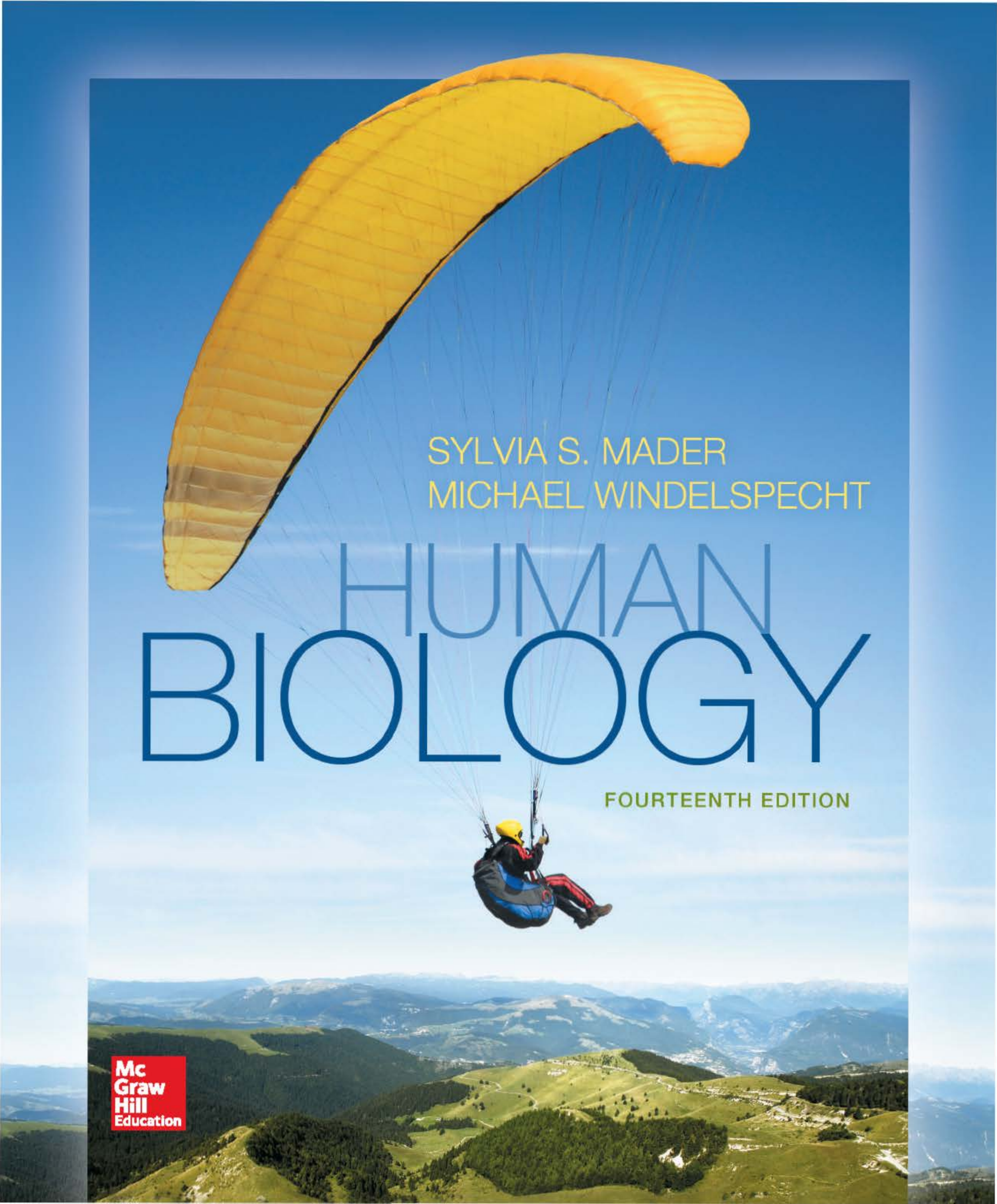
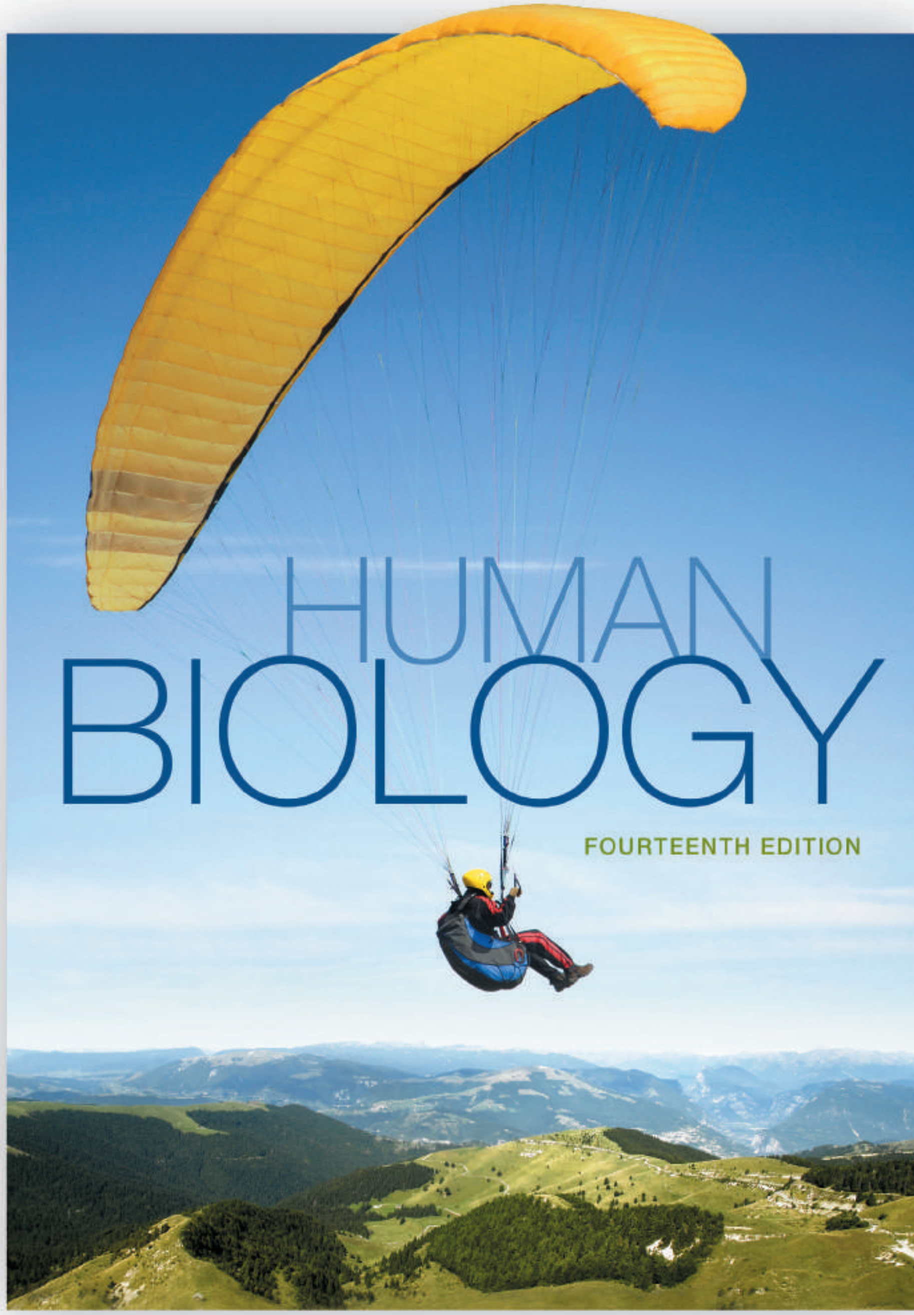


SYLVIA S. MADER
MICHAEL WINDELSPECHT

HUMAN BIOLOGY

FOURTEENTH EDITION

Mc Graw Hill Education



Sylvia S. Mader

Michael Windelspecht
Appalachian State University

Mc Graw Hill Education

HUMAN BIOLOGY, FOURTEENTH EDITION

Published by McGraw-Hill Education, 2 Penn Plaza, New York, NY 10121.

