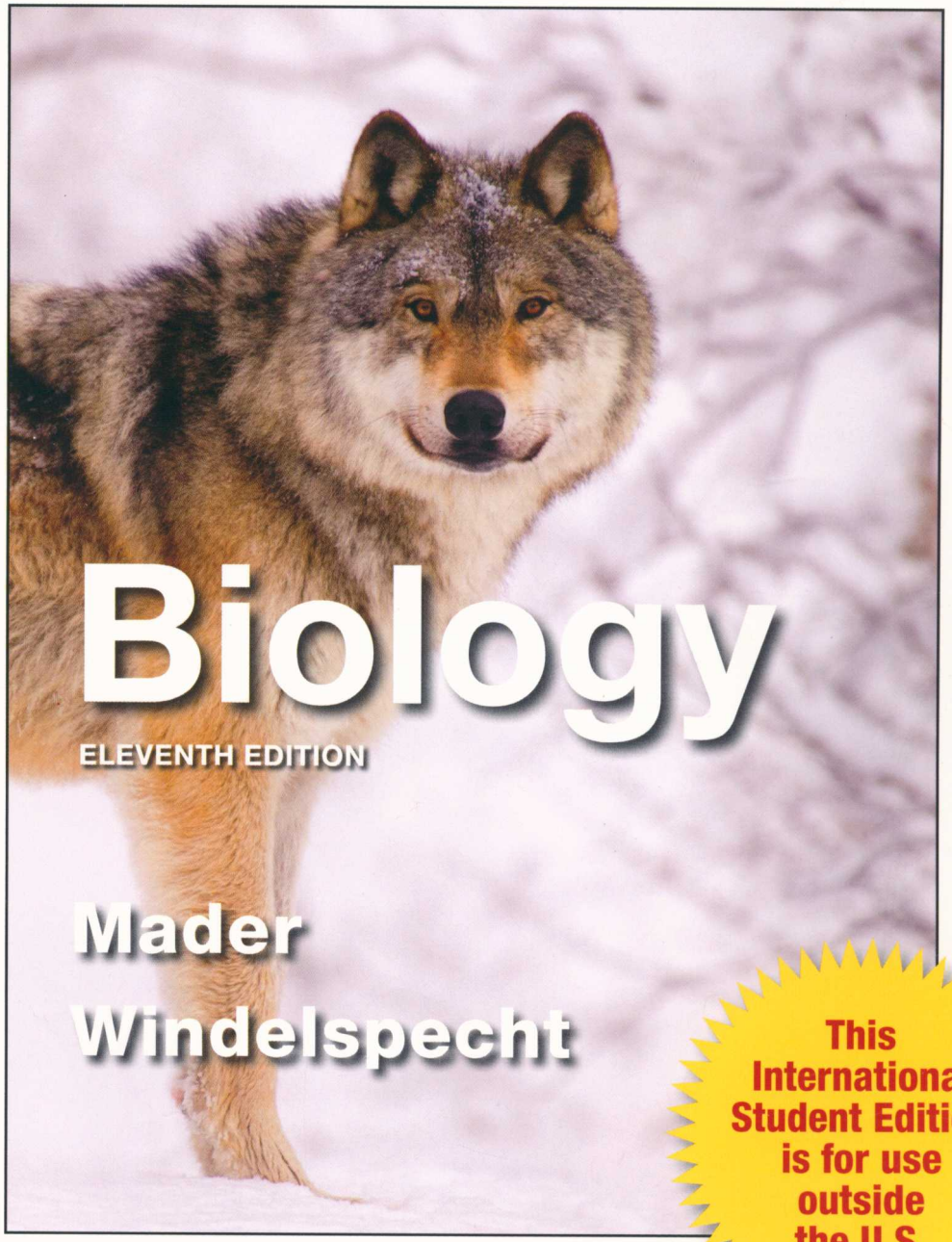

Biology

ELEVENTH EDITION

Mader
Windelspecht

This International Student Edition is for use outside the U.S.

McGRAW-HILL INTERNATIONAL EDITION

Eleventh Edition

BIOLOGY

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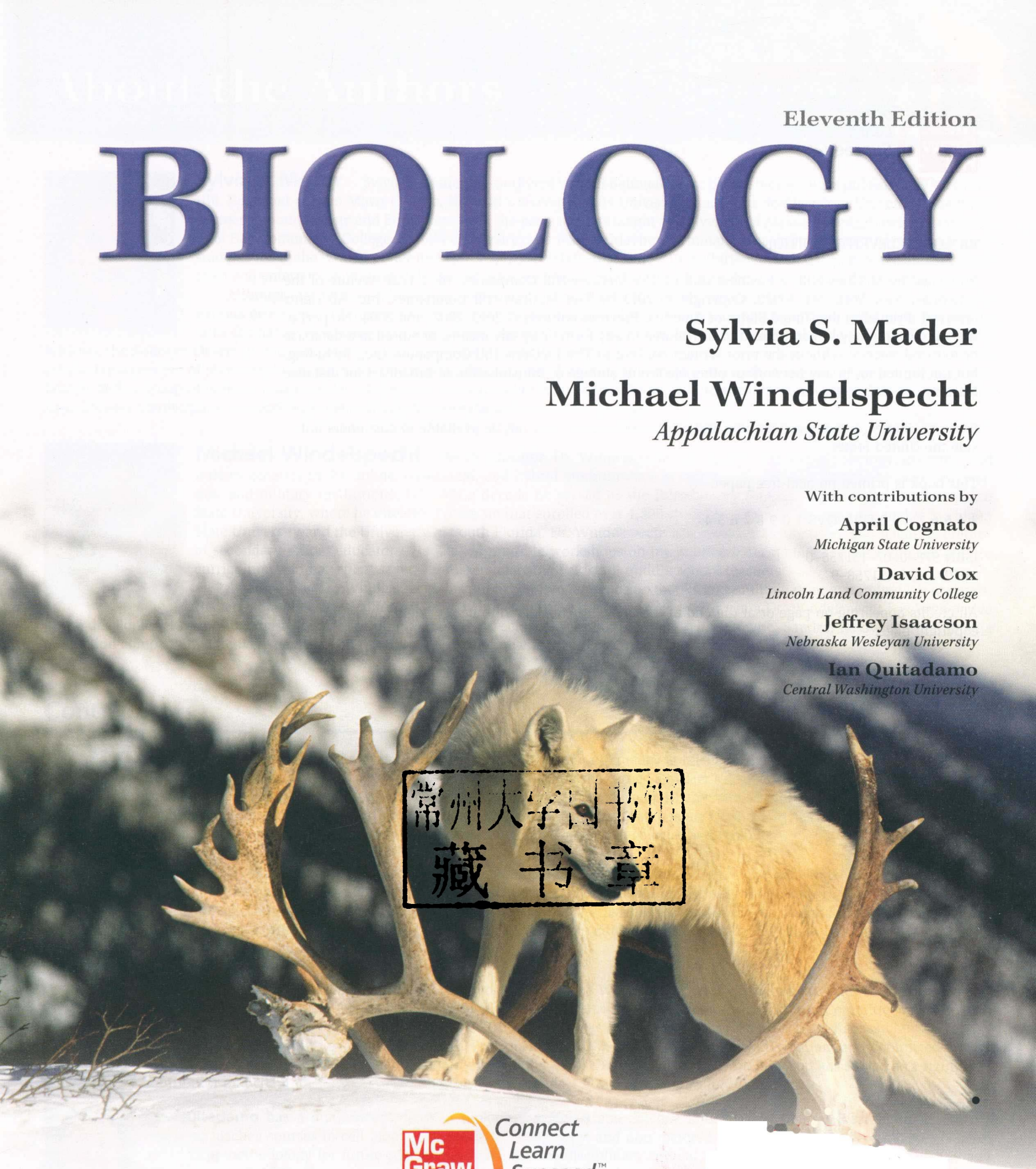

