Chapter 1

Wednesday, April 17, 2019 7:31 PM

CHAPTER 1: BIOLOGY IN THE 21ST CENTURY

BIG IDEA: Cells are the smallest unit of living matter that can carry out all processes required for life.

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Section 1.1 The Study of Life

Friday, January 15, 2021 1:07 PM

BIG IDEA: Biology is the study of all aspects of living things, and it shapes our understanding of our world, from human health in biotechnology to environmental preservation.

SECTION SUMMARY: Science is the knowledge obtained through observation of natural events and conditions in order to discover facts and formulate laws or principles that can be verified or tested. Biology is the study of all forms of life and their interactions with each other and the environment. Everywhere that organisms are found on earth is considered to be the biosphere. Biology has been studied throughout history.

KEY CONCEPT: Biologists Study life in all its forms

MAIN IDEAS:

- Earth is home to an incredible diversity of life.
- Biology is the scientific study of all forms of life.
- Humans studied living things throughout history.

VOCABULARY:

- Biosphere: All organisms and the part of Earth where they exist.
- Biodiversity: The variety of organisms in a given area, the genetic vaiation within a population, the variety of species in a community, or the variety of communities in an ecosystem.
- Species: A group of organisms that are closely related and can mate to produce fertile offspring also the level of classification below genus and above subspecies.
- Biology: The scientific study of living organisms and their interactions with the environment.
- Science: The knowledge obtained by observing natural events and conditions in order to discover facts and formulate laws and principles that can be verified or tested.

TEKS:

- 2A: Know the definition of science and understand that it has limitations, as specified in subsection (b)(2) of this section.
- 3D: evaluate the impact of scientific research on society and the environment.
- 3F: research and describe the history of biology and contributions of scientists.

CONNECT TO YOUR WORLD:

It's a warm summer evening. Maybe you're laughing and choking while waiting to eat at a family barbecue. As you sit down for dinner, mosquitoes flying around have the same idea. But their dinner is you, not the barbecue. Probably the most attention that you paid to a mosquito

MAIN IDEA Earth is home to an incredible diversity of life

In Yellowstone National Park, there are pools of hot water as acetic as vinegar. It might be difficult to believe, but those pools are also full of life. Life is found in the darkness of the deepest ocean floors and then thousands–of–years –old ice in Antarctica. Not only are living things found just about anywhere on Earth, but they also come in a huge variety of shapes and sizes. Plans, for example include tiny mosses and the giant redwood trees on which Moss can grow. There are massive animals such as the blue whale, which is the largest animal living on earth. There are tiny animals such as the honeypot ant in **FIGURE 1.1**, which can store so much food for other ants that is swells to the size of a grape

THE BIOSPHERE:

All living things and all the places they are found on Earth make up the **biosphere.** Every part of the biosphere is connected, however distantly, with every other part of the biosphere. The biosphere includes land environments such as deserts, grasslands, and different types of forests. The biosphere also includes saltwater and freshwater environments, as well as portions of the atmosphere. And different types of plants, animals, and other living things are found in different areas of the biosphere. Even the inside of nose, which is home bacteria and fungi, is a part of the biosphere

BIODIVERSITY:

The variety of organisms in a given area is con biological diversity, or biodiversity. Biodiversity generally increases from the earth's poles to the equator. More living things are able to survive and constantly warm temperatures than in the areas that have large temperature changes during the year. Because more living things, especially plants, can survive and warm areas, those areas provide a larger, more consistent food supply for many different species.

There are several different ways the term species can be defined. One definition of species is a group of organisms the are closely related and can produce fertile offspring. About 2 million different living species have been identified, but biologists estimate that tens of millions of species remains to be discovered. Over half of the known species are insects, but no one knows how many insect species actually exist.

Every year, biologists discover more than 10,000 new species. In contrast, some scientists estimate that over 50,000 species die out, or become extinct, every year. Occasionally, however a species thought to be extinct is found again. For example, the ivory– billed woodpecker was thought to have become extinct in 1949, but a team of scientists reported seeing is an Arkansas in 2004.

MAIN IDEA: Biology is the scientific study of all forms of life.

The diverse organisms that live on Earth relate and interact with other organisms and their environments. **FIGURE 1.2** shows a bee collecting pollen from a flower, an interaction that benefits both the bee and the plant. When a bee collects pollen to use as food, the pollen sticks to the bee's body. Then, as the bee flies from plant to plant, the pollen from one plant is left behind on other plants. This interaction pollinates the plants and allows them to reproduce. Biology, or life science, is the scientific study of living things and their interactions with their environment.

The study of living things sheds new light on our understanding of hu-mans and our world. For example, until chimpanzees were observed to use sticks and other tools to hunt insects and other organisms, high intelligence and the ability to make and use tools were considered strictly human characteristics. Science is the knowledge obtained by observing natural events and conditions in order to discover facts and formulate laws or principles that can be verified or tested. People who contribute to science come from all back-grounds and different fields of interest. Biology is one of three basic areas of science: life science, earth science, and physical science.

MAIN IDEA: Humans have studied living things throughout history

The study of living things began long before the invention of computers, microscopes, or other scientific tools and techniques. Early records, such as the prehistoric cave painting in **FIGURE 1.3**, show that prehistoric people were interested in the animals they observed and used as food. Other art, carvings, and papyri show how early humans began to understand basic biological concepts such as anatomy, medicinal use of herbs, and embalming. Evidence shows that some human populations began domesticating animals as early as 8500 BCE. Even without knowing it, these early humans were using genetics to select for characteristics that were most valuable in the organism, such as high milk production and taste or high yield in crops.

SCIENCE IN ACCIENT CIVILIZATIONS:

Many ancient civilizations studied biology. Just as we do now, they learned about natural processes and used this knowledge to address the needs of society. Asian civilizations used herbal medicines. South American civilizations developed agricultural techniques, such as crop do mastication and irrigation. Ancient Egyptian civilizations practiced mummification of royalty, nobility, and the wealthy, as shown in **FIGURE 1.4**.

Greek civilization made significant contributions to the development of life science. They are credited with originating the basic principles of modern science. Around 400 BCE, Greek physician Hippocrates established a school of medicine. He taught that all living bodies were made up of four humors or fluids: blood, black bile, phlegm, and yellow bile. Imbalances in the four humors were thought to cause most illnesses.