This book is printed on acid-free paper.

1 2 3 4 5 6 7 8 9 0 RMN/RMN 10 9 8 7 6 5

ISBN 978-1-259-24574-9
MHID 1-259-24574-8

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Cover Image: *Paragliding ©Getty Images/E+/RF*
Content Licensing Specialists: *Lori Hancock/Lenny Behnke*
Compositor: *Aptara® Inc.*
Typeface: *10/12 Times Lt Std*
Printer: *R. R. Donnelley*

Library of Congress Cataloging-in-Publication Data

Mader, Sylvia S.
Human biology / Sylvia S. Mader, Michael Windelspecht, Appalachian State University. — Fourteenth edition.
pages cm
ISBN 978-1-259-24574-9 (alk. paper) — ISBN 1-259-24574-8 (alk. paper) 1. Human biology—Textbooks. I. Windelspecht, Michael, 1963– II. Title.
QP36.M2 2016
612—dc23

2014041579

www.mhhe.com

Brief Contents

About the Authors

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,* that is now in its fourteenth edition. Highly acclaimed for her crisp and entertaining writing style, her books have become models for others who write in the field of biology.

Although her writing schedule is always quite demanding, Dr. Mader enjoys taking time to visit and explore the various ecosystems of the biosphere. Her several trips to the Florida Everglades and Caribbean coral reefs resulted in talks she has given to various groups around the country. She has visited the tundra in Alaska, the taiga in the Canadian Rockies, the Sonoran Desert in Arizona, and tropical rain forests in South America and Australia. A photo safari to the Serengeti in Kenya resulted in a number of photographs for her texts. She was thrilled to think of walking in Darwin's steps when she journeyed to the Galápagos Islands with a group of biology educators. Dr. Mader was also a member of a group of biology educators who traveled to China to meet with their Chinese counterparts and exchange ideas about the teaching of modern-day biology.

Michael Windelspecht As an educator, Michael 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 is currently an adjunct Professor of biology at ASU. His educational background includes degrees from the University of Maryland, Michigan State University, and the University of South Florida. Dr. Windelspecht is also active in promoting the scientific literacy of secondary school educators. He has received funding for workshops integrating water quality research into the science curriculum, and has spent several summers working with Fulbright programs involving Pakistani middle school teachers.

As an author, Dr. Windelspecht is a member of the National Association of Science writers. He has published five reference textbooks and multiple print and online lab manuals, and previously served as the series editor for a ten-volume work on the human body that may be found in many reference libraries. This is his seventh book as lead author for the Mader series.

For years Dr. Windelspecht has been active in the development of multimedia resources for online and hybrid science classrooms. He is one of the original Digital Faculty Consultants to McGraw-Hill Education and conducts multiple workshops each year on the integration of technology into the general science classroom. Along with his wife, Sandra, he owns a multimedia production company, Ricochet Creative Productions, which actively develops and assesses new technologies for the science classroom.

Preface

Goals of the Fourteenth Edition

Humans are a naturally inquisitive species. As children, we become fascinated with life 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, children are acting like 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 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.

This edition of *Human Biology* is the second textbook in the Mader series which utilized the student data derived from the LearnSmart platform as a form of review. The premise is very straightforward. Students don't know what they don't know—but LearnSmart does. By compiling data from all of the probes answered by all of the students, and then overlaying that data on the text, we are able to visualize areas of content where the students are having problems.

In addition, this revision of *Human Biology,* Foureenth Edition had the following goals:

1. build upon the strengths of the previous editions of the text
2. reorganization of the content to include a more robust discussion of the biology of infectious diseases
3. refinement of digital assets to provide a more effective assessment of learning outcomes to enable instructors in the flipped, online, and hybrid teaching environments

Media Integration

Students can improve the effectiveness of their learning by integrating the digital assets of today's courses into their study habits. These assets may easily be uploaded into any course management system to provide your students with useful study tutorials.

As educators, the authors recognize that today's students are digital learners. Therefore, almost every section of the textbook is now linked to MP3 files, animations of biological processes, and videos. In addition, McGraw-Hill's collection of 3D animations are integrated into the more difficult chapters of the text.

MP3 These three- to five-minute audio files serve as a review of the material in the chapter, and they also assist the student in the pronunciation of scientific terms.

Animation Drawing on McGraw-Hill's vast library of animations, the authors have selected animations that will enhance the student's understanding of complex biological processes.

3D Animation For topics such as photosynthesis and cellular respiration, McGraw-Hill has produced a series of dynamic animations that may be used both as presentation tools in the classroom, and as mini-tutorials that can be assigned within Connect or your course management system.

Video The National Geographic videos provide students with a glimpse of the complexity of life that normally would not be possible in the classroom.

Tutorial The authors of the textbook have prepared a series of 2-minute guided tutorials of some of the more difficult topics in the text.

Author's Guide to Using the Textbook

I encourage my students to use the **Before You Begin** feature to identify concepts they need to review before beginning to read the chapter content.

BEFORE YOU BEGIN

Before beginning this chapter, take a few moments to review the following discussions:

Section 2.2 What properties of water make it a crucial molecule for life as we know it?

Sections 2.3 to 2.7 What are the basic roles of carbohydrates, fats, proteins, and nucleic acids in the cell?

Section 2.7 What is the role of ATP in a cell?

LearnSmart Labs encourages critical thinking and teaches the scientific process. It also allows an instructor to integrate lab activities into the classroom environment.

ENGAGE

The following LearnSmart Labs contain exercises that are related to the content of this chapter:

- Microscopy Biology
- Cell Anatomy
- Diffusion
- Osmosis

LEARNSMART LABS®

Pre-Class

Built-in Preview and Review Tools

Students come to class prepared

During Class

Discussion Questions and Activities

Flip class and engage students

Learning Outcomes at the start of each section provide a preview of the content to come, while the **Check Your Progress** feature at the end of the section helps my students assess how well they understood the material. The learning outcomes are the same ones used in **Connect,** so I can easily assign a quiz to assess which topics I need to clarify during class.

3.1 What Is a Cell?

LEARNING OUTCOMES

Upon completion of this section, you should be able to

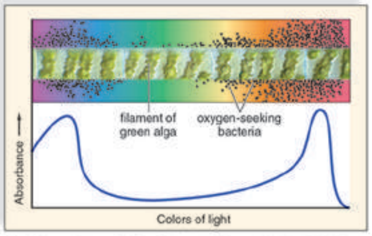
1. State the basic principles of the cell theory.
2. Explain ... cell size ...
3. Summar...

CHECK YOUR PROGRESS 3.1

1. Summarize the cell theory, and state its importance to the study of biology.
2. Explain how a cell's size relates to its function.
3. Compare and contrast the information that may be obtained from a light microscope and an electron microscope.

THINKING SCIENTIFICALLY

1. In the image below, the alga is the autotroph and undergoes photosynthesis, whereas the bacteria (small, black dots) are the heterotrophs. Explain why the bacteria are clustered at the far ends after the alga was exposed to different color wavelengths of light.



2. A Belgian doctor, Jan Baptista van Helmont (1580–1644) planted a small willow tree in a pot of soil. He weighed the tree and the soil. The tree was watered for 5 years and weighed 74.4 kg more than when he began, and the soil lost 57 g of mass. Explain what accounts for the plant's increase in biomass.

