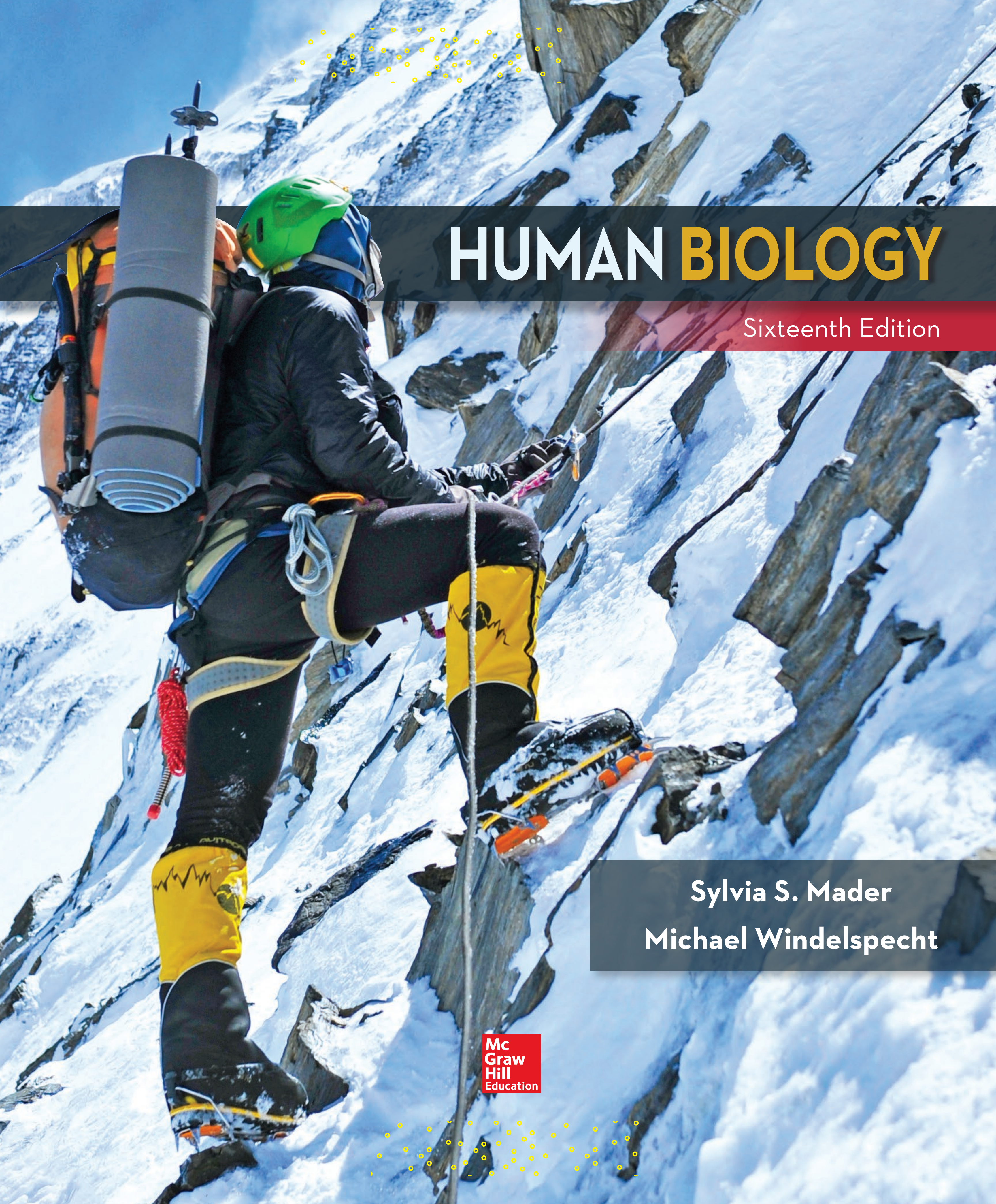
Sylvia S. Mader | Michael Windelspecht

HUMAN BIOLOGY

Sixteenth Edition

Mc Graw Hill Education



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ABOUT THE AUTHORS

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Sylvia S. Mader

Sylvia S. Mader has authored several nationally recognized biology texts published by McGraw-Hill. Educated at Bryn Mawr College, Harvard University, Tufts University, and Nova Southeastern University, she holds degrees in both biology and education. Over the years she has taught at University of Massachusetts, Lowell; Massachusetts Bay Community College; Suffolk University; and Nathan Mayhew Seminars. Her ability to reach out to science-shy students led to the writing of her first text, *Inquiry into Life*. Highly acclaimed for her crisp and entertaining writing style, her books have become models for others who write in the field of biology.

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Michael Windelspecht

As an educator, Dr. Windelspecht has taught introductory biology, genetics, and human genetics in the online, traditional, and hybrid environments at community colleges, comprehensive universities, and military institutions. For over a decade he served as the Introductory Biology Coordinator at Appalachian State University, where he directed a program that enrolled over 4,500 students annually.

He received degrees from Michigan State University (BS, zoology-genetics) and the University of South Florida (PhD, evolutionary genetics) and has published papers in areas as diverse as science education, water quality, and the evolution of insecticide resistance. His current interests are in the analysis of data from digital learning platforms for the development of personalized microlearning assets and next-generation publication platforms. He is currently a member of the National Association of Science Writers and several science education associations. He has served as the keynote speaker on the development of multimedia resources for online and hybrid science classrooms. In 2015 he won the DevLearn HyperDrive competition for a strategy to integrate student data into the textbook revision process.

As an author and editor, Dr. Windelspecht has over 20 reference textbooks and multiple print and online lab manuals. He has founded several science communication companies, including Ricochet Creative Productions, which actively develops and assesses new technologies for the science classroom. You can learn more about Dr. Windelspecht by visiting his website at www.michaelwindelspecht.com

ACKNOWLEDGMENTS

Dr. Sylvia Mader is one of the icons of science education. Her dedication to her students, coupled with her clear, concise writing style, has benefited the education of thousands of students over the past four decades. As an educator, it is an honor to continue her legacy and to bring her message to the next generation of students.

