The Nature of Life

UNIT 1

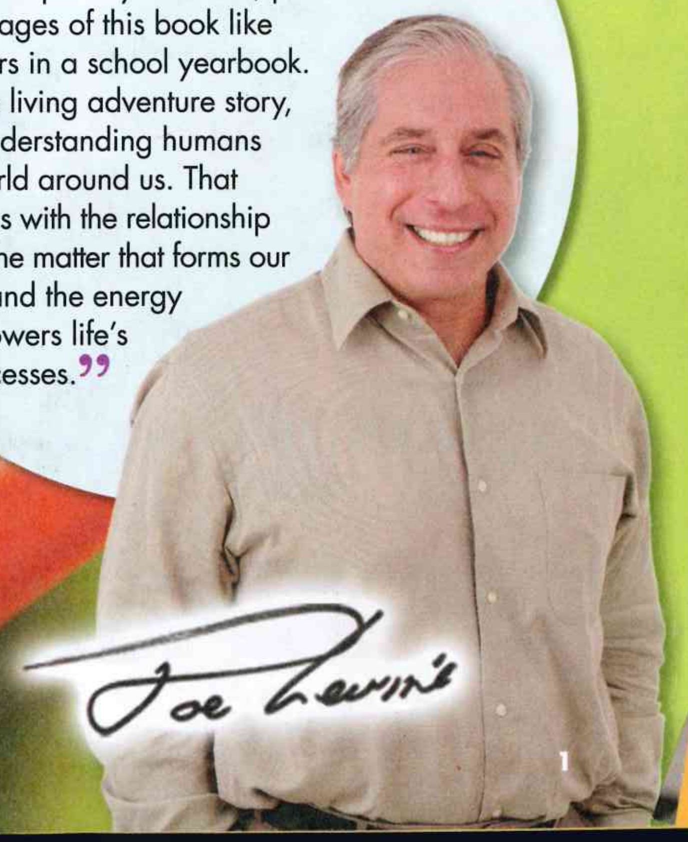
Chapters

1 The Science of Biology
2 The Chemistry of Life

INTRODUCE the **Big ideas**

- **Science as a Way of Knowing**
- **Matter and Energy**

“Science is ‘a way of knowing’— a way of explaining the natural world through observations, questions, and experiments. But science isn’t just dry old data, pressed between pages of this book like prom flowers in a school yearbook. Science is a living adventure story, aimed at understanding humans and the world around us. That story begins with the relationship between the matter that forms our bodies and the energy that powers life’s processes.”



