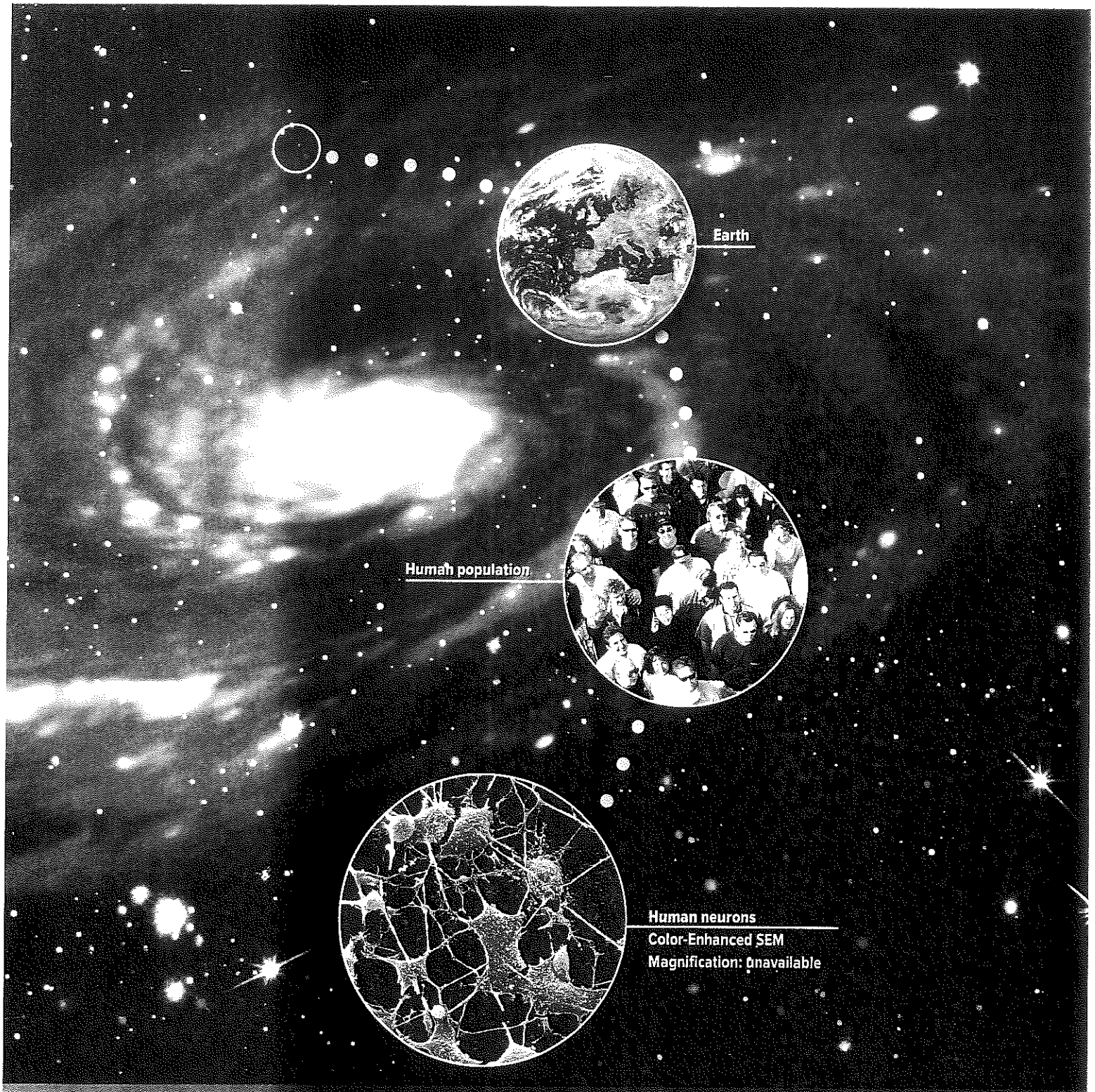


THEME FOCUS Stability and Change
All living things have structures and functions that help them maintain homeostasis.

KEY IDEA Biology is the study of life.

Introduction to Biology

Reading Preview

Essential Questions

- What is biology?
- What are possible benefits of studying biology?
- What are the characteristics of living things?

Review Vocabulary

environment: 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

Multilingual eGlossary

Key Idea **All living things share the characteristics of life.**

Real-World Reading Link Think of as many living things as you can. What do oak trees, cheetahs, grass, snakes, planaria, and sharks have in common? What makes them unique? How do we know?

The Science of Life

Before Jane Goodall arrived in Gombe Stream National Park in Tanzania, Africa, in 1960 to study chimpanzees, pictured in **Figure 1,** 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 study of life. Biology comes from the Greek word *bio,* meaning *life,* and from *logos,* meaning *study.*

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.

Fuse/Getty Images

Figure 1 Jane Goodall conducted field research for many years to observe chimpanzee behavior. Predict *the types of questions you would ask if you observed chimpanzee behavior.*

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 2,** obtain food? Will the AIDS virus be defeated? Is there life on other planets or anywhere else in the universe? Biologists are people who study biology. They 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,** traveled to Africa for the first time in the summer of 1960 to study chimpanzees in their natural environment. By studying chimps in the wild, Goodall witnessed behaviors that had not been observed before. For example, she saw chimps pulling leaves off twigs and using the twigs to retrieve termites from a mound. Before this observation, scientists thought only humans used tools. From her detailed notes, sketches, and maps of chimpanzees' daily travels, Goodall learned how chimpanzees grow and develop and how they gather food. Through Goodall's research we better understand chimpanzees and how to protect them.

Research disease Mary-Claire King studies chimpanzees from a different perspective. King studies chimpanzee genetics, and in 1973, she established that the genomes of chimpanzees and humans are 99 percent identical. This discovery has changed the field of biology. King's understanding of genetics has led to more research that helps us understand how diseases work and how to treat them.

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, chicken pox, and diphtheria, and currently, some biologists are researching the development of a vaccine for HIV. Biologists worldwide are researching new treatments 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 has a broader definition. Technology is defined as the application of scientific knowledge to solve human needs and to extend human capabilities. **Figure 3** shows how "bionic" hand technology can help someone who has lost an arm.

