, and the winners split the pot. The wagering has resulted in a nearly 100-year

record of the date the river has broken up each year. A Stanford University scientist who researches *phenology*, the study of the timing of natural events, used the records as data for a correlation study. In 2001 the ice breakup occurred, on average, 5.5 days sooner than it did in 1917. This indicates that the climate around Nenana has warmed over the course of 80 years.



## Transparencies

TT Rainfall and Tree Ring Width

## Teach, continued

### BIOLOGY

#### CONNECTION GENERAL

**Jane Goodall** Jane Goodall is famous for studying chimpanzees in the Gombe Forest in Tanzania. Before she began her research in 1960, people knew little about chimps and thought they were dangerous. She would spend days at a time patiently observing the chimps in their habitat. She initially had little money for her studies but was able to survive on little food and drink. She made the most of the resources she had, going on to be one of the most successful woman scientists in history. To learn more about the Gombe chimps and the researchers studying them today, students can visit the Jane Goodall Institute's Center for Primate Studies on the Internet.

#### MISCONCEPTION ALERT

**Scientific Methods** Point out that the title of this section is plural. Emphasize that there is no single scientific method. Scientists approach problems from a variety of viewpoints. They conduct their research using available tools, data, time, and people. Research often leads scientists to develop new tools and techniques, but the basic methods remain unchanged.

#### Transparencies

TT John Snow's Cholera Spot Map

#### Connection to Biology

**Discovering Penicillin** Alexander Fleming discovered penicillin by accident. Someone left a window open near his dishes of bacteria, and the dishes were infected with spores of fungi. Instead of throwing the dishes away, Fleming looked at them closely and saw that the bacteria had died on the side of a dish where a colony of green *Penicillium* mold had started to grow. If he had not been a careful observer, penicillin might not have been discovered. You may find *Penicillium* yourself on moldy bread.

## Scientific Habits of Mind

Scientists actually approach questions in many different ways. But good scientists tend to share several key habits of mind, or ways of approaching and thinking about things.

**Curiosity** Good scientists are endlessly curious. Jane Goodall, pictured in Figure 6, is an inspiring example. She studied a chimpanzee troop in Africa for years. She observed the troop so closely that she came to know the personality and behavior of each member of the troop and greatly contributed to our knowledge of that species.

**The Habit of Skepticism** Good scientists also tend to be skeptical, which means that they don't believe everything they are told. For example, 19th century doctors were taught that men and women breathe differently—men use the diaphragm (the sheet of muscle below the rib cage) to expand their chest, whereas women raise their ribs near the top of their chest. Finally, a female doctor found that women seemed to breathe differently because their clothes were so tight that their ribs could not move far enough to pull air into their lungs.

**Openness to New Ideas** As the example above shows, skepticism can go hand in hand with being open to new ideas. Good scientists keep an open mind about how the world works.



**Figure 6** ▶ Jane Goodall is famous for her close observations of chimpanzees—observations fueled in part by her endless curiosity.

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#### INCLUSION Strategies

GENERAL

- Visually Impaired
- Developmentally Delayed
- Learning Disabled

Have students observe people, objects, systems and the environment of the classroom for 8–10 minutes. Then have them label four note cards with the following: “See,” “Hear,” “Smell,” and “Touch.” Students can draw or write about their observations for each of the senses. Observations should indicate time, date, and room conditions. This exercise can also be repeated, and students can compare and discuss the results.

#### Notable Quotes

GENERAL

“The whole of science is nothing more than a refinement of everyday thinking.”

—Albert Einstein

Discuss the quotation with students. Ask, “Are there tools of environmental science that are useful to people in everyday situations?” If necessary, prompt them to consider how a mechanic uses the experimental method to diagnose a problem with a car. **LS Logical**

**Intellectual Honesty** A scientist may be certain that a hypothesis is correct before it has been fully tested. But when an experiment is repeated, the results may differ from those obtained the first time. A good scientist will consider the possibility that the new results may be accurate, even if this means that the hypothesis might be wrong.

**Imagination and Creativity** Good scientists are not only open to new ideas but able to conceive of new ideas themselves. The ability to see patterns where others do not, or to imagine things that others cannot, allows a good scientist to expand the boundaries of what we know.

An example of an imaginative and creative scientist is John Snow, shown in Figure 7. Snow was a physician in London during a cholera epidemic in 1854. Cholera, a potentially fatal disease, is caused by a bacterium found in water that is polluted with human waste. Few people had indoor plumbing in 1854. Most people got their water from public pumps; each pump had its own well. To find the polluted water source, Snow made a map showing the homes of everyone who died of cholera. The map also showed the public water pumps. In this example of a correlation study, he found that more deaths occurred around a pump in Broad Street than around other pumps in the area. London authorities ended the cholera epidemic by shutting off the Broad Street pump. Using observation, imagination, and creativity, Snow solved an environmental problem and saved lives.

**Reading Check** How did drawing a map of London help John Snow solve the cholera problem in 1854?



**Figure 7** ▶ John Snow (bottom) created his famous spot map (top), which enabled him to see a pattern that no one had noticed before.

**Answer to Reading Check** Snow's map helped him see that the homes of people who died from cholera were concentrated around the Broad Street pump.

## Close

### Reteaching **BASIC**

**Scientific Methods** Remind students that not all questions can be answered using scientific methods. Ask students to give examples of questions. Then ask students which questions scientists could answer and which ones they could not.

**LS Logical**

### Quiz **GENERAL**

1. Why should the results of an experiment be repeatable? (If the results of an experiment cannot be replicated, scientists cannot trust the reliability of their conclusions.)
2. Why are experiments designed to have as few variables as possible? (Limiting variables allows scientists to pinpoint causes and effects.)

### Alternative Assessment **GENERAL**

**Identifying Scientific Methods** Provide students with a copy of an article about an environmental issue from a magazine such as *Discover*, *National Geographic*, or *Scientific American*. Have students highlight and label parts of the article that demonstrate the scientific method.

## SECTION 1 Review

1. **Describe** the steps of the experimental method.
2. **Name** three scientific habits of mind and explain their importance.
3. **Explain** why a hypothesis is not just a guess.
4. **Explain** how scientists try to answer questions that cannot be tested with experiments.

### CRITICAL THINKING

5. **Analyzing Methods** Read the description of experiments. Describe the two essential parts of a good experiment, and explain their importance. **READING SKILLS**
6. **Analyzing Relationships** How can a scientist be both skeptical and open to new ideas at the same time? Write a one-page story that describes such a situation. **WRITING SKILLS**

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### Answers to Section Review

1. First, make observations or measurements to gather information. Second, use these observations to form a hypothesis, and make a prediction based on the hypothesis. Next, conduct an experiment to test the hypothesis under controlled conditions. Organize and analyze information, or data, that is gathered from the experiment. Use the data to form conclusions about the original hypothesis. Repeat the experiment and share the results.
2. Sample answers: Curiosity leads scientists to ask new questions. Skepticism leads scientists to question explanations they doubt. Openness to new ideas prevents scientists

from limiting their thinking. Intellectual honesty helps ensure accurate conclusions. Imagination and creativity help scientists conceive new ideas and explanations.

3. A hypothesis considers information gathered by observation, while a guess might not. A hypothesis is also a testable explanation, while a guess may not be testable.
4. Scientists study correlations, reliable associations between two events, to answer questions that cannot be investigated with experiments. The more correlations that exist between variables, the more sure scientists can be of their conclusions.

5. The two essential parts of a good experiment are testing only one variable and using a control. It is important to test only one variable so you can be sure that this variable is the cause of any changes that occur. It is important to use a control so that you have something to compare with the experimental treatment.
6. Answers may vary. A skeptical scientist does not believe everything he or she is told. In being skeptical about established ideas, a scientist is open to new ones.

## Focus

## Overview

Before beginning this section, review with your students the Objectives in the Student Edition.

This section discusses statistics and explains how scientists apply statistics to data. Students will also learn about the importance of physical, graphical, conceptual, and mathematical models in science.


 Bellringer

Bring in a few news clippings that include statistics. Discuss the statistics and how they are used with the class. Point out, in particular, advertisements that include statistics to promote a product. Discuss with the class the difference between responsible uses of statistics and misleading uses of statistics.

 Verbal/Visual

## Motivate

Group Activity GENERAL

**That's MY Birthday** Write the 12 months of the year on the board. Ask everyone in the room to tell you his or her birthday. If more than one student shares a birthday, call attention to this fact. Ask students if they are surprised. Start a discussion about the probability of this occurrence. Ask interested students to research why this might be the case. (Probability is not as simple as it seems. In a group of 23 people, there is a 50 percent chance that two will share a birthday. In a group of 40, the chance is nearly 90 percent. Have students research in the library or on the Internet to find the probability of a shared birthday.)  Logical

## Statistics and Models

## Objectives

- ▶ Explain how scientists use statistics.
- ▶ Explain why the size of a statistical sample is important.
- ▶ Describe three types of models commonly used by scientists.
- ▶ Explain the relationship between probability and risk.
- ▶ Explain the importance of conceptual and mathematical models.

## Key Terms

statistics  
mean  
distribution  
probability  
sample  
risk  
model  
conceptual model  
mathematical model

Environmental science provides a lot of data that need to be organized and interpreted before they are useful. **Statistics** is the collection and classification of data that are in the form of numbers. People commonly use the term statistics to describe numbers, such as the batting record of a baseball player. Sportswriters also use the methods of statistics to translate a player's batting record over many games into a batting average, which allows people to easily compare the batting records of different players.

## How Scientists Use Statistics

Scientists are also interested in comparing things, but scientists use statistics for a wide range of purposes. Scientists rely on and use statistics to summarize, characterize, analyze, and compare data. Statistics is actually a branch of mathematics that provides scientists with important tools for analyzing and understanding their data.

Consider the experiment in which students studied mussels to see if the mussels were harmed by fertilizer in their water. Students collected data on mussel length and phosphate levels during this experiment. Some mussels in the control group grew more than some mussels in the experimental group, yet some grew less. How could the students turn this data into meaningful numbers?

**Statistics Works with Populations** Scientists use statistics to describe statistical populations. A *statistical population* is a group of similar things that a scientist is interested in learning about. For example, the dwarf wedge mussels shown in **Figure 8** are part of the population of all dwarf wedge mussels on the Ashuelot River.



**Figure 8** ▶ Students found these dwarf wedge mussel shells in a muskrat den. These mussels are part of the statistical population of all dwarf wedge mussels on the Ashuelot River.