The Science of Biology

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Science as a Way of Knowing

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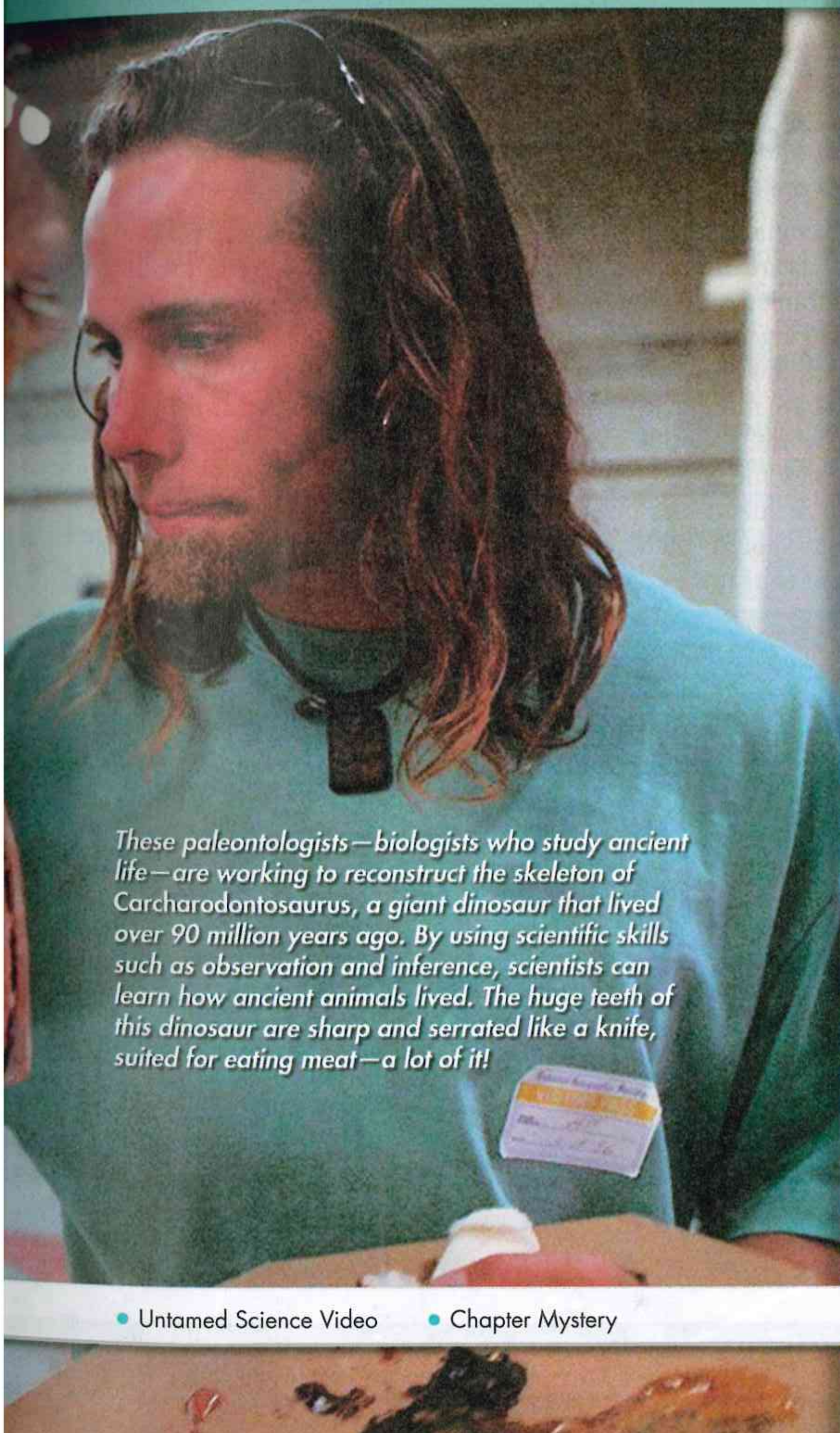
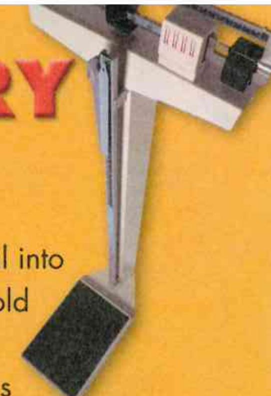
INSIDE:



These paleontologists—biologists who study ancient life—are working to reconstruct the skeleton of Carcharodontosaurus, a giant dinosaur that lived over 90 million years ago. By using scientific skills such as observation and inference, scientists can learn how ancient animals lived. The huge teeth of this dinosaur are sharp and serrated like a knife, suited for eating meat—a lot of it!

- Untamed Science Video
- Chapter Mystery

CHAPTER MYSTERY



HEIGHT BY PRESCRIPTION

A doctor injects a chemical into the body of an eight-year-old boy named David. This healthy boy shows no signs of disease. The "condition" for which he is being treated is quite common—David is short for his age. The medication he is taking is human growth hormone, or HGH.

HGH, together with genes and diet, controls growth during childhood. People who produce little or no HGH are abnormally short and may have other related health problems. But David has normal HGH levels. He is short simply because his parents are both healthy, short people.

But if David isn't sick, why does his doctor prescribe HGH? Where does medicinal HGH come from? Is it safe? What does this case say about science and society? As you read this chapter, look for clues about the nature of science, the role of technology in our modern world, and the relationship between science and society. Then, solve the mystery.

Never Stop Exploring Your World. Finding the solution to the growth hormone mystery is only the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where this mystery leads.

