Chapter 1 • Biology and You

Opening Activity

Everyday Biology  Write the following statement on the board: Biology is the study of life. Under this, write the following list: Taking care of your pet; Recycling your junk mail; Watering your lawn; Eating breakfast; Taking medicine; Visiting a zoo. Ask the students: How do all of these activities involve biology? (Answers may vary. Encourage students to recognize the many ways in which biology applies to their everyday activities.)

Reading Activity

Looking Ahead

Section 1
Themes of Biology
Characteristics of Living Organisms
Unifying Themes of Biology

Section 2
Biology in Your World
Solving Real-World Problems
Fighting Disease

Section 3
Scientific Processes
Observation: The Basis of Scientific Research
Stages of Scientific Investigations
Scientific Explanations

Reading Activity

Before you read this chapter, write the word biology on your paper. Refer to a dictionary, and write out the definition of the prefix bio– and the suffix –logy. Think of names of other branches of life science that include the suffix –logy, and write them down. Use the Reading and Study Skills appendix at the back of this book to define the prefixes in the words you thought of.

Just as this orphaned rabbit needs food and water to live and grow, it also depends on oxygen from plants to survive. Our knowledge of biology helps us understand how all life on Earth is interconnected.

Chapter Resource File

- Vocabulary Worksheets
- Concept Mapping

www.scilinks.org
National Science Teachers Association scilinks Internet resources are located throughout this chapter.

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Overview

Before beginning this section, review with your students the objectives listed in the Student Edition. This section describes the seven properties shared by all living organisms at some stage of their life cycles. The first five properties are major themes in biology, along with evolution and interdependence.

Bellringer

Ask students to list all the characteristics that they have in common with a beetle, then have students share some of their answers. (Answers will vary, but could include eating, growing, having specific body parts, being able to move and respond to the environment, and being able to produce offspring.)

Motivate

Discussion/Question

Without using their textbooks, have students list the characteristics of life. Next, have the students determine if any nonliving object might have any of these characteristics. If yes, have the students give a specific example for each (crystals grow, fire requires “food” and gives off heat, viruses reproduce, etc.) and discuss each one. Emphasize that living organisms may not have all seven characteristics at one time (such as the ability to reproduce), but that organisms have these characteristics at some point in their life.

Objectives

- Relate the seven properties of life to a living organism.
- Describe seven themes that can help you organize what you learn about biology.
- Identify the tiny structures that make up all living organisms.
- Differentiate between reproduction and heredity and between metabolism and homeostasis.

Key Terms

- biology
- cell
- reproduction
- metabolism
- homeostasis
- gene
- heredity
- mutation
- evolution
- species
- natural selection
- ecology

Characteristics of Living Organisms

You are surrounded by living things, which a scientist calls organisms. Many organisms, such as people, plants, and animals, are obvious. Other living things are so small that you cannot see them without a microscope. How do we know if something is alive? What does it mean to be alive?

While most people are capable of distinguishing between living and nonliving, actually defining life can be quite difficult. Perhaps you consider movement, sensitivity, development, and even death as characteristics of living organisms. While present in all living things, these properties are not enough to describe life.

Clouds, for example, move when stimulated by the wind and develop from moisture that is suspended in the atmosphere. Clouds grow and change shapes. Some might view the breakup of clouds as being similar to death. Disorder, however, is not the same as death. Clouds may break up and vanish, but they do not die.

Biology is the study of life. Biologists recognize that all living organisms, such as the cheetahs shown in Figure 1, share certain general properties that separate them from nonliving things. As summarized in Figure 1, every living organism is composed of one or more cells, is able to reproduce, and obtains and uses energy to run the processes of life. Living organisms also maintain a constant internal environment and pass on traits to offspring. Responding and adjusting to the environment as well as growing and developing are other characteristics shared by all living organisms.

As you read further, you will have an opportunity to think more about the properties that help define life. Life is characterized by the presence of all of these properties at some stage in an organism’s life. Remember this fact as you attempt to determine what is living and what is not.

Properties of Life

- Cellular organization
- Reproduction
- Metabolism
- Homeostasis
- Heredity
- Responsiveness
- Growth and development

Figure 1

What does it mean to be alive? Life is characterized by the presence of all seven of these properties at some stage in an organism’s life.
Unifying Themes of Biology

In the study of biology, certain broad themes emerge that both unify living things and help explain biology as a science. The word science comes from Latin for “to know.” Science is a systematic process of inquiry. As you study the science of biology by reading this textbook, you will repeatedly encounter these themes.

Theme 1: Cellular Structure and Function
All living things are made of one or more cells. Cells are highly organized, tiny structures with thin coverings called membranes. A cell is the smallest unit capable of all life functions. The basic structure of cells is the same in all organisms, although some cells are more complex than others. Some organisms have only a single cell, while others are multicellular (composed of many cells). Your body contains more than 100 trillion cells. Figure 2 shows a single-celled organism called a paramecium.

Theme 2: Reproduction
All living things can reproduce. Reproduction is the process by which organisms make more of their own kind from one generation to the next. Some rapidly growing bacteria divide into offspring cells approximately every 15 minutes, and bristlecone pine trees that are 5,000 years old still produce seedlings. Because no organism lives forever, reproduction, as represented in Figure 2, is an essential part of living.

Theme 3: Metabolism
Living organisms carry out many different chemical reactions in order to obtain and use energy to run the processes of life. All living things use energy to grow, to move, and to process information. Without energy, life soon stops. Metabolism is the sum of all of the chemical reactions carried out in an organism.

Almost all the energy used by living organisms is originally captured from sunlight. Plants, algae, and some bacteria capture this solar energy and use it to make complex molecules in a process called photosynthesis. These molecules then serve as the source of energy, or food, for other organisms. For example, paramecia, such as the one shown in Figure 2, eat bacteria. Humans eat plants or animals that, in turn, have eaten plants. Energy flows from the sun to plants, from these plants to plant-eating organisms, and from plant-eating organisms to meat-eating organisms. The teens shown in Figure 4 are extracting energy from the food they eat.

did you know?

Metabolism on the Fly  A hummingbird’s metabolic rate is about 1,400 calories per kilogram. Compare that to the rate of a mourning dove—about 127 calories per kilogram. Hummingbirds use enormous amounts of energy in part because of their racing wings and hearts. Hummingbirds can move their wings up to 80 times per second, and their heart can beat up to 1,200 beats per minute. Because of their high metabolic rate, hummingbirds feed almost continuously throughout the day.

Integrating Physics and Chemistry

Discuss the differences between physical and chemical changes. During physical changes the form of a substance or its properties may change, but its chemical composition remains unchanged. During chemical changes elements recombine to form new chemical compounds with different properties. Have the students classify the following observations as physical or chemical changes: evolution of a gas, mixing oil and water by shaking, color change, temperature increase or decrease when two substances are mixed, crushing a large rock into small pieces, changing ice into water, bioluminescence of marine plankton. Ask them to explain why metabolic processes are chemical rather than physical changes.
Theme 1 Homeostasis

All living organisms must maintain a stable internal environment in order to function properly. Organisms respond to changes in their external environment, and their internal processes adjust accordingly. The maintenance of stable internal conditions in spite of changes in the external environment is called homeostasis. An organism unable to balance its internal conditions with its environmental conditions could become ill and die. Arctic seals, such as the one shown in Figure 5, are able to maintain a constant body temperature in spite of their cold environment because of their body shape and thick layer of body fat.

