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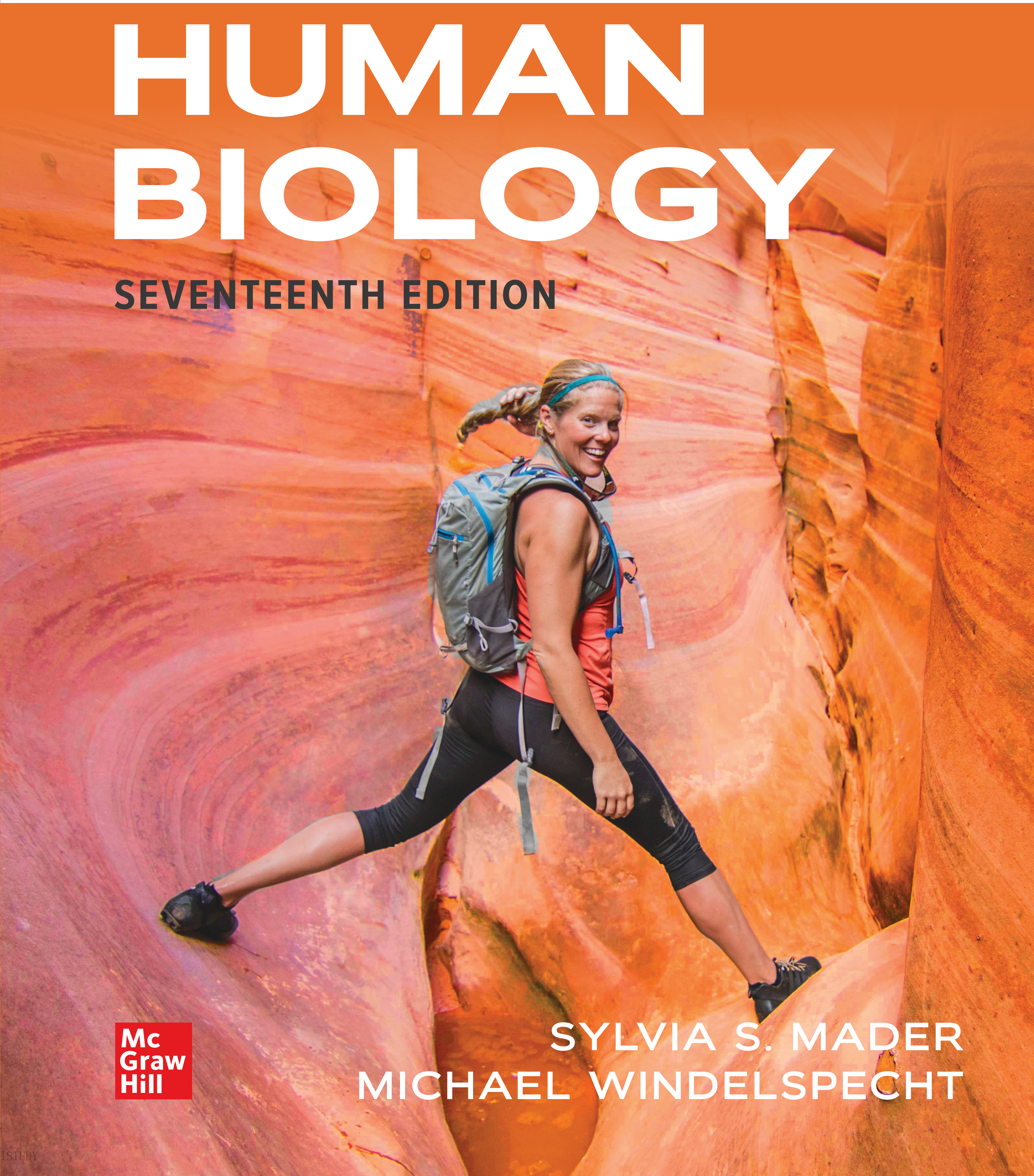
HUMAN BIOLOGY

SEVENTEENTH EDITION



SYLVIA S. MADER
MICHAEL WINDELSPECHT

Mc Graw Hill

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ABOUT THE AUTHORS


Courtesy of Sylvia S. Mader

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.