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BIOLOGY, ELEVENTH EDITION

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A Brief History of Biology

Year	Name	Contribution
1628	William Harvey	Demonstrates that the blood circulates and the heart is a pump.
1665	Robert Hooke	Uses the word cell to describe compartments he sees in cork under the microscope.
1668	Francesco Redi	Shows that decaying meat protected from flies does not spontaneously produce maggots.
1673	Antonie van Leeuwenhoek	Uses microscope to view living microorganisms.
1735	Carolus Linnaeus	Initiates the binomial system of naming organisms.
1809	Jean B. Lamarck	Supports the idea of evolution by the inheritance of acquired characteristics.
1825	Georges Cuvier	Founds the science of paleontology and shows that fossils are related to living forms.
1828	Karl E. von Baer	Establishes the germ layer theory of development.
1838	Matthias Schleiden	States that plants are multicellular organisms.
1839	Theodor Schwann	States that animals are multicellular organisms.
1851	Claude Bernard	Concludes that a relatively constant internal environment allows organisms to survive under varying conditions.
1858	Rudolf Virchow	States that cells come only from preexisting cells.
1858	Charles Darwin, Alfred Wallace	Independently present evidence that natural selection guides the evolutionary process.
1865	Louis Pasteur	Disproves the theory of spontaneous generation for bacteria; shows that infections are caused by bacteria.
1866	Gregor Mendel	Proposes basic laws of genetics based on his experiments with garden peas.
1882	Robert Koch	Establishes the germ theory of disease and develops many techniques used in bacteriology.
1902	Walter S. Sutton, Theodor Boveri	Suggest that genes are on the chromosomes, after noting the similar behavior of genes and chromosomes.
1904	Ivan Pavlov	Shows that conditioned reflexes affect behavior, based on experiments with dogs.
1910	Thomas H. Morgan	States that each gene has a locus on a particular chromosome, based on experiments with Drosophila.
1924	Hans Spemann, Hilde Mangold	Show that induction occurs during development, based on experiments with frog embryos.
1929	Sir Alexander Fleming	Discovers the toxic effect of a mold product he called penicillin on certain bacteria.
1937	Konrad Z. Lorenz	Founds the study of ethology and shows the importance of imprinting in learning.
1937	Sir Hans A. Krebs	Discovers the reactions of a cycle that produces carbon dioxide during cellular respiration.
1940	George Beadle, Edward Tatum	Develop the one gene—one enzyme theory, based on red bread mold studies.
1944	O. T. Avery, Colin MacLeod, Maclyn McCarty	Demonstrate that DNA alone from virulent bacteria can transform nonvirulent bacteria.
1945	Melvin Calvin, Andrew A. Benson	Discover the individual reactions of a cycle that reduces carbon dioxide during photosynthesis.
1950	Barbara McClintock	Discovers transposons (jumping genes) while doing experiments with corn.
1952	Alfred D. Hershey, Martha Chase	Find that only DNA from viruses enters cells and directs the reproduction of new viruses.
1953	James Watson, Francis Crick, Rosalind Franklin	Establish that the molecular structure for DNA is a double helix.
1953	Harold Urey, Stanley Miller	Demonstrate that the first organic molecules may have arisen from the gases of the primitive atmosphere.
1954	Linus Pauling	States that disease-causing abnormal hemoglobins are due to mutations.
1954	Jonas Salk	Develops a vaccine that protects against polio.
1958	Matthew S. Meselson, Franklin W. Stahl	Demonstrate that DNA replication is semiconservative.
1961	Francois Jacob, Jacques Monod	Discover that genetic expression is controlled by regulatory genes.
1964	Marshall W. Nirenberg, Philip Leder	Produce synthetic RNA, enabling them to break the DNA code.
1973	Stanley Cohen	Uses recombinant DNA technique (genetic engineering) to place plant and animal genes in Escherichia coli.
1977	Carl Woese	Based on differences in ribosomal RNA sequences, proposes the three domain system of classifications.
1978	Peter Mitchell	Determines chemiosmotic mechanism by which ATP is produced in chloroplasts and mitochondria.
1989	Sidney Altman, Thomas R. Check	Independently discover that some RNA molecules can act as enzymes.
1990	R. Michael Blaese, W. French Anderson, Kenneth W. Culver	Develop procedure to infuse genetically engineered blood cells for treatment of immune system disorder—first gene therapy used in a human.
1997	Ian Wilmut	Clones an adult mammal for the first time.
2003	Human Genome Project	Complete human genome sequenced, creating push to discover genomic links to health and disease.
2010	Craig Venter	Leads team that develops the first synthetic life form.

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 thirteenth 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, 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 was educated at 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 led multiple workshops on integrating water quality research into the science curriculum, and has spent several summers teaching Pakistani middle school teachers.

As an author, Dr. Windelspecht has published five reference textbooks and multiple print and online lab manuals. He served as the series editor for a ten-volume work on the human body. For years Dr. Windelspecht has been active in the development of multimedia resources for online and hybrid science classrooms. Along with his wife, Sandra, he owns a multimedia production company that actively develops and assesses the use of new technologies in the classroom.

Contributors

April Cognato serves as an Assistant Professor in the Department of Zoology at Michigan State University. She was educated at University of California–Davis, and at Texas A&M University where she earned a master's degree and Ph.D. in evolutionary biology. Dr. Cognato is an accomplished research biologist and educator. As an educator, Dr. Cognato designs and teaches introductory non-majors biology, majors biology, and genetics. In addition to her teaching assignments, Dr. Cognato has expertise in the integration of digital resources into education, and she authors fully online courses in genetics and evolution.

Dave Cox serves as Associate 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 non-majors 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 serves as the Educational Director for the Sibun Education and Adventure Lodge, located in Belmopan, Belize.

Jeffrey Isaacson is an Associate Professor of Biology at Nebraska Wesleyan University, where he teaches courses in microbiology, immunology, and cell biology. He currently serves as Chair of the Undergraduate Curriculum Committee and Co-Chair of the General Education Revision Team at NWU. Dr. Isaacson was educated at Nebraska Wesleyan, Kansas State College of Veterinary Medicine, and Iowa State University. Previously, he worked as a small-animal veterinarian, and completed a post-doctoral fellowship in the Department of Immunology at the Mayo Clinic. As an author, Dr. Isaacson has served as a significant contributor and coauthor for the twelfth and thirteenth editions of Mader's *Inquiry Into Life*.

Ian Quitadamo has a dual appointment in Biological Sciences and Science Education at Central Washington University where he teaches courses in cell biology, genetics, biotechnology, and non-majors biology. In addition, he facilitates courses in teaching methodology for future science teachers and interdisciplinary content courses focused on alternative energy and sustainability. Dr. Quitadamo was educated at Washington State University where he earned an interdisciplinary Ph.D. in science, education, and technology. Dr. Quitadamo is a recipient of the Crystal Apple award for teaching excellence. He is a fourth-degree black belt in Kyokushin Karate and owns an academic consulting company.

Preface

Goals of the Eleventh Edition

The mission of Dr. Sylvia Mader's text, *Biology*, has always been to give students an understanding of biological concepts and a working knowledge of the scientific process. The concepts of biology and the methodology of science can be used to understand the particulars of new ideas or of a system, on any scale, from the cell to the biosphere.

In the twenty-first century, students are being exposed, almost on a daily basis, to exciting new discoveries and insights that, in many cases, were beyond our predictions even a few short years ago. It is our task, as instructors, not only to make these findings available to our students, but to enlighten students as to why these discoveries are important to their lives and society. At the same time, we must provide students with a firm foundation in those core principles on which biology is founded, and in doing so, provide them with the background to keep up with the many discoveries still to come. In this text, we integrate a tested, traditional learning system with modern digital and pedagogical approaches designed to stimulate and engage today's student.

The authors of the text identified several goals that guided them through the revision of *Biology*, Eleventh Edition:

1. build upon the strengths of the previous editions of the text,
2. introduce themes that connect the content of the text across multiple chapters,
3. deploy new pedagogical elements, including multimedia assets, to increase student interaction with the text,
4. develop a new series of digital assets designed to engage the modern student and provide assessment of learning outcomes.

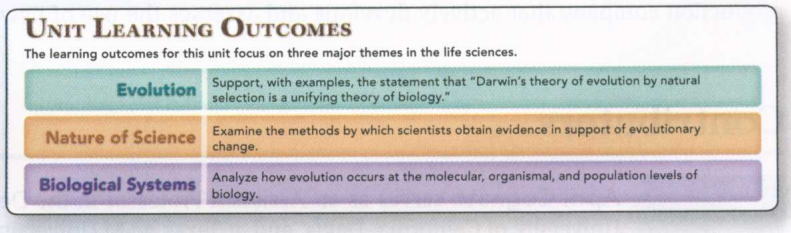
Unit Themes

We recognize that scientific literacy is not based upon the memorization of a series of facts. Instead, learning is based on establishing associations and links between what, at first glance, appear to be diverse topics. The main themes we have chosen to emphasize include

- Evolution
- Nature of Science
- Biological Systems

The cover of this textbook, a gray wolf over a caribou skeleton with the Colorado mountain range in the background, was selected to reflect the importance of these three themes to the life sciences. By studying the historical evolutionary relationship of these species in their natural environment, biologists have been able to better understand the interdependence of the occupants of this ecosystem.

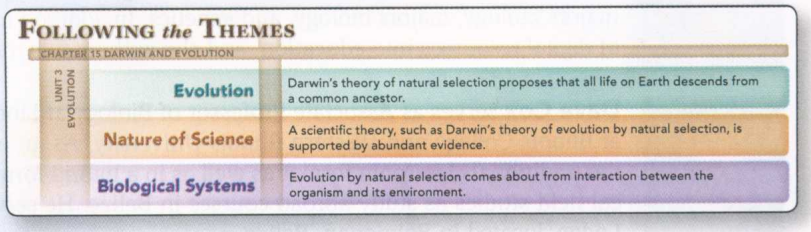
These themes are integrated into all aspects of the textbook, from the unit learning outcomes to the theme-based feature readings in the text. At the start of each chapter, "Following the Themes" introduces the relationship of the chapter's content to each of the themes. At the end of each chapter, "Connecting the Concepts with the Themes" not only reminds the student of the relationships between chapter content and the three core themes, but also acts as a prelude to topics in the next few chapters of the text. In essence, the themes act as the threads that unite the concepts throughout the text, enabling the student to see relationships from the molecular to ecosystem levels of biology.



UNIT LEARNING OUTCOMES

The learning outcomes for this unit focus on three major themes in the life sciences.

Evolution	Support, with examples, the statement that "Darwin's theory of evolution by natural selection is a unifying theory of biology."
Nature of Science	Examine the methods by which scientists obtain evidence in support of evolutionary change.
Biological Systems	Analyze how evolution occurs at the molecular, organismal, and population levels of biology.