I use the **Questions to Consider** at the end of each reading and **Thinking Scientifically** questions at the end of the chapter as the basis for class discussions and active learning exercises.

MEDIA STUDY TOOLS http://connect.mheducation.com

SMARTBOOK® Study smart. SmartBook helps you maximize your study time by identifying what you know and don't know. The recharge feature in SmartBook helps you prepare for the test by identifying the material that you are most likely to forget.

connect BIOLOGY Find even more resources to learn the chapter concepts including animations, tutorial videos, and interactive practice questions.

MP3 Files	Animations	3D Animations	Tutorials	Videos
3.2 Cellular Organelles **3.3** Membrane Structure • Diffusion • Osmosis **3.6** Cellular Respiration	**3.2** Endosymbiosis **3.3** How Diffusion Works • Hemolysis and Crenation • How Osmosis Works • How Facilitated Diffusion Works • How the Sodium-Potassium Pump Works • Endocytosis and	**3.3** Membrane Transport: Lipid Bilayer • Membrane Transport: Diffusion • Membrane Transport: Osmosis • Membrane Transport: Active Transport **3.6** Cellular Respiration:	**3.2** Endosymbiotic Theory **3.3** Osmosis and Tonicity • Sodium-Potassium Pump **3.4** Endomembrane System **3.6** Energy of Activation • Cellular Respiration	**3.5** Human Sperm

Media Study Tools includes a table that shows students the animations, videos, and multimedia assets that are available to further explain difficult topics. These may be used as tutorials for the students, and I may assign the accompanying Connect activities to gauge whether my students understand the content.

Post-Class

Assessment and Integration

Apply content and build critical thinking

THINKING CRITICALLY ABOUT THE CONCEPTS

In the case study at the beginning of the chapter, the child had malfunctioning lysosomes, which caused an accumulation of fatty acid in the system. Each part of a cell plays an important role in the homeostasis of the entire body.

1. What might occur if the cells of the body contain malfunctioning mitochondria?
2. What would happen to homeostasis if enzymes were no longer produced in the body?
3. Knowing what you know about the function of a lysosome, what might occur if the cells' lysosomes are overproductive instead of malfunctioning?

Traditional end-of-chapter summaries and review questions provide students with an opportunity for low-stakes assessment of their comprehension of the chapter's topics.

The **Connecting the Concepts** box at the end of each section helps students understand how the main concepts of the chapter relate to other areas of the text, building a deeper understanding of the content.

CONNECTING THE CONCEPTS

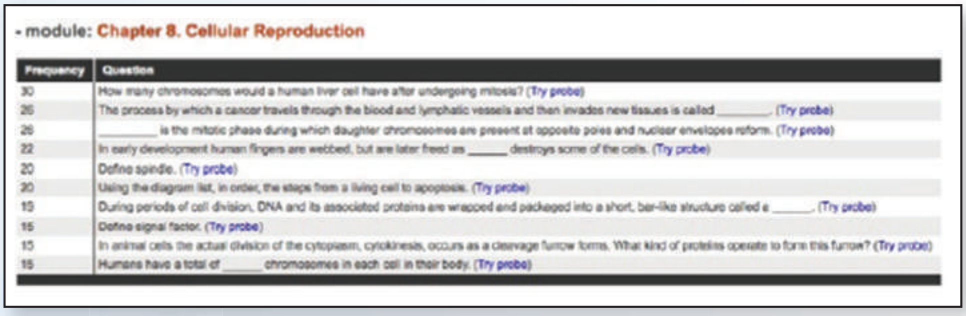
The movement of materials across a plasma membrane is crucial to the maintenance of homeostasis for many organ systems in humans. For some examples, refer to the following discussions:

Section 9.3 examines how nutrients, including glucose, are moved into the cells of the digestive system.

Section 11.4 investigates how the movement of salts by the urinary system maintains blood homeostasis.

Section 21.2 explains the patterns of inheritance associated with cystic fibrosis.

Author's Guide to the Digital Classroom



- module: Chapter 8. Cellular Reproduction

Frequency	Question
30	How many chromosomes would a human liver cell have after undergoing mitosis? (Try probe)
26	The process by which a cancer travels through the blood and lymphatic vessels and then invades new tissues is called ________. (Try probe)
26	________ is the mitotic phase during which daughter chromosomes are present at opposite poles and nuclear envelopes reform. (Try probe)
22	In early development human fingers are webbed, but are later freed as ______ destroys some of the cells. (Try probe)
20	Define spindle. (Try probe)
20	Using the diagram list, in order, the steps from a living cell to apoptosis. (Try probe)
15	During periods of cell division, DNA and its associated proteins are wrapped and packaged into a short, bar-like structure called a ______. (Try probe)
15	Define signal factor. (Try probe)
15	In animal cells the actual division of the cytoplasm, cytokinesis, occurs as a cleavage furrow forms. What kind of proteins operate to form this furrow? (Try probe)
15	Humans have a total of ______ chromosomes in each cell in their body. (Try probe)

Using reports from within the LearnSmart system, especially the Most Missed Questions report, I am able to identify areas of content that my students are struggling with before they enter the lecture.

Pre-Class

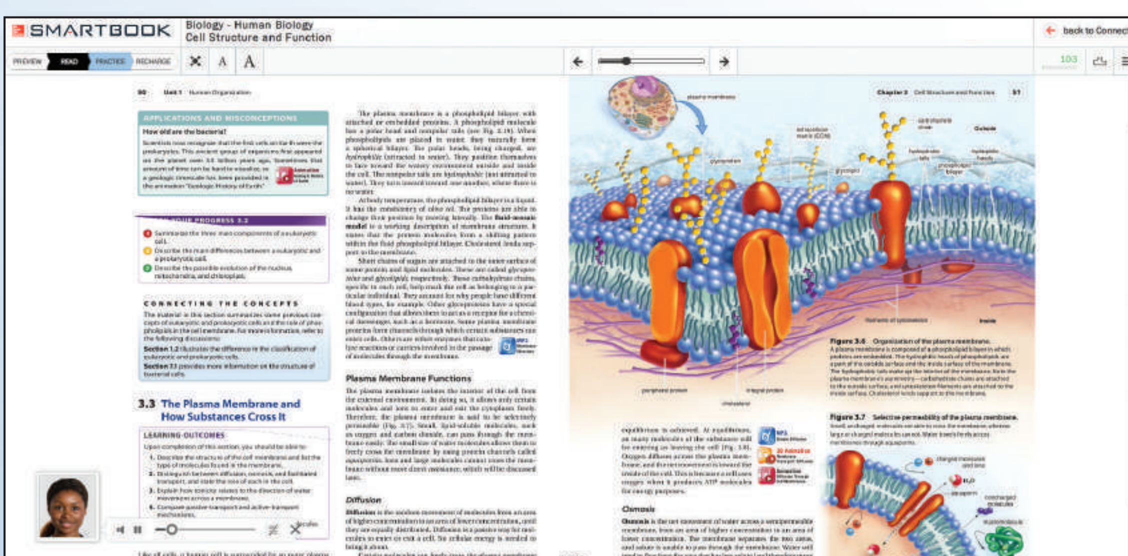
LearnSmart & SmartBook

Students come to class prepared

During Class

Instructor Resources

Flip class and engage students



I generally assign 20-30 minutes of SmartBook 3-5 days before class. The assignments cover only the core topics for the upcoming lesson.

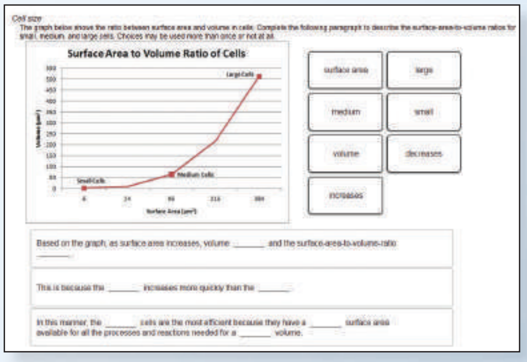
During class I can focus on engaging the students with the relevancy of the content using the BioNow Sessions videos, active learning exercises, and animations. Tegrity lecture capture lets my students review these concepts later.

