There are approximately 200 billion stars that make up the Milky Way galaxy.

Humans are 1 out of an estimated 100 million species of life on Earth.

The human brain is made up of 100 billion neurons.
Why is observation important in science?

Scientists use a planned, organized approach to solving problems. A key element of this approach is gathering information through detailed observations. Scientists extend their ability to observe by using scientific tools and techniques.

**Procedure**

1. Read and complete the lab safety form.
2. Pick an unshelled peanut from the container of peanuts. Carefully observe the peanut using your senses and available tools. Record your observations.
3. Do not change or mark the peanut. Return your peanut to the container.
4. After the peanuts are mixed, locate your peanut based on your recorded observations.

**Analysis**

1. List the observations that were the most helpful in identifying your peanut. Which were the least helpful?
2. Classify your observations into groups.
3. Justify why it was important to record detailed observations in this lab. Infer why observations are important in biology.

Visit biologygmh.com to:
- study the entire chapter online
- explore the Interactive Time Line, Concepts in Motion, Interactive Tables, Microscopy Links, Virtual Labs, and links to virtual dissections
- access Web links for more information, projects, and activities
- review content online with Interactive Tutor and take Self-Check Quizzes

**Biologists**

Make the following Foldable to help you organize examples of things biologists do.

**STEP 1** Stack three sheets of notebook paper 2.5 cm apart as illustrated.

**STEP 2** Bring up the bottom edges and fold to form five tabs of equal size.

**STEP 3** Rotate your Foldable 180°. Staple along the folded edge to secure all sheets. Label the tabs Some Roles of Biologists, Study the diversity of life, Research diseases, Develop technology, Improve agriculture, and Preserve the environment.

**Some Roles of Biologists**

- Study the diversity of life
- Research diseases
- Develop technology
- Improve agriculture
- Preserve the environment

**Foldables**

Use this Foldable with Section 1.1. As you study the section, summarize these examples of the different roles of biologists.
Section 1.1

Objectives

◗ Define biology.
◗ Identify possible benefits from studying biology.
◗ Summarize the characteristics of living things.

Review Vocabulary

evironment: the living and nonliving things that surround an organism and with which the organism interacts

New Vocabulary

biology
organism
organization
growth
development
reproduction
species
stimulus
response
homeostasis
adaptation

Introduction to Biology

All living things share the characteristics of life.

Real-World Reading Link  Think about several different living or once-living things. The bacteria that live in your small intestine, the great white sharks in the ocean, a field of corn, a skateboarder, and the extinct *Tyrannosaurus rex* differ in structure and function. Who discovered what all these things have in common?

The Science of Life

Before Jane Goodall, pictured in Figure 1.1, arrived in Gombe Stream National Park in Tanzania in 1960 to study chimpanzees, the world of chimpanzees was a mystery. Jane’s curiosity, determination, and patience over a long period of time resulted in the chimpanzee troop’s acceptance of her presence so that she was able to observe their behavior closely.

When people study living things or pose questions about how living things interact with the environment, they are learning about biology—the science of life. Life flourishes on Earth, and a curiosity about life is a major reason why some people study biology.

In biology, you will study the origins and history of life and once-living things, the structures of living things, how living things interact with one another, and how living things function. This will help you understand how humans have a vital role in preserving the natural environment and sustaining life on Earth.

Have you ever hiked in a forest and wondered why different trees have leaves with different shapes? Maybe you have watched an ant quickly cross the sidewalk toward a breadcrumb and wondered how the ant knew that the breadcrumb was there. When you ask these questions, you are observing, and you are asking questions about life.
What do biologists do?

Imagine being the first person to look into a microscope and discover cells. What do you think it was like to find the first dinosaur fossils that indicated feathers? Who studies how organisms, including the marbled stargazer fish in Figure 1.2, obtain food? Will the AIDS virus be defeated? Is there life on other planets or anywhere else in the universe? The people who study biology—biologists—make discoveries and seek explanations by performing laboratory and field investigations. Throughout this textbook, you will discover what biologists in the real world do and you will learn about careers in biology.

Study the diversity of life  Jane Goodall, shown in Figure 1.1, studied chimpanzees in their natural environments. She asked questions such as, “How do chimpanzees behave in the wild?” and “How can chimpanzee behaviors be characterized?” From her recorded and detailed observations, sketches, and maps of chimpanzees’ daily travels, Goodall learned how chimpanzees grow and develop and how they gather food. She studied and recorded chimpanzee reproductive habits and their aggressive nature. She learned that they use tools. Goodall’s data provided a better understanding of chimpanzees, and as a result, scientists know how to best protect them.

Research diseases  Mary-Claire King also studied chimpanzees—not their behavior but their genetics. In 1973, she established that the genomes (genes) of chimpanzees and humans are 99 percent identical. Her work currently focuses on unraveling the genetic basis of breast cancer, a disease that affects one out of eight women.

Many biologists research diseases. Questions such as “What causes the disease?”, “How does the body fight the disease?”, and “How does the disease spread?” often guide biologists’ research. Biologists have developed vaccines for smallpox, chickenpox, and diphtheria, and currently, some biologists are researching the development of a vaccine for HIV. Other biologists focus their research on diseases such as diabetes, avian flu, anorexia, and alcoholism, or on trauma such as spinal cord injuries that result in paralysis. Biologists worldwide are researching new medicines for such things as lowering cholesterol levels, fighting obesity, reducing the risk of heart attacks, and preventing Alzheimer’s disease.

Develop technologies  When you hear the word technology, you might think of high-speed computers, cell phones, and DVD players. However, technology is defined as the application of scientific knowledge to solve human needs and to extend human capabilities. Figure 1.3 shows how new technology—a “bionic” hand—can help someone who has lost an arm.
For example, Charles Drew was a doctor who pioneered methods to separate blood plasma from blood cells and safely store and transport blood plasma for transfusions. His research led to blood banks that saved soldiers during World War II and helps countless patients today.

Biologists today continue to discover new ways to improve and save lives. For example, the field of bioengineering applies knowledge gained from studying the function of living systems to the design of mechanical devices such as artificial limbs. In addition, biologists in the field of biotechnology research cells, DNA, and living systems to discover new medicines and medical treatments.