Ricochet Creative Productions, LLC

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 30 reference textbooks and multiple print and online lab manuals to his credit. He has founded several science communication companies, including Ricochet Creative Productions, which actively develops and assesses new technologies for the science classroom, and Inspire-EdVentures, which provides experiential learning opportunities online and in Belize. You can learn more about Dr. Windelspecht by visiting his website at www.windelspectrum.com.


Courtesy of Dave Cox

Contributor

Dave Cox serves as professor of biology at Lincoln Land Community College, in Springfield, Illinois. He was educated at Illinois College and Western Illinois University. As an educator, Professor Cox teaches introductory biology for nonmajors in the traditional classroom format, as well as in a hybrid format. He also teaches biology for majors, and marine biology and biological field studies as study-abroad courses in Belize. He is the co-owner of Howler Publications, a company that specializes in scientific study abroad courses. Professor Cox has served as a contributor to multiple McGraw Hill titles over the past 12 years. He also develops educational resources for the ecotourism industry in Belize.

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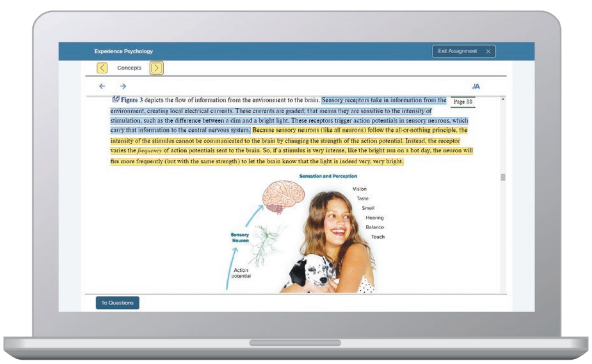

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PREFACE

Goals of the Seventeenth 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.

Students in today's world 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—from revolutionary new techniques to develop vaccines to stop pandemics, to the impacts of climate change on their local environments and advances in medical techniques to fight diseases such as cancer. Therefore, it is important that we know not only why we are different, but how we are the same as the species we share the planet with. 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 better understand the many discoveries still to come.

As educators, the authors of this text understand the needs of our colleagues in developing curricula that increasingly focus on relevancy and delivery in the online environment. McGraw Hill Education has long been an innovator in the development of educational resources, and the *Human Biology* text is at the forefront in integrating these resources and digital technologies into the science classroom. In this edition, that involved the following:

- Making the content more relevant to the current generation of students by updating chapter openers and themed readings to focus on issues and topics important to the discussions that students are hearing in the world around them.
- Integrating relevancy modules to supplement the format of a traditional textbook and provide another avenue for students to engage with the content.
- Redesigning the artwork to ensure it transitions to the digital world of mobile devices.
- Developing a new Featured Reading Series, The Diversity of Science, to emphasize the contributions of unrecognized scientists to our understanding of biology.

Virtual Labs and Lab Simulations

While the biological sciences are hands-on disciplines, instructors today are often asked to deliver some of their lab content online, as full online replacements, supplements to prepare for in-person labs, or make-up labs. These simulations help each

student learn the practical and conceptual skills needed, and then let them check their understanding of the lessons by providing feedback. With adaptive pre-lab and post-lab assessments available, instructors can customize each assignment.

From the instructor's perspective, these simulations may be used in the lecture environment to help students visualize complex scientific processes, such as DNA technology or Gram staining, while at the same time providing a valuable connection between the lecture and lab environments.

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 for the authors of the Mader series of texts. Some examples of how we have increased the relevancy content of this edition are explained in the following paragraphs.

