Section

2 Scientific Inquiry

Handout #: ______

Reading Preview

Key Concepts

- What is scientific inquiry?
- What makes a hypothesis testable?
- How do scientific theories differ from scientific laws?

Key Terms

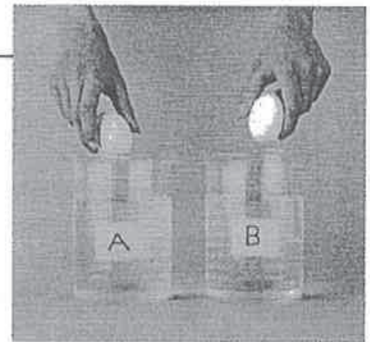
- scientific inquiry
- hypothesis • variable
- manipulated variable
- responding variable
- controlled experiment
- operational definition • data
- communicating
- scientific theory • scientific law

Target Reading Skill

Building Vocabulary A definition states the meaning of a word or phrase by telling about its most important feature or function. After you read this section, reread the paragraphs that contain definitions of Key Terms. Use all the information you have learned to write a definition of each Key Term in your own words.

▼ A snowy tree cricket

Lab zone Discover Activity



What's Happening?

1. Your teacher will give you two eggs and two beakers filled with water.
2. Put one egg in each beaker. Observe what happens.

Think It Over

Posing Questions Write down three questions you have about your observations. How could you find out the answer?

"Chirp, chirp, chirp." It is one of the hottest nights of summer and your bedroom windows are wide open. On most nights, the quiet chirping of crickets gently lulls you to sleep, but not tonight. The noise from the crickets is almost deafening. "Chirp, chirp, chirp, chirp, chirp!"

Why do all the crickets in your neighborhood seem determined to keep you awake tonight? Could the crickets be chirping more because of the heat? How could you find out?

As you lie awake, you are probably not thinking much about science. But, in fact, you are thinking just as a scientist would. You made observations—you heard the loud chirping of the crickets and felt the heat of the summer night. Your observations led you to infer that heat might cause increased chirping. You might even make a prediction: "If it's cooler tomorrow night, the crickets will be quieter, and I can sleep!"

Although you might not know it, your thinking and questioning is the start of the scientific inquiry process. **Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence they gather.** If you have ever tried to figure out why your MP3 player has stopped working, then you have used scientific inquiry. Similarly, you could use scientific inquiry to find out whether there is a relationship between the air temperature and crickets' chirping.

Lab zone Skills Activity

Classifying

Which of the following questions can be answered by scientific inquiry?

- Is running a better sport than swimming?
- Does running make your muscles stronger than swimming does?
- Which brand of running shoes looks best?

How did you make your decision in each case?

Posing Questions

Scientific inquiry often begins with a problem or question about an observation. In the case of the crickets, your question might be: Does the air temperature affect the chirping of crickets? Of course, questions don't just come to you from nowhere. Instead, questions come from experiences that you have and from observations and inferences that you make. Curiosity plays a large role as well. Think of a time that you observed something unusual or unexpected. Chances are good that your curiosity sparked a number of questions.

Some questions cannot be investigated by scientific inquiry. Think about the difference between the two questions below.

- Why has my MP3 player stopped working?
- What kind of music should I listen to on my MP3 player?

The first question is a scientific question because it can be answered by making observations and gathering evidence. For example, you could charge your MP3 player and observe whether it begins to work. In contrast, the second question has to do with personal opinions or values. Scientific inquiry cannot answer questions about personal tastes or judgments.