As always, I had the privilege to work with a phenomenal group of people on this edition. I would especially like to thank you, the numerous instructors who have shared e-mails with me or have invited me into your classrooms, both physically and virtually, to discuss your needs as instructors and the needs of your students. You are all dedicated and talented teachers, and your energy and devotion to quality teaching is what drives a textbook revision.

Many dedicated and talented individuals assisted in the development of this edition of *Human Biology*. I am very grateful for the help of so many professionals at McGraw-Hill who were involved in bringing this book to fruition. Therefore, I would like to thank the following:

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- Dawnelle Krouse, Michael McGee, and Sharon O'Donnell, who acted as my proofreaders and copyeditors for this edition.

As both an educator and an author, communicating the importance of science represents one of my greatest passions. Our modern society is based largely on advances in science and technology over the past few decades. As I present in this text, there are many challenges facing humans, and an understanding of how science can help analyze, and offer solutions to, these problems is critical to our species' health and survival.

I also want to acknowledge my family for all of their support. My wife, Sandy, has never wavered in her energy and support of my projects. The natural curiosity of my children, Devin and Kayla, has provided me with the motivation to make this world a better place for everyone.

Michael Windelspecht, PhD
Blowing Rock, NC

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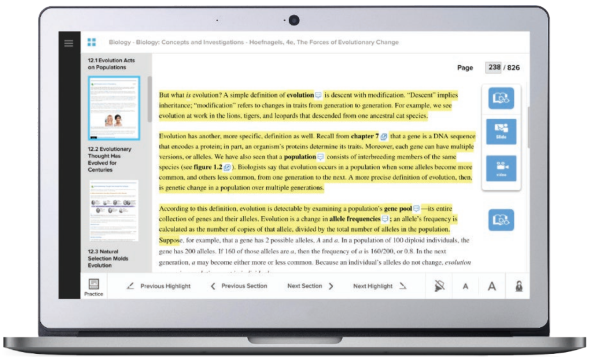

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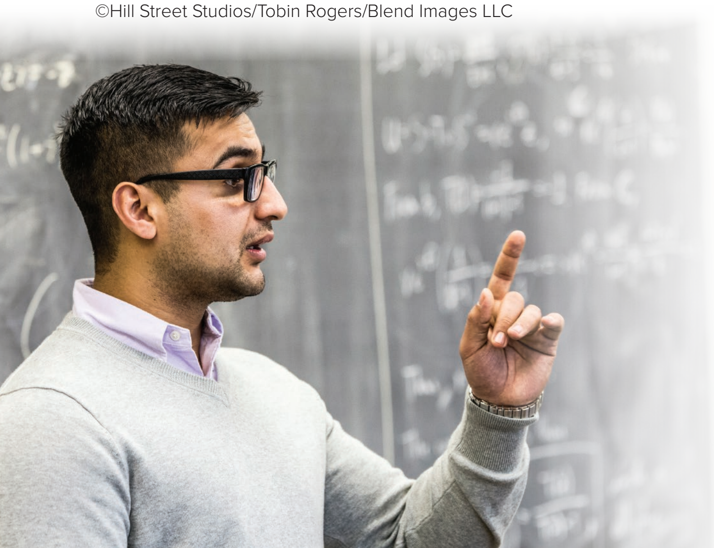

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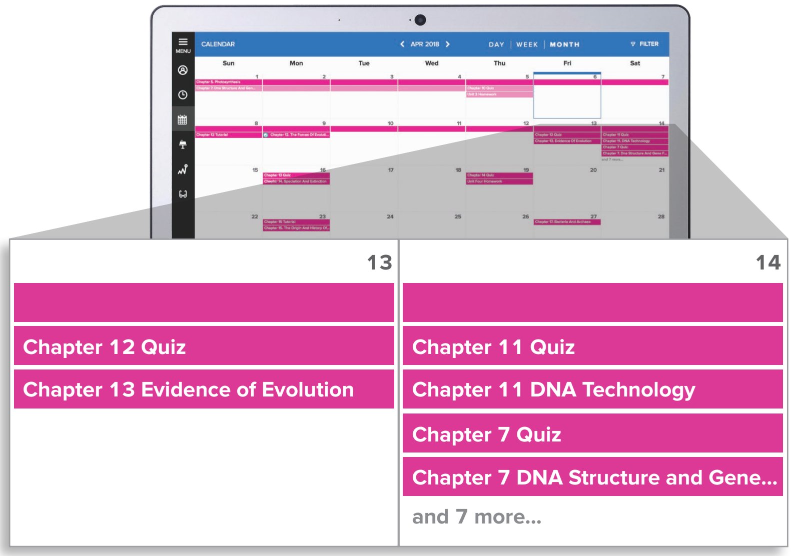

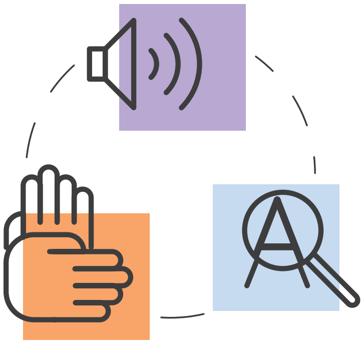

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PREFACE

Goals of the Sixteenth Edition

Humans are a naturally inquisitive species. As children, we become fascinated with our bodies, and life in general, at a very early age. We want to know how our bodies work, why there are differences, and similarities, between ourselves and the other children around us. In other words, at a very early age, we are all biologists.

In many ways, today's students in the science classroom face some of the same challenges their parents did decades ago. The abundance of new terms often overwhelms even the best prepared student, and the study of biological processes and methods of scientific thinking may convince some students that "science isn't their thing." The study of human biology creates an opportunity for teachers to instruct their students using the ultimate model organism—their own bodies. Whether this is their last science class or the first in a long career in allied health, the study of human biology is pertinent to everyone.