The first classification system for living organisms is attributed to the Greek philosopher Aristotle and dates back to 330 BCE. Aristotle's system divided animals up into those with red blood, such as wolves and rabbits, and those without blood, such as mollusks and arthropods. Aristotle is also credited with developing a system of logic and a dependence on empirical evidence in science.

THE SCIENTIFIC REVOLUTION:

Scientist of any era are limited by the demands and rules of society. The ancient Greek and Roman societies are known for their milestones in science and philosophy, but changes in politics and governance also influenced the progress of science. The Middle Ages of European history (500s-1450s CE) are marked by little scientific development, though scientific knowledge continued to grow in other parts of the world, such as India and China.

Fifteenth century European societies gave rise to a renewal of interest in art and science and the beginning of the Scientific Revolution (1450s–1700). Early in this time period, Italian artist and scientist Leonardo da Vinci began close studies of the anatomy of both animals and humans. The drawing Vitruvian Man, shown in FIGURE 1.5, gives evidence of da Vinci's detailed understanding of anatomy and movement. His legacy includes the introduction of systematic observation and documentation methods that are still in use today. Andreas Vesalius, a Flemish physician, published a book of anatomy in the mid-1500s. Vesalius challenged anatomical concepts made from limited observations by the ancient Greeks. Vesalius practiced dissection of corpses, so his descriptions of anatomy were based on repeated explorations of the insides of bodies, whereas the Greeks based their descriptions only on external observation and philosophy.

Scientific understanding is always limited by available technology. Many of the advances in biology and other areas of science that occurred during the Scientific Revolution were made possible by new technologies. For example, the invention of the microscope around the start of the 1600s allowed for the discovery of cells and microorganisms

SCIENCE FROM THE INDUSTRIAL REVOLUTION TO TODAY:

The Industrial Revolution, which began in the last half of the 18th century, brought about significant advances in science. Travel and communication allowed for the exchange of ideas, universities developed robust science programs, and technology enabled scientists to explore the natural world with greater accuracy and precision. Such explorations led to new knowledge and built upon or replaced old knowledge.

For example, the development of cell theory replaced the notion of spontaneous generation, a belief that some life forms arose from non-living matter. Experiments by Louis Pasteur in 1859, using broth in the equipment shown in FIGURE 1.6, demonstrated that living things did not come from nonliving matter but were the result of reproduction by other living things. As a result of this and other studies, three German scientists, Theodor Schwann, Matthias Schleiden, and Rudolph Virchow, proposed a theory summarizing the basic properties of living organisms. These basic concepts are collectively known as the cell theory. You will read more about cell theory in the chapter Cell Structure and Function. Other important advances in biology are also discussed throughout the book.

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Section 1.2 Unifying Themes of Biology

Friday, January 15, 2021 3:56 PM

BIG IDEA: Biology is the study of all aspects of living things, and it shapes our understanding of our world, from human health in biotechnology to environmental preservation.
SECTION SUMMARY: Unifying themes connect concepts from many fields of biology. Organisms are made of one or more cell's, need energy for all of their functions, respond to their environment, and reproduce by passing their genetic information to offspring. Interactions occur at various levels, from chemical processes within cells to interactions between species within an ecosystem. Individual organisms depend on the relationship between structure and function, and on the ability to maintain homeostasis to reproduce. Over billions of years, evolution and adaptation have given rise to all the species on earth.
KEY CONCEPT: Unifying themes connect concepts from many fields of biology

MAIN IDEAS:
- All organisms share certain characteristics.
- All levels of life have systems of related parts.
- Structure and function are related in biology.
- Organisms must maintain homeostasis to survive in diverse environments.
- Evaluation explains the unity and diversity of life.

VOCABULARY:
- Organism: A living thing: anything that can carry out life processes independently.
- Cell: In biology, a cell is the smallest unit that can perform all life processes; cells are covered by a membrane and contain DNA and cytoplasm.
- Metabolism: The sum of all chemical processes that occur in an organism.
- DNA: Deoxyribonucleic acid, the material that contains the information that determines inherited characteristics.
- System: Changing, organized group of related parts that interact to form a whole.
- Ecosystem: A community of organisms and their abiotic environment.
- Homeostasis: The maintenance of a constant internal state that is maintained in a changing environment by continually making adjustments to the internal and external environment.
- Evolution: generally, in biology, the process of change by which new species develop from preexisting species over time; at the genetic level, the process in which inherited characteristics within populations change over time; the process defined by Darwin as "decent with modification"
- Adaptation: The process of becoming adapted to an environment; an anatomical, physiological, or behavioral change that improves a population's ability to survive.

TEKS
- 4B: Investigate and explain cellular processes, including homeostasis, energy conversions, transport of molecules, and synthesis of new molecules.
- 7E: analyze and evaluate the relationship of natural selection to adaptation and to the development of diversity in and among species
- 10A: Describe the interactions that occur among systems.
- 10C: Analyze the levels of organization in biological systems and relate the levels to each other and to the whole system.
- 11A: Describe the role of internal feedback mechanisms in the maintenance of homeostasis.

CONNECT TO YOUR WORLD

What do you think about when you here the term theme? Maybe you think about the music at the start of your favorite TV show or the colors and organization of a computer desktop. In both cases, that theme shows up over and over again. In biology, you will see something similar. That is, some concepts come up time after time, even in topics that might seem to be completely unrelated. Understanding these themes, or concepts, can help you to connect to different areas in biology.

MAIN IDEA: All organisms share certain characteristics.
An organism is any individual living thing. All organisms on Earth share certain characteristics, but an actual

definition of life is not simple. Why? The categories of living and nonliving are constructed by humans, and they are not perfect. For example, viruses fall into a middle range between living and nonliving. They show some, but not all, of the characteristics of living things.

CELLES

All organisms are made up of one or more cells. A **cell** is the basic unit of life. In fact, microscopic, single celled-organisms are the most common forms of life on Earth. A single-celled, or unicellular, organism carries out all of the functions of life, just as you do. Larger organisms that you see every day are made of many cells and are called multicellular organisms. Different types of cells in a multicellular organism have specialized functions, as shown in **FIGURE 2.1.** Your muscle cells contract and relax, your stomach cells secrete digestive juices, and your brain cells interpret sensory information. Together, specialized cells make you a complete organisms.