Reading Checkpoint **What role does curiosity play in posing questions?**

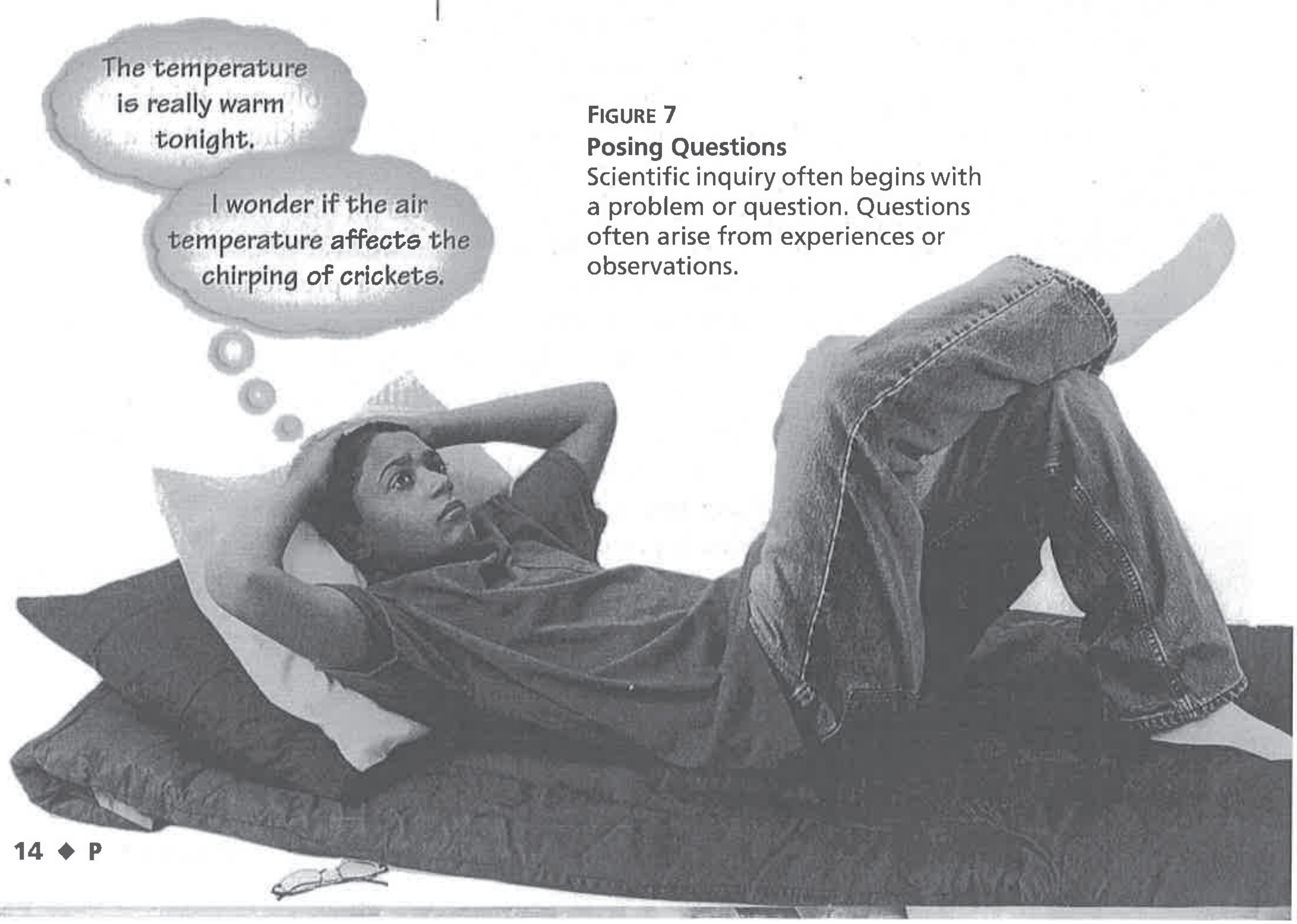


FIGURE 7
Posing Questions
Scientific inquiry often begins with a problem or question. Questions often arise from experiences or observations.

Developing a Hypothesis

How could you explain your observation of noisy crickets on that summer night? "Perhaps crickets chirp more when the temperature is higher," you think. In trying to answer the question, you are in fact developing a hypothesis. A **hypothesis** (plural: *hypotheses*) is a possible explanation for a set of observations or answer to a scientific question. In this case, your hypothesis would be that cricket chirping increases at higher air temperatures.

It is important to realize that a hypothesis is *not* a fact. Instead, it is only one possible way to explain a group of observations. In the case of the crickets, perhaps they only sounded louder that night because you had left more windows open than you usually do. Or, maybe there were more crickets around that night.

In science, a hypothesis must be testable. This means that researchers must be able to carry out investigations and gather evidence that will either support or disprove the hypothesis. Many trials will be needed before a hypothesis can be accepted as true.

Reading Checkpoint What is a hypothesis?

Discovery Channel School

What Is Science?