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## Chapter Resource File

- Lesson Plan
- Active Reading BASIC
- Section Quiz GENERAL




## Transparencies

- TT Bellringer
- TT Size Distribution of Dwarf Wedge Mussels

## Homework

GENERAL

**Critiquing Advertorials** Ask students to search newspapers and magazines for advertorials. These features often resemble magazine or newspaper content but are created by advertisers. Ask students to annotate an advertorial with their own critique of the statements and statistics provided in the text. A good method to prepare a critique of the advertorial is to photocopy and reduce the feature so there is a margin of white space for students to work in.  Logical

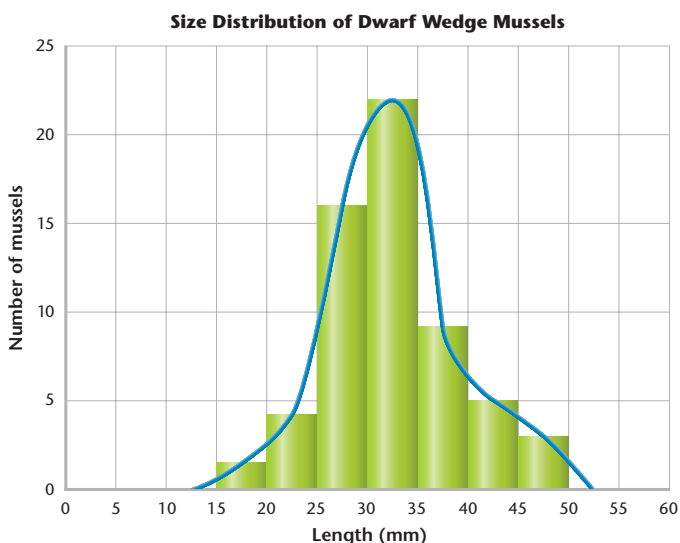
**What Is the Average?** Although statistical populations are composed of similar individuals, these individuals often have different characteristics. For example, in the population of students in your classroom, each student has a different height, weight, and so on.

The Keene High School students measured the lengths of dwarf wedge mussels in a population, as shown in Figure 8. They added the lengths of the mussels and then divided by the number of mussels. This gave the average length of the mussels, which in statistical terms is called the mean. The **mean** is the number obtained by adding the data for a characteristic and dividing this sum by the number of individuals. The mean provides a single measure for a given characteristic of a population. Scientists can compare different populations by comparing their means. The mean length of the mussels in Figure 9 is about 30 mm.

**The Distribution** The bar graph in Figure 9 shows the lengths of dwarf wedge mussels in a population. The pattern that the bars create when viewed as a whole is called the *distribution*. A **distribution** is the relative arrangement of the members of a statistical population. In Figure 9, the lengths of the individuals are arranged between 15 and 50 mm.

The overall shape of the bars, which rise to form a hump in the middle of the graph, is also part of the distribution. The line connecting the tops of the bars in Figure 9 forms the shape of a bell. The graphs of many characteristics of populations, such as the heights of people, form bell-shaped curves. A bell-shaped curve indicates a *normal distribution*. In a normal distribution, the data are grouped symmetrically around the mean.

**Reading Check** How was the mean length of the dwarf wedge mussel population calculated?



**Graphic**

**Organizer** **Venn Diagram**  
Create the **Graphic Organizer** entitled "Venn Diagram" described in the Appendix. Label the circles with "Statistics" and "Models." Then, fill in the diagram with the characteristics that each way of interpreting the data shares with the other.

**Figure 9** ▶ This bar graph shows the distribution of lengths in a population of dwarf wedge mussels. For example, the second bar from the left indicates that the population studied contained four mussels between 20 and 25 mm long.

**LANGUAGE ARTS**

**CONNECTION** **ADVANCED**

**"Rosencrantz and Guildenstern Are Dead"** In Tom Stoppard's play, minor characters from Shakespeare's "Hamlet" become the protagonists. Ask students to read the first act of the play or watch the movie of the same name. In the play, a character is tossing a coin with some improbable results. Despite continuous tossing, the coin always comes up heads. Ask students to interpret this scene. Ask, "What does Tom Stoppard mean to say about the world that the characters inhabit?" (Students may think that Stoppard was trying to present a

world in which the laws of logic and reason are suspended. In truth, Rosencrantz and Guildenstern inhabit a world that is determined by mathematical concepts of probability. Mathematicians define *probability* as the long-run pattern that predictably emerges from a series of random outcomes. If 100 coin flips were made, the results can be surprisingly uneven. Coin tosses only yield about a .5 probability after one thousand flips. The characters may function with free will, but they are beholden to a fate—or a probability—that they cannot perceive.) **Logical**

**Teach**

**Reteaching** **BASIC**

**Distribution** Students may have trouble with the concept of distributions. Show them a number of graphs throughout the book and explain the arrangement of data. You may want to discuss some general grading strategies with students to further explain what a bell-shaped curve is. **Visual** **English Language Learners**

**READING SKILL BUILDER** **BASIC**

**Paired Summarizing** Have students pair with a partner. Each student should read and summarize the meaning of the terms *distribution* and *mean*. Ask each pair to share an example of a distribution and a mean. **Interpersonal**

**SKILL BUILDER** **BASIC**

**Math Skills** Ask students to create a set of data that has a mean of 12 and that includes at least five numbers. Then, ask students to create a line graph that shows the distribution of this data. Ask them if the data appears to be in a bell-shaped curve. (Accept any set of data that has a mean of 12.) **Logical**

**Graphic**

**Organizer** **GENERAL**

**Venn Diagram**

You may want to have students work in groups to create this Venn Diagram. Have one student draw the map and fill in information provided by other students from the group.

**Answer to Reading Check**

The students calculated the mean length of the mussels by adding the lengths of the mussels and then dividing by the number of mussels.

## Teach, continued

### MATH PRACTICE

#### Answers

$$\frac{40}{200} = \frac{20}{100} = 0.2$$

There is a probability of 0.2 that the next pine tree will have pine cones.

### Activity

GENERAL

#### M&M® Samples and Population

The distribution of colors in a typical bag of M&M's® is available on the Internet. Download this information for the following activity. Randomly draw five M&M's® from a bag and ask students to compare the color distribution of these five to the distribution given. Draw 10, 20, and finally, 30 candies, having students consider the distribution each time. Ask students how this exercise demonstrates the importance of sample size in science. As an extension, students can graph the results of larger samples.

### MISCONCEPTION ALERT

#### Probability and Possibility

There is a difference between *probability* and *possibility*. When something is possible, it can occur. Mathematical probability refers to the likelihood of possible events. For example, it is possible that a tornado might sweep up a winning lottery ticket and drop it gently at someone's feet on his or her birthday, but it is not probable.

### MATH PRACTICE

**Probability** Probability is often determined by observing ratios or patterns. For example, imagine that you count 200 pine trees in a forest and notice that 40 of those trees have pine cones. What is the probability that the next pine tree you come across will have pine cones?

**What Is the Probability?** The chance that something will happen is called **probability**. For example, if you toss a penny, what is the probability that it will come up heads? Most people would say “half and half,” and they would be right. The chance of a tossed penny coming up heads is  $\frac{1}{2}$ , which can also be expressed as 0.5 or 50%. In fact, probability is usually expressed as a number between 0 and 1 and written as a decimal rather than as a fraction. Suppose the penny comes up heads 7 out of 10 times. Does this result prove that the probability of a penny coming up heads is 0.7? No, it does not. So what is the problem?

The problem is that the *sample size*—the number of objects or events sampled—is too small to yield an accurate result. In statistics, a **sample** is a group of individuals or events selected to represent the population. If you toss a penny 10 times, your sample size is 10. If you continue tossing 1,000 times, you are almost certain to get about 50% heads and 50% tails. In this example, the sample is the number of coin tosses you make, while the population is the total number of coin tosses possible. Scientists try to make sure that the samples they take are large enough to give an accurate estimate for the whole population.

### Statistics in Everyday Life

You have probably heard, “There is a 50 percent chance of rain today.” **Figure 10** shows an example of a natural event that we often associate with probability—a thunderstorm. You encounter statistics often and use them more than you may think. People are constantly trying to determine the chance of something happening. A guess or gut instinct is probably just an unconscious sense of probability.

**Figure 10** ▶ Most people are familiar with statistics regarding the weather, such as the chance, or probability, of a thunderstorm.



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**Understanding the News** The news contains statistics every day, even if they are not obvious.

For example, a reporter may say, “A study shows that forest fires increased air pollution in the city last year.” We could ask many statistical questions about this news item. We might first ask what the average amount of air pollution in the city is. We could gather data on air pollution levels over the past 20 years and graph them. Then we could calculate the mean, and ask ourselves how different last year's data are from the average. We might graph the data and look at the distribution. Do this year's pollution levels seem unusually high compared to levels in other years? Recognizing and paying attention to statistics will make you a better consumer of information, including information about the environment.

### HISTORY

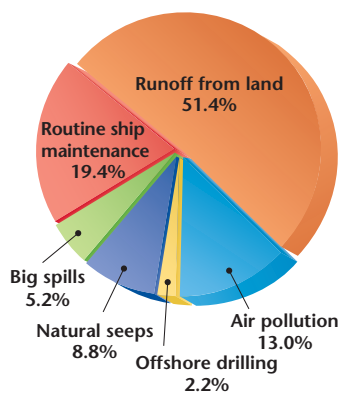
CONNECTION GENERAL

**Pascal's Triangle** In 1653, French mathematician Blaise Pascal created “Pascal's Triangle,” an arrangement of numbers which describes simple probabilities. For example, if there are five slippers in a closet, and you want to figure out how many different ways you can choose two of them to wear, Pascal's Triangle can help determine how many

different ways you can choose two objects from a set of five. Pascal's Triangle can be easily downloaded from the Internet and is discussed in many upper-level math texts. Bring in a number of objects such as hats, slippers, bracelets, or ties to clearly demonstrate how Pascal's Triangle is useful in the study of probability. **Visual/Logical**



**Figure 11** ▶ The graph below shows the sources of oil that pollute the ocean. The photo at left shows an oil spill off the coast of Galveston, Texas. Big oil spills are a relatively minor source of oil pollution.



## Group Activity — GENERAL

**Teaching To the Class** Have students create teaching materials on probability, statistics, and risk for other students. Split the class into three groups. One group should devise a lesson on probability, another on statistics, and a third on risk. Ask students to present the lessons to the class. **LS Interpersonal**  
Co-op Learning

## SKILL BUILDER — BASIC

**Math Skills** Lightning kills about 80 people each year in the United States. Those are not bad odds when you consider that the population is about 280 million and that the behaviors you choose—such as whether or not to stand next to large metal objects during inclement weather—play a large part in your safety. Ask students to assume that everyone in the United States has equal risk for being struck by lightning. Ask students what an individual's chance of being killed would be. (The chance of being killed is 80/280 million. Expressed as a probability, the chance is 0.0000028, or .000028%.)

**LS Logical**

**Thinking About Risk** In scientific terms, **risk** is the probability of an unwanted outcome. For example, if you have a 1 in 4 chance of failing a class, the risk of failing is  $\frac{1}{4}$ , or 0.25. Figure 11 shows a well-publicized environmental problem—oil spills. But as you can see in the pie graph, the risk of pollution from large oil spills is much smaller than the risk of oil pollution from everyday sources.

The most important risk we consider is the risk of death. Most people overestimate the risk of dying from sensational causes, such as terrorism, and underestimate the risk from common causes, such as smoking. Likewise, most citizens overestimate the risk of sensational environmental problems and underestimate the risk of ordinary ones, as shown in Table 2.

**Table 2** ▼

Perceptions of Risk by Experts and Ordinary Citizens		
	High risk	Low risk
<b>Experts</b>	ozone depletion; global climate change	oil spills; radioactive materials; water pollution
<b>Citizens</b>	ozone depletion; radioactive waste; oil spills	global climate change; water pollution

Source: U.S. Environmental Protection Agency.