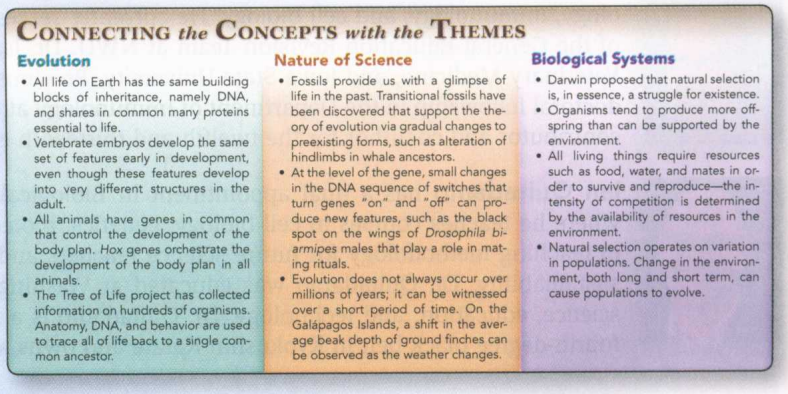


FOLLOWING *the* THEMES

CHAPTER 15 DARWIN AND EVOLUTION

UNIT 3 EVOLUTION

Evolution	Darwin's theory of natural selection proposes that all life on Earth descends from a common ancestor.
Nature of Science	A scientific theory, such as Darwin's theory of evolution by natural selection, is supported by abundant evidence.
Biological Systems	Evolution by natural selection comes about from interaction between the organism and its environment.



CONNECTING *the* CONCEPTS *with the* THEMES

Evolution

- All life on Earth has the same building blocks of inheritance, namely DNA, and shares in common many proteins essential to life.
- Vertebrate embryos develop the same set of features early in development, even though these features develop into very different structures in the adult.
- All animals have genes in common that control the development of the body plan. *Hox* genes orchestrate the development of the body plan in all animals.
- The Tree of Life project has collected information on hundreds of organisms. Anatomy, DNA, and behavior are used to trace all of life back to a single common ancestor.

Nature of Science

- Fossils provide us with a glimpse of life in the past. Transitional fossils have been discovered that support the theory of evolution via gradual changes to preexisting forms, such as alteration of hindlimbs in whale ancestors.
- At the level of the gene, small changes in the DNA sequence of switches that turn genes "on" and "off" can produce new features, such as the black spot on the wings of *Drosophila biarmipes* males that play a role in mating rituals.
- Evolution does not always occur over millions of years; it can be witnessed over a short period of time. On the Galápagos Islands, a shift in the average beak depth of ground finches can be observed as the weather changes.

Biological Systems

- Darwin proposed that natural selection is, in essence, a struggle for existence.
- Organisms tend to produce more offspring than can be supported by the environment.
- All living things require resources such as food, water, and mates in order to survive and reproduce—the intensity of competition is determined by the availability of resources in the environment.
- Natural selection operates on variation in populations. Change in the environment, both long and short term, can cause populations to evolve.

Evolution Theme

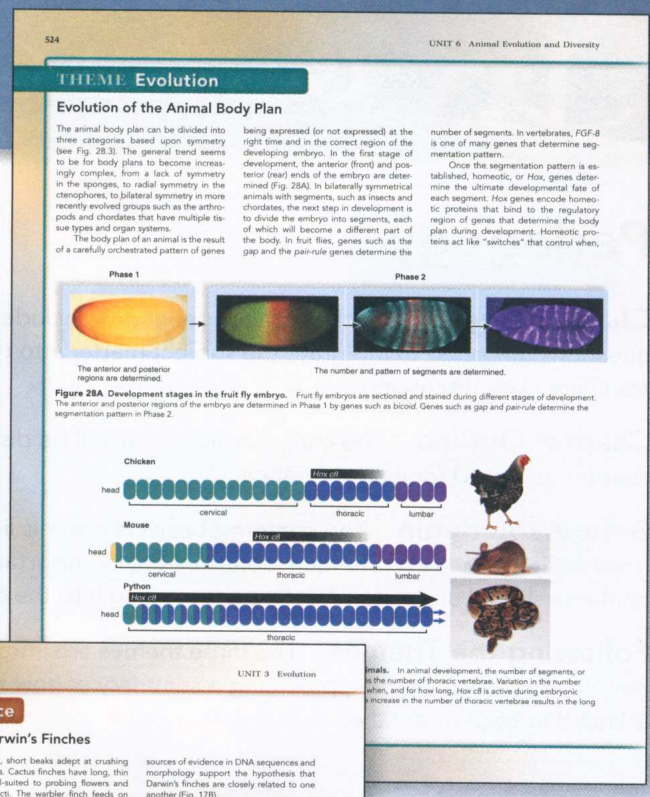
Evolutionary change, along with the mechanism of natural selection, represents the unifying concept of the biological sciences. In essence, biological evolution is the thread that links all life together. Throughout this textbook, feature readings on this theme both demonstrate the process of evolution and illustrate how scientists study and measure evolutionary change. By following this theme through the book, students develop a better understanding of why evolution is a dynamic process, and one that has shaped, and will continue to influence, life on this planet.

Nature of Science Theme

Through the processes of observation, the application of the scientific method, and the use of both inductive and deductive reasoning, scientists study life. To develop a deeper understanding of the biological sciences, students must appreciate that the study of life is a process, and that this process has application in their everyday lives. This theme focuses not only on how biologists do science, but also on the influences scientific inquiry has on our understanding of our world.

Biological Systems Theme

From cells to ecosystems, all life is interconnected. Increasingly, scientists are becoming aware that small changes in the chemical composition of an ecosystem can have a tremendous influence on the life in that ecosystem. This theme was chosen to provide a holistic approach to the study of the life sciences, by demonstrating not only that all life is interconnected, but also that the principles regulating life at the cellular level play a role in physiology and ecosystem biology as well.

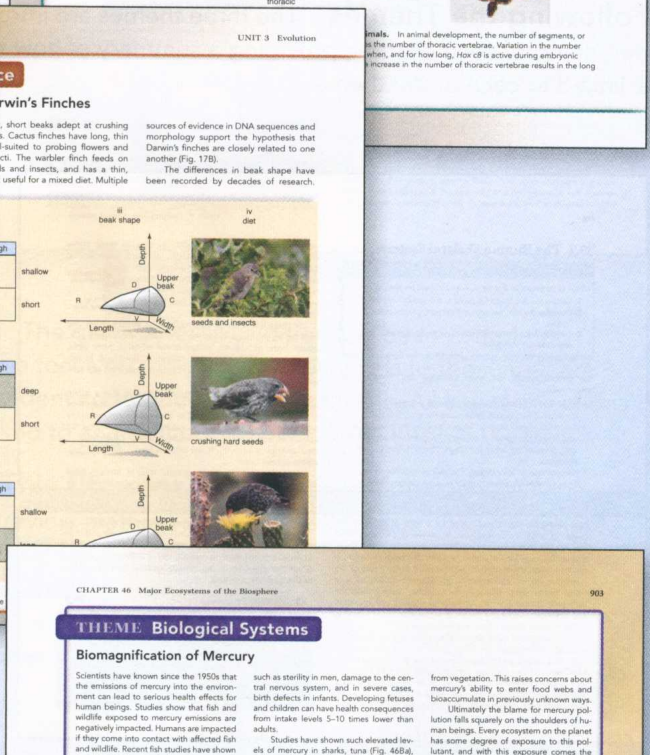

524 UNIT 6 Animal Evolution and Diversity

THEME Evolution

Evolution of the Animal Body Plan

The anterior and posterior regions are determined. The number and pattern of segments are determined.

Figure 28A Development stages in the fruit fly embryo.


318 UNIT 3 Evolution

THEME Nature of Science

Genetic Basis of Beak Shape in Darwin's Finches

Figure 17B Genetic basis of finch beak size and shape.


CHAPTER 46 Major Ecosystems of the Biosphere 903

THEME Biological Systems

Biomagnification of Mercury

Figure 46B Biomagnification of mercury.

Guided Chapter Tour

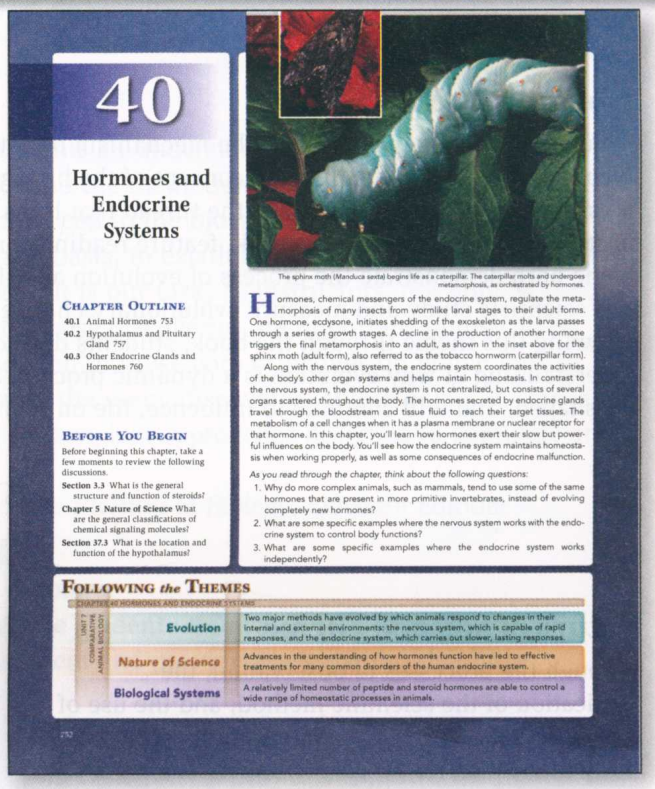
Pedagogy

Chapter Opener Each chapter opener now includes two to three questions designed to integrate the subject matter into the chapter and stimulate class discussions.

Chapter Outline The major sections that will be discussed in the chapter are listed for easy reference.

Before You Begin The content of each chapter is linked with material from earlier in the text. The questions designate important topics that students should understand before proceeding into the chapter.