Video Preview
▶ **Video Field Trip**
Video Assessment

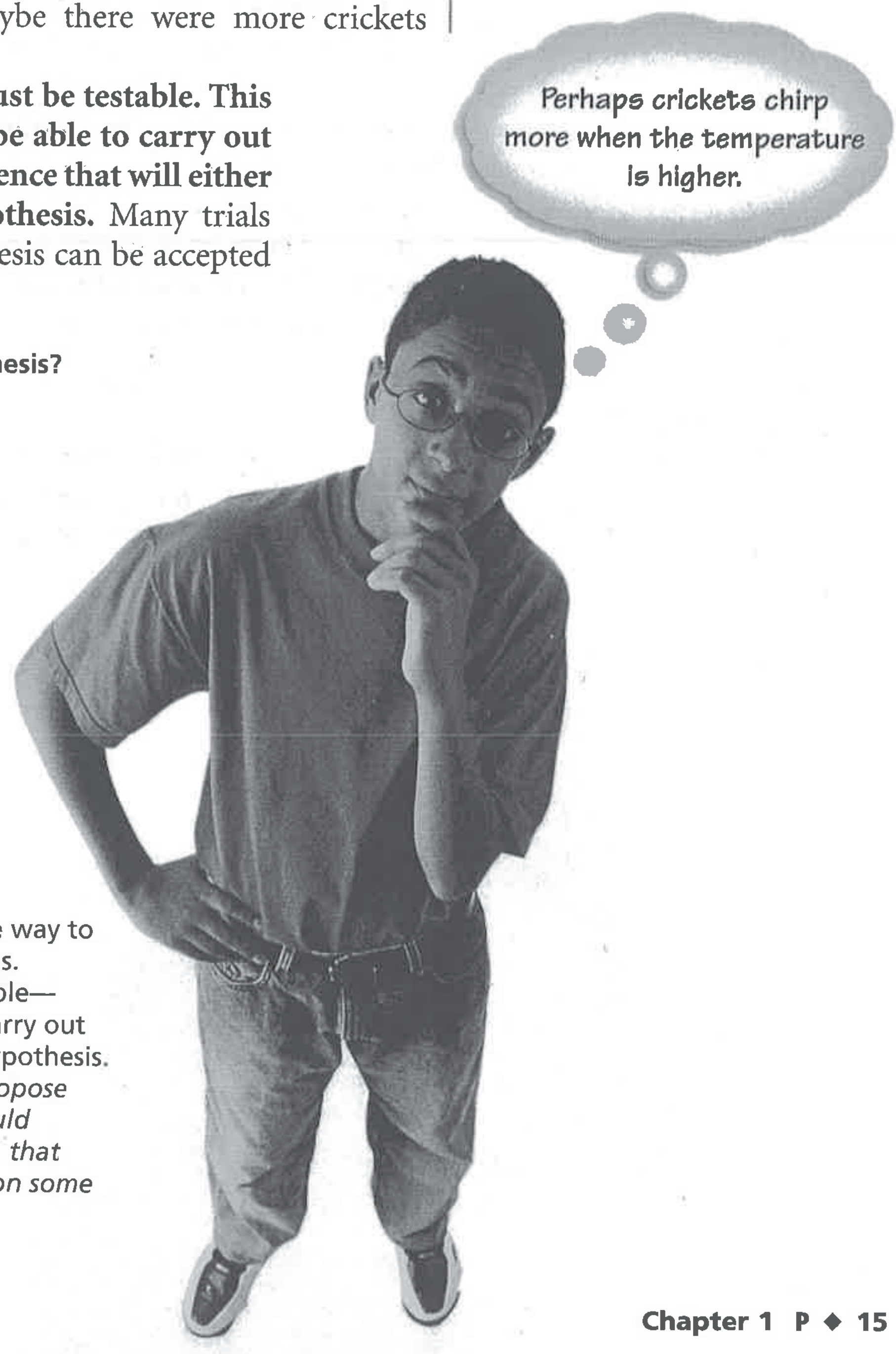


FIGURE 8
Developing Hypotheses
A hypothesis is one possible way to explain a set of observations. A hypothesis must be testable—scientists must be able to carry out investigations to test the hypothesis.
Developing Hypotheses *Propose another hypothesis that could account for the observation that crickets seem to be noisier on some nights than others.*

Lab zone Skills Activity

Controlling Variables

Suppose you are designing an experiment to determine whether sugar or salt dissolves more quickly in water. What is your manipulated variable? What is your responding variable? What other variables would you need to control?

Designing an Experiment

After you state your hypothesis, you are ready to design an experiment to test it. You know that your experiment will involve counting how many times crickets chirp when the air temperature is high. But how will you know how many times the crickets would chirp at a lower temperature? You would need to include other crickets in your experiment for comparison.

Controlling Variables To test your hypothesis, then, you will need to observe crickets at different air temperatures. All other **variables,** or factors that can change in an experiment, must be exactly the same. Other variables include the kind of crickets, the type of container you test them in, and the type of thermometer. By keeping all of these variables the same, you will know that any difference in cricket chirping must be due to temperature alone.

The one variable that is purposely changed to test a hypothesis is called the **manipulated variable** (also called the independent variable). In your cricket experiment, the manipulated variable is the air temperature. The factor that may change in response to the manipulated variable is called the **responding variable** (also called the dependent variable). The responding variable here is the number of cricket chirps.

Setting Up a Controlled Experiment An experiment in which only one variable is manipulated at a time is called a **controlled experiment.** Figure 9 shows one way to set up a controlled experiment to test your cricket hypothesis. Notice that identical containers, thermometers, leaves, and crickets are used in each setup. In one container, the temperature will be maintained at 15°C. In the other two containers, the temperatures will be kept at 20°C and 25°C.

The Importance of Controlling Variables Suppose you decide to test the crickets at 15°C in the morning and the crickets at 20°C and 25°C in the afternoon. Is this a controlled experiment? The answer is no. Your experiment would have two variables—temperature and time of day. Would increased chirping be due to the temperature difference? Or are crickets more active at certain times of day? There would be no way to know which variable explained your results.

Forming Operational Definitions One other important aspect of a well-designed experiment is having clear operational definitions. An **operational definition** is a statement that describes how to measure a particular variable or define a particular term. For example, in this experiment you would need to determine what sounds will count as a single "chirp."

Reading Checkpoint What is a manipulated variable?