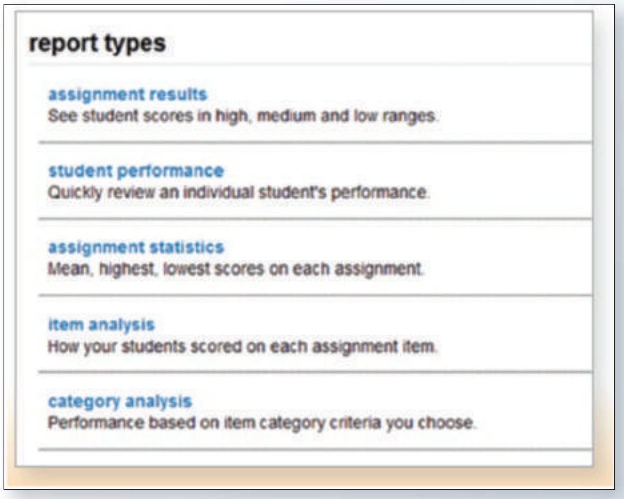
Using feedback from the LearnSmart reports, I am able to design Connect assignments that act as tutorials that target the concepts my students are struggling with.

Post-Class

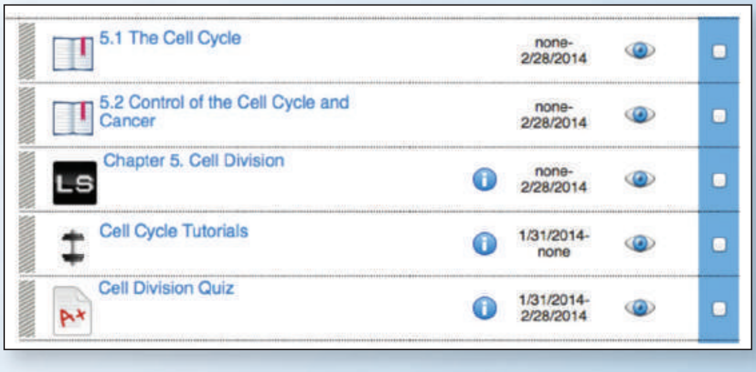
Connect

Apply content and build critical thinking





The Connect reports allow me to assess whether my students have met the learning objectives.



The quizzing option within Connect allows me to develop assessments for any classroom environment.

Engaging Your Students

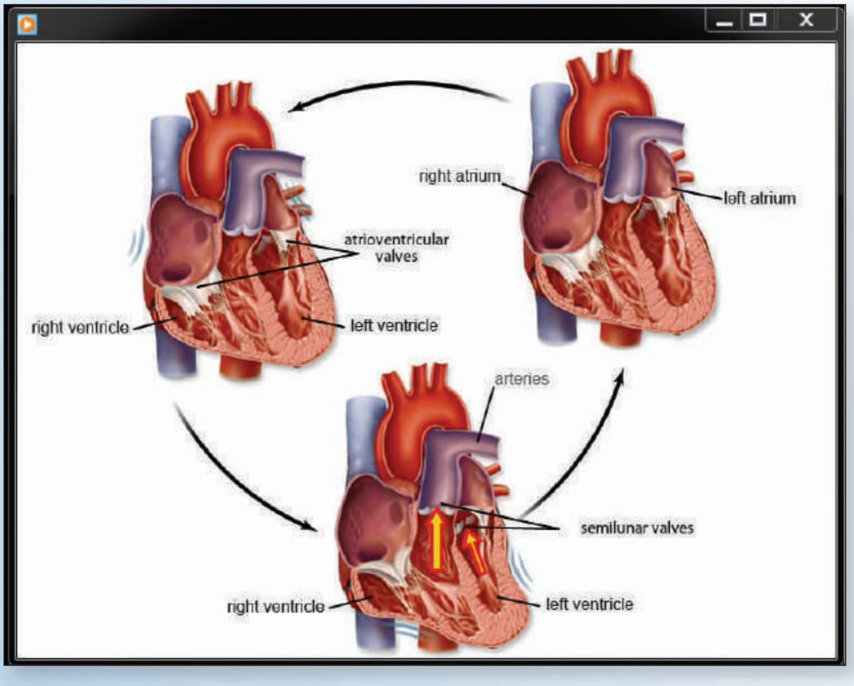
Today's science classroom relies heavily on the use of digital assets, including animations and videos, to engage students and reinforce difficult concepts. Human Biology 14e includes two resources specifically designed for the introductory science class to help you achieve these goals.

BioNow Sessions Videos

A relevant, applied approach allows your students to feel they can actually do and learn biology themselves. While tying directly to the content of your course, the videos help students relate their daily lives to the biology you teach and then 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 any regular person could perform, so your students see the science as something they could do and understand.

A 27-video series narrated and produced by Jason Carlson



A 36-animation series narrated by Michael Windelspecht and produced by Ricochet Creative Productions, LLC

The tutorials in this series were prepared to assist students in understanding some of the more difficult topics in biology. Each of the videos explores a specific figure in the text.

For students, these act as informal office hours, where they can review the most difficult concepts in the chapter at a pace which helps them learn.

Instructors of hybrid and flipped courses will find these useful as online supplements.

Readings

BIOLOGY MATTERS  Bioethical

BIOLOGY MATTERS  Health

BIOLOGY MATTERS  Science

Detailed List of Content Changes in *Human Biology*, Fourteenth Edition

This edition of the text includes the addition of a new chapter, Chapter 8 "The Biology of Infectious Diseases." This new chapter combines the material on prokaryotic cells and viruses previously located in Chapter 7 with the Infectious Disease Supplement.

The chapter opener for **Chapter 1: Exploring Life and Science** has been revised to include new information from the science of exobiology. Section 1.3 has been reworked to include a new diagram of the scientific method (Fig. 1.7) and discussion of the scientific process. A new Science feature "Discovering the Cause of Ulcers" has been added. Section 1.5 now focuses on the scientific challenges facing human society.

Unit 1: Human Organization

Chapter 2: Chemistry of Life contains a new figure on the structure of a nucleotide (Fig. 2.24). **Chapter 3: Cell Structure and Function** has been reworked to include a more detailed description of the energy reactions (section 3.6) and includes additional information on the energy of activation (Fig. 3.19). **Chapter 4: Organization and Regulation of the Body Systems** has a new Science in Your Life box on how cancers are named.

Unit 2: Maintenance of the Human Body

Chapter 5: Cardiovascular System: Heart and Blood Vessels contains a new Science in Your Life box on the safety of statins. The content on prokaryotic cells and viruses has been moved from **Chapter 7: The Lymphatic and Immune Systems** to Chapter 8. The chapter also now contains a new Health feature on adult vaccination schedules. **Chapter 8: Biology of Infectious Diseases** is a new chapter that combines content from the previous edition on prokaryotic cells, viruses, and infectious diseases. The chapter also contains new content on MERs. The mechanisms of breathing content in **Chapter 10: Respiratory System** now contains references to Boyle's Law.