**Improve agriculture** Some biologists study the possibilities of genetically engineering plants to grow in poor soils or to resist insects, fungal infections, or frost damage. Other biologists research agricultural issues to improve food production to feed the world’s growing human population.

Joanne Chory, a plant biologist shown in Figure 1.4, studies mustard plants’ sensitivity to light and their responses when exposed to different light sources, different times of exposure, and other conditions. Because of her work with plant growth hormones and light, agriculturists might be able to increase the amount of food produced from crops or to grow crops in areas where they normally would not grow.

**Preserve the environment** Environmental biologists seek to prevent the extinction of animals and plants by developing ways to protect them. Some biologists study the reproductive strategies of endangered species while they are in captivity. Other biologists work in nature preserves that provide safe places for endangered species to live, reproduce, and have protection against poachers.

Lee Anne Martinez is an ecologist who worked to protect the environment where outdoor toilets are common. She helped people in rural Africa construct composting toilets that use no water. The composted waste from the toilets can be added to soil to improve it for agricultural use.

### The Characteristics of Life

Have you ever tried to define the word *alive*? If you were to watch a grizzly bear catch a salmon from a river, you obviously would conclude that the bear and salmon are both alive. Is fire alive? Fire moves, increases in size, has energy, and seems to reproduce, but how does fire differ from the bear and salmon?

Over time and after many observations, biologists concluded that all living things have certain characteristics, as listed in Table 1.1. An **organism** is anything that has or once had all these characteristics.

**Made of one or more cells** Have you ever had strep throat? It probably was caused by a group A streptococcal bacteria, such as the *Streptococcus pyogenes* shown in Figure 1.5. A bacterium is unicellular—it has just one cell—yet it displays all the characteristics of life just like a skin cell on your body or a cell in a plant’s leaf. Humans and plants are multicellular—they have many cells.
### Table 1.1 Characteristics of Living Organisms

<table>
<thead>
<tr>
<th>Characteristic of Life</th>
<th>Example</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Made of one or more cells</td>
<td><img src="image" alt="Cell Image" /></td>
<td>All organisms are made of one or more cells. The cell is the basic unit of life. Some organisms, such as the <em>Paramecium sp.</em>, are unicellular.</td>
</tr>
<tr>
<td>Displays organization</td>
<td><img src="image" alt="Organization Image" /></td>
<td>The levels of organization in biological systems begin with atoms and molecules and increase in complexity. Each organized structure in an organism has a specific function. The structure of an anteater’s snout relates to one of its functions—a container for the anteater’s long tongue.</td>
</tr>
<tr>
<td>Grows and develops</td>
<td><img src="image" alt="Growth Image" /></td>
<td>Growth results in an increase in mass. Development results in different abilities. A bullfrog tadpole grows and develops into an adult bullfrog.</td>
</tr>
<tr>
<td>Reproduces</td>
<td><img src="image" alt="Reproduction Image" /></td>
<td>Organisms reproduce and pass along traits from one generation to the next. For a species like the koala to continue to exist, reproduction must occur.</td>
</tr>
<tr>
<td>Responds to stimuli</td>
<td><img src="image" alt="Stimulus Image" /></td>
<td>Reactions to internal and external stimuli are called responses. This cheetah responds to the need for food by chasing a gazelle. The gazelle responds by running away.</td>
</tr>
<tr>
<td>Requires energy</td>
<td><img src="image" alt="Energy Image" /></td>
<td>Energy is required for all life processes. Many organisms, like this squirrel, must take in food. Other organisms make their own food.</td>
</tr>
<tr>
<td>Maintains homeostasis</td>
<td><img src="image" alt="Homeostasis Image" /></td>
<td>All organisms keep internal conditions stable by a process called homeostasis. For example, humans perspire to prevent their body temperature from rising too high.</td>
</tr>
<tr>
<td>Adaptations evolve over time</td>
<td><img src="image" alt="Adaptation Image" /></td>
<td>Adaptations are inherited changes that occur over time that help the species survive. Tropical orchids have roots that are adapted to life in a soil-less environment.</td>
</tr>
</tbody>
</table>
Cells are the basic units of structure and function in all living things. For example, each heart cell has a structure that enables it to contribute to the heart’s function—continually pumping blood throughout the body. Likewise, each cell in a tree’s roots has a structure that enables it to help anchor the tree in the ground and to take in water and dissolved minerals from the surrounding soil.

Displays organization Think of all the people in your high school building each day. Students, faculty, counselors, administrators, building service personnel, and food service personnel are organized based on the different tasks they perform and the characteristics they share. For example, the students are designated freshmen, sophomores, juniors, and seniors based on age and coursework.

Living things also display organization, which means they are arranged in an orderly way. The Paramecium in Table 1.1 is made up of one cell, yet that cell is a collection of organized structures that carries on life functions. Each of those structures is composed of atoms and molecules. The many cells that make up the robin chicks in Figure 1.6 also contain structures made of atoms and molecules. However, in multicellular organisms, specialized cells are organized into groups that work together called tissues. These tissues are organized into organs, which carry on functions such as digestion and reproduction. Organ systems work together to support an organism. You will learn in Chapter 3 how individual organisms are organized and supported by the biosphere.

Figure 1.6 In less than a month, these robin chicks grow and develop from helpless chicks to birds capable of flying. Infer how the robins have developed in other ways.

In less than a month, these robin chicks grow and develop from helpless chicks to birds capable of flying.

Infer how the robins have developed in other ways.

---

Observe Characteristics of Life

Is it living or nonliving? In this lab, you will observe several objects to determine if they are living or nonliving.

**Procedure**

1. Read and complete the lab safety form.
2. Create a data table with four columns titled Object, Prediction, Characteristic of Life, and Evidence.
3. Your teacher will provide several objects for observation. List each object in your table. Predict whether each object is living or nonliving.
4. Carefully observe each object. Discuss with your lab partner what characteristics of life it might exhibit.
5. Use Table 1.1 to determine whether each object is living or nonliving. List the evidence in your data table.