## Connection to Law

**Oil Tankers** The Oil Pollution Act of 1990 was a response to a huge oil spill from an oil tanker, the *Exxon Valdez*, in Alaska in 1989. The controversial bill had been debated for 14 years; it passed swiftly in the aftermath of the disaster. Under the law, all oil tankers operating in United States waters must be protected with double hulls by 2015.

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## REAL-LIFE

### CONNECTION — GENERAL

**Federal Emergency Management Agency (FEMA)** After a disaster occurs, such as a hurricane, flood, drought, or terrorist attack, FEMA helps a community recover. Another responsibility of FEMA is *mitigation*, the effort to lessen the impact of a disaster before it occurs. With mitigation in mind, FEMA provides the public with information on how to protect houses and public buildings from flooding, earthquakes, and wind. This

information is based upon risks that have been determined by experts. The probability of a flood is something that can be calculated by analyzing the geography and the historic weather and climatic patterns of a region. Mitigation is not limited to FEMA. Architects and structural engineers also consider how to engineer buildings and other structures to withstand the forces of earthquakes, floods, and tornadoes.

## Teach, continued

### Discussion GENERAL

**Giant's Causeway** Giant's Causeway in Northern Ireland is said to have been built by the mythical giant Finn McCool. According to legend, McCool built the plateau, composed of about 40,000 columns, to woo a lady giant. Geologists know that when lava cools it forms regular polygonal columns like the ones at Giant's Causeway. But scientists did not know why, until physicists Alberto G. Rojo and Eduardo A. Jagla started to “play” with computer models. “If you want to fracture a material with the least energy, hexagons are the way to do it,” explains Rojo. The scientists realized that they could model their results using simple materials. With cornstarch, water, and tape, they duplicated the fracturing of lava. Ask students to categorize the two types of models that Rojo and Jagla employed. (The first model was a computer model, which is conceptual and mathematical. The second model is a physical model.)

### Group Activity GENERAL

**Modeling Lava Fractures** To demonstrate how lava behaves as it cools, mix cornstarch with water in equal parts by volume. Spread the mixture onto a flat surface to a depth of one-half of an inch. When the mixture dries, place a wide swath of clear tape across the top and pull up. The mix of polygons that appear on the plate mimic those of Giant's Causeway, as well as those in the Palisades in New Jersey and in Devil's Postpile, in California. **KS Kinesthetic/Visual**

**Figure 12** ▶ This plastic model of a DNA molecule is an example of a physical model.



### Geo fact

**Fossil-Fuel Deposits** Fossil fuels, such as coal and oil, are often buried deep underground in particular rock formations. We find fossil fuels by drilling for rocks that indicate the presence of fossil fuels and then we make models of where the coal or oil is likely to be found.

**Figure 13** ▶ This map of the Denver, Colorado, area is an example of a graphical model.

## Models

You are probably already familiar with models. Museums have models of ships, dinosaurs, and atoms. Architects build models of buildings. Even crash-test dummies are models. **Models** are representations of objects or systems. Although people usually think of models as things they can touch, scientists use several different types of models to help them learn about our environment.

**Physical Models** All of the models mentioned above are physical models. *Physical models* are three-dimensional models you can touch. Their most important feature is that they closely resemble the object or system they represent, although they may be larger or smaller.

One of the most famous physical models was used to discover the structure of DNA. The two scientists who built the structural model of DNA knew information about the size, shape, and bonding qualities of the subunits of DNA. With this knowledge, the scientists created model pieces that resembled the subunits and the bonds between them. These pieces helped them figure out the possible structures of DNA. Discovering the structure of DNA furthered other research that helped scientists understand how DNA replicates in a living cell. **Figure 12** shows a modern model of a DNA molecule. The most useful models teach scientists something new and help to further other discoveries.

**Graphical Models** Maps and charts are the most common examples of *graphical models*. Showing someone a road map is easier than telling him or her how to get somewhere. An example of a graphical model is the map of the Denver, Colorado, area in **Figure 13**. Scientists use graphical models to show things such as the positions of the stars, the amount of forest cover in a given area, and the depth of water in a river or along a coast.



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### READING SKILL BUILDER

BASIC

**Paired Reading** Group students in pairs. Have each student read the “Models” section silently while taking note of any passages he or she finds confusing. After students finish reading, ask one student to summarize the section and the second student to add any ideas that were omitted. Both readers should help each other with any parts the other person did not understand. Have the students prepare a list of questions (with answers) to ask the class. Students may still have unanswered questions. Ask the class if it can provide the answers. **KS Verbal/Interpersonal**

### Homework

BASIC

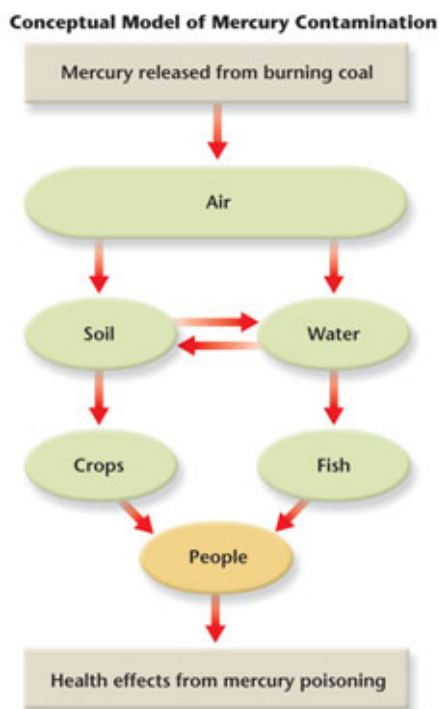
**Identifying Models** Have students use the weather section of the newspaper to identify uses of graphical, mathematical, and conceptual models. For example, a mathematical model may be used to predict the likelihood of rain on a certain day. A graphical model, such as a map, may be used to show the locations of pressure fronts or storms. A conceptual model may be used to explain long-term trends in the weather. **KS Logical**

**Conceptual Models** A **conceptual model** is a verbal or graphical explanation of how a system works or is organized. A flow-chart diagram is an example of a type of conceptual model. A flow-chart uses boxes linked by arrows to illustrate what a system contains and how those contents are organized.

Consider this example. Suppose that a scientist wants to know how mercury, a poisonous metal, moves through the environment to reach people after the mercury is released from burning coal. The scientist would use an understanding of mercury in the environment to build a conceptual model, as shown in **Figure 14**. Scientists often create such diagrams to help them understand how a system works—what components the system contains, how they are arranged, and how they affect one another.

Conceptual models are not always diagrams. They can also be verbal descriptions or even drawings of how something works or is put together. For example, the model of an atom as a large ball circled by smaller balls is a conceptual model of the structure of an atom. As this example shows, an actual model can be more than one type. An atomic model made of plastic balls is both a conceptual model and a physical model.

**Reading Check** How does building a conceptual model help scientists in their work?



**SCILINKS**  
[www.scilinks.org](http://www.scilinks.org)  
 Topic: Using Models  
 Code: HE81588

**Figure 14** ▶ This conceptual model shows how mercury released from burning coal could end up reaching people, where it could cause poisoning.

**FIELD ACTIVITY**

**Conceptual Model** Accompany your class outdoors. Observe your surroundings, and write down observations about what you see. In your *Ecolog*, draw a conceptual model of something you observe. Your model should represent a system with components that interact, such as a small community of organisms.

**Using the Figure** — **GENERAL**

**Mercury Sources** Ask students to review **Figure 14**. Can they see another way in which people might ingest mercury besides the ways shown in the figure? (People could consume water contaminated by mercury.) Ask students to think about why people might not be affected by mercury directly through the water supply. (Untreated drinking water can be contaminated by low levels of inorganic mercury, but the process of biomagnification concentrates mercury in the tissues of living things. So, ingesting dangerous levels of mercury from food represents a much greater health risk.) **LS Visual**

**Group Activity** — **BASIC**

**Making Models** Introduce students to the concept of a *scale model*. In a scale model, there is a constant ratio between the dimensions of the model and the object it represents. Most maps and many toys are examples of scale models. Divide students into groups of five, and challenge the groups to make a scale map of the classroom. **LS Visual**

**Answer to Reading Check**  
 A conceptual model helps scientists to understand a system by showing what components the system contains, how they are arranged, and how they affect one another.

**Transparencies**

**TT** Conceptual Model of Mercury Contamination

**CHEMISTRY** — **GENERAL**

**The Periodic Table** The periodic table of the elements is a conceptual model. Russian chemist Dmitri Mendeleev used the properties of each element to arrange and categorize all the known elements. Scientists all over the world have been using updated versions of Mendeleev's periodic table since the time that the periodic table was first published, in 1869. Ask students why the periodic table is such an important conceptual model and what might happen if there were no way to classify the elements. **LS Logical**

## Close

### Reteaching

BASIC

**Models** Reinforce students' comprehension of models by dividing the class into groups of three. Ask each group to have a representative explain to you what a physical, graphical, conceptual, and mathematical model is. Be sure to ask for an example of each.

### Quiz

GENERAL

1. Why do murders make front-page news, but lung cancer deaths do not? (Answers may vary. Students should incorporate the idea that rare and sensational events receive more attention than daily risks.)
2. Provide an example of a conceptual model. (Answers may vary.)

### Alternative Assessment

GENERAL

**Risks** Ask students to identify different risks in their lives—things they are scared of or things they may live with that do not bother them. They should also include dangers that seem very remote as well as environmental issues. Ask students to rank the risks and then do research to determine which are likely to be high risks for them and which are likely to be low risks. Ask them to share their results with you or with the class.

**IS Intrapersonal**

**Mathematical Models** A **mathematical model** is one or more equations that represents the way a system or process works. You can represent many common situations using math models.

For example, suppose that the grapes in a fruit basket at home are getting moldy. You notice that every day the mold covers two more grapes. Here is a mathematical model for the number of moldy grapes on Tuesday:

$$M_{\text{Tue}} = M_{\text{Mon}} + 2, \text{ where } M = \text{number of moldy grapes}$$

Mathematical models are especially useful in cases with many variables, such as the many things that affect the weather.

Because mathematical models use numbers and equations, people may think the models are always right. But weather models, for example, sometimes predict rain on dry days. In fact, people are the ones who interpret data and write the equations.

If the data or the equations are wrong, the model will not be realistic and so will provide incorrect information. Like all models, mathematical models are only as good as the data that went into building them.

People may think of mathematical models as being confined to blackboards and paper, but scientists can use the models to create amazing, useful images. Look at the image of the San Francisco Bay Area in Figure 15. This is a “false color” digital satellite image. The satellite measures energy reflected from the Earth's surface. Scientists use mathematical models to relate the amount of energy reflected from objects to the objects' physical condition.

**Figure 15** ▶ This is a satellite image of the San Francisco Bay Area. Scientists use mathematical models to understand the terrain from the way objects on the surface reflect light. In this image, healthy vegetation is red.



## SECTION 2 Review

1. **Explain** why sample size is important in determining probability.
2. **Explain** what “the mean number of weeds in three plots of land” means.
3. **Describe** three types of models used by scientists.

### CRITICAL THINKING

4. **Analyzing Relationships** Explain the relationship between probability and risk.
5. **Applying Ideas** Write a paragraph that uses examples to show how scientists use statistics. **WRITING SKILLS**
6. **Evaluating Ideas** Why are conceptual and mathematical models especially powerful?