Theme 3 Heredity

All living things are able to pass on traits to their offspring through genes that are passed from parent to offspring each generation. A gene is the basic unit of heredity. Genes are coded in a molecule called deoxyribonucleic (dee AHKS ee rie boh nu klay ik) acid (DNA) and determine an organism’s traits. The passing of traits from parent to offspring is called heredity. Heredity is the reason children tend to resemble their parents, as shown in Figure 6.

Sometimes damage causes genes to change. A change in the DNA of a gene is called a mutation. Most mutations are harmful, but sometimes mutations can help an organism survive. For example, in humans a mutation for the blood protein hemoglobin, which carries oxygen to the body’s cells, has both a harmful effect and a positive effect. The harmful effect is that the mutated form of the gene results in sickle cell anemia. Sickle cell anemia is a disease in which the defective form of hemoglobin causes many red blood cells to bend into a sickled—that is, a hooked—shape that reduces the oxygen-carrying capability of the cell. The positive effect is that the mutation produces resistance to malaria, a deadly infectious disease.

Mutations that occur in sex cells (egg and sperm) are passed on to other generations. Mutations that occur in body cells are not passed on, but they can disrupt the control of cell reproduction and result in cancer.

Teach, continued

Teaching Tip Maintaining Homeostasis

Point out to students that many arctic animals are able to maintain a constant body temperature because they have a thick layer of fat under their skin that keeps much of their body heat from escaping. Ask students for ways in which humans maintain a constant body temperature.

(Answers may include sweating, shivering, wearing clothing, and being physically active. If students suggest having body fat, tell them that fat does not insulate humans as it does in many arctic animals.) To illustrate the maintenance of human body temperature, ask a student to volunteer to have his or her body temperature monitored before and immediately after vigorous exercise. Note that human body temperature fluctuates a bit around 37°C (98.7°F) based on the time of day and the amount of activity.

MISCONCEPTION ALERT

Maintaining Homeostasis

Students may believe that the human body temperature remains a constant 37°C under all environmental conditions. When immersed in water, however, the human body loses heat rapidly—up to 26 times faster than in air of the same temperature. The condition that is produced, called hypothermia, becomes serious when body temperature drops below 35°C, as metabolic functions begin to cease.

MEDICINE CONNECTION

Proper nutrition is important for maintaining a healthy internal environment. Invite a local clinical nutritionist or dietician to speak to the class about proper nutrition, dieting, and exercise for teenagers. For several days before the talk, have students prepare a list of the foods they have consumed and a list of questions for the nutritionist. Ask students to compare their lists with the information provided by the speaker.

Chapter 1 • Biology and You
Theme 6 Evolution

The great diversity of life on Earth is the result of a long history of change. Change in the inherited characteristics of species over generations is called evolution. A species is a group of genetically similar organisms that can produce fertile offspring. Individuals in a species are similar, but not identical. Those individuals with genetic traits that better enable them to meet nature's challenges tend to survive and reproduce in greater numbers, causing these favorable traits to become more common. Charles Darwin, the nineteenth-century British naturalist, used the term natural selection for the process in which organisms with favorable traits are more likely to survive and reproduce.

Darwin's theory of evolution by natural selection provides a consistent explanation for life's diversity. Most scientists believe that the many different species of animals, plants, and other organisms on Earth today are the result of a long process of evolution. Figure 7 shows an example of a plant that has flowers modified for attracting insects.

Theme 7 Interdependence

The organisms in a biological community live and interact with other organisms, as shown in Figure 8. A biological community is a group of interacting organisms. Ecology is the branch of biology that studies the interactions of organisms with one another and with the nonliving part of their environment. Organisms are dependent on one another and their environment—that is, they are interdependent. Interdependence within biological communities is the result of a long history of evolutionary adjustments. The complex web of interactions in a biological community depends on the proper functioning of all of its members, even those too small to be seen without a microscope.

Section 1 Review

1. Identify the seven properties that all living organisms share.
2. Relate three of the seven major themes of biology to the life of a harp seal.
3. Name the very small, organized structure that is bound by a membrane and that is the basic unit of structure and function in all organisms.
4. Define homeostasis and metabolism, and describe their differences.

Critical Thinking Recognizing Verifiable Facts If you find an object that looks like an organism, how might you determine if your discovery is indeed alive?

Standardized Test Prep The mutation that results in sickle cell anemia produces effects that are
A. only harmful.
B. only positive.
C. both harmful and positive.
D. unimportant.

Answers to Section Review

1. Cellular organization, reproduction, metabolism, homeostasis, heredity, responsiveness, growth and development
2. Answers might include homeostasis, cellular structure and function, or reproduction.
3. the cell
4. Homeostasis is the ability to maintain a stable internal environment in spite of changes in the external environment. Metabolism is the sum total of all the chemical reactions that are carried out in an organism.
5. Answers might include testing for several of the characteristics of living organisms, such as signs of growth, cellular organization, metabolism, or responses to stimuli.

Using the Figure

Have students look at the image of an owl capturing a rat in Figure 8. Tell students to write down as many of the seven themes in biology that are illustrated by this figure. Discuss their answers. (Interdependence—the owl depends on the rat for food; evolution—both the owl and rat have adaptations that have evolved over time; homeostasis—both the owl and rat have coverings to conserve heat; metabolism—the owl has captured the rat for food.) Point out that the other themes are present but not apparent. Visual

Close

Reteaching Have students play a timed game in which one student tries to get his or her team members to guess a particular theme of biology. The student can give clues but cannot use either the actual word or certain designated words. For example, if the theme is heredity, you might designate genetics, traits, and mutation as words that cannot be given as clues.

Quiz

1. A change in the DNA of a gene is called a _________.
2. The many different species of organisms on Earth today are the result of ________.
3. The maintenance of a stable internal environment is called ________.

Alternative Assessment Have students cut out magazine photos that depict one or more of the seven themes of biology. Students should glue or tape the photos onto a sheet of paper and then label each photo with the theme(s) that is (are) represented. Students should find enough photos to represent all seven themes.
Before beginning this section, review with your students the objectives listed in the Student Edition. In this section, students will learn how biologists are currently engaged in some of the most challenging and potentially controversial issues in the world today. These challenges include finding resources to sustain a growing population, fighting deadly diseases, using genetic engineering and cloning responsibly, controlling the spread of AIDS, and treating cancer, and limiting the use of bio-warfare.

**Bellringer**

Ask students to list five issues in the area of biology that they believe are important in the world today. Tell them that the responses on the board to determine which issues the class feels are most important. Assess what students know about each challenge and how scientists are working to solve it.

**Motivate**

**Discussion/Question**

Have students break into groups of four. Within the groups, have students discuss the possible results of human cloning. Students should consider both positive and negative outcomes. Have the class discuss each group’s conclusions. (Answers will vary widely. Encourage students to support their positions.)