**Analysis**

1. Compare and contrast your predictions and observations.
2. Explain why it was difficult to classify some objects as living or nonliving.
Grows and develops  Most organisms begin as one cell. Growth results in the addition of mass to an organism and, in many organisms, the formation of new cells and new structures. Even a bacterium grows. Think about how you have grown throughout your life.

Robin chicks, like those in Figure 1.6, cannot fly for the first few weeks of their lives. Like most organisms, robins develop structures that give them specific abilities, such as flying. Development is the process of natural changes that take place during the life of an organism.

Reproduces  Most living things are the result of reproduction—the production of offspring. Reproduction is not an essential characteristic for individual organisms. Many pets are spayed or neutered to prevent unwanted births. Obviously, these pets can still live even though they cannot reproduce. However, if a species is to continue to exist, then members of that species must reproduce. A species is a group of organisms that can breed with one another and produce fertile offspring. If the individuals of a species do not reproduce, then when the last individual of that species dies, the species becomes extinct.

Responds to stimuli  An organism’s external environment includes all things that surround it, such as air, water, soil, rocks, and other organisms. An organism’s internal environment is all things inside it. Anything that is part of either environment and causes some sort of reaction by the organism is called a stimulus (plural, stimuli). The reaction to a stimulus is a response. For example, if a shark smells blood in the ocean, it will respond quickly by moving toward the blood and attacking any organism present. Plants also respond to their environments, but they do so more slowly than most other organisms. If you have a houseplant and you place it near a sunny window, it will grow toward the window in response to the light. How does the Venus flytrap in Figure 1.7 respond to stimuli?

Being able to respond to the environment is critical for an organism’s safety and survival. If an organism is unable to respond to danger or to react to potential enemies, it might not live long enough to reproduce.

CAREERS IN BIOLOGY

Biology Teacher  An enthusiasm for biology is one of the many reasons people become biology teachers. Other than courses in biological sciences, prospective biology teachers might take classroom management, teaching methods, and other courses needed to develop teaching skills. For more information on biology careers, visit biologygmh.com.
Requires energy  Living things need sources of energy to fuel their life functions. Living things get their energy from food. Most plants and some unicellular organisms use light energy from the Sun to make their own food and fuel their activities. Other unicellular organisms can transform the energy in chemical compounds to make their food.

Organisms that cannot make their own food, such as animals and fungi, get energy by consuming other organisms. Some of the energy that an organism takes in is used for growth, development, and maintaining homeostasis. However, most of the energy is transformed into thermal energy and is radiated to the environment as heat.

Maintains homeostasis  Regulation of an organism’s internal conditions to maintain life is called homeostasis (hoh mee oh STAY sus). Homeostasis occurs in all living things. If anything happens within or to an organism that affects its normal state, processes to restore the normal state begin. If homeostasis is not restored, death might occur.

Adaptations evolve over time  Many trees in rain forests have leaves with drip tips, like the one shown in Figure 1.8. Water runs off more easily and quickly from leaves with drip tips. Harmful molds and mildews will not grow on dry leaves. This means a plant with dry leaves is healthier and has a better chance to survive. Drip tips are an adaptation to the rain forest environment. An adaptation is any inherited characteristic that results from changes to a species over time. Adaptations like rain forest trees with drip tips enable species to survive and, therefore, they are better able to pass their genes to their offspring.

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**Figure 1.8** The structure of a drip-tip leaf is an adaptation to rainy environments.

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**Section 1.1 Assessment**

**Section Summary**

- Biology is the science of life.
- Biologists study the structure and function of living things, their history, their interactions with the environment, and many other aspects of life.
- All organisms have one or more cells, display organization, grow and develop, reproduce, respond to stimuli, use energy, maintain homeostasis, and have adaptations that evolve over time.

**Understand Main Ideas**

1. **MAIN Idea** Describe four characteristics used to identify whether something is alive.
2. **Explain** why cells are considered the basic units of living things.
3. **List** some of the benefits of studying biology.
4. **Differentiate** between response and adaptation.

**Think Scientifically**

5. **MATH in Biology** Survey students in your school—biology students and non-biology students—and adults. Have participants choose characteristics of life from a list of various characteristics and rank their choices from most important to least important. Record, tabulate, average, and graph your results. Prepare a report that summarizes your findings.
Section 1.2

Objectives

- **Explain** the characteristics of science.
- **Compare** something that is scientific with something that is pseudoscientific.
- **Describe** the importance of the metric system and SI.

**Review Vocabulary**

*investigation*: a careful search or examination to uncover facts

**New Vocabulary**

- science
- theory
- peer review
- metric system
- SI
- forensics
- ethics

### The Nature of Science

**Main Idea**  
Science is a process based on inquiry that seeks to develop explanations.

**Real-World Reading Link**  
If you see a headline that reads “Alien baby found in campsite,” how do you know whether you should believe it or not? How do you know when to trust claims made in an advertisement on television or the Internet, or in a newspaper or magazine? What makes something science-based?

### What is science?

Have you ever wondered how science is different from art, music, and writing? **Science** is a body of knowledge based on the study of nature. Biology is a science, as are chemistry, physics, and Earth science, which you might also study during high school. The nature, or essential characteristic, of science is scientific inquiry—the development of explanations. Scientific inquiry is both a creative process and a process rooted in unbiased observations and experimentation. Sometimes scientists go to extreme places to observe and experiment, as shown in Figure 1.9.

**Relies on evidence**  
Has anyone ever said to you, “I have a theory about that?” That person probably meant that he or she had a possible explanation about something. Scientific explanations combine what is already known with consistent evidence gathered from many observations and experiments.

When enough evidence from many related investigations supports an idea, scientists consider that idea a **theory**—an explanation of a natural phenomenon supported by many observations and experiments over time. For example, what happens when you throw a ball up in the air anywhere on Earth? The results are always the same. Scientists explain how the ball is attracted to Earth in the theory of universal gravitation. In biology, two of the most highly regarded theories are the cell theory and the theory of evolution. Both theories are based on countless observations and investigations, have extensive supporting evidence, and enable biologists to make accurate predictions.