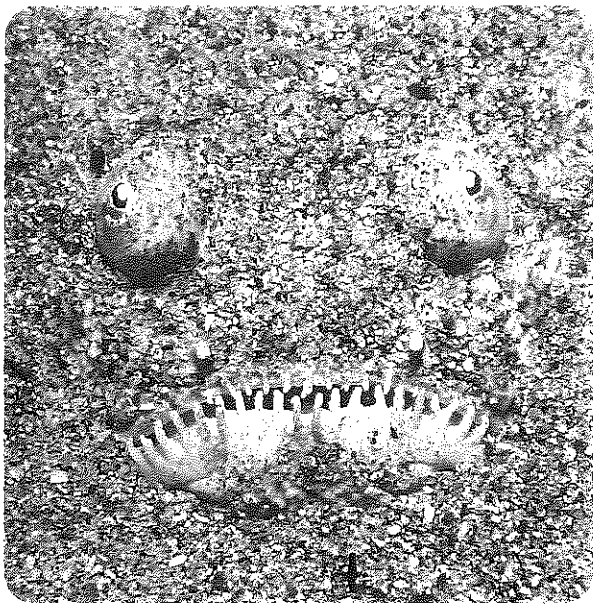


Figure 2 The marbled stargazer fish lives beneath the ocean floor off the coast of Indonesia. It explodes upward from beneath the sand to grab its food.

Observe ***How does this fish hide from its food?***

FOLDABLES™
Incorporate information from this section into your Foldable.

Figure 3 A prosthetic "bionic" hand is new technology that can help extend human capabilities.

(t)Reinhard Dirscherl/WaterFrame/Getty Images; (b)Mike Derer/AP Images

Figure 4 Plant biologists, such as Joanne Chory, research how mustard plants respond to light.

Other examples of technology include the work of Charles Drew, 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.

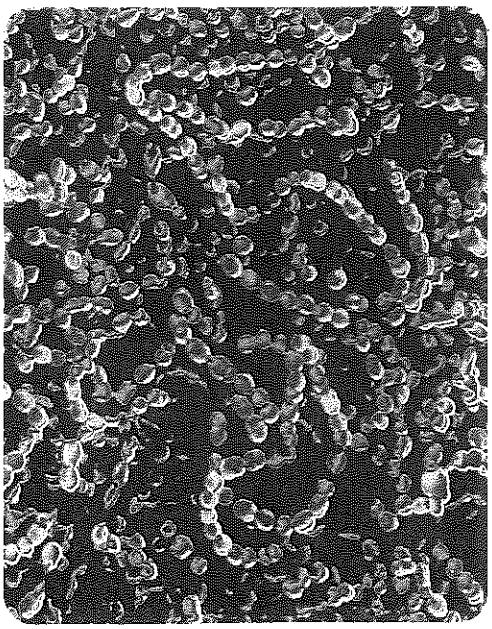
Improve agriculture Some biologists study the possibilities of genetically engineering plants to grow in poor soils or to resist insects, fungal infections, or frost damage. Other biologists research agricultural issues to improve food production to feed the world's growing human population.

Joanne Chory is a plant biologist who studies mustard plants, such as those shown in **Figure 4.** She researches the 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.

Figure 5 *Streptococcus pyogenes* is a unicellular organism. It can infect the throat, sinuses, or middle ear.



SEM Magnification: 7300×

The Characteristics of Life

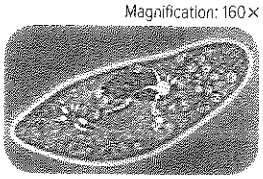
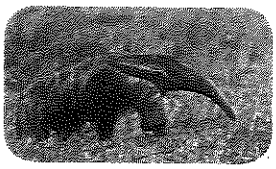
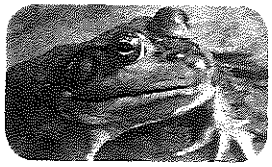
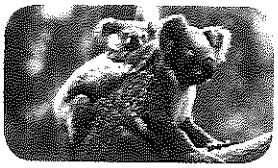
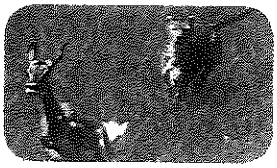
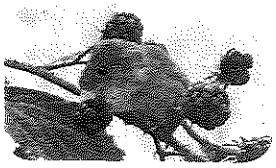
Have you ever tried to define the word *alive?* If you were to watch a grizzly bear catch a salmon from a river, you obviously would conclude that the bear and salmon are both alive. Is fire alive? Fire moves, increases in size, has energy, and seems to reproduce, but how does fire differ from the bear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

Over time and after many observations, biologists concluded that all living things have certain characteristics, as listed in **Table 1.** 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 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 Characteristics of Living Organisms

Interactive Table

Characteristic of Life	Example	Description
Made of one or more cells	 Magnification: 160×	All organisms are made of one or more cells. The cell is the basic unit of life. Some organisms, such as the *Paramecium sp.*, are unicellular.
Displays organization		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.
Grows and develops	 	Growth results in an increase in mass. Development results in different abilities. A bullfrog tadpole grows and develops into an adult bullfrog.
Reproduces		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.
Responds to stimuli		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.
Requires energy		Energy is required for all life processes. Many organisms, like this mouse, must take in food. Other organisms make their own food.
Maintains homeostasis		All organisms keep internal conditions stable by a process called homeostasis. For example, humans perspire to prevent their body temperature from rising too high.
Adaptations evolve over time		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.

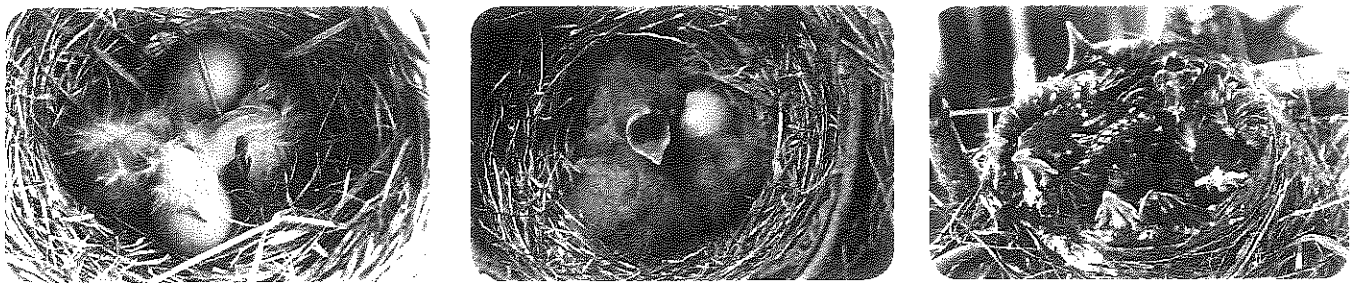


Figure 6 In less than a month, these robin chicks grow and develop from helpless chicks to birds capable of flying.
Infer *how the robins have developed in other ways.*

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** 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 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.

MiniLab 1

Observe Characteristics of Life

MiniLab

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** 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 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 often defined as a group of organisms that can breed with one another and produce fertile offspring. There are multiple ways to define species, which you will learn about in Chapter 17.

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 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.