**Co-op Learning**

In this section, students will learn how biologists are currently engaged in some of the most challenging and potentially controversial issues in the world today. These challenges include finding resources to sustain a growing population, fighting deadly diseases, using genetic engineering and cloning responsibly, controlling the spread of AIDS, treating cancer, and limiting the use of bio-warfare.

**Objectives**

- Evaluate the impact of scientific research on the environment.
- Evaluate the impact of scientific research on society with respect to increasing food supplies.
- Explain the primary task of the Human Genome Project.
- Describe the contributions of scientists in fighting AIDS and cancer.
- Define the term gene therapy.

**Key Terms**

- genome
- HIV
- cancer
- cystic fibrosis
- gene therapy

**Solving Real-World Problems**

You are unlikely to read a newspaper or magazine today without noticing issues that relate to biology. In this textbook, you will learn about many areas in which biologists are actively working to solve today's problems.

**Preserving Our Environment**

More than 6 billion people now live on Earth. The increasing human population has had a significant impact on other organisms with which we share this planet. For example, tropical rain forests are home to one-half of the world’s species of plants and animals, such as the bird shown in Figure 9. The rain forests are being destroyed at the rate of more than one acre every second. At this rate, tropical rain forests—and a million species—may be gone in 30 years. Who knows what potential medicines and foods we are discarding? Like burning a library without reading the books, extinction on this large scale is a tragedy. However, conservation biologists are now exploring ways to achieve a balance between people’s growing need for land and the need to preserve the environment.

One of the great achievements of today’s biology has been to show the practical benefits of taking better care of our environment. Consider, for example, the fast-food french fry. Because french fries are made from potatoes, a network of agriculture has been developed to produce potatoes in large quantities. The potatoes are dried, cut, sliced, and deep-fried, then salted and seasoned. The garbage resulting from this process include billions of pounds of waste. Mix it with grain to feed cattle. Leftover potato particles in the potato processing water are also used, serving as a source of methane gas for power plants. Finally, the processing water, rich in nutrients, is used to water and fertilize agricultural crops. The environmental concern that promotes these sensible changes is a major contribution of biology to a better future. Conservation and preservation are now everyday activities of government, industry, and individuals.

**Chapter Resource File**

- Directed Reading  
- Active Reading

**Transparencies**

- TR Bellringer
- TR A6 SI Base Units
- TR A7 Some SI Prefixes
- TR A8 SI Units

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Improving the Food Supply

One of the greatest impacts of modern biology on society in recent years has been the genetic engineering of crop plants. As illustrated in Figure 10, biologists have learned how to transfer genes from one kind of plant to another, which changes the hereditary information in its cells. Genetic engineering, shown in Figure 10, has made some crop plants resistant to herbicides (so that weeds can be killed without harming the food crop). Genetic engineering has also made some crop plants poisonous to insect pests, but not humans, and has produced new varieties of crop plants with improved nutritional balance and protein content.

For example, rice, one of the world’s most important food crops, lacks iron and vitamin A levels needed for a balanced diet. These deficiencies affect the billions of people worldwide for whom rice is a daily food. The addition of genes from other plants to rice has increased the nutritional value of rice, thus improving the diet of many of the world’s people. The long-term safety of genetically engineered food crops is still being studied. These crops may offer great promise, however, of improving the world’s food supplies.

Understanding the Human Genome

Another great achievement of today’s biology was completed in April of 2003. Government-funded and private research teams from several countries had been racing to complete the sequencing of the human genome, and on that day they announced joint success. The task had been formidable. A genome is the complete genetic material contained in an individual. The human genome contains an astonishing 3 billion individual units! At the height of the research, automated gene-sequencing machines were sequencing DNA fragments at a rate of 1,000 units per second, around the clock.

Biologists are now able to read every human gene, providing them with a detailed road map, as you see in Figure 11, of human genes. It will be many years before this information is fully analyzed, but it is already proving to be an invaluable tool in medical research.
Teaching Tip

Politicians and Biology

Ask students to suggest what role politicians play or might play in biological research. (Politicians must understand the biology of important diseases, such as AIDS, if they are to make informed decisions about providing care facilities, funding research, and protecting the rights of people with the disease.) Emphasize that most research is supported through grants given by government agencies such as the National Institutes of Health, the National Science Foundation, and the Department of Energy.

Activity

Bring several science magazines to class. Have students mark the pages that show photos of scientists. On the board, make a list of the environment in which the scientist is shown working; the type of research he or she is doing; and, if shown, the organism the scientist is working with. Describe the various work environments and areas of study; point out how biologists work with many different types of organisms.

Teaching Tip

A Biologist’s Life

Ask students to imagine life as a biologist. Ask them to picture themselves working as biologists. What area would they study? What type of environment would they like to work in? How would they help improve our way of life?

Trends in Genome Research

Now that the human genome has been mapped, scientists are hard at work identifying the genes along the DNA strands, as well as the proteins that are encoded by these genes. This research is extending to microbes as well. Eventually, such research may result in new medical treatments and ways of cleaning up the environment, producing energy, and protecting against bioterrorism.

Fighting Disease

Progress in biology directly affects our lives through medicine, in which scientific advances are curing disease and improving health every day. New technologies have enabled biologists to combat disease in ways scarcely imagined only a few years ago. Among the many diseases that you will study in this text, consider the following.

AIDS

For more than 20 years, biologists have been battling AIDS. AIDS is a fatal disease caused by HIV, a virus that attacks and destroys the human immune system. HIV, shown in Figure 12, is transmitted by contact with body fluids from an infected person. While biologists have been successful in developing a combination of drugs that slow the progression of AIDS, it has proven very difficult to make a vaccine capable of halting its spread. The problem is that HIV changes as it passes from person to person, altering itself too frequently for any single vaccine to protect many people. This problem soon may be solved. New vaccines now being tested target two or more parts of the virus at the same time. While one part may change, it is very unlikely that two parts will change at the same time in the very same virus particle. For the first time, there is hope of a successful vaccine to control the worldwide outbreak of AIDS.

Cancer

When U.S. President Richard Nixon recruited biologists to join a “War on Cancer” in 1972, we did not know very much about the causes of cancer, although many Americans were dying of it. In the 30 years since then, biologists have learned a lot. Cancer is a growth defect in cells, a breakdown of the mechanism that controls cell division.

We now know that many cancers can be largely avoided. To sharply reduce your risk of lung cancer, for example, don’t smoke. Many other cancers can be treated successfully when detected early. Colon cancer, for example, develops slowly from intestinal tissue growths called polyps. A simple medical examination enables the detection and removal of the polyps.

Great progress is being made in curing many cancers. More than 25 percent of breast cancers, for example, result from having too many copies of a cell protein that starts cell division. As many as 70 percent of colon and prostate cancers have extra copies of a similar protein. Anticancer drugs that stick to these extra cell proteins, gumming them up so they cannot promote excessive cell division, appear to offer great promise.