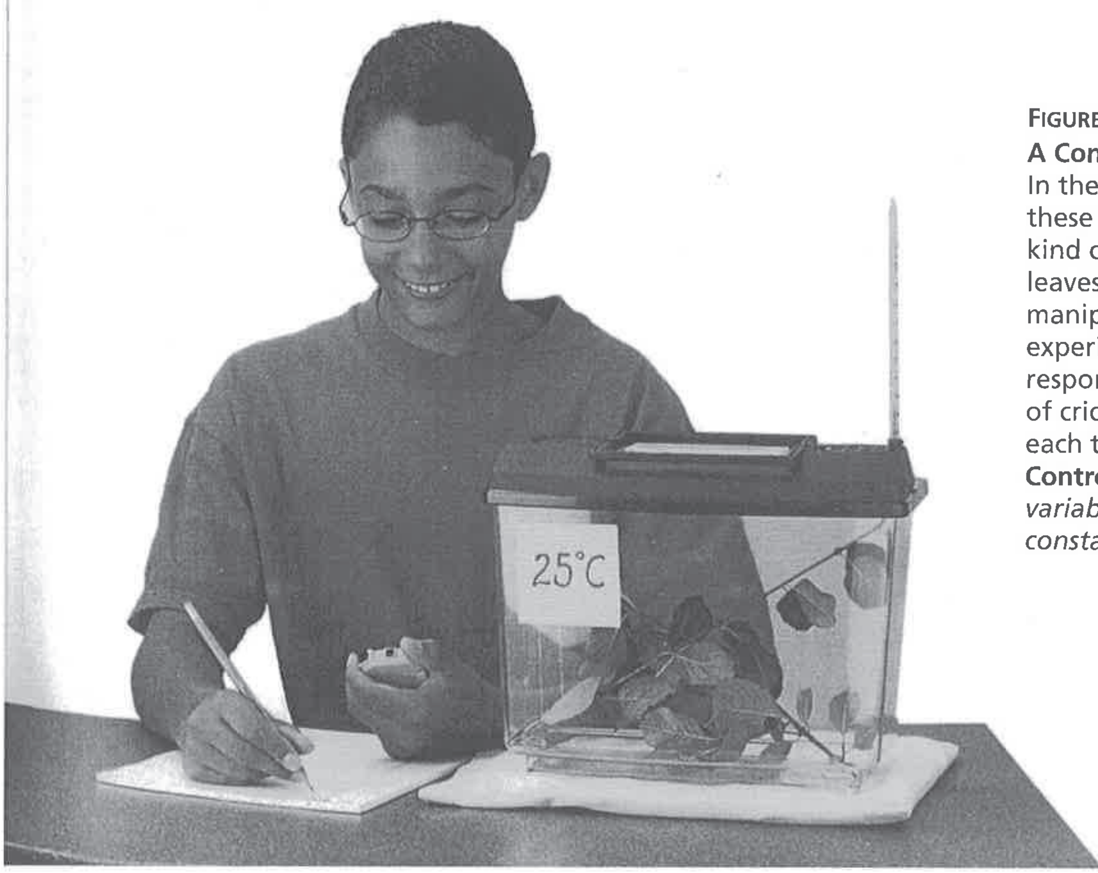


FIGURE 9
A Controlled Experiment
In their controlled experiment, these students are using the same kind of containers, thermometers, leaves, and crickets. The manipulated variable in this experiment is temperature. The responding variable is the number of cricket chirps per minute at each temperature.
Controlling Variables *What other variables must the students keep constant in this experiment?*

Collecting and Interpreting Data

You are almost ready to begin your experiment. But first, you must decide how many crickets to test. Because individual differences exist from cricket to cricket, you will need to test more than just one or two. You decide to test five crickets at each temperature.

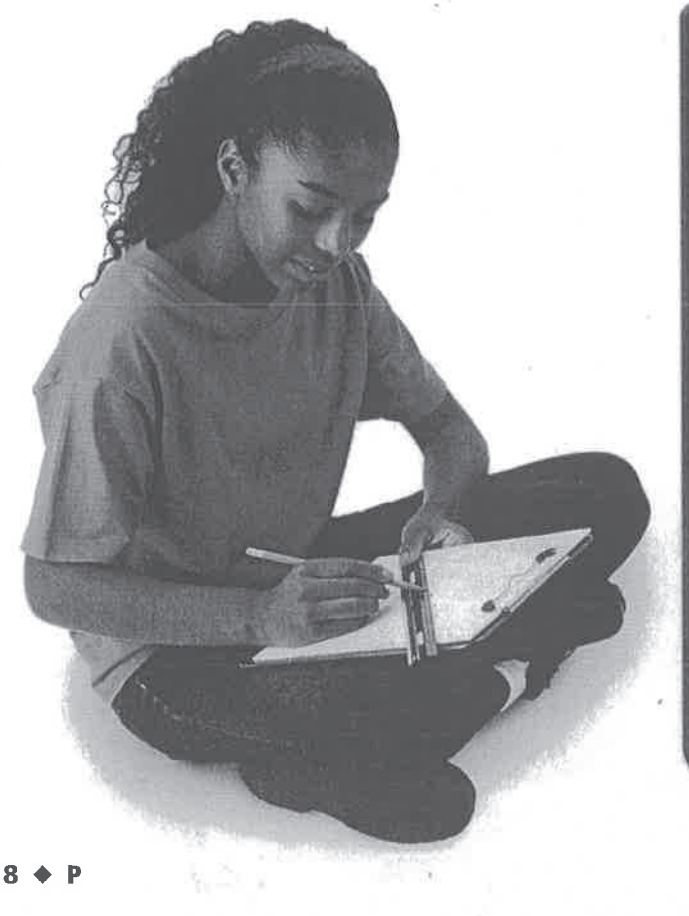
Organizing Your Data Before you begin your experiment, you should create a table like the one in Figure 10 in which to record your data. **Data** are the facts, figures, and other evidence gathered through observations. A data table provides you with an organized way to collect and record your observations.