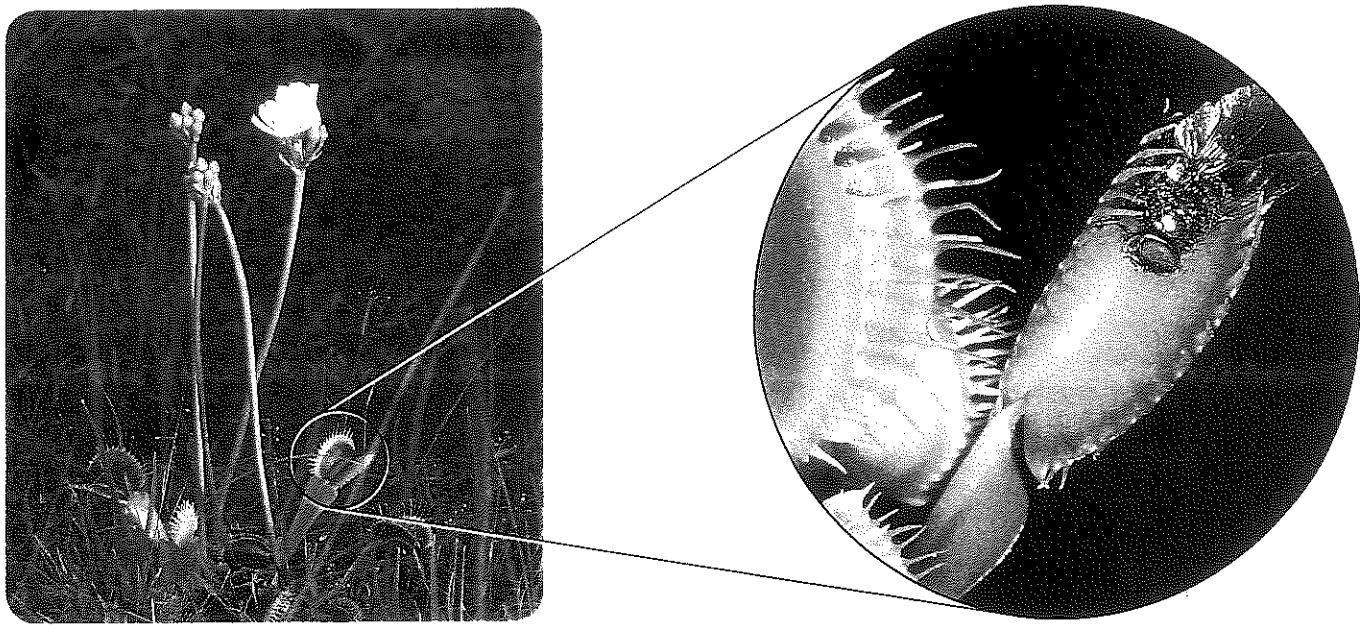


Figure 7 In nature, this Venus flytrap grows in soils that lack certain nutrients. The plant captures and digests insects and takes in needed nutrients.
Explain *how this plant responds to stimuli to obtain food.*

(l)©Hal Horwitz/Corbis; (r)Steven P. Lynch

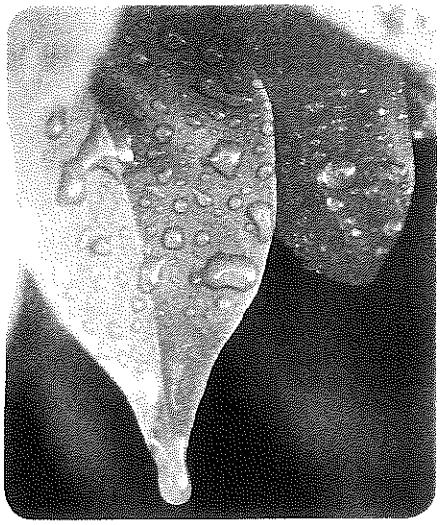


Figure 8 The structure of a drip-tip leaf is an adaptation to rainy environments.

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.

Connection to Earth Science When athletes travel to a location that is at a higher altitude than where they live, they generally arrive long before the competition so that their bodies have time to adjust to the thinner air. At higher altitudes, air has fewer molecules of gases, including oxygen, per unit of volume. Therefore, there is less oxygen available for an athlete's red blood cells to deliver to the cells and tissues, which disrupts his or her body's homeostasis. To restore homeostasis, the athlete's body produces more red blood cells. Having more red blood cells results in an adequate amount of oxygen delivered to the athlete's cells.

Adaptations evolve over time Many trees in rain forests have leaves with drip tips, like the one shown in **Figure 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.

Section 1 Assessment

Section Summary

- 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 characteristics that scientists use to determine whether the organisms are alive. All living organisms share these certain characteristics.

Understand Main Ideas

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

Think Critically

5. **MATH in Biology** Survey students in your school—biology students and nonbiology 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.

Online Quiz

Reading Preview

Essential Questions

- What are the characteristics of scientific inquiry?
- What are the differences between science and pseudoscience?
- Why is scientific literacy important?

Review Vocabulary

investigation: a careful search or examination to uncover facts

New Vocabulary

science
theory
law
peer review
ethics

Multilingual eGlossary

The Nature of Science

Main Idea **Science is a process based on inquiry that develops 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?

You probably have taken science class since you were in elementary school. But have you ever compared science to music, art, or math? **Science** is a body of knowledge based on the study of the natural world. There is science in almost everything we do. 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.

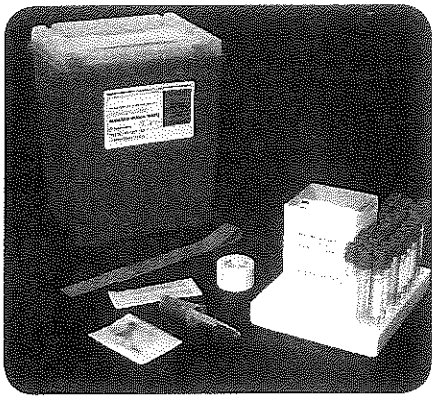
When many people think of a scientist, they think of someone in a white lab coat working in a laboratory. Scientists work all over the world in many locations, such as the volcanologist shown in **Figure 9.**

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. 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.

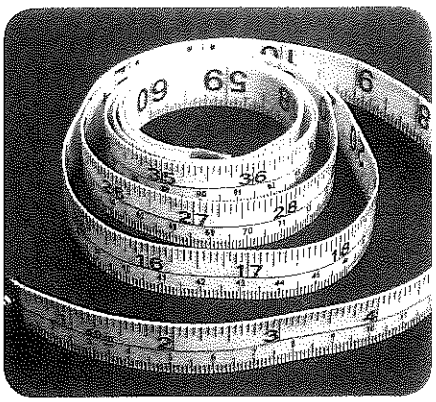
A scientific **law** describes relationships under certain conditions in nature. For example, the law of conservation of matter indicates that before and after a change the same amount of matter exists. The law does not explain why this occurs, but it describes the relationship between matter before a change and matter after a change. It is important to note that because they are fundamentally different, theories do not become laws and laws do not become theories.

