1–1 What Is Science?

BIIE 1.f. Distinguish between hypothesis and theory as scientific terms.

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.

Guide for Reading

Key Concept
- What is the goal of science?

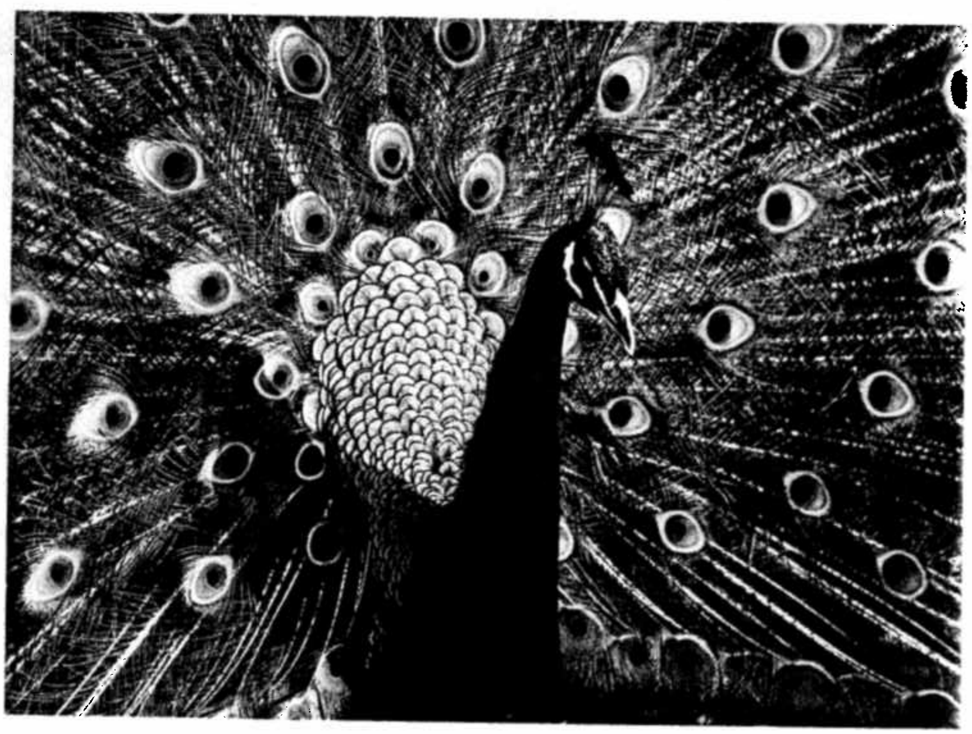
Vocabulary
science
observation
data
inference
hypothesis

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.

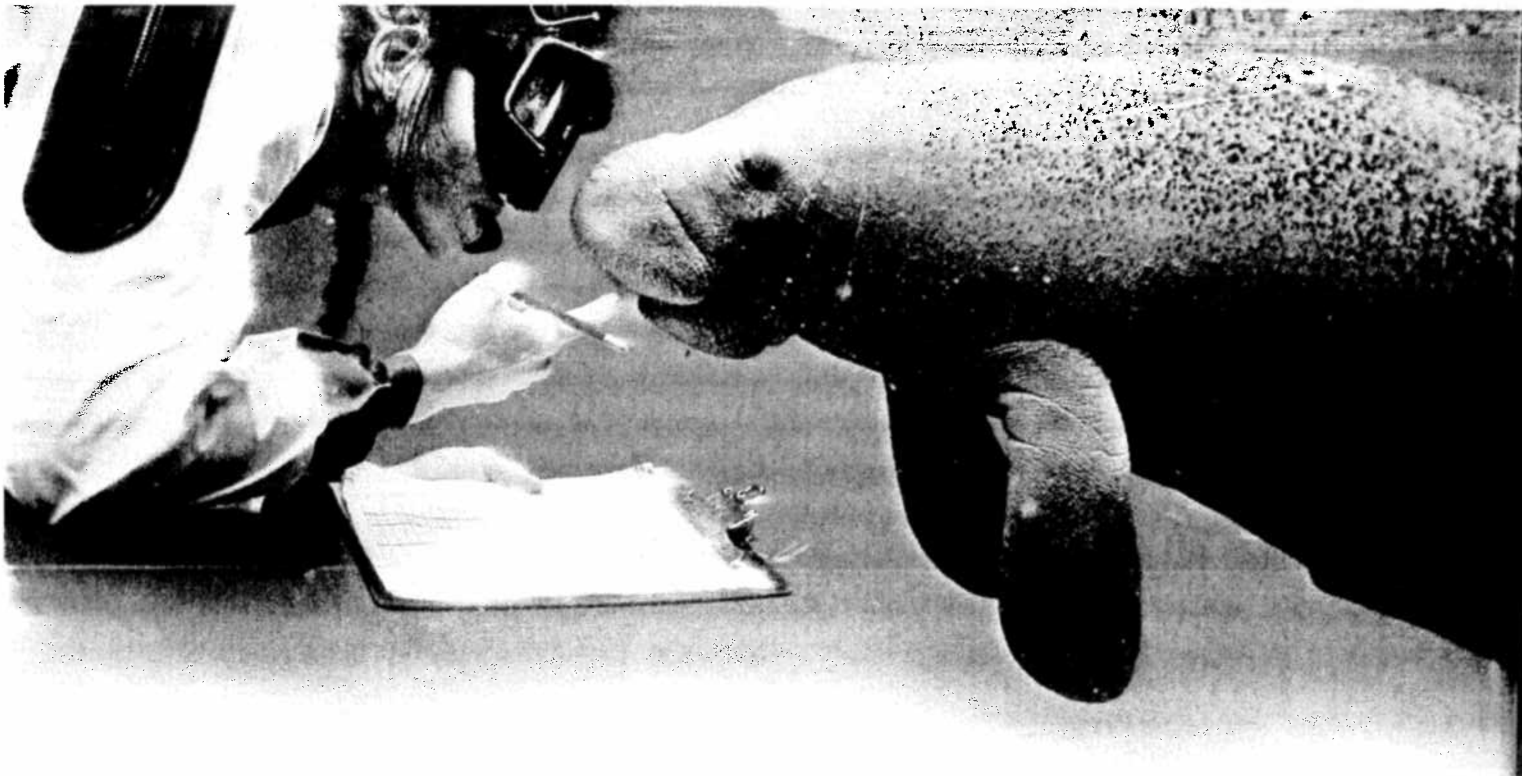
What Science Is and Is Not

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.



◀ **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.



▲ **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?*

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?*

Science as a Way of Knowing

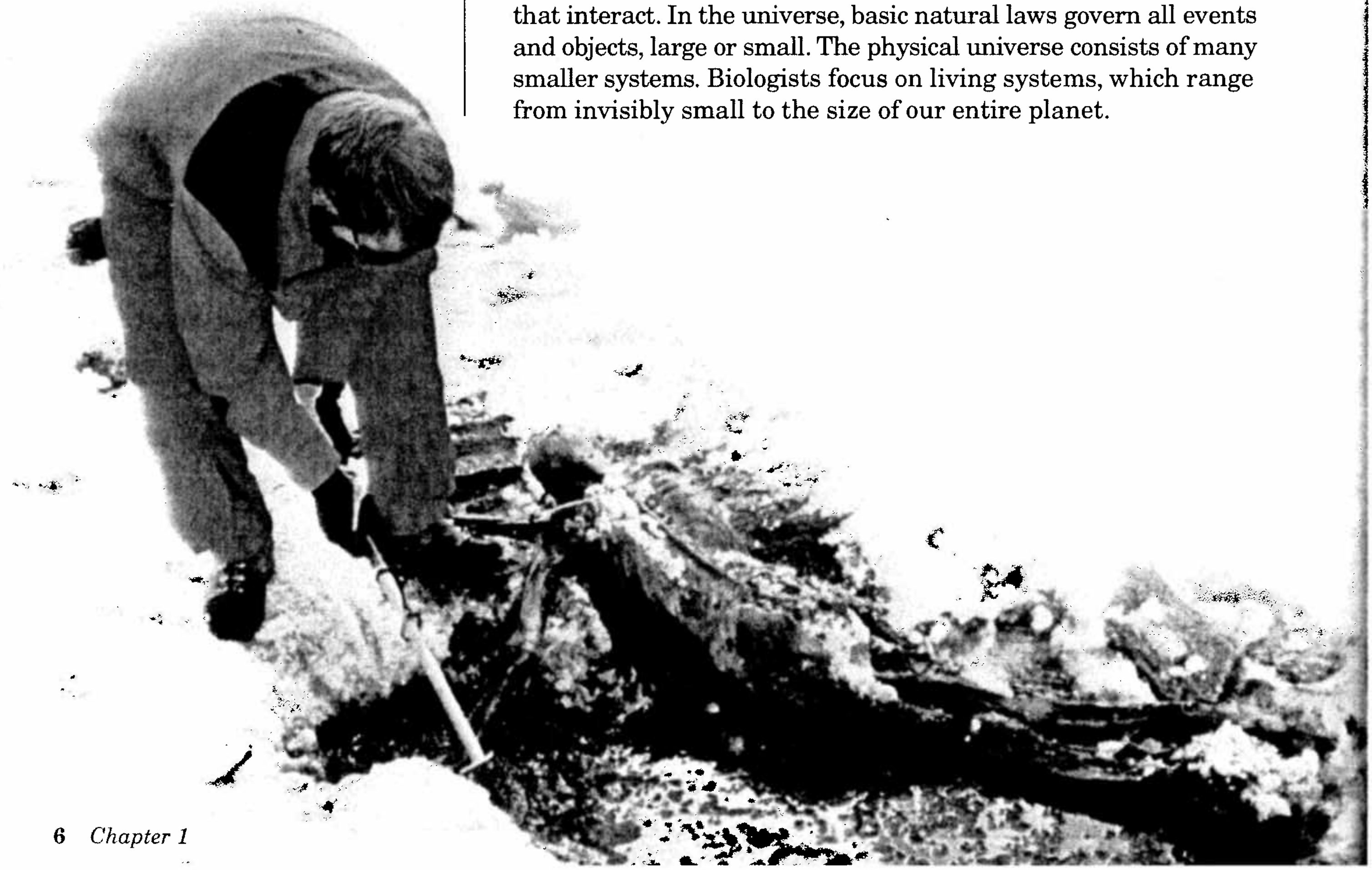
This book contains lots of facts, but don't think biological science is a set of truths that never change. Instead, science is a way of knowing. This means that rather than unchanging knowledge, science is an ongoing *process*—a process that involves asking questions, observing, making inferences, and 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?*

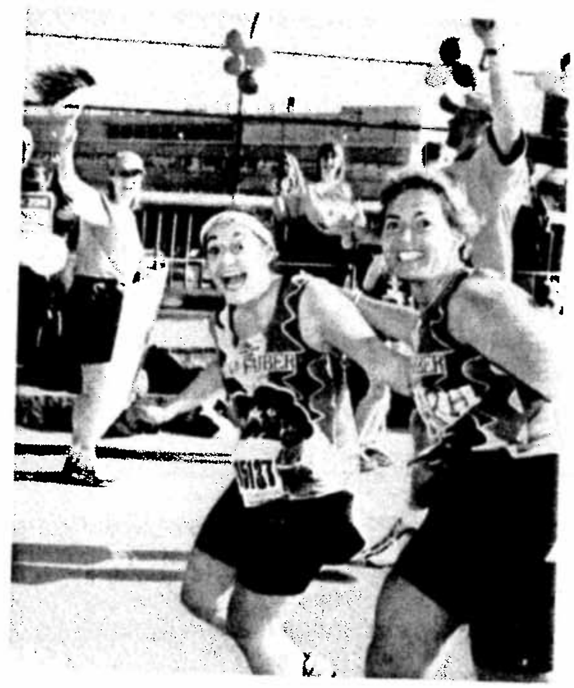


Science and Human Values

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.

