UNIT

1

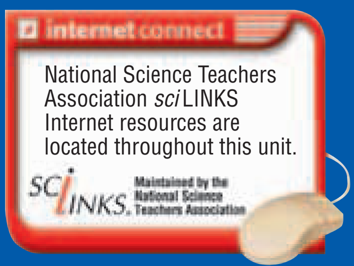
FOUNDATIONS OF BIOLOGY

CHAPTERS

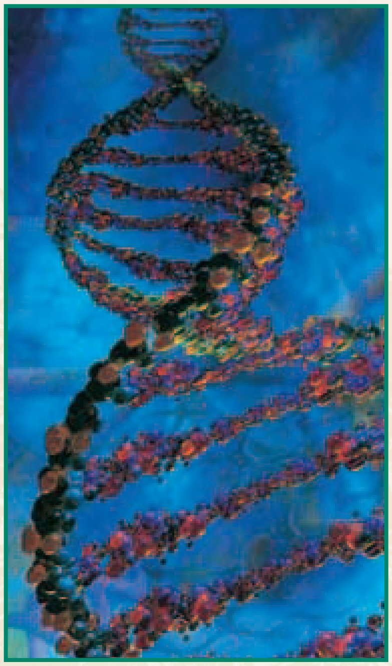
"Our ideas are only instruments which we use to break into phenomena; we must change them when they have served their purpose, as we change a blunt lancet that we have used long enough."

Claude Bernard

Organisms living in this taiga ecosystem are adapted to dry, cold weather and to reduced availability of food in winter.



This giant panda gets its energy by eating bamboo leaves. The Amazon water lily, above left, lives in shallow eutrophic ponds.



DNA is responsible for transmitting genetic information to offspring.

Red-eyed tree frog

CHAPTER 1 THE SCIENCE OF LIFE

Snowy owls are keen hunters that live in Arctic forests and on open tundra. These juveniles of the species *Nyctea scandiaca* hatched on a flower-filled alpine meadow.

SECTION 1

THE WORLD OF BIOLOGY

Owls, such as the young snowy owls on the previous page, have for centuries been symbols of both wisdom and mystery. To many cultures their piercing eyes have conveyed a look of intelligence. Their silent flight through darkened landscapes in search of prey has projected an air of power or wonder. For this chapter and this book, owls are an engaging example of a living organism from the world of biology—the study of life.

OBJECTIVES

- **Relate** the relevance of biology to a person's daily life.
- **Describe** the importance of biology in human society.
- **List** the characteristics of living things.
- **Summarize** the hierarchy of organization within complex multicellular organisms.
- **Distinguish** between homeostasis and metabolism and between growth, development, and reproduction.

VOCABULARY

biology
organization
cell
unicellular
multicellular
organ
tissue
organelle
biological molecule
homeostasis
metabolism
cell division
development
reproduction
gene

BIOLOGY AND YOU

Living in a small town, in the country, or at the edge of the suburbs, one may be lucky enough to hear an owl's hooting. This experience can lead to questions about where the bird lives, what it hunts, and how it finds its prey on dark, moonless nights. **Biology,** or the study of life, offers an organized and scientific framework for posing and answering such questions about the natural world. Biologists study questions about how living things work, how they interact with the environment, and how they change over time. Biologists study many different kinds of living things ranging from tiny organisms, such as bacteria, to very large organisms, such as elephants.

Each day, biologists investigate subjects that affect you and the way you live. For example, biologists determine which foods are healthy. As shown in Figure 1-1, everyone is affected by this important topic. Biologists also study how much a person should exercise and how one can avoid getting sick. Biologists also study what your air, land, and food supply will be like in the near future.

FIGURE 1-1

Biology, the study of life, directly applies to your health, life, and future in ways as simple as daily food choices.

Biology and Society

By studying biology you can make informed decisions on issues that impact you and our society. Every day newspapers, television, and the Internet contain issues that relate to biology. For example, you may read that your local water or air supply is polluted. How will that pollution affect your health and the health of other living things? You may hear about new technologies or tools that biologists have invented. How will we control how those technologies and tools are used? Biologists actively work to solve these and other real-world issues and problems, including improving our food supply, curing diseases and preserving our environment.

CHARACTERISTICS OF LIFE

The world is filled with familiar objects, such as tables, rocks, plants, pets, and automobiles. Which of these objects are living or were once living? What are the criteria for assigning something to the living world or the nonliving world? Biologists have established that living things share seven characteristics of life. These characteristics are organization and the presence of one or more cells, response to a stimulus (plural, *stimuli*), homeostasis, metabolism, growth and development, reproduction, and change through time.

Organization and Cells

Organization is the high degree of order within an organism's internal and external parts and in its interactions with the living world. For example, compare an owl to a rock. The rock has a specific shape, but that shape is usually irregular. Furthermore, different rocks, even rocks of the same type, are likely to have different shapes and sizes. In contrast, the owl is an amazingly organized individual, as shown in Figure 1-2. Owls of the same species have the same body parts arranged in nearly the same way and interact with the environment in the same way.

FIGURE 1-2

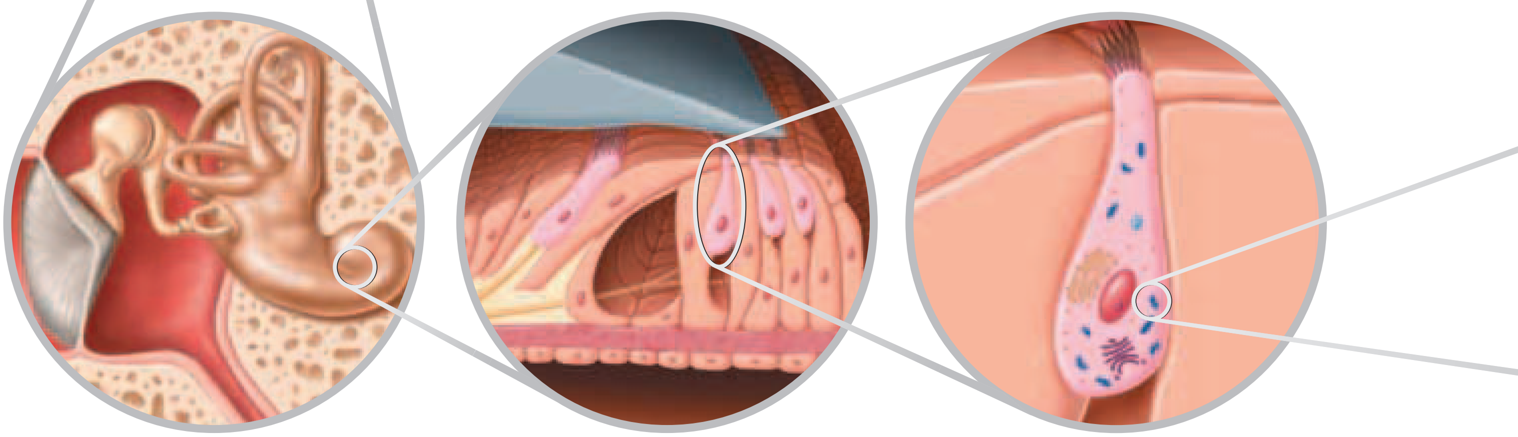
Every living organism has a level of organization. The different levels of organization for a complex multicellular organism, such as an owl, are shown in the figure below.

ORGANISM
(Barn Owl)

ORGAN
(Owl's Ear)

TISSUE
(Nervous Tissue Within the Ear)

CELL
(Nerve Cell)



All living organisms, whether made up of one cell or many cells, have some degree of organization. A **cell** is the smallest unit that can perform all life's processes. Some organisms, such as bacteria, are made up of one cell and are called **unicellular** (YOON-uh-SEL-yoo-luhr) organisms. Other organisms, such as humans or trees, are made up of multiple cells and are called **multicellular** (MUHL-ti-SEL-yoo-luhr) organisms. Complex multicellular organisms have the level of organization shown in Figure 1-2. In the highest level, the organism is made up of *organ systems,* or groups of specialized parts that carry out a certain function in the organism. For example, an owl's nervous system is made up of a brain, sense organs, nerve cells, and other parts that sense and respond to the owl's surroundings.

Organ systems are made up of organs. **Organs** are structures that carry out specialized jobs within an organ system. An owl's ear is an organ that allows the owl to hear. All organs are made up of tissues. **Tissues** are groups of cells that have similar abilities and that allow the organ to function. For example, nervous tissue in the ear allows the ear to detect sound. Tissues are made up of cells. A cell must be covered by a membrane, contain all genetic information necessary for replication, and be able to carry out all cell functions.

Within each cell are organelles. **Organelles** are tiny structures that carry out functions necessary for the cell to stay alive. Organelles contain **biological molecules,** the chemical compounds that provide physical structure and that bring about movement, energy use, and other cellular functions. All biological molecules are made up of *atoms.* Atoms are the simplest particle of an element that retains all the properties of a certain element.

Response to Stimuli

Another characteristic of life is that an organism can respond to a *stimulus*—a physical or chemical change in the internal or external environment. For example, an owl dilates its pupils to keep the level of light entering the eye constant. Organisms must be able to respond and react to changes in their environment to stay alive.