Emerging Diseases

The past few years have seen the emergence of new diseases not known in the past and the incidence in the United States of diseases from other parts of the world. West Nile virus is one such disease. West Nile virus was not found in the United States until 1999, when...
birds in the northeastern United States were found to have died from it. The West Nile virus is transmitted by mosquitoes and is known to infect humans as well as birds, horses, and possibly other animals. In humans, the illness that results from infection by the West Nile virus may cause only mild symptoms in some individuals. Other people who have contracted a severe form of the disease, however, have died.

Another disease that has emerged in Europe is commonly known as mad cow disease. Mad cow disease is a fatal disease of cattle caused by eating the body parts of infected animals. Although cattle are grazing animals, their food is sometimes supplemented with protein from parts of other cattle. Humans, too, can be infected by eating meat or other products of infected cattle. No cases of mad cow disease have been reported in the United States, but a similar disorder has been found to affect elk and deer herds throughout the United States.

Gene Therapy
Biologists have searched for many years for a way to introduce “healthy” genes into people suffering from hereditary disorders. The person shown in Figure 13 has cystic fibrosis, which is caused by an inherited defect in a gene. Cystic fibrosis is a fatal disorder in which a thick, sticky mucus clogs passages in many of the body’s organs.

Researchers believe that it is possible to use a virus to transfer a normal copy of the defective gene into the cells of cystic fibrosis patients. Early attempts failed because the virus used to transport the healthy gene posed health problems. New attempts using a different virus are more promising. The replacement of a defective gene with a normal version is called gene therapy. Other serious genetic disorders, such as muscular dystrophy and hemophilia, are also good candidates for gene therapy. Though still experimental, the future of gene therapy seems bright.

Section 2 Review
1. Describe the relationship between scientific research and the use of environmental resources.
2. Explain how genetic engineering can improve food supplies.
3. Describe one problem that scientists must overcome to develop a vaccine for HIV.
4. Explain how gene therapy might be used to treat cystic fibrosis.
5. Critical Thinking Evaluating Viewpoints
   Do you agree or disagree that a knowledge of biology is essential in the battle against diseases? Explain your answer.
6. Standardized Test Prep
   One goal of researchers who transplant beneficial plant genes into other plants is to
   A. accelerate extinction. C. halt the spread of AIDS.
   B. cure cancer. D. reduce pesticide use.

Answers to Section Review
1. An increasing population is putting more demands on environmental resources. Scientific research can suggest ways of preserving the environment while still obtaining needed resources.
2. Genetic engineering can be used to develop crops that are more tolerant to certain conditions, that are insect resistant, and that produce a higher crop yield.
3. The HIV changes as it passes from one host to another. Frequent changes, or mutations, in the HIV structure quickly make potential vaccines obsolete.
4. Cystic fibrosis is caused by a defective gene. Researchers are attempting to use a virus to insert a healthy form of the gene into the cells of patients with cystic fibrosis.
5. Students should agree. To discover treatments or cures for diseases, the researchers must understand the biology of the symptoms and the cause of each disease.
6. A. Incorrect. Extinction of plants is not a goal of researchers. B. Incorrect. Researchers are working to improve the world’s food supplies. C. Incorrect. See answer B. D. Correct. Genetic engineering can make crop plants poisonous to insect pests.
Before beginning this section, review with your students the objectives listed in the Student Edition. In this section, students will follow the events of an actual scientific investigation. The case study reveals the stages common to all scientific research: making observations, asking questions, forming hypotheses and predictions, confirming predictions, and drawing conclusions.

Bellringer

Ask students to imagine that all of the birds around their school are dying. How might they investigate the problem? Ask students to write a brief description of their investigation. Which stages of a scientific investigation are represented in their answers?

Motivate

Discussion/Question

Ask students to think of some current biological questions or problems. Then have them describe the steps they think might be involved in a scientific investigation of those questions or problems. Explain that the scientific process outlines a general method of investigating questions.

Solving Scientific Puzzles

In the summer of 1988, Bradford reflected on the silence that surrounded him. He had spent the summer looking for a species of small frog in the many lakes of Sequoia and Kings Canyon National Parks. The frog species had lived in the parks’ lakes for as long as anyone had kept records. In the last count of the frog’s populations, the frogs had been everywhere. Now, for some reason, they had disappeared from 98 percent of the lakes.

Observation is the act of noting or perceiving objects or events using the senses. As Bradford reported his observations to other biologists, he found that local populations of amphibians (frogs, toads, and salamanders) elsewhere were also disappearing. Amphibians have been around for 370 million years. The disappearance of amphibians from their natural homes sounded an alarm among biologists that something was altering the environment. Amphibians are particularly sensitive to their environment; their moist skin absorbs chemicals from water.

Between the years 1984 and 1988, John Harte, a professor at the University of California, Berkeley, was also studying amphibians. He was studying the tiger salamander, Ambystoma tigrinum, shown in Figure 14. Tiger salamanders live in ponds high on the western slopes of the Rocky Mountains of Colorado. Harte had seen their numbers fall by 65 percent as he and his students had collected and analyzed water samples from the ponds in the area over the years.

Harte wanted to discover the facts surrounding the disappearance of the salamanders. Like other scientists, Harte began a scientific investigation that combined knowledge, imagination, and intuition to get a sense of what might be true. Even though scientists might expect certain results, they do not form conclusions until they have enough evidence to support them.
Where Have All The Frogs Gone? The disappearance of frogs is not a local phenomenon or one that is limited to polluted areas. In the late 1980s, biologists around the world noted disappearing amphibians, even in pristine national parks and nature preserves. Today, a network of volunteers from 90 countries makes up a task force dedicated to investigating the loss of amphibians.

Teaching Tip
Identifying Factors Students should recognize that an observable phenomenon, such as the decline in a salamander population, might be the result of any one of many possible factors. A scientist could try to identify the factor(s) that is/are actually responsible. Have each student list as many factors as possible that could be responsible for the population’s decline. (Possibilities include pollution, UV radiation, and disease, as well as increased predation, climate changes, loss of habitat, and loss of prey.)

Activity
Have students locate Arizona, California, and the Rocky Mountains of Colorado on a map of the United States. Inform them that acidic compounds from Arizona smelters and the California smog may be responsible for the decline of the tiger salamander in the Colorado Rockies. Now have them locate Wheeling, West Virginia. Inform them that the pH of precipitation in Wheeling has been recorded at 1.5, which is highly acidic. Ask what might be the source of the acidity. (Acidic compounds probably originated from industries in the upper Midwest and coal mines in the more immediate areas.)

Answer
A 5K race is about 16,404 ft, which is equal to 5,468 yd, or 3.11 mi. Students should find the metric system easier to use because converting among metric units is much simpler than conversions in the English system.
- Point out to students that in clinical drug trials, the control group receives a placebo so that the subjects do not know whether or not they are receiving the drug that is being tested. In what is called a single blind study, only the subjects are unaware of whether they are taking the drug or the placebo. In a double-blind study both the experimenters and the subjects are unaware of which subjects are receiving the drug.

### MOMENT OF TRUTH

**Confirming Predictions**

Harte gathered data from many years of observations, including measurements of the acidity of the ponds before, during, and after snowmelt. Harte and his students had taken water samples at frequent intervals from several ponds. Data for part of one year, after snowmelt, are shown in Figure 16.