1–2 How Scientists Work

IE 7.a. Communicate the logical connections among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence. BIIE 1.e. Distinguish between variable and controlled parameters in a test. BIIE 1.f. Distinguish between hypothesis and theory as scientific terms. BIIE 1.i. Recognize the issues of statistical variability and the need for controlled tests. **BIIE 1.n. Know that when an observation does not agree with an accepted scientific theory, the observation is sometimes mistaken or fraudulent (e.g. the Piltdown Man fossil or unidentified flying objects) and that the theory is sometimes wrong (e.g. the Ptolemaic model of the movement of the Sun, Moon, and planets).**

Guide for Reading

Key Concepts
- How do scientists test hypotheses?
- How does a scientific theory develop?

Vocabulary
spontaneous generation
controlled experiment
manipulated variable
responding variable
theory

Reading Strategy: Outlining As you read, make an outline of the main steps in a controlled experiment.

Have you ever noticed what happens to food that is left in an open trash can for a few days in summer? Creatures that look like worms appear on the discarded food. These creatures are called maggots. For thousands of years people have been observing maggots on food that is not protected. The maggots seem to suddenly appear out of nowhere. Where do they come from?

Designing an Experiment

People's ideas about where some living things come from have changed over the centuries. Exploring this change can help show how science works. Remember that what might seem obvious today was not so obvious thousands of years ago.

About 2300 years ago, the Greek philosopher Aristotle made extensive observations of the natural world. He tried to explain his observations through reasoning. During and after his lifetime, people thought that living things followed a set of natural rules that were different from those for nonliving things. They also thought that special "vital" forces brought some living things into being from nonliving material. These ideas, exemplified by the directions in **Figure 1–7**, persisted for many centuries. About 400 years ago, some people began to challenge these established ideas. They also began to use experiments to answer their questions about life.

Asking a Question For many years, observations seemed to indicate that some living things could just suddenly appear: Maggots showed up on meat; mice were found on grain; and beetles turned up on cow dung. People wondered how these events happened. They were, in their own everyday way, identifying a problem to be solved by asking a question: How do new living things, or organisms, come into being?

Forming a Hypothesis For centuries, people accepted the prevailing explanation for the sudden appearance of some organisms, that some life somehow "arose" from nonliving matter. The maggots arose from the meat, the mice from the grain, and the beetles from the dung. Scholars of the day even gave a name to the idea that life could arise from nonliving matter—**spontaneous generation.** In today's terms, the idea of spontaneous generation can be considered a hypothesis.

In 1668, Francesco Redi, an Italian physician, proposed a different hypothesis for the appearance of maggots. Redi had observed that these organisms appeared on meat a few days after flies were present. He considered it likely that the flies laid eggs too small for people to see. Thus, Redi was proposing a new hypothesis—flies produce maggots. Redi's next step was to test his hypothesis.

▼ **Figure 1–7** About 2000 years ago, a Roman poet wrote these directions for producing bees. **Inferring** *Why do you think reasonable individuals once accepted the ideas behind this recipe?*

Recipe for Bees

1. Kill a bull during the first thaw of winter.
2. Build a shed.
3. Place the dead bull on branches and herbs inside the shed.
4. Wait for summer. The decaying body of the bull will produce bees.

Setting Up a Controlled Experiment In science, testing a hypothesis often involves designing an experiment. The factors in an experiment that can change are called variables. Examples of variables include equipment used, type of material, amount of material, temperature, light, and time.

Suppose you want to know whether an increase in water, light, or fertilizer can speed up plant growth. If you change all three variables at once, you will not be able to tell which variable is responsible for the observed results. **Whenever possible, a hypothesis should be tested by an experiment in which only one variable is changed at a time. All other variables should be kept unchanged, or controlled.** This type of experiment is called a **controlled experiment.** The variable that is deliberately changed is called the **manipulated variable.** The variable that is observed and that changes in response to the manipulated variable is called the **responding variable.**

Based on his hypothesis, Redi made a prediction that keeping flies away from meat would prevent the appearance of maggots. To test this hypothesis, he planned the experiment shown in **Figure 1–8.** Notice that Redi controlled all variables except one—whether or not there was gauze over each jar. The gauze was important because it kept flies off the meat.

CHECKPOINT *What was the responding variable in Redi's experiment?*

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Figure 1–8 In a controlled experiment, only one variable is tested at a time. Redi designed an experiment to determine what caused the sudden appearance of maggots. In his experiment, the manipulated variable was the presence or absence of the gauze covering. The results of this experiment helped disprove the hypothesis of spontaneous generation.

Redi's Experiment on Spontaneous Generation

OBSERVATIONS: Flies land on meat that is left uncovered. Later, maggots appear on the meat.
HYPOTHESIS: Flies produce maggots.

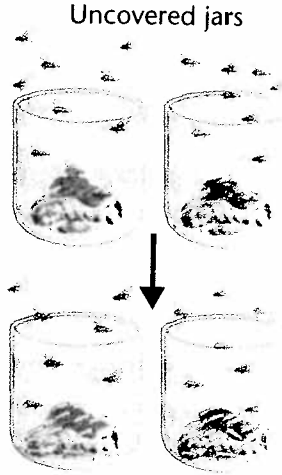
PROCEDURE

Controlled Variables: jars, type of meat, location, temperature, time

Manipulated Variable: gauze covering that keeps flies away from meat

Responding Variable: whether maggots appear

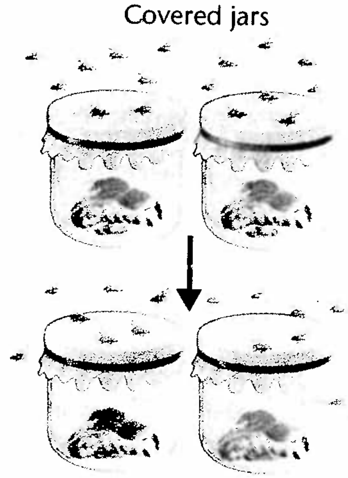
Uncovered jars



Maggots appear.

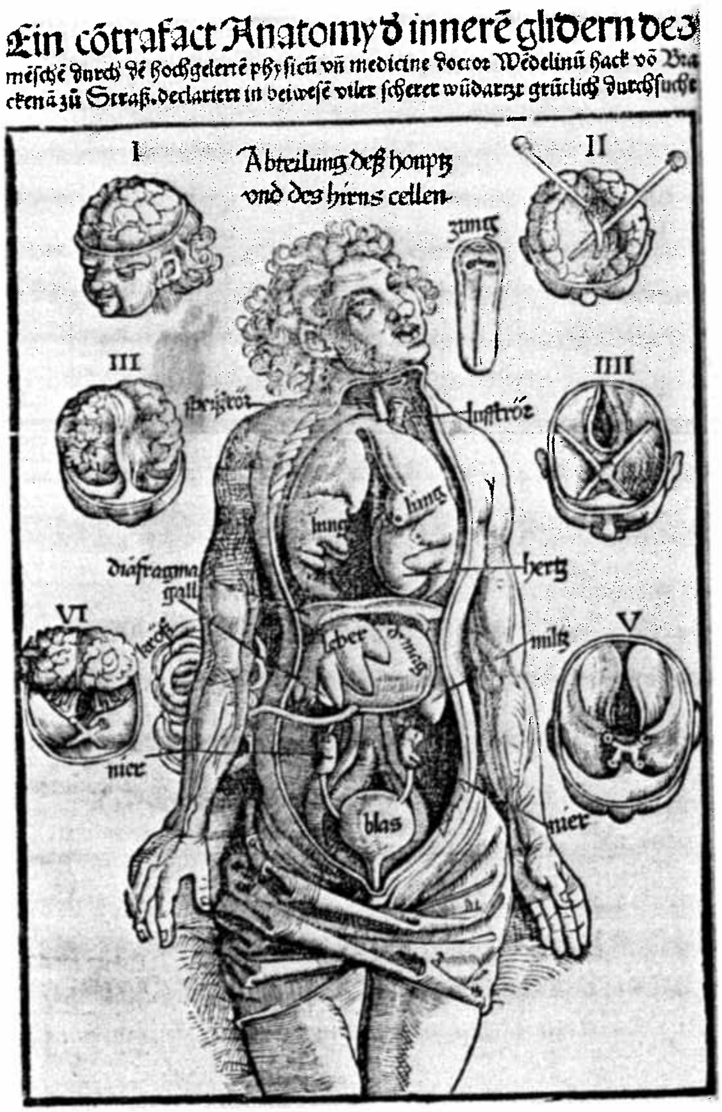
Several days pass.

Covered jars



No maggots appear.

CONCLUSION: Maggots form only when flies come in contact with meat. Spontaneous generation of maggots did not occur.



▲ **Figure 1–9** For centuries, the workings of the human body remained a mystery. Gradually, scientists observed the body's structures and recorded their work in drawings like this. This diagram dates back to fifteenth-century Austria. **Comparing and Contrasting** *How does this drawing compare with the modern illustrations in Unit 10?*

Recording and Analyzing Results
Scientists usually keep written records of their observations, or data. In the past, data were usually recorded by hand, often in notebooks or personal journals. Sometimes, drawings such as **Figure 1–9** recorded certain kinds of observations more completely and accurately than a verbal description could. Today, researchers may record their work on computers. Online storage often makes it easier for researchers to review the data at any time and, if necessary, offer a new explanation for the data. Scientists know that Redi recorded his data because copies of his work were available to later generations of scientists. His investigation showed that maggots appeared on the meat in the control jars. No maggots appeared in the jars covered with gauze.

Drawing a Conclusion Scientists use the data from an experiment to evaluate the hypothesis and draw a valid conclusion. That is, they use the evidence to determine whether the hypothesis was supported or refuted. Redi's results supported his hypothesis. He therefore concluded that the maggots were indeed produced by flies.

As scientists look for explanations for specific observations, they assume that the patterns in nature are consistent. Thus, Redi's results could be viewed not only as an explanation about maggots and flies but also as a refutation of the hypothesis of spontaneous generation.

✓CHECKPOINT *What did Redi conclude?*

Repeating Investigations

A key assumption in science is that experimental results can be reproduced because nature behaves in a consistent manner. When one particular variable is manipulated in a given set of variables, the result should always be the same. In keeping with this assumption, scientists expect to test one another's investigations. Thus, communicating a description of an experiment is an essential part of science. Today's researchers often publish a report of their work in a scientific journal. Other scientists review the experimental procedures to make sure that the design was without flaws. They often repeat experiments to be sure that the results match those already obtained. In Redi's day, scientific journals were not common, but he communicated his conclusion in a book that included a description of his investigation and its results.