Word Roots and Origins

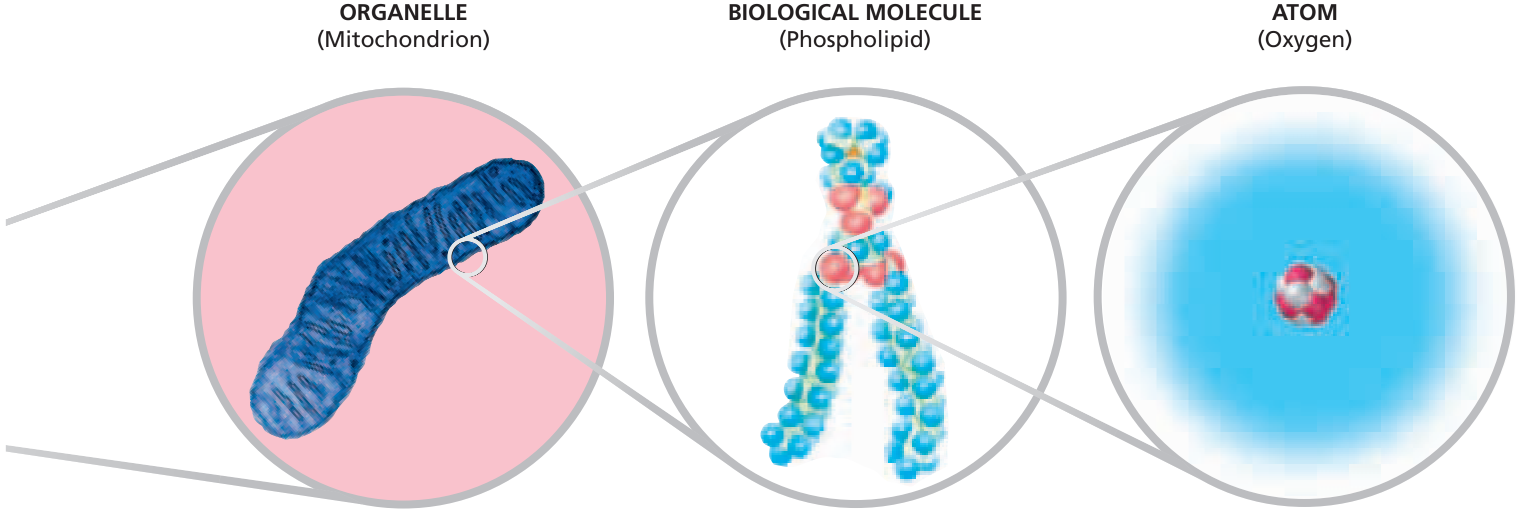
cell

from the Latin, *cella* meaning "small room," or "hut"

internet connect

www.scilinks.org
Topic: Characteristics of Life
Keyword: HM60257

SCILINKS. Maintained by the National Science Teachers Association



Quick Lab

Observing Homeostasis

Materials 500 mL beakers (3), wax pen, tap water, thermometer, ice, hot water, goldfish, small dip net, watch or clock with a second hand

Procedure

1. Use a wax pen to label three 500 mL beakers as follows: 27°C (80°F), 20°C (68°F), 10°C (50°F). Put 250 mL of tap water in each beaker. Use hot water or ice to adjust the temperature of the water in each beaker to match the temperature on the label.
2. Put the goldfish in the beaker of 27°C water. Record the number of times the gills move in 1 minute.
3. Move the goldfish to the beaker of 20°C water. Repeat observations. Move the goldfish to the beaker of 10°C. Repeat observations.

Analysis What happens to the rate at which gills move when the temperature changes? Why? How do gills help fish maintain homeostasis?

Homeostasis

All living things, from single cells to entire organisms, have mechanisms that allow them to maintain stable internal conditions. Without these mechanisms, organisms can die. For example, a cell's water content is closely controlled by the taking in or releasing of water. A cell that takes in too much water will rupture and die. A cell that doesn't get enough water will also shrivel and die.

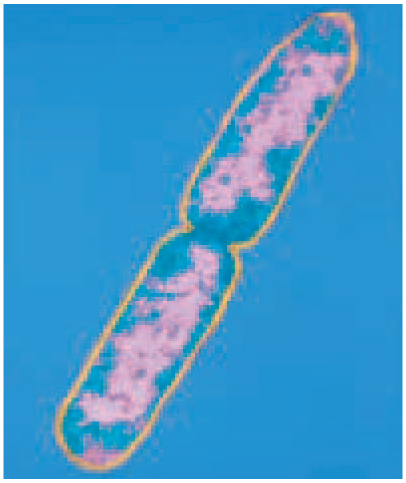
Homeostasis (HOH-mee-OH-STAY-sis) is the maintenance of a stable level of internal conditions even though environmental conditions are constantly changing. Organisms have regulatory systems that maintain internal conditions, such as temperature, water content, and uptake of nutrients by the cell. In fact, multicellular organisms usually have more than one way of maintaining important aspects of their internal environment. For example, an owl's temperature is maintained at about 40°C (104°F). To keep a constant temperature, an owl's cells burn fuel to produce body heat. In addition, an owl's feathers can fluff up in cold weather. In this way, they trap an insulating layer of air next to the bird's body to maintain its body temperature.

Metabolism

Living organisms use energy to power all the life processes, such as repair, movement, and growth. This energy use depends on metabolism (muh-TAB-uh-LIZ-uhm). **Metabolism** is the sum of all the chemical reactions that take in and transform energy and materials from the environment. For example, plants, algae, and some bacteria use the sun's energy to generate sugar molecules during a process called *photosynthesis*. Some organisms depend on obtaining food energy from other organisms. For instance, an owl's metabolism allows the owl to extract and modify the chemicals trapped in its nightly prey and use them as energy to fuel activities and growth.

FIGURE 1-3

This unicellular organism, *Escherichia coli,* inhabits the human intestines. *E. coli* reproduces by means of cell division, during which the original cell splits into two identical offspring cells.



Growth and Development

All living things grow and increase in size. Some nonliving things, such as crystals or icicles, grow by accumulating more of the same material of which they are made. In contrast, the growth of living things results from the division and enlargement of cells. **Cell division** is the formation of two new cells from an existing cell, as shown in Figure 1-3. In unicellular organisms, the primary change that occurs following cell division is cell enlargement. In multicellular life, however, organisms mature through cell division, cell enlargement, and development.

Development is the process by which an organism becomes a mature adult. Development involves cell division and cell differentiation, or specialization. As a result of development, an adult organism is composed of many cells specialized for different functions, such as carrying oxygen in the blood or hearing. In fact, the human body is composed of trillions of specialized cells, all of which originated from a single cell, the fertilized egg.

Reproduction

All organisms produce new organisms like themselves in a process called **reproduction.** Reproduction, unlike other characteristics, is not essential to the survival of an individual organism. However, because no organism lives forever, reproduction is essential for the continuation of a species. Glass frogs, as shown in Figure 1-4, lay many eggs in their lifetime. However, only a few of the frogs' offspring reach adulthood and successfully reproduce.

During reproduction, organisms transmit hereditary information to their offspring. Hereditary information is encoded in a large molecule called *deoxyribonucleic acid,* or *DNA*. A short segment of DNA that contains the instructions for a single trait of an organism is called a **gene.** DNA is like a large library. It contains all the books—genes—that the cell will ever need for making all the structures and chemicals necessary for life.

Hereditary information is transferred to offspring during two kinds of reproduction. In *sexual reproduction,* hereditary information recombines from two organisms of the same species. The resulting offspring are similar but not identical to their parents. For example, a male frog's sperm can fertilize a female's egg and form a single fertilized egg cell. The fertilized egg then develops into a new frog.

In *asexual reproduction,* hereditary information from different organisms is not combined; thus the original organism and the new organism are genetically the same. A bacterium, for example, reproduces asexually when it splits into two identical cells.

FIGURE 1-4

Like many animal species, this glass frog, *Centrolenella* sp., produces and lays a large number of eggs. However, a high percentage of these eggs die. In contrast, the offspring of animals that give birth to just a few live offspring typically have a high rate of survival.

Change Through Time

Although individual organisms experience many changes during their lifetime, their basic genetic characteristics do not change. However, populations of living organisms *evolve* or change through time. The ability of populations of organisms to change over time is important for survival in a changing world. This factor is also important in explaining the diversity of life-forms we see on Earth today.

SECTION 1 REVIEW

1. How does biology affect a person's daily life?
2. How does biology affect society?
3. Name the characteristics shared by living things.
4. Summarize the hierarchy of organization found in complex multicellular organisms.
5. What are the different functions of homeostasis and metabolism in living organisms?
6. How does the growth among living and nonliving things differ?
7. Why is reproduction an important characteristic of life?

CRITICAL THINKING

8. **Applying Information** Crystals of salt grow and are highly organized. Why don't biologists consider them to be alive?
9. **Analyzing Models** When a scientist designs a space probe to detect life on a distant planet, what kinds of things should it measure?
10. **Making Comparisons** Both cells and organisms share the characteristics of life. How are cells and organisms different?

SECTION 2

THEMES IN BIOLOGY

OBJECTIVES

- **Identify** three important themes that help explain the living world.
- **Explain** how life can be diverse, yet unified.
- **Describe** how living organisms are interdependent.
- **Summarize** why evolution is an important theme in biology.

VOCABULARY

domain
kingdom
ecology
ecosystem
evolution
natural selection
adaptation

A snowy owl, with all its beauty and complexity, is just one species among the millions of species on Earth. How can one understand so many different living organisms? Important unifying themes help explain the living world and are part of biology. These themes are found within this book and include the diversity and unity of life, the interdependence of living organisms, and the evolution of life.

DIVERSITY AND UNITY OF LIFE

The *diversity,* or variety, of life, is amazing. For example, there are single-celled organisms that thrive inside thick Antarctic ice that never thaws. There are whales that contain about 1,000 trillion cells that can easily cruise the Pacific and migrate each year from Alaska to Mexico. There are even plants that can capture and eat insects. Biologists have identified more than 1.5 million species on Earth. And there may be many more species that remain to be identified.