A. Barrington Brown/Photo Researchers

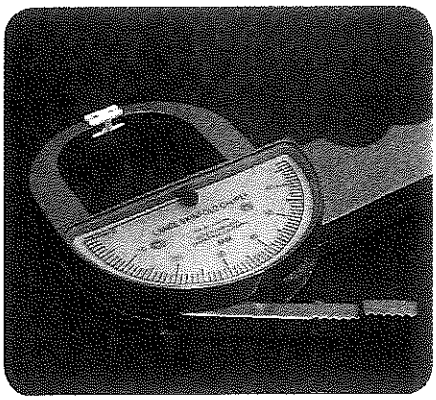
Figure 9 This volcanologist is collecting samples near molten lava flowing from Mount Etna. Lava temperatures can reach 750°C.



Blood draw kit



Tape measure



Caliper

Figure 10 Dr. Buell and her team used supplies like these to collect data for her study. Blood was collected and tested by using sterile needles and syringes. Her team used a tape measure to measure waist circumference, and they used a caliper to determine body mass composition.

Makes observations and draws conclusions Dr. Jackie Buell is a scientist who conducts research at The Ohio State University in Columbus, Ohio. One of Dr. Buell's focuses is sports nutrition. Do you think a marathon runner, a college football player, and a golfer all need the same types of food and the same number of calories every day? Through the work of many scientists, we know how to calculate the number of calories a person needs every day. We also know what types of nutrients, vitamins, and minerals are needed, as well as other information about nutrition.

Subject selection Dr. Buell conducted a study on college football linemen to help further the understanding of sports nutrition. Dr. Buell investigated the presence of a condition called metabolic syndrome. A person with metabolic syndrome has risk factors such as abdominal obesity and elevated blood pressure. These risk factors are known to lead to heart disease, stroke, and diabetes.

Why do you think Dr. Buell studied college athletes? Many people assume that all athletes are healthy because they exercise and do many of the things doctors recommend for a healthy lifestyle. For this reason, an athlete with metabolic syndrome might not be aware that they are at risk for things such as heart disease or stroke.

Dr. Buell's research, however, showed that 34 of the 70 college linemen studied were at risk for metabolic syndrome. This information can be used to treat the athletes in the study. It can also be used to increase awareness. Athletes and doctors might be more likely to take health concerns in athletes more seriously. In addition, athletes can be given access to information regarding diet and exercise to help them decrease their risk factors.

Reading Check **Explain** why some people think all athletes are healthy.

Data collection What sort of data do you think Dr. Buell and her team gathered to study metabolic syndrome in her subjects? First, they measured the subjects' height, mass, blood pressure, upper-body skin folds, and waist circumference. Dr. Buell and her team also collected blood samples, family health histories, and information about exercise routines and nutrition habits. They used tools like the ones shown in **Figure 10** to collect the data.

Once all of these data were collected, they were analyzed to determine which athletes were at risk. Dr. Buell identified five risk factors for metabolic syndrome in her study. For one of the data sets, blood work, athletes that were found to have three, four, or all five risk factors were determined to have metabolic syndrome. Dr. Buell used this evidence to conclude that college athletes, specifically college football linemen, should not be assumed to be in good health simply because they are athletes.

Expands 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.

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.

In 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.

Scientists have done the research to identify metabolic syndrome. They know why the risk factors associated with it can lead to heart disease and other health concerns. Dr. Buell applied this information to athletes, specifically college football linemen. She expanded knowledge by showing that athletes, those often assumed to be healthy, might have metabolic syndrome. What do you think scientists might study next?

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. When disagreements occur, more research is done to find which ideas are supported.

Sciences advance by accommodating new information as it is discovered. As we have discussed, athletes are often assumed to be at low risk for cardiovascular disease and other health concerns because they exercise regularly and often live what is considered to be a healthy lifestyle. However, Dr. Buell challenged this idea. Her research showed that there was a high incidence of metabolic syndrome in the athletes studied, putting them at risk for cardiovascular disease, diabetes, and stroke.

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 11.** 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. In pseudoscience, observations or data that are not consistent with beliefs are discarded or ignored.

Reading Check **Describe** how observations or data that are not consistent with current scientific understanding should be treated.

CAREERS IN BIOLOGY

Science Writer Communicating scientific information to the public is one of the goals of a science writer. He or she might write news stories, manuals, or press releases, or edit and summarize the written materials of scientists.

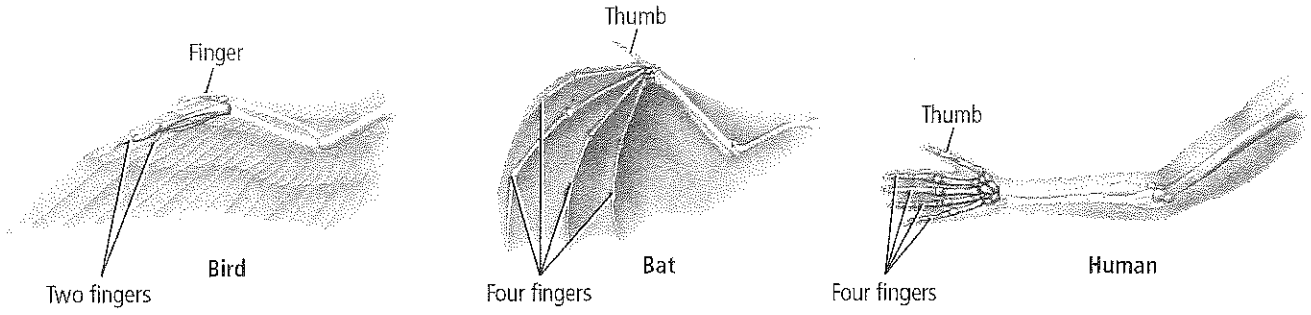


Figure 11 The structure of a bat's wing is more like that of a human arm than a bird's wing.

Vocabulary

Unbiased
to be objective, impartial, or fair
The judges were unbiased in choosing the winner.

Tests claims Biologists use standard experimental procedures in their research. They make claims and draw conclusions based on a large amount of data and observations obtained from unbiased investigations and carefully controlled experimentation. Bias can occur when a scientist unfairly influences the results or conclusions of an investigation or experiment. Pseudoscientists often make claims that cannot be tested. These claims are often mixtures of fact and opinion and are heavily biased.

