1–1 What Is Science?

One ancient evening, lost in the mists of time, someone looked into the sky and wondered for the first time: What are those lights? Where did plants and animals come from? How did I come to be? Since then, humans have tried to answer those questions. At first, the answers our ancestors came up with involved tales of magic or legends like the one that accounted for the eye-like markings on the peacock's tail in **Figure 1–1.** Then, slowly, humans began to explore the natural world using a scientific approach.

What Science Is and Is Not

What does it mean to say that an approach to a problem is scientific? **The goal of science is to investigate and understand the natural world, to explain events in the natural world, and to use those explanations to make useful predictions.**

Science has several features that make it different from other human endeavors. First, science deals only with the natural world. Second, scientists collect and organize information in a careful, orderly way, looking for patterns and connections between events. Third, scientists propose explanations that can be tested by examining evidence. In other words, **science** is an organized way of using evidence to learn about the natural world. The word *science* also refers to the body of knowledge that scientists have built up after years of using this process.

Guide for Reading

Key Concept
- What is the goal of science?

Vocabulary
science
observation
data
inference
hypothesis

Reading Strategy: Making Comparisons As you read, list steps that scientists use to solve problems. After you read, compare the methods you use to solve problems with those used by scientists.

Figure 1–1 Male peacocks have markings on their tails that resemble giant eyes. According to an ancient Greek myth, the peacock's "eyes" once belonged to Argus, a giant with 100 eyes. An angry goddess had Argus killed, but she transferred the giant's eyes to the tail of the peacock.

TIME SAVER — SECTION RESOURCES

Print:
- ***Teaching Resources,*** Lesson Plan 1–1, Adapted Section Summary 1–1, Adapted Worksheets 1–1, Section Summary 1–1, Worksheets 1–1, Section Review 1–1
- ***Reading and Study Workbook A,*** Section 1–1
- ***Adapted Reading and Study Workbook B,*** Section 1–1
- ***Biotechnology Manual,*** Concept 1

Technology:
- ***iText,*** Section 1–1
- ***Transparencies Plus,*** Section 1–1

Section 1–1

1 FOCUS

Objectives

1.1.1 ***Explain*** what the goal of science is.
1.1.2 ***Explain*** what a hypothesis is.

Guide for Reading

Vocabulary Preview

Have students write the Vocabulary words, dividing each into its separate syllables as best they can. Remind students that each syllable usually has only one vowel sound. The correct syllabications are: sci•ence, ob•ser•va•tion, da•ta, in•fer•ence, hy•poth•e•sis.

Reading Strategy

Tell students that they should write at least one phrase about how a scientist works for each of the blue heads in the section.

2 INSTRUCT

What Science Is and Is Not

Build Science Skills

Applying Concepts Divide the class into small groups, and ask each group to propose an explanation for why it rains, without including any scientific thinking in their explanation. Groups might propose that clouds are crying, that there is an invisible river in the sky, or that an invisible rain god pours water on Earth when angry. Once each group has agreed upon an explanation, have a member from each present it to the class. Then, ask: **Suppose someone does not believe your explanation. Could you supply evidence to support your explanation?** *(For almost all explanations, the answer will be no.)* **Why not?** *(There is no way to gather evidence, there is no way to observe a cloud that is "crying," and so on.)* Emphasize that scientists propose explanations that can be tested by examining evidence. L1 L2

1–1 (continued)

Thinking Like a Scientist

Build Science Skills

Observing Place moldy bread or cheese in a sealed plastic bag. Show it to the class and ask: **Can you describe in detail what you see?** *(Observations should include the color and texture of the mold, the extent to which it covers the bread or cheese, and whether the mold is in solid patches or small spots.)* **What questions would you as a biologist ask after seeing the mold?** *(Possible questions: What caused the mold? Will the mold cover more of the bread or cheese? Does all bread or cheese get moldy?)* L2

Build Science Skills

Inferring Explain to students that some scientists use the following method when confronted with a problem to be solved: organize, analyze, evaluate, make inferences, and predict trends from data. Explain what each of these skills involves. For example, scientists often organize data into tables and graphs. They analyze the data through processes such as noting how manipulated variables affect responding variables. They evaluate data by checking its accuracy and reliability, including any measurements. Scientists make logical interpretations, or inferences, based on observations and knowledge. They predict trends by looking at trends shown in the data they already have. Also refer students to Appendix A in their textbooks. After you have explained and discussed science process skills, have students apply them to a real-world situation. For example, students might analyze newspaper weather data and predict trends based on the data. L2 L3

▲ **Figure 1–2** **The goal of science is to investigate and understand nature.** The first step in this process is making observations. This researcher is observing the behavior of a manatee in Florida.