Following the Themes The three themes are introduced at the beginning of each chapter, providing a summary of how the chapter content is linked to each of the themes.


40

Hormones and Endocrine Systems

The sphinx moth (Manduca sexta) begins life as a caterpillar. The caterpillar molts and undergoes metamorphosis, as orchestrated by hormones.

CHAPTER OUTLINE

40.1 Animal Hormones 753
40.2 Hypothalamus and Pituitary Gland 757
40.3 Other Endocrine Glands and Hormones 760

BEFORE YOU BEGIN

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

Section 3.3 What is the general structure and function of steroids?
Chapter 5 Nature of Science What are the general classifications of chemical signaling molecules?
Section 37.3 What is the location and function of the hypothalamus?

Hormones, chemical messengers of the endocrine system, regulate the metamorphosis of many insects from wormlike larval stages to their adult forms. One hormone, ecdysone, initiates shedding of the exoskeleton as the larva passes through a series of growth stages. A decline in the production of another hormone triggers the final metamorphosis into an adult, as shown in the inset above for the sphinx moth (adult form), also referred to as the tobacco hornworm (caterpillar form).

Along with the nervous system, the endocrine system coordinates the activities of the body's other organ systems and helps maintain homeostasis. In contrast to the nervous system, the endocrine system is not centralized, but consists of several organs scattered throughout the body. The hormones secreted by endocrine glands travel through the bloodstream and tissue fluid to reach their target tissues. The metabolism of a cell changes when it has a plasma membrane or nuclear receptor for that hormone. In this chapter, you'll learn how hormones exert their slow but powerful influences on the body. You'll see how the endocrine system maintains homeostasis when working properly, as well as some consequences of endocrine malfunction.

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

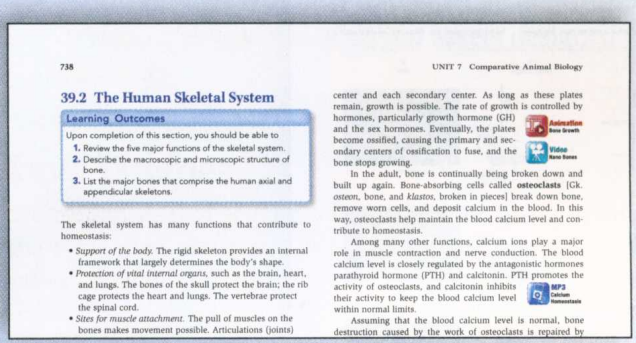
1. Why do more complex animals, such as mammals, tend to use some of the same hormones that are present in more primitive invertebrates, instead of evolving completely new hormones?
2. What are some specific examples where the nervous system works with the endocrine system to control body functions?
3. What are some specific examples where the endocrine system works independently?

FOLLOWING *the* THEMES

CHAPTER 40 HORMONES AND ENDOCRINE SYSTEMS

UNIT 7 COMPARATIVE ANIMAL BIOLOGY

Evolution	Two major methods have evolved by which animals respond to changes in their internal and external environments: the nervous system, which is capable of rapid responses, and the endocrine system, which carries out slower, lasting responses.
Nature of Science	Advances in the understanding of how hormones function have led to effective treatments for many common disorders of the human endocrine system.
Biological Systems	A relatively limited number of peptide and steroid hormones are able to control a wide range of homeostatic processes in animals.


738 UNIT 7 Comparative Animal Biology

39.2 The Human Skeletal System

Learning Outcomes

Upon completion of this section, you should be able to

1. Review the five major functions of the skeletal system.
2. Describe the macroscopic and microscopic structure of bone.
3. List the major bones that comprise the human axial and appendicular skeletons.

The skeletal system has many functions that contribute to homeostasis:

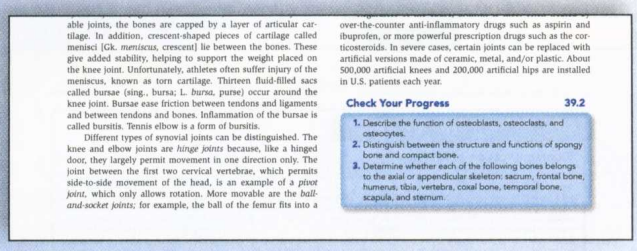
- *Support of the body.* The rigid skeleton provides an internal framework that largely determines the body's shape.
- *Protection of vital internal organs,* such as the brain, heart, and lungs. The bones of the skull protect the brain; the rib cage protects the heart and lungs. The vertebrae protect the spinal cord.
- *Sites for muscle attachment.* The pull of muscles on the bones makes movement possible. Articulations (joints)

center and each secondary center. As long as these plates remain, growth is possible. The rate of growth is controlled by hormones, particularly growth hormone (GH) and the sex hormones. Eventually, the plates become ossified, causing the primary and secondary centers of ossification to fuse, and the bone stops growing.

In the adult, bone is continually being broken down and built up again. Bone-absorbing cells called **osteoclasts** [Gk. *osteon,* bone, and *klastos,* broken in pieces] break down bone, remove worn cells, and deposit calcium in the blood. In this way, osteoclasts help maintain the blood calcium level and contribute to homeostasis.

Among many other functions, calcium ions play a major role in muscle contraction and nerve conduction. The blood calcium level is closely regulated by the antagonistic hormones parathyroid hormone (PTH) and calcitonin. PTH promotes the activity of osteoclasts, and calcitonin inhibits their activity to keep the blood calcium level within normal limits.

Assuming that the blood calcium level is normal, bone destruction caused by the work of osteoclasts is repaired by


able joints, the bones are capped by a layer of articular cartilage. In addition, crescent-shaped pieces of cartilage called menisci [Gk. *meniscus,* crescent] lie between the bones. These give added stability, helping to support the weight placed on the knee joint. Unfortunately, athletes often suffer injury of the meniscus, known as torn cartilage. Thirteen fluid-filled sacs called bursae (sing., bursa; L. *bursa,* purse) occur around the knee joint. Bursae ease friction between tendons and ligaments and between tendons and bones. Inflammation of the bursae is called bursitis. Tennis elbow is a form of bursitis.

Different types of synovial joints can be distinguished. The knee and elbow joints are *hinge joints* because, like a hinged door, they largely permit movement in one direction only. The joint between the first two cervical vertebrae, which permits side-to-side movement of the head, is an example of a *pivot joint,* which only allows rotation. More movable are the *ball-and-socket joints;* for example, the ball of the femur fits into a

over-the-counter anti-inflammatory drugs such as aspirin and ibuprofen, or more powerful prescription drugs such as the corticosteroids. In severe cases, certain joints can be replaced with artificial versions made of ceramic, metal, and/or plastic. About 500,000 artificial knees and 200,000 artificial hips are installed in U.S. patients each year.

Check Your Progress 39.2

1. Describe the function of osteoblasts, osteoclasts, and osteocytes.
2. Distinguish between the structure and functions of spongy bone and compact bone.
3. Determine whether each of the following bones belongs to the axial or appendicular skeleton: sacrum, frontal bone, humerus, tibia, vertebra, coxal bone, temporal bone, scapula, and sternum.

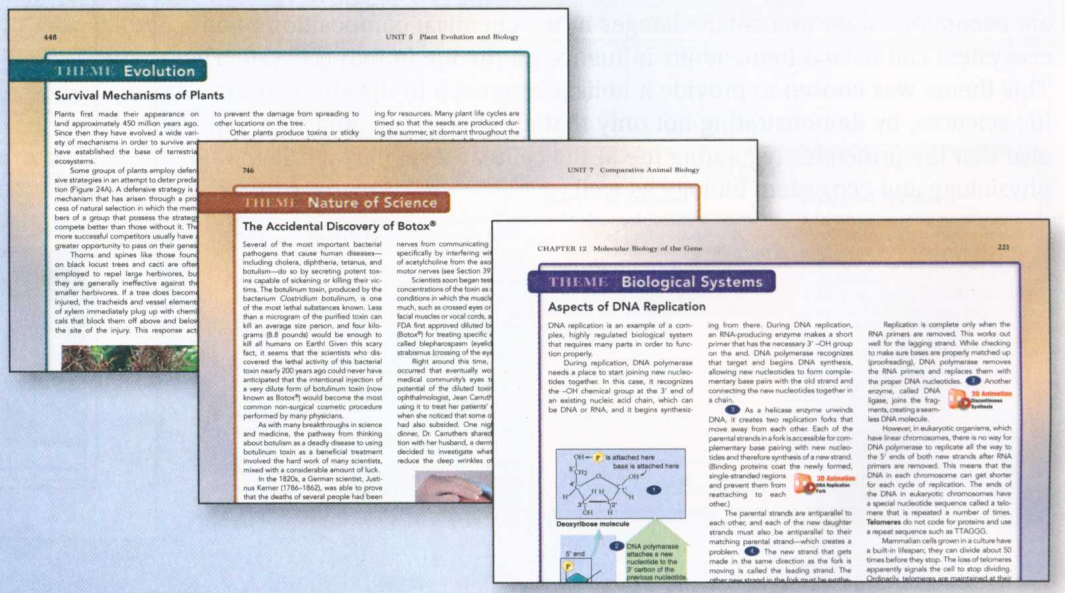
Learning Outcomes The major goals of each section of the chapter are provided for the student. All learning outcomes may be fully assessed using McGraw-Hill Connect® Biology activities.

Media Integration Media enhances the study of biology. Go to Connect or **www.mhhe.com/maderbiology11** to access the animations, videos, and MP3 files referenced throughout this book. Related quizzes are available through Connect® Biology for instructors to assign.