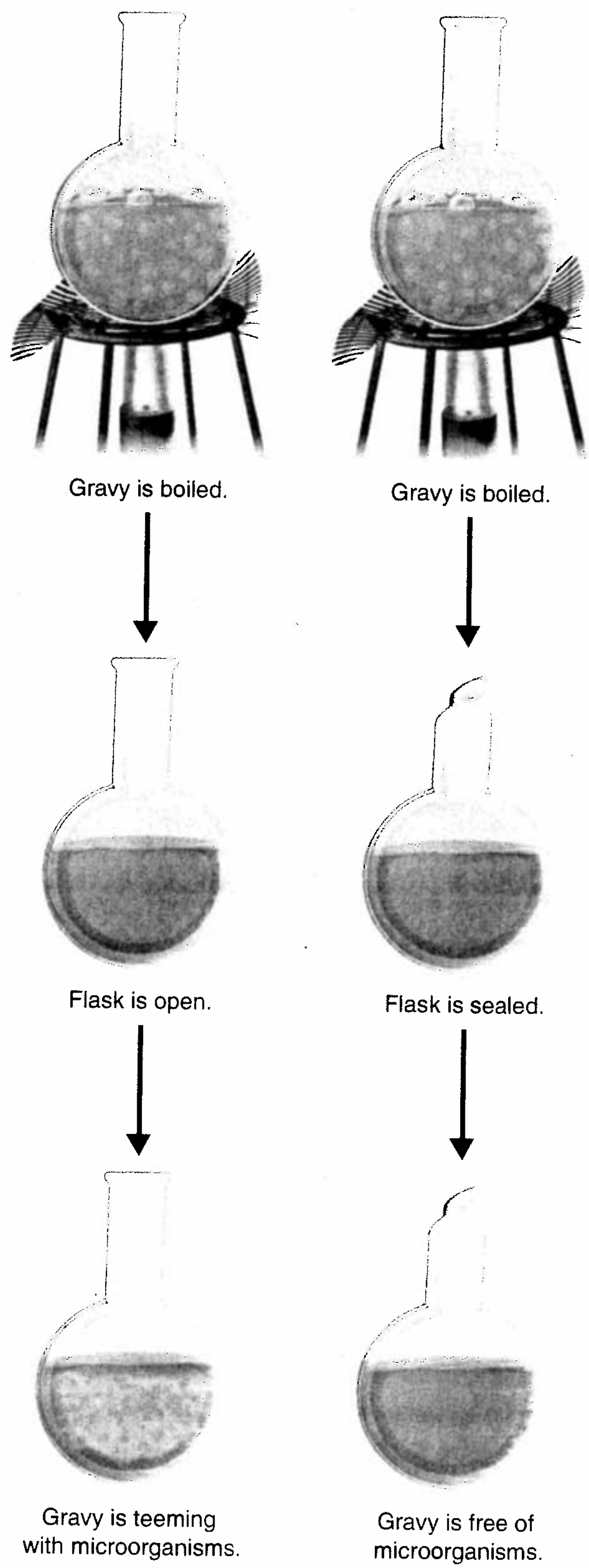
Needham's Test of Redi's Findings Some later tests of Redi's work were influenced by an unexpected discovery. About the time Redi was carrying out his experiment, Anton van Leeuwenhoek (LAY-vun-hook) of the Netherlands discovered a world of tiny moving objects in rainwater, pond water, and dust. Inferring that these objects were alive, he called them "animalcules," or tiny animals. He made drawings of his observations and shared them with other scientists. For the next 200 years or so, scientists could not agree on whether the animalcules were alive or how they came to exist.

In the mid-1700s, John Needham, an English scientist, used an experiment involving animalcules to attack Redi's work. Needham claimed that spontaneous generation could occur under the right conditions. To prove his claim, he sealed a bottle of gravy and heated it. He claimed that the heat had killed any living things that might be in the gravy. After several days, he examined the contents of the bottle and found it swarming with activity. "These little animals," he inferred, "can only have come from juice of the gravy."

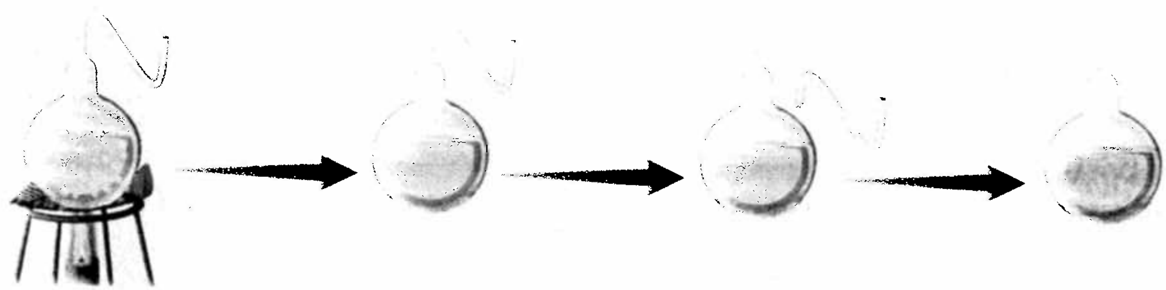
Spallanzani's Test of Redi's Findings An Italian scholar, Lazzaro Spallanzani, read about Redi's and Needham's work. Spallanzani thought that Needham had not heated his samples enough and decided to improve upon Needham's experiment. **Figure 1–10** shows that Spallanzani boiled two containers of gravy, assuming that the boiling would kill any tiny living things, or microorganisms, that were present. He sealed one jar immediately and left the other jar open. After a few days, the gravy in the open jar was teeming with microorganisms. The sealed jar remained free of microorganisms.

Spallanzani concluded that nonliving gravy did not produce living things. The microorganisms in the unsealed jar were offspring of microorganisms that had entered the jar through the air. This experiment and Redi's work supported the hypothesis that new organisms are produced only by existing organisms.

✓CHECKPOINT *How did Spallanzani's investigative procedures improve upon Needham's work?*



▶ **Figure 1–10** Spallanzani's experiment showed that microorganisms will not grow in boiled gravy that has been sealed but will grow in boiled gravy that is left open to the air. **Interpreting Graphics** *What variable was controlled in this experiment?*



▲ **Figure 1–11** Pasteur's experiment showed that boiled broth would remain free of microorganisms even if air was allowed in, as long as dust and other particles were kept out. **Inferring** *Why did microorganisms grow after Pasteur broke the neck of the flask?*

Pasteur's Test of Spontaneous Generation Well into the 1800s, some scientists continued to support the spontaneous generation hypothesis. Some of them argued that air was a necessary factor in the process of generating life because air contained the "life force" needed to produce new life. They pointed out that Spallanzani's experiment was not a fair test because air had been excluded from the sealed jar.

In 1864, French scientist, Louis Pasteur, found a way to finally disprove the hypothesis of spontaneous generation. He designed a flask that had a long curved neck, as shown in **Figure 1–11.** The flask remained open to the air, but microorganisms from the air did not make their way through the neck into the flask. Pasteur boiled the flask thoroughly to kill any microorganisms it might contain. Pasteur waited an entire year. In that time, no microorganisms could be found in the flask.

About a year after the experiment began, Pasteur broke the neck of the flask, allowing air dust and other particles to enter the broth. In just one day, the flask was clouded from the growth of microorganisms. Pasteur had clearly shown that microorganisms had entered the flask with particles from the air. His work convinced other scientists that the hypothesis of spontaneous generation was not correct. In other words, Pasteur showed that all living things come from other living things. This change in thinking represented a major shift in the way scientists viewed living things.

✓CHECKPOINT *What improvement did Pasteur make to Redi's experiment?*

The Impact of Pasteur's Work During his lifetime, Pasteur made many discoveries related to microorganisms. His research had an impact on society as well as on scientific thought. He saved the French wine industry, which was troubled by unexplained souring of wine, and the silk industry, which was endangered by a silkworm disease. Moreover, he began to uncover the very nature of infectious diseases, showing that they were the result of microorganisms entering the bodies of the victims. Pasteur is considered one of biology's most remarkable problem solvers.

◀ **Figure 1–12** In some animal field studies, scientists observe the animals from a distance. In other studies, researchers make measurements and attach tracking devices to learn more about the animal.

When Experiments Are Not Possible

It is not always possible to do an experiment to test a hypothesis. For example, to learn how animals in the wild interact with others in their group, researchers carry out field studies. It is necessary to observe the animals without disturbing them. Ethical considerations prevent certain experiments, such as determining the effect on people of a chemical suspected of causing cancer. In such cases, medical researchers may choose volunteers who have already been exposed to the chemical. For comparison, they would study a group of people who have not been exposed to the chemical.

When researchers design such alternative investigations, they try to maintain the rigorous thinking associated with a controlled experiment. They often study large groups of subjects so that small differences do not produce misleading results. They try to identify as many relevant variables as possible so that most variables are controlled. For example, in a study of a cancer-causing chemical, they might exclude volunteers who have other serious health problems. By exerting great care in planning these kinds of investigations, scientists can discover reliable patterns that add to scientific knowledge.

✔ *CHECKPOINT* ***Why are controlled experiments sometimes impossible?***

How a Theory Develops

As evidence from numerous investigations builds up, a particular hypothesis may become so well supported that scientists consider it a **theory.** That is what happened with the hypothesis that new organisms come from existing organisms. This idea is now considered one of the major ideas in science. It is called biogenesis, meaning "generating from life."

You may have heard the word *theory* used in everyday conversations as people discuss ideas. Someone might say, "Oh, that's just a theory," to criticize an idea that is not supported by evidence. **In science, the word *theory* applies to a well-tested explanation that unifies a broad range of observations.** A theory enables scientists to make accurate predictions about new situations.

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Figure 1–13 **A theory is a well-tested explanation that unifies a broad range of observations.** The theories of plate tectonics and evolution help explain why marsupials such as the koala (top) and kangaroo (below) can be found only in Australia and some nearby islands.

Sometimes, more than one theory is needed to explain a particular circumstance. For example, why are the marsupial mammals in **Figure 1–13** found only in Australia and some nearby islands? An answer lies with the theories of plate tectonics and evolution. Millions of years ago, when marsupials were evolving, Australia, Antarctica, and South America were joined as a single landmass. That landmass began to break apart, and Australia became a separate continent. Its marsupials were thus separated from other kinds of mammals, and they evolved as a unique group.

A useful theory may become the dominant view among the majority of scientists, but no theory is considered absolute truth. Scientists analyze and critique the strengths and weaknesses of theories. As new evidence is uncovered, a theory may be revised or replaced by a more useful explanation. Sometimes, scientists resist a new way of looking at nature, but over time new evidence determines which ideas survive and which are replaced. Thus, science is characterized by both continuity and change.

1–2 Section Assessment

1. **Key Concept** Why is Redi's experiment on spontaneous generation considered a controlled experiment?
2. **Key Concept** How does a scientific theory compare with a scientific hypothesis?
3. How do scientists today usually communicate their results and conclusions?
4. How did the design of Pasteur's flask help him successfully refute the hypothesis of spontaneous generation?
5. **Critical Thinking Making Judgments** Evaluate the impact of Pasteur's research on both scientific thought and society. What was the effect of Pasteur's investigations on scientists' ideas and people's lives?