Graphing Your Results After all the data have been collected, they need to be interpreted. One useful tool that can help you interpret data is a graph. Graphs will be discussed in more detail in Chapter 2.

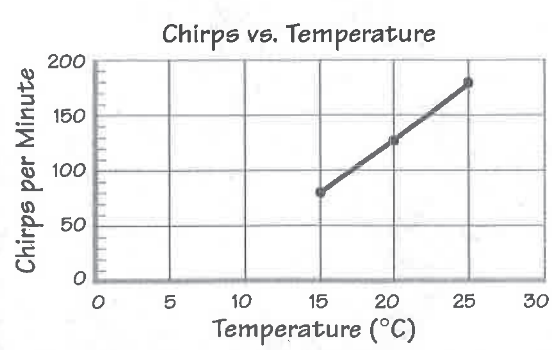
Study the graph in Figure 10 to see how graphing can help you make sense of your data. Graphs can reveal patterns or trends in data. For example, notice that your data points seem to fall in a line. You can see that as the temperature increases from 15°C to 25°C, the number of chirps per minute also increases.

Reading Checkpoint **What are data?**

FIGURE 10
Collecting and Interpreting Data
A data table helps you organize the information you collect in an experiment. Graphing the data may reveal any patterns in your data.
Interpreting Data *Did all of the crickets chirp more at 25°C than at 20°C? Did you use the data table or the graph to answer this question?*



Number of Chirps per Minute			
Cricket	15°C	20°C	25°C
1	91	135	180
2	80	124	169
3	89	130	176
4	78	125	158
5	77	121	157
Average	83	127	168



Drawing Conclusions

Now that you have gathered and interpreted your data, you can draw conclusions about your hypothesis. A conclusion is a summary of what you have learned from an experiment. In drawing your conclusion, you should ask yourself whether the data supports the hypothesis. You also need to consider whether you collected enough data and whether anything happened during the experiment that might have affected the results. You should address these questions in your summary of the experiment.

After reviewing the data, you decide that the evidence supports your original hypothesis. You conclude that cricket chirping does increase with temperature. It's no wonder that you have trouble sleeping on those warm summer nights!

Inquiry Leads to Inquiry Scientific inquiry usually doesn't end once a set of experiments is done. Often, one scientific inquiry leads into another one. You have found that crickets do indeed chirp more as the temperature rises. But does this apply to all kinds of crickets everywhere? And what happens at lower temperatures? These new questions can lead to new hypotheses and new experiments.

Lab zone Try This Activity

Which Falls Fastest?

Design an experiment to determine which falls fastest—an unfolded sheet of paper, a sheet of paper folded in fourths, or a crumpled sheet of paper. Be sure to develop a hypothesis, design a controlled experiment, and collect data.

Drawing Conclusions Does your data support your hypothesis?