There are also challenges that are unique to the modern classroom. Today's students are being exposed, almost on a daily basis, to exciting new discoveries and insights that, in many cases, were beyond our predictions even a few short years ago. It is our task, as instructors, not only to make these findings available to our students, but to enlighten students as to why these discoveries are important to their lives and society. At the same time, we must provide students with a firm foundation in those core principles on which biology is founded, and in doing so, provide them with the background to keep up with the many discoveries still to come.

The author identified the following goals for the sixteenth edition of *Human Biology*:

- Updating of chapter openers, featured readings, and Connections content to focus on issues and topics important to this generation of students.
- Integrate more information on emerging diseases (such as Zika) and new technologies (for example, CRISPR).
- Update statistics, maps and tables to reflect changes in our scientific understanding of the various topics in the text.
- Assessment and redesign of art to better fit the digital learning environment.

Relevancy

The use of real-world examples to demonstrate the importance of biology in the lives of students is widely recognized as an effective teaching strategy for the introductory biology classroom. Students want to learn about the topics they are interested in. The development of relevancy-based resources is a major focus of the authors. Some examples of how we have increased the relevancy content of this edition include:

- A series of new chapter openers to introduce relevancy to the chapter. The authors chose topics that would be of interest to a nonscience major, and represent what would typically be found on a major news source.
- The inclusion of a series of the relevancy-based BioNow videos that offer relevant, applied classroom resources to allow students to feel that they can actually do and learn biology themselves.
- A website, RicochetScience.com, managed by Dr. Windelspecht, that provides updates on news and stories that are interesting to nonscience majors. The Biology101 project links these resources to the major topics of an introductory biology text. The site also features videos and tutorial animations to assist the students in recognizing the relevancy of what they are learning in the classroom.

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BRIEF CONTENTS

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Unit 7 Human Evolution and Ecology

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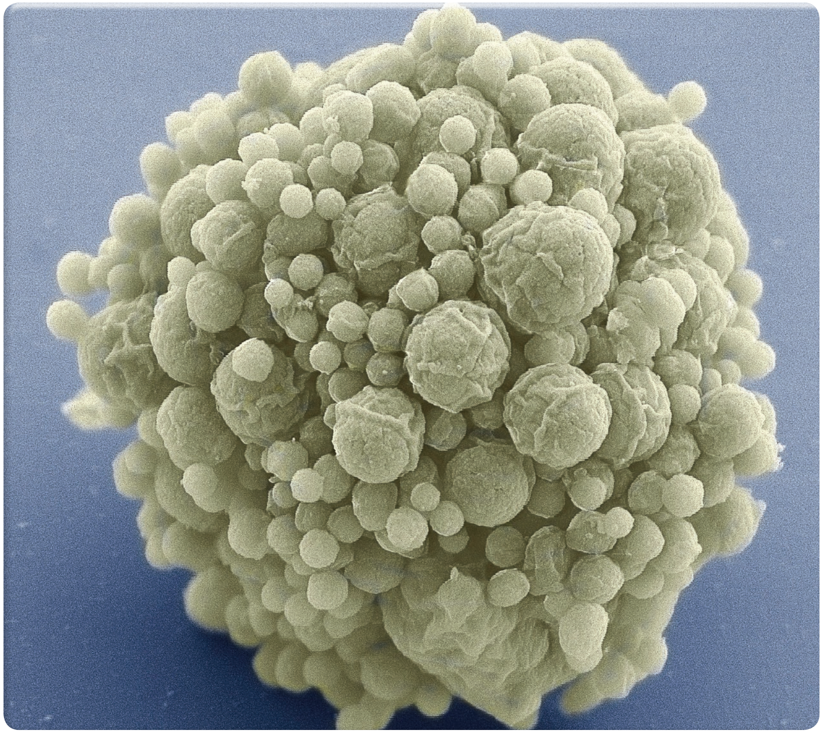

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CHAPTER

1

Exploring Life and Science

Artificial Life

What are the minimal requirements for life? That question has occupied the minds of philosophers and scientists for thousands of years. However, in just the past decade, answers to this question have begun to emerge from a developing field of scientific study called artificial life.

One of the first of these studies occurred in 2010, when a research team led by Craig Venter (a pioneer in genetic research) was successful in removing the genetic information contained within the DNA of a bacterium and replacing it with a synthetic form of DNA.

In 2016, the same group of researchers took their research one step further. This time, they asked what minimal instructions were needed by a cell for it to be considered alive. They constructed a cell that functioned on just 473 genes (humans have around 19,000). In the process, they not only narrowed in on what the minimal requirements for life are, but also created the first example of an artificial species.

The development of artificial life opens up the opportunity for humans to construct cells that perform specific tasks, such as producing insulin, cleaning toxic waste, or producing fuel more efficiently. However, there are concerns about these new endeavors, and some scientists are urging constraint until the risks have been determined.

In this chapter, we are going to explore the concept of life by examining the general characteristics that are shared by all living organisms on our planet.

As you read through the chapter, think about the following questions:

1. What are the basic characteristics that define life?
2. How do the processes of adaptation and evolution shape life over time?
3. How might the use of artificial life help scientists address some of the challenges facing society?

CHAPTER OUTLINE

1.1 The Characteristics of Life

LEARNING OUTCOMES

Upon completion of this section, you should be able to

1. Explain the basic characteristics common to all living organisms.
2. Describe the levels of organization of life.
3. Explain why the study of evolution is important in understanding life.

The science of **biology** is the study of living organisms and the environments they live in. All living organisms (Fig. 1.1) share several basic characteristics. They (1) are organized, (2) acquire materials and energy, (3) are homeostatic, (4) respond to stimuli, (5) reproduce and have the potential for growth, and (6) have an evolutionary history.