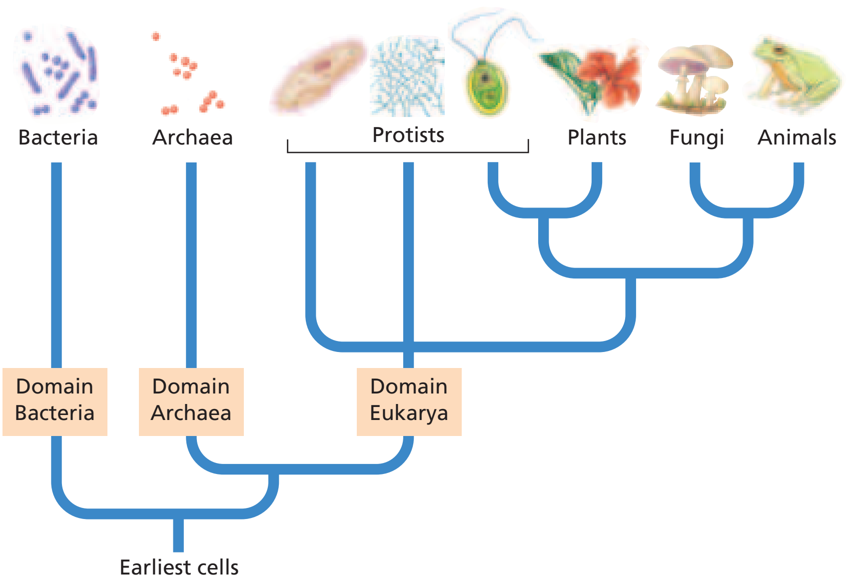
Unity in the Diversity of Life

Life is so diverse, yet life is also characterized by *unity,* or features that all living things have in common. One feature is the *genetic code,* the rules that govern how cells use the hereditary information in DNA. Another unifying feature is the presence of organelles that carry out all cellular activities.

The "tree of life" shown in Figure 1-5 is a model of the relationships by ancestry among organisms. All living things share certain genes, yet no two types of organisms have the same full sets of genes. One way biologists build a "tree of life" is to place organisms that have more similar sets of genes on closer branches, or *lineages,* of the "tree." They place the more distantly related organisms on more distant branches. The placement of all kinds of organisms produces a "tree" that relates and unites life's diversity.

FIGURE 1-5

This "tree of life," is a model of the relationships by ancestry among all major groups of organisms. The model is based on comparisons of organisms' characteristics, including body structures and genetic information. For updates on such "trees," visit **go.hrw.com** and enter the keyword **HM6 Phylo.**



So, how does the "tree of life" represent the unity in the diversity of life? Scientists think that all living things have descended with modification from a single common ancestor. Thus, all of life is connected. Yet, there are many different lineages representing different species. This diversity stems from the fact that genetic changes accumulate over the years. Also, organisms change as they become suited to their own special environments.

Three Domains of Life

Notice in Figure 1-5 that the "tree" has three main branches. Biologists call these major subdivisions of all organisms **domains.** The three domains are Bacteria, Archaea, and Eukarya. Bacteria and Archaea have less complex cells than those of Eukarya. Later chapters describe these domains in more detail. Notice that the largest and most familiar organisms, the animals, plants, and fungi, occupy parts of the Eukarya branch of the "tree."

Another system of grouping organisms divides all life into six major categories called **kingdoms.** The six kingdoms consist of four kingdoms within the domain Eukarya (the Kingdoms Animalia, Plantae, Fungi, and Protista), one kingdom in the domain Archaea (Kingdom Archaea) and one kingdom in the domain Bacteria (Kingdom Bacteria). Many biologists recognize these six kingdoms and three domains, but some biologists use other systems of grouping.

Word Roots and Origins

ecosystem

from the Greek word, *eco,* meaning "house," and *system*, meaning "ordered parts in a whole"

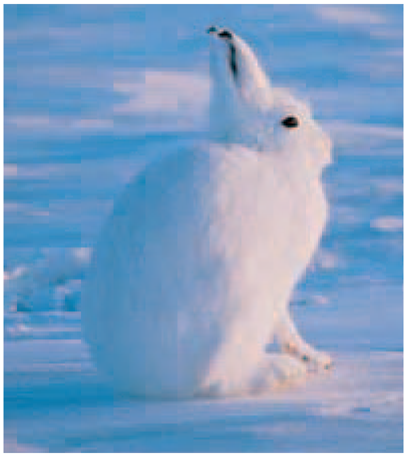
INTERDEPENDENCE OF ORGANISMS

Organisms interact with each other throughout the living world. **Ecology** is the branch of biology that studies organisms interacting with each other and with the environment. Ecologists study single species as well as ecosystems (EK-oh-SIS-tuhmz). **Ecosystems** are communities of living species and their physical environments. Such studies reveal that organisms depend on each other as well as on minerals, nutrients, water, gases, heat, and other elements of their physical surroundings. For example, a panther eats a bird, which eats nuts from trees. The tree needs carbon dioxide and water. Carbon dioxide is a main byproduct of all animals.

Scientists now recognize the huge effect that humans have had on the world's environment. For millions of years, tropical rain forests, as shown in Figure 1-6, have existed as stable—but fragile—environments. These forests play a vital role in the global environment. Humans have cleared vast areas of these forests in recent years. The destruction of these forests, in addition to other ecological changes in other regions, could impact all life on Earth.

FIGURE 1-6

Tropical rain forests, such as this one in the Amazon River basin in Ecuador, support an extraordinary variety and number of plants and animals, which are all on top of a very thin layer of fertile topsoil.



(a)

(b)

FIGURE 1-7

(a) This short-eared arctic hare, *Lepus arcticus,* is hidden from predators and protected from frostbite in a snowy environment. (b) The mottled brown coats of desert rabbits blend in with the dirt and dry grasses, and their long ears help them radiate excess heat and thus avoid overheating.

EVOLUTION OF LIFE

Individual organisms change during their lifetime, but their basic genetic characteristics do not change. However, populations of living organisms do change through time, or evolve. **Evolution,** or descent with modification, is the process in which the inherited characteristics within populations change over generations, such that genetically distinct populations and new species can develop.

Evolution as a theme in biology helps us understand how the various branches of the "tree of life" came into existence and have changed over time. It also explains how organisms alive today are related to those that lived in the past. Finally, it helps us understand the mechanisms that underlie the way organisms look and behave.

Natural Selection

The ability of populations of organisms to change over time is important for survival in a changing world. According to the theory of evolution by **natural selection,** organisms that have certain favorable traits are better able to survive and reproduce successfully than organisms that lack these traits.

One product of natural selection is the adaptation of organisms to their environment. **Adaptations** are traits that improve an individual's ability to survive and reproduce. For example, rabbits with white fur and short ears in a snowy place, such as the one in Figure 1-7a, may avoid predators and frostbitten ears more often than those with dark fur and long ears. Thus, the next generation of rabbits will have a greater percentage of animals carrying the genes for white fur and short ears. In contrast, the brown, long-eared rabbit, as shown in Figure 1-7b, would survive and reproduce more successfully in a hot desert environment.

The survival and reproductive success of organisms with favorable traits cause a change in populations of organisms over generations. This descent with modification is an important factor in explaining the diversity of organisms we see on Earth today.

SECTION 2 REVIEW

1. Name three unifying themes found in biology.
2. How is the unity and diversity in the living world represented?
3. Identify the three domains and the kingdoms found in each domain.
4. How are organisms interdependent?
5. Describe why evolution is important in explaining the diversity of life.
6. Distinguish between evolution and natural selection.

CRITICAL THINKING

7. **Applying Information** Assign the various toppings you put on pizza to the appropriate domains and kingdoms of life.
8. **Analyzing Graphics** According to the "tree" in Figure 1-5, which of these pairs are more closely related: Archaea:Bacteria or Archaea:Eukarya?
9. **Making Hypotheses** Fossil evidence shows that bats descended from shrewlike organisms that could not fly. Write a hypothesis for how natural selection might have led to flying bats.

SECTION 3

THE STUDY OF BIOLOGY

Curiosity leads us to ask questions about life. Science provides a way of answering such questions about the natural world. Science is a systematic method that involves forming and testing hypotheses. More importantly, science relies on evidence, not beliefs, for drawing conclusions.

OBJECTIVES

- **Outline** the main steps in the scientific method.
- **Summarize** how observations are used to form hypotheses.
- **List** the elements of a controlled experiment.
- **Describe** how scientists use data to draw conclusions.
- **Compare** a scientific hypothesis and a scientific theory.
- **State** how communication in science helps prevent dishonesty and bias.

VOCABULARY

scientific method
observation
hypothesis
prediction
experiment
control group
experimental group
independent variable
dependent variable
theory
peer review

SCIENCE AS A PROCESS

Science is characterized by an organized approach, called the **scientific method,** to learn how the natural world works. The methods of science are based on two important principles. The first principle is that events in the natural world have natural causes. For example, the ancient Greeks believed that lightning and thunder occurred because a supernatural god Zeus hurled thunderbolts from the heavens. By contrast, a scientist considers lightning and thunder to result from electric charges in the atmosphere. When trying to solve a puzzle from nature, all scientists, such as the one in Figure 1-8, accept that there is a natural cause to solve that puzzle.

A second principle of science is uniformity. *Uniformity* is the idea that the fundamental laws of nature operate the same way at all places and at all times. For example, scientists assume that the law of gravity works the same way on Mars as it does on Earth.