NEED FOR ENERGY

All organisms need a source of energy to carry out life processes. Energy is the ability to cause a change or to do work. All living things, from bacteria to ferrets to ferns, use chemical energy. Some organisms, such as plants, algae, and some bacteria, absorb energy from sunlight and store some of it in chemicals that can be used later as a source of energy. Animals obtain energy by eating other organisms. In all organisms, energy is important for metabolism, or all of processes that build up or break down materials.

RESPONSE TO ENVIRONMENT

All organisms must react to their environment to survive. Light, temperature, and touch are just a few of the physical factors, called stimuli, to which organisms must respond. Think about how you respond to light when you leave a dimly lit room and go into bright sunlight. One of your body's responses is to contact the pupils of your eyes. Your behavior might also change. You might put on sunglasses or raise your head to shade your eyes. Other organisms also respond to change in light. For example, plants grow toward light. Some fungi need light to form the structures that you know as mushrooms.

REPORDUCTION AND DEVELOPMENT:

Members of a species must have the ability to produce new individuals or reproduce. When organisms reproduce, they pass their genetic material to their offspring. In all organisms, the genetic material the contains the information that determines inherited characteristics is a molecule called deoxyribose nucleic acid, or DNA. Single-celled can reproduce when one cell divides into two cells. Both new cells have genetic information that is identical to the original cell. Many multicellular organisms, such as the gold-specs jawfish in **FIGURE 2.2** reproduced by combining the genetic information from two parents. In both cases, the instructions for growth and development of organisms, from bacteria to people, are carried by the same chemicals-DNA and ribonucleic acid (RNA). The process of development allows organisms to mature and gain the ability to reproduce.

ALL LEVLS OF LIFE HAVE SYSTEMS OF RELATED PARTS

Think about the separate parts of a car-tires, engine, seats, and so on. Even if you have a complete set of car parts, you might not have a functioning car. Only when all the arts that make up a car are put together in the correct way do you have a working car. A car is a system. A system is an organized group of related parts that interact to form a whole. Like any other system, a car's characteristics come from the arrangement and interaction of its parts

Two organisms that interact can also be a system, as you can see in **FIGURE 2.3.** On a larger scale, you are a part of a biological system-an ecosystem-that has living and nonliving parts. An ecosystem is a community of organisms and their physical environment. When you here the *term* ecosystem, you might think about a large region, such as a desert, a carol reef, or a forest. But an ecosystem can also be a very small area, such as an individual tree.

Systems exist on all scales in biology, from molecules that cannot be seen, to cells that can be seen only with a microscope, to the biosphere. In just one heart muscle cell for example, chemicals and processes interact in a precise way so that the cell has energy to do its work. Moving up a level, heart muscle, valves, arteries, and veins form a system in your body-the circulatory system.

Often, different biologist study different systems. For example, a person studying DNA might focus on very specific chemical reactions that take place in a cell. A person studying behavior in birds might focus on predator-prey relationships in an ecosystem. However, more and more biologist are working across different system levels. For example, some scientists study how chemicals in the brain affect social interactions.

STRUCTURE AND FUNCTION ARE RELATED ON BIOLOGY

Think about a car again. In a car, different parts have different structures. The structure of a car part gives the part a specific function. For example, a tire's function is directly related to its structure. No other part of the car can perform that function. Structure and function are also related in living things. What something does in an organism is directly related to its shape or form. For example, when you eat, you probably bite into food with your sharp front teeth. Then you probably chew it mostly with your grinding molars. All of your teeth help you eat, but different types of teeth have different functions.

Structure and function are related at the level of chemicals in cells. For example, membrane channels and enzymes are both proteins, but they have very different structures and functions. A channel is a protein molecule that extends through the membrane, or outer layer of a cell. It has a structure like a tube that allows specific chemicals to pass into and out of a cell. Enzymes are protein molecules that make chemical processes possible in living things. These proteins have shapes that allow them to attach to only certain chemicals and then cause the chemicals to react with each other.

Different types of cells also have different functions that depend on their specialized structures. For example, cells in your brain process information. They have many branches that receive information from other cells. They also have long extensions that allow them to send messages to other cells. Red blood cells are very different. They are much smaller, disk shaped, and are specialized to carry oxygen. Their structure allows them to fit through even the smallest blood vessels to deliver oxygen throughout your body. Of course, a brain cell cannot take the place of a red blood cell.

Structure and function are also related on the level of the organism. For example, your foot structure allows you to walk easily on rough, fairly level surfaces. Walking on a surface such as ice is more difficult and walking up a wall is impossible for you. The beetle in FIGURE 2.4 is different. Its tarsi, or feet, have sharp prongs that can grip smooth or vertical surfaces, as well as soft pads for walking on rough surfaces. The beetle's tarsus has a different structure and function than your foot has, but both are specialized for walking.

ORGANISMS MUST MAINTAIN HOMEOSTASIS TO SURVIVE IN DIVERSE ENVIRONMENTS

Temperature and other environmental conditions are always changing, but the conditions inside organisms usually stay quite stable. How does the polar bear in FIGURE 2.5 live in the Arctic? How can people be outside when the temperature is below freezing, but still have a stable body temperature around 37°C (98.6°F)? Why do you shiver when you are cold, sweat when you are hot, and feel thirsty when you need water?

Homeostasis is the maintenance of constant internal conditions in an organism. Homeostasis is important because cells function best within a limited range of conditions. Temperature, blood sugar, acidity, and other conditions must be controlled. Breakdowns in homeostasis are often life threatening.

Homeostasis is usually maintained through a process called negative feedback. In negative feedback, a change in a system causes a response that tends to return that system to its original state. For example, think about how a car's cruise control keeps a car moving at a constant set speed. A cruise control system has sensors that monitor the car's speed and then send that information to a computer. If the car begins to go faster than the set speed, the computer tells the car to slow down. If the car slows below the set speed, the computer tells the car to speed up. Similarly, if your body temperature drops below normal, systems in your body act to return your temperature to normal. Your muscles cause you to shiver, and blood vessels near your skin's surface constrict. If your body temperature rises above normal, different responses cool your body.