![Figure 1.9](https://example.com/figure1.9)  
This volcanologist is near molten lava flowing from Mount Etna. Lava temperatures can reach 750°C.
Figure 1.11 Milestones in Biology

Major events and discoveries in the past century greatly contributed to our understanding of biology today.

In the eighteenth and nineteenth centuries, many people practiced physiognomy (fih zee AHG nuh mee)—judging someone’s character or personality based on physical features, especially facial features. Phrenology (frih NAH luh jee), the practice of reading the bumps on a person’s head, illustrated in Figure 1.10, also is a type of physiognomy. Physiognomy often was used to determine whether individuals were appropriate for employment and other roles in society, or whether they had criminal tendencies. In fact, Charles Darwin almost did not get to take his famous voyage on the HMS Beagle because of the shape of his nose. Physiognomy was used and accepted even though there was no scientific evidence to support it.

Although physiognomy was based on observations and what was known at the time, it was not supported by scientific explanation. Physiognomy is considered a pseudoscience (soo doh SI uhnts). Pseudosciences are those areas of study that try to imitate science, often driven by cultural or commercial goals. Astrology, horoscopes, psychic reading, tarot card reading, face reading, and palmistry are pseudosciences. They do not provide science-based explanations about the natural world.

Reading Check Describe one way that science and pseudoscience differ.

Expands scientific knowledge How can you know what information is science-based? Most scientific fields are guided by research that results in a constant reevaluation of what is known. This reevaluation often leads to new knowledge that scientists then evaluate. The search for new knowledge is the driving force that moves science forward. Nearly every new finding, like the discoveries shown in Figure 1.11, causes scientists to ask more questions that require additional research.

With pseudoscience, little research is done. If research is done, then often it is simply to justify existing knowledge rather than to extend the knowledge base. Pseudoscientific ideas generally do not ask new questions or welcome more research.

1953 The structure of DNA is identified due to research by Rosalind Franklin, Maurice Wilkins, James Watson, and Francis Crick. Chapter 12

1912–1939 Writings on cell biology by Ernest Everett Just influence the use of scientific methods in biology. Chapter 7

1962 Rachel Carson’s book Silent Spring, about the environmental dangers of pollution and pesticide use, is published. Chapter 2
Challenges accepted theories  Scientists welcome debate about one another’s ideas. They regularly attend conferences and meetings where they discuss new developments and findings. Often, disagreements occur among scientists. Then additional investigations and/or experiments are done to substantiate claims.

Sciences advance by accommodating new information as it is discovered. For example, since the emergence of AIDS in the 1980s, our understanding of HIV, our ideas about how HIV is transmitted, the manner in which we treat AIDS, and the ways in which we educate people about the disease have changed dramatically due to new information from many scientific studies.

Questions results  Observations or data that are not consistent with current scientific understanding are of interest to scientists. These inconsistencies often lead to further investigations. For example, early biologists grouped bats with birds because both had wings. Further study showed that bat wings are more similar to mammalian limbs than they are to bird wings, as shown in Figure 1.12. This led to an examination of the anatomy, genes, and proteins of rats and bats. The relationship was confirmed, and scientists established that bats were more closely related to mammals than birds. With pseudoscience, observations or data that are not consistent with beliefs are discarded or ignored.

Figure 1.12  The structure of a bat’s wing is more like that of a human arm than a bird’s wing.
Tests claims Whenever biologists engage in research, they use standard experimental procedures. Science-based information makes claims based on a large amount of data and observations obtained from unbiased investigations and carefully controlled experimentation. Conclusions are reached from the evidence. However, pseudoscientists often make claims that cannot be tested. These claims often are mixtures of fact and opinion.

Undergoes peer review Before it is made public, science-based information is reviewed by scientists’ peers—scientists who are working in the same field of study. Peer review is a process by which, in science, the procedures used during an experiment and the results are evaluated by other scientists who are in the same field or who are conducting similar research.

Uses metric system Scientists can repeat the work of others as part of a new experiment. Using the same system of measurements helps make this possible. Most scientists use the metric system when collecting data and performing experiments. The metric system uses units with divisions that are powers of ten. The General Conference of Weights and Measures established the unit standards of the metric system in 1960. The system is called the International System of Units, commonly known as SI. In biology, the SI units you will use most often are meter (to measure length), gram (to measure mass), liter (to measure volume), and second (to measure time).

**DATA ANALYSIS LAB 1.1**

**Based on Real Data**

**Peer Review**

Can temperature be predicted by counting cricket chirps? Many outdoors enthusiasts claim that air temperature (°F) can be estimated by adding the number 40 to the number of cricket chirps counted in 15 seconds. Is there scientific evidence to support this idea?

**Data and Observations**

A group of students collected the data at right. They concluded that the claim is correct.

**Think Critically**

1. **Convert** the number of chirps per minute to the number of chirps per 15 seconds.
2. **Plot** the number of chirps per 15-second interval versus Fahrenheit temperature. Draw the best-fit line on your graph. Refer to the Skillbuilder Handbook, pages 1115–1118, for help with graphs.
3. **Write** the equation for the best-fit line.
4. **Peer review** Do the results support the students’ conclusion? Explain.

**Effect of Temperature on Chirping**

<table>
<thead>
<tr>
<th>Temperature (°F)</th>
<th>Cricket Chirps (per min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>68</td>
<td>121</td>
</tr>
<tr>
<td>75</td>
<td>140</td>
</tr>
<tr>
<td>80</td>
<td>160</td>
</tr>
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<td>81</td>
<td>166</td>
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<td>84</td>
<td>181</td>
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<td>189</td>
</tr>
<tr>
<td>91</td>
<td>200</td>
</tr>
<tr>
<td>94</td>
<td>227</td>
</tr>
</tbody>
</table>

Science in Everyday Life

There is widespread fascination with science. Popular television programs about crime are based on forensics, which is the field of study that applies science to matters of legal interest. The media is filled with information on flu epidemics, the latest medical advances, discoveries of new species, and technologies that improve or extend human lives. Clearly, science is not limited to the laboratory. The results of research go far beyond reports in scientific journals and meetings.