To describe how acidic a solution is, scientists use a number between 0 and 14 to represent pH, which is a relative measure of the hydrogen ion concentration within a solution. Solutions with a low pH (below 7) are acidic, solutions above 7 are basic, and solutions at pH 7 are neutral. Acid rain usually has a pH of between 2 and 6. A solution with a pH of 2 is 10,000 times more acidic than one with a pH of 6.

In the metric (SI) system of measurement, the units of measurement are based on powers of 10. Conversion between units is easily done and only changes the prefix of the unit. For example, a runner in a 5K race runs 5 kilometers, 5,000 meters, or 5,000,000 millimeters.

Calculating

Calculate the length of a 5K race using the English system of measurement in feet, yards, and miles.

**Real Life**

**Scientists use the metric system.**

In the metric (SI) system of measurement, the units of measurement are based on powers of 10. Conversion between units is easily done and only changes the prefix of the unit. For example, a runner in a 5K race runs 5 kilometers, 5,000 meters, or 5,000,000 millimeters.

**Calculating**

Calculate the length of a 5K race using the English system of measurement in feet, yards, and miles.

**Forming Hypotheses and Making Predictions**

A **hypothesis** (hih PAHTH uh sis) is an explanation that might be true—a statement that can be tested by additional observations or experimentation. In that respect, a hypothesis (plural form, hypotheses) is not just a guess—it is an educated guess based on what is already known. Harte formed two hypotheses that together he believed explained the disappearance of the amphibians:

1. Acids that were formed in the upper atmosphere by pollutants were falling onto the mountains in the winter snows.
2. Melting snow was making the ponds acidic and harming the salamander embryos.

If Harte’s hypotheses were correct, he could expect several possible outcomes. A **prediction** is the expected outcome of a test, assuming the hypothesis is correct. For his first hypothesis, Harte predicted he would find acid in the ponds after the snow melted. For his second hypothesis, he predicted that there would be enough acid in the ponds to harm salamander embryos. Using his predictions as a starting point, Harte set out to test his hypotheses.

**Confirming Predictions**

Harte gathered data from many years of observations, including measurements of the acidity of the ponds before, during, and after snowmelt. Harte and his students had taken water samples at frequent intervals from several ponds. Data for part of one year, after snowmelt, are shown in Figure 16.

To describe how acidic a solution is, scientists use a number between 0 and 14 to represent pH, which is a relative measure of the hydrogen ion concentration within a solution. Solutions with a low pH (below 7) are acidic, solutions above 7 are basic, and solutions at pH 7 are neutral. Acid rain usually has a pH of between 2 and 6. A solution with a pH of 2 is 10,000 times more acidic than one with a pH of 6.

In the metric (SI) system of measurement, the units of measurement are based on powers of 10. Conversion between units is easily done and only changes the prefix of the unit. For example, a runner in a 5K race runs 5 kilometers, 5,000 meters, or 5,000,000 millimeters.

Calculating

Calculate the length of a 5K race using the English system of measurement in feet, yards, and miles.

**Real Life**

**Scientists use the metric system.**

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Harte’s data indicated that the ponds became more acidic when the snow melted. After a few weeks, the pH rose and then leveled off. The data confirmed Harte’s first prediction and supported his first hypothesis—melting snow caused acid to be released into the ponds at snowmelt, as shown in Figure 16. After snowmelt, the acid was neutralized, probably by minerals that dissolved from the rocks in the ponds, and pond pH returned to normal for the rest of the summer.

To confirm his second hypothesis (melting snow was making the ponds acidic and harming the salamander embryos), Harte did an experiment—a planned procedure to test a hypothesis. Salamanders lay eggs in the ponds once a year; as soon as pond ice melts, Harte wanted to test whether exposure to the pH levels he had recorded at that time of year would harm the salamanders that hatched from the eggs.

Harte performed a controlled experiment. In a controlled experiment, an experimental group (a group that receives some type of experimental treatment) is compared with a control group. A control group is a group in an experiment that receives no experimental treatment. The control and experimental groups are designed to be identical except for one factor, or variable. The factor that is changed in an experiment is called the independent variable. In Harte’s experiment, the independent variable was the acid (pH) level. The variable that is measured in an experiment is called the dependent variable. Harte’s dependent variable was the number of salamanders that hatched from the eggs.

**Determining the pH of Common Substances**

You can use pH indicator paper to determine the pH of various solutions. The pH indicator paper changes color when it is exposed to a solution. The change in color indicates how acidic or basic the solution is.

**Materials**
- paper, pencil, wide-range pH paper, three different solutions, beaker or small jar, water

**Procedure**

1. Make a data table with three columns and the following headings: Solution, Predicted pH, and Measured pH. Make a row for each solution to be tested.
2. Predict the pH (acid or base) of each solution, and record your predictions in your data table.
3. Test each solution with pH paper, and record the results in the appropriate row in your data table.

**Analysis**

1. Summarize your findings in two sentences.
2. Determine whether the predictions that you made were correct. Explain any differences between your predictions and your results.

**Skills Acquired**
- Observing, predicting, analyzing, comparing and measuring

**Teacher’s Notes**

Warn students not to get the liquids on their hands. They should wash their hands after the lab is completed. Containers (jars or beakers) with “mystery” solutions should be labeled “1,” “2,” or “3.” This will allow students to make comparisons later. Suggested solutions include apple juice (acid), orange juice (acid), and ammonia (base, diluted 4:1). Be careful to use only dilute solutions. All the solutions mentioned above can safely be put into school drainage systems.

**Answers to Analysis**

1. Answers will depend on the solutions used. Students should state which solutions were acidic, which were basic, and which were neutral.
2. Explanation of the differences might include the student’s perceptions of the different substances.
3. Reasons for differences might include human error, differences in interpretation, contamination, and improper labeling.
4. prediction, experimentation, drawing conclusions

**Integrating Physics and Chemistry**

After completing the Quick Lab—“What is the pH of some common substances?”—review the pH scale (0-14) with the students (For a pH graph and its meaning, see Chapter 2). Explain that the numbers are a measure of a mathematical way to represent the relative hydrogen ion concentration of a solution and that as a solution becomes more acidic the hydrogen ion (H+) concentration increases while the hydroxide ion (OH-) concentration decreases. In a similar way, as a solution becomes more basic the hydroxide ion (OH-) concentration increases while the hydrogen ion (H+) concentration decreases.
Harte allowed captive salamanders to lay eggs in regular pond water. He collected and then divided the eggs into five groups. One group, the control group, contained eggs placed in pond water with a neutral pH. Each of the other four groups, the experimental groups, contained eggs placed in pond water with different amounts of acid added, similar to the acid levels found in the ponds after snowmelt.

Harte found that acid did indeed affect development. Many of the salamanders never hatched from the eggs placed in acid water. Some of the salamanders that did hatch were born with developmental abnormalities. Other scientists have found abnormalities in amphibians, as shown in Figure 17.

### Drawing Conclusions

Once data are collected and analyzed, a conclusion is made as to whether the data support the hypothesis. The hypothesis may be supported or rejected. A hypothesis can be supported but never proven because another experiment with new data and new information may alter the conclusion.