Behavior is also involved in homeostasis. For example, animals regulate their temperature through behavior. If you feel cold, you may put on a jacket. Reptiles sit on a warm rock in sunlight if they get too cold, and they move into shade if they get too warm.

EVOLUTION EXPLAINS THE UNITY AND DIVERSITY OF LIFE

Evolution is the change in living things over time. More specifically, evolution is a change in the genetic makeup of a sub group, or population, of a species. The concept of evolution links observations from all levels of biology, from cells to the biosphere. A wide range of scientific evidence, including the fossil record and genetic comparisons of species, shows that evolution is continuing today.

ADAPTATION

One-way evaluation occurs is through natural selection of adaptions. In natural selection, a genetic, or inherited, trait helps some individuals of a species survive and reproduce more successfully than other individuals in a particular environment. An inherited trait that gives an advantage to individual organisms and is passed on to future generations is an adaptation Over time, the makeup of a population changes because more individuals have the adaptation. Two different populations of the same species might have different adaptations in different environments. The two populations may continue to evolve to the point at which they are different species.

Consider the orchid and the thorn bug in FIGURE 2.6. Both organisms have adapted in ways that make them resemble other organisms. The orchid that looks like an insect lures other insects to it. The insects that are attracted to the orchid can pollinate the flower, helping the orchid to reproduce. The thorn bug's appearance is an adaptation that makes predators less likely to see and eat it. This adaptation allows the thorn bug to survive and reproduce.

In different environments, however, you would find other orchid and insect species that have different

adaptations.
Adaptation in evolution is different from the common meaning of adaptation. For example, if you say that you are adapting to a new classroom or to a new town, you are not talking about evolution. Instead, you are talking about consciously getting used to something new. Evolutionary adaptations are changes in a species that occur over many generations due to environmental pressures, not through choices made by organisms. Evolution is simply a long-term response to the environment. The process does not necessarily lead to more complex organisms, and it does not have any special end point. Evolution continues today, and it will continue as long as life exists on Earth.

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Section 1.3 Scientific Thinking and Processes

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SECTION SUMMARY: Science is a way of thinking, questioning, and gathering evidence. Scientists test hypotheses, or proposed explanations, through observation and experimentation. In a scientific experiment, a scientist controls constants, manipulates independent variables, and measures dependent variables. A scientific theory explains a wide range of observations and experimental results. A theory is supported by a wide range of evidence, and it is widely accepted by the scientific community

KEY CONCEPT Science Is A Way of Thinking, Questioning, and Gathering Evidence.

MAIN IDEAS:

- Like all science, biology is a process of inquiry.
- Biologist use experiments to test hypotheses.
- A theory explains a wide range of observation.
- Scientists communicate information in many different ways.

VOCABULARY

- Observation: The process of obtaining information by using the senses; the information obtained by using the senses
- Data: Observations and measurements recorded during an experiment.
- Hypothesis: A testable idea or explanation that leads to scientific investigation.
- Experiment: A procedure that is carried out under controlled conditions to discover, demonstrate, or test a fact, theory, or general truth.
- Independent variable: Condition or factor that is manipulated by a scientist during an experiment.
- Dependent variable: Experimental data collected through observation and measurement.
- Constant: Condition that is controlled so that it does not change during and experiment.
- Theory: Proposed explanation for a wide variety of observations and experimental results.

TEKS

- 2A: Know the definition of science and understand that it has limitations.
- 2B: Know that hypotheses are tentative and testable statements that must be capable of being supported or not supported by observational evidence.
- 2C: know scientific theories are based on natural and physical phenomena and are capable of being tested by multiple independent researchers. Unlike hypotheses, scientific theories are well established and highly reliable explanations, but they may be subject to change as new areas of science and new technologies are developed.
- 2D: Distinguish between scientific hypotheses and scientific theories.
- 3A: In all fields of science analyze, evaluate, and critique scientific explanations by using empirical evidence, logic reasoning, and experimental and observational testing.
- 3B: Communicate and apply scientific information extracted from various sources.

CONNECT TO YOUR WORLD: What does the study of fungus have in common with the study of human heart disease? How is research in the laboratory similar to research in a rain forest? Biologist, like all scientist, ask questions about the world and try to find answers through observation and experimentation. How do your daily observations help answer questions that you have about the world?

MAIN IDEA: Like all science, biology is a process of inquiry.

Science is a human process of trying to understand the world around us. There is no method used by all scientist, but all scientific inquiry is based on the same principles. Scientific thinking is based on curiosity, skepticism, and logical thinking.

- *Curiosity is what drives scientists to ask questions about the world around them.*
- *Skepticism is the use of critical thinking to question results and conclusions.*
- *Logical thinking is the use of reasoning through information to make conclusions that are supported by evidence.*

One of the most important points of science is that scientific evidence may support or even overturn long-standing ideas. Scientists depend on empirical evidence as the basis for scientific knowledge. Empirical evidence is evidence that is observed directly through research and investigation. Such evidence is used to construct testable explanations and predictions of natural phenomena. The written descriptions and drawings of the gorilla in FIGURE 3.1 are examples of observations and empirical evidence from a field investigation of gorillas. To improve our understanding of the world, scientists share their findings with each other. The open and honest exchange of data is extremely important in science.

OBSERVATIONS, DATA, AND HYPOTHESES

All scientific inquiry begins with careful and systematic observations. Of course, observation includes using our senses to study the world, but it may also involve other tools. For example, scientist use computer to collect measurements or to examine past research results. Empirical evidence is gathered through observation.

Observations are often recorded as data that can be analyzed. Scientist collect two general types of data: quantitative data and quantitative data. quantitative data are descriptions of a phenomenon that can include sights, sounds, and smells. This type of data is useful to report what happens but not how it happens. In contrast, quantitative data are characteristics that can be measured or counted, such as mass, volume, and temperature. Anything that is expressed as a number is quantitative data that can be used to explore how something happens.