Life Is Organized

Life can be organized in a hierarchy of levels (Fig. 1.2). Note that, at the very base of this organization, **atoms** join together to form the **molecules,** which in turn make up a cell. A **cell** is the smallest structural and functional unit of an organism. Some organisms, such as bacteria, are single-celled organisms. Humans are multicellular, because they are composed of many different types of cells. For example, the structure of nerve cells in the human body allows these cells to conduct nerve impulses.

A **tissue** is a group of similar cells that perform a particular function. Nervous tissue is composed of millions of nerve cells that transmit signals to all parts of the body. An **organ** is made up of several types of tissues, and each organ belongs to an **organ system.** The organs of an organ system work together to accomplish a common purpose. The brain works with the spinal cord to send commands to body parts by way of nerves. **Organisms,** such as trees and humans, are a collection of organ systems.

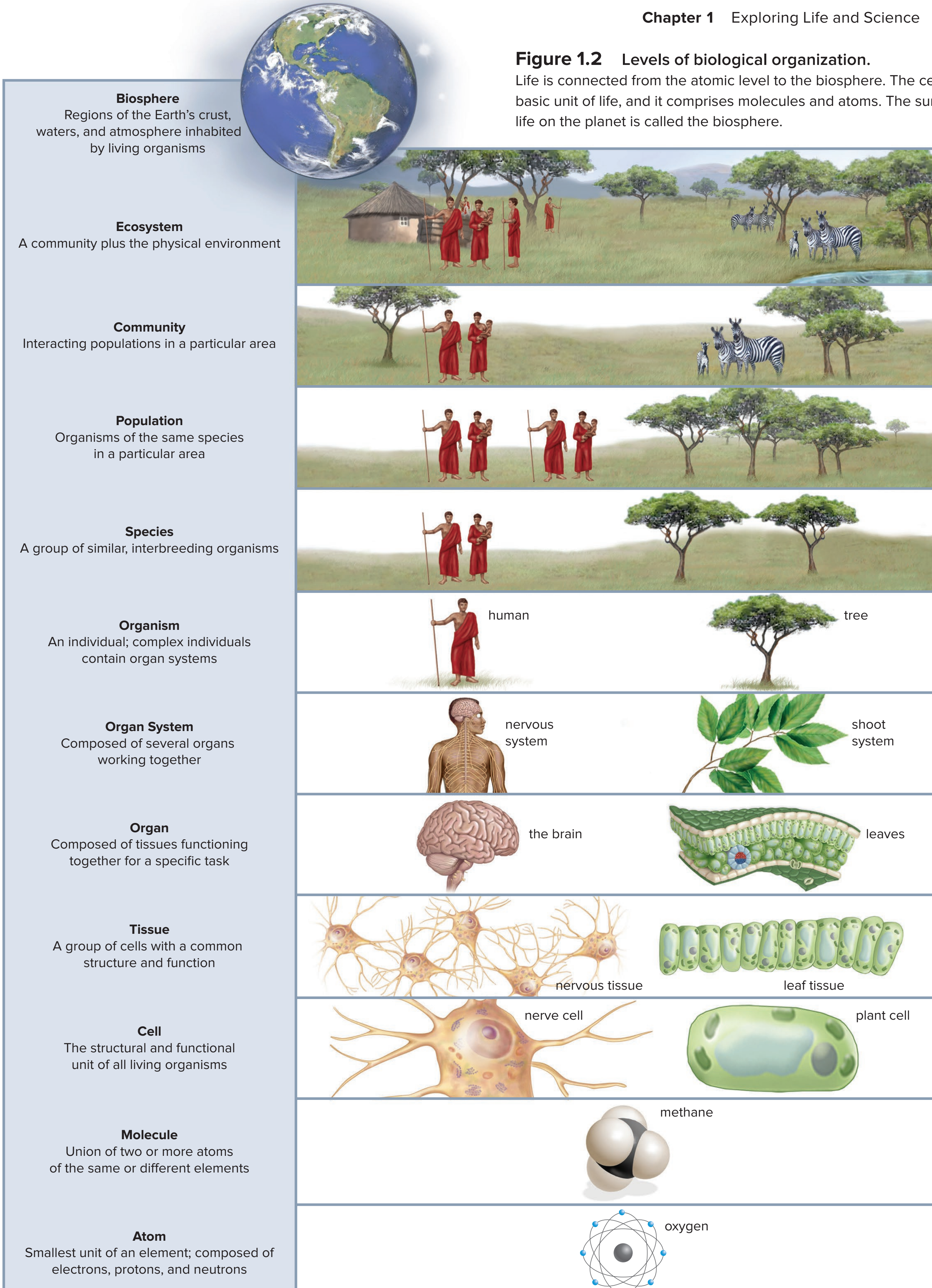
The levels of biological organization extend beyond the individual. All the members of one **species** (a group of interbreeding organisms) in a particular area belong to a **population.** A tropical grassland may have a population of zebras, acacia trees, and humans, for example. The interacting populations of the grasslands make up a **community.** The community of populations interacts with the physical environment to form an **ecosystem.** Finally, all the Earth's ecosystems collectively make up the **biosphere** (Fig. 1.2, *top*).

Figure 1.1 All life shares common characteristics.

From the simplest one-celled organisms to complex plants and animals, all life shares several basic characteristics.

(leech): ©Sergei Primakov/Shutterstock; (mushrooms): ©IT Stock/age fotostock; (bacteria): ©Paul Gunning/Science Photo Library/Getty Images; (meerkats): ©Jami Tarris/Getty Images; (sunflower): ©MedioImages/Punchstock; (*Giardia*): Source: Dr. Stan Erlandsen/CDC

Figure 1.2 Levels of biological organization. Life is connected from the atomic level to the biosphere. The cell is the basic unit of life, and it comprises molecules and atoms. The sum of all life on the planet is called the biosphere.



SCIENCE IN YOUR LIFE

How many cells are in your body?

The number of cells in a human body varies depending on the size of the person and whether cells have been damaged or lost. However, most estimates suggest there are well over 100 trillion cells in a human body.