Unit 6: Human Genetics

Chapter 19: Patterns of Chromosome Inheritance contains a new comparison of meiosis I and meiosis II (Figure 19.10) that makes it easier to identify the differences between these processes. The section on meiosis (section 19.4) now includes the content on spermatogenesis and oogenesis. The comparison of mitosis and meiosis (Fig. 19.14) is set in a new format. A new illustration of nondisjunction (Fig. 19.15) is provided in the chapter. **Chapter 21: Patterns of Genetic Inheritance** has had new examples of human Mendelian genetic traits added (Figs. 21.1 to 21.7). **Chapter 22: DNA Biology and Technology** has been updated with new figures on semi-conservative replication (Fig. 22.2) and translation (Fig. 22.10). The content on reproductive and therapeutic cloning has been moved to this chapter.

Unit 7: Human Evolution and Ecology

Chapter 23: Human Evolution has been updated to contain new information on human evolution (section 23.5). Also included are a revised graph of human evolution (Fig. 23.16) and a new image of early human migration patterns (Fig. 23.19). **Chapter 24: Global Ecology and Human Interferences** begins with a new chapter opener on the wolves of Yellowstone. The chapter also contains a new graphic of the major terrestrial biomes (Fig. 24.1). **Chapter 25: Human Population, Global Resources, and Conservation** now includes a new Science feature on wildlife conservation and DNA.


C H A P T E R

8

Biology of Infectious Diseases

CASE STUDY: BIRD FLU: H5N1 AND H7N9

H5N1 is commonly called the bird flu or avian flu. However, this influenza virus infects more than just birds. Since 2003, over 600 people have been infected with H5N1. While cases of H5N1 are still rare, there is a 60% mortality rate among individuals who are exposed to H5N1, making it a concern of health officials around the world. And H5N1 is not the only form of bird flu. In 2013, a new strain of avian flu, called H7N9, was reported in Southeast Asia. Although present in bird populations for some time, H7N9 has just recently made the jump to humans. While both H5N1 and H7N9 cannot be transmitted from one human to another, other forms of viruses are easily passed between people.

In this chapter, we will see that certain viruses and other microbes, such as bacteria, are the cause of many serious diseases in plants and animals, including humans. The reason is that microbes such as the H5N1 virus have the ability to evolve, often fast enough to outmaneuver our own immune systems and our ability to develop effective immunizations and medical treatments. However, not all microbes cause illness. Our skin is home to over 180 different bacterial species, and our guts are full of bacteria that assist with digestion. Bacteria have uses that include cleaning up oil spills, treating sewage, and even producing human proteins through genetic engineering. In addition, microbes are an essential component of ecosystems. Archaea and bacteria are at the base of the tree of life and were the first living organisms on Earth. Surprisingly, molecular biologists tell us we are more closely related to archaea than to bacteria. In this chapter, we examine these amazing microbes—viruses and prokaryotes.

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

1. Based on the characteristics shared by all living organisms, should viruses be considered living?
2. Although some cause disease, why are microorganisms essential to life?

CHAPTER CONCEPTS

8.1 Bacteria and Viruses
Bacteria and viruses are microbes that are responsible for a variety of human diseases.

8.2 Infectious Diseases and Human Health
Epidemiology is the study of diseases in populations. The terms *epidemic* and *pandemic* are used to describe disease outbreaks. HIV/AIDS, tuberculosis, malaria, and influenza are examples of pandemic diseases.

8.3 Emerging Diseases
Emerging diseases include diseases that have never before been seen, as well as those previously recognized in a small number of people in isolated settings. Diseases that have been present throughout history, but not known to be caused by a pathogen, are also considered to be emerging diseases. Reemerging diseases are previously known diseases undergoing resurgence, often due to human carelessness.

8.4 Antibiotic Resistance
Misuse of antibiotics has led to the selection of antibiotic-resistant organisms. Some organisms have developed multidrug resistances, and these organisms are very difficult to treat.

BEFORE YOU BEGIN

Before beginning this chapter, take a few moments to review the following discussions:

Section 1.1 What are the basic characteristics of living organisms?

Section 7.4 What is the role of a T cell in the immune response?

Section 7.5 How do immunizations protect an individual against disease?

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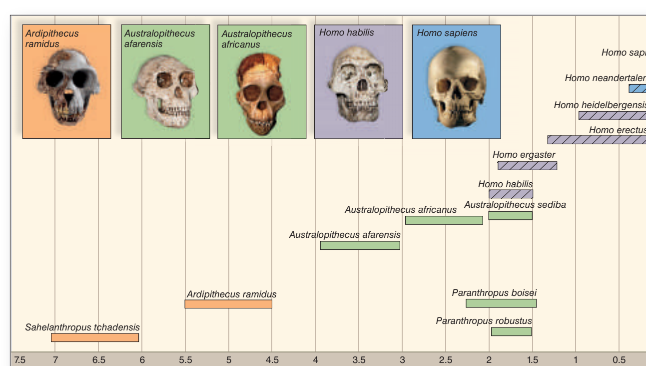

Figure 23.16 Human evolution.
Several groups of extinct hominins preceded the evolution of modern humans. The groups have been divided into the early humanlike hominins (orange), later humanlike hominins (green), early *Homo* species (lavender), and finally the later *Homo* species (blue). The cross marks indicate areas where current research is focusing on combining groups into single species.

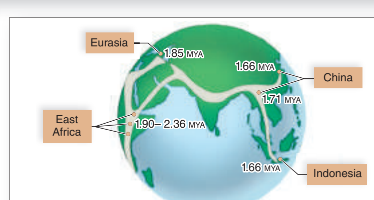

Figure 23.19 Migration of early *Homo* from Africa.
The dates indicate the migration of early *Homo erectus* from Africa.[1]

[1]Derived from "Evolution of Early Homo: An Integrated Biological Perspective," S. Antón et al., *Science* 4 July 2014: 345 (6192).

Acknowledgments

Dr. Sylvia Mader represents one of the icons of science education. Her dedication to her students, coupled to her clear, concise writing style, has benefited the education of thousands of students over the past 4 decades. As an educator, it is an honor to continue her legacy, and to bring her message to the next generation of students.

Any textbook revision is based on the input of numerous instructors and professors. They are all dedicated and talented teachers, and their passion is evident in the quality of this text. Thank you also to the countless instructors who have invited me into their classrooms, both physically and virtually, to discuss their needs as instructors and the needs of their students. Your energy, and devotion to quality teaching, is what drives a textbook revision.

This project was one of the first at McGraw-Hill be to produced within a new authoring platform, and luckily for me, I had the assistance of many dedicated and talented individuals to produce this project. I would like to thank Inkling, specifically Dana Lindsey and Stephen Hayes for their assistance and encouragement. I am also very grateful for the help of so many professionals at McGraw-Hill who were involved in the development of this project. In particular, let me thank my program manager, Angela Fitzpatrick, and product developer, Anne Winch, for not only keeping me on track and offering their valuable advice at every step of the project, but for their endless patience. My brand manager for this text was Chris Loewenberg. The digital production of this text was a pilot for McGraw-Hill, and Chris has the natural ability of keeping me focused and reminding me of the impact we are making in education. Thanks also to my marketing manager, Chris Ho, who offers an unique insight on the needs of our students. No modern team would be complete without digital support, and for that I thank Eric Weber and Christine Carlson.

Production of this text was directed by Jayne Klein, who faithfully steered this project through the publication process. I was very lucky to have Dawnelle Krouse, Deb Debord, and Rose Kramer as proofreaders and copy editors. Today's textbooks are visual productions, and so I need to thank the creative talents of David Hash. David consistently provided innovative solutions for this edition. As always, Lori Hancock and Evelyn Jo Johnson did a superb job of finding just the right photographs and micrographs. Electronic Publishing Services assisted in the development of the art found in this text, and Aptara was responsible for integrating all of the content into the digital environment.

Who I am, as an educator and an author, is a direct reflection of what I have learned from my students. Education is a mutualistic relationship, and it is my honest opinion that while I am a teacher, both my professional and personal life have been enriched by interactions with my students. They have encouraged me to learn more, teach better, and never stop questioning the world around me.