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### Answers to Section Review

1. A statistical sample needs to be large enough to reflect a population. If a sample is not large enough it can easily misrepresent probability.
2. The statement means that someone has determined how many weeds are in each of three plots of land, added these numbers together, and divided by three. In this case, the “mean” represents the average number of weeds in the three plots.
3. Answers may vary. Students should include three of the following: Physical models are three dimensional and closely resemble the object or system they represent. Graphical

models, which include maps and charts, illustrate data such as positions or amounts graphically. Conceptual models show how something works or how it is organized. Mathematical models use one or more equations to represent how a system or process works.

4. Probability is the chance that an event will occur. Risk is the probability of an unwanted outcome.
5. Answers may vary.
6. Answers may vary. Students may say that conceptual and mathematical models represent ideas and relationships clearly and precisely.

Scientific research is an essential first step to solve environmental problems. However, many other factors must also be considered. How will the proposed solution affect people's lives? How much will it cost? Is the solution ethical? Questions like these require an examination of **values**, which are principles or standards we consider important. What values should influence decisions that affect the environment? Table 3 lists some values that often affect environmental decisions. You might think of others as well.

### An Environmental Decision-Making Model

Forming an opinion about an environmental issue is often difficult and may seem overwhelming. It helps to have a systematic way of analyzing the issues and deciding what is important. One way to guide yourself through this process is to use a decision-making model. A **decision-making model** is a conceptual model that provides a systematic process for making decisions.

Figure 16 shows one possible decision-making model. The first step of the model is to gather information. In addition to watching news reports and reading about environmental issues, you should listen to well-informed people on all sides of an issue. Then consider which values apply to the issue. Explore the consequences of each option. Finally, evaluate all of the information to make a decision.

**Reading Check** Why is a decision-making model helpful for making environmental decisions?

Table 3 ▼

Values That Affect Environmental Decision Making	
Value	Definition
Aesthetic	what is beautiful or pleasing
Economic	the gain or loss of money or jobs
Environmental	the protection of natural resources
Educational	the accumulation and sharing of knowledge
Ethical/moral	what is right or wrong
Health	the maintenance of human health
Recreational	human leisure activities
Scientific	understanding of the natural world
Social/cultural	the maintenance of human communities and their values and traditions

### Objectives

- ▶ Describe three values that people consider when making decisions about the environment.
- ▶ Describe the four steps in a simple environmental decision-making model.
- ▶ Compare the short-term and long-term consequences of two decisions regarding a hypothetical environmental issue.

### Key Terms

value  
decision-making model

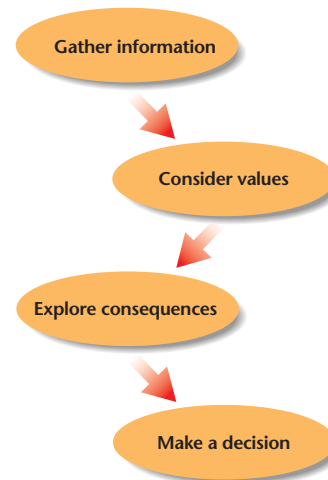


Figure 16 ▶ The diagram above shows a simple decision-making model.

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### Chapter Resource File

- Lesson Plan
- Active Reading **BASIC**
- Section Quiz **GENERAL**



### Transparencies

TT Bellringer

### SKILL BUILDER

GENERAL

**Writing** Ask students to imagine that they live in a town with a coal-fired power plant nearby. Many people are employed by the power plant and at a nearby coal mine. A neighboring county, which is generally more affluent, is building a wind farm to generate electricity. The wind farm will be operational in a few years. The press has raised the question of whether the existing plant should be closed. Ask students to write a sentence for each value in Table 3, explaining how it relates to this situation. **Logical**

## Focus

**Before beginning this section, review with your students the Objectives in the Student Edition.** This section introduces the idea that environmental decisions involve different values that are often competing. Difficult decisions can be managed systematically by using a decision-making model.

### Bellringer

Ask students to write down a problem in their life that presented a difficult decision. Ask them to consider how they usually approach decisions. Ask, “Is it by flipping a coin or by talking to your friends? How do you weigh what is important to you?” **Intrapersonal**

## Motivate

### Discussion

GENERAL

**Alien Invasion** Present students with the following scenario: A highly-evolved alien race has invaded Earth and is quickly descending upon your home town. You are forced to evacuate immediately, perhaps leaving your home behind forever. You do not know where you will go or what you will do next. There is only time to take 10 items with you. Food is supplied on the evacuation ship. Ask students what items they would decide to take. Discuss the pros and cons of each choice and come up with a common list for the class. Ask students what values influenced their decision. (Answers may vary. Ethical, educational, environmental, health, and social values may influence students' choices.) **Verbal**

### Answer to Reading Check

A decision-making model is helpful for making environmental decisions because it provides a systematic way of analyzing the issues and determining what is important.

## Teach

### Discussion **BASIC**

#### Emotions and Decision-Making

Point out to students that it is important to distinguish between emotional arguments and factual arguments while making decisions. People often confuse the two. Have students come up with a list of emotional statements and a list of factual statements and explore the differences between the two. You might also stress that emotional arguments have value and should be considered. **LS Verbal**

### REAL-LIFE

#### CONNECTION **GENERAL**

**NIMBY** NIMBY, which stands for **Not In My Backyard**, refers to the reaction many people have towards something they consider unpleasant being located near their homes. NIMBY may apply to things that are dangerous, unsightly, noisy or inconvenient. Have students give examples of what might elicit a NIMBY response. (Examples may include the proposed building of nuclear power plants, power lines, landfills, highways, airports, or cellular phone antennas.)



**Figure 17** ▶ The map (above) shows the proposed nature preserve, which would be home to warblers like the one pictured (right).



### A Hypothetical Situation

Consider the following hypothetical example. In the town of Pleasanton, in Valley County, biologists from the local college have been studying the golden-cheeked warbler, shown in **Figure 17**. The warblers have already disappeared from most areas around the state, and the warbler population is declining in Valley County. The biologists warn county officials that if the officials do not take action, the state fish and wildlife service may list the bird as an endangered species.

Pleasanton is growing rapidly, and much of the new development is occurring outside the city limits. This development is destroying warbler habitat. Valley County already has strict environmental controls on building, but these controls do not prevent the clearing of land.

Several groups join together to propose that the county buy several hundred acres of land where the birds are known to



## Saving the Everglades: Making Informed Decisions

The Florida Everglades is an enormous, shallow freshwater marsh. The water in the Everglades slowly flows from Lake Okeechobee to Florida Bay. Much of the marsh is filled with sawgrass, mangroves, and other water-loving plants. It is also home to wildlife, from 40 species of fish to panthers, alligators, and wading birds such as herons and roseate spoonbills.

In the 1880s, marshlands were considered wastelands. Developers began to drain the Everglades. They replaced marsh with houses and sugarcane fields. Between 1940 and 1971, the Army Corps of Engineers built dikes, canals, and pumping stations that drained even more water. The Corps also straightened the Kissimmee River, which runs into Lake Okeechobee.

Scientists have shown that what remains of the Everglades is dying. Its islands and mangrove swamps are vanishing, its water is polluted with fertilizer from farms, and its wading-bird colonies are much smaller than before. These effects have economic consequences. Because much of the Everglades' water has been diverted from Florida Bay into the Atlantic Ocean, the towns of southeast Florida are running out of fresh water and much of the marine life in Florida Bay has died.

In the 1990s, a commission reported that the destruction of the Everglades had jeopardized the state's tourism industry, farming, and the economic future of south Florida. The solution was obvious—undo the water diversion dikes and dams and restore water to the Everglades.



▶ **The roseate spoonbill** is a colorful resident of the Everglades.

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### Internet Activity **GENERAL**

**Acronym Glossary** Acronyms are popular in environmental science. Have students research environmental science acronyms on the Internet so that they can create an acronym glossary. Knowledge of these acronyms will help students better understand articles that relate to environmental issues. The following acronyms will help students get started:

**NGO**—**Non Governmental Organization**—refers to organizations that do not receive government funds. **NIMEY**—**Not In My Election Year**—refers to a politician's decision

to forestall something unpleasant for the constituency during an election year. **GOOMBY**—**Get Out Of My Backyard**—refers to an individual's desire to remove an environmental hazard from a neighborhood or community. **BANANA**—**Build Absolutely Nothing Anywhere Near Anything**—refers to a person who is opposed to any form of real estate development. **LULU** stands for **Locally Undesirable Land Use**. Other acronyms include **EPA**, **USGS**, **FWS**, **NRDC**, **IPCC**, **WWF** and **WMO**.

breed and save that land as a nature preserve. The groups also propose limiting development on land surrounding the preserve. The group obtains enough signatures on a petition to put the issue to a vote, and the public begins to discuss the proposal.

Some people who own property within the proposed preserve oppose the plan. These property owners have an economic interest in this discussion. They believe that they will lose money if they are forced to sell their land to the county instead of developing it.

Other landowners support the plan. They fear that without the preserve the warbler may be placed on the state's endangered species list. If the bird is listed as endangered, the state will impose a plan to protect the bird that will require even stricter limits on land development. People who have land near the proposed preserve think their land will become more valuable. Many residents of Pleasanton look forward to hiking and camping in the proposed preserve. Other residents do not like the idea of more government regulations on how private property can be used.



► **The Everglades** can be thought of as a shallow, slow-moving river that empties into Florida Bay.

In 2000, the \$7.8 billion Everglades Restoration Plan was signed into law. The plan was put together by groups that had been fighting over the Everglades for decades: environmentalists, politicians, farmers, tourism advocates, and developers. Over the course of 5 years, members from the groups met and crafted a plan. At

first people were afraid to break up into committees for fear that other people would make deals behind their backs. The director instituted social gatherings, and the members got to know and trust each other.

In the end, no one was completely satisfied, but all agreed that they would be better off with the



## Ecofact

**The Everglades** There are 112 threatened or endangered plant and animal species in the Florida Everglades, according to the U.S. Fish & Wildlife Service.

scilinks.

[www.scilinks.org](http://www.scilinks.org)

Topic: Environmental

Decision Making

Code: HE80525

plan than without it. Already Florida has restored 7 miles of the Kissimmee River to its original path. Native plants are absorbing some of the pollution that has killed an estimated \$200 million worth of fish and wildfowl. The Everglades Restoration Plan is not perfect, but the process of creating and approving it shows how science and thoughtful negotiation can help solve complex environmental problems.

## CRITICAL THINKING

**1. Analyzing Processes** Explain why it was so difficult for people to agree on how to restore the Everglades.

**2. Analyzing Relationships** If your county decided to build a landfill, do you think the decision-making process would resemble the Everglades example?

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## INCLUSION Strategies

- Visually Impaired
- Developmentally Delayed
- Learning Disabled

Ask students to locate Key Terms in the chapter by using the Chapter Highlights and page numbers. Students should copy the sentence where the term appears in the text. Students can also write an original sentence using the term. If the student has difficulty with writing, the student can read or compose the sentences aloud into a tape recorder. Students may use the tape or written activity as a study guide for independent or small group work.