Thinking Like a Scientist

Suppose a car won't start. Is the car out of gas? A glance at the fuel gauge tests that idea. Perhaps the battery is dead. An auto mechanic can use an instrument to test that idea. To figure out what is wrong with the car, people perform tests and observe the results of the tests.

This familiar activity uses the approach scientists take in research. Scientific thinking usually begins with **observation,** the process of gathering information about events or processes in a careful, orderly way. Observation generally involves using the senses, particularly sight and hearing. The information gathered from observations is called **data.**

There are two main categories of data. Quantitative data are expressed as numbers, obtained by counting or measuring. The researcher in **Figure 1–2,** for example, might note that the manatee "has one scar on its back." Qualitative data are descriptive and involve characteristics that can't usually be counted. The researcher might make the qualitative observations that "the scar appears old" and "the animal seems healthy and alert."

Scientists may use data to make inferences. An **inference** is a logical interpretation based on prior knowledge or experience. The researcher in **Figure 1–3,** for example, is testing water in a reservoir. Because she cannot test *all* the water, she collects water samples from several different parts of the reservoir. If all the samples are clean enough to drink, she may infer that all the water is safe to drink.

◀ **Figure 1–3** Researchers testing water for lead pollution cannot test every drop, so they check small amounts, called samples. **Inferring** *How might a local community use such scientific information?*

ESL SUPPORT FOR ENGLISH LANGUAGE LEARNERS

Vocabulary: Writing

Beginning Write the word *observation* on the board. Ask English-proficient and ESL students to make observations about the classroom. Using single words or short phrases, write their responses on the board under the word *observation*. Then, have your ESL students write the word *observation* on their papers. Have them use single words or pictures to name several things they observe in the classroom. L1

Intermediate Extend the Beginning activity by recording observations on the board using complete sentences. Then, when the ESL students prepare their own list, have them speak complete sentences to describe their observations instead of single words or pictures. Students who need assistance with their sentences can be paired with an English-proficient student. L2

Explaining and Interpreting Evidence

Scientists try to explain events in the natural world by interpreting evidence logically and analytically. Suppose, for example, that many people contract an unknown disease after attending a public event. Public health researchers will use scientific methods to try to determine how those people became ill.

After initial observations, the researchers will propose one or more hypotheses. A **hypothesis** is a proposed scientific explanation for a set of observations. Scientists generate hypotheses using prior knowledge, or what they already know; logical inference; and informed, creative imagination. For the unknown disease, there might be several competing hypotheses, such as these: (1) The disease was spread from person to person by contact. (2) The disease was spread through insect bites. (3) The disease was spread through air, water, or food.

Scientific hypotheses must be proposed in a way that enables them to be tested. Some hypotheses are tested by performing controlled experiments, as you will learn in the next section. Other hypotheses are tested by gathering more data. In the case of the mystery illness, data would be collected by studying the location of the event; by examining air, water, and food people were exposed to; and by questioning people about their actions before falling ill. Some hypotheses would be ruled out. Others might be supported and eventually confirmed.

Researchers working on complex questions often collaborate in teams like the one in **Figure 1–4.** These groups have regular meetings at which the members analyze, review, and critique one another's data and hypotheses. This review process helps ensure that their conclusions are valid. To be valid, a conclusion must be based on logical interpretation of reliable data. To learn about sources of error in scientific investigations, see Appendix A.

CHECKPOINT *How do scientists develop hypotheses?*

◀ **Figure 1–4** Researchers often collaborate by working in teams, combining imagination and logic to develop and test hypotheses. **Applying Concepts** *How do scientists decide whether to accept or reject a hypothesis?*

Explaining and Interpreting Evidence

Build Science Skills

Formulating Hypotheses Divide the class into small groups, and give each group a "mystery box." Prepare each box ahead of time, each with a different arrangement of partitions and each containing one or more marbles. Explain to groups what the boxes contain, in general terms. Tell students their task is to formulate a hypothesis about the specific arrangement of partitions in their group's box. Have them tilt, turn, and tap the box to move the marbles inside so that sounds and sensations will provide clues about the internal arrangement. Each group should make a sketch of its hypothesis of how the partitions are arranged inside its mystery box. Then, groups should make a list of what further tests could be performed to support or refute the hypothesis, short of opening the box. (Students may have the misconception that hypotheses are always confirmed, because the activities they have done in science classes were usually designed to support a hypothesis.) L2 L3