Science literacy In order to evaluate the vast amount of information available in print, online, and on television, and to participate in the fast-paced world of the twenty-first century, each of us must be scientifically literate. A person who is scientifically literate combines a basic understanding of science and its processes with reasoning and thinking skills.

Many of the issues that are faced every day relate to the world of biology. Drugs, alcohol, tobacco, AIDS, mental illness, cancer, heart disease, and eating disorders provide subjects for biological research worldwide. Environmental issues such as global warming, pollution, deforestation, the use of fossil fuels, nuclear power, genetically modified foods, and conserving biodiversity are issues that you and future generations will face. Also, genetic engineering, cloning—producing genetically identical individuals, genetic screening—searching for genetic disorders in people, euthanasia (yoo thuh NAY zhuh)—permitting a death for reasons of mercy, and cryonics (kri AH niks)—freezing a dead person or animal with the hope of reviving it in the future—all involve ethics, which is a set of moral principles or values. Ethical issues must be addressed by society based on the values it holds important.

Scientists provide information about the continued expansion of science and technology. As a scientifically literate adult, you will be an educated consumer who can participate in discussions about important issues and support policies that reflect your views. Who knows? You might serve on a jury where DNA evidence, like that shown in Figure 1.13, is presented. You will need to understand the evidence, comprehend its implications, and decide the outcome of the trial.

Section 1.2 Assessment

Section Summary

Science is the study of nature and is rooted in observation and experimentation.

Pseudoscience is not based on standard scientific research; it does not deal with testable questions, welcome critical review, or change its ideas when new discoveries are made.

Science and ethics affect issues in health, medicine, the environment, and technology.

Understand Main Ideas

1. MAIN IDEA Describe the characteristics of science.
2. Define scientific theory.
3. Defend the use of the metric system to a scientist who does not want to use it.
4. Compare and contrast science with pseudoscience.

Think Scientifically

5. WRITING in Biology Predict what might happen to a population of people who do not understand the nature of science. Use examples of key issues facing our society.

6. MATH in Biology One kilogram equals 1000 grams. One milligram equals 0.001 grams. How many milligrams are in one kilogram?
Section 1.3

Objectives

- **Describe** the difference between an observation and an inference.
- **Differentiate** among control, independent variable, and dependent variable.
- **Identify** the scientific methods a biologist uses for research.

Review Vocabulary

**theory**: an explanation of a natural phenomenon supported by many observations and experiments over time

New Vocabulary

observation 
inference 
scientific method 
experiment 
serendipity 
control group 
experimental group 
independent variable 
dependent variable 
constant 
data 
safety symbol

Methods of Science

**Main Idea** Biologists use specific methods when conducting research.

**Real-World Reading Link** What do you do to find answers to questions? Do you ask other people, read, investigate, or observe? Are your methods haphazard or methodical? Over time, scientists have established standard procedures to find answers to questions.

**Ask a Question**

Imagine that you saw an unfamiliar bird in your neighborhood. You might develop a plan to observe the bird for a period of time. Scientific inquiry begins with **observation**, a direct method of gathering information in an orderly way. Often, observation involves recording information. In the example of your newly discovered bird, you might take photographs or draw a picture of it. You might write detailed notes about its behavior, including when and what it ate.

Science inquiry involves asking questions and processing information from a variety of reliable sources. After observing the bird, you might combine what you know with what you have learned and begin a process of making logical conclusions. This process is called making **inferences**, or inferring. For instance, if you saw a photo of a bird similar to the unfamiliar bird in your neighborhood, you might infer that your bird and the bird in the photo are related. **Figure 1.14** illustrates how a field guide might be helpful in making inferences.

**Scientific methods** Biologists work in different places to answer their questions. For example, some biologists work in laboratories, perhaps developing new medicines, while others work outdoors in natural settings. No matter where they work, biologists all use similar methods to gather information and to answer questions. These methods sometimes are referred to as **scientific methods**, illustrated in **Figure 1.15**. Even though scientists do not use scientific methods in the same way each time they conduct an experiment, they observe and infer throughout the entire process.

![Figure 1.14 Scientists might use a field guide to help them identify or draw conclusions about things they observe in nature, such as this peregrine falcon.](image-url)
Figure 1.15
The way that scientists answer questions is through an organized series of events called scientific methods. There are no wrong answers to questions, only answers that provide scientists with more information about those questions. Questions and collected information help scientists form hypotheses. As experiments are conducted, hypotheses might or might not be supported.

Visualizing Scientific Methods

Interactive Figure To see an animation of scientific methods, visit biologygmh.com
Form a Hypothesis

Imagination, curiosity, creativity, and logic are key elements of the way biologists approach their research. In 1969, the U.S. Air Force asked Dr. Ron Wiley to investigate how to enhance a pilot’s ability to endure the effects of an increase in gravity (g-force) while traveling at high speed in an F-16 aircraft. It was known that isometrics, which is a form of exercise in which muscles are held in a contracted position, raised blood pressure. Wiley formed the hypothesis that the use of isometric exercise to raise blood pressure during maneuvers might increase tolerance to g-force and prevent blackouts. A hypothesis (hi PAH thuh sus) is a testable explanation of a situation.

Before Wiley formed his hypothesis, he made inferences based on his experience as a physiologist, what he read, discussions with Air Force personnel, and previous investigations. He did find that increasing a pilot’s blood pressure could help the pilot withstand g-forces. But he also made an unexpected discovery.

During his study, Dr. Wiley discovered that isometric exercise decreased the resting blood pressure of the pilots. As a result, weight lifting and muscle-strengthening exercises are recommended today to help people lower blood pressure. Serendipity is the occurrence of accidental or unexpected but fortunate results. There are other examples of serendipity throughout science. For example, the discovery of penicillin was partially due to serendipity.

When a hypothesis is supported by data from additional investigations, usually it is considered valid and is accepted by the scientific community. If not, the hypothesis is revised, and additional investigations are conducted.