## Reteaching BASIC

**Revisiting Einstein** After discussing decision-making models, ask students to think again about the following quote from Albert Einstein: “The whole of science is nothing more than a refinement of everyday thinking.” Ask students to review their comments in their *EcoLog*, and ask them if they have any further insights. How is the decision-making model similar to the scientific method? **Logical**

## CASE STUDY

**Saving the Everglades** Much of south Florida would be uninhabitable if it were not for the Central and Southern Florida Project (CS&F Project), which was initiated in 1948. The U.S. Army Corps of Engineers constructed one of the largest water management projects in the world to drain portions of the Everglades in an attempt to mitigate flooding, conserve water, preserve fish and wildlife, and make land available for development. Unfortunately, the project had adverse effects on south Florida ecosystems. In 1992 the Central & South Florida Project began to be re-evaluated, leading to the comprehensive restoration efforts in place today. These efforts must consider how to protect the ecosystem while ensuring that Florida's water needs continue to be met.

### Answers to Critical Thinking

1. Answers may vary but students should focus on the idea that people are motivated by different values and interests. Even when different groups could agree that action had to be taken, they argued on the scope and methods of restoration.
2. Answers may vary, but students should recognize that democratic community decisions occur when people with different values come to an agreement and establish trust.

## Teach, continued

### Interpreting Statistics

GENERAL

#### What Happened to the Warblers?

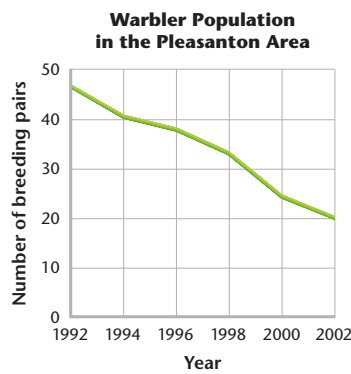
Ask students to analyze the data in **Figure 18**. Have them create a table or bar graph that shows the population of warblers every two years. Have students brainstorm ways that biologists could have collected this data. Begin a discussion about whether the data in such a graph could be misleading. Encourage skepticism and imagination in the class. (Biologists could have collected this data by surveying a sample of the entire county area for warblers. The data could be misleading if the scientists did not sample a representative area. For example, the warblers might prefer to nest in certain trees or in specific areas. If the scientists sampled the land area randomly, the chances are that their results would misrepresent the size of the warbler population.)

**LS Visual**

### Student Opportunities

#### Understanding Local Issues

Making environmental decisions involves a variety of people who have different roles in the community. Have students pick a local environmental issue and identify some of the people involved with it. Then encourage them to choose one of these people and interview them. Have students summarize the interviews and bring the summaries to class. Then have students discuss the issue using information from the people involved. **LS Verbal**



**Figure 18** ▶ The population of golden-cheeked warblers in the Pleasanton area has declined in recent years.

## How to Use the Decision-Making Model

The hypothetical situation in Pleasanton can be used to illustrate how to use the decision-making model. Michael Price is a voter in Valley County who will vote on whether the county should create a nature preserve to protect the golden-cheeked warbler. The steps Michael took to make his decision about the proposal are outlined below.

**Gather Information** Michael studied the warbler issue thoroughly by watching local news reports, reading the newspaper, learning more about golden-cheeked warblers from various Web sites, and attending forums where the issues were discussed. An example of scientific information that Michael considered includes the graph of warbler population decline in **Figure 18**. Several of the arguments on both sides made sense to him.

**Consider Values** Michael made a table similar to **Table 4** to clarify his thoughts. The values listed are environmental, economic, and recreational. Someone else might have thought other values were more important to consider.

**Table 4** ▼

Should Valley County Set Aside a Nature Preserve?			
	Environmental	Economic	Recreational
<b>Positive short-term consequences</b>	Habitat destruction in the nature preserve area is slowed or stopped.	Landowners whose property was bought by the county receive a payment for their land.  Property outside the preserve area can be developed with fewer restrictions.	Parts of the preserve are made available immediately for hiking and picnicking.
<b>Negative short-term consequences</b>	Environmental controls are made less strict in parts of the county outside the preserve area.	Property owners inside the preserve area do not make as much money as if they had developed their land.  Taxpayers must pay higher taxes to buy preserve land.	Michael could not think of any negative short-term consequences.
<b>Positive long-term consequences</b>	The population of warblers increases, and the bird does not become endangered.  Other species of organisms are also protected.  An entire habitat is preserved.	Property near the preserve increases in value because it is near a natural area.  Businesses move to Valley County because of its beauty and recreational opportunities, which results in job growth.  The warbler is not listed as endangered, which avoids stricter controls on land use.	Large areas of the preserve are available for hiking and picnicking.  Landowners near the preserve may develop campgrounds with bike trails, swimming, and fishing available on land adjacent to the preserve.
<b>Negative long-term consequences</b>	Other habitat outside the preserve may be damaged by overdevelopment.	Taxpayers must continue to pay for maintaining the preserve.  Taxpayers lose the tax revenue that this land would have provided if it was developed.	State officials might restrict some recreational activities on private land within the preserve.

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## Career

**Architect** Architect Samuel Mockbee asked, “Does the architect have a role in addressing political or economic inequities, or transportation issues, or environmental issues? Because I think we do.” In 1993, Mockbee and Dennis K. Ruth started a program called the “Rural Studio” at the University of Alabama. Students work with poor, rural residents of Hale County, Alabama, to improve their quality of life by designing affordable housing and other buildings

using materials that would otherwise end up in landfills. They work with a community to address its needs from within. Mockbee decided to use his talent to combine a social commitment to the poor with an environmental focus. Have students find out more about the Rural Studio and the connections between architecture and environmental science. Students can also look for information about “Green Architecture” programs on the Internet.


**Explore Consequences** Michael decided that in the short term the positive and negative consequences listed in his table were almost equally balanced. He saw that some people would suffer financially from the plan, but others would benefit. Taxpayers would have to pay for the preserve, but all the residents would have access to land that was previously off-limits because it was privately owned. Some parts of the county would have more protection from development, and some would have less.

The long-term consequences of the plan helped Michael make his decision. He realized that environmental values were an important factor. The idea of a bird becoming extinct distressed him. Also, protecting warbler habitat now would cost less than doing it later under a state-imposed plan.

Michael considered that there were long-term benefits to add to the analysis as well. He had read that property values were rising more rapidly in counties with land for recreation. He found that people would pay more to live in counties that have open spaces. Michael had found that Valley County had very little preserved land. He thought that creating the preserve would bring the county long-term economic benefits. He also highly valued the aesthetic and recreational benefits a preserve would offer, such as the walking trail in Figure 19.

**Make A Decision** Michael chose to vote for the nature preserve. Other people who looked at the same table of pros and cons might have voted differently. If you lived in Valley County, how would you have voted?

As you learn about issues affecting the environment, both in this course and in the future, use this decision-making model as a starting point to making your decisions. Make sure to consider your values, weigh pros and cons, and keep in mind both the short-term and long-term consequences of your decision.

 **Reading Check** How did considering long-term consequences help Michael make a decision about creating a nature preserve in Valley County?

**Figure 19** ► Land set aside for a nature preserve can benefit people as well as wildlife.



## SECTION 3 Review

- Explain** the importance of each of the four steps in a simple decision-making model.
- List** and define three possible values to consider when making environmental decisions.
- Describe** in a short paragraph examples of two situations in which environmental values come into conflict with other values. **WRITING SKILLS**

### CRITICAL THINKING

- Making Decisions** Pick one of the situations you described in question 3. Make a decision-making table that shows the positive and negative consequences of either of two possible decisions.
- Analyzing Ideas** Suggest how to make the decision-making model presented here more powerful.

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### Answers to Section Review

- Gathering information is important to fully understand a problem. It is necessary to consider values so that a decision is made based on what is important to the decision-maker. Exploring the consequences is important because it is necessary to consider the long-term impact of a decision. It is important to make a decision so that something can be done and the decision maker's values can be implemented.
- Answers may vary, but may include the following: Environmental values are values based on how important nature and the environment are to you. Economic values are values based

on monetary costs and benefits. Recreational values are values based on the importance of leisure and having fun.

- Answers may vary. Accept any reasonable, thoughtful answer.
- The tables may vary but should show an understanding of the decision-making model and a thoughtful exploration of an issue.
- Answers may vary. Students may offer improvements such as quantifying the positive and negative consequences to better assess the situation.

## Close

### Reteaching **BASIC**

**Applying the Decision-Making Model** Have students identify a local environmental issue. Ask students to research the issue and then prepare an environmental decision-making table similar to Table 4. Review and discuss the tables in class. Then have students write a paragraph that describes their decision-making model and the decision they made. Ask students to use the model throughout the school year. **LS Intrapersonal**

### Quiz **GENERAL**

- What are four values that are very important to you when you make everyday decisions? Explain why. (Answers may vary.)
- Why is it important to identify the different values that influence decision making? (Answers may vary. Students should recognize that different values influence decisions and these values can conflict with each other.)

### Alternative Assessment **ADVANCED**

**Land Use** One of the most controversial topics in urban development is land use, the way that a city will be organized in order to be a functional place. Ask students to choose a city in the United States or abroad that interests them and analyze the infrastructure, including public transportation, schools, public land, shopping districts, and living areas. Ask students to include their findings in a report that focuses on the environmental characteristics of the city they studied. Students should supplement their report with a map illustrating land use in the city they chose. **LS Verbal/Visual**

### Answer to Reading Check

Michael found out that people are willing to pay more to live in counties with open spaces. He voted in favor of the preserve because he took this long-term economic benefit into account.

**Alternative Assessment**

GENERAL

**Models in Our Lives** Ask students to identify five models they use in their daily lives. Have them describe how they use each model and identify whether it is a physical, mathematical, conceptual, or graphical model. Students should include examples of five models they use in their **Portfolio**.

**Decision-Making** Have students think of an environmental issue that might also be an emotional issue for them. Have them create a decision-making table that includes risks and use the table to help make a decision. Ask students to make persuasive use of statistics from the newspaper, Internet, or books to support their reasoning.

**LS Intrapersonal**

**1 Scientific Methods****Key Terms**

observation, 33  
hypothesis, 34  
prediction, 34  
experiment, 35  
variable, 35  
experimental group, 35  
control group, 35  
data, 36  
correlation, 37

**Main Ideas**

- ▶ Science is a process by which we learn about the world around us. Science progresses mainly by the experimental method.
- ▶ The experimental method involves making observations, forming a hypothesis, performing an experiment, interpreting data, and communicating results.
- ▶ In cases in which experiments are impossible, scientists look for correlations between different phenomena.
- ▶ Good scientists are curious, creative, honest, skeptical, and open to new ideas.

**2 Statistics and Models**

statistics, 40  
mean, 41  
distribution, 41  
probability, 42  
sample, 42  
risk, 43  
model, 44  
conceptual model, 45  
mathematical model, 46

- ▶ Scientists use statistics to classify, organize, and interpret data.
- ▶ Measures such as means and probabilities are used to describe populations and events.
- ▶ Statistics provides a powerful tool for evaluating information about the environment.
- ▶ Scientists use models, including conceptual and mathematical models, to understand the systems they study.

**3 Making Informed Decisions**

value, 47  
decision-making model, 47

- ▶ Making environmental decisions involves gathering information, considering values, and exploring consequences.
- ▶ Decisions about the environment should be made thoughtfully. Using a decision-making model will provide you with a systematic process for making knowledgeable decisions.
- ▶ Making a table that lists positive and negative short-term and long-term consequences will help you recognize and weigh your values about an environmental decision.