Scientists use observation, data, and scientific literature to form a hypothesis. A hypothesis *(plural hypotheses)* is a proposed answer for a scientific question. A hypothesis must be specific and testable. You probably form and test many hypotheses every day, even though you may not be aware of it. Suppose you oversleep for example. You need to get up at 7 a.m. but when you wake up you observe that it is 8 a.m. What happened? Did the alarm not go off? Was it set to the wrong time? Did it go off, but you slept through it? You just made three hypotheses to explain why you overslept-the alarm did not go off, the alarm was set to the wrong time, or the alarm went off, but you didn't hear it

HYPOTHESES, RESULTS, AND CONCLUSIONS

A hypothesis leads to testable predictions of what would happen if the hypothesis is valid. How could you use scientific thinking to test a hypothesis about oversleeping? If you slept late because the alarm was set for the wrong time, you could check the alarm to find out the time for which it is set. Suppose you check, and the alarm was actually set for 7 p.m. In this case your hypothesis would be supported by your data.

For scientists, just one test of a hypothesis is usually not enough. Most of the time, it is only by repeating tests that scientists can be more certain that their results are not mistaken or due to chance. Biological systems are highly variable. By repeating tests scientists take this variability into account and try to decrease its effects on the experimental results. After scientists collect data, they use statistics to mathematically analyze whether a hypothesis is supported. Analyzed data are the results of the experiment. There are two possible outcomes or results.

- **Nonsignificant**: The data shows no effect, or an effect so small that the results could have happened by chance.
- **Statistically significant:** The data shows in effect that is likely not due to chance. When data do not support a hypothesis, the hypothesis is rejected. But the data is still useful because the often lead to new hypotheses.

Experimental methods and results are evaluated by other scientists in a process called peer review. Only after this review is complete are research results accepted. Whether the results support an existing theory or disagree with earlier research, they are often used as a starting point for new questions. In FIGURE 3.3, you see the cycle of observing, forming hypotheses, testing hypotheses, analyzing data, and evaluating results that keeps inquiry going.

MAIN IDEA: Biologists use experiments to test hypotheses

Observational studies help biologists describe and explain something in the world. But in observational studies, scientist try not to interfere with what happens. They try to simply observe a phenomenon. One example involves the endangered white stork. The number of white storks had decreased sharply by 1950, even becoming extinct in some countries. To help protect the storks, biologists studied the migration patterns of the birds. Observational studies can tell a biologist about changes in migration path and distance. They told scientists where the storks were breeding and how many eggs they would lay. Because of these efforts, stork populations have rebounded by 20% worldwide. Observational studies can provide much information and answer many questions. But there is one question that observations cannot answer: What causes any changes that might be observed? The only to answer that question is through an experiment.

Scientific experiments allow scientists to test hypotheses and find out how something happens. In experiments, scientists study factors called independent variables and dependent variables to find cause-and-effect relationships.

The independent variable in an experiment is a condition that is manipulated, or changed, by a scientist. The effects of manipulating an independent variable are measured by changes in dependent variables.

Dependent variables are observed and measured during an experiment; they are the experimental data. Changes in dependent variables depend upon the manipulation of the independent variable. Suppose a scientist is testing medications to treat high blood pressure. The independent variable is the dose of medication. The dependent variable is the is blood pressure as shown in FIGURE 3.4.

Ideally, only one independent variable should be tested in an experiment. Thus, all of the other conditions have to stay the same. The conditions that do not change during an experiment are called *constants*. To study the effects of an independent variable, a scientist uses a control group or control condition. Subjects in a control group are treated exactly like experimental subjects except for the independent variable being studied. The independent variable is manipulated into experimental groups or experimental conditions.

Constants in the blood pressure medication experiment include how often the medication is given and how the medication is taken. To control the experiment, these factors must remain the same, or be held constant. For example, the medication could be tested with 0, 25, 50, or 100 milligram doses, twice a day, taken by swallowing a pill. By changing only one variable at a time-the amount of medication-a scientist can be more confident that the results are due to that variable.

MAIN IDEA: A theory explains a wide range of observation.

The meaning of a word may change depending on the context in which it is used. The word theory has different meanings. In everyday conversation, the word theory means a guess or a hunch. In science, the meaning of the word theory is very different. A theory is a proposed explanation for a wide range and experimental results that is supported by a wide range of evidence. Recall that a hypothesis is a proposed answer to a scientific question. Hypotheses about natural and physical phenomena that have been tested of a wide variety of conditions are incorporated into theories. For example, natural selection is a scientific theory. It is supported by a large amount of data, and it explains how populations can evolve.

Hypotheses propose answers to scientific questions. Scientific theories provide explanations to a phenomenon. In contrast to hypotheses and theories, a scientific law defines relationships that are valid everywhere in the universe. For example, the law of conservation of energy may change form, but it cannot be created or destroyed. A law describes without providing any explanations.

Theories are not easily accepted in science, and by definition they are never proved. Eventually a theory may be broadly accepted into a scientific community. Scientific hypotheses and theories may be supported, or refuted, and they are subject to change. New theories that better explain observations and experimental results can replace older theories. Scientists must always be willing to revise theories and conclusions as new evidence about living things in the world is gathered. Science is an ongoing process. New experiments and observations refine and expand scientific knowledge.

One example of how scientific understanding can change involves the cause of disease. Until the mid-1800s, illnesses were thought to be related to supernatural causes or to imbalances of the body's humors, or fluids. Then scientific research suggested that diseases were caused by microscopic organisms, such as bacteria. This is the basis of the germ theory of disease, which is still accepted today. However, the germ theory has changed over time. For example, the germ theory has been expanded due to the discoveries of viruses and prions. Viruses and prions are not living organisms, but they do cause disease. The link between prions and disease was not even suggested until the early 1980s when evidence pointed to prions as the cause of mad cow disease and, in humans, both classic and variant Creutzfeldt–Jakob disease.

Scientific inquiry is important to understanding nature, but there are limitations to the kinds of questions that scientific inquiry can answer. For example, observations must be testable and verifiable. Observations that cannot be verified or replicated cannot count as evidence in scientific inquiry. Some phenomena that are not scientifically testable now may become testable with new or better technology. Other phenomena, such as supernatural phenomena, may never be testable or scientific

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MAIN IDEA: SCIENTISTS COMMUNICATE INFORMATION IN MANY DIFFERENT WAYS.