Dr. Buell made claims based on 14 data points for all the athletes in the study. The data were analyzed before any conclusions were drawn. The use of data to test and support claims is one way to differentiate science from pseudoscience.

Undergoes peer review Finally, before Dr. Buell's study was made public, it was reviewed by peers—scientists who are working in the same field of study. **Peer review** is a process by which the procedures and results of an experiment are evaluated by other scientists who are in the same field or who are conducting similar research. Peer review gives credibility to research papers and prevents false information from being printed in scientific journals.

When scientists publish their work, they make it available for other scientists to examine. You can examine data from Dr. Buell's study in Data Analysis Lab 1.

Reading Check **Infer** why scientists utilize peer reviews.

DATA ANALYSIS LAB 1

Based on Real Data*

Make and Use Graphs

How can graphs help us interpret data? The table shows the number risk factors for metabolic syndrome college linemen exhibited. The more factors a player exhibited, the greater the chance they had metabolic syndrome. The data are separated into players that play at a college identified as Division I, II, or III, according to the NCAA.

Think Critically

1. **Identify** which division had the largest sample size.
2. **Determine** which division had the largest percentage of participants with three or more risk factors.
3. **Construct** a line graph that shows the number of risk factors and the number of athletes that possess these risk factors.
4. **Extrapolate** If you were a doctor treating these athletes, what would your advice to them be?

Number of Risk Factors for Metabolic Syndrome

Number of Risk Factors	Division			
	I	II	III	Total
0	0	1	0	1
1	3	5	5	13
2	10	6	6	22
3	7	8	10	25
4	2	6	0	8
5	0	1	0	1

*Data obtained from: Buell, Jackie L., et al. 2008. Presence of Metabolic Syndrome in Football Linemen. *Journal of Athletic Training* 43(6):608-616

Science in Everyday Life

There is widespread fascination with science. Popular television programs about crime are based on forensics, which 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 our world faces every day relate to 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 individual, you will be an educated consumer who can participate in discussions about important issues and support policies that reflect your views. You might also serve on a jury where DNA evidence, like that shown in **Figure 12,** is presented. You will need to understand the evidence, comprehend its implications, and decide the outcome of the trial.

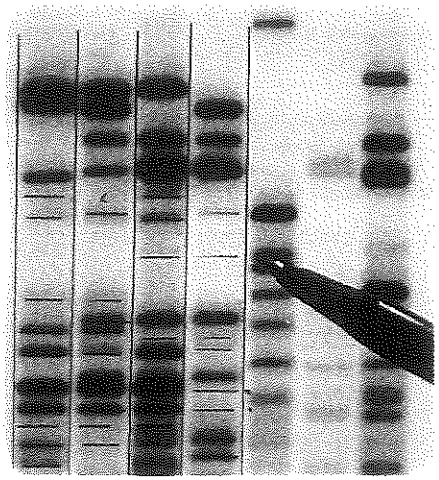


Figure 12 DNA analysis might exclude an alleged thief because his or her DNA does not match the DNA from the crime scene.

David Parker/SPL/Photo Researchers

Section 2 Assessment

Section Summary

- Science is the study of the natural world and is rooted in scientific inquiry.
- Pseudoscience is not based on standard scientific research.
- Scientific literacy is important for everyday life.
- Ethics are moral principals that guide society and influnce science.

Understand Main Ideas

1. MAIN Idea **Describe** the characteristics of scientific inquiry.
2. **Define** *scientific theory.*
3. **Compare and contrast** science with pseudoscience.
4. **Defend** the importance of scientific literacy to a classmate who doesn't want to learn about science.

Think Critically

5. **Organize** the characteristics of science in a concept map.

WRITING IN Biology

6. Write an article for the school newspaper that explains the nature of science. Use examples from Dr. Buell's research.

Online Quiz

Section 3

Methods of Science

Reading Preview

Essential Questions

- What are the differences between an observation and an inference?
- What are the differences among a control, independent variable, and dependent variable?
- What are the scientific methods a biologist uses for research?
- Why are the metric system and SI important?

Review Vocabulary

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

New Vocabulary

observation
inference
scientific method
hypothesis
experiment
control group
experimental group
independent variable
dependent variable
constant
data
metric system
SI

Multilingual eGlossary

Key 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.

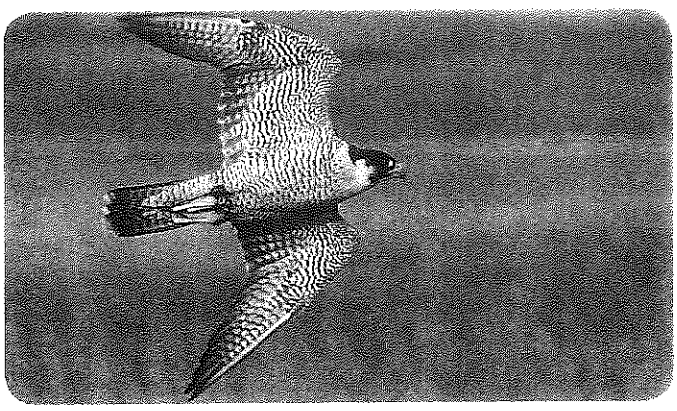
Ask a Question

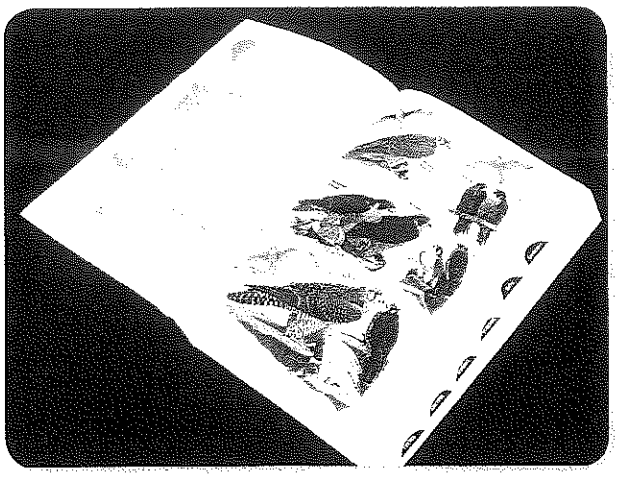
Imagine that you saw an unfamiliar bird in your neighborhood. You might develop a plan to observe the bird for a period of time. Scientific inquiry begins with **observation,** a direct method of gathering information in an orderly way. Often, observation involves recording information. In the example 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. The process of combining what you know with what you have learned to draw logical conclusions is called inferring; the conclusions themselves are called **inferences**. 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 13** 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 14.** 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 13 Scientists might use a field guide to help them identify or draw conclusions about things they observe in nature, such as this peregrine falcon.