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**Chapter Resource File**

- Chapter Test **GENERAL**
- Chapter Test **ADVANCED**
- Concept Review **GENERAL**
- Critical Thinking **ADVANCED**
- Test Item Listing
- Observation Lab **BASIC**
- Design Your Own Lab **GENERAL**
- CBL™ Probeware Lab **GENERAL**
- Consumer Lab **GENERAL**
- Long-Term Project **GENERAL**

**Using Key Terms**

Use each of the following terms in a separate sentence.

1. *experiment*
2. *correlation*
3. *model*
4. *distribution*
5. *values*

For each pair of terms, explain how the meanings of the terms differ.

6. *hypothesis* and *prediction*
7. *risk* and *probability*
8. *distribution* and *population*
9. *sample* and *population*

**STUDY TIP**

**Imagining Examples** To understand how key terms apply to actual examples, work with a partner and take turns describing an environmental problem and explaining how the key terms relate to the problem.

**Understanding Key Ideas**

10. Scientists form \_\_\_\_\_ hypotheses to answer questions.
  - a. accurate
  - b. short
  - c. mathematical
  - d. testable
11. Risk is the \_\_\_\_\_ of a negative outcome.
  - a. sample
  - b. statistic
  - c. probability
  - d. event
12. If the results of your experiment do not support your hypothesis, you should
  - a. publish your results anyway.
  - b. consider the results abnormal and continue working.
  - c. find a way to rationalize your results.
  - d. try another method.
13. In a population, characteristics such as size will often be clustered around the
  - a. sample.
  - b. mean.
  - c. distribution.
  - d. collection.
14. Models used by scientists include
  - a. conceptual models.
  - b. variable models.
  - c. physical models.
  - d. Both (a) and (c)
15. Reading scientific reports is an example of
  - a. assessing risk.
  - b. considering values.
  - c. gathering information.
  - d. exploring consequences.
16. A conceptual model represents a way of thinking about
  - a. relationships.
  - b. variables.
  - c. data.
  - d. positions.
17. In an experiment, the experimental treatment differs from the control treatment only in the \_\_\_\_\_ being studied.
  - a. experiment
  - b. variable
  - c. hypothesis
  - d. data
18. To fully understand a complex environmental issue, you may need to consider
  - a. economics.
  - b. values.
  - c. scientific information.
  - d. All of the above
19. Scientists \_\_\_\_\_ experiments to make sure the results are meaningful.
  - a. perform
  - b. repeat
  - c. conclude
  - d. communicate

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**Assignment Guide**

Section	Questions
1	1, 2, 6, 10, 12, 17, 19–21, 28, 33, 35–37
2	3, 4, 7–9, 11, 13, 14, 16, 22, 23, 29–32
3	5, 15, 18, 24, 34, 38

**ANSWERS****Using Key Terms**

1. Sample answer: The scientist conducted an experiment to verify her hypothesis.
2. Sample answer: Storm clouds and rain have a strong correlation.
3. Sample answer: The doctor showed his patient a model to demonstrate how the heart works.
4. Sample answer: To see if there are more elderly people than young people, you could look at a distribution of ages.
5. Sample answer: My mother always considers her values before making a decision.
6. A hypothesis is a testable explanation for an observation, while a prediction is an educated guess of what will happen when the hypothesis is tested.
7. A risk is the chance that an unwanted event will occur. A probability is the likelihood that something will happen.
8. A distribution is the arrangement of the members of a population in relation to a characteristic. A population is a group of similar things that is being studied.
9. A population is a group of similar things that is being studied, while a sample is a smaller group studied to represent the population.

**Understanding Key Ideas**

10. d
11. c
12. a
13. b
14. d
15. c
16. a
17. b
18. d
19. b

**Short Answer**

20. When an observation warrants further examination, a good scientist knows what questions to investigate to fully understand the observation.
21. In an experiment, the control group provides a standard to compare with the experimental treatment. The control group provides a set of data unaffected by the variable or with the variable at a baseline value.
22. Statistics help people quantify and analyze different kinds of information, including information about the environment.
23. Environmental scientists use mathematical models to express quantifiable relationships in the most precise form possible.
24. Making a table can help in a decision-making situation by organizing all the positive and negative consequences of a decision for comparison.

**Interpreting Graphics**

25. The density of the alligator population fell drastically—from almost 22 per kilometer of shoreline to about 3 per kilometer of shoreline.
26. The alligator concentration increased. In 1994 there was less than one alligator per kilometer. In 1998 there were almost 5 alligators per kilometer.
27. The alligator population was more than five times greater in 1986.

**Concept Mapping**

28. Answers to the concept mapping questions are on pp. 715–720.

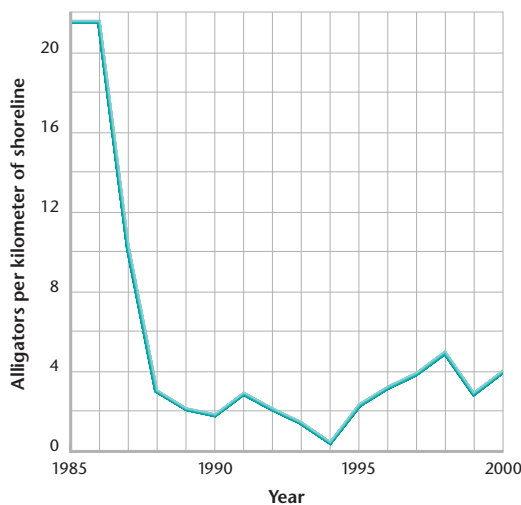
**Short Answer**

20. Explain the statement, “A good scientist is one who asks the right questions.”
21. Explain the role of a control group in a scientific experiment.
22. How are statistics helpful for evaluating information about the environment?
23. Explain why environmental scientists use mathematical models.
24. How does making a table help you evaluate the values and concerns you have when making a decision?

**Interpreting Graphics**

The graph below shows the change in size of a shoreline alligator population over time. Use the graph to answer questions 25–27.

25. What happened to the density of alligators between 1986 and 1988?
26. What happened to the trend in the alligator concentration between 1994 and 1998?
27. How many times greater was the alligator population in 1986 than it was in 2000?



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**Critical Thinking**

29. The scientist means that there is an 8 out of 10 chance that a tornado will strike the area over the next 10 years.
30. Answers may vary, but students should recognize that a map is a graphical model of the city that illustrates the relative size and location of streets and landmarks.
31. No, complicated models are not necessarily more accurate. Adding detail to a model is only justified if that detail truly reflects relevant aspects of the system in question.

**Concept Mapping**

28. Use the following terms to create a concept map: *control group*, *experiment*, *experimental group*, *prediction*, *data*, *observations*, *conclusions*, and *hypothesis*.

**Critical Thinking**

29. **Drawing Conclusions** What does a scientist mean by the statement, “There is an 80 percent probability that a tornado will hit this area within the next 10 years”?
30. **Making Inferences** How does a map of Denver allow you to navigate around the city?
31. **Evaluating Assumptions** Are complicated models always more accurate? Write a paragraph that uses examples to explain your answer. **WRITING SKILLS**
32. **Interpreting Statistics** Explain what the following statement proves: “We sampled pet owners and found that three out of five surveyed own dogs and two out of five surveyed own cats.”

**Cross-Disciplinary Connection**

33. **Language Arts** The word *serendipity*, which means “luck in finding something accidentally,” came from a Persian fairy tale called *The Three Princes of Serendip*. In the story, each of the princes discovers something by accident. Research and write a short report on a serendipitous discovery about the environment. **WRITING SKILLS**

**Portfolio Project**

34. **Make a Poster** Choose an environmental issue in your area. You can choose a real-life problem that you have heard about on the news, such as improving the sewage system or building a new landfill, or you can choose a project that you think should be considered. Research the issue at your school or local library. Prepare a poster listing the groups of people likely to be involved in the decision and the factors that may be taken into consideration, including economic, social, and environmental factors.

32. The statement proves very little because it does not state the sample size in relation to the population size. It only proves that 60% of those surveyed own dogs and 40% own cats.

**Cross-Disciplinary Connection**

33. Answers may vary.

**Portfolio Project**

34. Answers may vary.



## MATH SKILLS

This table shows the results of an experiment that tested the hypothesis that butterflies are attracted to some substances but not to others. Twenty-four trays containing four substances were placed in random order on a sandbank to see if butterflies landed on the trays. The number of butterflies that landed on each type of tray and stayed for more than 5 min during a 2 h period was recorded in the table. Use the data in the table below to answer questions 35–36.

Butterfly Feeding Preferences				
	Sugar solution	Nitrogen solution	Water	Salt solution
Number of butterflies attracted	5	87	7	403

- 35. Evaluating Data** Do the results in the table show that butterflies are attracted to salt solution but not any other substance? Why or why not? What other data would you like to see to help you evaluate the results of this experiment?
- 36. Analyzing Data** Are there any controls shown in this table?



## WRITING SKILLS

- 37. Communicating Main Ideas** How is the experimental method an important scientific tool?
- 38. Writing Persuasively** Write a letter to the editor of your local paper outlining your opinion on a local environmental issue.



## READING SKILLS

Read the passage below, and then answer the questions that follow.

Jane and Jim observed a group of male butterflies by the roadside. Jane said that this behavior was called puddling and that the butterflies were counting each other to see if there was room to set up a territory in the area. Jim said he did not think butterflies could count each other and suggested the butterflies were feeding on nitrogen in the sand. Jane agreed that the butterflies appeared to be feeding, but she said that they may not be feeding on nitrogen, because female butterflies need more nitrogen than males.

Jim and Jane decided to perform some experiments on the butterflies. They put out trays full of sand in an area where butterflies had been seen. Two trays contained only sand. Two contained sand and water, two contained sand and a salt solution, and two contained sand and a solution containing nitrogen. Butterflies came to all the trays, but they stayed for more than 1 min only at the trays that contained the salt solution.

- Which of the following statements is a testable hypothesis about the experiment?
  - Male butterflies mate with female butterflies.
  - Salt is a compound and nitrogen is an element.
  - Butterflies are never seen in groups except on sandy surfaces.
  - Butterflies are attracted to salt.
- Which of the following conclusions is supported by the observations Jane and Jim made?
  - Male butterflies can count each other.
  - The butterflies were probably feeding on nitrogen in the sand.
  - The butterflies were probably feeding on salts in the sand.
  - Female butterflies need less nitrogen than male butterflies.

## Math Skills

- 35.** No, butterflies do not appear to be attracted only to salt solution, because 87 stayed for more than 5 minutes at the nitrogen solution. How the butterflies behaved afterwards and whether any died might be interesting data. The experiment should be repeated before the results are evaluated. Data on combinations of ingredients might also be helpful.
- 36.** Yes, the tray with water functions as the control. The only difference between this tray and the others is in the substances that are dissolved in the water.

## Writing Skills

- 37.** Answers may vary. The experimental method is an important scientific tool because it provides a method for using observations to provide explanations for phenomena in the natural world. The experimental method allows people to study the impact of a variable as objectively as possible.
- 38.** Answers may vary.

## Reading Skills

- d
- c



## Estimated Time

To give students practice under more realistic testing conditions, allow them 30 minutes to answer all of the questions in this practice test.