Steps of the Scientific Method

Although there is no single method for doing science, scientific studies involve a series of common steps.

1. The process of science begins with an observation. An **observation** is the act of perceiving a natural occurrence that causes someone to pose a question.
2. One tries to answer the question by forming hypotheses (singular, *hypothesis*). A **hypothesis** is a proposed explanation for the way a particular aspect of the natural world functions.
3. A **prediction** is a statement that forecasts what would happen in a test situation if the hypothesis were true. A prediction is recorded for each hypothesis.
4. An **experiment** is used to test a hypothesis and its predictions.
5. Once the experiment has been concluded, the data are analyzed and used to draw conclusions.
6. After the data have been analyzed, the data and conclusions are communicated to scientific peers and to the public. This way others can verify, reject, or modify the researcher's conclusions.

FIGURE 1-8
All researchers, such as the one releasing an owl above, use the scientific method to answer the questions they have about nature.

OBSERVING AND ASKING QUESTIONS

The scientific method generally begins with an unexplained observation about nature. For example, people have noticed for thousands of years that owls can catch prey in near total darkness. As shown in steps 1 and 2 of Figure 1-9, an observation may then raise questions. The owl observation raises the question: How does an owl detect prey in the dark?

FORMING A HYPOTHESIS

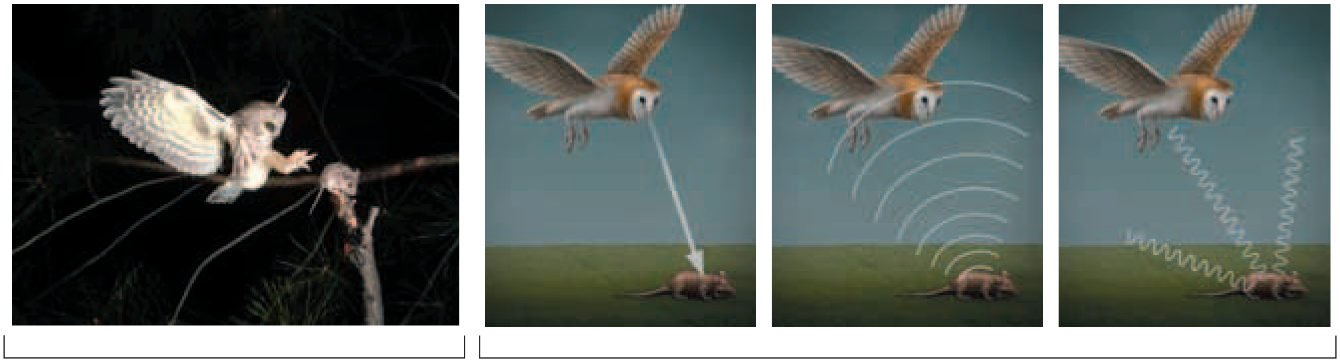
After stating a question, a biologist lists possible answers to a scientific question—hypotheses. Good hypotheses answer a question and are testable in the natural world. For example, as shown in step 3 Figure 1-9, there are several possible hypotheses for the question of how owls hunt at night: (a) owls hunt by keen vision in the dark; (b) owls hunt by superb hearing; or (c) owls hunt by detecting the prey's body heat.

Predicting

To test a hypothesis, scientists make a prediction that logically follows from the hypothesis. A prediction is what is expected to happen if each hypothesis were true. For example, if hypothesis (a) is true, (owls hunt by keen night vision) then one can predict that the owl will pounce only on the mouse in either a light or a dark room. If hypothesis (b) is true (owls hunt by hearing), then one can predict that in a lighted room, the owl will pounce closer to the mouse's head. But, in a dark room, the owl should pounce closer to a rustling leaf attached to the mouse. Finally, if hypothesis (c) is true (owls hunt by sensing body heat), then an owl would strike only the prey no matter the room conditions, because owls hunt by detecting the prey's body heat.

FIGURE 1-9

A scientific study includes observations, questions, hypotheses, predictions, experiments, data analysis, and conclusions. A biologist can use the scientific method to set up an experiment to learn how an owl captures prey at night.



1 OBSERVATION Owls capture prey on dark nights.

2 QUESTION How do owls detect prey on dark nights?

3 HYPOTHESES

a) Owls hunt in the dark by vision.

b) Owls hunt in the dark by hearing.

c) Owls hunt in the dark by sensing body heat.

Notice that these predictions make it difficult to distinguish between the vision and body heat hypotheses. The reason is that both hypotheses predict that the owl could grab the mouse in a dark room. Also, these three hypotheses do not eliminate all other factors that could influence how the owl finds its prey. However, testing predictions can allow one to begin rejecting hypotheses and thus to get closer to determining the answer(s) to a question.

DESIGNING AN EXPERIMENT

Biologists often test hypotheses by setting up an experiment. Step 4 in Figure 1-9 outlines an experiment to test the hypotheses about how an owl hunts at night. First, experimenters set up a room with an owl perch high on one side and a small trap door on the other side for releasing mice. Then, they tied a leaf to each mouse's tail with a string and released each mouse into the room. Next, each mouse ran silently across the room, but the leaf trailed behind, making a rustling noise. During half of the trials, the lights were on. During the other half, the room was dark. Technicians videotaped all the action in the chamber with an infrared light, which owls cannot see. The researchers then viewed the videos and measured the position of the owl's strike relative to each mouse's head.

Performing the Experiment

Many scientists use a controlled experiment to test their hypotheses. A *controlled experiment* compares an experimental group and a control group and only has one variable. The **control group** provides a normal standard against which the biologist can compare results of the experimental group. The **experimental group** is identical to the control group except for one factor, the **independent variable.** The experimenter manipulates the independent variable, sometimes called the *manipulated variable.*

Quick Lab

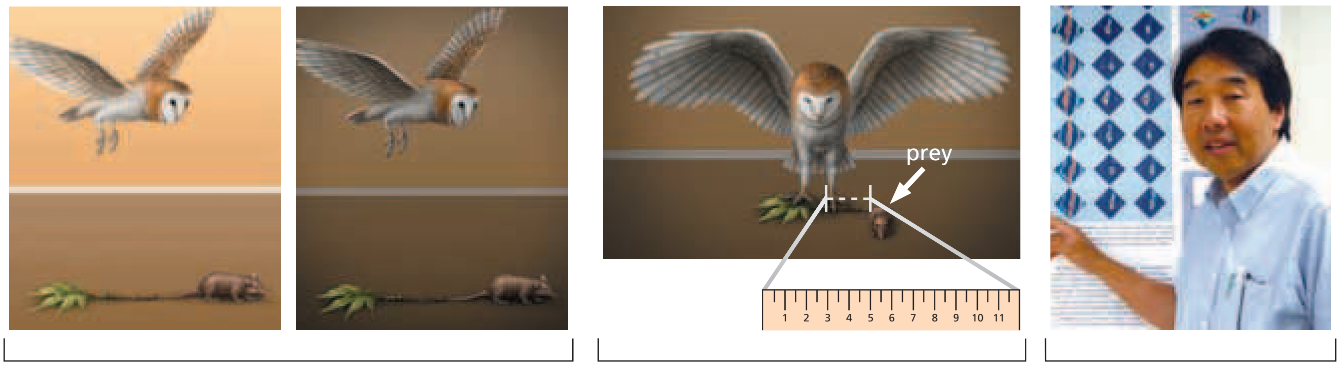
Predicting Results

Materials 2 Petri dishes with agar, cellophane tape, wax pen

Procedure

1. Open one of the Petri dishes, and streak your finger across the surface of the agar.
2. Replace the lid, and seal it with the tape. Label this Petri dish with your name and a number 1.
3. Seal the second Petri dish without removing the lid. Label this Petri dish with your name and the number 2.
4. Write a prediction about what will happen in each dish. Store your dishes as your teacher directs. Record your observations.

Analysis Was your prediction accurate? What evidence can you cite to support your prediction? If you did not obtain the results you predicted, would you change your testing method or your prediction? Explain. Evaluate the importance of obtaining a result that does not support your prediction.



4 **EXPERIMENT**
Test predictions of the three hypotheses.
Control: In the light **Experimental:** In the dark

5 **DATA COLLECTION AND ANALYSIS**
Measure and compare the distance from the owl's strike to the mouse and to the leaf in light and dark.

6 **CONCLUSION**
Data supported the hearing hypothesis: Owls hunt in the dark by hearing.

The independent variable in the owl experiment is the presence or absence of light. In the owl experiment, the control group hunts in the light, and the experimental group hunts in the dark. In addition to varying the independent variable, a scientist observes or measures another factor called the **dependent variable,** or *responding variable,* because it is affected by the independent variable. In the owl experiment, the dependent variable is distance from the owl's strike to the mouse's head.

Testing the Experiment

Some controlled experiments are conducted "blind." In other words, the biologist who scores the results is unaware of whether a given subject is part of the experimental or control group. This factor helps eliminate experimenter bias. Experiments should also be repeated, because living systems are variable. Moreover, scientists must collect enough data to find meaningful results.