Writing in Science

Critique a Hypothesis

Write a paragraph in which you analyze the spontaneous generation hypothesis. *Hint:* In preparation, ask yourself questions such as these: What observations did the hypothesis account for? Why did it seem logical at that time? What evidence was overlooked or ignored?

1–3 Studying Life

Deep in the skull of a British teenager, an invisible invader eats away at brain tissue until it resembles a sponge. In a Costa Rican rain forest, a chameleon crawls past a bright red tree frog whose blue legs look like a pair of blue jeans, while a toucan uses its rainbow-colored bill to slice into a wild avocado. These scenes all involve biology—the study of life. (The Greek word *bios* means "life," and *-logy* means "study of.") **Biology** is the science that employs the scientific method to study living things.

The scientific study of life has never been more exciting than it is today. Why? Think about headline news stories you may have heard about over the last couple of years—and even over the last couple of days. Hantavirus crops up in Southwestern states. Dengue fever threatens the Gulf Coast. Mice, sheep, and even dogs have been cloned. Genetically-engineered crop plants are designed to resist insect pests. The stories behind these and many other headlines come from the study of living things.

Guide for Reading

Key Concepts
- What are some characteristics of living things?
- How can life be studied at different levels?

Vocabulary
biology
cell
homeostasis
sexual reproduction
asexual reproduction
metabolism
stimulus

Reading Strategy: Summarizing As you read, make a list of the properties of living things. Write one sentence describing each property.

Characteristics of Living Things

Are the firefly and the fire in **Figure 1–14** alive? They are both giving off energy. Describing what makes something alive is not easy. No single characteristic is enough to describe a living thing. Also, some nonliving things share one or more traits with living things. Mechanical toys, automobiles, and clouds move around, for example, whereas mushrooms and trees live their lives in one spot. Other things, such as viruses, exist at the border between organisms and nonliving things.

Despite these difficulties, it is possible to describe what most living things have in common. **Living things share the following characteristics:**

- **Living things are made up of units called cells.**
- **Living things reproduce.**
- **Living things are based on a universal genetic code.**
- **Living things grow and develop.**
- **Living things obtain and use materials and energy.**
- **Living things respond to their environment.**
- **Living things maintain a stable internal environment.**
- **Taken as a group, living things change over time.**

Figure 1–14 A Colorado firefly beetle (top) has all of the characteristics of living things. Even though fire (bottom) uses materials and can grow as living things do, fire is not alive because it does not have other characteristics of living things.

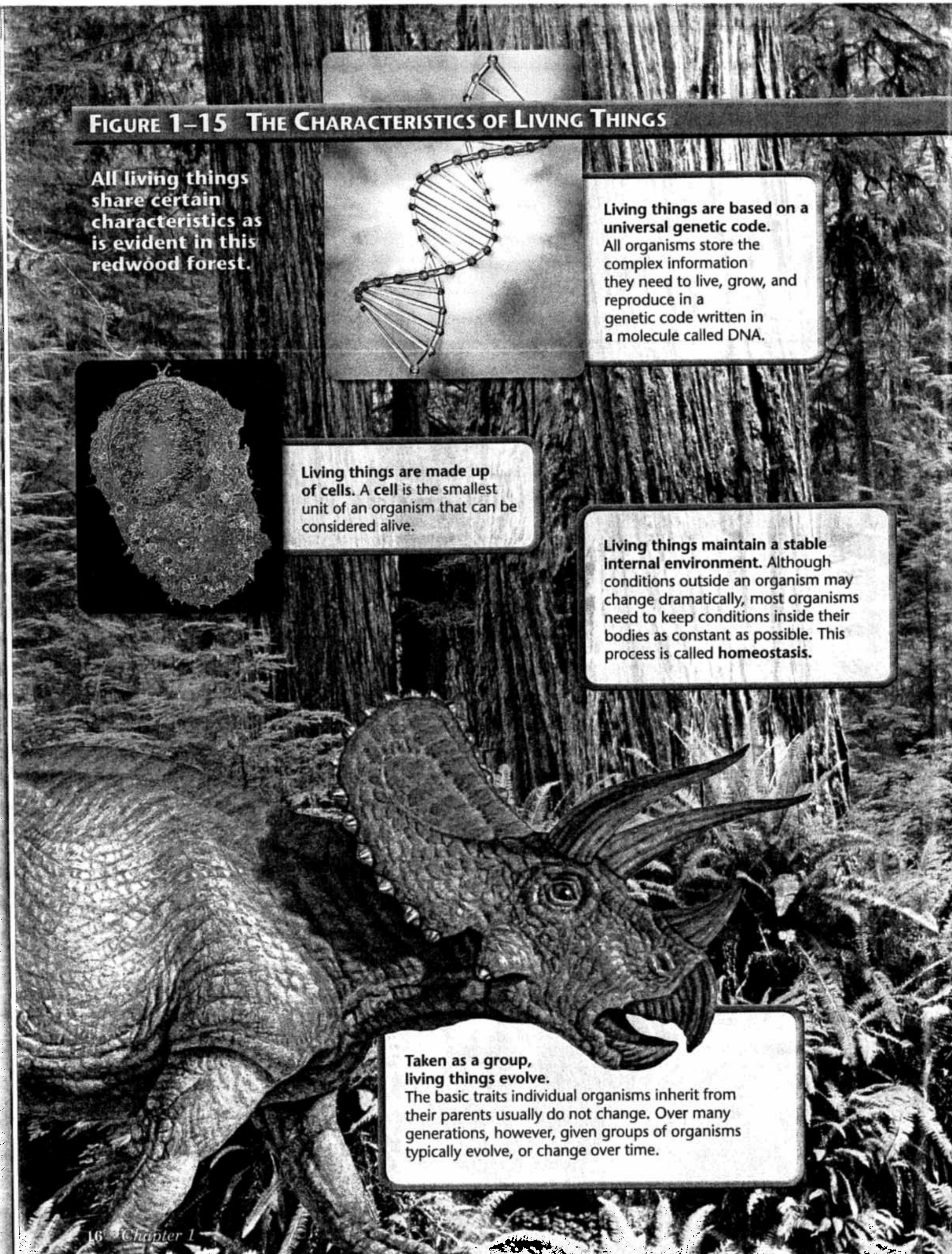
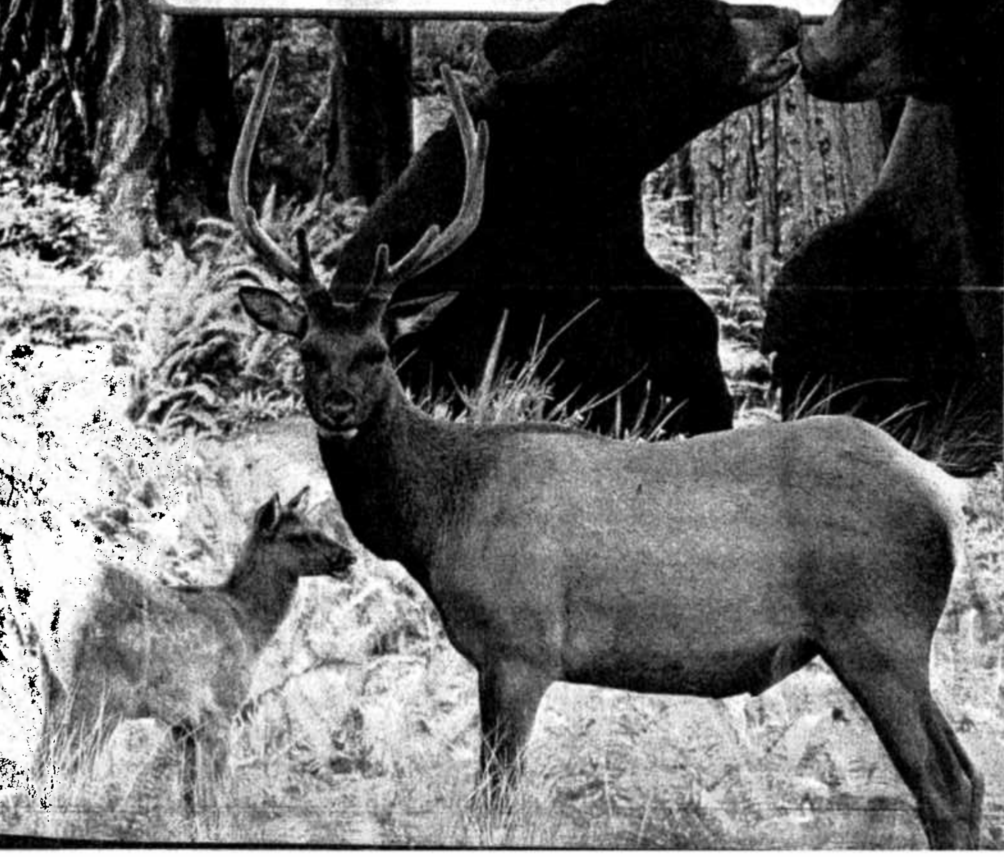


FIGURE 1–15 THE CHARACTERISTICS OF LIVING THINGS

Living things grow and develop. Every organism has a particular pattern of growth and development. During development, a single fertilized egg divides again and again. As these cells divide, they undergo differentiation, which means that the cells begin to look different from one another and to perform different functions.

Living things respond to their environment. Organisms detect and respond to **stimuli** from their environment. A stimulus is a signal to which an organism responds.

Living things reproduce. All organisms reproduce, which means that they produce new organisms. Most plants and animals, including this black bear, engage in sexual reproduction. In **sexual reproduction,** cells from two different parents unite to form the first cell of the new organism. Other organisms reproduce using **asexual reproduction,** in which a single parent produces offspring that are identical to itself.



Living things obtain and use material and energy. All organisms, including this Pacific salamander, must take in materials and energy to grow, develop, and reproduce. The combination of chemical reactions through which an organism builds up or breaks down materials is called **metabolism.**

Quick Lab

TIHE 7.c

What are the characteristics of living things?

Materials hand lens, unknown objects (dry), same objects soaked in water

Procedure

1. Examine the dry unknown object your teacher provides. Record your observations.
2. **Predicting** In step 3, you will observe the same kind of object after it has been soaked in water. Write a prediction describing what you expect to see.
3. Examine one of the objects that has been soaking in water for a period of time. Record your observations. Wash your hands when you have finished.

Analyze and Conclude

1. **Evaluating** Was the prediction you made in step 2 correct? Explain your answer.
2. **Inferring** Were the objects you observed in step 1 living or nonliving? Were the objects you observed in step 3 living or nonliving? Use the observations you made as supporting evidence for your answers.
3. **Formulating Hypotheses** Suggest one or more ways to explain the differences between the dry and wet objects.