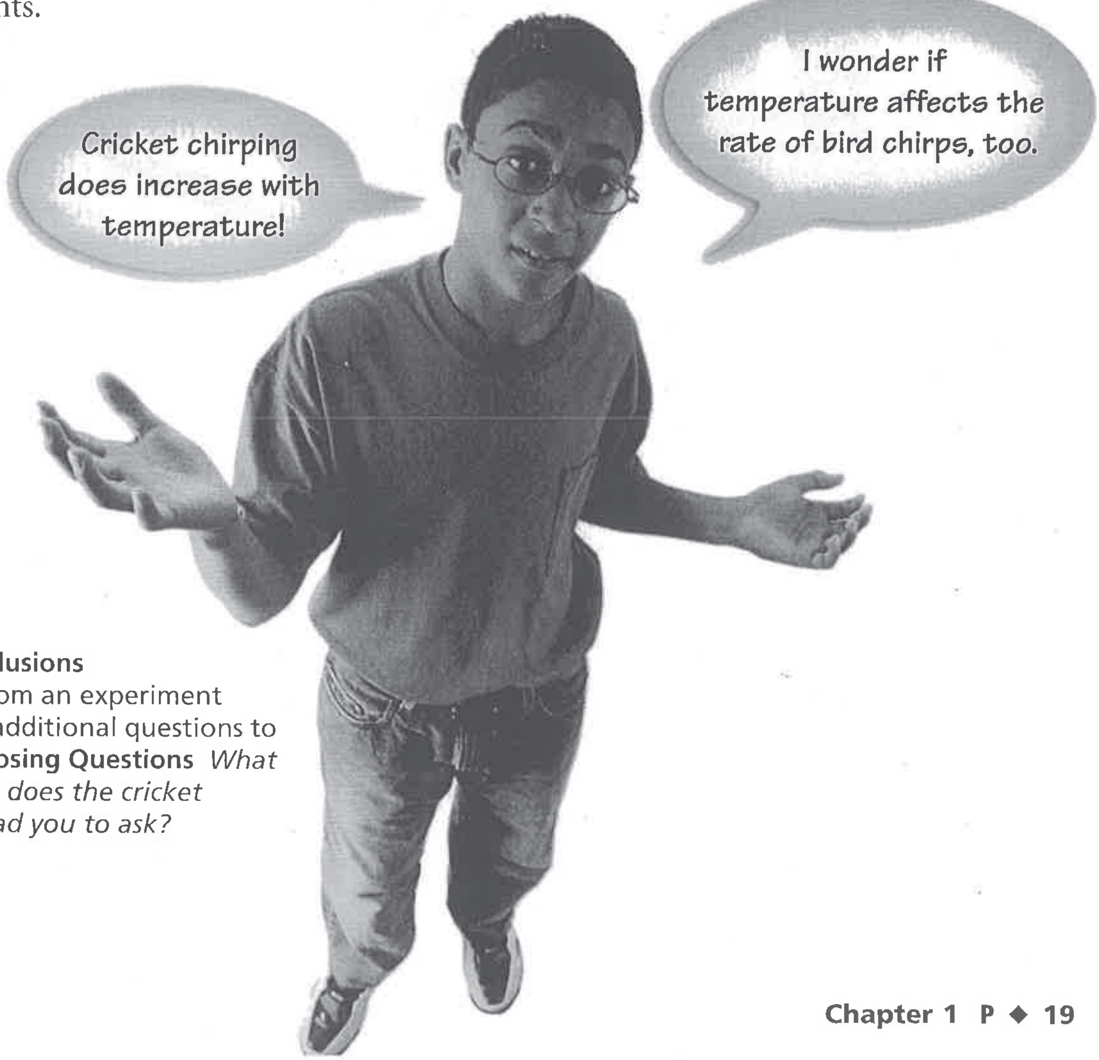
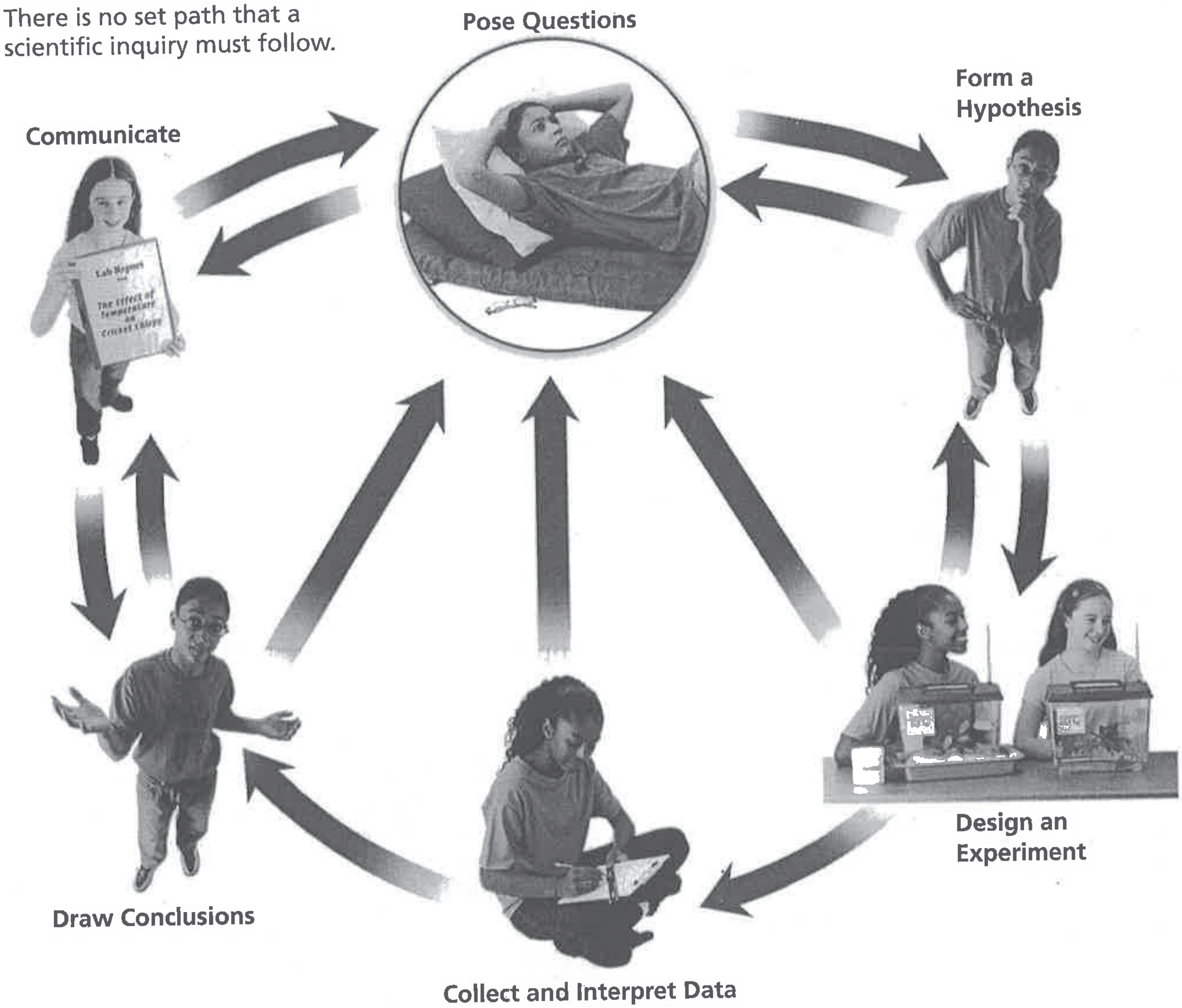