### TEST DOCTOR

**Question 3** Answer A is the correct choice. Answers B, C, and D are incorrect because they are all examples of images. Although scientists use maps, diagrams, and satellite images for scientific study, these tools are not physical representations.

**Question 5** Full-credit answers should include the following points:

- no; every time a penny is tossed, the probability of its outcome is independent of the tosses that have come before
- the probability of heads or tails is always 50%

**Question 6** Full-credit answers should include the following points:

- the mean is a numerical measure for a given population
- the mean allows scientists to compare characteristics of different populations

## Understanding Concepts

**Directions (1–4):** For each question, write on a separate sheet of paper the letter of the correct answer.

- How would a scientist categorize a testable explanation for an observation?
  - a correlation
  - an experiment
  - a hypothesis
  - a prediction
- What happens when an observation is submitted for peer review?
  - The article is proofread before it is published.
  - A professor gives a lecture based on a published article.
  - The results are looked at closely by other scientific experts.
  - Information on the experimental design is included in published works.
- Which of the following is an example of a scientist's physical model?
  - a crash-test dummy for a car company
  - a diagram of the structure of an atom
  - a map of Denver, Colorado
  - a satellite image of South America
- What attribute of a skeptic would contribute to a good scientific mind?
  - willingness to travel
  - empathetic nature
  - desire to conduct experiments
  - continual questioning of observations

**Directions (5–6):** For each question, write a short response.

- A penny is tossed and comes up heads 7 out of 10 times. Is the probability that it will be heads on the next toss 70%? Why or why not?
- A mean is the number obtained by adding up the data for a given characteristic of a statistical population, and dividing the sum by the total number of individuals in the given population. Why do scientists calculate the mean of a statistical population?

## Reading Skills

**Directions (7–9):** Read the passage below. Then answer the questions.

We use statistics everyday. Weather experts report the forecast in terms of probabilities, such as "There is a 50 percent chance of rain today." People are constantly guessing the possibility that something will or will not happen. A guess is one of the ways we express probability.

In scientific terms, risk is the probability of an unwanted outcome. Most people overestimate the risk of dying from sensational causes, such as terrorism, and underestimate the risk from common causes such as smoking. Likewise, most citizens overestimate the risk of sensational environmental problems such as oil spills, and underestimate the risk of ordinary ones, like ozone depletion. However, when decisions must be made on proposals affecting the environment, it is important that all the benefits and risks of the possible action are calculated.

- Assess which of the following experts would perceive as having the **highest** risk.
  - the threat of global climate change
  - the radioactivity from the waste of a nuclear power plant
  - the possibility of a tidal wave reaching a highly populated land mass
  - the danger of widespread water pollution
- How would a scientist define the term risk?
  - the likelihood of something good
  - a chance event
  - the probability of an unwanted outcome
  - a benefit that is overestimated
- How could a decision-making model be helpful for estimating the benefits and risks of a proposal?
  - It would eliminate uncertainty.
  - It would create a digital image.
  - It would predict the outcome of the decision.
  - It would allow consideration of all the variables.

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## Answers

- C
- H
- A
- I
- Answers will vary. See Test Doctor for detailed scoring rubric.
- Answers will vary. See Test Doctor for detailed scoring rubric.
- A
- H
- D
- H
- A
- F
- C

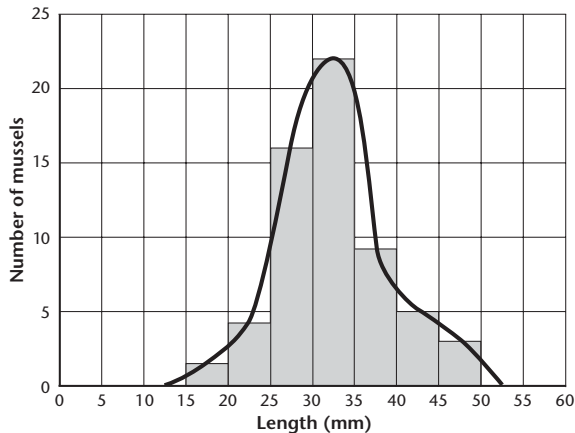


## Interpreting Graphics

**Directions (10–13):** For *each* question below, record the correct answer on a separate sheet of paper.

The bar graph below shows the distribution of lengths in a population of dwarf wedge mussels. Use this graph to answer questions 10 through 13.

**Size Distribution of Dwarf Wedge Mussels**



- 10** What type of distribution does this bell-shaped curve depict?
- F. asymmetric
  - G. correlative
  - H. normal
  - I. random
- 11** How many mussels are less than 25 mm in length?
- A. 6
  - B. 9
  - C. 12
  - D. 15
- 12** Determine the total size of this statistical population of dwarf wedge mussels.
- F. 60
  - G. 70
  - H. 80
  - I. 90
- 13** What is the **most** likely size predictable for a mussel randomly drawn from this population?
- A. 15–20 mm
  - B. 25–30 mm
  - C. 30–35 mm
  - D. 40–45 mm

### Test TIP

Probability is the chance of an outcome occurring. The highest probability occurs in the group with the largest number of individuals.

## + TEST DOCTOR

**Question 10** Answer H is the correct choice because a bell curve represents a normal distribution. Answer F is incorrect because asymmetric curves are dramatically asymmetrical, while this curve is only slightly asymmetrical. Answer G is incorrect because a correlative curve most resembles a straight line. Answer I is incorrect because random distributions have no distinct shape or pattern.

**Question 13** Answer C is correct. Students struggling with this type of question may benefit from practicing calculating probability. For example, ask students what the probability would be of a rolling a 6 on a six-sided die. Then ask students what the probability of rolling a 6 would be if two of the sides on the die were 6.

## SCIENTIFIC INVESTIGATIONS

## Teacher's Notes

## Time Required

one 45-minute class period

## Lab Ratings



TEACHER PREPARATION 

STUDENT SETUP 

CONCEPT LEVEL 

CLEANUP 

## Skills Acquired

- Predicting
- Experimenting
- Measuring
- Collecting Data
- Classifying
- Organizing and Analyzing Data
- Communicating

## The Scientific Method

In this lab, students will:

- Make Observations
- Ask Questions
- Test the Hypothesis
- Analyze the Results
- Draw Conclusions
- Communicate the Results

## Materials

The materials listed are for a group of 3 to 4 students. For each working group, you will need two ice cubes.

## Objectives

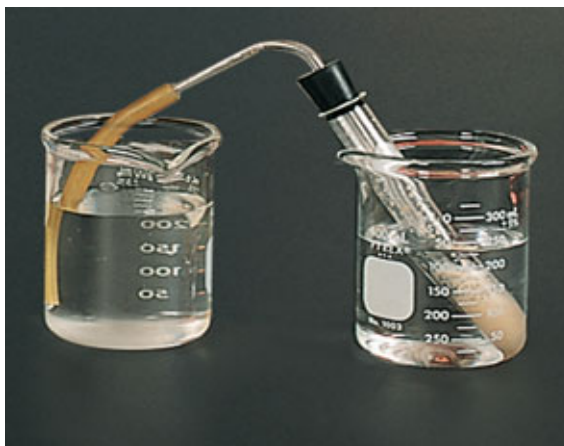
- ▶ **USING SCIENTIFIC METHODS** Formulate a hypothesis about the relationship between temperature and fermentation by yeast.
- ▶ **USING SCIENTIFIC METHODS** Test your hypothesis.
- ▶ Analyze your data.
- ▶ Explain whether your data support or refute your hypothesis.

## Materials

- beakers, 100 mL (3)
- beakers, 400 mL (3)
- clock
- delivery tubes, rubber or plastic (3)
- graph paper
- ice cubes
- solution of yeast, corn syrup, and water
- stoppers, no. 2, one-hole (3)
- test tubes, 20 mm × 200 mm (3)
- thermometer



- ▶ **Step 3** Carbon dioxide bubbles will be released from the delivery tube.



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## Tips and Tricks

This lab could be a 2-day activity; the first day could focus on hypotheses writing practice, and the second day could be used to complete the lab. Large empty jars may be substituted for 400 mL beakers. To prepare the yeast liquid, add 1 tbsp dry active yeast and 200 mL corn syrup to 1 L warm water. Combine the ingredients 15–20 minutes

## Scientific Investigations

A scientist considers all the factors that might be responsible for what he or she observes. Factors that can vary and that can be measured are called *variables*. The variable that you experimentally manipulate is the *independent variable*. The variable that you think will respond to this manipulation is the *dependent variable*.

You can practice the scientific method as it relates to everyday observations, such as the observation that bread dough rises when it is baked. According to a bread recipe, you dissolve a package of yeast in warm water and add flour, corn syrup, salt, and oil. Yeast is a microorganism that plays an important role in making bread. Yeast obtains energy by converting sugar to alcohol and carbon dioxide gas in a process called *fermentation*. The carbon dioxide forms bubbles, which make the bread dough rise. But what role, if any, does temperature play in this process? In this investigation, you will work as part of a team to try to answer these questions. Together, you will form a hypothesis and conduct an experiment that tests your hypothesis.

## Procedure

1. Restate the question relating temperature to fermentation in yeast as a hypothesis.
2. Set up three test tubes containing yeast, water, and corn syrup stoppered with a gas-delivery tube. Label the test tubes “A”, “B”, and “C”. Place each test tube in a water bath of different temperature. Place tube A in a water bath cooled by a few ice cubes, place tube B in room-temperature water, and place tube C in a warm water bath.
3. Allow the apparatus to sit for 5 min. Then place the open end of the delivery tube under water and begin to collect data on gas production. For the next 10 min, count the number of gas bubbles released from each tube, and record your data in the table on the next page.
4. Prepare a graph of data by placing time on the *x*-axis and the total number of gas bubbles released on the *y*-axis. Plot three curves on the same graph, and label each with the temperature you recorded for each test tube. Compare your graph with that of three other teams before handing in your report.

before class. Note that sugar will be provided in the corn syrup. To assure consistency, you will want to make sure that each test tube contains the same level of yeast solution. Test tubes should be filled about halfway. Using water temperatures around 4°C–10°C, 20°C–25°C, and 40°C–45°C will provide good results.

Carbon Dioxide Bubbles Released by Yeast										
Time (min)	1	2	3	4	5	6	7	8	9	10
Tube A: _____										
Tube B: _____										
Tube C: _____										

### Analysis

- Classifying Data** Which set of conditions is most similar to the conditions for the bread dough in the recipe? Why were two other conditions used in this experiment?
- Classifying Data** What was the independent variable in this experiment? Explain your answer.
- Classifying Data** What was the dependent variable in this experiment? Explain your answer.

### Conclusions

- Drawing Conclusions** Write a conclusion for this experiment. Describe how the independent and dependent variables are related. Tell how the data supports your conclusion.
- Evaluating Results** What does temperature have to do with making bread dough rise?
- Evaluating Methods** Why did you compare your results with those of other teams before writing your conclusions?
- Applying Conclusions** Science is not just something you know but also something you do. Explain this statement in light of what you have learned in this investigation.



► **Recording Data** Count the number of bubbles produced under each experimental condition and record the data in a table.

### Extension

- Designing Experiments** Formulate a new hypothesis about the effect of different types of sugar on carbon dioxide production by yeast. Test your new hypothesis under controlled conditions. Did your results support your hypothesis? Research the types of sugar you used, and write a short explanation for your findings.