Life Requires Materials and Energy

Humans, like all living organisms, cannot maintain their organization or carry on life's activities without an outside source of materials and energy. **Energy** is the capacity to do work. Like other animals, humans acquire materials and energy by eating food (Fig. 1.3).

Food provides nutrient molecules, which are used as building blocks or for energy. It takes energy to maintain the organization of the cell and the organism itself. Some nutrient molecules are broken down completely to provide the energy necessary to convert other nutrient molecules into the parts and products of cells. The term **metabolism** describes all the chemical reactions that occur within a cell.

a.

b.

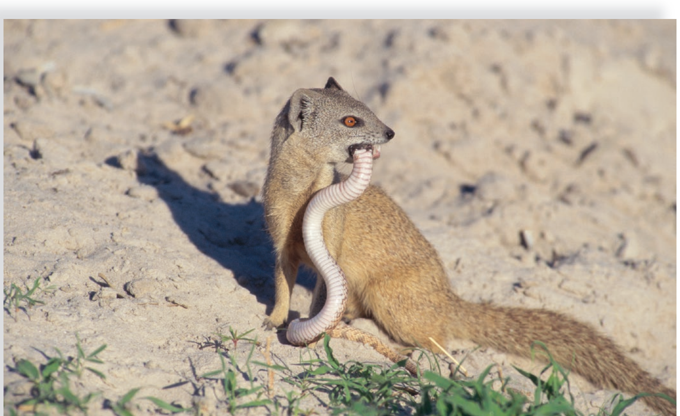


Figure 1.3 **Humans and other animals must acquire energy.** All life, including humans (**a**) and other animals, such as this mongoose (**b**), must acquire energy to survive. The method by which organisms acquire energy is dependent on the species.

(a): ©Ariel Skelley/Getty Images; (b): ©Gallo Images-Dave Hamman/Getty Images

The ultimate source of energy for the majority of life on Earth is the sun. Plants, algae, and some bacteria are able to harvest the energy of the sun and convert it to chemical energy by a process called **photosynthesis.** Photosynthesis produces organic molecules, such as sugars, that serve as the basis of the food chain for many other organisms, including humans and all other animals.

Living Organisms Maintain an Internal Environment

For the metabolic pathways within a cell to function correctly, the environmental conditions of the cell must be kept within strict operating limits. Many of the metabolic activities of a cell, or organism, function in maintaining **homeostasis**—a constant internal environment.

In humans, many of our organ systems work to maintain homeostasis. For example, human body temperature normally fluctuates slightly between 36.5 and 37.5°C (97.7 and 99.5°F) during the day. In general, the lowest temperature usually occurs between 2 A.M. and 4 A.M., and the highest usually occurs between 6 P.M. and 10 P.M. However, activity can cause the body temperature to rise, and inactivity can cause it to decline. The metabolic activities of our cells, tissues, and organs are dependent on maintaining a relatively constant body temperature. Therefore, a number of body systems, including the cardiovascular system and the nervous system, work together to maintain a constant temperature. The body's ability to maintain a normal temperature is also somewhat dependent on the external temperature. Even though we can shiver when we are cold and perspire when we are hot, we will die if the external temperature becomes overly cold or hot.

This text emphasizes how all the systems of the human body help maintain homeostasis. For example, the digestive system takes in nutrients, and the respiratory system exchanges gases with the environment. The cardiovascular system distributes nutrients and oxygen to the cells and picks up their wastes. The metabolic waste products of cells are excreted by the urinary system. The work of the nervous and endocrine systems is critical, because these systems coordinate the functions of the other systems.

Living Organisms Respond

It would be impossible to maintain homeostasis without the body's ability to respond to stimuli, both from the internal and external environments. Response to external stimuli is more apparent to us, because it involves movement, as when we quickly remove a hand from a hot stove. Certain sensory receptors also detect a change in the internal environment, and then the central nervous system brings about an appropriate response. When you are startled by a loud noise, your heartbeat increases, which causes your blood pressure to increase. If blood pressure rises too high, the brain directs blood vessels to dilate, helping restore normal blood pressure.

All life responds to external stimuli, often by moving toward or away from a stimulus, such as the sight of food. Organisms may use a variety of mechanisms to move, but movement in humans and other animals is dependent on their nervous and musculoskeletal systems. The leaves of plants track the passage of the sun during the day; when a houseplant is placed near a window, its stems bend to face the sun. The movement of an animal, whether

a. b.

Figure 1.4 Growth and development define life.

a. A small acorn becomes a tree, and (**b**) following fertilization an embryo becomes a fetus by the process of growth and development.

(a) (seedling): ©Bogdan Ionescu/Shutterstock; (a) (tree): ©Photographer's Choice/Getty Images; (b) (sperm/egg): ©David M. Phillips/Science Source; (b) (fetus): ©Brand X Pictures/Punchstock

self-directed or in response to a stimulus, constitutes a large part of its *behavior*. Some behaviors help us acquire food and reproduce.

Living Organisms Reproduce and Develop

Reproduction is a fundamental characteristic of life. Cells come into being only from preexisting cells, and all living organisms have parents. When organisms **reproduce,** they pass on their genetic information to the next generation. Following the fertilization of an egg by a sperm cell, the resulting zygote undergoes a rapid period of growth and development. This is common in most forms of life. Figure 1.4*a* illustrates that an acorn progresses to a seedling before it becomes an adult oak tree. In humans, growth occurs as the fertilized egg develops into a fetus (Fig. 1.4*b*). **Growth,** recognized by an increase in size and often in the number of cells, is a part of development. In multicellular organisms, such as humans, the term **development** is used to indicate all the changes that occur from the time the egg is fertilized until death. Therefore, it includes all the changes that occur during childhood, adolescence, and adulthood. Development also includes the repair that takes place following an injury.