COLLECTING AND ANALYZING DATA

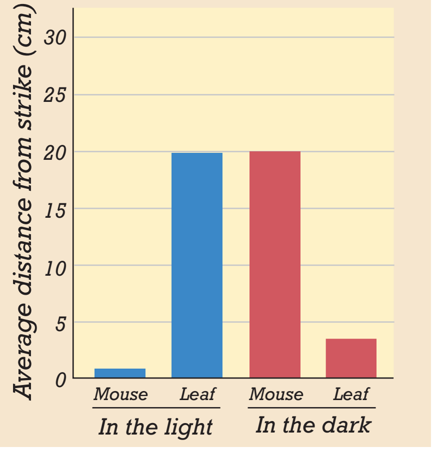
Most experiments measure a variable—the dependent variable. This measurement provides *quantitative data,* data measured in numbers. For example, in the experiment above, scientists measured the distance of an owl's strike from the prey's head in centimeters, as shown in step 5 of Figure 1-9. An event's duration in milliseconds is also an example of quantitative data.

Biologists usually score the results of an experiment by using one of their senses. They might see or hear the results of an experiment. Scientists also extend their senses with a microscope for tiny objects or a microphone for soft sounds. In the owl experiment, biologists extended their vision with infrared cameras.

FIGURE 1-10

The data below are hypothetical results that might occur from the described owl experiment. The independent variable is the darkness of the room, and the dependent variable is how far the owl struck from the mouse's head. The data show that the owl strikes more accurately at the mouse in the light but strikes more accurately at the leaf in the dark.

Distance Between Owl Strike and a Mouse or From a Leaf Attached to Mouse



Analyzing and Comparing Data

After collecting data from a field study or an experiment and then organizing it, biologists then analyze the data. In analyzing data, the goal is to determine whether the data are reliable, and whether they support or fail to support the predictions of the hypothesis. To do so, scientists may use statistics to help determine relationships between the variables involved.

They can then compare their data with other data that were obtained in other similar studies. It is also important at this time to determine possible sources of error in the experiment just performed. Scientists usually display their data in tables or graphs when analyzing it. For the owl study, biologists could have made a bar graph such as the one in Figure 1-10, which shows the average distance from the owl's strike relative to the mouse's head or the leaf in the light and in the dark.

DRAWING CONCLUSIONS

Biologists analyze their tables, graphs, and charts to draw conclusions about whether or not a hypothesis is supported, as shown in step 6 of Figure 1-9. The hypothetical owl data show that in the light, owls struck with greater accuracy at the mouse than at the leaf, but in the dark, owls struck with greater accuracy at the leaf than the mouse. Thus, the findings support the hearing hypothesis, but not the vision hypothesis.

An experiment can only disprove, not prove, a hypothesis. For example, one cannot conclude from the results that the hearing hypothesis is *proven* to be true. Perhaps the owl uses an unknown smell to strike at the mouse. One can only reject the vision hypothesis because it did not predict the results of the experiment correctly.

Acceptance of a hypothesis is always tentative in science. The scientific community revises its understanding of phenomena, based on new data. Having ruled out one hypothesis, a biologist will devise more tests to try to rule out any remaining hypotheses.

Making Inferences

Scientists often draw inferences from data gathered during a field study or experiment. An *inference* (IN-fuhr-uhns) is a conclusion made on the basis of facts and previous knowledge rather than on direct observations. Unlike a hypothesis, an inference is not directly testable. In the owl study, it is inferred that the owl detects prey from a distance rather than by direct touch.

Applying Results and Building Models

As shown in Figure 1-11, scientists often apply their findings to solve practical problems. They also build models to represent or describe things. For example in 1953, James Watson and Francis Crick used cardboard balls and wire bars to build physical models of atoms in an attempt to understand the structure of DNA. Mathematical models are sets of equations that describe how different measurable items interact in a system. The experimenter can adjust variables to better model the real-world data.

FIGURE 1-11

Biologists often apply their knowledge of the natural world to practical problems. Studies on the owl's keen ability to locate sounds in space despite background noise are helping biotechnologists and bioengineers develop better solutions for people with impaired hearing, such as the people shown in this picture.

CONSTRUCTING A THEORY

When a set of related hypotheses is confirmed to be true many times, and it can explain a great amount of data, scientists often reclassify it as a **theory.** Some examples include the quantum theory, the cell theory, or the theory of evolution. People commonly use the word "theory" in a different way than scientists use the word. People may say "It's just a theory" suggesting that an idea is untested, but scientists view a theory as a highly tested, generally accepted principle that explains a vast number of observations and experimental data.

COMMUNICATING IDEAS

internet connect

www.scilinks.org
Topic: Scientific Investigations
Keyword: HM61358

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An essential aspect of scientific research is scientists working together. Scientists often work together in research teams or simply share research results with other scientists. This is done by publishing findings in scientific journals or presenting them at scientific meetings, as shown in Figure 1-12. Sharing information allows others working independently to verify findings or to continue work on established results. For example, Roger Payne published the results of his owl experiments in a journal in 1971. Then, other biologists could repeat it for verification or use it to study the mechanisms introduced by the paper. With the growing importance of science in solving societal issues, it is becoming increasingly vital for scientists to be able to communicate with the public at large.

Publishing a Paper

Scientists submit research papers to scientific journals for publication. A typical research paper has four sections. First, the *Introduction* poses the problem and hypotheses to be investigated. Next, the *Materials and Methods* describe how researchers proceeded with the experiment. Third, the *Results* state the findings the experiment presented, and finally, the *Discussion* gives the significance of the experiment and future directions the scientists will take.

Careers in BIOLOGY

Forensic Biologist

Job Description Forensic biologists are scientists who study biological materials to investigate potential crimes and other legal issues against humans and animals. Forensic scientists have knowledge in areas of biology, such as DNA and blood pattern analysis, and work in private sector and public laboratories.

Focus On a Forensic Biologist
As a law enforcement forensic specialist for the Texas Parks and Wildlife Department, Beverly Villarreal assists the game warden in investigations of fish and wildlife violations, such as illegal hunting and fishing. Villarreal analyzes blood and tissue samples to identify species of animals such as fish, birds, and reptiles. Her work helps game wardens as they enforce state laws regarding hunting and fishing. Most people think of forensic scientists as the glamorous crime investigators on TV, but according to Villarreal real forensic scientists "spend a great deal of time at a lab bench running analysis after analysis." Many of the methods used in animal forensics, such as DNA sequencing, are also used in human forensics.

Education and Skills
- **High school**—three years of science courses and four years of math courses.
- **College**—bachelor of science in biology, including course work in zoology and genetics, plus experience in performing DNA analyses.
- **Skills**—patience, attention to detail, and ability to use fine tools.

For more about careers, visit go.hrw.com and type in the keyword HM6 Careers.

After scientists submit their papers to a scientific journal, the editors of that journal will send the paper out for peer review. In a **peer review,** scientists who are experts in the field anonymously read and critique that research paper. They determine if a paper provides enough information so that the experiment can be duplicated and if the author used good experimental controls and reached an accurate conclusion. They also check if the paper is written clearly enough for broad understanding. Careful analysis of each other's research by fellow scientists is essential to making scientific progress and preventing scientific dishonesty.

FIGURE 1-12
Scientists present their experiments in various forms. The scientists above are presenting their work in the form of a poster at a scientific meeting.

HONESTY AND BIAS

The scientific community depends on both honesty and good science. While designing new studies, experimenters must be very careful to prevent previous ideas and biases from tainting both the experimental process and the conclusions. Scientists have to keep in mind that they are always trying to disprove their favorite ideas. Scientists repeat experiments to verify previous findings. This allows for science to have a method for self-correction and it also keeps researchers honest and credible to their peers in the field.

Conflict of Interest

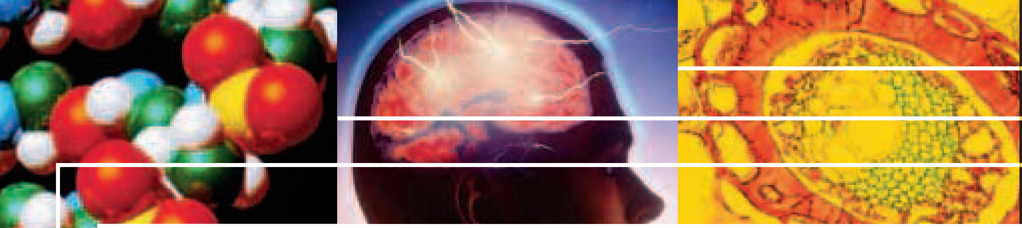
For most scientists, maintaining a good reputation for collecting and presenting valid data is more important than temporary prestige or income. So, scientists try to avoid any potential conflicts of interest. For example, a scientist who owns a biotechnology company and manufactures a drug would not be the best researcher to critically test that drug's safety and effectiveness. To avoid this potential conflict of interest, the scientist allows an unaffected party, such as a research group, to test the drug's effectiveness. The threat of a potential scandal based on misleading data or conclusions is a powerful force in science that helps keep scientists honest and fair.

SECTION 3 REVIEW

1. What two principles make the scientific method a unique process?
2. Define the roles of observations and hypotheses in science.
3. Summarize the parts of a controlled experiment.
4. Summarize how we make conclusions about the results of an experiment.
5. Why is the phrase, "it's just a theory" misleading?
6. Give another example of a conflict of interest.

CRITICAL THINKING

7. **Making Hypotheses** On a nocturnal owl's skull, one ear points up, and the other ear points down. Suggest a hypothesis for this observation.
8. **Designing Experiments** Design an experiment to establish if owls hunt by keen sight or hunt by heat seeking.
9. **Calculating Information** What was the average distance between the owl's strike and the mouse if the recorded differences in this experiment were 25, 22, 19, 19, and 15?



SCIENCE ON THE INTERNET: A New Information Age

In the past, students researching a science topic would typically begin their research by visiting a library to use printed reference materials, such as encyclopedias. Today, most students research topics by using a computer and searching for information on the Internet.