Check Your Progress Each of the statements in this section is designed to help the student assess or apply their understanding of the material in the section.

Thematic Feature Readings

The author team has prepared feature readings to engage students in the three major themes of the textbook—evolution, nature of science, and biological systems. Each feature reading contains a series of "Questions to Consider" that may be used to stimulate classroom discussions.


448 UNIT 5 Plant Evolution and Biology

THEME Evolution

Survival Mechanisms of Plants

746 UNIT 7 Comparative Animal Biology

THEME Nature of Science

The Accidental Discovery of Botox®

CHAPTER 12 Molecular Biology of the Gene 221

THEME Biological Systems

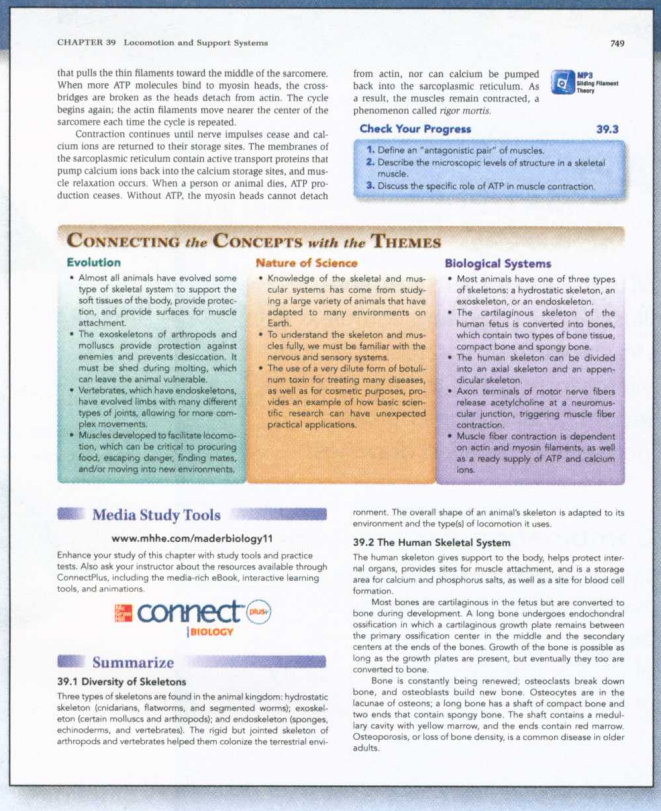
Aspects of DNA Replication

Connecting the Concepts with the Themes At the end of each chapter, the authors have provided a brief synopsis of how each theme was integrated into the chapter. This further develops the themes as a series of learning threads, allowing the instructors and students to link related concepts more easily and facilitate the interconnectedness of the topics in the text.

Media Study Tools This feature provides a link to the *Biology* website, which contains practice tests and other assets to assist the student in comprehending the topics of the chapter. Also present on this site are animations, videos, and multimedia assets that can help the student succeed in their study of biology. In many chapters, icons in this section direct the instructor to the presence of 3D animations that may be used in the classroom, or placed on course management systems, to further student comprehension of difficult topics.

The McGraw-Hill ConnectPlus® platform provides a media-rich eBook, interactive learning tools, and access to the LearnSmart system and Tegrity lecture-capture materials.

Summary A concise overview of the chapter is provided in an easy-to-read paragraph style.



CHAPTER 39 Locomotion and Support Systems 749

that pulls the thin filaments toward the middle of the sarcomere. When more ATP molecules bind to myosin heads, the cross-bridges are broken as the heads detach from actin. The cycle begins again; the actin filaments move nearer the center of the sarcomere each time the cycle is repeated.

Contraction continues until nerve impulses cease and calcium ions are returned to their storage sites. The membranes of the sarcoplasmic reticulum contain active transport proteins that pump calcium ions back into the calcium storage sites, and muscle relaxation occurs. When a person or animal dies, ATP production ceases. Without ATP, the myosin heads cannot detach from actin, nor can calcium be pumped back into the sarcoplasmic reticulum. As a result, the muscles remain contracted, a phenomenon called *rigor mortis*.

MP3 Sliding Filament Theory

Check Your Progress 39.3

1. Define an "antagonistic pair" of muscles.
2. Describe the microscopic levels of structure in a skeletal muscle.
3. Discuss the specific role of ATP in muscle contraction.

CONNECTING *the* CONCEPTS *with the* THEMES

Evolution

- Almost all animals have evolved some type of skeletal system to support the soft tissues of the body, provide protection, and provide surfaces for muscle attachment.
- The exoskeletons of arthropods and molluscs provide protection against enemies and prevents desiccation. It must be shed during molting, which can leave the animal vulnerable.
- Vertebrates, which have endoskeletons, have evolved limbs with many different types of joints, allowing for more complex movements.
- Muscles developed to facilitate locomotion, which can be critical to procuring food, escaping danger, finding mates, and/or moving into new environments.

Nature of Science

- Knowledge of the skeletal and muscular systems has come from studying a large variety of animals that have adapted to many environments on Earth.
- To understand the skeleton and muscles fully, we must be familiar with the nervous and sensory systems.
- The use of a very dilute form of botulinum toxin for treating many diseases, as well as for cosmetic purposes, provides an example of how basic scientific research can have unexpected practical applications.

Biological Systems

- Most animals have one of three types of skeletons: a hydrostatic skeleton, an exoskeleton, or an endoskeleton.
- The cartilaginous skeleton of the human fetus is converted into bones, which contain two types of bone tissue, compact bone and spongy bone.
- The human skeleton can be divided into an axial skeleton and an appendicular skeleton.
- Axon terminals of motor nerve fibers release acetylcholine at a neuromuscular junction, triggering muscle fiber contraction.
- Muscle fiber contraction is dependent on actin and myosin filaments, as well as a ready supply of ATP and calcium ions.

Media Study Tools

www.mhhe.com/maderbiology11

Enhance your study of this chapter with study tools and practice tests. Also ask your instructor about the resources available through ConnectPlus, including the media-rich eBook, interactive learning tools, and animations.

connect plus+ | BIOLOGY

Summarize

39.1 Diversity of Skeletons

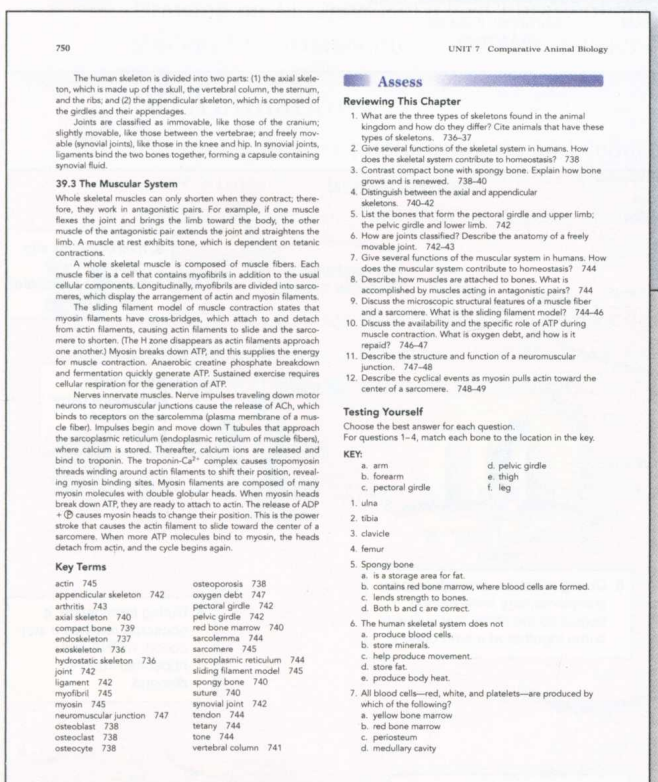
Three types of skeletons are found in the animal kingdom: hydrostatic skeleton (cnidarians, flatworms, and segmented worms); exoskeleton (certain molluscs and arthropods); and endoskeleton (sponges, echinoderms, and vertebrates). The rigid but jointed skeleton of arthropods and vertebrates helped them colonize the terrestrial environment. The overall shape of an animal's skeleton is adapted to its environment and the type(s) of locomotion it uses.

39.2 The Human Skeletal System

The human skeleton gives support to the body, helps protect internal organs, provides sites for muscle attachment, and is a storage area for calcium and phosphorus salts, as well as a site for blood cell formation.

Most bones are cartilaginous in the fetus but are converted to bone during development. A long bone undergoes endochondral ossification in which a cartilaginous growth plate remains between the primary ossification center in the middle and the secondary centers at the ends of the bones. Growth of the bone is possible as long as the growth plates are present, but eventually they too are converted to bone.

Bone is constantly being renewed; osteoclasts break down bone, and osteoblasts build new bone. Osteocytes are in the lacunae of osteons; a long bone has a shaft of compact bone and two ends that contain spongy bone. The shaft contains a medullary cavity with yellow marrow, and the ends contain red marrow. Osteoporosis, or loss of bone density, is a common disease in older adults.



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The human skeleton is divided into two parts: (1) the axial skeleton, which is made up of the skull, the vertebral column, the sternum, and the ribs; and (2) the appendicular skeleton, which is composed of the girdles and their appendages.

Joints are classified as immovable, like those of the cranium; slightly movable, like those between the vertebrae; and freely movable (synovial joints), like those in the knee and hip. In synovial joints, ligaments bind the two bones together, forming a capsule containing synovial fluid.

39.3 The Muscular System

Whole skeletal muscles can only shorten when they contract; therefore, they work in antagonistic pairs. For example, if one muscle flexes the joint and brings the limb toward the body, the other muscle of the antagonistic pair extends the joint and straightens the limb. A muscle at rest exhibits tone, which is dependent on tetanic contractions.