UntamedScience™

1.1 What Is Science?

Key Questions

What are the goals of science?

What procedures are at the core of scientific methodology?

Vocabulary

science • observation • inference • hypothesis • controlled experiment • independent variable • dependent variable • control group • data

Taking Notes

Flowchart As you read, create a flowchart showing the steps scientists use to answer questions about the natural world.

THINK ABOUT IT One day long ago, someone looked around and wondered: Where did plants and animals come from? How did I come to be? Since then, humans have tried to answer those questions in different ways. Some ways of explaining the world have stayed the same over time. Science, however, is always changing.

What Science Is and Is Not

What are the goals of science?

This book contains lots of facts and ideas about living things. Many of those facts are important, and you will be tested on them! But you shouldn't think that biology, or any science, is just a collection of never-changing facts. For one thing, you can be sure that some "facts" presented in this book will change soon—if they haven't changed already. What's more, science is not a collection of unchanging beliefs about the world. Scientific ideas are open to testing, discussion, and revision. So, some ideas presented in this book will also change.

These statements may puzzle you. If "facts" and ideas in science change, why should you bother learning them? And if science is neither a list of facts nor a collection of unchanging beliefs, what is it?

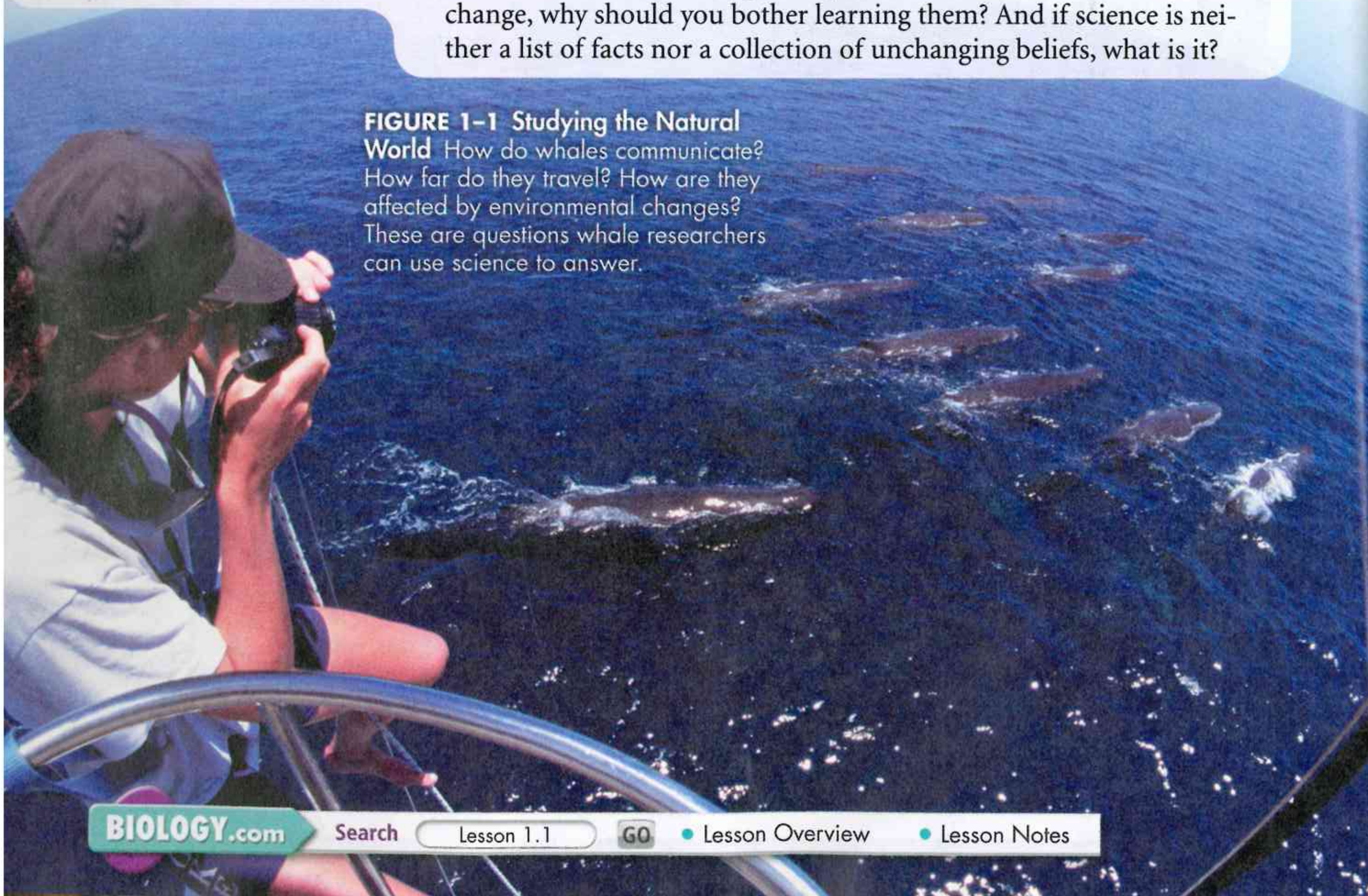


FIGURE 1–1 Studying the Natural World How do whales communicate? How far do they travel? How are they affected by environmental changes? These are questions whale researchers can use science to answer.

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way of gathering and analyzing evidence about the natural world. It is a way of observing, a way of thinking, and "a way of knowing" about the world. In other words, science is a *process,* not a "thing." The word *science* also refers to the body of knowledge that scientific studies have gathered over the years.

Several features make science different from other human endeavors. First, science deals only with the natural world. Scientific endeavors never concern, in any way, supernatural phenomena of any kind. Second, scientists collect and organize information in an orderly way, looking for patterns and connections among events. Third, scientists propose explanations that are based on evidence, not belief. Then they test those explanations with more evidence.