FIGURE 11
Drawing Conclusions
Conclusions from an experiment often lead to additional questions to investigate. **Posing Questions** *What new questions does the cricket experiment lead you to ask?*

FIGURE 12
The Nature of Inquiry
There is no set path that a scientific inquiry must follow.



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The Nature of Inquiry In this cricket experiment, you decided to test your hypothesis in one particular way. Your friend may do it another way. Furthermore, different questions may require different approaches to finding answers. For example, a scientist studying the moon may rely more on observations rather than controlled experiments to test a hypothesis.

Scientific inquiry is a process with many paths, not a rigid sequence of steps. Often, a surprising observation or accidental discovery leads into inquiry. New information springs up, then a scientist's path takes a different turn. Work may go forward—or even backward—when testing a hunch or fitting a new idea with existing ones.

Communicating

An important part of the scientific inquiry process is communicating your results. **Communicating** is the sharing of ideas and experimental findings with others through writing and speaking. Scientists share their ideas in many ways. For example, they give talks at scientific meetings, exchange information on the Internet, or publish articles in scientific journals.

Sometimes, a scientific inquiry can be part of a huge project with many scientists working together around the world. On such projects, scientists must share their ideas and findings on a regular basis. When scientists communicate their research, they describe their procedures in full detail so that others can repeat their experiments.

Reading Checkpoint **Why is communicating important to scientists?**

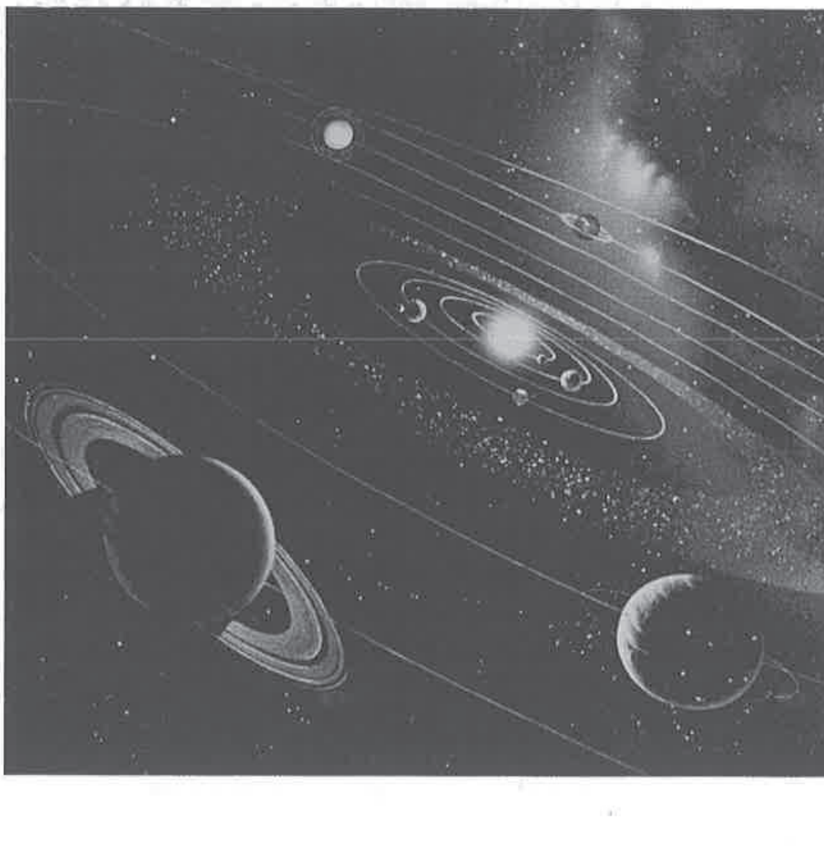
Scientific Theories and Laws

As a body of knowledge, science is built up cautiously. Scientists do not accept a new hypothesis after just one successful experiment. Rather, a hypothesis is tested repeatedly as many different scientists try to apply it to their own work.