Harte's data supported both of his hypotheses. The pH levels in the ponds before and after snowmelt indicated that the ponds became more acidic after the snow melted. This supported his first hypothesis—acids that were formed in the upper atmosphere by pollutants were falling onto the mountains in the winter snows.

Harte's controlled experiment showed that acidic water reduces the number of salamanders that hatch from eggs. This supported his second hypothesis—melting snow could make the ponds acidic and harm the salamander embryos. Harte concluded that melting snow in the Rocky Mountains of Colorado could cause acid absorbed from atmospheric pollution to be released into the ponds at snowmelt, harming salamander embryos.

### Viewing Conclusions in Context

Scientists from many disciplines have been working together to sort out the causes of the global decline in amphibians. Like many important questions, this one does not have a simple answer.

Four factors seem to be contributing in major ways: (1) The animals’ habitats are deteriorating and being destroyed. (2) Nonnative species introduced into amphibian habitats out-compete local amphibian populations for resources. (3) Chemical pollutants accumulate in amphibian habitats. Acid rain released into ponds at snowmelt is but one example. (4) Amphibians have a high rate of fatal infections by parasites such as viruses or fungi. In the western United States, infection by ranavirus (a common pathogen in fish) probably has led to declines in populations of mountain salamanders and frogs. A soil fungus called a chytrid (\textit{Kl}	extsc{trid}) also kills amphibians. Amphibian larvae, such as the Pacific tree frog tadpole shown in Figure 18, can be infected with the fungus. The fungus dissolves the mouthparts of the larvae, killing them.
**Scientific Explanations**

Scientific progress is made the same way a marble statue is, by chipping away the unwanted bits. If a hypothesis does not provide a reasonable explanation for observations, it must be rejected. Harte was able to show that enough acid was being introduced into the ponds to kill the salamander embryos. His hypothesis—that acid from melting snow was killing the salamanders—was therefore supported. The hypothesis that acid rain is contributing to the loss of amphibian populations will require much more evidence before becoming accepted as a broader theory. Related to other scientific explanations, a model is a representation of an object or a system. In science, the term model is often used to mean a hypothetical description.

It is important in science not to be misled by an isolated observation. Only after many studies like Harte’s will scientists be able to assemble a picture that accurately reveals what is harming the amphibians. As you have just read, other environmental factors may play important roles. **Figure 19** summarizes the steps in the development of a theory. A theory is a set of related hypotheses that have been tested and confirmed many times by many scientists. A theory unites and explains a broad range of observations.

**Constructing a Theory**

Constructing a theory often involves considering contrasting ideas and conflicting hypotheses. For example, Harte’s conclusions have been questioned by scientists who suggest that his observations may be only coincidence. Argument, disagreement, and unresolved questions are a healthy part of scientific research, a true reflection of how science is done. Scientists routinely evaluate one another’s work. A key requirement of valid scientific research is that it can be replicated—that is, reproduced—by other scientists.

As you study biology, it is important to remember that the word theory is used very differently by scientists than by the general public. To scientists, a theory represents that of which they are most certain. In contrast to the general public, theory may imply a lack of knowledge, a guess. How often have you heard someone say, “It’s only a theory” to imply lack of certainty? As you can imagine, confusion often results. In this textbook, the word theory will always be used in its scientific sense—that is, a theory is a well-supported scientific explanation that makes useful predictions.

There is, however, no absolute certainty in a scientific theory. The possibility always remains that future evidence will cause a scientific theory to be revised or rejected. A scientist’s acceptance of a theory is always provisional.

Once a scientist completes an investigation, he or she often writes a report for publication in a scientific journal. Before publication, the research report is reviewed and evaluated by other scientists. The hypothesis that is accepted by the scientific community will cause the scientific community to become the theory. A related hypothesis is accepted by scientists who suggest that his observations may be only coincidence. Argument, disagreement, and unresolved questions are a healthy part of scientific research, a true reflection of how science is done. Scientists routinely evaluate one another’s work. A key requirement of valid scientific research is that it can be replicated—that is, reproduced—by other scientists.

**Figure 19**

**Theories**

Scientists build theories from questions, predictions, hypotheses, and the findings of their experiments. When related hypotheses consistently explain scientific events, a theory is formed.

**Questions**

**Predictions and hypotheses**

**Experimentation**

**Data support hypothesis**

**Theory**

Some hypotheses are supported. Some hypotheses are rejected. Related hypotheses are verified by many.

**Teacher’s Notes**

Set up a well slide containing *Daphnia*. Use a video microscope to show how you can count the number of heartbeats.

**Answers to Analysis**

1. dependent variable: heart rate; independent variable: substance tested
2. groups that received coffee or ethanol
3. water
4. Answers may include that the number of drops added should be the same for each substance; there should be more than one trial per substance; and more substances could be tested.
5. Answers will vary. Students need to compare the heart rate of *Daphnia* in water (control) to the heart rate in coffee. There should be more than one trial for the entire experiment. Students may wish to test the effects of varying amounts of coffee.

**Data Lab**

**Skills Acquired**

Comparing, predicting outcomes, analyzing, proposing

---

**Graphics Organizer**

Use this graphic organizer with [Teaching Tip on this page].

- reject original hypothesis
- make observations, ask questions, and form hypothesis
- make predictions and perform control experiments
- data support hypothesis
- form theory
Reteaching

Have students design an experiment using five apples that would support the hypothesis that the skin on an apple functions to protect the apple from drying out.

Quiz

True or False:
1. All scientists follow the same method for solving a problem. (False. There is no exact scientific method, but each investigation contains common stages.)
2. Conducting an experiment is one way of testing a hypothesis. (True. Some hypotheses require only observations for testing. Others require complex, controlled experiments.)

Alternative Assessment

Tell students that some insurance companies claim that white cars are safer than other cars. Have students work in groups to develop a plan for a research project that would determine the validity of the “white-car claim.”

Section 3 Review

1. Summarize how scientists use observations, hypotheses, predictions, and experiments in scientific investigations.
2. Differentiate independent variables from dependent variables.
3. Define the word theory in a scientific sense and then in a more general sense.
4. Critical Thinking Evaluating Results Is Harte’s hypothesis the only possible hypothesis for the decrease in the number of salamanders in the Rocky Mountains?
5. Standardized Test Prep A researcher finds that 90 percent of salamanders hatch from eggs in water at pH 7, 80 percent hatch at pH 6, 60 percent at pH 5, and 40 percent at pH 4. What is the approximate percentage that hatch at pH 5.5?
   - A 55 percent
   - B 61 percent
   - C 70 percent
   - D 85 percent

Answers to Section Review

1. Hypotheses explain a set of observations. Predictions state the expected outcome of an experiment designed to test the hypotheses.
2. Independent variables are factors that vary in an experiment. A dependent variable is the factor that is measured.
3. Scientific sense: A theory explains a set of related hypotheses that have been tested and confirmed by scientists. General sense: A theory is a guess.
4. Harte’s hypothesis was supported by the results of his experiment, but acid rain may be only one of several factors contributing to the population decline.
5. A. Incorrect. More than 60 percent hatch at pH 5.5. B. Incorrect. More than 61 percent hatch at pH 5.5. C. Correct. Approximately 70 percent hatch at pH 5.5. D. Incorrect. Fewer than 85 percent hatch at pH 5.5.
**Key Concepts**

1. **Themes of Biology**
   - Living organisms are diverse but share certain characteristics.
   - All living organisms are composed of cells, grow and develop, and are able to maintain homeostasis.
   - Living organisms reproduce, producing offspring similar to themselves.
   - Living organisms obtain and use energy to stay alive, and they respond to their environment.
   - Seven themes unify the science of biology: cellular structure and function, reproduction, metabolism, homeostasis, heredity, evolution, and interdependence.