Collect the Data

Imagine that while in Alaska on vacation, you noticed various kinds of gulls. You saw them nesting high in the cliffs, and you wondered how they maintain their energy levels during their breeding season. A group of biologists wondered the same thing and did a controlled experiment using gulls known as black-legged kittiwakes shown in Figure 1.16. When a biologist conducts an experiment, he or she investigates a phenomenon in a controlled setting to test a hypothesis.

Figure 1.16 This colony of black-legged kittiwakes along the Alaskan coast includes nesting pairs.
Controlled experiments  The biologists inferred that the kittiwakes would have more energy if they were given extra feedings while nesting. The biologists’ hypothesis was that the kittiwakes would use the extra energy to lay more eggs and raise more chicks.

Biologists found nesting pairs of kittiwakes in Alaska that were similar in mass, age, size, and all other features. They set up a control group and an experimental group. A control group in an experiment is a group used for comparison. In this experiment, the kittiwakes not given the supplemental feedings made up the control group. The experimental group is the group exposed to the factor being tested. The group of kittiwakes getting the supplemental feedings made up the experimental group.

Experimental design  When scientists design a controlled experiment, only one factor can change at a time. It is called the independent variable because it is the tested factor and it might affect the outcome of the experiment. In the kittiwakes experiment, the supplemental feeding was the independent variable. During an experiment, scientists measure a second factor. This factor is the dependent variable. It results from or depends on changes to the independent variable. The change in the kittiwakes’ energy levels, as measured in reproductive output, was the dependent variable. A constant is a factor that remains fixed during an experiment while the independent and dependent variables change.

Data gathering  As scientists test their hypotheses, they gather data—information gained from observations. The data can be quantitative or qualitative.

Data collected as numbers are called quantitative data. Numerical data can be measurements of time, temperature, length, mass, area, volume, density, or other factors. For example, when the biologists worked with the kittiwakes, they collected numerical data about the birds’ energy levels.

Qualitative data are descriptions of what our senses detect. Often, qualitative data are interpreted differently because everyone does not sense things in the same way. However, many times it is the only collectible data.

Investigations  Biologists conduct other kinds of scientific inquiry. They can engage in studies during which they investigate the behavior of organisms. Other biologists spend their careers discovering and identifying new species. Some biologists use computers to model the natural behavior of organisms and systems. In investigations such as these, the procedure involves observation and collection of data rather than controlled manipulation of variables.

MiniLab 1.2
Manipulate Variables

How does a biologist establish experimental conditions?  In a controlled experiment, a biologist develops an experimental procedure designed to investigate a question or problem. By manipulating variables and observing results, a biologist learns about relationships among factors in the experiment.

Procedure
1. Read and complete the lab safety form.
2. Create a data table with the columns labeled Control, Independent Variable, Constants, Hypothesis, and Dependent Variable.
3. Obtain a printed maze. Seated at your desk, have a classmate time how long it takes you to complete the maze. Record this time on the chart. This is the control in the experiment.
4. Choose a way to alter experimental conditions while completing the same maze. Record this as the independent variable.
5. In the column labeled Constants, list factors that will stay the same each time the experiment is performed.
6. Form a hypothesis about how the independent variable will affect the time it takes to complete the maze.
7. After your teacher approves your plan, carry out the experiment. Record the time required to complete the maze as the dependent variable.
8. Repeat Steps 3–7 as time allows.
9. Graph the data. Use the graph to analyze the relationship between the independent and dependent variables.

Analysis
1. Explain the importance of the control in this experiment.
2. Error Analysis  By completing the maze more than once, you introduced another variable, which likely affected the time required to complete the maze. Would eliminating this variable solve the problem? Explain.
After analyzing the data from an investigation, a biologist usually asks, “Has my hypothesis been supported?” He or she then might ask, “Are more data needed?” or “Are different procedures needed?” Often, the investigation must be repeated many times to obtain consistent results.

As biologists look for explanations, patterns generally are noted that help to explain the data. A simple way to display the data is in a table or on a graph, such as the ones in Figure 1.17, which describe the change in mass over time of a lizard called an anole. The graph of the data makes the pattern easier to grasp. In this case, there is a regular pattern. Notice that the mass increases over a three-day period and then levels off for three days before increasing again. For more review about making graphs, refer to the Skillbuilder Handbook, pp. 1115–1118.

Because biologists often work in teams, meetings are held to discuss ongoing investigations, to analyze the data, and to interpret the results. The teams continue to examine their research plan to be certain they avoid bias, repeat their trials, and collect a large enough sample size. Analysis of the data might lead to a conclusion that the hypothesis has been supported. It also could lead to additional hypotheses, to further experimentation, or to general explanations of nature. Even when a hypothesis has not been supported, it is valuable.

### Report Conclusions

Biologists report their findings and conclusions in scientific journals. Before a scientist can publish in a journal, the work is reviewed by peers. The reviewers examine the paper for originality, competence of the scientific method used, and accuracy. They might find fault with the reasoning or procedure, or suggest other explanations or conclusions. If the reviewers agree on the merit of the paper, then the paper is published for review by the public and use by other scientists.

**Reading Check**  
**Infer** How does the hypothesis guide data collection and interpretation?
Student Scientific Inquiry

You might be given many opportunities during your study of biology to do your own investigations and experiments. You might receive a lab assignment that spells out a series of steps to follow or you might design your own procedure. Whether you are planning a lab report or an entire procedure and its lab report, be sure to ask yourself questions like those in Figure 1.18. For additional help with setting up experiments and using equipment, go to Investigation and Experimentation on pp. xxvii–xli of this textbook.

Lab safety  During biology labs, you will be alerted of possible safety hazards by warning statements and safety symbols. A safety symbol is a logo designed to alert you about a specific danger. Always refer to the safety symbols chart at the front of this book before beginning any field investigation or lab activity. Carefully read the meaning of each lab’s safety symbols. Also, learn the location in the classroom of all safety equipment and how and when to use it. You are responsible for being safe at all times to protect yourself and your classmates.