The genetic information of all life is **DNA (deoxyribonucleic acid).** DNA contains the hereditary information that directs not only the structure of each cell but also its function. The information in DNA is contained within **genes,** short sequences of hereditary material that specify the instructions for a specific trait. Before reproduction occurs, DNA is replicated so an exact copy of each gene may be passed on to the offspring. When humans reproduce, a sperm carries genes contributed by a male into the egg, which contains genes contributed by a female. The genes direct both growth and development so that the organism will eventually resemble the parents. Sometimes **mutations,** minor variations in these genes, can cause an organism to be better suited for its environment. These mutations are the basis of evolutionary change.

Organisms Have an Evolutionary History

Evolution is the process by which a population changes over time. The mechanism by which evolution occurs is **natural selection** (see Section 23.2). When a new variation arises that allows certain members of a population to capture more resources, these members tend to survive and have more offspring than the other, unchanged members. Therefore, each successive generation will include more members with the new variation, which represents an **adaptation** to the environment. Consider, for example, populations of humans who live at high altitudes, such as the cultures living at elevations of over 4,000 meters (m) (14,000 ft) in the Tibetan Plateau. This environment is very low in oxygen. As the Science feature "Adapting to Life at High Elevations" investigates, these populations have evolved an adaptation that reduces the amount of hemoglobin, the oxygen-carrying pigment in the blood. As the feature explains, this adaptation makes life at these altitudes possible.

Evolution, which has been going on since the origin of life and will continue as long as life exists, explains both the unity and the diversity of life. All organisms share the same characteristics of life because their ancestry can be traced to the first cell or cells. Organisms are diverse because they are adapted to different ways of life.

BIOLOGY TODAY **Science**

Adapting to Life at High Elevations

Humans, like all other organisms, have an evolutionary history. This means not only that we share common ancestors with other animals but that over time we demonstrate adaptations to changing environmental conditions. One study of populations living in the high-elevation mountains of Tibet (Fig. 1A) demonstrates how the processes of evolution and adaptation influence humans.

Normally, when a person moves to a higher altitude, his or her body may respond by making more hemoglobin, the component of blood that carries oxygen, which in turn thickens the consistency of the blood. For minor elevation changes, this does not present much of a problem. But for people who live at extreme elevations (some people in the Himalayas can live at elevations of over 13,000 ft, or close to 4,000 m), excess hemoglobin can present a number of health problems, including chronic mountain sickness, a disease that affects people who live at high altitudes for extended periods of time. The problem is that, as the amount of hemoglobin increases, the blood thickens and becomes more viscous. This can cause elevated blood pressure, or hypertension, and an increase in the formation of blood clots, both of which have negative physiological effects.

Figure 1A
Individuals living at high elevations, such as these Tibetans, have become adapted to their environment.

Because high hemoglobin levels would be a detriment to people at high elevations, it makes sense that natural selection would favor individuals who produce less hemoglobin at high elevations. Such is the case with the Tibetans in this study. Researchers have identified an allele of a gene that reduces hemoglobin production at high elevations. Comparisons between Tibetans at both high and low elevations strongly suggest that selection has played a role in the prevalence of the high-elevation allele.

The gene is *EPSA1,* located on chromosome 2 of humans. *EPSA1* produces a transcription factor that basically regulates which genes are turned on and off in the body, a process called gene expression. The transcription factor produced by *EPSA1* has a number of functions in the body. For example, in addition to controlling the amount of hemoglobin in the blood, this transcription factor also regulates other genes that direct how the body uses oxygen.

When the researchers examined the variations in *EPSA1* in the Tibetan population, they discovered that the Tibetan version greatly reduces the production of hemoglobin. Therefore, the Tibetan population has lower hemoglobin levels than people living at lower altitudes, allowing these individuals to escape the consequences of thick blood.

How long did it take for the original population to adapt to living at higher elevations? Initially, the comparison of variations in these genes between high-elevation and low-elevation Tibetan populations suggested that the event may have occurred over a 3,000-year period. But researchers were skeptical of those data because they suggested a relatively rapid rate of evolutionary change. Additional studies of genetic databases yielded an interesting finding—the *EPSA1* gene in Tibetans was identical to a similar gene found in an ancient group of humans called the Denisovans (see Section 23.5). Scientists now believe that the *EPSA1* gene entered the Tibetan population around 40,000 years ago, either through interbreeding between early Tibetans and Denisovans, or from one of the immediate ancestors of this now-lost group of early humans.

Questions to Consider

1. What other environments do you think could be studied to look for examples of human adaptation?
2. In addition to hemoglobin levels, do you think people at high elevations may exhibit other adaptations?

CONNECTING THE CONCEPTS

Both homeostasis and evolution are central themes in the study of biology. For more examples of homeostasis and evolution, refer to the following discussions:

Section 4.8 explains how body temperature is regulated.

Section 11.4 explores the role of the kidneys in fluid and salt homeostasis.

Section 23.3 examines the evolutionary history of humans.

CHECK YOUR PROGRESS 1.1

1. List the basic characteristics of life.
2. Summarize the levels of biological organization.
3. Explain the relationship between adaptations and evolutionary change.

1.2 Humans Are Related to Other Animals

LEARNING OUTCOMES

Upon completion of this section, you should be able to

1. Summarize the place of humans in the overall classification of living organisms.
2. Understand that humans have a cultural heritage.
3. Describe the relationship between humans and the biosphere.

Biologists classify all life as belonging to one of three **domains.** The evolutionary relationships of these domains are presented in Figure 1.5.

Two of these domains, domain Bacteria and domain Archaea, contain prokaryotes, single-celled organisms that lack a nucleus (Fig. 1.6). Organisms in the third domain, Eukarya, all contain cells that possess a nucleus. Some of these organisms are single-celled; others are multicellular. Humans are multicelled Eukarya.

Historically, domain Eukarya was divided into one of four **kingdoms** (Fig. 1.6). The organisms in kingdom Protista comprise a very diverse group of organisms, ranging from single-celled forms to a few multicellular organisms. Some **protists** use photosynthesis to manufacture food, and some must acquire their own food.