### Answers to Analysis

- The solution sitting in the warm bath is most similar to the recipe conditions. The other conditions were used to test the role of temperature in fermentation.
- The independent variable was the temperature of the liquid bath, because the temperature is the only quality that varies between the three beakers of yeast liquid.
- The dependent variable in this experiment was the number of gas bubbles produced. The number of carbon dioxide bubbles is a measure of the rate at which the yeast are fermenting the sugar solution.

### Answers to Conclusions

- Answers may vary, but students will probably find higher water temperatures correlate positively with the rate of fermentation.
- Yeast becomes active in warm conditions. Active yeast ferments sugars in bread dough, creating alcohol and carbon dioxide bubbles. These bubbles make the dough rise.
- You should compare results with the results of other teams because this practice is similar to repeating the experiment.
- Answers may vary, but after performing this experiment students should have confidence in their abilities to use scientific methods to actively make discoveries.

### Answers to Extension

- Answers may vary.



**Catherine Cummings**  
Currituck County  
School System  
Currituck, North Carolina

### Chapter Resource File

- Datasheets for In-Text Labs
- Lab Notes and Answers

### Holt Lab Generator CD-ROM

Search for any lab by topic, standard, difficulty level, or time. Edit any lab to fit your needs, or create your own labs. Use the Lab Materials Quicklist software to customize your lab materials list.

A TOPOGRAPHIC MAP OF KEENE, NEW HAMPSHIRE

A TOPOGRAPHIC MAP OF KEENE, NEW HAMPSHIRE

Discussion — GENERAL

**Contour Intervals** Reproduce a mountainous portion of a contour map on the board. Discuss with students where the steepest slopes are (where the lines are closest together.) Then change the contour interval by erasing every other contour line. Point out to students that the contour interval is now twice as large. Discuss with students the advantages and the disadvantages of a map with a larger contour interval. (The map may seem easier to read, but detail is lost.)

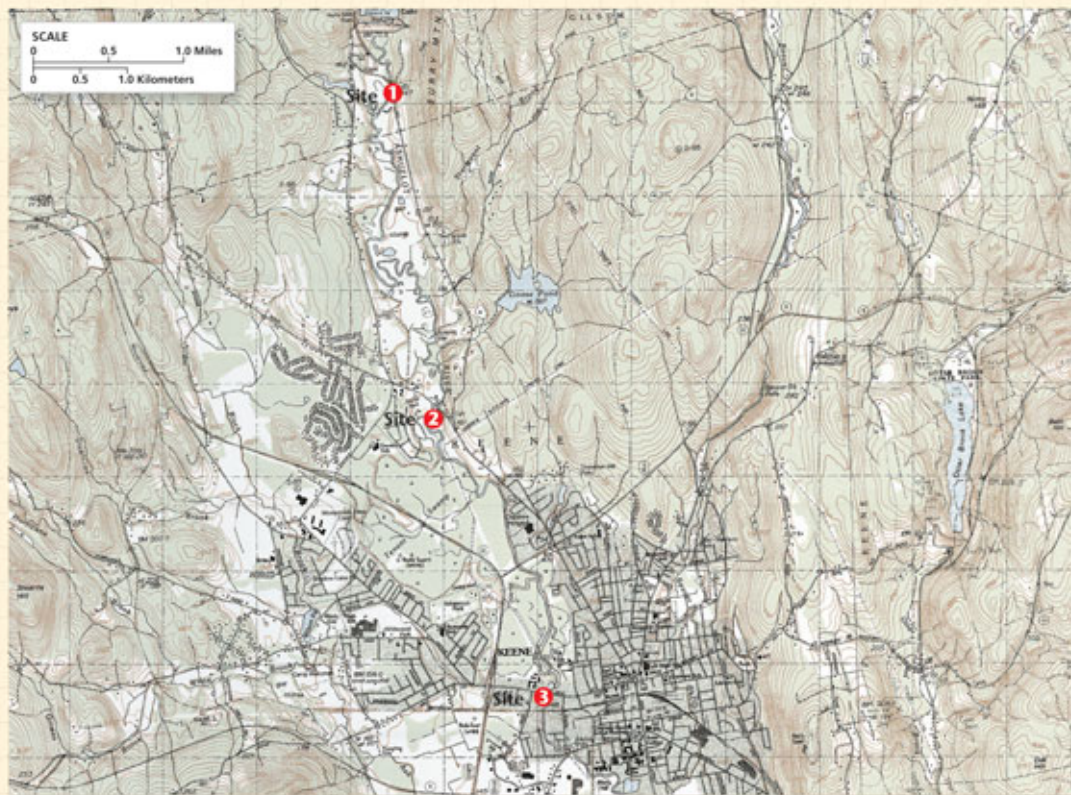
English Language Learners

Visual

Group Activity — BASIC

**Contour Mapping** Give each group a small bucket, a piece of clear, stiff plastic to cover the bucket, a ruler, a felt-tip pen, and some clay. Have groups create a landform out of the clay and place it in the bucket. Then have groups place the plastic over the bucket and mark the edges for alignment purposes. Groups should trace the outline of the bottom of the “hill” onto the plastic and then pour 1 cm of water into the bucket. After replacing the plastic sheet and aligning the corner marks, have students trace the waterline on the plastic. Students should repeat this until they reach the top of the hill.

Visual/Kinesthetic



MAP SKILLS

Topographic maps use contour lines to indicate areas that share a common elevation. Where the lines are close together, the terrain is steep. Where the lines are far apart, the landscape is flat. In this map, the Ashuelot River flows downhill from Site 1 to Site 3. Use the map to answer the questions below.

- Using a Key** Use the scale at the top of the map to calculate the distance between Sites 1 and 2 and between Sites 2 and 3.
- Understanding Topography** Are the hills to the east and west of the town of Keene more likely to drain into the river around Site 3 or Site 2? Explain your answer.
- Identifying Trends** Which site is more likely to be polluted? Explain your answer.
- Analyzing Data** Trace the sections of the Ashuelot River between each site to determine the length of stream between each site.
- Interpreting Landforms** A flood plain is an area that is periodically flooded when a river overflows its banks. Interpret the contour lines to locate the flood plain of the Ashuelot River.

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**Transparencies**  
TT Topographic Map of Keene, New Hampshire

Answers to Map Skills

- The distance between Site 1 and Site 2 is approximately 3.5 km. The distance between Site 2 and Site 3 is approximately 3.1 km.
- The hills are more likely to drain to Site 3 because many of the tributaries of the Ashuelot River flow into the river downstream from Site 2.
- Site 3 is the most likely to be polluted because it is downstream from the other sites. In addition, Site 3 is located in downtown Keene.
- Accept any measurement between 8 km and 9 km.
- Answers may vary. The flood plain of the Ashuelot River is widest south of Site 2. A large swamp begins in this area.

## BATS AND BRIDGES

## BATS AND BRIDGES

### Background

People have discussed the idea of attracting bats to artificial roosts since at least 1900, when Dr. Charles Campbell designed and installed bat boxes in San Antonio, Texas. Dr. Campbell installed the bat homes in an attempt to reduce the population of malarial mosquitoes in the area. The importance of preserving and creating bat habitat has gained popularity since the 1980s, largely due to the efforts of Bat Conservation International.

### Internet Activity — GENERAL

**Bats on the Web** There are numerous Internet sites that offer information on bats. Have students find a bat Web site and research the topic of their choice. Students may learn how to build a bat house, research how sonar works, or investigate the ecological role that certain bat species play. Have students share their findings with the class.

A large colony of Mexican free-tailed bats lives under the Congress Avenue Bridge in Austin, Texas. These bats eat millions of insects a night, so they are welcome neighbors. Communities around the country and around the world have learned of the bats and have asked Austin for help in building bat-friendly bridges. But all that the people of Austin knew was that the bats appeared after the Congress Avenue Bridge was rebuilt in the 1980s. What attracted the bats? The people of Austin had to do a little research.

In the 1990s, the Texas Department of Transportation and Bat Conservation International, a non-profit organization located in Austin, set out to discover what made a bridge attractive to bats. They collected data on 600 bridges, including some that had bat colonies and some that did not. They answered the following questions: Where was the bridge located? What was it made of? How was it constructed? Was it over water or land? What was the temperature under the bridge? How was the land around the bridge used?

Congress Avenue Bridge in Austin to find out. Crevices under the bridge appeared to be crucial, and the crevices had to be the right size. Free-tailed bats appeared to prefer crevices 1 to 3 cm wide and about 30 cm deep in hidden corners of the bridge, and they preferred bridges made of concrete, not steel.

The scientists looked again at their data on bridges. They discovered that 62 percent of bridges in central and southern Texas that had appropriate crevices were occupied by bats. Now, the Texas Department of Transportation is adding bat houses to existing bridges that do not have crevices. These houses are known as Texas Bat-Abodes, and they can make any bridge bat friendly.

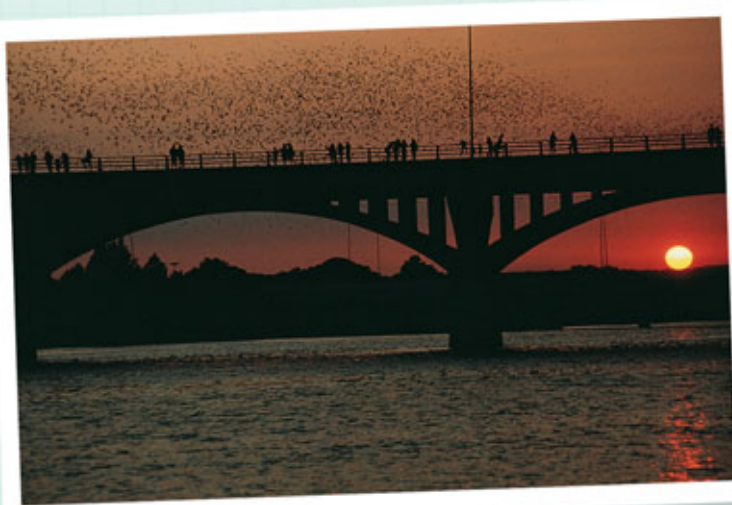
Bat Conservation International is collecting data on bats and bridges everywhere. Different bat species may have different preferences. A Texas Bat-Abode might not attract bats to a bridge in Minnesota or Maine. If we can figure out what features attract bats to bridges, we can incorporate these features into new bridges and make more bridges into bat-friendly abodes.

### Some Bridges are Better

Statistical analysis of the data revealed a number of differences between bridges occupied by bats and bridges unoccupied by bats. Which differences were important to the bats and which were not? The researchers returned to the

### A Crevice Will Do

In the wild, bats spend the day sleeping in groups in caves or in crevices under the flaking bark of old trees. They come back to the same place every day to roost. Deep crevices in tree bark are rare now that many of our old forests have been cut down, and many bats are in danger of extinction.



► **Mexican free-tailed bats** leave their roost under the Congress Avenue Bridge in Austin, Texas, to hunt for insects.

### What Do You Think?

Many bridges in the United States could provide roosting places for bats. Do you think communities should try to establish colonies of bats under local bridges? How should communities make this decision, and what information would they need to make it wisely?

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### Answers to What Do You Think?

Answers may vary according to student's opinions, but should take into consideration personal values, community values, and the decision-making models.