Last, but never least, I want to acknowledge my wife, Sandra. She has never wavered in her support of my projects, and is not only my best friend, but ultimate business partner. Devin and Kayla, your natural curiosity of the world we live in gives me the energy to want to make the world a better place.

Michael Windelspecht
Blowing Rock, NC

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Connect Test Bank: Dave Cox, *Lincoln Land Community College*

Tutorial Development: *Ricochet Creative Productions*

LearnSmart: Jeffrey Isaacson, *Nebraska Wesleyan University;* Patrick Galliart, *North Iowa Area Community College*

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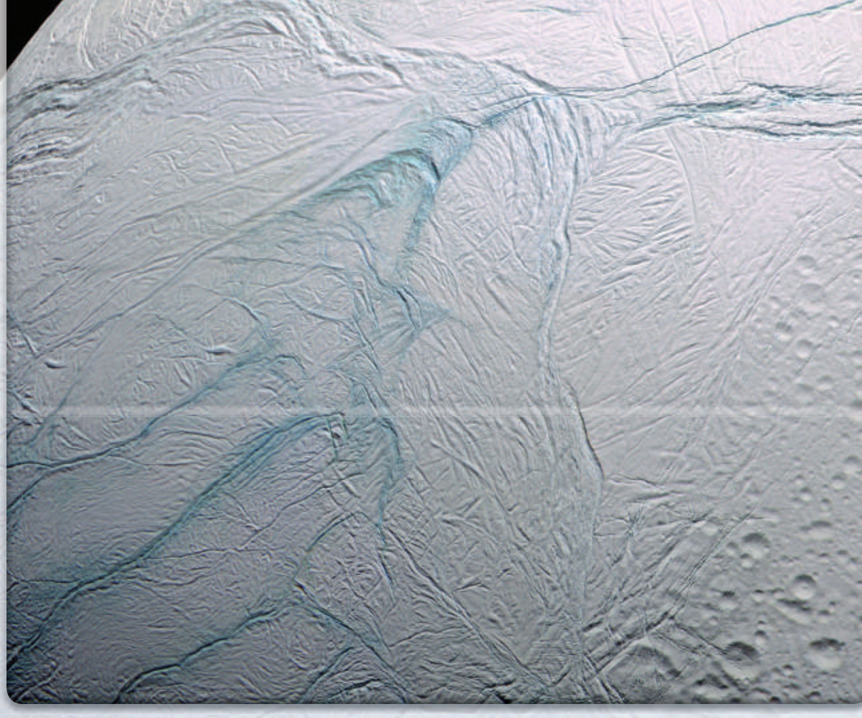


CHAPTER

1 Exploring Life and Science

CASE STUDY: THE SEARCH FOR LIFE

What do Enceladus, Europa, Titan, Mars, and Earth all have in common? Besides being part of our solar system, they are all at the frontline of our species' effort to understand the nature of life.

You may never have heard of Enceladus (shown above) or Europa, but they are both now prime candidates to harbor life outside of Earth. Enceladus is one of Saturn's moons, and Europa orbits Jupiter. Why are these moons so special? Because scientists believe that both of these moons contain water, and plenty of it. While both Enceladus and Europa are far from the sun, the gravitational pull of their parent planets means that beneath the frozen surface of both of these moons may be an ocean of liquid water. And as we will see, water has an important relationship with life.

Titan is the second-largest satellite in the solar system, larger than even our moon. Although it is in orbit around Saturn, and thus located some distance from the influence of the sun, Titan has become a focal point for the study of extraterrestrial life since the NASA space probe *Cassini-Huygens* first arrived at Saturn in 2004. *Cassini* has detected the presence of the building blocks of life on Titan, including lakes of methane and ammonia, and vast deposits of hydrogen and carbon compounds called hydrocarbons.

On Earth, scientists are exploring the extreme environments near volcanoes and deep-sea thermal vents to get a better picture of what life may have looked like under the inhospitable conditions that dominated at the time we now know life first began on our planet. On Mars, there is evidence that water may still be present on this planet, raising the hopes that we may still find evidence of early life there.

In this chapter, we will explore what it means to be alive. By looking to other areas of our solar system, we may develop a better understanding of how life first developed and our place in the universe.

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

1. What are the basic characteristics that define life?
2. What evidence would you look for on one of these moons that would tell you that life may have existed on them in the past?
3. What does it tell us if we discover life on one of these moons and it has characteristics similar to those of life on Earth? What if it is very different?

CHAPTER CONCEPTS

1.1 The Characteristics of Life
The process of evolution accounts for the diversity of living organisms and explains why all life shares the same basic characteristics.

1.2 Humans Are Related to Other Animals
Humans are eukaryotes and are further classified as mammals in the animal kingdom. We differ from other mammals, including apes, by our highly developed brain, upright stance, creative language, and ability to use a wide variety of tools.

1.3 Science as a Process
Biologists use the scientific process when they study the natural world. A hypothesis is formulated and tested to arrive at a conclusion. Theories explain how the natural world is organized.

1.4 Making Sense of a Scientific Study
Data are more easily understood if results are presented in the form of a graph and are accompanied by a statistical analysis.

1.5 Challenges Facing Science
Technology is the application of scientific information. Many challenges, including climate change and loss of biodiversity, are being studied by scientists.

1.1 The Characteristics of Life

LEARNING OUTCOMES

Upon completion of this section, you should be able to

1. Explain the basic characteristics that are common to all living organisms.
2. Describe the levels of organization of life.
3. Summarize how the terms *homeostasis, metabolism, development,* and *adaptation* all relate to living organisms.
4. Explain why the study of evolution is important in understanding life.

The science of **biology** is the study of living organisms and their environments. 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 grow, and (6) have an evolutionary history.

MP3 Life Characteristics

Life Is Organized

Figure 1.2 illustrates the levels of biological organization. Note that, at the bottom of the figure, **atoms** join together to form the **molecules** that make up a cell. A **cell** is the smallest structural and functional unit of an organism. Some organisms, such as bacteria, are single cells. Humans are *multicellular,* because they are composed of many different types of cells. A nerve cell is one of the types of cells in the human body. It has a structure suitable to conducting a nerve impulse.

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. Several types of tissues make up an **organ,** 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*).

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 that there are well over 100 trillion cells in a human body.

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.