The other three kingdoms of eukaryotes in Figure 1.6 (plants, fungi, and animals) all evolved from protists. **Plants** (kingdom Plantae) are multicellular, photosynthetic organisms. Example plants include azaleas, zinnias, and pines. Among the **fungi** (kingdom Fungi) are the familiar molds and mushrooms that, along with bacteria, help decompose dead organisms. **Animals** (kingdom Animalia) are multicellular organisms that must ingest and process their food. Aardvarks, jaguars, and humans are representative animals.

Recently, the development of improved techniques in analyzing the DNA of organisms suggests that not all of the protists share the same evolutionary lineage, meaning that the evolution of the eukaryotes has occurred along several paths. A new taxonomic group, called a **supergroup,** is being developed to explain these

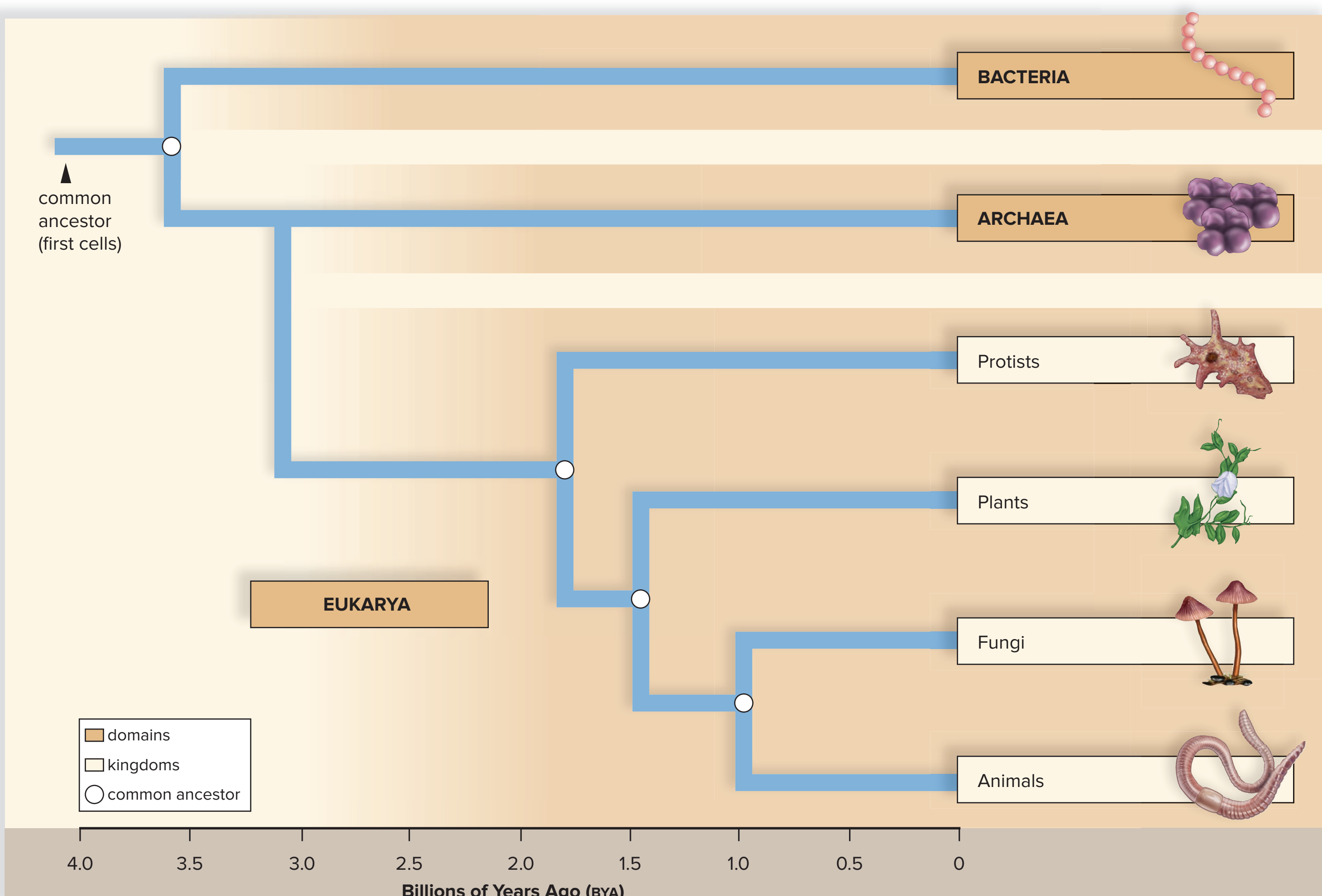


Figure 1.5 The evolutionary relationships of the three domains of life.
Living organisms are classified into three domains: Bacteria, Archaea, and Eukarya. The Eukarya are further divided into kingdoms (see Fig. 1.6).

Domain Archaea

- Prokaryotic cells of various shapes
- Adaptations to extreme environments
- Absorb or chemosynthesize food
- Unique chemical characteristics

Sulfolobus, an archaean

Domain Bacteria

- Prokaryotic cells of various shapes
- Adaptations to all environments
- Absorb, photosynthesize, or chemosynthesize food
- Unique chemical characteristics

E. coli, a bacterium

Domain Eukarya; Kingdom Protista

- Algae, protozoans, slime molds, and water molds
- Complex single cell (sometimes filaments, colonies, or even multicellular)
- Absorb, photosynthesize, or ingest food

Paramecium, a single-celled protozoan

Domain Eukarya; Kingdom Plantae

- Certain algae, mosses, ferns, conifers, and flowering plants
- Multicellular, usually with specialized tissues, containing complex cells
- Photosynthesize food

Phalaenopsis, orchid, a flowering plant

Domain Eukarya; Kingdom Fungi

- Molds, mushrooms, yeasts, and ringworms
- Mostly multicellular filaments with specialized, complex cells
- Absorb food

Cantharellula, a club fungi

Domain Eukarya; Kingdom Animalia

- Sponges, worms, insects, fishes, frogs, turtles, birds, and mammals
- Multicellular with specialized tissues containing complex cells
- Ingest food

Vulpes, a red fox

Figure 1.6 The classification of life.