Figure 1.18 To ask meaningful questions, form hypotheses, and conduct careful experiments, develop research plans based on scientific methods. Use your lab report to list your procedure, record your data, and report your conclusions.

Section 1.3 Assessment

Understanding Main Ideas

1. **MAIN IDEA** Describe how a biologist’s research can proceed from an idea to a published article.
2. **State** why an observation cannot be an inference.
3. **Indicate** the differences in the ways that data can be collected in biological research.
4. **Differentiate** between independent variables and dependent variables.

Think Scientifically

5. **Design** a controlled experiment to determine whether earthworms are more attracted to perfume or to vinegar.
6. **Form a hypothesis** about one of the characteristics of life you studied in Section 1.1 and design a research project to test it. What organism would you study? What questions would you ask?
Cancer Research

A whole new world  From the first time that she peered into a microscope and saw a tiny, fascinating new world, Jewell Plummer Cobb knew that a career in biology was for her. It is no surprise that biology would fascinate her. Cobb’s father was a physician, her mother was a teacher, and science often was the topic of dinner conversation. Cobb became a groundbreaking scientist, as well as a college dean, recipient of almost two dozen honorary degrees, and a champion of minority and women’s rights.

Individualized chemotherapy  In 1950, Dr. Cobb joined the Harlem Hospital Cancer Research Foundation, where she pioneered chemotherapy research with Jane Cooke Wright. The two scientists determined that there should be a way to tailor therapeutic drug dosages for individuals. Cobb designed new ways to grow tissue samples so that their responses to different drug doses could be observed under a microscope and recorded using time-lapse photography. Cobb and Wright’s methods of documenting cellular responses to potentially toxic drugs paved the way for further research. Their work provided scientists with another tool that could be used in the development of new, more effective chemotherapy drugs.

Skin cancer  Although her research in New York was groundbreaking, Dr. Cobb did not find her niche in cancer research until 1952, when she received a grant from the National Cancer Institute. With this grant, she began her research on cancerous pigment cells and the possible role of melanin in protecting the skin from the Sun’s ultraviolet rays—a cancer-causing agent. Skin cancer, called melanoma, occurs more in Caucasians than in African Americans. Because African Americans have more melanin than Caucasians, Cobb wanted to know if the melanin had protective qualities.

To determine how melanin affected the outcome of radiation therapy in cancer treatments, she designed an experiment using black and white mice that were bred to develop melanoma tumors. Dr. Cobb took samples from tumors and separated the tissue with high melanin from the tissue with low melanin. She exposed both tissues to different doses of X rays to determine if melanin protected cells against the effects of X rays. Immediately after exposure, she implanted the tissues into cancer-free mice or grew them in test tubes. The black tissues survived greater X-ray doses than the white tissues. After examination with a microscope, she concluded that melanin protected cells from X-ray damage.

Research ways to diagnose, treat, and prevent melanoma continue. For example, immunotherapy uses the body’s own defenses to destroy cancer cells. A melanoma might be surgically removed from the skin or treated with chemotherapy or radiation. Immunotherapy often is combined with other forms of therapy to make them more effective or lessen side effects.

Jewell Plummer Cobb has devoted her life to cancer research.

For more information about the accomplishments of various scientists, visit biologygmh.com. Write an article about one individual. Include his or her contributions to science.
HOW CAN YOU KEEP CUT FLOWERS FRESH?

Background: When first cut from the garden, a bouquet of flowers looks healthy and has a pleasant aroma. Over time, the flowers droop and lose their petals. Leaves and stems below the water line begin to decay.

Question: What steps can I take to extend the freshness of cut flowers?

Possible Materials
Choose materials that would be appropriate for this lab.
- fresh cut flowers
- water
- vases
- scissors

Safety Precautions

Plan and Perform the Experiment
1. Read and complete the lab safety form.
2. Research strategies for extending the life of cut flowers. During your research, look for possible reasons why a specific strategy might be effective.
3. Form a hypothesis based on your research. It must be possible to test the hypothesis by gathering and analyzing specific data.
4. Design an experiment to test the hypothesis. Remember, the experiment must include an independent and dependent variable. Identify a control sample. List all factors that will be held constant.
5. Design and construct a data table.
6. Make sure your teacher approves your plan before you proceed.
7. Implement the experimental design. Organize the data you collect using a graph or chart.
8. Cleanup and Disposal Properly dispose of plant material. Wash hands thoroughly after handling plant material. Clean and return all lab equipment to the designated locations.

Analyze and Conclude
1. Describe the strategy tested by your hypothesis. Why did you choose this strategy to examine?
2. Explain how you established the control sample.
3. Interpret Data What trends or patterns do the data show?
4. Analyze What is the relationship between your independent and dependent variables?
5. Draw Conclusions Based on your data, describe one way to extend the freshness of cut flowers.
6. Error Analysis Critique your experimental design. Is it possible that any other variables were introduced? Explain. How could these variables be controlled?

Brochure
Compare the strategy for extending the freshness of cut flowers your group examined with strategies tested by other groups. Based on class results, create a brochure with the title “Make Cut Flowers Stay Beautiful Longer.” Include tips for extending the life of cut flowers. Share the brochure with community members who might benefit from this information. To learn more about extending the freshness of cut flowers, visit BioLabs at biologygmh.com.
### Vocabulary

#### Section 1.1 Introduction to Biology

- **adaptation** (p. 10)
- **biology** (p. 4)
- **development** (p. 9)
- **growth** (p. 9)
- **homeostasis** (p. 10)
- **organism** (p. 6)
- **organization** (p. 8)
- **reproduction** (p. 9)
- **response** (p. 9)
- **species** (p. 9)
- **stimulus** (p. 9)

**Main Idea**

All living things share the characteristics of life.

- Biologists study the structure and function of living things, their history, their interactions with the environment, and many other aspects of life.
- All organisms have one or more cells, display organization, grow and develop, reproduce, respond to stimuli, use energy, maintain homeostasis, and have adaptations that evolve over time.

#### Section 1.2 The Nature of Science

- **ethics** (p. 15)
- **forensics** (p. 15)
- **metric system** (p. 14)
- **peer review** (p. 14)
- **science** (p. 11)
- **SI** (p. 14)
- **theory** (p. 11)

**Main Idea**

Science is a process based on inquiry that seeks to develop explanations.