FIGURE 1–2 Science in Action These marine scientists are recording information as they study whales in Alaska.

The Goals of Science The scientific way of knowing includes the view that the physical universe is a system composed of parts and processes that interact. From a scientific perspective, all objects in the universe, and all interactions among those objects, are governed by universal natural laws. The same natural laws apply whether the objects or events are large or small.

Aristotle and other Greek philosophers were among the first to try to view the universe in this way. They aimed to explain the world around them in terms of events and processes they could observe. Modern scientists continue that tradition. **One goal of science is to provide natural explanations for events in the natural world. Science also aims to use those explanations to understand patterns in nature and to make useful predictions about natural events.**

BUILD Vocabulary

WORD ORIGINS The word **science** derives from the Latin word *scientia,* which means "knowledge." Science represents knowledge that has been gathered over time.

Science, Change, and Uncertainty Over the centuries, scientists have gathered an enormous amount of information about the natural world. Scientific knowledge helps us cure diseases, place satellites in orbit, and send instantaneous electronic communications. Yet, despite all we know, much of nature remains a mystery. It is a mystery because science never stands still; almost every major scientific discovery raises more questions than it answers. Often, research yields surprises that point future studies in new and unexpected directions. This constant change doesn't mean science has failed. On the contrary, it shows that science continues to advance.

That's why learning about science means more than just understanding what we know. It also means understanding what we don't know. You may be surprised to hear this, but science rarely "proves" anything in absolute terms. Scientists aim for the best understanding of the natural world that current methods can reveal. Uncertainty is part of the scientific process and part of what makes science exciting! Happily, as you'll learn in later chapters, science has allowed us to build enough understanding to make useful predictions about the natural world.

In Your Notebook *Explain in your own words why there is uncertainty in science.*

The Heart of Science

What procedures are at the core of scientific methodology?