Relevancy Modules

A series of relevancy modules have been designed to accompany each unit in *Human Biology.* These modules demonstrate the connections between biological content and topics that are of interest to society as a whole. Each module consists of an introductory video, an overview of basic scientific concepts, and then a closer look at the application of these concepts to the topic. An infographic at the end of each module may be easily used in the lecture environment to initiate discussion of the topic. Discussion and assessment questions, specific to the modules, are available at the end of the module, and for automatic assessment in the Connect platform. Below is a list of our current relevancy modules.

These modules are available as a supplementary eBook to the existing text within Connect, and may be assigned by the instructor for use in a variety of ways in the classroom.

Slavica/E+/Getty Images

BioNOW Videos

The BioNOW series of videos, narrated and produced by educator Jason Carlson, provide a relevant, applied approach that allows your students to feel they can actually learn biology on their own. While tying directly to the content of your course, the videos help students relate their daily lives to the biology you teach, and lets them connect what they learn back to their lives.

Each video provides an engaging and entertaining story about applying the science of biology to a real situation or problem. Attention is taken to use tools and techniques that the average person would have access to, so your students see the science as something they could do and understand.

Photos: McGraw Hill

Ricochet Science Website

The website https://ricochetscience.com, managed by Michael Windelspecht, provides updates on news and stories that are interesting to science and nonscience majors alike. The PopScience articles on this site provide an excellent focus for classroom discussions on topics that are currently being debated in society. The site also features videos and tutorial animations to assist the students in recognizing the relevance of what they are learning in the classroom.

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 emails 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:

- My product developer, Anne Winch, for her incredible ability to manage all aspects of this project simultaneously.
- Portfolio director Michelle Vogler and portfolio manager Lora Neyens, for their guidance and for reminding me why what we do is important.
- My marketing manager, Erin Martin, for placing me in contact with great instructors, on campus and virtually, throughout this process.
- My content project manager, Jessica Portz, and lead content project manager, Kelly Hart, for guiding this project throughout the publication process.
- Content licensing specialist, Lori Hancock, and photo specialist, David Tietz, for the photos within this text. Biology is a visual science, and their contributions are evident on every page.
- Michael McGee and Sharon O'Donnell, who acted as my copy-editor and proofreader, respectively, for this edition.
- Jane Peden, for her behind-the-scenes work that keeps us all functioning.

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. The only solution to these problems is an increase in scientific literacy, and more importantly, a greater appreciation for the roles of scientists in society. It is my hope that this text helps with that process.

I also want to acknowledge my family and friends for all of their support. My family team of Sandy, Devin, and Kayla have always been my motivation and encouragement. And for my dearest friends, who have never wavered in their support, thank you for believing.

Michael Windelspecht, PhD
Blowing Rock, NC

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CHAPTER

1

Exploring Life and Science

Diversity in Science

Our planet is home to a staggering diversity of life. Our species, *Homo sapiens,* is just one of the estimated 8.7 million different species (not counting bacteria) that inhabit the globe. Life may be found everywhere, from the deepest ocean trenches to the tops of the highest mountains. Biology is the area of scientific study that focuses on understanding all aspects of living organisms. Human biology focuses not only on the biology of our species but also its interactions with other species on the planet. This diversity of life is important to humans, because it provides us with food, medicines, and the raw materials needed to manufacture the millions of items that make our way of life possible.

Equally as important as our planet's biodiversity is the diversity of the people who study biology. Scientists rely upon their own experiences to ask questions, develop hypotheses, and design experiments or models to explain natural phenomena. Therefore, in order for the scientific community to ably address the challenges facing human society, from climate change to emerging diseases, we need a diverse population of individuals, with unique experiences and viewpoints, to contribute their ideas and opinions. As we will see throughout this text, there are many ways to study our world, and our diversity is a major strength in developing solutions.

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

1. What are some of the many ways a scientist can study biology?
2. Why would diversity in the scientific community play an important role in addressing how science can address the needs of 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*).