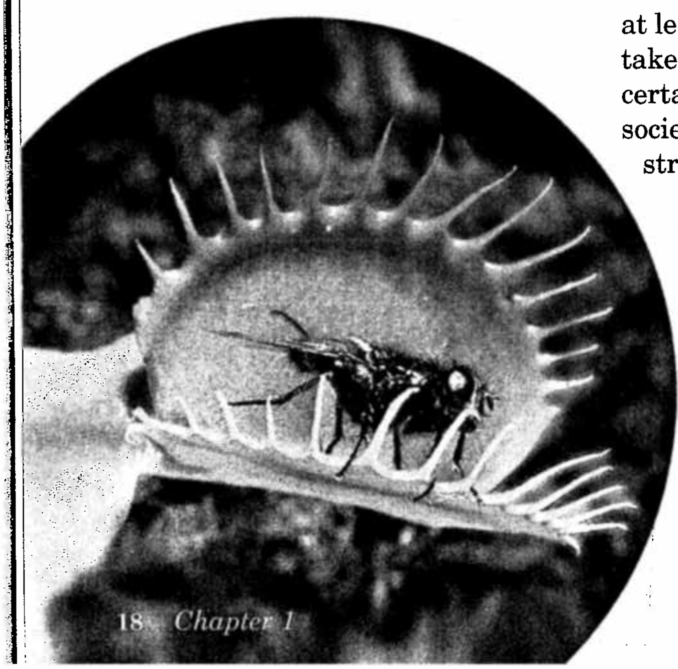
Big Ideas in Biology

The units of this book seem to cover different subjects. But we'll let you in on a secret: That's not how biology works. All biological sciences are tied together by themes and methods of study that cut across disciplines. Some of these "big ideas" may sound familiar because they overlap with the characteristics of life or the nature of science. You will see that these big ideas themselves overlap and interlock with one another. All of them crop up again and again in the chapters that follow.

Science as a Way of Knowing Science is not a list of "facts," but "a way of knowing." The job of science is to use observations, questions, and experiments to explain the natural world in terms of natural forces and events. Successful scientific research reveals rules and patterns that can explain and predict at least some events in nature. Science therefore enables us to take actions that affect events in the world around us. Making certain that scientific knowledge is used for the benefit of society requires an understanding of the nature of science—its strengths, its limitations, and its interactions with our culture.

Interdependence in Nature All forms of life on Earth are connected together into a biosphere, which literally means "living planet." Within the biosphere, organisms are linked to one another and to the land, water, and air around them. The relationships between organisms and their environment depend on two processes—the flow of energy and the cycling of matter. Human life and the economies of human societies also require matter and energy, so human life depends directly on the economy of nature.

▼ **Figure 1–16** Over time, as life has evolved into many different forms, organisms have entered into a variety of relationships. Interactions between predators and prey (including those between insect-eating plants and insects) and between hosts and parasites often play important roles in regulating the sizes of both plant and animal populations.



▲ **Figure 1–17** Certain types of sulphur-eating bacteria, which last shared common ancestors with humans more than 3.5 billion years ago, share surprising amounts of DNA with us. These unicellular organisms are poisoned by the oxygen we breathe, yet live in water that would boil us alive. They can literally "eat" sulphur but contain stretches of DNA that look remarkably like certain genes in our cells.

Matter and Energy Life's most basic requirements are matter that serves as nutrients to build body structures and energy to fuel the processes of life. Some organisms, such as plants, obtain energy from sunlight and take up the nutrients they need from air, water, and soil. Other organisms, including most animals, must eat plants or other animals to obtain both nutrients and energy. These requirements are the basis of the interdependence of all living things in the biosphere.

Cellular Basis of Life Organisms are composed of one or more cells, which are the smallest units that can be considered fully alive. Cells can grow, respond to their surroundings, and reproduce. Despite their small size, cells are complex and highly organized.

Many living things consist of only a single cell and are called unicellular organisms. The organisms you are most familiar with—for example, animals and plants—are multicellular. The cells in multicellular organisms are often remarkably diverse, existing in a variety of sizes and shapes. In some multicellular organisms, each type of cell is specialized to perform a different function. The human body, for example, contains at least 85 different cell types.

Information and Heredity Life's processes are directed by information carried in a genetic code that is common, with minor variations, to every organism on Earth. That information, carried in DNA, is copied and passed from parent to offspring. The information coded in DNA forms an unbroken chain that stretches back roughly three and a half billion years. Yet, the DNA inside your cells right now can influence your risk of getting cancer, the amount of cholesterol in your blood, and the color of your children's hair.

Unity and Diversity of Life The remarkable thing about the living world is that all living things are fundamentally alike at the molecular level, even though life takes an almost unbelievable variety of forms. All organisms are composed of a common set of carbon-based molecules, all use proteins to build their structures and carry out their functions, and all store information in a common genetic code. One great contribution of evolutionary theory is that it explains both this unity of life and its diversity.

Evolution In biology, evolution, or changes in living things through time, explains the inherited similarities as well as the diversity of life. Evolution is the unifying theme of biology. Evolutionary theory tells us that all forms of life on Earth are related because we all trace our ancestry back to a common origin more than 3.5 billion years ago. Evidence of this shared history is found in all aspects of living and fossil organisms, from physical features to structures of proteins to sequences of biological information found in DNA and RNA.

▲ Figure 1–18 Despite the cold temperatures of this robin's environment, its body temperature remains fairly constant, partly because its feathers provide a layer of insulation and partly because of the body heat it produces.

Structure and Function The structures of wings enable birds and insects to fly. The structures of legs enable horses to gallop and kangaroos to hop. When organisms need to do anything—from capturing food to digesting it and from reproducing to breathing—they use some kind of structure that has evolved in ways that make a particular function possible. Each major group of organisms has evolved its own particular body part, or "tool kit," that evolves into different forms as various species adapt to the challenges of life in a wide range of environments.

Homeostasis All living organisms expend energy to keep conditions inside their cells within certain limits. An organism's ability to maintain a tolerable internal environment in the face of changing external conditions is vital to its survival. Any breakdown of that stability may have serious or even fatal consequences. The robin shown in **Figure 1–18** is maintaining homeostasis by puffing up its feathers to stay warm.

Science, Technology, and Society Science seeks to provide useful information. But many discoveries raise ethical questions. Just because we can use scientific information in a particular way, should we do so? How should we use genetic engineering? Should cloning of humans be banned? Should cloning of any animals and plants be prohibited? How can we use our growing understanding of how human activity affects our world? Should we take action to stop global warming? What's the best way to protect our food and water supplies? In our democracy, these questions can only be answered by a public that truly understands what science is and how it works.

Branches of Biology

Living things come in an astonishing variety of shapes, sizes, and habits. Living systems also range in size from groups of molecules that make up structures inside cells to the collections of organisms that make up the biosphere. No single biologist could study all this diversity, so biology is divided into different fields. Some fields are based on the types of organisms being studied. Zoologists study animals. Botanists study plants. Other fields study life from a particular perspective. For example, paleontologists study ancient life.

Some fields focus on the study of living systems at different levels of organization, as shown in **Figure 1–19.** **Some of the levels at which life can be studied include molecules, cells, organisms, populations of a single kind of organism, communities of different organisms in an area, and the biosphere. At all these levels, smaller living systems are found within larger systems.** Molecular biologists and cell biologists study some of the smallest living systems. Population biologists and ecologists study some of the largest systems in nature. Studies at all these levels make important contributions to the quality of human life.

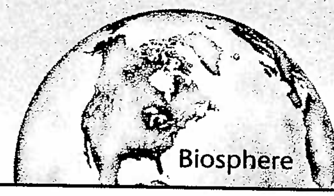
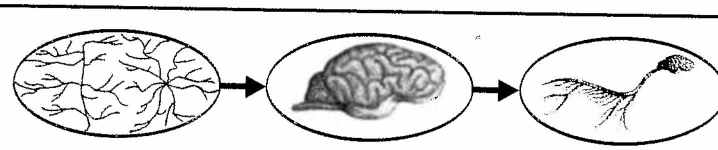
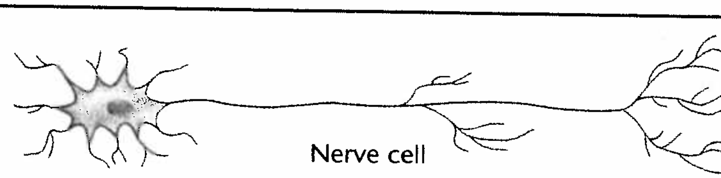
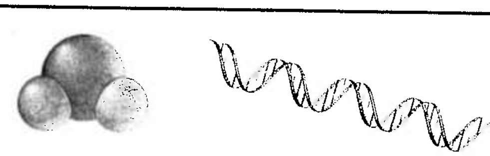
Levels of Organization		
Biosphere	The part of Earth that contains all ecosystems	
Ecosystem	Community and its nonliving surroundings	
Community	Populations that live together in a defined area	
Population	Group of organisms of one type that live in the same area	
Organism	Individual living thing	
Groups of Cells	Tissues, organs, and organ systems	
Cells	Smallest functional unit of life	
Molecules	Groups of atoms; smallest unit of most chemical compounds	

Figure 1–19 **Living things may be studied on many different levels.** The largest and most complex level is the biosphere. The smallest level is the molecules that make up living things.

▲ **Figure 1–20** Progress in biology has meant huge improvements in health not just for you and your family but, in some societies, for pets as well. **Predicting** *How do you expect advances in biology to change healthcare during your lifetime?*

Biology in Everyday Life

As you begin studying biology, you may be thinking of it as just another course, with a textbook to read plus labs, homework, and tests. It's also a *science* course, so you may worry that it will be too difficult. But you will see that more than any other area of study, biology touches your life every day. In fact, it's hard to think of anything you do that isn't affected by it. It helps you understand and appreciate every other form of life, from pets such as the dog in **Figure 1–20** to dinosaurs no longer present on Earth. It provides information about the food you need and the methods for sustaining the world's food supplies. It describes the conditions of good health and the behaviors and diseases that can harm you. It is used to diagnose and treat medical problems. It identifies environmental factors that might threaten you, such as disposal of wastes from human activities. More than any other science, biology helps you understand what affects the quality of your life.

Biologists do not make the decisions about most matters affecting human society or the natural world; citizens and governments do. In just a few years, you will be able to exercise the rights of a voting citizen, influencing public policy by the ballots you cast and the messages you send public officials. With others, you will make decisions based on many factors, including customs, values, ethical standards, and scientific knowledge. Biology can provide decision makers with useful information and analytical skills. It can help them envision the possible effects of their decisions. Biology can help people understand that humans are capable of predicting and trying to control their future and that of the planet.

1–3 Section Assessment

1. **Key Concept** Describe five characteristics of living things.
2. **Key Concept** What topics might biologists study at the community level of organization?
3. Compare sexual reproduction and asexual reproduction.
4. What biological process includes chemical reactions that break down materials?
5. What is homeostasis? Give an example of how it is maintained.
6. **Critical Thinking Applying Concepts** Suppose you feel hungry, so you reach for a peach you see in a fruit bowl. Explain how both external and internal stimuli are involved in your action.