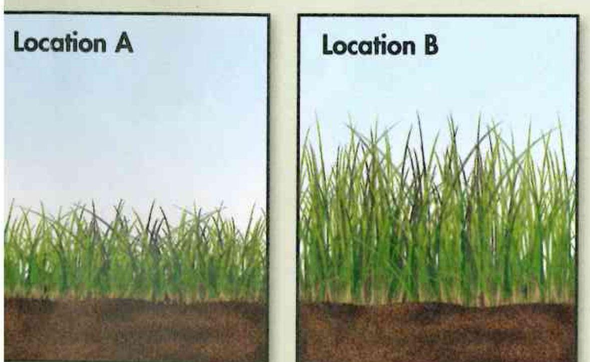
You might think that science is a mysterious process, used only by certain people under special circumstances. But that's not true, because you use scientific thinking all the time. Suppose your family's car won't start. What do you do? You use what you know about cars to come up with ideas to test. At first, you might think the battery is dead. So you test that idea by turning the key in the ignition. If the starter motor works but the engine doesn't start, you reject the dead-battery idea. You might guess next that the car is out of gas. A glance at the fuel gauge tests that idea. Again and again, you apply scientific thinking until the problem is solved—or until you run out of ideas and call a mechanic!

Scientists approach research in pretty much the same way. There isn't any single, cut-and-dried "scientific method." There is, however, a general style of investigation that we can call scientific methodology. **Scientific methodology involves observing and asking questions, making inferences and forming hypotheses, conducting controlled experiments, collecting and analyzing data, and drawing conclusions. Figure 1–3** shows how one research team used scientific methodology in its study of New England salt marshes.

Observing and Asking Questions Scientific investigations begin with **observation,** the act of noticing and describing events or processes in a careful, orderly way. Of course, scientific observation involves more than just looking at things. A good scientist can, as the philosopher Arthur Schopenhauer put it, "Think something that nobody has thought yet, while looking at something that everybody sees." That kind of observation leads to questions that no one has asked before.

FIGURE 1–3 Salt Marsh Experiment Salt marshes are coastal environments often found where rivers meet the sea. Researchers made an interesting observation on the way marsh grasses grow. Then, they applied scientific methodology to answer questions that arose from their observation.

OBSERVING AND ASKING QUESTIONS



Researchers observed that marsh grass grows taller in some places than others. This observation led to a question: *Why do marsh grasses grow to different heights in different places?*

INFERRING AND HYPOTHESIZING

The researchers inferred that something limits grass growth in some places. It could be any environmental factor—temperature, sunlight, water, or nutrients. Based on their knowledge of salt marshes, they proposed a hypothesis: *Marsh grass growth is limited by available nitrogen.*

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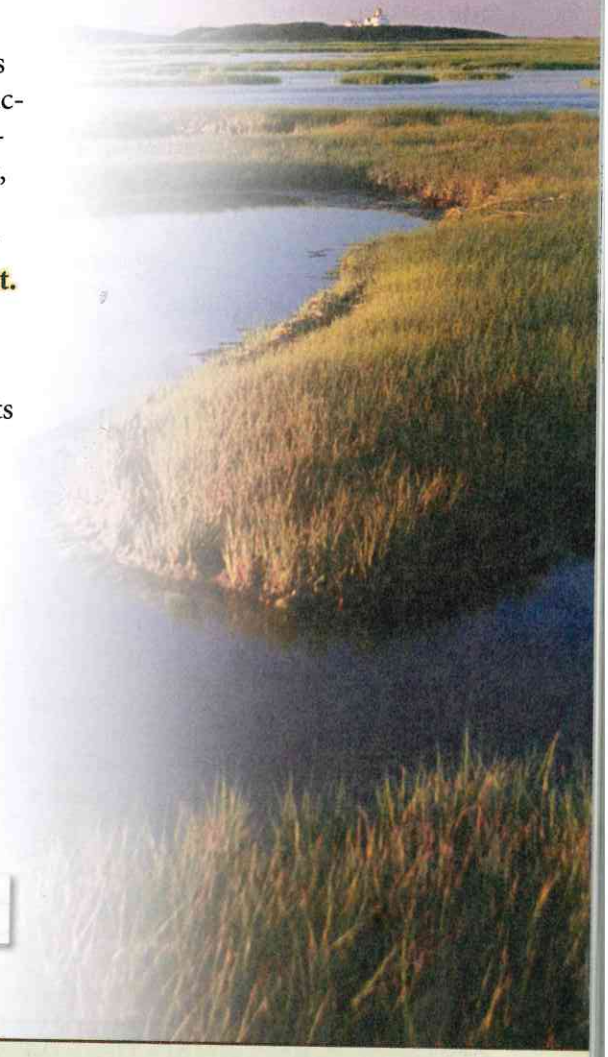
entists use further observations to make inferences. An **inference** is a logical interpretation based on what scientists already know. Inference, combined with a creative imagination, can lead to a hypothesis. A **hypothesis** is a scientific explanation for a set of observations that can be tested in ways that support or reject it.