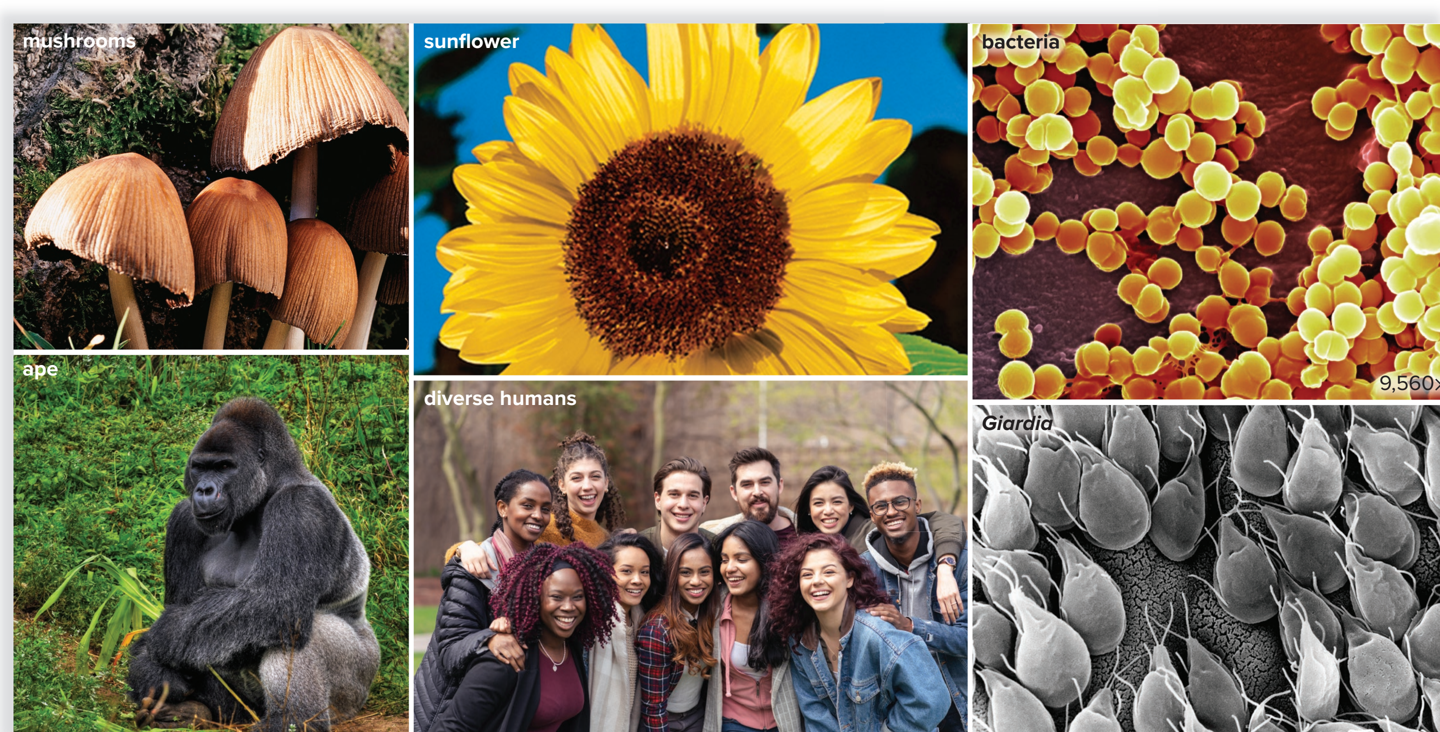


Figure 1.1 All life shares common characteristics.
From the simplest one-celled organisms to complex plants and animals, all life shares several basic characteristics.
(student group): FatCamera/E+/Getty Images; (mushrooms): IT Stock/age fotostock; (bacteria): Paul Gunning/Science Photo Library/Getty Images; (gorilla): Mike Price/Shutterstock; (sunflower): MedioImages/PunchStock/Getty Images; (*Giardia*): Dr. Stan Erlandsen/CDC