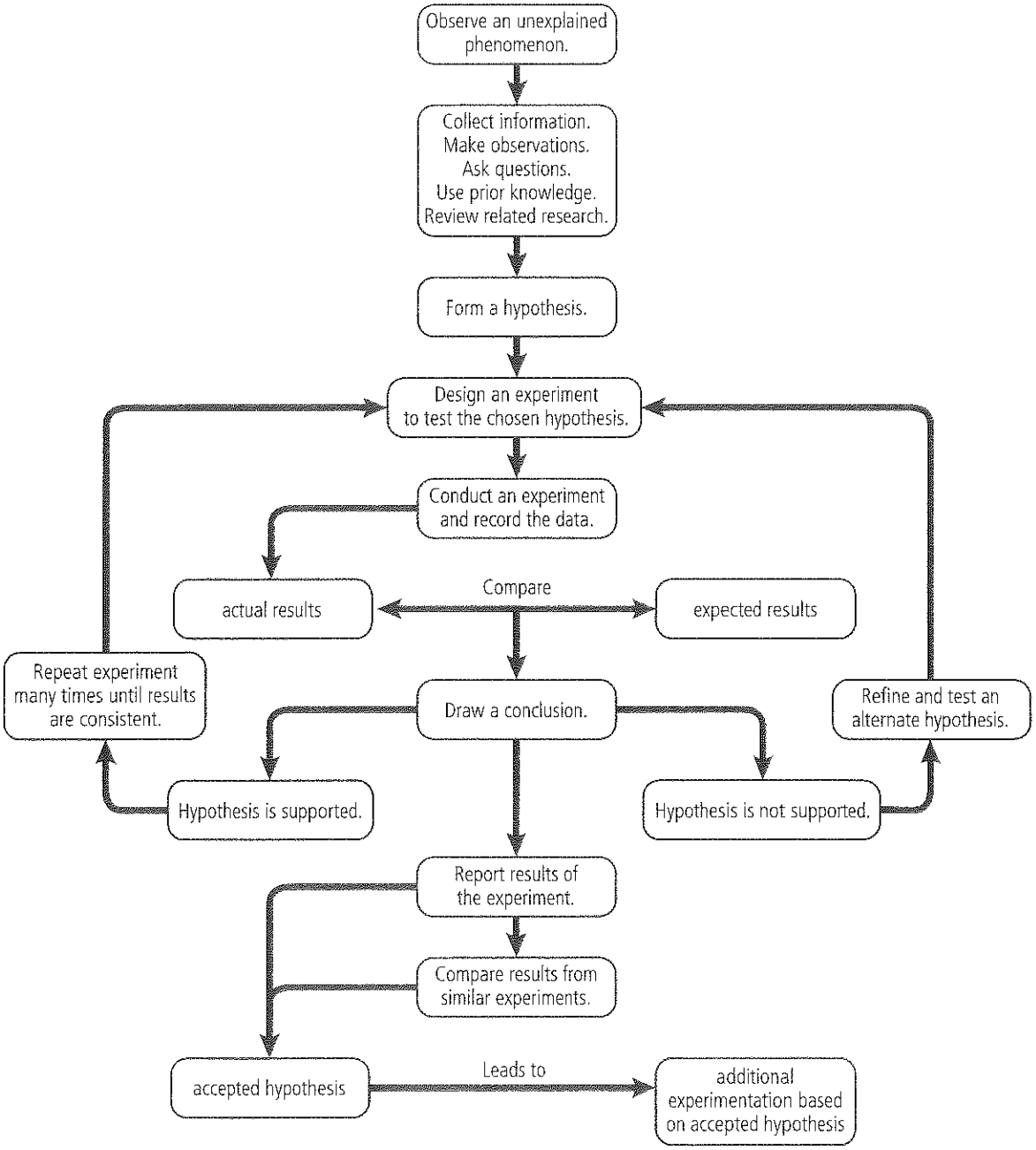


(l)SteveOehlenschlager/iStock/Getty Images Plus/Getty Images; (r)McGraw-Hill Education

Visualizing Scientific Methods

Figure 14

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.



Animation

Launch Lab

Review Based on what you've read about observing and inferring, how would you now answer the analysis questions?

Virtual Lab

BrainPOP

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. Ronald 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.

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 conducted a controlled experiment using gulls known as black-legged kittiwakes shown in **Figure 15.** When a biologist conducts an **experiment,** he or she investigates a phenomenon in a controlled setting to test a hypothesis.

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.

©George McCarthy/Corbis

Figure 15 This colony of black-legged kittiwakes along the Alaskan coast includes nesting pairs.

Biologists found nesting pairs of kittiwakes that were similar to each other and set up an experiment. A **control group** in an experiment is used for comparison. The kittiwakes not given the supplemental feedings were the control group. The **experimental group** is the group exposed to the factor being tested. The kittiwakes getting the supplemental feedings were 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 called 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, or density.

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 investigate the behavior of organisms or 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.

Metric system To make communication easier, 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).

MiniLab 2

MiniLab

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.

VOCABULARY

Conclusion

Science usage: judgment, decision, or opinion formed after an investigation
The researcher formed the conclusion that the hypothesis was not supported.

Common usage: the end or last part
The audience left at the conclusion of the movie.

Analyze the Data

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 16,** 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. 1129–1132.

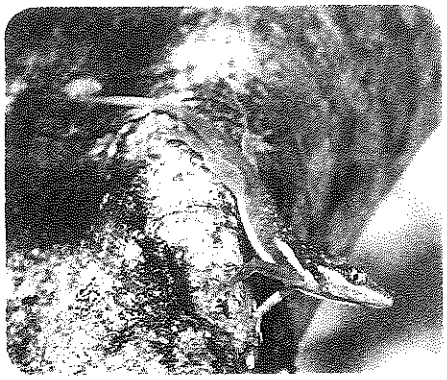
Because biologists often work in teams, meetings are held to discuss ongoing investigations, to analyze the data, and to interpret the results. The teams continue to examine their research plan to be certain they avoid bias, repeat their trials, and collect a large enough sample size. Analysis of the 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?