Focus on the BIG Idea

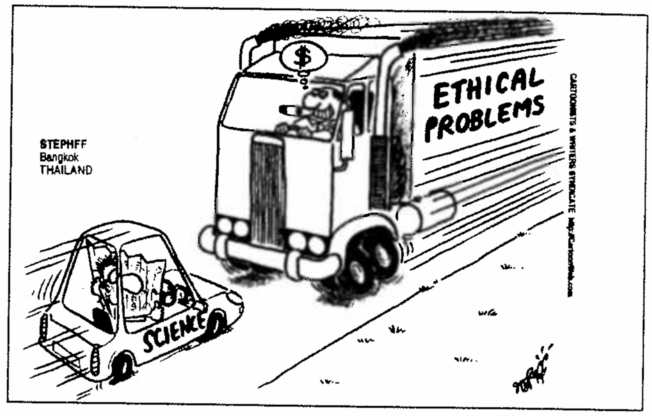
Science as a Way of Knowing List some observations that could be made to determine whether an object that is not moving is living or nonliving. Refer to Section 1–1 to help yourself recall what an observation is.

ISSUES in Biology

BIIE 1.m

When Scientists Have a Conflict of Interest

Scientists are expected to be completely honest about their investigations. Doctors are expected to place the welfare of their patients first. Yet, conflicts of interest can often threaten the credibility of a researcher. A conflict of interest exists when a person's work can be influenced by personal factors such as financial gain, fame, future work, or favoritism. For example, suppose scientists have received funds to test a potential anti-cancer drug. If experiments show that the drug is not very effective, the researchers may be tempted to conceal the results in order to avoid losing their funding.



The Viewpoints

Regulation Is Necessary

Some scientists argue that, because the public must be able to trust the work of science, some rules are essential for preserving scientific integrity. Every profession should regulate its members, and every science publication should have strict rules about avoiding conflicts of interest. In any published work, announcements of potential conflicts should be required. In some cases, scientists should avoid or be forbidden to do work that involves personal gain in addition to the usual payment for doing the work. Some form of government regulation may be needed.

Regulation Is Unnecessary

Other scientists insist that conflict-of-interest regulations are unnecessary for the majority of researchers, who are honest and objective about their work. It is unfair to assume that a researcher's discoveries would be different because of the nature of the financial support for the research. In fact, without the opportunity for scientists to get additional funding for successful work, many new drugs or new techniques would never have been developed. So it is important that scientists be allowed to investigate any topic, even those in which they have the opportunity for personal gain.

Research and Decide

1. **Analyzing the Viewpoints** To make an informed decision, learn more about this issue by consulting library or Internet sources. Then answer the following question: How might the views about a possible conflict of interest differ among a group of scientists, the company employing a scientist, and people seeking information from a scientist?
2. **Forming Your Opinion** How should this problem of possible conflicts of interest be decided? Include information or reasoning that answers people with the opposite view.
3. **Role-Playing** Suppose doctors who own a company developing a new medicine want their patients to help test the medicine. Let one person represent a doctor, a second person a patient, and a third person a medical reporter asking: Should the patients take part in the tests?

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PHSchool.com
For: Links from the authors
Visit: PHSchool.com
Web Code: cbe-1013

1–4 Tools and Procedures

BIIE 1.a. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.

Guide for Reading

Key Concepts
- What measurement system do most scientists use?
- How are light microscopes and electron microscopes similar? How are they different?

Vocabulary
metric system
microscope
compound light microscope
electron microscope
cell culture
cell fractionation

Reading Strategy: Using Graphic Organizers As you read, create a table that lists the equipment and techniques discussed in this section. List one example of what biologists can accomplish using each piece of equipment or procedure.

Go Online NSTA SCiLINKS
For: Links on microscopes
Visit: www.SciLinks.org
Web Code: cbn-1014

Imagine being one of the first people to see living things through a magnifying glass. How surprised you would have been to discover a whole new realm of life! Could there still be other types of life that remain undiscovered today because the right tools are not available?

Scientists select and use equipment, which sometimes includes technology such as computers, for their investigations. Electronic balances measure the mass of objects with great precision. Microscopes and telescopes make it possible to observe objects that are very small or very far away. With powerful computers, scientists can store and analyze vast collections of data. Biologists have even devised procedures that help them unlock the information stored in the DNA of different organisms.

A Common Measurement System

Because researchers need to replicate one another's experiments and most experiments involve measurements, scientists need a common system of measurement. **Most scientists use the metric system when collecting data and performing experiments.** The **metric system** is a decimal system of measurement whose units are based on certain physical standards and are scaled on multiples of 10. A revised version of the original metric system is called the International System of Units, or SI. The abbreviation SI comes from the French *Le Système International d'Unités.*

Because the metric system is based on multiples of 10, it is easy to use. Notice in **Figure 1–21** how the basic unit of length, the meter, can be multiplied or divided to measure objects and distances much larger or smaller than a meter. The same process can be used when measuring volume and mass. You can learn more about the metric system in Appendix C.

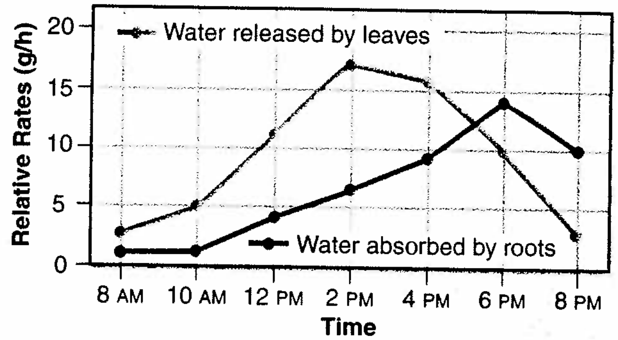
Common Metric Units

Length	Mass
1 meter (m) = 100 centimeters (cm) 1 meter = 1000 millimeters (mm) 1000 meters = 1 kilometer (km)	1 kilogram (kg) = 1000 grams (g) 1 gram = 1000 milligrams (mg) 1000 kilograms = 1 metric ton (t)
Volume	**Temperature**
1 liter (L) = 1000 milliliters (mL) 1 liter = 1000 cubic centimeters (cm^3)	0°C = freezing point of water 100°C = boiling point of water

Figure 1–21 **Scientists usually use the metric system in their work.** This system is easy to use because it is based on multiples of 10.

Water Released and Absorbed by Tree

Time	Absorbed by Roots (g/h)	Released by Leaves (g/h)
8 AM	1	2
10 AM	1	5
12 PM	4	12
2 PM	6	17
4 PM	9	16
6 PM	14	10
8 PM	10	3



▲ **Figure 1–22** One way to record data from an experiment is by using a data table. Then, the data may be plotted on a graph to make it easier to interpret. **Using Tables and Graphs** ***At what time of day is the rate of water released by leaves equal to the rate of water absorbed by roots?***

Analyzing Biological Data

When scientists collect data, they are often trying to find out whether certain factors changed or remained the same. Often, the simplest way to do that is to record the data in a table and then make a graph. Although you may be able to detect a pattern of change from a data table like the one in **Figure 1–22**, a graph of the data can make a pattern much easier to recognize and understand.

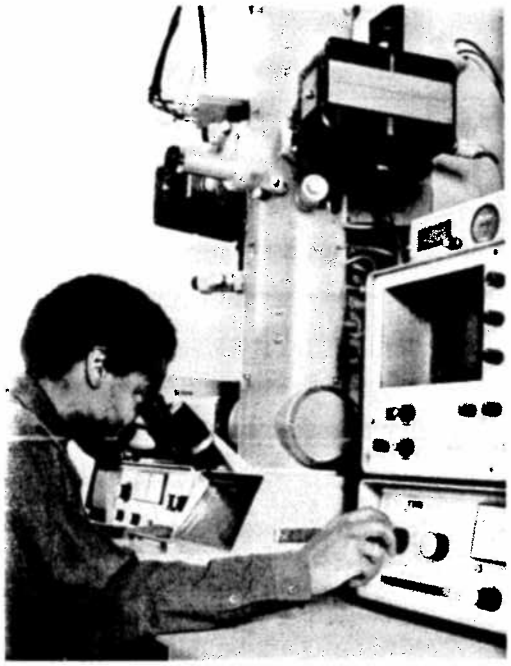
The amount of data produced by biologists today is so huge that no individual can look at more than a tiny fraction of it. To make sense of the data, biologists often turn to computers. For example, computers help determine the structure of molecules. They also allow biologists to search through a DNA molecule, find significant regions of the molecule, and discover how organisms are affected by those regions. At the opposite end of the scale, computers are essential to gathering data by satellite, analyzing the data, and presenting the results. Analyses of satellite data are used to make predictions about complex phenomena such as global climate changes.

✓*CHECKPOINT* *How can a graph help biologists analyze data?*

Microscopes

When people think of scientific equipment, one of the first tools that comes to mind is the microscope. **Microscopes,** such as the light microscope in **Figure 1–23**, are devices that produce magnified images of structures that are too small to see with the unaided eye. **Light microscopes produce magnified images by focusing visible light rays. Electron microscopes produce magnified images by focusing beams of electrons.** Since the first microscope was invented, microscope manufacturers have had to deal with two problems: What is the instrument's magnification—that is, how much larger can it make an object appear compared to the object's real size? And how sharp an image can the instrument produce?

▲ **Figure 1–23** **Light microscopes produce magnified images by focusing visible light rays.**



▲ **Figure 1–24** This scientist is using an electron microscope to make observations. **Electron microscopes produce images by focusing beams of electrons.**

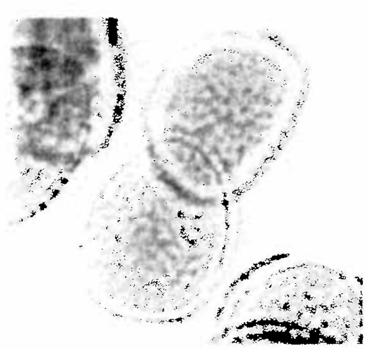
Light Microscopes The most commonly used microscope is the light microscope. Light microscopes can produce clear images of objects at a magnification of about 1000 times. **Compound light microscopes** allow light to pass through the specimen and use two lenses to form an image. Light microscopes make it possible to study dead organisms and their parts, and to observe some tiny organisms and cells while they are still alive. You can refer to Appendix D to learn how to use a compound light microscope.

Biologists have developed techniques and procedures to make light microscopes more useful. Chemical stains, also called dyes, can show specific structures in the cell. Fluorescent dyes have been combined with video cameras and computer processing to produce moving three-dimensional images of processes such as cell movement.

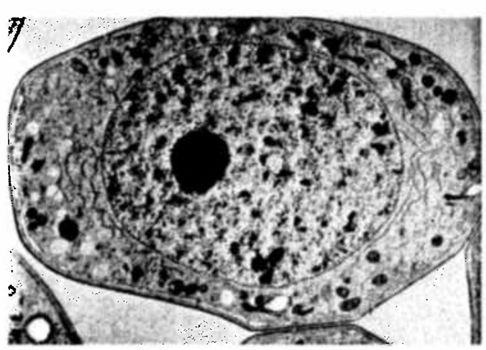
Electron Microscopes All microscopes are limited in what they reveal, and light microscopes cannot produce clear images of objects smaller than 0.2 micrometers, or about one-fiftieth the diameter of a typical cell. To study even smaller objects, scientists use electron microscopes. **Electron microscopes,** such as the one shown in **Figure 1–24,** use beams of electrons, rather than light, to produce images. The best electron microscopes can produce images almost 1000 times more detailed than light microscopes can.