This figure provides some of the characteristics of the organisms of each of the major domains and kingdoms of life. Humans belong to the domain Eukarya and kingdom Animalia.

evolutionary relationships. While these relationships are still being studied and analyzed, current thinking places the animals in the same supergroup as the fungi.

Most animals are *invertebrates,* such as earthworms, insects, and mollusks. *Vertebrates* are animals that have a nerve cord protected by a vertebral column, which gives them their name. Fish, reptiles, amphibians, and birds are all examples of vertebrates. Vertebrates with hair or fur and mammary glands are classified as *mammals*. Humans, raccoons, seals, and meerkats are examples of mammals.

Humans are primate mammals that are most closely related to apes. We are distinguished from apes by our (1) highly developed brains, (2) completely upright stance, (3) creative language, and (4) ability to use a wide variety of tools. Humans did not evolve from apes; apes and humans share a common, apelike ancestor. Today's apes are our evolutionary cousins. Our relationship to apes is analogous to you and your first cousin being descended from your grandparents. We could not have evolved directly from our cousins, because we are contemporaries—living on Earth at the same time.

Humans Have a Cultural Heritage

Humans have a cultural heritage in addition to a biological heritage. *Culture* encompasses human activities and products passed on from one generation to the next outside of direct biological inheritance. Among animals, only humans have a language that allows us to communicate information and experiences symbolically. We are born without knowledge of an accepted way to behave, but we gradually acquire this knowledge by adult instruction and the imitation of role models. Members of the previous generation pass on their beliefs, values, and skills to the next generation.

Many of the skills involve tool use, which can vary from how to hunt in the wild to how to use a computer. Human skills have also produced a rich heritage in the arts and sciences. However, a society highly dependent on science and technology has its drawbacks as well. Unfortunately, this cultural development may mislead us into believing that humans are somehow not part of the natural world surrounding us.

Humans Are Members of the Biosphere

All life on Earth is part of the biosphere, the living network that spans the surface of the Earth into the atmosphere and down into the soil and seas. Although humans can raise animals and crops for food, we depend on the environment for many services. Without microorganisms that decompose, the waste we create would soon cover the Earth's surface. Some species of bacteria help us by cleaning up pollutants like heavy metals and pesticides.

Freshwater ecosystems, such as rivers and lakes, provide fish to eat, drinking water, and water to irrigate crops. Many of our crops and prescription drugs were originally derived from plants that grew naturally in an ecosystem. Some human populations around the globe still depend on wild animals as a food source. The water-holding capacity of forests prevents flooding, and the ability of forests and other ecosystems to retain soil prevents soil erosion. For many people, these forests provide a place for recreational activities like hiking and camping.

SCIENCE IN YOUR LIFE

How many humans are there?

As of 2017, it was estimated that there were over 7.6 billion humans on the planet. Each of those humans needs food, shelter, clean water and air, and materials to maintain a healthy lifestyle. We add an additional 80 million people per year—that is like adding the population of ten New York Cities per year! This makes human population growth one of the greatest threats to the biosphere.

CHECK YOUR PROGRESS 1.2

1. Define the term *biosphere*.
2. Define *culture*.
3. Explain why humans belong to the domain Eukarya and kingdom Animalia.

CONNECTING THE CONCEPTS

To learn more about the preceding material, refer to the following discussions:

Chapter 23 examines recent developments in the study of human evolution.

Chapter 24 provides a more detailed look at ecosystems.

Chapter 25 explores how humans interact with the biosphere.

1.3 Science as a Process

LEARNING OUTCOMES

Upon completion of this section, you should be able to

1. Describe the general process of the scientific method.
2. Distinguish between a control group and an experimental group in a scientific test.
3. Recognize the importance of scientific journals in the reporting of scientific information.
4. Interpret information that is presented in a scientific graph.
5. Recognize the importance of statistical analysis to the study of science.

Science is a way of knowing about the natural world. When scientists study the natural world, they aim to be objective, rather than subjective. Objective observations are supported by factual information, whereas subjective observations involve personal judgment. For example, the fat content of a particular food would be an objective observation of a nutritional study. Reporting about the good or bad taste of the food would be a subjective observation. It is difficult to make objective observations and conclusions, because we are often influenced by our prejudices. Scientists must keep in mind that scientific conclusions can change because of new findings. New findings are often made because of recent advances in techniques or equipment.

Religion, aesthetics, ethics, and science are all ways in which humans seek order in the natural world. The nature of scientific inquiry differs from these other ways of knowing and learning, because the scientific process employs the **scientific method,** a standard series of steps used in gaining new knowledge that is widely accepted among scientists. The scientific method (Fig. 1.7) acts as a guideline for scientific studies.

The approach of individual scientists to their work is as varied as the scientists. However, much of the scientific process is descriptive. For example, an observation of a new disease may lead a scientist to describe all the aspects of the disease, such as the environment, the age of onset, and the characteristics of the disease. Some areas of biology, such as the study of biodiversity in the ecological sciences (see Section 1.4), lend themselves more to this descriptive approach. Regardless of their area of study, most scientists spend a considerable amount of time performing a descriptive analysis of their observation before proceeding into the steps of the scientific method. Scientists often modify or adapt the process to suit their particular field of study, but for the sake of discussion it is useful to think of the scientific method as consisting of certain steps.

Start with an Observation

Scientists believe that nature is orderly and measurable—that natural laws, such as the law of gravity, do not change with time—and that a natural event, or *phenomenon,* can be understood more fully through **observation**—a formal way of watching the natural world.

Observations may be made with the senses, such as sight and smell, or with instruments; for example, a microscope enables us to see objects that could never be seen by the naked eye. Scientists