BIO INSIGHTS — FACTS AND FIGURES

Evidence can be misused
There have been times in human history when scientific evidence or apparent evidence has been misused to serve the ends of racial prejudice and sexual bias. For example, the Swiss-American biologist Louis Agassiz (1807–1873) expressed the racist belief that non-European peoples were inferior to Europeans. Other scientists at the turn of the nineteenth century shared his view. They accepted unsubstantiated or inaccurate data to try to support their ideas. In the late nineteenth century, a group of scientists called craniologists made measurements of brain and skull size to prove that women were intellectually inferior to men. These "scientific studies" were cited in attempts to deny women equal rights. Today, scientists know that among humans, brain size has nothing to do with intelligence.

Answers to . . .

CHECKPOINT *Hypotheses may arise from prior knowledge; logical inference; and informed, creative imagination.*

Figure 1–3 *The leaders of a community might use the test results to warn residents about water pollution, take steps to prevent or remedy pollution problems, or assure residents that the water is safe to drink.*

Figure 1–4 *Scientists accept or reject a hypothesis by evaluating the outcome of a controlled experiment or by gathering more data.*

1–1 **(continued)**

Science as a Way of Knowing

Use Community Resources

Scientists from the community can provide students with firsthand knowledge about careers in science. Invite a local scientist to speak to the class about his or her career and about looking at the world with a scientific view. Also, identify some local people with careers related to science. As much as possible, mention women and individuals of different ethnicities and backgrounds with whom students can relate. These neighbors will help students see that they too can enter careers in science. Keep in mind that some findings of modern science as well as some types of scientific experiments may be incompatible with the beliefs of certain ethnic or religious groups. The support of respected members of the community of different cultural backgrounds may help promote understanding. L1 L2

Use Visuals

Figure 1–5 Lead a discussion about differences in the way the hikers who discovered the corpse might have thought about the body and the way the scientists who removed the corpse probably thought about the body. Then, ask: **After the initial observations, what are some ways that scientists could find out more about this ancient corpse?** *(Accept any reasonable response. Students might suggest X-raying the body or even dissecting it.)* L2

Science and Human Values

Use Community Resources

Invite a university biologist and a member of the local clergy to address the class on an issue related to science, such as cloning, research using stem cells, or laws about endangered species. Ask the speakers to talk about how people who agree with their viewpoints might confront such an issue. L1 L2

Science as a Way of Knowing

This book contains lots of facts, but don't think biological science is a set of truths that never change. Instead, science is a way of knowing. This means that rather than unchanging knowledge, science is an ongoing *process*—a process that involves asking questions, observing, making inferences, and testing hypotheses. You can learn more about these and other science skills in Appendix A.

Because of new tools, techniques, and discoveries, such as the discovery of the iceman shown in **Figure 1–5,** scientific understanding is always changing. Research can have a profound impact on scientific thought. For example, the discovery of cells revolutionized understanding of the structure of living things. Without doubt, some things you learn from this book will soon be revised because of new information. But this doesn't mean that science has failed. On the contrary, it means that science continues to succeed in advancing understanding.

Good scientists are skeptics, which means that they question both existing ideas and new hypotheses. Scientists continually evaluate the strengths and weaknesses of hypotheses. Scientists must be open-minded and consider new hypotheses if data demand it. And despite the power of science, it has definite limits. For example, science cannot help you decide whether a painting is beautiful or whether school sports teams should be limited to only the best athletes.

The scientific way of knowing includes the view that the whole physical universe is a system, or a collection of parts and processes that interact. In the universe, basic natural laws govern all events and objects, large or small. The physical universe consists of many smaller systems. Biologists focus on living systems, which range from invisibly small to the size of our entire planet.