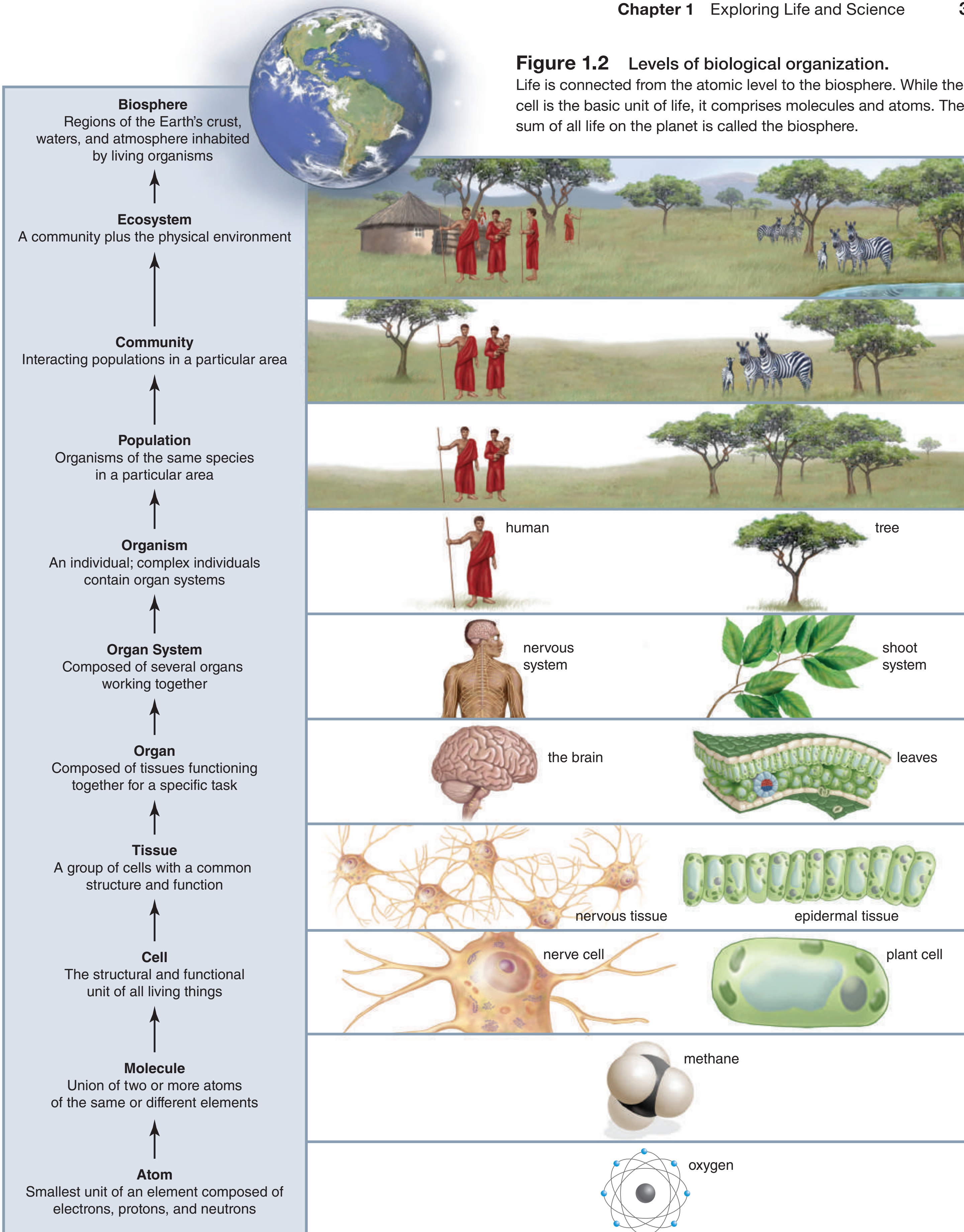


Figure 1.2 Levels of biological organization.
Life is connected from the atomic level to the biosphere. While the cell is the basic unit of life, it comprises molecules and atoms. The sum of all life on the planet is called the biosphere.

Organisms Acquire 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. Humans and other animals acquire materials and energy when they eat food (Fig. 1.3).

Food provides nutrient molecules, which are used as building blocks or for energy. It takes energy (work) to maintain the organization of the cell and of the organism. 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.

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.

a.

b.

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

Organisms Maintain Homeostasis

For the metabolic pathways within a cell to function correctly, the environmental conditions of the cell must be kept within strict operating limits. The ability of a cell or an organism to maintain an internal environment that operates under specific conditions is called **homeostasis.** 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. A number of body systems, including the cardiovascular system and the nervous system, work together to maintain a constant temperature. However, the body's ability to maintain a normal temperature is 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. Throughout the text, the Connecting the Concepts sections will provide you with links to more information on homeostasis.

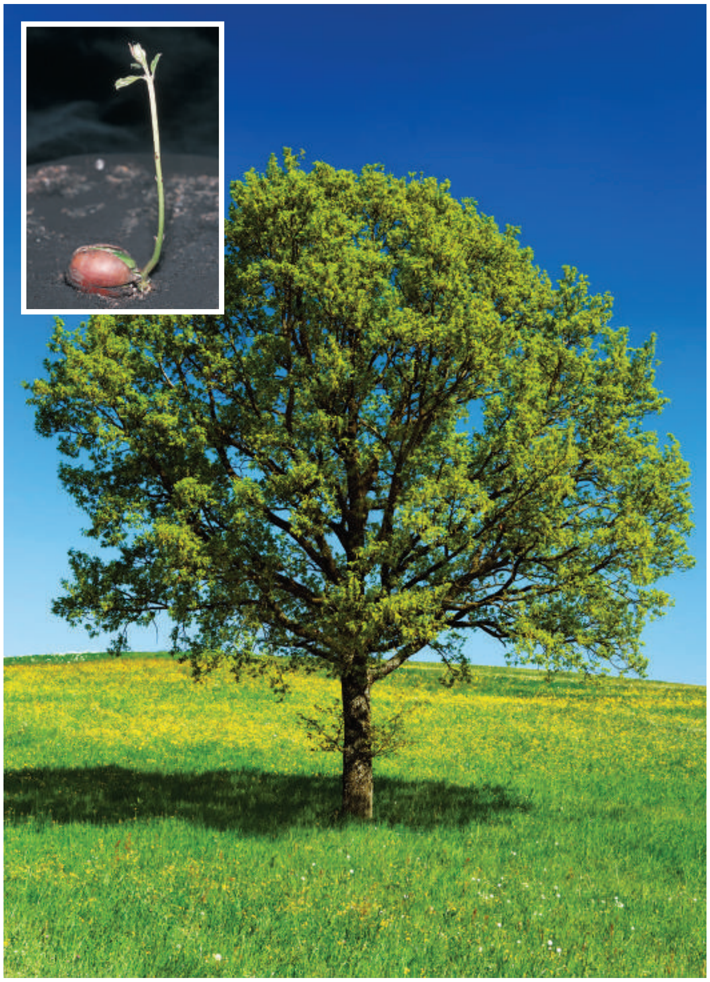
Organisms Respond to Stimuli

Homeostasis would be impossible without the body's ability to respond to stimuli. 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 or in response to a stimulus, constitutes a large part of its behavior. Some behaviors help us acquire food and reproduce.

Organisms Reproduce and Grow

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



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.

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 deoxyribonucleic acid, or DNA. 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 that 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** cause minor variations in these genes, potentially causing 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 Chapter 23). 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 that 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 actually 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 which will continue as long as life exists, explains both the

BIOLOGY MATTERS 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 also 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.

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

Normally, if a person moves to a higher altitude, his or her body responds by making more hemoglobin, the component of blood that carries oxygen, which thickens 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), this 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.

Because high hemoglobin levels would be a detriment to people at high elevations, it makes sense that natural selection would favor individuals who produced 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, which 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 their 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? Modern genetic analysis allows scientists to model the rate of evolutionary change. By comparing these genes in high-elevation and low-elevation Tibetan populations, the researchers were able to determine that the process probably occurred over less than 3,000 years. If we use a 25-year generation time for humans, that means that the adaptation to the high-elevation environment probably took less than 120 generations for this Tibetan population.

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 that people at high elevations may exhibit other adaptations?

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.

CHECK YOUR PROGRESS 1.1

1. Describe the basic characteristics of life.
2. Summarize the levels of biological organization.
3. Explain the relationship between adapations 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. Describe the relationship between humans and the biosphere, as well as the role of culture in shaping that relationship.

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, domain Bacteria and domain Archaea, contain prokaryotes, one-celled organisms that lack a nucleus. Organisms in the third domain, Eukarya, all contain cells that possess a nucleus. Some of these organisms are single-celled; others are multicellular. Domain Eukarya is divided into one of four **kingdoms** (Fig. 1.6)—plants (Plantae), fungi (Fungi), animals (Animalia), and protists (Protista). Most organisms in kingdom Animalia 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 vertebrates. Vertebrates with hair or fur and mammary glands are classified as mammals. Humans, raccoons, seals, and meerkats are examples of mammals.

Humans 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 from our cousins, because we are contemporaries—living on Earth at the same time.