A whole skeletal muscle is composed of muscle fibers. Each muscle fiber is a cell that contains myofibrils in addition to the usual cellular components. Longitudinally, myofibrils are divided into sarcomeres, which display the arrangement of actin and myosin filaments.

The sliding filament model of muscle contraction states that myosin filaments have cross-bridges, which attach to and detach from actin filaments, causing actin filaments to slide and the sarcomere to shorten. (The H zone disappears as actin filaments approach one another.) Myosin breaks down ATP, and this supplies the energy for muscle contraction. Anaerobic creatine phosphate breakdown and fermentation quickly generate ATP. Sustained exercise requires cellular respiration for the generation of ATP.

Nerves innervate muscles. Nerve impulses traveling down motor neurons to neuromuscular junctions cause the release of ACh, which binds to receptors on the sarcolemma (plasma membrane of a muscle fiber). Impulses begin and move down T tubules that approach the sarcoplasmic reticulum (endoplasmic reticulum of muscle fibers), where calcium is stored. Thereafter, calcium ions are released and bind to troponin. The troponin-Ca^{2+} complex causes tropomyosin threads winding around actin filaments to shift their position, revealing myosin binding sites. Myosin filaments are composed of many myosin molecules with double globular heads. When myosin heads break down ATP, they are ready to attach to actin. The release of ADP + Ⓟ causes myosin heads to change their position. This is the power stroke that causes the actin filament to slide toward the center of a sarcomere. When more ATP molecules bind to myosin, the heads detach from actin, and the cycle begins again.

Key Terms

actin 745
appendicular skeleton 742
arthritis 743
axial skeleton 740
compact bone 739
endoskeleton 737
exoskeleton 736
hydrostatic skeleton 736
joint 742
ligament 742
myofibril 745
myosin 745
neuromuscular junction 747
osteoblast 738
osteoclast 738
osteocyte 738
osteoporosis 738
oxygen debt 747
pectoral girdle 742
pelvic girdle 742
red bone marrow 740
sarcolemma 744
sarcomere 745
sarcoplasmic reticulum 744
sliding filament model 745
spongy bone 740
suture 740
synovial joint 742
tendon 744
tetany 744
tone 744
vertebral column 741

Assess

Reviewing This Chapter

1. What are the three types of skeletons found in the animal kingdom and how do they differ? Cite animals that have these types of skeletons. 736–37
2. Give several functions of the skeletal system in humans. How does the skeletal system contribute to homeostasis? 738
3. Contrast compact bone with spongy bone. Explain how bone grows and is renewed. 738–40
4. Distinguish between the axial and appendicular skeletons. 740–42
5. List the bones that form the pectoral girdle and upper limb; the pelvic girdle and lower limb. 742
6. How are joints classified? Describe the anatomy of a freely movable joint. 742–43
7. Give several functions of the muscular system in humans. How does the muscular system contribute to homeostasis? 744
8. Describe how muscles are attached to bones. What is accomplished by muscles acting in antagonistic pairs? 744
9. Discuss the microscopic structural features of a muscle fiber and a sarcomere. What is the sliding filament model? 744–46
10. Discuss the availability and the specific role of ATP during muscle contraction. What is oxygen debt, and how is it repaid? 746–47
11. Describe the structure and function of a neuromuscular junction. 747–48
12. Describe the cyclical events as myosin pulls actin toward the center of a sarcomere. 748–49

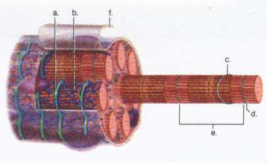
Testing Yourself

Choose the best answer for each question.
For questions 1–4, match each bone to the location in the key.

KEY:

a. arm
b. forearm
c. pectoral girdle
d. pelvic girdle
e. thigh
f. leg

1. ulna
2. tibia
3. clavicle
4. femur
5. Spongy bone
   a. is a storage area for fat.
   b. contains red bone marrow, where blood cells are formed.
   c. lends strength to bones.
   d. Both b and c are correct.
6. The human skeletal system does not
   a. produce blood cells.
   b. store minerals.
   c. help produce movement.
   d. store fat.
   e. produce body heat.
7. All blood cells—red, white, and platelets—are produced by which of the following?
   a. yellow bone marrow
   b. red bone marrow
   c. periosteum
   d. medullary cavity
   d. is stored in the sarcoplasmic reticulum.
   e. Both b and d are correct.
15. Label this diagram of a muscle fiber, using these terms: myofibril, Z line, T tubule, sarcomere, sarcolemma, sarcoplasmic reticulum.



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Engage

Virtual Lab Muscle Stimulation

The virtual lab "Muscle Stimulation" allows you to visualize how the load on a muscle influences the structures of the muscle at the microscopic level.

Thinking Scientifically

1. It is observed that some motor neurons innervate only a few muscle fibers in the biceps brachii. Other motor neurons each innervate many muscle fibers. How might this observation correlate with our ability to pick up a pencil or a 2-liter soda bottle? On what basis would the brain bring about the correct level of contraction?
2. Some athletes believe that taking oral creatine will increase their endurance because it will increase the amount of phosphate available to their muscles for ATP synthesis. This statement can be regarded as two hypotheses: (a) oral creatine increases endurance, and (b) oral creatine increases the amount of creatine available in muscles for ATP synthesis. How could these two hypotheses be tested?

Bioethical Issue

Anabolic Steroids and Muscle Enhancement

A natural advantage does not bar an athlete from participating in and winning a medal in a particular sport at the Olympic Games. Nor are athletes restricted to a certain amount of practice or required to eliminate certain foods from their diets.

Athletes are, however, prevented from participating in the Olympic Games if they have taken certain performance-enhancing drugs. There is no doubt that regular use of drugs such as anabolic steroids leads to kidney disease, liver dysfunction, hypertension, increased aggression, and a myriad of other undesirable side effects (see Fig. 40.16). Even so, shouldn't the individual be allowed to take these drugs if he or she wants to? Anabolic steroids are synthetic forms of the male sex hormone testosterone. Taking large doses, along with strength training, leads to much larger muscles than otherwise. Extra strength and endurance can give an athlete an advantage in certain sports, such as racing, swimming, and weight lifting.

On what basis have anabolic steroids been banned by the Olympic Committee and other sports organizations? The basis can't be an unfair advantage, because some athletes naturally have an unfair advantage over other athletes. Should these drugs be outlawed because of long-term health effects? Excessive practice or a purposeful decrease or increase in weight to better perform in a sport can also be injurious to one's health. In other words, how can we justify allowing some behaviors that enhance performance and not others? (See also the Nature of Science feature, "Misuse of Erythropoietin in Sports," in Chapter 36, which described the controversy over use of erythropoietin in the Tour de France.)

Key Terms The glossary of this edition has been completely reworked, with a focus on reducing the key terms to those that are essential for student comprehension of the topic. All key terms in this section are linked to an updated glossary at the back of the text.

Reviewing This Chapter and Testing Yourself Questions help students review material and prepare for tests. (See Appendix A for Testing Yourself answers.)

Virtual Labs The virtual lab links provide the students with tutorial exercises that can help deepen their understanding of the chapter content. Each of the virtual labs has been enhanced with pre- and post-lab questions and interactive exercises that are assignable through Connect.

Thinking Scientifically and Bioethical Issues These questions provide students with an opportunity to explore additional aspects of the chapter content, including bioethical issues and the design of experiments. These questions are ideal for classroom discussions.

Guided Chapter Tour

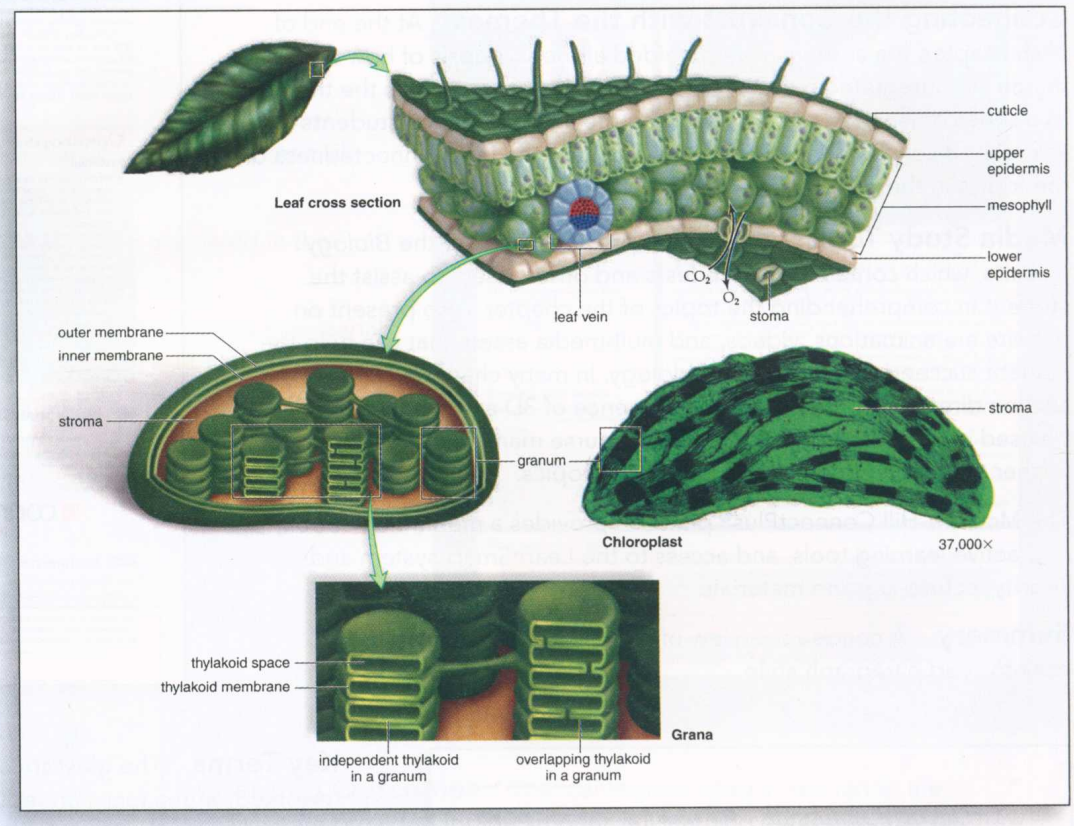
Art

Multi-Level Perspective

Illustrations depicting complex structures show macroscopic and microscopic views to help students see the relationships between increasingly detailed drawings.