2. **Biology in Your World**
   - Pollution of the atmosphere, extinction of plants and animals, and a growing demand for food are current environmental problems caused by the growing human population.
   - Biologists are using genetic engineering to develop crops that require fewer fertilizers and pesticides and to develop new crops.
   - Biological research and new technologies will help scientists battle diseases such as AIDS, cancer, and cystic fibrosis.

3. **Scientific Processes**
   - Scientists add to scientific knowledge by sharing observations and posing questions about those observations.
   - Although there is no single method, observing, asking questions, and forming and testing hypotheses are important in planning a scientific investigation.
   - In a controlled experiment, the independent variable is varied between the experimental and control groups. The measured variable is the dependent variable.
   - A collection of hypotheses that have been repeatedly tested and are supported by a great deal of evidence forms a theory.

**Answer to Concept Map**

The following is one possible answer to Performance Zone item 15.

```
Biology is based on observations that can explain hypotheses, which stimulate predictions. These predictions are tested by experiments, which can be explained by theories. Theories are made up of predictions that are tested by experiments.
```

**Key Terms**

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<td>theory (19)</td>
</tr>
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</table>

**Alternative Assessment**

Have students find a current news report about the work of a current scientist or have them research the discoveries of a famous scientist in history. Ask students to draw a flowchart that shows the events leading up to the scientist’s conclusion. Then have the students write a brief paragraph that compares the events in their flowchart with the elements of scientific investigation discussed in this chapter.
Understanding Key Ideas

1. Toads that live in hot, dry regions bury themselves in the soil during the day. What theme of biology does this phenomenon describe?
   a. metabolism  b. evolution  c. heredity

2. Which of the following issues is not an existing problem that biologists can help solve?
   a. destruction of rain forests  b. extinction of plants and animals  c. AIDS  d. snowmelt in the Rockies

3. The demand for more food is due to
   a. the spread of disease.  b. the growth of the human population.  c. uncontrolled scientific experimentation.  d. extinction.

4. The disorder characterized by cells dividing uncontrollably within the body is called
   a. AIDS  b. cystic fibrosis  c. mad cow disease.

5. The factor that is varied in a controlled experiment is called the
   a. control  b. hypothesis  c. dependent variable  d. independent variable.

6. Which statement is false?
   a. Observations are an important part of the scientific process.  b. A solution with a low pH is more acidic than a solution with a high pH.  c. A hypothesis can be proven with a well-designed experiment.  d. A prediction is the expected outcome of a test.

7. For each pair of terms, write one or more sentences summarizing what you learned in this chapter about those terms.
   a. evolution, natural selection  b. metabolism, homeostasis  c. control group, experimental group

8. Is the word theory in the newspaper headline shown below used in a scientific sense or in a more general sense? Explain.

9. Why might it be difficult to determine whether or not microscopic particles are alive?

10. What arguments could you offer for and against the removal of forests to make room for new neighborhoods?

11. **Concept Mapping** Make a concept map that outlines scientific investigations in biology. Try to include the following terms: biology, observation, communication, hypotheses, predictions, experiments, and theories.

Critical Thinking

12. **Forming Reasoned Opinions** Some people believe that scientists should not tamper with a person’s genes. Do you think biologists should use gene therapy to try to cure diseases? Explain your answer.

13. **Applying Information** One of the first branches of biology to be developed was taxonomy, the naming and grouping of organisms. Why is taxonomy important to communication about biology?

Alternative Assessment

14. **Interactive Tutor Unit 5 Heredity** Write a report summarizing how an understanding of heredity allows animal breeders to develop animals that have desirable traits. Find out what kinds of animals are bred for special purposes.

11. One possible answer to the concept map is found at the bottom of the Study Zone page.

**Critical Thinking**

12. Answers will vary, and students should be able to support their positions.

13. Answers will vary. Since each species of living organism has its own scientific name, scientists can communicate with each other about the species, regardless of their native language.

**Alternative Assessment**

14. Answers will vary. A knowledge of heredity helps animal breeders select desirable traits to pass to offspring while minimizing the harmful traits that may arise from inbreeding. Animals are bred for appearance, such as show dogs, for food or commercial products, such as milk cows and beef cattle, or for work, such as oxen.

| Assignment Guide |
|------------------|------------------|
| **Section** | **Questions** |
| 1 | 1, 7 |
| 2 | 2, 3, 4, 10, 12 |
| 3 | 5, 6, 8, 11 |
**Understanding Concepts**

**Directions (1–6):** For each question, write on a separate sheet of paper the letter of the correct answer.

1. What is a statement that can be tested by additional observations or experimentation?
   - A. hypothesis
   - C. theory
   - B. prediction
   - D. variable

2. What is a group of organisms that can produce fertile offspring?
   - F. gene
   - H. reproduction
   - G. kingdom
   - I. species

3. What is the basic unit of heredity?
   - A. cell
   - B. chromosome
   - D. species

4. What is the sum of all the chemical reactions carried out in an organism?
   - F. homeostasis
   - H. reproduction
   - G. metabolism
   - I. sensitivity

5. What is a change in inherited characteristics of species over time called?
   - A. evolution
   - B. homeostasis
   - C. reproduction
   - D. responsiveness

6. To describe the acidity of a solution, scientists use a number between 0 and 14. What does this number represent?
   - F. experimental life
   - G. neutrality
   - H. pH
   - I. solution rate

**Directions (7):** For the following question, write a short response.

7. A scientist on television states that a hypothesis cannot be proven. Assess why this statement is correct.

---

**Reading Skills**

**Directions (8):** Read the passage below. Then answer the question.

One of the most important parts of any scientific publication is the section that describes methods and materials used. In this section, the authors describe how they set up the experiment, what instruments they used to collect the data, and how they recorded the data.

8. Why is it important for scientists to include in their scientific publications a section that describes the methods and materials used?
   - A. It shows how the data can be applied to other fields of study.
   - B. It proves how expensive their experiment is to carry out.
   - C. It allows other scientists to reproduce the experiment accurately.
   - D. It prevents other scientists from repeating the experiment and claiming it as their own.