Scientific Theories Sometimes, a large set of related observations can be connected by a single explanation. This can lead to the development of a scientific theory. A **scientific theory** is a well-tested explanation for a wide range of observations or experimental results. For example, according to the atomic theory, all substances are composed of tiny particles called atoms. The atomic theory helps to explain many observations, such as why ice melts at a particular temperature and why iron nails rust.

Scientists accept a theory only when there is a large body of evidence that supports it. However, future testing can still prove an accepted theory to be incorrect. If that happens, scientists may modify the theory, or discard it altogether. This illustrates the ever growing—and exciting—nature of scientific knowledge.

FIGURE 13
A Scientific Theory
Based on observations of sunsets and sunrises, ancient people theorized that the sun revolved around Earth. New evidence led scientists to abandon that ancient theory. Today, scientists know that Earth, along with the other planets in the solar system, revolves around the sun.



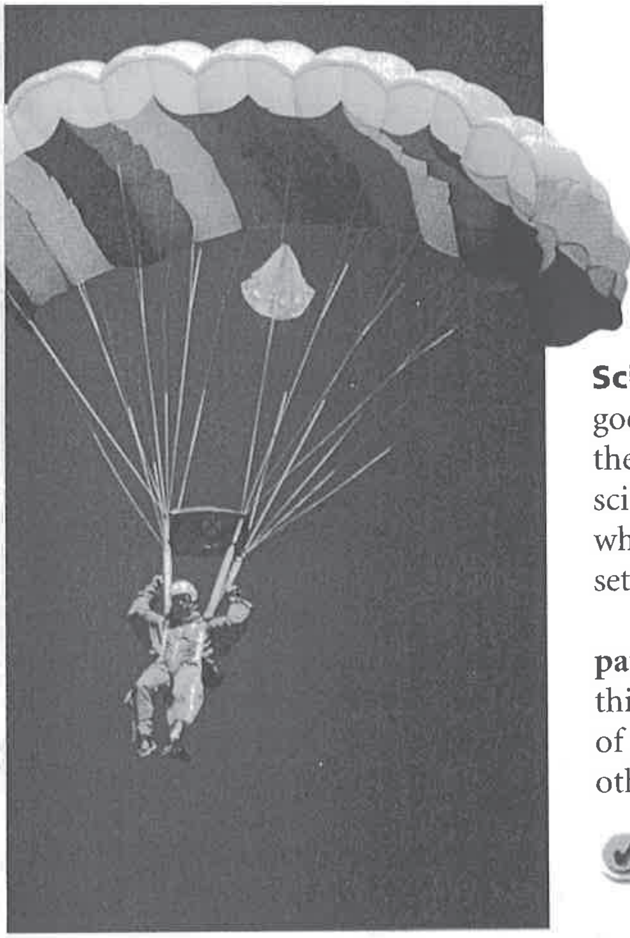


FIGURE 14
A Scientific Law
According to the law of gravity, this parachutist will eventually land back on Earth.

Scientific Laws Have you ever heard someone say, "What goes up must come down"? When scientists repeatedly observe the same result in specific circumstances, they may arrive at a scientific law. A **scientific law** is a statement that describes what scientists expect to happen every time under a particular set of conditions.

Unlike a theory, a scientific law describes an observed pattern in nature without attempting to explain it. You can think of a scientific law as a rule of nature. For example, the law of gravity states that all objects in the universe attract each other. This law has been verified over and over again.

Reading Checkpoint **What does a scientific law describe?**

Section 2 Assessment

Target Reading Skill Building Vocabulary Use your definitions to help you answer the questions below.

Reviewing Key Concepts

1. a. **Defining** Define the term *scientific inquiry.*
   b. **Explaining** A friend claims that ceiling fans are better than air conditioning because they cool the air faster than air conditioners do. Could you investigate this through scientific inquiry? Explain.
   c. **Problem Solving** What kind of data would you need to collect to carry out this experiment?
2. a. **Reviewing** What is meant by saying that a hypothesis must be testable?
   b. **Developing Hypotheses** Every time you and your friend study for an exam while listening to classical music, both of you do well on the exam. What testable hypothesis can you develop from your observations?
3. a. **Defining** What is a scientific theory? What is a scientific law?
   b. **Comparing and Contrasting** How do scientific theories differ from scientific laws?
   c. **Classifying** The students who conducted the cricket experiment concluded that their results supported their hypothesis. Can their supported hypothesis be called a theory? Why or why not?

Writing in Science

Summary Suppose you will be traveling to a convention of cricket scientists from around the world. Write a paragraph describing the results of your cricket experiment. Include questions you'd like to ask other cricket scientists while at the conference.