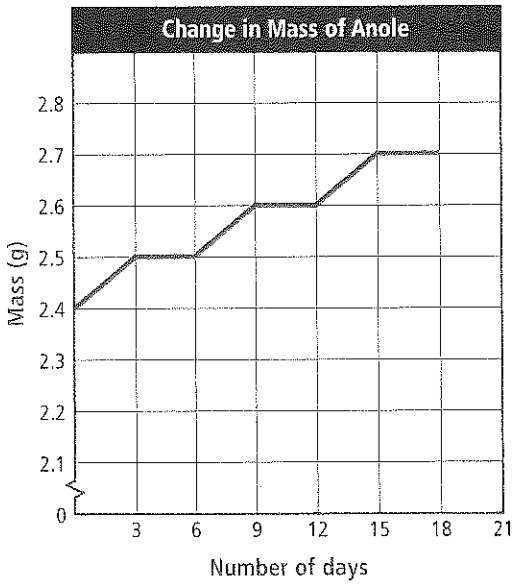
Figure 16 After plotting the data points from the table on graph paper, draw a line that fits the pattern of the data rather than connects the dots.
Extrapolate *What do you think the mass of the anole will be at 21 days?*

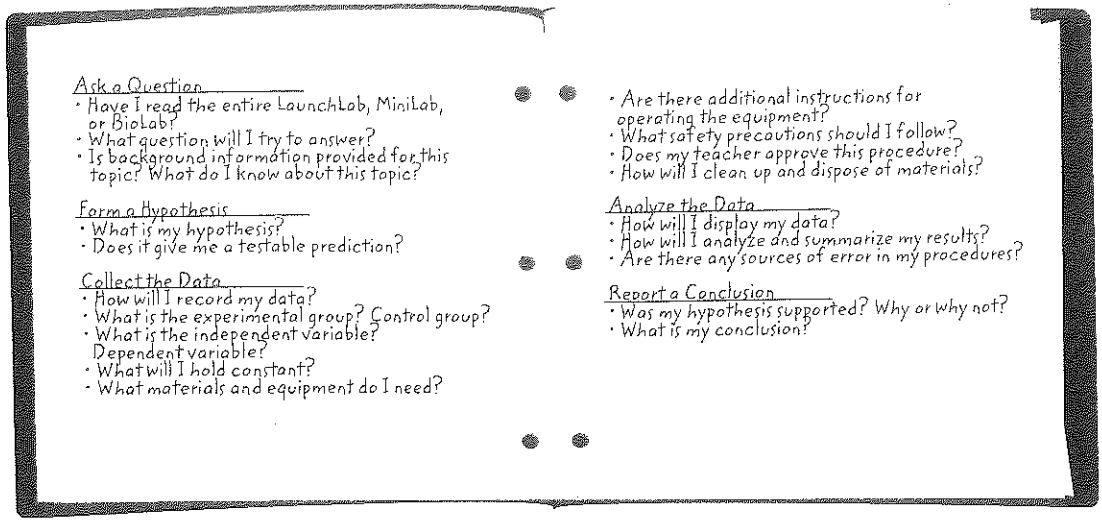


Anole

Change in Mass of Anole

Date	Mass (g)
April 11	2.4
April 14	2.5
April 17	2.5
April 20	2.6
April 23	2.6
April 26	2.7
April 29	2.7





Student Scientific Inquiry

You will be given many opportunities during your study of biology to do your own investigations and experiments. You might also 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 17.** For additional help with setting up experiments and using equipment, go to Investigation and Experimentation in the Student Handbook 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 17 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.

What's BIOLOGY Got To Do With It?

Section 3 Assessment

Section Summary

- Careful observation involves an orderly way of gathering information.
- Controlled experiments involve a control group and an experimental group.
- SI units include meters, grams, and liters.

Understand 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. **Explain** why the metric system and SI are important.
4. **Differentiate** between controls, independent variables, and dependent variables.

Think Critically

5. **Design** a controlled experiment to determine whether earthworms are more attracted to perfume or to vinegar.

MATH in Biology

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

Online Quiz

CUTTING-EDGE BIOLOGY

MEASURING BONE DENSITY

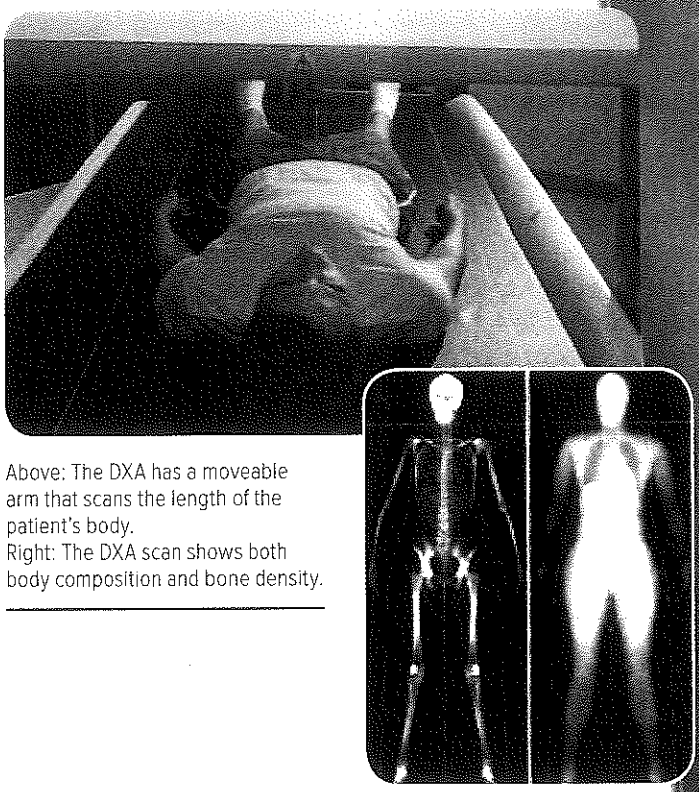
You have probably been told that you need to drink milk or eat dairy products to get calcium, but do you know why? Your body uses calcium to build strong (dense) bones and teeth. Your body also uses calcium to help your heart beat and your nervous system and muscular system function properly.

How are calcium and bone density related? If you don't get enough calcium in your diet, your body will pull calcium from your bones and teeth, where it is stored naturally. About 85-90% of bone mass is acquired in adolescence. It is important to consume enough calcium when you are in your teens to ensure that you have strong, dense bones later in life. People cannot feel their bones getting weaker. This is another reason that adequate calcium intake is important at any age.

When calcium is depleted you are more susceptible to broken bones, cavities, and osteoporosis. Osteoporosis is a condition that is characterized by the loss of bone density. When bones are less dense they are brittle and full of air pockets, and they can break more easily.

How do you measure bone density? A scanner called dual energy X ray absorptiometry (DXA) measures bone mineral density so that doctors can get an accurate picture of how much calcium is present in the bones. Dense bones have more calcium in them and are stronger than low-density bones.

How does the DXA machine work? The X rays are similar to visible light rays but have a much shorter wavelength. They reflect differently off tissues with different densities. On a traditional X ray, all bone appears white and soft tissue might not appear at all, or might appear a shade of gray.



Above: The DXA has a moveable arm that scans the length of the patient's body.
Right: The DXA scan shows both body composition and bone density.