Designing Controlled Experiments Testing a scientific hypothesis often involves designing an experiment that keeps track of various factors that can change, or variables. Examples of variables include temperature, light, time, and availability of nutrients. Whenever possible, a hypothesis should be tested by an experiment in which only one variable is changed. All other variables should be kept unchanged, or controlled. This type of experiment is called a **controlled experiment.**

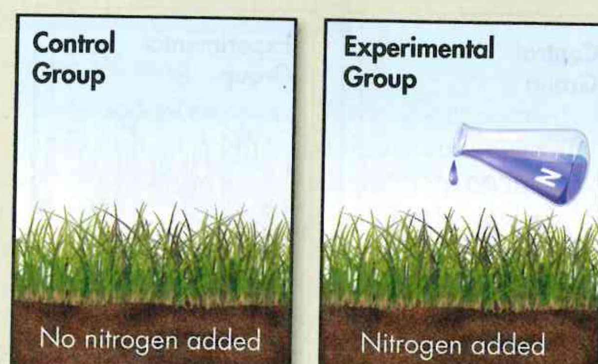
▶ ***Controlling Variables*** Why is it important to control variables? The reason is that if several variables are changed in the experiment, researchers can't easily tell which variable is responsible for any results they observe. The variable that is deliberately changed is called the **independent variable** (also called the manipulated variable). The variable that is observed and that changes in response to the independent variable is called the **dependent variable** (also called the responding variable).

▶ ***Control and Experimental Groups*** Typically, an experiment is divided into control and experimental groups. A **control group** is exposed to the same conditions as the experimental group except for one independent variable. Scientists always try to reproduce or replicate their observations. Therefore, they set up several sets of control and experimental groups, rather than just a single pair.

In Your Notebook *What is the difference between an observation and an inference? List three examples of each.*

DESIGNING CONTROLLED EXPERIMENTS

The researchers selected similar plots of marsh grass. All plots had similar plant density, soil type, input of freshwater, and height above average tide level. The plots were divided into control and experimental groups.