**Interpreting Graphics**

**Directions (9):** Base your answer to question 9 on the chart below.

### Municipal Solid Waste by Weight

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper and cardboard</td>
<td>(40%)</td>
</tr>
<tr>
<td>Other waste</td>
<td>(19%)</td>
</tr>
<tr>
<td>Yard waste</td>
<td>(18%)</td>
</tr>
<tr>
<td>Glass</td>
<td>(7%)</td>
</tr>
<tr>
<td>Aluminum</td>
<td>(1%)</td>
</tr>
<tr>
<td>Plastics</td>
<td>(8%)</td>
</tr>
<tr>
<td>Metals containing iron</td>
<td>(7%)</td>
</tr>
</tbody>
</table>

9. If each type of solid waste were recycled, which type would have the biggest impact on conserving trees?
   - F. aluminum
   - G. glass
   - H. paper and cardboard
   - I. plastics

---

**Answers**

1. A
2. I
3. C
4. G
5. A
6. H
7. A hypothesis can be supported or rejected, but it cannot be proven.
8. C
9. H
Exploration Lab

Observing the Effects of Acid Rain on Seeds

Teacher’s Notes

Time Required: Day 1: 45–55 minutes; Days 3–10: 15 minutes, every other day.

Safety Precautions

1. CAUTION: Always wear safety goggles and a lab apron to protect your eyes and clothing.

2. CAUTION: Do not touch or taste any chemicals. Know the location of the emergency shower and eyewash station and how to use them. If you get a chemical on your skin or clothing, wash it off at the sink while calling to the teacher. Notify the teacher of a spill. Spills should be cleaned up promptly, according to your teacher’s directions.

3. CAUTION: Glassware is fragile. Notify the teacher of broken glass or cuts. Do not clean up broken glass or spills with broken glass unless the teacher tells you to do so.

Skills Acquired

Collecting Data
Designing Experiments
Analyzing Data
Predicting

Scientific Methods

In this lab, students will:
1. Make Observations
2. Test the Hypothesis
3. Analyze the Results
4. Draw Conclusions

Objectives

• Use a scientific method to investigate a problem.
• Predict how acid rain affects germination and growth.

Materials

• safety goggles
• protective gloves
• lab apron
• 50 seeds
• 250 mL beakers
• 20 mL mold inhibitor
• distilled water
• paper towels
• solutions of different pH
• wax pencil or marker
• zip-lock plastic bags
• metric ruler
• graph paper

Procedure

PART A: Design an Experiment

1. Work with members of your lab group to explore one of the questions written for step 2 of Before You Begin. To explore the question, design an experiment that uses the materials listed for this lab.

You Choose

As you design your experiment, decide the following:

a. what question you will explore
b. what hypothesis you will test
c. how to simulate growing seeds in soil moistened by acid rain
d. how to keep seeds moist during the experiment
e. what your test solutions and control will be
f. how to measure seedling growth
g. what to record in your data table

PART B: Perform the Experiment

1. Arrange 10 seeds that have been treated with mold inhibitor on one half of each set of treated paper towels. Fold the other half over the seeds. Place paper towels and seeds in the proper bag and seal the bag.

2. Record the number of seeds germinated and the length of each seedling. Note any other changes in the seedlings.

3. After each observation, re-wet the paper towels with the same solution as noted on each bag. Return the seeds to the bag.
2. Write a procedure for your experiment. Make a list of all the safety precautions you will take. Have your teacher approve your procedure and safety precautions before you begin the experiment.

**PART B: Conduct Your Experiment**

3. Put on safety goggles, protective gloves, and a lab apron.

4. Place your seeds in a 250 mL beaker, and slowly add enough mold inhibitor to cover the seeds. **CAUTION:** The mold inhibitor contains household bleach, which is a base. Soak the seeds for 10 minutes, and then pour the mold inhibitor into the proper waste container. Gently rinse the seeds with distilled water, and place them on clean paper towels.

5. Set up your group’s experiment. **CAUTION:** Solutions with a pH below 7.0 are acids. Conduct your experiment for 7–10 days. Make observations every 1–2 days, and note any changes. Record each day’s observations in a data table, similar to the one below.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Date</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**PART C: Cleanup and Disposal**

6. Dispose of solutions, broken glass, and seeds in the designated waste containers. Do not pour chemicals down the drain or put lab materials in the trash unless your teacher tells you to do so.

7. Clean up your work area and all lab equipment. Return lab equipment to its proper place. Wash your hands thoroughly before you leave the lab and after you finish all work.

### Analyze and Conclude

1. **Summarizing Results** Describe any changes in the look of your seeds during the experiment. Discuss seed type, average seed size, number of germinated seeds, and changes in seedling length.

2. **Analyzing Results** Were there any differences between the solutions? Explain.

3. **Analyzing Methods** What was the control group in your experiment?

4. **Analyzing Data** Make graphs of your group’s data. Plot seedling growth (in millimeters) on the y-axis. Plot number of days on the x-axis.

5. **Relating Concepts** What scientific methods did you use to design and conduct your experiment?

6. **Evaluating Methods** How could your experiment be improved?

7. **Inferring Conclusions** How do acidic conditions appear to affect seeds?

8. **Predicting Outcomes** How might acid rain affect the plants in an ecosystem?

9. **Further Inquiry** Write a new question about the effect of acid rain that could be explored with another investigation.

### Do You Know?

**Questions:**

1. Which parts of the United States are most affected by acid rain, and why?
2. How have factories been changed to reduce the amount of acid rain?

**Internet Resources:**

- [www.scilinks.org](http://www.scilinks.org)
  - Topic: Acid Rain
  - Keyword: HX4001

Answers to Before You Begin

1. **acid rain**—rain with a pH lower than 7 due to the pollutants it contains
2. **experiment**—a planned procedure to test a hypothesis
3. **observation**—the act of noting or perceiving objects or events using the senses
4. **pH**—a relative measure of the hydrogen ion concentration within a solution
5. **hypothesis**—an explanation that might be true and that can be tested by additional observations or experimentation
6. **prediction**—the expected outcome of a test, assuming the hypothesis is correct
7. **variable**—factor that can change
8. **control group**—a group in an experiment that receives no experimental treatment and serves as a standard with which experimental groups can be compared

### Answers to Analyze and Conclude

1. Answers will vary.
2. Answers will vary. Plants usually grow best in a pH of 4.5 to 6.5.
3. Seeds germinated in distilled water grow best in a pH of 4.5 to 6.5.
4. Answers will vary. See the sample data table below left.
5. Answers should include collecting data, analyzing data, and making conclusions.
6. Answers should include collecting data, analyzing data, and making conclusions.
7. Answers will vary. General acidic conditions inhibit seedling growth.
8. Answers will vary. Acidic rain might inhibit plant growth or kill plants.
9. Answers will vary. For example: What are the effects of acidic solutions on mature plants?

### Sample Data: Seedling Growth (mm)

<table>
<thead>
<tr>
<th>Day</th>
<th>pH 3</th>
<th>pH 4</th>
<th>pH 5</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>15</td>
<td>21</td>
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<tr>
<td>5</td>
<td>24</td>
<td>27</td>
<td>37</td>
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</tr>
<tr>
<td>7</td>
<td>32</td>
<td>35</td>
<td>50</td>
<td>58</td>
</tr>
</tbody>
</table>

*Lengths recorded are to the nearest millimeter.

### Answers to Do You Know?

1. upstate New York and other eastern states, the Pacific Northwest, and several midwestern states
2. Industries have installed devices that remove sulfur and nitrogen compounds from industrial emissions before they reach the atmosphere.