You may have seen written sources that include scientific information, such as product advertisements, magazine articles, or webpages. Scientific information may be presented at science fairs and symposia, which are forums for professional scientists to present and discuss new research, as in **FIGURE 3.6.** Because there are so many ways to communicate scientific information, it is important to know how to evaluate different methods of communication.

PRIMARY AND SECONDARY SOURCES

Recall that new scientific research is reviewed by other scientists through the peer review process. During peer review, scientists consider many things. How was an experiment done? How were the data analyzed? Do the data support the conclusions? Is there bias in the experimental design or in the conclusions? Peer-reviewed scientific information is published in scientific journals. Scientific journals are primary sources of scientific information and include results and conclusions, along with experimental methods, data, and details that other scientists would need to recreate the investigation. Almost all scientific knowledge presented to the public comes from secondary sources. Secondary sources summarize or report only portions of primary information. Magazine articles, news reports, textbooks, and advertisements are examples of secondary sources of information. Secondary sources may contain pieces of data that are most relevant to the source.

EVALUATING SCIENTIFIC INFORMATION

Not all information that is presented as scientific is reliable. Reliable sources of scientific information are based on empirical evidence, logical reasoning, and testing. When evaluating scientific information, consider the evidence that supports the scientific claim, the purpose of the source, and whether any bias is present. Use critical thinking skills to evaluate the information.

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Section 1.4 Biologists' Tools and Technology

Friday, January 15, 2021 4:05 PM

BIG IDEA: Biology is the study of all aspects of living things, and it shapes our understanding of our world, from human health in biotechnology to environmental preservation.

SECTION SUMMARY: Science is a way of thinking, questioning, and gathering evidence. Scientists test hypotheses, or proposed explanations, through observation and experimentation. In a scientific experiment, a scientist controls constants, manipulates independent variables, and measures dependent variables. A scientific theory explains a wide range of observations and experimental results. A theory is supported by a wide range of evidence, and it is widely accepted by the scientific community.

KEY CONCEPT: Technology continually changes the way biologist work.

MAIN IDEAS:

- Observations include making measurements.
- Technology contributes to the progress of science.
- Complex systems are modeled on computers.
- The tools of molecular genetics give rise to new biological studies

VOCAB:

- Measurement: A determination of the dimensions of something using a standard unit \.
- Accuracy: a description of how close a measurement is to the true value of the quantity measured
- Precision**:** the exactness of a measurement
- Microscope: tool that provides an enlarged image of an object
- Gene: the most basic physical unit of heredity; a segment of nucleic acids that codes for a functional unit of RNA and/or a protein
- Molecular Genetics: study of DNA structure and function on the molecular level
- Genomics: the study of entire genomes, especially by using technology to compare genes within and between species.

TEKS:

2F: Collect and organize qualitative and quantitative data and make measurements with accuracy and precision using tools

3E: Evaluate models according to their limitations in representing biological objects or events

CONNECT TO YOUR WORLD: Can you imagine life without cars, computers, or cell phones? Technology changes the way we live and work. Technology also plays a major part in the rapid increase of biological knowledge. In the early days of biology, scientists were limited to making measurements and observations with simple tools. Today, technology allows biologists to view tiny structures within cells and activity within a human brain. Technology even allows biologists to study and change genes. What will technology allow next?

MAIN IDEA: Observations include making measurements

A wildlife biologist records a description of the alligator mating rituals she observes in her field journal. A pharmaceutical researcher uses probes and computers to measure and calculate the pH of stomach acids. Though very different, these situations are both examples of observation and the use of tools in scientific investigations. Tools serve a variety of purposes. Some tools, such as laboratory glassware and hot plates, allow scientists to set up experiments. Tools such as microscopes and hand lenses are used to enhance senses. Rulers, balances, and timing devices enable the gathering of quantitative data. Computer software is a tool that enables scientists to analyze and report data.

Quantitative data are gathered through measurement, the determination of the dimensions of something using a standard unit. The modern metric system, called the International System of Units, or SI, is the language for all scientific measurement. The quality of measurements can be described by their accuracy and precision. Accuracy is a description of how close a measurement is to the true value of the quantity measured. Precision is the exactness of a measurement. Accuracy and precision are demonstrated by the results of horseshoes tosses in **FIGURE 4.1.** When the horseshoes are close to each other, even if they are not near the goal post, the results are precise. When the horseshoes are centered around the goal post, even if they are not near each other, the results are accurate. When the horseshoes are centered around the goal post and close to each other, the results are both precise and accurate.

MAIN IDEA: Technology contributes to the progress of science.

Until the late 1600s, no one knew about cells or single-celled organisms. Then the microscope was invented. Scientists suddenly had the ability to study living things at a level they never knew existed. Thus, the microscope was the first in a long line of technologies that changed the study of biology.

MICROSCOPES:

A microscope provides an enlarged image of an object. Some of the most basic concepts of biology—such as the fact that cells make up all organisms—were not even imaginable before microscopes. The first microscopes magnified objects but did not produce clear images. By the 1800s, most microscopes had combinations of lenses that provided clearer images. Today's light microscopes, such as the one in **FIGURE 4.2** that you might use, are still based on the same principles. They are used to see living or preserved specimens, and they provide clear images of cells as small as bacteria. Light microscopes clearly magnify specimens up to about 1500 times their actual size, and samples are often stained with chemicals to make details stand out.

Electron microscopes, first developed in the 1930s, use beams of electrons instead of light to magnify objects. These microscopes can be used to see cells, but they produce much higher magnifications so they can also show much smaller things. Electron microscopes can clearly magnify specimens as much as 1,000,000 times their actual size. They can even be used to directly study individual protein molecules. However, electron microscopes, unlike light microscopes, cannot be used to study living organisms because the specimens being studied have to be in a vacuum.

There are two main types of electron microscopes.

- A scanning electron microscope (SEM) scans the surface of a specimen with a beam of electrons. Usually, the specimen's surface is coated with a very thin layer of a metal that deflects the electrons. A computer forms a three-dimensional image from measurements of the deflected electrons.
- A transmission electron microscope (TEM) transmits electrons through a thin slice of a specimen. The TEM makes a two-dimensional image similar to that of a light microscope, but a TEM has a much higher magnification.