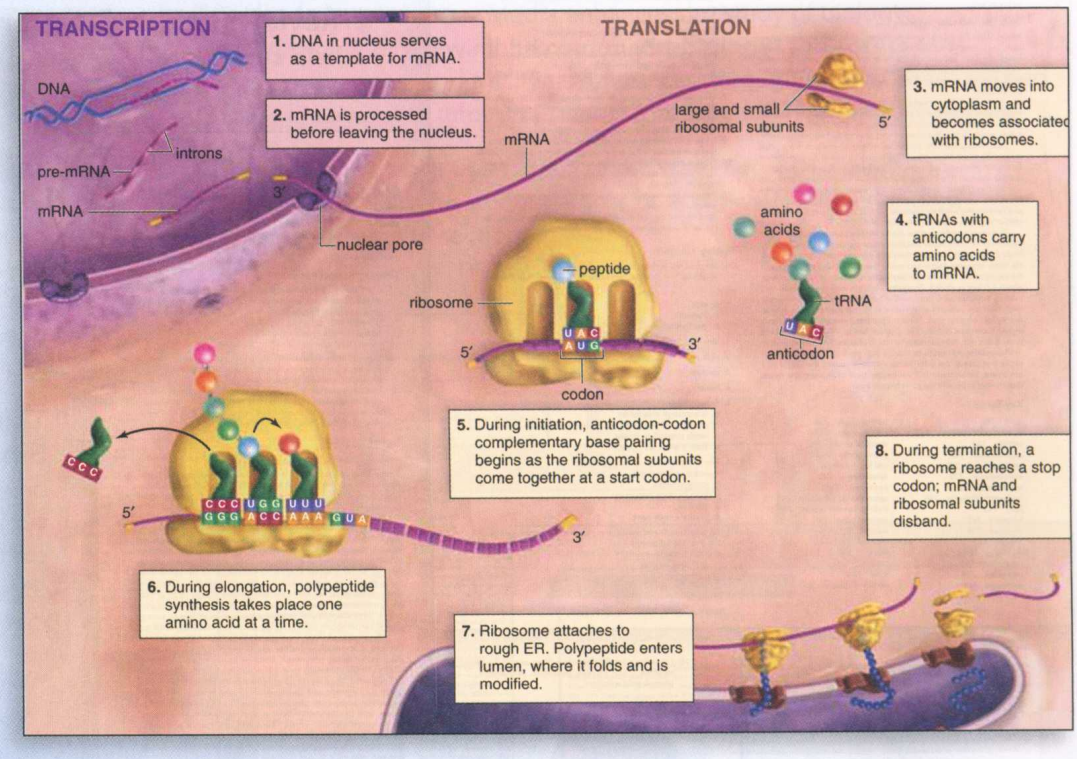
Combination Art

Drawings of structures are paired with micrographs to provide the best of both perspectives: the realism of photos and the explanatory clarity of line drawings.



Process Figures

Complex processes are broken down into a series of smaller steps that are easy to follow. Numbers guide readers through the process.



A Student's Guide to Media

Students can improve the effectiveness of their learning by integrating the digital assets of today's courses into their study habits. To facilitate this integration, the authors have prepared a video tutorial that not only outlines the role of each asset, but also explains to the student how to best utilize these materials for the comprehension of the course content. Included are descriptions on how both LearnSmart™ and Connect®, McGraw-Hill's flagship digital tools, can increase student preparedness for class as well as increase retention of difficult topics.

These assets may easily be uploaded into any course management system to provide your students with useful study tutorials.

Media Integration

As educators, the authors recognize that today's students are digital learners. Therefore, a significant new feature of this edition is the integration of media assets into the chapter content. Virtually every section of the textbook is now linked to MP3 files, animations of biological processes, and National Geographic and ScienCentral videos. In addition, McGraw-Hill's new 3D animations are integrated into the more difficult chapters of the text.

MP3 Files

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.

Animations

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 Animations

For topics such as photosynthesis and cellular respiration, McGraw-Hill has produced a series of dynamic 3D 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.

Videos

Two different types of movies are integrated into this edition of the text. The ScienCentral videos are short news clips on advances in the sciences. The National Geographic videos provide students with a glimpse of the complexity of life that normally would not be possible in the classroom.

Virtual Labs

These simulated experiments serve as excellent tutorials, allowing students to explore the topics covered in select chapters of the text.

Teaching and Learning Tools

McGraw-Hill Higher Education and Blackboard Have Teamed Up

The Best of Both Worlds

Blackboard®, the Web-based course-management system, has partnered with McGraw-Hill to better allow students and faculty to use online materials and activities to complement face-to-face teaching. Blackboard features exciting social learning and teaching tools that foster more logical, visually impactful, and active learning opportunities for students. You'll transform your closed-door classrooms into communities where students remain connected to their educational experience 24 hours a day.

This partnership allows you and your students access to McGraw-Hill's Connect® and McGraw-Hill Create™ right from within your Blackboard course—all with one single sign-on.

Not only do you get single sign-on with Connect and Create, you also get deep integration of McGraw-Hill content and content engines right in Blackboard. Whether you're choosing a book for your course or building Connect assignments, all the tools you need are right where you want them—inside of Blackboard.

Gradebooks are now seamless. When a student completes an integrated Connect assignment, the grade for that assignment automatically (and instantly) feeds your Blackboard grade center.

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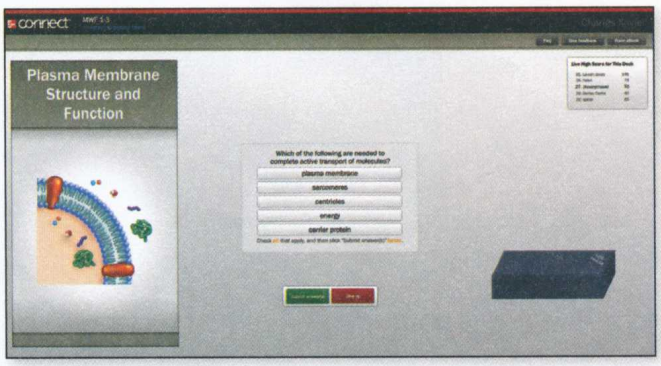
McGraw-Hill LearnSmart™

McGraw-Hill LearnSmart™ is available as an integrated feature of McGraw-Hill Connect® Biology and provides students with a GPS (Guided Path to Success) for your course. Using artificial intelligence, LearnSmart intelligently assesses a student's knowledge of course content through a series of adaptive questions. It pinpoints concepts the student does not understand and maps out a personalized study plan for success. This innovative study tool also has features that allow instructors to see exactly what students have accomplished and a built-in assessment tool for graded assignments. Visit the following site for a demonstration.

www.mhlearnsmart.com



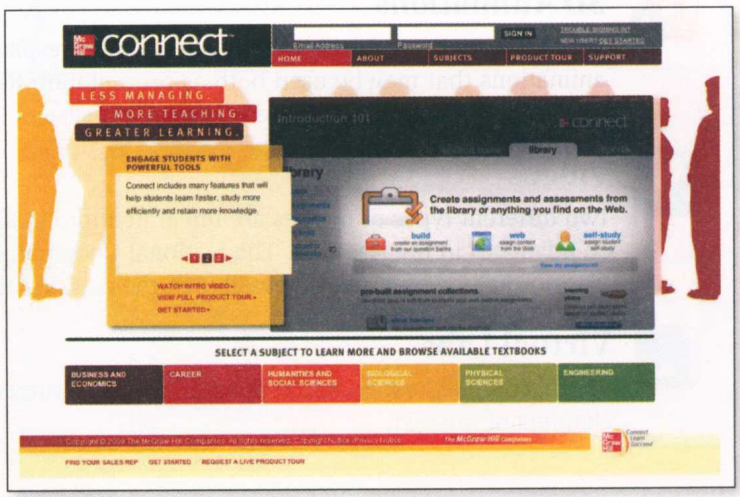
McGraw-Hill Connect® Biology

McGraw-Hill Connect® Biology provides online presentation, assignment, and assessment solutions. It connects your students with the tools and resources they'll need to achieve success.

With Connect Biology, you can deliver assignments, quizzes, and tests online. A robust set of questions and activities are presented and aligned with the textbook's learning outcomes. As an instructor, you can edit existing questions and author entirely new problems. Track individual student performance—by question, assignment, or in relation to the class overall—with detailed grade reports. Integrate grade reports easily with Learning Management Systems (LMS), such as WebCT and Blackboard—and much more.

ConnectPlus Biology provides students with all the advantages of Connect Biology, plus 24/7 online access to an eBook. This media-rich version of the book is available through the McGraw-Hill Connect platform and allows seamless integration of text, media, and assessments.