Biologists use two main types of electron microscopes. Transmission electron microscopes (TEMs) shine a beam of electrons through a thin specimen. Scanning electron microscopes (SEMs) scan a narrow beam of electrons back and forth across the surface of a specimen. TEMs can reveal a wealth of detail inside the cell. SEMs produce realistic, and often dramatic, three-dimensional images of the surfaces of objects. Because electron microscopes require a vacuum to operate, samples for both TEM and SEM work must be preserved and dehydrated before they are placed inside the microscope. This means that living cells cannot be observed with electron microscopes, only with the light microscope. **Figure 1–25** shows images taken with a light microscope, a transmission electron microscope, and a scanning electron microscope.

▼ **Figure 1–25** Observe the images of pollen grains as seen with a light microscope (left), transmission electron microscope (center), and scanning electron microscope (right). **Interpreting Graphics** *In which image can you see the most detail on the pollen grain's surface?*



(magnification: about 400×)



(magnification: about 2200×)

(magnification: about 1000×)

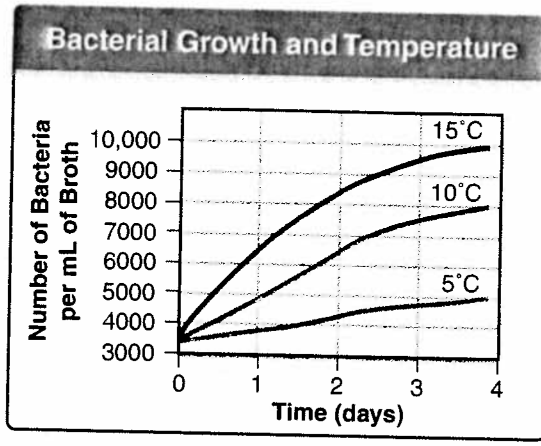
Analyzing Data

6IIE 7.c, 8IIE 9.c

Bacterial Reproduction

Bacteria are microorganisms that can reproduce by dividing into two. The graph shows the results of an experiment on the effect of temperature on bacterial reproduction. At the beginning, three populations of bacteria, all of the same type, were of equal size. Each population was kept at a different temperature for 4 days.

1. **Classifying** What variable did the researcher change during this experiment?
2. **Inferring** What do the shapes of the curves tell you about the changes in population size?
3. **Calculating** For the bacteria kept at 15°C, how did population size change during the experiment?
4. **Drawing Conclusions** What effect did the different temperatures have on the growth of the bacterial populations?



5. **Predicting** Suppose some bacteria used in this experiment were kept at a temperature of 100°C (the temperature of boiling water). Would you expect the population sizes to increase even faster than at 15°C? Explain your reasoning.

Laboratory Techniques

Biologists use a variety of techniques to study cells. Two common laboratory techniques are cell culturing and cell fractionation.

Cell Cultures To obtain enough material to study, biologists like the one in **Figure 1–26** sometimes place a single cell into a dish containing a nutrient solution. The cell is able to reproduce so that a group of cells, called a **cell culture,** develops from the single original cell. Cell cultures can be used to test cell responses under controlled conditions, to study interactions between cells, and to select specific cells for further study.

Cell Fractionation Suppose you want to study just one part of a cell. How could you separate that one part from the rest of the cell? Biologists often use a technique known as **cell fractionation** to separate the different cell parts. First, the cells are broken into pieces in a special blender. Then, the broken cell bits are added to a liquid and placed in a tube. The tube is inserted into a centrifuge, which is an instrument that can spin the tube. Spinning causes the cell parts to separate, with the most dense parts settling near the bottom of the tube. A biologist can then remove the specific part of the cell to be studied by selecting the appropriate layer.

✓CHECKPOINT *What is a cell culture?*

▼ **Figure 1–26** This researcher is transferring bacteria to a solid that contains nutrients, which will enable the bacteria to reproduce. **Comparing and Contrasting** ***How do the results of a cell culture differ from the products of cell fractionation?***

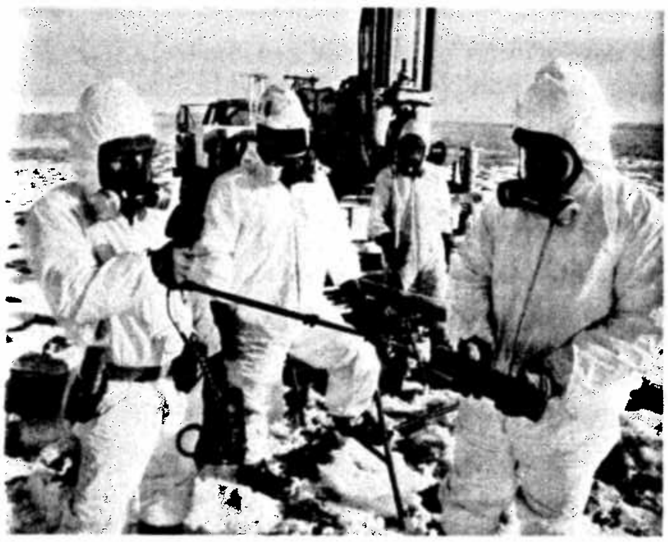
Working Safely in Biology

Scientists working in a laboratory or in the field like those in **Figure 1–27** are trained to use safe procedures when carrying out investigations. Laboratory work may involve flames or heating elements, electricity, chemicals, hot liquids, sharp instruments, and breakable glassware. Laboratory or field work may involve contact with living or dead organisms—not just the plants, animals, and other living things you can see but other organisms you cannot see without a microscope.

Whenever you work in your biology laboratory, it's important for you to follow safe practices as well. Before performing any activity in this course, study the safety rules in Appendix B. Before you start any activity, read all the steps, and make sure that you understand the entire procedure, including any safety precautions that must be followed.

The single most important rule for your safety is simple: Always follow your teacher's instructions and the textbook directions exactly. If you are in doubt about any part of an activity, always ask your teacher for an explanation. And, because you may be in contact with organisms you cannot see, it is essential that you wash your hands thoroughly after every scientific activity. Remember, you are responsible for your own safety and that of your teacher and classmates. If you are handling live animals, you are responsible for their safety as well.

▼ **Figure 1–27** These workers are cleaning up Rocky Flats, a Colorado site once used for producing nuclear weapons. **Applying Concepts** *Why must they wear heavy protective gear?*



1–4 Section Assessment

1. **Key Concept** Why do scientists use a common system of measurement?
2. **Key Concept** What is the difference in the way light microscopes and electron microscopes produce images?
3. What types of objects can be studied with a light microscope? What types can be studied with an electron microscope?
4. Describe the technique and purpose of cell fractionation.
5. **Critical Thinking Applying Concepts** It has been said that many great discoveries lie in wait for the tools needed to make them. What does this statement mean to you? If possible, include an example in your answer.

You & Your Community

Safety Poster
After reading the safety guidelines in Appendix B, prepare a poster on lab safety to display in your school in which you describe at least five safety rules. You might organize your poster or brochure in two columns labeled *Dangerous Way* and *Safe Way,* and contrast unsafe behaviors with their safe alternatives.

Exploration

Using a Compound Microscope

In this investigation, you will use a compound microscope to determine the positions and sizes of objects. Before you begin, read the safety rules described in Appendix B. Then, read Appendix D to learn how to use a microscope.

Problem

What kinds of information can a compound microscope provide?

Materials

- compound microscope
- microscope slide
- newspaper or other small-print text
- scissors
- dropper pipette
- coverslips
- prepared slide of crossed fibers
- transparent 15-cm plastic ruler
- prepared slide of root or stem
- prepared slide of bacteria

Skills

Observing, Measuring, Calculating

Procedure

1. Use scissors to cut out a square of printed text approximately 1 cm wide. Place the paper square on a microscope slide. **CAUTION:** *Be careful when handling sharp instruments.*
2. Use a dropper pipette to place a drop of water on the paper square. Add a coverslip. Place the slide on the stage of a compound microscope. Use the stage clips to hold the slide in place.
3. Use the low-power objective to bring the letters on the paper square into focus. Slowly move the slide in different directions along the stage. Record how the image changes. **CAUTION:** *Handle the microscope carefully.*
4. Observe a prepared slide of crossed fibers through the low-power objective. Use the fine adjustment to focus up and down through the area where the fibers cross. Record the order of the fibers, from top to bottom.
5. Observe a transparent ruler through the low-power objective. Use the ruler to measure in millimeters the diameter of your field of view as precisely as you can. Record this distance and the magnification of the low-power objective.
6. Calculate and record the diameter of the field of view through the other objectives. For example, if a 4× objective has a field of 2 mm (2000 micrometers), then a 10× objective will have a field of $(4 \div 10) \times 2$ mm = 0.8 mm (800 micrometers).
7. Examine a prepared slide of a plant stem or root at low and high powers. The small round shapes you see are cells. Use the field diameters you calculated in step 6 to estimate and record the size of a typical plant cell. For example, if 4 cells fit across an 800-micrometer field, then each cell is 200 micrometers long.
8. Repeat step 7 with a prepared slide of bacteria.

Analyze and Conclude

1. **Applying Concepts** What are the advantages of using the high-power objective? What are the disadvantages?
2. **Inferring** Some plant diseases are caused by bacteria. Could a bacterium injure a plant by surrounding a plant cell and consuming it? By entering a plant cell? Explain your answer.
3. **Drawing Conclusions** In what ways did the microscope alter the image in step 3? How did moving the slide affect the image?
4. **Drawing Conclusions** In what order were the fibers arranged on the slide you observed in step 4?

Go Further

Measuring With your teacher's permission, use the microscope to observe one of your hairs and estimate its width.

Chapter 1 Study Guide

1-1 What Is Science?

Key Concept BIIE 1.f

- 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.

Vocabulary
science, p. 3 • observation, p. 4 • data, p. 4
inference, p. 4 • hypothesis, p. 5

1-2 How Scientists Work

Key Concepts 7IIE 7.c, 8IIE 9.c, BIIE 1.f, BIIE 1.i, BIIE 1.n

- Whenever possible, a hypothesis should be tested by an experiment in which only one variable is changed at a time. All other variables should be kept unchanged, or controlled.
- In science, the word *theory* applies to a well-tested explanation that unifies a broad range of observations.

Vocabulary
spontaneous generation, p. 8
controlled experiment, p. 9
manipulated variable, p. 9
responding variable, p. 9 • theory, p. 13

1-3 Studying Life

Key Concepts

- Living things share characteristics including cellular organization, reproduction, a universal genetic code, growth and development, use of materials and energy, response to their environment, maintaining an internal stability, and, as a group, change over time.
- Some of the levels at which life can be studied include molecules, cells, organisms, populations of a single kind of organism, communities of populations living in the same area, and the biosphere. At all these levels, smaller living systems are found within larger systems.