The Internet can provide students with a wealth of information. But which Web sites have accurate information, and which Web sites do not?

Checking Web Addresses

Students should use the Web address, or *URL,* to establish the Web site's credibility. Usually, the domain name can suggest who has published the Web site. Web sites can be published by governmental agencies (ends in "dot gov" or .gov), by educational institutions (ends in "dot edu" or .edu), by organizations (ends in "dot org" or .org), or by commercial businesses (ends in "dot com" or .com).

Government Web sites are usually reliable. Examples of credible governmental Web sites are the National Institutes of Health (NIH) and the Food and Drug Administration (FDA). University and medical school sites are also reliable sources of information. Many organizations that research and teach the public about specific diseases and conditions can also provide reliable information. Examples of such organizations are the American Cancer Society and the American Heart Association.

Evaluating Web Sites

The credibility of the author of the Web site should also be checked. Make sure the author is not trying to sell anything and is established in his or her field. For example, a health Web site's author should be a medical professional.

It is also important to check the date that the information was posted on the Web to ensure that the information is current. Also, the Web site should provide references from valid sources, such as scientific journals or government publications.

Finally, the student should always double-check information between several reliable Web sites. If two or three reliable sites provide the same information, the student can feel confident in using that information.

Web Sites for Students

The Internet Connect boxes in this textbook have all been reviewed by professionals at the National Science Teachers Association (NSTA). Students can trust that these sites are reliable sources for science- or health-related topics.

The Internet can provide a wealth of scientific information for a report, but the information may not always be credible or accurate. You can use the methods above to check the accuracy and credibility of your sources.

REVIEW

1. Which types of Web addresses are the most reliable?
2. List four important features to evaluate when using a Web site for research.
3. **Supporting Reasoned Opinions** Why do you think a Web site that is advertising a product may not offer accurate information?

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Topic: Using the Internet
Keyword: HM61589
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Tools and Techniques

SECTION 4

With proper equipment and good methods, biologists can see, manipulate, and understand the natural world in new ways. Microscopes are one of many useful tools used to unlock nature's biological secrets.

OBJECTIVES

- **List** the function of each of the major parts of a compound light microscope.
- **Compare** two kinds of electron microscopes.
- **Describe** the importance of having the SI system of measurement.
- **State** some examples of good laboratory practice.

VOCABULARY

compound light microscope
eyepiece (ocular lens)
objective lens
stage
light source
magnification
nosepiece
resolution
scanning electron microscope
transmission electron microscope
metric system
base unit

MICROSCOPES AS TOOLS

Tools are objects used to improve the performance of a task. *Microscopes* are tools that extend human vision by making enlarged images of objects. Biologists use microscopes to study organisms, cells, cell parts, and molecules. Microscopes reveal details that otherwise might be difficult or impossible to see.

Light Microscopes

To see small organisms and cells, biologists typically use a light microscope, such as the one shown in Figure 1-13. A **compound light microscope** is a microscope that shines light through a specimen and has two lenses to magnify an image. To use this microscope, one first mounts the specimen to be viewed on a glass slide. The specimen must be thin enough for light to pass through it. For tiny pond organisms, such as the single-celled paramecium, light passing through the organism is not a problem. For thick objects, such as plant stems, biologists must cut thin slices for viewing. There are four major parts of a compound light microscope. For further description of the parts of a microscope, see the Appendix.

1. **Eyepiece** The **eyepiece (ocular** (AHK-yoo-luhr) **lens)** magnifies the image, usually 10 times.
2. **Objective Lens** Light passes through the specimen and then through the objective lens, which is located directly above the specimen. The **objective lens** enlarges the image of the specimen. Scientists sometimes use stains to make the image easier to see.
3. **Stage** The **stage** is a platform that supports a slide holding the specimen. The slide is placed over the opening in the stage of the microscope.
4. **Light Source** The **light source** is a light bulb that provides light for viewing the image. It can be either light reflected with a mirror or an incandescent light from a small lamp.

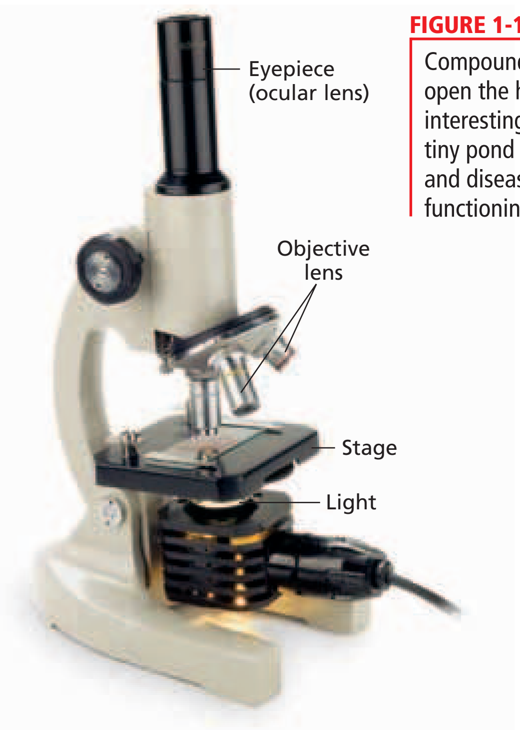
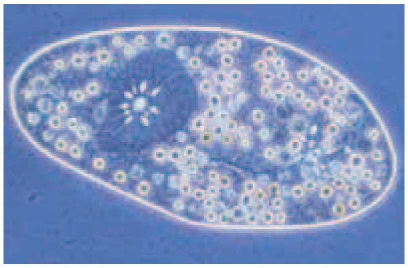
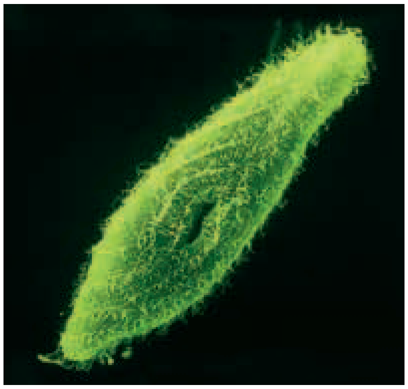


FIGURE 1-13
Compound light microscopes open the human eye to an interesting world including tiny pond organisms, healthy and diseased cells, and the functioning of cell parts.



(a) *Paramecium* (light microscope)



(b) *Paramecium* (scanning electron microscope)

(c) *Paramecium* (transmission electron microscope)

FIGURE 1-14

The images above show a *Paramecium* as viewed under three different types of microscopes. (a) Light microscopes can produce an image that is up to 1,000 times larger than the actual specimen. (b) Scanning electron microscopes produce images up to 100,000 times larger than the specimen. SEMs provide a view of surface features. (c) Transmission electron microscopes produce images up to 200,000 times larger than the actual specimen.

Magnification and Resolution

Microscopes vary in powers of magnification and resolution. **Magnification** is the increase of an object's apparent size. Revolving the **nosepiece,** the structure that holds the set of objective lens, rotates these lenses into place above the specimen. In a typical compound light microscope, the most powerful objective lens produces an image up to 100 times (100×) the specimen's actual size. The degree of enlargement is called the *power of magnification* of the lens. The standard ocular lens magnifies a specimen 10 times (10×). To compute the power of magnification of a microscope, the power of magnification of the strongest objective lens (in this case, 100×) is multiplied by the power of magnification of the ocular lens (10×). The result is a total power of magnification of 1000×.

Resolution (REZ-uh-LOO-shuhn) is the power to show details clearly in an image. The physical properties of light limit the ability of light microscopes to resolve images, as shown in Figure 1-14a. At powers of magnification beyond about 2,000×, the image of the specimen becomes fuzzy. For this reason, scientists use other microscopes to view very small cells and cell parts.

Electron Microscopes

To examine cells in more detail or to view cell parts or viruses, scientists can use other microscopes, such as an electron microscope. In an *electron microscope,* a beam of electrons produces an enlarged image of the specimen. Electron microscopes are more powerful in magnification and resolution than light microscopes. Some electron microscopes can even show the contours of individual atoms in a specimen. Electron microscope images are always in black and white. However, scientists can use computers to add artificial colors to help identify structures in the image. Also, the specimen must be placed in a vacuum chamber. Because cells cannot survive in a vacuum, electron microscopes cannot be used to view living specimens.

There are two main types of electron microscopes. The first type of electron microscope is the **scanning electron microscope (SEM).** The SEM passes a beam of electrons over the specimen's surface. SEMs provide three-dimensional images of the specimen's surface, as shown in Figure 1-14b. First, the specimen is sprayed with a fine metal coating. Then, a beam of electrons is aimed at the specimen, which causes the metal coating to emit a shower of electrons. These electrons project onto a fluorescent screen or photographic plate. The result is an image of the object's surface. SEMs can magnify objects up to 100,000 times.

The second type is the **transmission electron microscope (TEM).** The TEM transmits a beam of electrons through a very thinly sliced specimen. Magnetic lenses enlarge the image and focus it on a screen or photographic plate. The result is an image such as the one shown in Figure 1-14c. Note the great resolution of the paramecium's internal structure. Transmission electron microscopes can magnify objects up to 200,000 times.