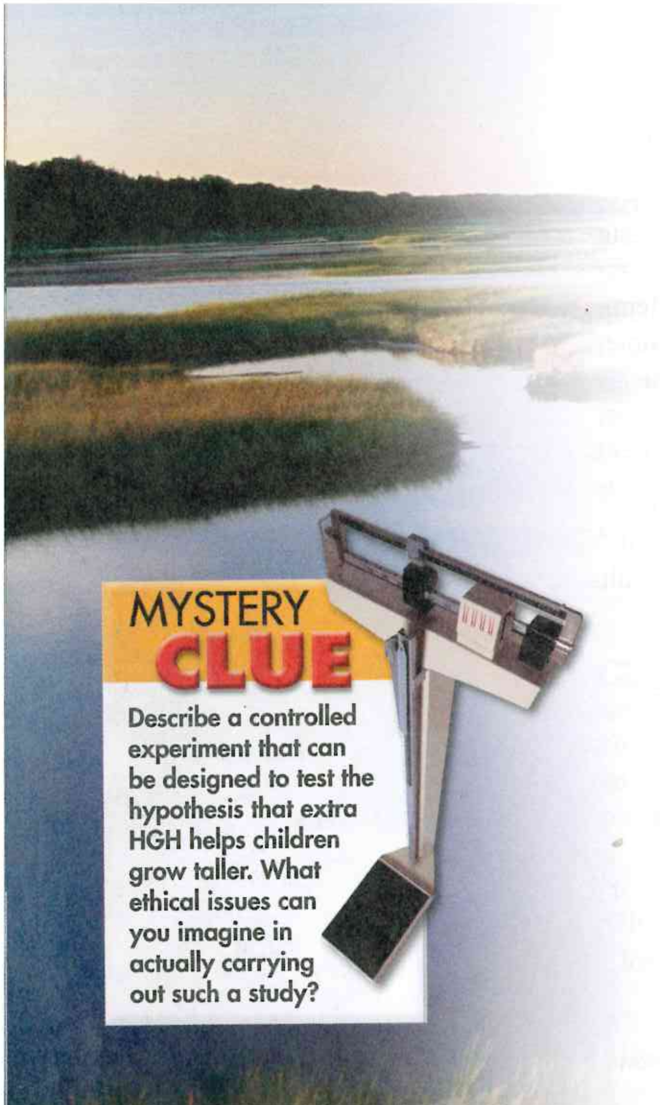


The researchers added nitrogen fertilizer (the independent variable) to the experimental plots. They then observed the growth of marsh grass (the dependent variable) in both experimental and control plots.

records of experimental observations, gathering information called **data.** There are two main types of data. Quantitative data are numbers obtained by counting or measuring. In the marsh grass experiment, quantitative data could include the number of plants per plot, the length, width, and weight of each blade of grass, and so on. Qualitative data are descriptive and involve characteristics that cannot usually be counted. Qualitative data in the marsh grass experiment might include notes about foreign objects in the sample plots or information on whether the grass was growing upright or sideways.

▶ ***Research Tools*** Scientists choose appropriate tools for collecting and analyzing data. The tools may range from simple devices such as metersticks and calculators to sophisticated equipment such as machines that measure nitrogen content in plants and soil. Charts and graphs are also tools that help scientists organize their data. In the past, data were recorded by hand, often in notebooks or personal journals. Today, researchers typically enter data into computers, which make organizing and analyzing data easier. Many kinds of data are now gathered directly by computer-controlled equipment.

▶ ***Sources of Error*** Researchers must be careful to avoid errors in data collection and analysis. Tools used to measure the size and weight of marsh grasses, for example, have limited accuracy. Data analysis and sample size must be chosen carefully. In medical studies, for example, both experimental and control groups should be quite large. Why? Because there is always variation among individuals in control and experimental groups. The larger the sample size, the more reliably researchers can analyze that variation and evaluate the differences between experimental and control groups.

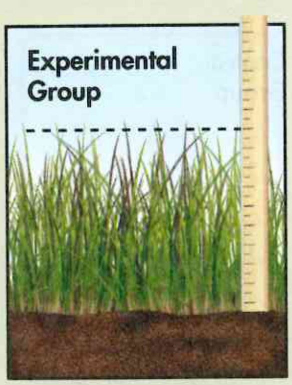


MYSTERY CLUE

Describe a controlled experiment that can be designed to test the hypothesis that extra HGH helps children grow taller. What ethical issues can you imagine in actually carrying out such a study?

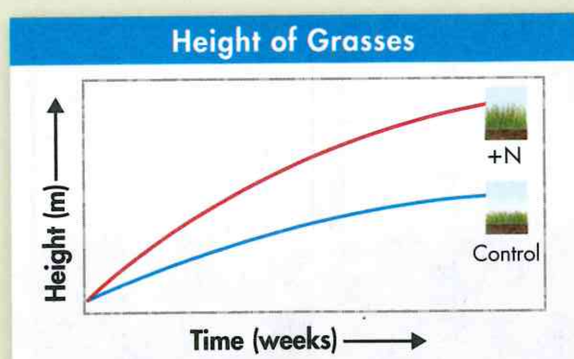
FIGURE 1–3 Continued

COLLECTING AND ANALYZING DATA



The researchers sampled all the plots throughout the growing season. They measured growth rates and plant sizes, and analyzed the chemical composition of living leaves.

DRAWING CONCLUSIONS



Data from all plots were compared and evaluated by statistical tests. Data analysis confirmed that marsh grasses in experimental plots with additional nitrogen did, in fact, grow taller and larger than controls. The hypothesis and its predictions were supported.