SEM and TEM images are artificially colorized with computers so that tiny details, such as the leaf pores, or stoma, shown in **FIGURE 4.3**, are easier to see.

MEDICAL IMAGING:

Imaging technology is not limited to microscopes. For example, doctors or dentists have probably taken x-ray images of you several times. An x-ray image is formed by x-rays, which pass through soft tissues, such as skin and muscle, but are absorbed by bones and teeth. Thus, x-ray images are very useful for looking at the skeleton but not so useful for examining soft tissues such as ligaments, cartilage, or the brain.

To image soft tissues, another imaging technology called magnetic resonance imaging (MRI) is used. MRI uses a strong magnetic field to produce a cross-section image of a part of the body. A series of MRI images can be put together to give a complete view of all of the tissues in that area, as you can see in FIGURE 4.4. Advances in technology have led to new uses for MRI. For example, a technique called functional MRI (fMRI) can show which areas of the brain are active while a person is doing a particular task.

COMPUTER AND PROBEARE:

The first digital, electronic computers were invented in the 1940s. They were expensive and so large that one computer filled an entire room. As technology improved, computers, computer software, and hardware, such as probeware, have become invaluable to the practice of biology. Word processing software is used to generate reports. Spreadsheet software is used to quickly and accurately calculate, analyze, and display data in charts, graphs, and other visual representations. The use of probeware in conjunction with computers allows both data collection and analysis. Probeware are measuring tools that can take constant readings of data such as temperature and pH. When probeware is connected to a computer, the data can be calculated and analyzed instantly.

MAIN IDEA: Complex systems are modeled on computers.

Computer-based technology has greatly expanded biological research. As computers have become faster and more powerful, biologists have found ways to use them to model living systems that cannot be studied directly. A computer model simulates the interactions among many different variables to provide scientists with a general idea of how a biological system may work.

Computers can model complex systems within organisms. For example, computer models are used to study how medicines might affect the body or, as you can see in FIGURE 4.5, the effects of a heart attack. Scientists have even used computer models to find out how water molecules travel into and out of cells. The scientists made a computer program that took into account more than 50,000 virtual atoms in a virtual cell. The computer model showed that water molecules must spin around in the middle of a channel, or a passage into the cell, to fit through the channel. Water molecules had a specific fit that other molecules could not match. Computer models can also help biologists' study complex systems on a much larger scale. Epidemiology, which is the study of how diseases spread, depends on computer models. For example, the computer model in FIGURE 4.6can predict how fast and how far a disease might spread through a herd of cattle. A model can calculate the number of cattle who might get sick and suggest where the disease could be spread to humans through eating contaminated meat or other sources. This study cannot be done with real cattle and people. Computer models are used when actual experiments are not safe, ethical, or practical. However, all models have limitations, and they are not able to replicate exactly all aspects of the system they are showing

MAIN IDEA: The tools of molecular genetics give rise to new biological studies

Computer-based technologies, such as those shown in FIGURE 4.7, have led to major changes in biology. But perhaps the greatest leap forward in our knowledge of life has happened in genetics. In just 40 years, we have gone from learning how the genetic code works, to changing genes, to implanting genes from one species into another.

What is a gene? A gene is a segment of DNA that stores genetic information. Our understanding of the DNA molecule has led to many technologies that were unimaginable when your parents were in high school—genetically modified foods, transgenic plants and animals, even replacement of faulty genes. These advances come from molecular genetics. Molecular genetics is the study and manipulation of DNA on a molecular level. Molecular genetics is used to study evolution, ecology, biochemistry, and many other areas of biology.

Entirely new areas of biology have arisen from combining molecular genetics with computer technology. For example, computers are used to quickly find DNA sequences. Through the use of computers, the entire DNA sequences, or genomes, of humans and other organisms have been found. Genomics (juh-NOH-mihks) is the study and comparison of genomes both within and across species. All of the information from genomics is managed by computer databases. By searching computer databases, a process called data mining, a biologist can find patterns, similarities, and differences in biological data. Suppose a biologist identifies a molecule that prevents the growth of cancerous tumors. The biologist could use computer databases to search for similar molecules. This is the cutting edge of biology today. Where will biology be when your children are in high school?

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Section 1.5 Biology and Your Future

Friday, January 15, 2021 4:06 PM

BIG IDEA: Biology is the study of all aspects of living things, and it shapes our understanding of our world, from human health in biotechnology to environmental preservation.

SECTION SUMMARY: Understanding biology can help you make informed decisions. An understanding of biology can help you to make important decisions about your own health and lifestyle, as well as decisions that will shape the world around you. The development of biotechnology and genetic manipulation is just one issue in biology that will affect you and the rest of society in the coming years.

KEY CONCEPT: Understanding biology can help you make informed decisions.

MAIN IDEAS:

- Your health and the health of the environment depend on your knowledge of biology.
- Biotechnology offers great promise but also raises many issues
- Biology presents many unanswered questions.

VOCAB:

- Biotechnology: Use and application of living things and biological processes
- Transgenic: organism whose genome has been altered to contain one or more genes from another organism or species.

CONNECT TO YOUR WORLD:

Should brain imaging technology be used to tell if someone is lying? Is an endangered moth's habitat more important than a new highway? Would you vote for or against the pursuit of stem cell research? An informed answer to any of these questions requires an understanding of biology and scientific thinking. And although science alone cannot answer these questions, gathering evidence and analyzing data can help every decision maker.

MAIN IDEA: Your health and the health of the environment depend on your knowledge of biology.

Decisions are based on opinions, emotions, education, experiences, values, and logic. Many of your decisions, now and in the future, at both personal and societal levels, involve biology. Your knowledge of biology can help you make informed decisions about issues involving endangered species, biotechnology, medical research, and pollution control, to name a few. How will your decisions affect the future of yourself and others?

BIOLOGY AND YOUR HEALTH

What you eat and drink is directly related to your health. But you may not think twice about the possibility of contaminated food or water, or a lack of vitamins in your diet. Not long ago, diseases caused by vitamin deficiencies were still fairly common. The first vitamins were identified less than 100 years ago, but today the vitamins found in foods are printed on labels.