TABLE 1-1 SI Base Units

Base quantity	Name	Abbreviation
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Luminous (light) intensity	candela	cd

TABLE 1-2 Some SI prefixes

Prefix	Abbreviation	Factor of base unit
giga	G	1,000,000,000 (10^9)
mega	M	1,000,000 (10^6)
kilo	k	1,000 (10^3)
hecto	h	100 (10^2)
deka	da	10 (10^1)
base unit		1
deci	d	0.1 (10^{-1})
centi	c	0.01 (10^{-2})
milli	m	0.001 (10^{-3})
micro	µ	0.000001 (10^{-6})
nano	n	0.000000001 (10^{-9})
pico	p	0.000000000001 (10^{-12})

UNITS OF MEASUREMENT

Scientists use a common measurement system so that they can compare their results. Scientists use a single, standard system of measurement, called the **metric system.** The metric system is a decimal system and thus is based on powers of 10. The official name of this measurement system is *Système International d'Unités*. The English translation of this French title is the International System of Units, or simply SI. Biology students use SI while making measurements in the laboratory.

Base and Other Units

The SI has seven fundamental **base units** that describe length, mass, time, and other quantities, as shown in Table 1-1. Multiples of a base unit (in powers of 10) are designated by prefixes, as shown in Table 1-2. For example, the base unit for length is the meter. One kilometer (km) is equal in length to 1,000 meters (m).

Although the base units in Table 1-1 are extremely useful, they can't be applied to certain measurements, such as surface area or velocity. Scientists use other important units called derived units for these types of quantities. *Derived units* are produced by the mathematical relationship between two base units or between two derived units. Table 1-3 shows some common derived units. There are some additional units of measurement that are not part of the SI but that can be used with SI units such as units of time, volume, and mass, as shown in Table 1-3.

TABLE 1-3 Some Derived and Other Units

Quantity	Name	Abbreviation
Area	square meter	m^2
Volume	cubic meter	m^3
Density	kilogram per cubic meter	kg/m^3
Specific volume	cubic meter per kilogram	m^3/kg
Celsius temperature	degree Celsius	°C
Time	minute	1 min = 60 s
Time	hour	1 h = 60 min
Time	day	1 d = 24 h
Volume	liter	1 L = 1,000 cm^3
Mass	kilogram metric ton	1,000 g = 1 kg 1 t = 1,000 kg

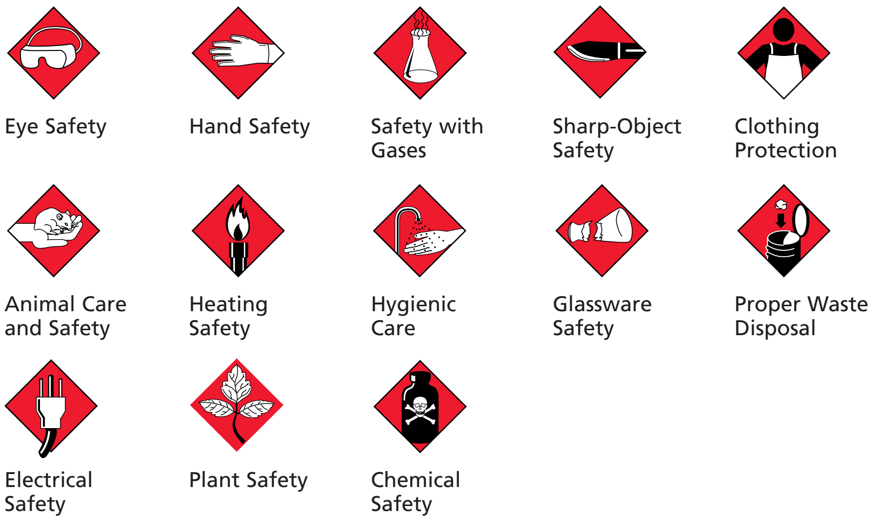
FIGURE 1-15
Good laboratory practice involves protecting yourself and others by being safe.

SAFETY

Studying living things is interesting, fun, and rewarding, but it can be hazardous. The hazards can be chemical, physical, radiological, or biological and can vary between the the lab and the field. For example, getting splashed in the eye with a blinding chemical is more likely to occur in the laboratory, but falling down a cliff or getting bitten by a poisonous spider is more likely to occur in the field.

Good Laboratory Practice

Lab safety involves good laboratory practice, which means establishing safe, common-sense habits, as shown in Figure 1-15. Never work alone in the lab or without proper supervision by the teacher, and always ask your teacher before using any equipment. The diagram below shows the safety symbols used in this book. More information on lab safety and the safety symbols can be found in the Appendix.



SECTION 4 REVIEW

1. List the four major parts of a compound light microscope.
2. What is the difference between the magnification and resolution of an image under a microscope?
3. Compare the function of a transmission electron microscope with that of a scanning electron microscope.
4. What is the importance of scientists using a common SI system of measurement?
5. How would you convert kilometers to millimeters?
6. Name the safety symbols used in this textbook.

CRITICAL THINKING

7. **Applying Information** A biologist thinks a virus, which is much smaller than a cell, is likely to cause a disease. Which type of microscope is most likely to be used to view the internal structure of a virus?
8. **Calculating Information** How would you convert cubic meters to cubic centimeters?
9. **Calculating Information** On a light microscope, an objective lens magnifies the view of some pond water 25 times, and the ocular lens magnifies it 10 times further. What is the final magnification of the image?

CHAPTER HIGHLIGHTS

SECTION 1 The World of Biology

- Biology is the study of life and can be used to both solve societal problems and explain aspects of our daily lives.
- Living things share the same 7 characteristics: organization and cells, response to stimuli, homeostasis, metabolism, growth and development, reproduction, and evolution.
- Multicellular organisms show a hierarchy of organization going from the organism to the atom.
- To stay alive, living things must maintain homeostasis, obtain and use energy, and pass on hereditary information from parents to offspring, also called reproduction.

Vocabulary

biology (p. 5)	**multicellular** (p. 7)	**biological molecule** (p. 7)	**development** (p. 8)
organization (p. 6)	**organ** (p. 7)	**homeostasis** (p. 8)	**reproduction** (p. 9)
cell (p. 7)	**tissue** (p. 7)	**metabolism** (p. 8)	**gene** (p. 9)
unicellular (p. 7)	**organelle** (p. 7)	**cell division** (p. 8)	

SECTION 2 Themes in Biology

- Three themes in biology are the unity of life's diversity, the interdependence of organisms, and evolution of life.
- Living organisms show diversity and can be classified into domains and kingdoms.
- Organisms live in interdependent communities and interact with both organisms and the environment.
- Evolution helps to explain how species came to exist, have changed over time, and adapt to their environment.

Vocabulary

domain (p. 11)	**ecology** (p. 11)	**evolution** (p. 12)	**adaptation** (p. 12)
kingdom (p. 11)	**ecosystem** (p. 11)	**natural selection** (p. 12)	

SECTION 3 The Study of Biology

- The scientific method involves making observations, asking questions, forming hypotheses, designing experiments, analyzing data, and drawing conclusions.
- Trying to answer questions about observations helps scientists form hypotheses.
- A controlled experiment has a control and experimental group, and tests independent and dependent variables.
- Scientists analyze data to draw conclusions about the experiment performed.
- A theory is a set of related hypotheses confirmed to be true many times.
- Communication between scientists about their methods and results helps prevent dishonesty and bias in science.

Vocabulary

scientific method (p. 13)	**prediction** (p. 13)	**experimental group** (p. 15)	**dependent variable** (p. 16)
observation (p. 13)	**experiment** (p. 13)	**independent variable** (p. 15)	**theory** (p. 17)
hypothesis (p. 13)	**control group** (p. 15)		**peer review** (p. 19)

SECTION 4 Tools and Techniques

- Four major parts of a compound light microscope are the ocular lens, objective lens, stage, and light source.
- Transmission and scanning electron microscopes provide greater magnification than light microscopes.
- Scientists use the metric system to take scientific measurements.
- Lab safety is a good laboratory practice.

Vocabulary

compound light microscope (p. 21)	**objective lens** (p. 21)	**nosepiece** (p. 22)	**transmission electron microscope (TEM)** (p. 22)
eyepiece (ocular lens) (p. 21)	**stage** (p. 21)	**resolution** (p. 22)	**metric system** (p. 23)
	light source (p. 21)	**scanning electron microscope (SEM)** (p. 22)	**base unit** (p .23)
	magnification (p. 22)		

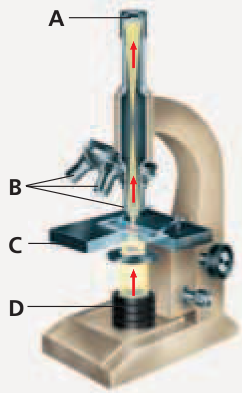
CHAPTER REVIEW

Using Vocabulary

1. For each pair of terms, explain how the meanings of the terms differ.
   a. *unicellular* and *multicellular*
   b. *homeostasis* and *metabolism*
   c. *natural selection* and *adaptation*
   d. *hypothesis* and *theory*
   e. *magnification* and *resolution*
2. Explain the relationship between an independent variable and a dependent variable.
3. Use the following terms in the same sentence: *observation, hypothesis, prediction,* and *experiment.*
4. **Word Roots and Origins** The word *magnification* is derived from the Latin *magnificus* or *magnus,* which means "large" or "great." Using this information, explain why the term *magnification* is a good name for the function it describes.