- Science is the study of nature and is rooted in observation and experimentation.
- Pseudoscience is not based on standard scientific research; it does not deal with testable questions, welcome critical review, or change its ideas when new discoveries are made.
- Scientists worldwide use SI.
- Science and ethics affect issues in health, medicine, the environment, and technology.

#### Section 1.3 Methods of Science

- **control group** (p. 19)
- **constant** (p. 19)
- **data** (p. 19)
- **dependent variable** (p. 19)
- **experiment** (p. 18)
- **experimental group** (p. 19)
- **hypothesis** (p. 18)
- **independent variable** (p. 19)
- **inference** (p. 16)
- **observation** (p. 16)
- **safety symbol** (p. 21)
- **scientific method** (p. 16)
- **serendipity** (p. 18)

**Main Idea**

Biologists use specific methods when conducting research.

- Observations are an orderly way of gathering information.
- Inferences are based on prior experiences.
- Controlled experiments involve a control group and an experimental group.
- An independent variable is the condition being tested, and the dependent variable results from the change to the independent variable.

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**Foldables**

**Brainstorm** other roles that biologists fulfill in addition to those discussed in Section 1.1. List these roles on the back of your Foldable and give examples.
Section 1.1

Vocabulary Review
Replace the underlined phrase with the correct vocabulary term from the Study Guide page.

1. The production of offspring is a characteristic of life that enables the continuation of a species.
2. The internal control of mechanisms allows for an organism’s systems to remain in balance.
3. The science of life involves learning about the natural world.

Understand Key Concepts
Use the graph below to answer question 4.

4. Which characteristic of life should be the title of this graph?
A. Cellular Basis C. Homeostasis
B. Growth D. Reproduction

5. Which best describes adaptation?
A. reproducing as a species
B. a short-term change in behavior in response to a stimuli
C. inherited changes in response to environmental factors
D. change in size as an organism ages

Constructed Response

6. Open Ended What is the role of energy in living organisms? Is it a more or less important role than other characteristics of life? Defend your response.

Think Critically

7. Evaluate how the contributions made by Goodall, Chory, and Drew reinforce our understanding of the characteristics of life.

8. Compare and contrast a response and an adaptation. Use examples from your everyday world in your answer.

Section 1.2

Vocabulary Review
Replace the underlined phrase with the correct vocabulary term from the Study Guide page.

9. the measurements based on powers of ten used by scientists when conducting research
10. a well-tested explanation that brings together many observations in science such as evolution, plate tectonics, biogenesis

Understand Key Concepts
Use the photo below to answer question 11.

11. Which SI base unit would be used to describe the physical characteristics of dolphins?
A. second C. inches
B. kilogram D. gallon

12. Which is true about scientific inquiry?
A. It poses questions about astrology.
B. It can be done only by one person.
C. It is resistant to change and not open to criticism.
D. It is testable.

Constructed Response

13. Short Answer Differentiate between pseudoscience and science.
Think Critically

14. **Evaluate** how technology impacts society in a positive and negative way at the same time.

### Section 1.3

**Vocabulary Review**

*Explain the differences between the terms in the following sets.*

15. observation, data

16. control group, experimental group

17. independent variable, dependent variable

**Understand Key Concepts**

18. Which describes this statement, “The frog is 4 cm long”?
   A. quantitative data  
   B. inference  
   C. control group  
   D. qualitative data

19. Which is a testable explanation?
   A. dependent variable  
   B. independent variable  
   C. hypothesis  
   D. observation

**Constructed Response**

*Use the table below to answer question 20.*

### Mean Body Mass and Field Metabolic Rate (FMR) of Black-Legged Kittiwakes

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<th>Number</th>
<th>Mean body mass (g)</th>
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<tr>
<td>Fed females</td>
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<td>426.8</td>
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<tr>
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<td>351.1</td>
<td>3.08</td>
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<tr>
<td>Fed males</td>
<td>16</td>
<td>475.4</td>
<td>2.31</td>
</tr>
<tr>
<td>Control males</td>
<td>18</td>
<td>397.6</td>
<td>2.85</td>
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</table>

20. **Short Answer** Examine the data shown above. Describe the effects of feedings on the energy expenditure, FMR, of male and female kittiwakes.

**Think Critically**

21. **Design** a survey to investigate students’ opinions about current movies. Use 10 questions and survey 50 students. Graph the data. Report the findings to the class.

### Additional Assessment

22. **WRITING in Biology** Prepare a letter to the editor of your school newspaper that encourages citizens to be scientifically literate about topics such as cancer, the environment, ethical issues, AIDS, smoking, lung diseases, cloning, genetic diseases, and eating disorders.

**Document Based Questions**

*Use the data below to answer questions 23 and 24.*


23. Identify the water depth with the highest relative fish biomass.

24. Determine which seabird colony has access to the highest fish biomass at a depth of 40 m.

### CUMULATIVE REVIEW

In Chapters 2–37, Cumulative Review questions will help you review and check your understanding of concepts discussed in previous chapters.
**Multiple Choice**

1. Many scientific discoveries begin with direct observations. Which could be a direct observation?
   A. Ants communicate by airborne chemicals.
   B. Birds navigate by using magnetic fields.
   C. Butterflies eat nectar from flowers.
   D. Fish feel vibrations through special sensors.

**Extended Response**

*Use this drawing to answer question 4.*

4. Look at the drawing and write five specific questions about the organisms shown that a biologist might try to investigate.

**Essay Question**

A researcher experimented with adhesives and glues to find new and stronger adhesives. In 1968, he discovered an adhesive that was very weak rather than strong. The adhesive would stick to paper but it could be removed easily without leaving a trace of adhesive. Because he was trying to find stronger adhesives, the results of that experiment were considered a failure. Several years later, he had the idea of coating paper with the weak adhesive. This meant that notes could be stuck to paper and easily removed at a later time. Today, these removable notes are used by millions of people.

**If You Missed Question . . .**

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