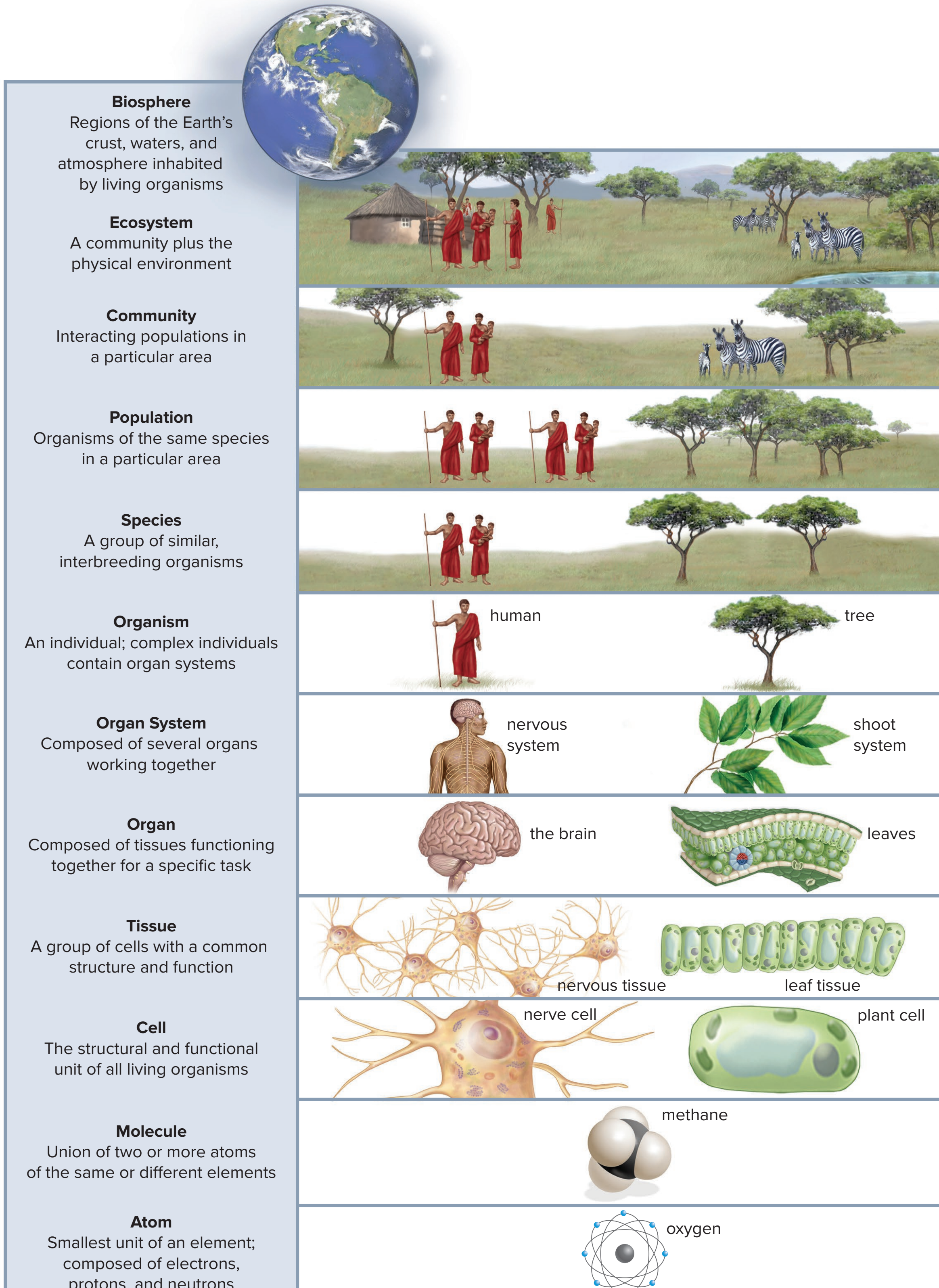


Figure 1.2 **Levels of biological organization.**
Life is connected from the atomic level to the biosphere. The cell is the basic unit of life, and it comprises molecules and atoms. The sum of all life on the planet is called the biosphere.