Understanding Key Concepts

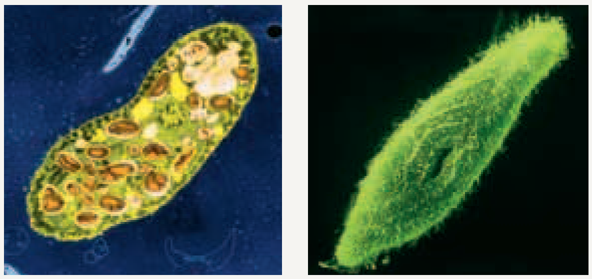
5. **Describe** why learning about biology is relevant to a person's life.
6. **Describe** one way in which biology affects our society.
7. **Summarize** the characteristics of living things.
8. **List** the hierarchy of organization in a snowy owl.
9. **Explain** how homeostasis and metabolism are interrelated.
10. **Compare** the processes of growth, development, and reproduction.
11. **State** three major themes found in biology.
12. **Identify** how the "tree of life" can help explain both the unity and diversity of life.
13. **Describe** the interdependence of living organisms.
14. **Summarize** how evolution helps explain the diversity of life.
15. **Sequence** the main steps of the scientific method.
16. **Explain** how observations are used to form hypotheses.
17. **Summarize** how biologists set up controlled experiments.
18. **State** the purpose of analyzing data that are collected during an experiment.
19. **Summarize** how a hypothesis becomes a theory.
20. **Describe** two types of scientific models.
21. **Identify** how a peer review keeps scientists honest.
22. **Name** the part of the compound light microscope denoted by each letter in the figure below.



23. **Differentiate** between the scanning electron microscope and the transmission electron microscope.
24. **Describe** the relationship between a kilometer, meter, and micrometer.
25. **Explain** why scientists throughout the world use the SI system.
26. **List** three safety symbols used in this textbook.
27. **CONCEPT MAPPING** Use the following terms to create a concept map that outlines the steps of the scientific method: *observations, experiments, conclusions, questions, hypotheses, data analyses, predictions, theories,* and *communication.*

Critical Thinking

28. **Forming Hypotheses** Go to a window or outside, and observe a bird's behavior for a few minutes. Record your observations, and write down one question about bird behavior and one hypothesis that answers the question.
29. **Analyzing Concepts** One of the most important parts of any scientific publication is the part called Methods and Materials, in which the scientist describes the procedure used in the experiment. Why do you think such details are so important?
30. **Making Calculations** Determine the number of liters that are in 150 kiloliters.
31. **Making Comparisons** Look at the photographs below. The TEM (left) is a photo of a paramecium. The SEM (right) is also a photo of a paramecium. Compare and contrast what each electron micrograph reveals to you about this organism.



Standardized Test Preparation

DIRECTIONS: Choose the letter of the answer choice that best answers the question.

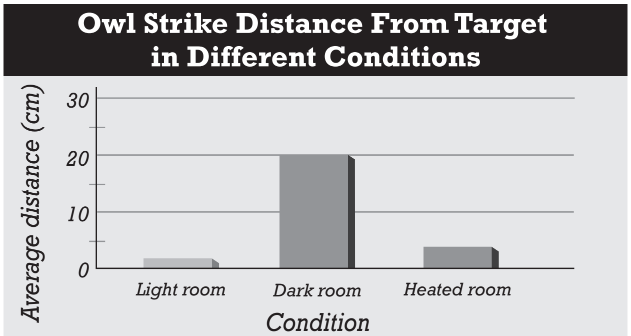
1. Which of the following does evolution help explain?
   A. how organisms reproduce
   B. how organisms grow and develop
   C. how organisms are related to each other
   D. how organisms obtain and metabolize energy

2. Which of the following is the hereditary material in most living things?
   F. DNA
   G. lipids
   H. oxygen
   J. carbon dioxide

3. Which of the following does the hierarchy of organization within an organism describe?
   A. metabolism
   B. homeostasis
   C. internal structures
   D. relationship to the physical environment

4. To which of the following does the resolution of a microscope refer?
   F. its ability to show detail clearly
   G. its power to scan the surface of an object
   H. its series of interchangeable objective lenses
   J. its power to increase an object's apparent size

INTERPRETING GRAPHICS: The graph below shows the distance it takes an owl to strike a mouse under different conditions. Use the graph to answer the question that follows.



5. An owl strikes a mouse more closely and on target in which of the following rooms?
   A. dark room
   B. light room
   C. heated room
   D. dark and lighted rooms

DIRECTIONS: Complete the following analogy.

6. compound light microscope : light :: TEM:
   F. tissues
   G. electrons
   H. organelles
   J. organ systems

INTERPRETING GRAPHICS: The figure below shows a newspaper clipping. Use the figure to answer the question that follows.

7. Which of the following terms most accurately reflects the use of the term theory in the newspaper headline above?
   A. law
   B. fact
   C. hypothesis
   D. experiment

SHORT RESPONSE

Dolly was cloned from mammary cells from an adult female sheep. She was an exact genetic copy of her mother.

Explain whether Dolly represents a product of sexual reproduction or asexual reproduction.

EXTENDED RESPONSE

Life is so diverse, yet it is characterized by a unity. The tree of life can relate life's unity and diversity.

Part A Describe the relationship between animals, plants, fungi, protists, bacteria, and archaea in the "tree of life."

Part B Explain how the "tree of life" represents and relates both the unity and diversity of life.

Test TIP When faced with similar answers, define the answer choices and then use that definition to narrow down the choices on a multiple-choice question.

SKILLS PRACTICE LAB

Using SI Units

OBJECTIVES

- Express measurements in SI units.
- Read a thermometer.
- Measure liquid volume using a graduated cylinder.
- Measure mass using a balance.
- Determine the density (mass-to-volume ratio) of two different liquids.

PROCESS SKILLS

- measuring
- calculating

MATERIALS

- 75 mL light-colored sand
- 75 mL dark-colored sand
- 1 100 mL graduated cylinder
- Celsius thermometers, alcohol filled (2)
- 5 oz plastic cups (4)
- graph paper
- heat-protective gloves
- light source
- stopwatch or clock
- ring stand or lamp support
- 25 mL corn oil
- 25 mL water
- clear-plastic cup
- balance

Background

1. What does the abbreviation *SI* stand for?
2. List the seven SI base units.

PART A Measuring Temperature

1. In your lab report, prepare a data table similar to Table A, above right.
2. Using a graduated cylinder, measure 75 mL of light-colored sand and pour it into one of the small plastic cups. Repeat this procedure with the dark-colored sand and another plastic cup.
3. Level the sand by placing the cup on your desk and sliding the cup back and forth.

TABLE A *SAND TEMPERATURE*

	Temperature (°C)	
Time (min)	Dark-colored sand	Light-colored sand
Start		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

4. Insert one thermometer into each cup. The zero line on the thermometer should be level with the sand, as shown in the figure below. Re-level the sand if necessary.

5. **CAUTION Wear heat-protective gloves when handling the lamp. The lamp will become very hot and may burn you.** Using a ring stand or lamp support, position the lamp approximately 9 cm from the top of the sand, as shown in the figure on p. 28. Make sure the lamp is evenly positioned between the two cups.
6. Before turning on the lamp, record the initial temperature of each cup of sand in your data table.
7. Note the time or start the stopwatch when you turn on the lamp. The lamp will become hot and warm the sand. Check the temperature of the sand in each container at one-minute intervals for 10 minutes. Record the temperature of the sand after each minute in your data table.

PART B Comparing the Density of Oil and Water

8. In your lab report, prepare a data table similar to Table B below.

TABLE B *DENSITY OF TWO LIQUIDS*

a. Mass of empty oil cup	________	g
b. Mass of empty water cup	________	g
c. Mass of cup and oil	________	g
d. Mass of cup and water	________	g
e. Volume of oil		25 mL
f. Volume of water		25 mL
Calculating Actual Mass		
Oil	Item c − Item a = ________	g
Water	Item d − Item b = ________	g
g. Density of oil	________	g/ml
h. Density of water	________	g/ml

9. Label one clean plastic cup "oil," and label another "water." Using a balance, measure the mass of each plastic cup, and record the value in your data table.
10. Using a clean graduated cylinder, measure 25 mL of corn oil and pour it into the plastic cup labeled "oil." Using a balance, measure the mass of the plastic cup containing the corn oil, and record the mass in your data table.
11. Using a clean graduated cylinder, measure 25 mL of water and pour it into the plastic cup labeled "water." Using a balance, measure the mass of the plastic cup containing the water, and record the mass in your data table.
12. To find the mass of the oil, subtract the mass of the empty cup from the mass of the cup and the oil together.
13. To find the density of the oil, divide the mass of the oil by the volume of the oil, as shown in the equation below:

$$\text{Density of oil} = \frac{\text{mass of oil}}{\text{volume of oil}} = \underline{\qquad\qquad} \text{ g/mL}$$

14. To find the mass of water, subtract the mass of the empty cup from the mass of the cup and the water together.
15. To find the density of the water, divide the mass of the water by the volume of the water, as shown in the equation below:

$$\text{Density of water} = \frac{\text{mass of water}}{\text{volume of water}} = \underline{\qquad\qquad} \text{ g/mL}$$

16. Combine the oil and water in the clear cup, and record your observations in your lab report.
17. Clean up your materials, and wash your hands before leaving the lab.

Analysis and Conclusions

1. Graph the data you collected in Part A. Plot time on the *x*-axis and temperature on the *y*-axis.
2. Based on your data from Part A, what is the relationship between color and heat absorption?
3. How might the color of the clothes you wear affect how warm you are on a sunny 90° day?
4. In Part B, what did you observe when you combined the oil and water in the clear cup? Relate your observation to the densities that you calculated.
5. What could you infer about the value for the density of ice if you observe it to float in water?
6. How would your calculated values for density be affected if you misread the volume measurement on the graduated cylinder?

Further Inquiry

Pumice is a volcanic rock that has a density less than 1.00 g/cm^3. How would you prove this if you did not have a balance to weigh the pumice? (Hint: The density of water is 1.00 g/cm^3.)