▼ **Figure 1–5** In 1991, hikers in the Italian Alps discovered a well-preserved corpse that was about 5000 years old. Scientists might have asked how the corpse could be so well preserved, but they already knew the answer. Sub-zero temperatures keep the organisms that cause decomposition from doing their job. **Asking Questions** *What are some other scientific questions that might be asked about this discovery?*

BIO INSIGHTS **FACTS AND FIGURES**

Ötzi the Ice Man

The human remains shown in Figure 1–5 were discovered at the end of a warm summer in a barren Alpine pass near the Italian-Austrian border. Carbon-14 testing showed that the man had died some 5300 years earlier, during the Neolithic Age. He was named Ötzi the Ice Man because he was found in the Ötzal Alps and he had been preserved in glacial ice since his death. The unusually warm summer of 1991 had melted ice on the pass and exposed the body to view. Ötzi now lies on display at the South Tyrol Museum of Archaeology in Bolzano, Italy. Researchers have done many studies on Ötzi, including some using X-rays and CAT scans. Chemical analysis of a tiny clump at the top of his colon showed that he had eaten food from a nearby valley just eight hours before he died. His last meal had been a cracker-hard, unleavened bread made from einkorn wheat.

Science and Human Values

Because of new knowledge gained through research, scientists continually revise and reevaluate their ideas. The importance of science, however, reaches far beyond the scientific world. Today, scientists contribute information to discussions about health and disease, and about the relationship between human beings and the living and nonliving environment.

Make a list of things that you need to understand to protect your life and the lives of others close to you. Chances are that your list will include drugs and alcohol, smoking and lung disease, AIDS, cancer, and heart disease. Other questions focus on public health and the environment. How can we best use antibiotics to make sure that those "wonder drugs" keep working for a long time? How much of the information in your genes should you be able to keep private? Should communities produce electricity using fossil fuels, nuclear power, or hydroelectric dams? How should chemical wastes be disposed of? Who should be responsible for their disposal?

All of these questions involve scientific information. For that reason, an understanding of science and the scientific approach is essential to making intelligent decisions about them. None of these questions, however, can be answered by science alone. They involve the society in which we live and the economy that provides jobs, food, and shelter. They may require us to consider laws and moral principles. In our society, scientists alone do not make final decisions—they make recommendations. Who makes the decisions? We, the citizens of our democracy do—when we vote to express our opinions to elected officials. That is why it is more important than ever that everyone understand what science is, what it can do, and what it cannot do.

▲ **Figure 1–6** Scientific research has an impact on many aspects of our lives. These racers are raising money to help support research directed at preventing and treating cancer. **Applying Concepts** *Identify three ways in which science affects your life.*

1–1 Section Assessment

1. **Key Concept** What does science study?
2. What does it mean to describe a scientist as skeptical? Why is skepticism considered a valuable quality in a scientist?
3. What is the main difference between qualitative and quantitative observations?
4. What is a scientific hypothesis? In what two ways can a hypothesis be tested?
5. Is a scientific hypothesis accepted if there is no way to demonstrate that the hypothesis is wrong? Explain your answer.
6. **Critical Thinking Making Judgments** Suppose a community proposes a law to require the wearing of seatbelts in all moving vehicles. How could scientific research have an impact on the decision?

Thinking Visually

Making a Table
List the five main senses—vision, hearing, smell, taste, and touch—and give an example of an observation that you have made using each sense. Then, add at least one inference that could be made based on each observation.

3 ASSESS

Evaluate Understanding

Have students write an explanation in their own words of what a hypothesis is and the three ways in which a hypothesis may arise.

Reteach

Direct students' attention to the manatee pictured in Figure 1–2, and ask students at random to explain what quantitative and qualitative observations a biologist might make about this animal.

Thinking Visually

Students should list an observation and a logical inference for each sense. For example, if you see wet pavement, it may have rained or someone may have washed a car in that location. If you hear a bird sing, it may be singing to mark a territory or attract a mate. If a tabletop feels sticky, someone may have spilled syrup on the table.

Interactive Textbook

If your class subscribes to the iText, use it to review the Key Concepts in Section 1–1.

1–1 Section Assessment

1. Science is the study of the natural world, the search for patterns and connections between events.
2. Skeptics question both existing ideas and new hypotheses. Skepticism is valuable because scientific understanding is always changing.
3. Qualitative observations involve characteristics that cannot be measured or counted.
4. A hypothesis is a proposed scientific explanation for a set of observations. One can be tested by performing a controlled experiment or by gathering more data.
5. No. Scientific hypotheses must be proposed in a way that enables them to be tested.
6. Answers will vary. A typical response might suggest that research could determine whether seatbelts would reduce accident fatalities.

Answers to . . .

Figure 1–5 *Typical answers might include: Was the corpse male or female? How did the person die? How old was the person? Where might the person have been going at the time that he or she died?*

Figure 1–6 *Answers will vary. A typical answer might suggest how science affects a student's life in the areas of health care, environment, and communication.*