The DXA machine uses X rays with several wavelengths that reflect differently off different densities of bone. This allows doctors to detect bone density in patients. The DXA machine can also download information to a computer program where the data can be compiled and presented to the patient in the form of a graph and image.

Doctors and scientists use the data provided by the DXA to help patients prevent or treat low bone density and osteoporosis. For some patients who are at risk for osteoporosis, regular DXA scans can track bone loss.

WRITING in Biology

Define technology Research a technology in the medical research field other than DXA. Present information about the technology you researched in a poster or pamphlet.

WebQuest

BIOLAB

Design Your Own

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?

WRITING in Biology

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.

Chapter 1 Study Guide

THEME FOCUS Stability and Change All living things have structures and functions that help them maintain homeostasis.

Big Idea Biology is the study of life.

Section 1 Introduction to Biology

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

Key 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 characteristics that scientists use to determine whether the organisms are alive. All living organisms share these certain characteristics.

Section 2 The Nature of Science

science (p. 11)
law (p. 11)
theory (p. 11)
peer review (p. 14)
ethics (p. 15)

Key Idea Science is a process based on inquiry that develops explanations.

- Science is the study of the natural world and is rooted in scientific inquiry.
- Pseudoscience is not based on standard scientific research.
- Scientific literacy is important for everyday life.
- Ethics are moral principles that guide society and influence science.

Section 3 Methods of Science

inference (p. 16)
observation (p. 16)
scientific method (p. 16)
experiment (p. 18)
hypothesis (p. 18)
constant (p. 19)
control group (p. 19)
data (p. 19)
dependent variable (p. 19)
experimental group (p. 19)
independent variable (p. 19)
metric system (p. 19)
SI (p. 19)

Key Idea Biologists use specific methods when conducting research.

- Careful observation involves an orderly way of gathering information.
- Controlled experiments involve a control group and an experimental group.
- SI units include meters, grams, and liters.

Chapter 1 Assessment

Section 1

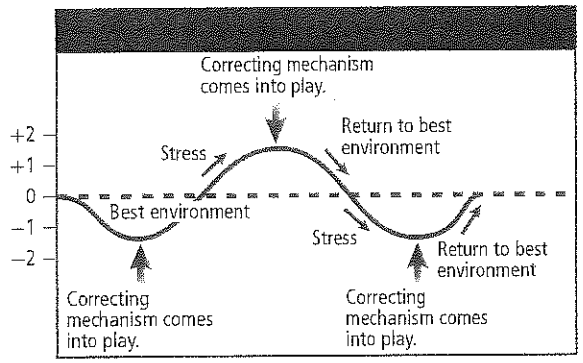
Vocabulary Review

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 study of life involves learning about the natural world.

Understand Main Ideas

Use the graph below to answer question 4.



4. Which characteristic of life should be the title of this graph?
   A. Cellular Basis
   B. Growth
   C. Homeostasis
   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. MAIN IDEA 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 2

Vocabulary Review

Identify the correct vocabulary term from the Study Guide page that corresponds to each phrase.

9. the set of moral principles or values that guide decisions about scientific and medical topics
10. a well-tested explanation that brings together many observations in science such as evolution, plate tectonics, biogenesis

Understand Main Ideas

11. Which best describes a scientific theory?
    A. a possible explanation of an event
    B. a set of moral values or principles
    C. a description of the relationship between objects
    D. an explanation supported by many experiments over time
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. MAIN IDEA Evaluate the statement: "Scientists just perform experiments to prove what they already believe."

Chapter 1 Assessment

Section 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 Main Ideas

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

	Number	Mean body mass (g)	FMR
Fed females	14	426.8	2.04
Control females	14	351.1	3.08
Fed males	16	475.4	2.31
Control males	18	397.6	2.85

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. **Short Answer** Defend the metric system to a scientist who does not want to use it.

22. 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.

Summative Assessment

23. Big Idea Biology is the study of life. Write a paragraph about one area of biology that interests you. Include information about what the area is, what you already know about it, and what you would like to know.

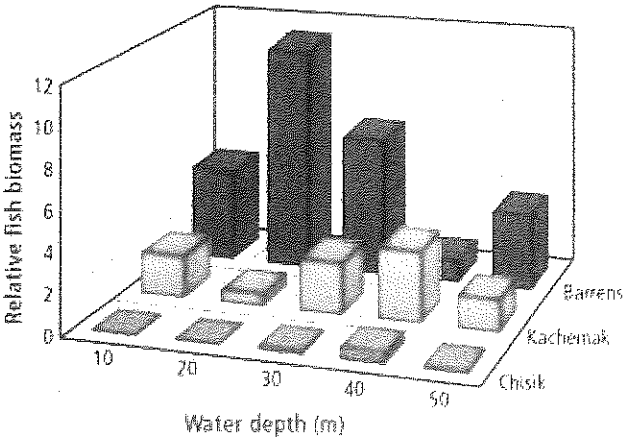
24. MATH In Biology Which metric unit of measurement would you use to measure the distance from your home to your school?

25. 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 26 and 27.

Data obtained from: U.S. Geological Survey. *Seabirds, forage fish, and marine ecosystems.* http://www.absc.usgs.gov/research/seabird_foragefish/foragefish/index.html



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

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

Online Test Practice

Standardized Test Practice

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.

Use this experimental description and data table to answer question 2.

A student reads that some seeds must be exposed to cold before they germinate. She wants to test seeds from one kind of plant to see if they germinate better after freezing. The student put the seeds in the freezer, took samples out at certain times, and tried to germinate them. Then she recorded her results in the table.

Germination Rate for Seeds Stored in a Freezer

Time in Freezer at –15°C	Germination Rate
30 days	48%
60 days	56%
90 days	66%
120 days	52%

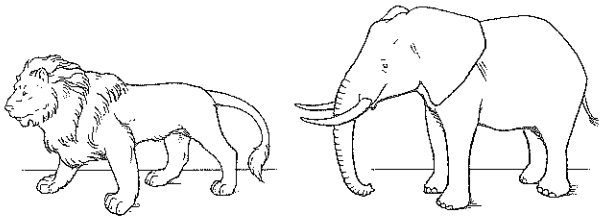
2. According to the results of this experiment, how many days should seeds be stored in the freezer before planting for best germination?
   A. 30
   B. 60
   C. 90
   D. 120

Short Answer

3. Appraise one benefit to scientists of using SI units as standard units of measurement.

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.

5. Compare and contrast a scientific hypothesis and a scientific theory.

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.

Using the information in the paragraph above, answer the following question in essay format.

6. The original adhesive experiment was considered a failure. Appraise the importance of evaluating the results of an experiment with an open mind.

NEED EXTRA HELP?						
If You Missed Question . . .	1	2	3	4	5	6
Review Section . . .	1.3	1.3	1.3	1.1	1.3	1.2