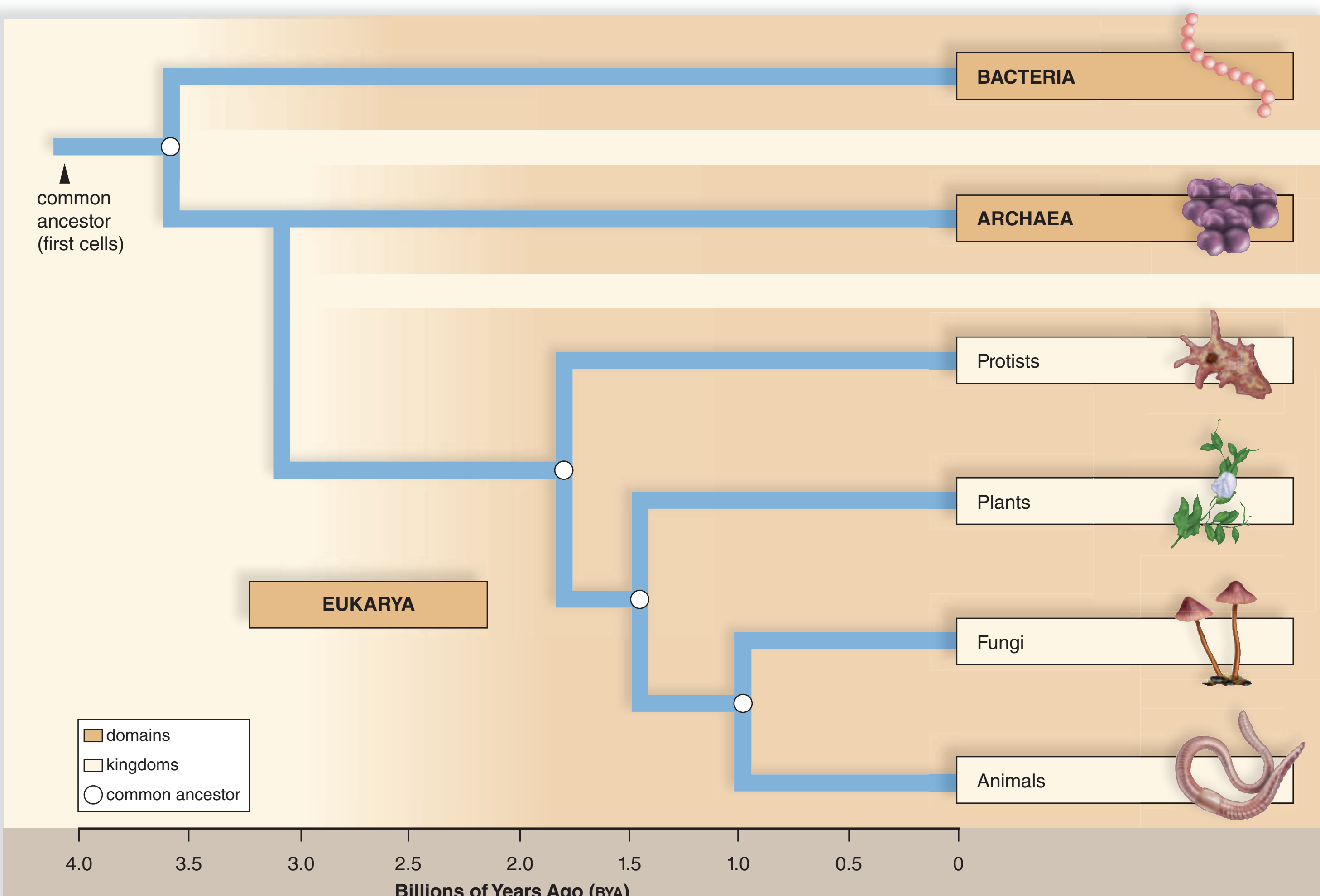


Figure 1.5 The evolutionary relationships of the three domains of life.
Living organisms are classified into three domains: Bacteria, Archaea, and Eukarya. The Eukarya are further divided into kingdoms (see Fig. 1.6). A geologic timescale is provided on the bottom for reference.

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 Animalia

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

Vulpes, a red fox

Domain Eukarya; Kingdom Fungi

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

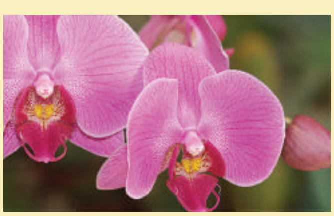
Cantharellula, a club fungi

Domain Archaea

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

Sulfolobus, an archaean

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 Bacteria

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

E.coli, a bacterium

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.

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 can clean 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 the end of 2014, it was estimated that there were over 7.2 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 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. Explain why it is important to know the evolutionary relationships between organisms.
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.

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.

The Scientific Method Has Steps

Unlike other types of information available to us, scientific information is acquired by a process known as the **scientific method** (Fig. 1.7). It is important to note that the scientific method provides a general framework for how scientists study the world around

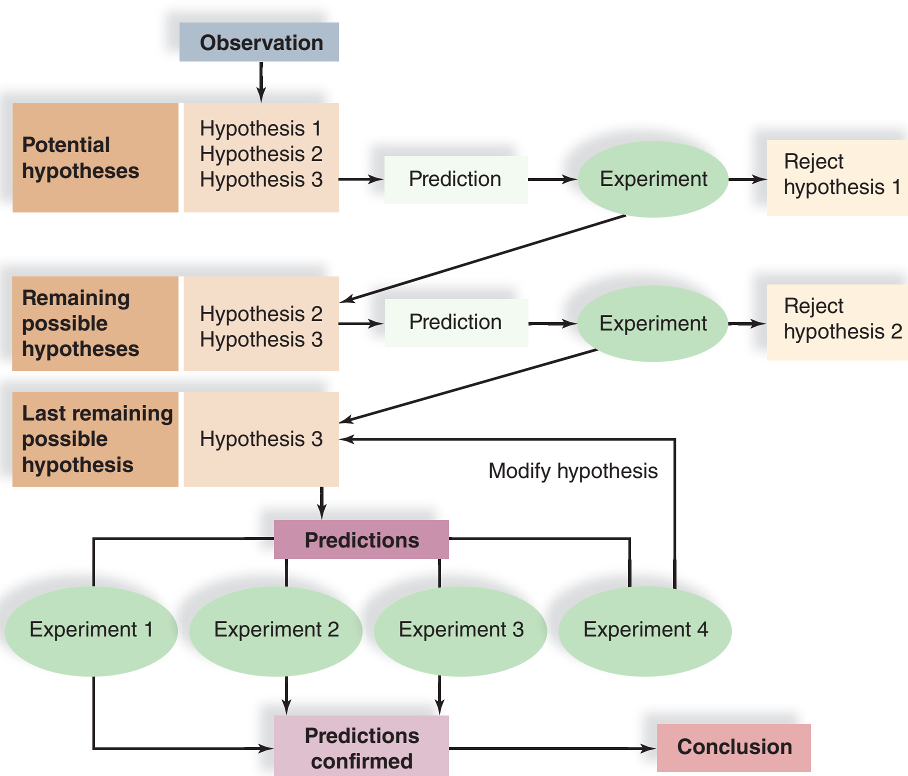


Figure 1.7 The scientific method.
On the basis of new and/or previous observations, a scientist formulates a hypothesis. The hypothesis is tested by further observations and/or experiments, and new data either support or do not support the hypothesis. The return arrow from experiment 4 indicates that a scientist often chooses to retest the same hypothesis or to test a related hypothesis. Conclusions from many different but related experiments may lead to the development of a scientific theory. For example, studies pertaining to development, anatomy, and fossil remains all support the theory of evolution.