Vocabulary
biology, p. 15 • cell, p. 16
homeostasis, p. 16
sexual reproduction, p. 17
asexual reproduction, p. 17
metabolism, p. 17
stimulus, p. 17

1-4 Tools and Procedures BIIE 1.a

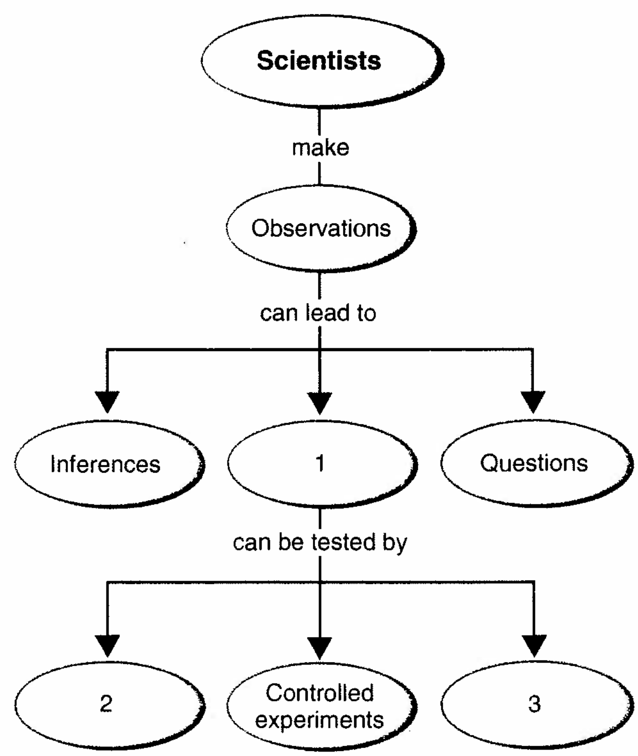
Key Concepts

- Most scientists use the metric system when collecting data and performing experiments.
- Light microscopes produce magnified images by focusing visible light rays. Electron microscopes produce magnified images by focusing beams of electrons.

Vocabulary
metric system, p. 24
microscope, p. 25
compound light microscope, p. 26
electron microscope, p. 26
cell culture, p. 27
cell fractionation, p. 27

Thinking Visually

Make a concept map that shows some ways scientists think and work. You can start with the partial concept map shown below or create your own. Recalling how scientists investigated spontaneous generation may help you identify important ideas to include.



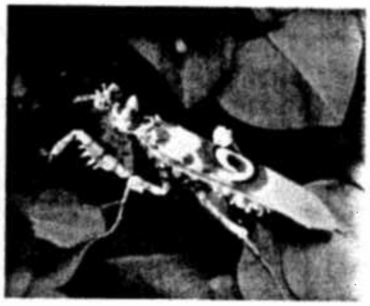
Chapter 1 Assessment

Reviewing Content

Interactive textbook with assessment at PHSchool.com

Choose the letter that best answers the question or completes the statement.

1. Which of the following statements about the image shown below is NOT an observation?
   a. The insect has three legs on the left side.
   b. The insect has a pattern on its back.
   c. The insect's pattern shows that it is poisonous.
   d. The insect is green, white, and black.



2. The statement "the worm is 2 cm long" is a(an)
   a. quantitative observation.
   b. qualitative observation.
   c. inference.
   d. hypothesis.
3. An inference is
   a. the same as an observation.
   b. a logical interpretation of an observation.
   c. a statement involving numbers.
   d. a way to avoid bias.
4. To be useful in science, a hypothesis must be
   a. measurable.
   b. observable.
   c. testable.
   d. correct.
5. The term *spontaneous generation* means that
   a. living things can arise from nonliving matter.
   b. living things arise from other living things.
   c. a maggot is part of the life cycle of a fly.
   d. living things evolve over time.
6. Which of the following statements about a controlled experiment is true?
   a. All the variables must be kept the same.
   b. Only one variable is tested at a time.
   c. Scientists always use controlled experiments.
   d. Controlled experiments cannot be performed on living things.
7. A scientific theory is
   a. another word for hypothesis.
   b. a well-tested explanation that unifies a broad range of observations.
   c. the same as the conclusion of an experiment.
   d. the first step in a controlled experiment.
8. The process in which cells from two different parents unite to produce the first cell of a new organism is called
   a. homeostasis.
   b. development.
   c. asexual reproduction.
   d. sexual reproduction.
9. The process by which organisms keep their internal conditions relatively stable is called
   a. metabolism.
   b. a genome.
   c. evolution.
   d. homeostasis.
10. An instrument that produces images by focusing light rays is called a(an)
    a. light microscope.
    b. transmission electron microscope.
    c. scanning electron microscope.
    d. electronic balance.

Understanding Concepts

11. What is the goal of science?
12. How does an observation about an object differ from an inference about that object?
13. How does a hypothesis help scientists understand the natural world?
14. Describe three possible ways in which a hypothesis may arise.
15. Why is it advantageous for scientists to test only one variable at a time during an experiment?
16. Distinguish between a variable and a control.
17. What steps are involved in making a valid conclusion?
18. What equipment did Redi use in his experiment? Why was the gauze important?
19. What question was Spallanzani's experiment designed to answer?
20. What must happen for a hypothesis to become a theory?
21. What is differentiation?
22. How can a graph of data be more informative than a table of the same data?
23. What is a cell culture? How can a cell culture be useful to biologists?

Critical Thinking

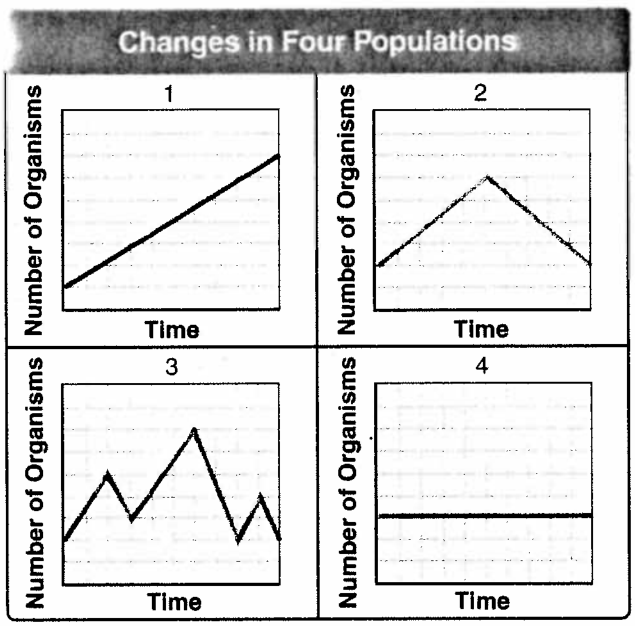
24. **Measuring** Use a ruler to find the precise length and width of this book in millimeters.

25. **Evaluating** Why is it misleading to describe science as a collection of facts?

26. **Comparing and Contrasting** What are some advantages and disadvantages of light microscopes and electron microscopes?

27. **Evaluating** Analyze and critique the theory of biogenesis. What are the strengths of the theory? Does it have any weaknesses?

28. **Analyzing Data** The following graphs show the sizes of four different populations over a period of time. Write a sentence summarizing what each graph shows.



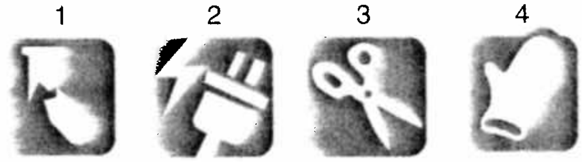
29. **Comparing and Contrasting** Graphs of completely different events can have the same appearance. Select one of the graphs from question 28 and explain how the shape of the graph could apply to a different set of events.

30. **Designing Experiments** Suggest an experiment that would show whether one type of food was better than another at helping an animal to grow faster.

31. **Controlling Variables** Explain why you cannot draw a conclusion about the effect of one variable in an investigation when the other key variables are not controlled.

32. **Interpreting Graphics** Each of the following safety symbols might appear in a laboratory activity in this book. Describe what each symbol stands for. (*Hint:* Refer to Appendix B.)

1 2 3 4



Focus on the BIG Idea

Science as a Way of Knowing Use the information in Section 1–2 to explain how having a scientific attitude might help you in everyday activities, for example, in trying to learn a new skill. Describe your ideas in your journal.

Writing in Science

Suppose you have a pet cat and want to determine which type of cat food it prefers. Write an explanation of how you might use scientific thinking, including making observations and inferences, to determine this. (*Hint:* To prepare to write, list the steps you might take, and then arrange them in order beginning with the first step.)

Performance-Based Assessment

Planning an Experiment Many people add fertilizers to house or garden plants. Make a hypothesis about whether you think these fertilizers really help plants grow. Next, design an experiment to test your hypothesis. Include in your plan what variable you will test and what variables you will control. Then, listen to other students' plans. Which plans would properly test their hypotheses?

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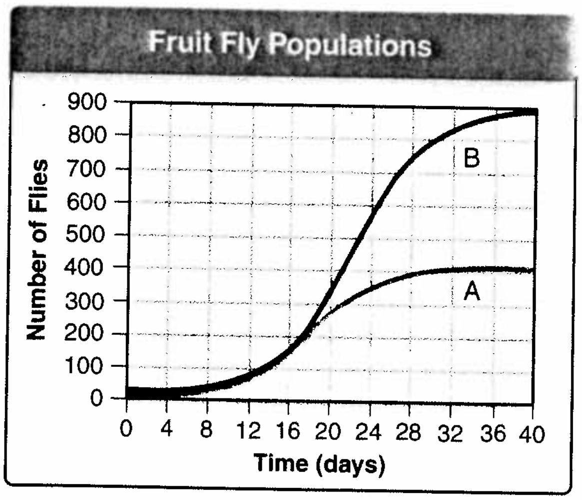
Test-Taking Tip Before taking a standardized test, it helps to become familiar with the format of the test, including the different question types. One helpful method is to complete practice tests, such as this one.

Questions 1–2

A researcher investigated two groups of fruit flies. Population A was kept in a 0.5-L container. Population B was kept in a 1-L container.



1. The manipulated variable was the 6IIE 7.c
   A number of flies.
   B time in days.
   C difference in time per group.
   D size of the containers.

2. Which of the following is a logical inference based on the contents of the graph? 7IIE 7.c
   A The flies in Group B were healthier than those in Group A.
   B A fly population with more available space will grow larger than a population with less space.
   C If Group B were observed for 40 more days, the size of the population would double.
   D In 40 more days, the sizes of both populations would decrease at the same rate.

Directions: Choose the letter that best answers the question or completes the statement.

3. Unlike sexual reproduction, asexual reproduction involves 7 2.a
   A spontaneous generation.
   B two cells.
   C two parents.
   D one parent.

4. One meter is equal to
   A 1000 millimeters. **C** 10 kilometers.
   B 1 millimeter. **D** 1 milliliter.

Questions 5–6

Once a month, a pet owner recorded the mass of her puppy in a table. When the puppy was 3 months old, she started to feed it a "special puppy food" she saw advertised on TV.

Change in a Puppy's Mass Over Time

Age (months)	Mass at Start of Month (kg)	Change in Mass per Month (kg)
2	5	—
3	8	+3
4	13	+5

5. According to the table, which statement is true?
   A The puppy's mass increased at the same rate for each month shown.
   B The puppy's increase in mass during month 4 was greater than 4 kg.
   C The puppy added more mass during month 2 than during month 3.
   D The puppy added more mass during month 3 than during month 2.

6. All of the following statements about the pet owner's study are true EXCEPT
   A The owner made quantitative observations.
   B The owner used the metric system.
   C The owner recorded data.
   D The owner conducted a controlled experiment.