Even today we still face food-related causes of illness. For example, you might hear about an outbreak of food poisoning, and mad cow disease was only recognized in the late 1980s. Of perhaps greater concern to you are food allergies. Many people suffer from severe, even life-threatening, allergies to foods such as peanuts and shellfish. Beyond questions about the sources of food are questions and concerns about what people eat and how much they eat. For example, scientists estimate that more than 60% of adults in the United States are overweight or obese. The health consequences of obesity include increased risks of diabetes, stroke, heart disease, breast cancer, colon cancer, and other health problems. Biology can help you to better understand all of these health-related issues.

An understanding of biology on many different levels—genetic, chemical, and cellular, for example—can help you make any number of lifestyle choices that affect your health. Why is it important to use sunscreen? What are the benefits of exercise? What are the effects of using alcohol, illegal drugs, and tobacco? Cigarette smoke does not just affect the lungs; it can also change a person's body chemistry, as you can see in **FIGURE 5.1**. Lower levels of monoamine oxidase in the brain can affect mood, and lower levels in the liver could contribute to high blood pressure.

BIOLOGY AND THE WORLD AROUND YOU

In 1995, some middle school students from Minnesota were walking through a wetland and collecting frogs for a school project. The students stopped to look at the frogs, and what they saw shocked them.

Many of the frogs had deformities, including missing legs, extra legs, and missing eyes. What caused the deformities? Scientists investigated that question by testing several hypotheses. They studied whether the deformities could have been caused by factors such as a chemical in the water, ultraviolet radiation, or some type of infection.

Why would frog deformities such as that in FIGURE 5.2 provoke such scientific interest? The frogs are a part of an ecosystem, so whatever affected them could affect other species in the area. If the deformities were caused by a chemical in the water, might the chemical pose a risk to people living in the area? In other regions of the United States, parasites caused similar deformities in frogs. Might that parasite also be present in Minnesota? If so, did it pose a risk to other species?

At first, parasites were not found in the frogs. However, scientists now suggest that the frog deformities were due to a combination of infection by parasites, called trematodes, and predation by dragonfly nymphs. Science has answered some questions about the cause of the leg deformities. However, scientists now think that a chemical may be connected to the increased number of parasite infections. Suppose that the chemical comes from a factory in the area. Is it reason- able to ban the chemical? Should the factory be closed or fined? In any instance like this, political, legal, economic, and biological concerns have to be considered. What is the economic impact of the factory on the area? Is there any evidence of human health problems in the area? Is there a different chemical that could be used? Without an understanding of biology, how could you make an informed decision related to any of these questions?

These are the types of questions that people try to answer every day. Biologists and other scientists research environmental issues such as pollution, biodiversity, habitat preservation, land conservation, and natural resource use, but decisions about the future are not in the hands of scientists. It is up to everyone to make decisions based on evidence and conclusions from many different sources.

MAIN IDEA: Biotechnology offers great promise but also raises many issues.

Biotechnology is the use and application of living things and biological processes. Biotechnology includes a very broad range of products, processes, and techniques. In fact, some forms of biotechnology have been around for centuries, such as the use of microorganisms to make bread and cheese. Today, biotechnology is used in medicine, agriculture, forensic science, and many other fields. For example, people wrongly convicted of crimes have been freed from prison when DNA testing has shown that their DNA did not match DNA found at crime scenes. Biotechnology has great potential to help solve a variety of modern problems, such as the search for alternative energy sources using algae, as shown in FIGURE 5.3. However, along with the advances in biotechnology come questions about its uses.

BENEFITS AND BIOLOGICAL RISKS

All domestic plants and animals are the result of centuries of genetic manipulation through selective breeding. Today, genetic manipulation can mean the transfer of genetic information from one organism to a very different organism. Organisms that have genes from more than one species, or have altered copies of their own genes, are called transgenic organisms. Transgenic bacteria can make human insulin to treat people with diabetes. Transgenic sheep and cows can make human antibodies and proteins. When you hear about genetically modified foods, you are hearing about transgenic organisms. Genetically modified foods have many potential benefits. Crop plants are changed to increase the nutrients and yield of the plants and to resist insects. Insect-resistant crops could reduce or end the need for chemical pesticides. However, the long-term effects of genetically modified crops are not fully known. Is it safe to eat foods with genetically modified insect resistance? What if genetically modified plants spread undesirable genes, such as those for herbicide resistance, to wild plants? Around the world, the benefits and risks of biotechnology are debated. Understanding these benefits and risks requires knowledge of ecosystems, genetic principles, and even the functions of genes.

BENEFITS AND ETHICAL CONSIDERATIONS

Another form of biotechnology is human genetic screening, which is the analysis of a person's genes to identify genetic variations. Genetic screening can indicate whether individuals or their potential offspring may be at risk for certain diseases or genetic disorders. Genetic screening has the potential for early diagnosis of conditions that can be treated before an illness occurs.

Genetic screening also raises ethical concerns. For example, who should have access to a person's genetic information? Some people are concerned that insurance companies might refuse health insurance to someone with a gene that might cause a disease. Suppose genetic screening reveals that a child might have a genetic disorder. How should that information be used? Genetic screening has the potential to eliminate some disorders, but what should be considered a disorder? Of greater concern is the possibility that people might use genetic screening to choose the characteristics of their children. Is it ethical to allow people to choose to have only brown-eyed male children who would be at least 6 feet (ft) tall?

MAIN IDEA: Biology presents many unanswered questions.

The structure of DNA was described in 1953. By 2003, the entire human DNA sequence was known. Since 1953, our biological knowledge has exploded. But even today there are more questions than answers. Can cancer be prevented or cured? How do viruses mutate? How are memories stored in the brain? One of the most interesting questions is whether life exists on planets other than Earth. Extreme environments on Earth are home to living things like the methane worms in FIGURE 5.4. Thus, it is logical to suspect that other planets may also support life. But even if life exists elsewhere in the universe, it may be completely different from life on Earth. How might biological theories change to take into account the characteristics of those organisms?

A large number of questions in biology are not just unanswered—they are unasked. Before the microscope was developed, no one investigated anything microscopic. Before the middle of the 20th century, biologists did not know for sure what the genetic material in organisms was made of. As technology and biology advance, who knows what will be discovered in the next 20 years.

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