BIOLOGY 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 30 trillion cells in a human body. To put this into perspective, there are only an estimated 3 trillion trees on Earth.

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 breakdown of food is a component of our **metabolism,** or the sum of all the chemical reactions that occur within a cell or organism.

a.

b.

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

(a): Ariel Skelley/Blend Images/Getty Images; (b): Brian E Kushner/Shutterstock

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 gas 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 self-directed

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): Frank Krahmer/Photographer's Choice/Getty Images; (b) (sperm/egg): David M. Phillips/Science Source; (b) (fetus): Steve Allen/Brand X Pictures/Getty Images

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 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 not only means we share common ancestors with other animals, but 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, the 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 **High-elevation adaptations.**
Individuals living at high elevations, such as Tibetans, have become adapted to their high-elevation environment.
Michael Freeman/Corbis

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?

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.

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.

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 an example of multicelled Eukarya.

Historically, domain Eukarya was divided into one of four **kingdoms** (Fig. 1.6). However, the development of improved techniques in analyzing the DNA of organisms suggests that not all of the Protistas (the earliest eukaryotes) share the same evolutionary lineage, meaning that the evolution of the eukaryotes has occurred along several paths. A new taxonomic group, called a **supergroup,** was developed to explain these evolutionary relationships. There are currently six supergroups for domain Eukarya. Over the past several years, changes have been made to the supergroup classification as new research unveils relationships between these organisms. While these relationships are still being studied and analyzed, current thinking places the animals in the same supergroup (the Opisthikonts) as the fungi.

The traditional kingdom level of classification within domain Eukarya is still widely used, and is often placed beneath the

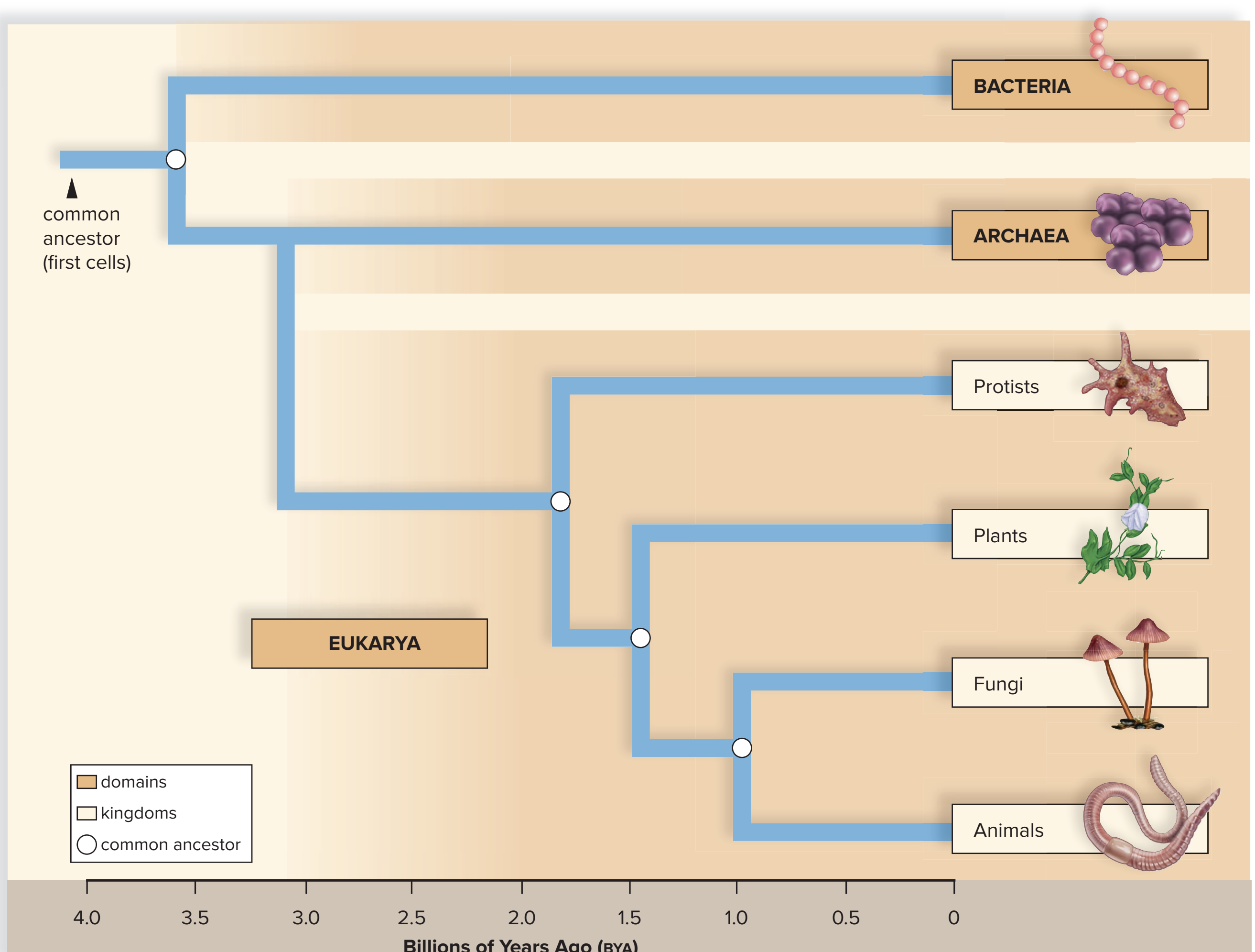


Figure 1.5 **The evolutionary relationships of the three domains of life.**
Living organisms are classified into three domains: Bacteria, Archaea, and Eukarya. The Eukarya are further divided into kingdoms (see Fig. 1.6).

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

Escherichia 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

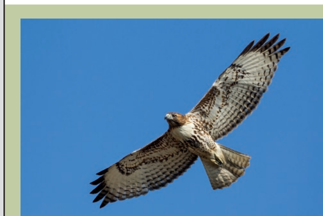
Ophrys apifera, bee orchid

Domain Eukarya: Kingdom Fungi

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

Amanita muscaria, a mushroom

Domain Eukarya: Kingdom Animalia



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

Buteo jamaicensis, red-tailed hawk

Figure 1.6 **The classification of life.**

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

(archaea): Eye of Science/Science Source; (bacteria): A. Barry Dowsett/Science Source; (paramecium): M.I. Walker/Science Source; (orchids): CreativeNature_nl/iStock/Getty Images; (mushrooms): Ingram Publishing/Getty Images; (hawk): Keneva Photography/Shutterstock

supergroup classification. The four kingdoms are shown in Figure 1.6 and include the following:

- *Kingdom Protista*. Commonly called the **protists,** this is a very diverse group of eukaryotic 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. As we mentioned, the diverse nature of these organisms indicates they have multiple evolutionary origins, and thus belong to different supergroups.
- *Kingdom Plantae*. The **plants** are multicellular, photosynthetic organisms.
- *Kingdom Fungi*. **Fungi** are the familiar molds and mushrooms that help decompose dead organisms. Some fungi are parasites of plants and animals.
- *Kingdom Animalia*. **Animals** are multicellular organisms that must ingest and process their food. They are capable of motion at some point in their life cycle.

Among the animals are the *invertebrates,* which lack an internal skeletal support structure, called vertebrae. Most animals are invertebrates. Examples include 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 and 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, water to drink, 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.

BIOLOGY IN YOUR LIFE

How many humans are there?

In 2021, it was estimated there were over 7.9 billion humans on the planet. Each human needs food, shelter, clean water and air, and materials to maintain a healthy lifestyle. Our species adds an additional 83 million people per year—that is like adding the population of ten New York Cities annually! 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. 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