To learn more, visit
www.mcgrawhillconnect.com



My Lectures—Tegrity®

McGraw-Hill Tegrity® records and distributes your class lecture with just a click of a button. Students can view anytime/anywhere via computer, iPod, or mobile device. It indexes as it records your PowerPoint® presentations and anything shown on your computer so students can use keywords to find exactly what they want to study. Tegrity is available as an integrated feature of McGraw-Hill Connect Biology and as a standalone.

Animations for a New Generation

Dynamic, 3D animations of key biological processes bring an unprecedented level of control to the classroom. Innovative features keep the emphasis on teaching rather than entertaining.

- An options menu lets you control the animation's level of detail, speed, length, and appearance, so you can create the experience you want.
- Draw on the animation using the whiteboard pen to highlight important areas.
- The scroll bar lets you fast forward and rewind while seeing what happens in the animation, so you can start at the exact moment you want.
- A scene menu lets you instantly jump to a specific point in the animation.
- Pop-ups add detail at important points and help students relate the animation back to concepts from lecture and the textbook.
- A complete visual summary at the end of the animation reminds students of the big picture.
- Animation topics include: Cellular Respiration, Photosynthesis, Molecular Biology of the Gene, DNA Replication, Cell Cycle and Mitosis, Membrane Transport, and Plant Transport.

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With **McGraw-Hill Create™**, you can easily rearrange chapters, combine material from other content sources, and quickly upload content you have written, like your course syllabus or teaching notes. Find the content you need in Create by searching through thousands of leading McGraw-Hill textbooks. Arrange your book to fit your teaching style. Create even allows you to personalize your book's appearance by selecting the cover and adding your name, school, and course information. Order a Create book and you'll receive a complimentary print review copy in 3–5 business days or a complimentary electronic review copy (eComp) via e-mail in minutes. Go to www.mcgrawhillcreate.com today and register to experience how McGraw-Hill Create empowers you to teach *your* students *your* way.

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Presentation Tools

Everything you need for outstanding presentations in one place.

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FlexArt Image Powerpoints—including every piece of art that has been sized and cropped specifically for superior presentations, as well as labels that can be edited and flexible art that can be picked up and moved on key figures. Also included are tables, photographs, and unlabeled art pieces.

Lecture PowerPoints with Animations—animations illustrating important processes are embedded in the lecture material.

Animation PowerPoints—animations only are provided in PowerPoint.

Labeled JPEG Images—full-color digital files of all illustrations that can be readily incorporated into presentations, exams, or custom-made classroom materials.

Base Art Image Files—unlabeled digital files of all illustrations.

Presentation Center

In addition to the images from your book, this online digital library contains photos, artwork, animations, and other media from an array of McGraw-Hill textbooks.

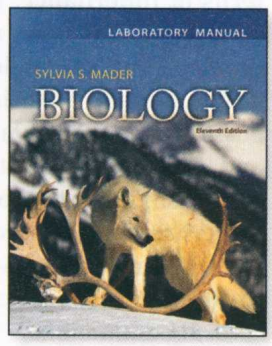
Computerized Test Bank

A comprehensive bank of test questions is provided within a computerized test bank powered by McGraw-Hill's flexible electronic testing program, **EZ Test Online.** A new tagging scheme allows you to sort questions by Bloom's difficulty level, learning outcome, topic, and section. With EZ Test Online, instructors can select questions from multiple McGraw-Hill test banks or author their own, and then either print the test for paper distribution or give it online.

Instructor's Manual

The instructor's manual contains chapter outlines, lecture enrichment ideas, and discussion questions.

Laboratory Manual



The *Biology Laboratory Manual* is written by Dr. Sylvia Mader. Every laboratory has been written to help students learn the fundamental concepts of biology and the specific content of the chapter to which the lab relates, as well as gain a better understanding of the scientific method.

Companion Website

www.mhhe.com/maderbiology11

The Mader *Biology* companion website allows students to access a variety of free digital learning tools that include

- Chapter-level quizzing
- Animations and videos
- Vocabulary flashcards
- Virtual labs

Overview of Content Changes to *Biology*, Eleventh Edition

Chapter 1: A View of Life. This chapter introduces the three themes, Evolution, the Nature of Science, and Biological Systems, that will act as the focal points for the text. The virtual lab "Dependent and Independent Variables" has been added to the end of the chapter.

Unit 1: The Cell

Chapter 2: Basic Chemistry. The pH scale (Fig. 2.13) has been revised to provide students with a better understanding of acid/base relationships. The Biological Systems feature has been enhanced to include graphs of U.S. acid rain–causing emissions. **Chapter 3: The Chemistry of Organic Molecules** contains a new Nature of Science feature on fats in the diet. **Chapter 4: Cell Structure and Function.** The graphic on the endosymbiotic theory has been enhanced to include a more detailed explanation of the evolutionary significance of each stage of the process. **Chapter 5: Membrane Structure and Function** now contains links to the 3D animation "Membrane Transport." **Chapter 6: Metabolism: Energy and Enzymes** has been linked to the virtual lab "Enzyme Controlled Reactions." The 3D animation "Photosynthesis" has been integrated into **Chapter 7: Photosynthesis**. **Chapter 8: Cellular Respiration** includes links to the 3D animation "Cellular Respiration" and contains updated explanations on theoretical versus actual ATP yields.

Unit 2: Genetic Basis of Life

Chapter 9: The Cell Cycle and Cellular Reproduction has been enhanced by links to the 3D animation "Cell Cycle and Mitosis" and the virtual lab "Cell Reproduction." **Chapter 10: Meiosis and Sexual Reproduction** has been revised to include a more detailed explanation of chromosomes, including bivalent and tetrad combinations. In **Chapter 11: Mendelian Patterns of Inheritance,** an additional figure (Fig. 11.5) has been added to enhance an understanding of how the 3:1 ratio was developed using Mendel's data. The Science Focus box on Mendel's Laws and Meiosis is now integrated directly into the discussion of Mendel's laws. Two virtual labs, "Punnett Squares" and "Sex-Linked Traits," are now linked to this chapter as tutorials. Figure 12.5 of **Chapter 12: Molecular Biology of the Gene** has been revised to better indicate the directionality of the DNA molecule. In addition, Figure 12.6 has been modified to illustrate the role of RNA polymerase in DNA replication. Two 3D animations, "DNA replication" and "Molecular Biology of the Gene," have been added to the chapter. **Chapter 13: Regulation of Gene Expression** now contains a revised discussion of how sRNA molecules influence gene expression and new illustrations on the role of sRNAs in the cell (Fig. 13.9) and the action of proteasomes (Fig. 13.10). **Chapter 14: Biotechnology and Genomics** now starts with a new chapter opener on biotechnology-produced fuels. Also included is a more detailed explanation of intergenic sequences. The virtual labs "Knocking out Genes," "Gene Splicing," and "Classifying Using Biotechnology" have been linked to the chapter.

Unit 3: Evolution

Chapter 15: Darwin and Evolution has been substantially revised to better present the historical basis behind the theory of evolution to students. The chapter begins with a new article on *Tiktaalik*. New figures include Lamarck's inheritance of acquired characteristics (Fig. 15.2), the role of wingspots in *Drosophila* species (Fig. 15.11), and transitional fossils (Figs. 15.12 and 15.13). The material on Alfred Wallace is now integrated into the main text, and the evolution theme is enforced by an evolution feature reading on the "Tree of Life Project." The chapter also includes material on the criticisms of evolution. **Chapter 16: How Populations Evolve** begins with a new article on HIV. The discussion of microevolution now focuses on the peppered moth and a discussion of allele frequencies, and it includes new figures (Figs. 16.1, 16.2, 16.4, and 16.7) and a summary table (Table 16.1) to enforce these concepts. New figures on directional (Fig. 16.10) and disruptive (Fig. 16.11) selection have been added. A new Nature of Science feature reading on achromatopsia and the Pingelapese population reinforces the fact that microevolution occurs in humans. **Chapter 17: Speciation and Macroevolution** starts with a new article on micro-frogs. The chapter has been revised to include more detailed discussions on the various concepts of species, including new figures (Figs. 17.1 and 17.3). The cichlids of Africa are the focus of a new figure (Fig. 17.12) on convergent evolution. Two new feature readings are included: one of how to interpret phylogenetic trees, and a second on the genetic basis of beak shape in Galápagos finches. **Chapter 18: Origin and History of Life** has been reorganized to make a clear connection between chemical and biological evolution (Fig. 18.1). This includes more detailed discussions of the various hypotheses involved in these processes (Figs. 18.4 and 18.5). **Chapter 19: Taxonomy, Systematics, and Phylogeny** has been reorganized so that the material on the three-domain system (Section 19.2) occurs prior to the discussion of phylogeny (Section 19.3). The chapter starts with a new article on how systematics may be used in crime investigations. Figure 19.3 provides an enhanced visual explanation of classification categories, and Figure 19.5 illustrates the relationship between phylogeny, classification, and traits. A new Nature of Science feature reading examines the concept of DNA barcoding.

Unit 4: Microbiology and Evolution

Chapter 20: Viruses, Bacteria, and Archaea now begins with an article on the H1N1 virus. The structure of the influenza virus has been updated in Figure 20.1. New figures on emerging diseases (Fig. 20.5) and the features of prokaryotic cells (Fig. 20.7) have been provided. **Chapter 21: Protist Evolution and Diversity** now contains a focus on neglected tropical diseases

and contains an opening article and Biological Systems feature reading on this topic. The chapter format reflects the current concept of protist "supergroups" (Table 21.1, Fig. 21.1). **Chapter 22: Fungi Evolution and Diversity** begins with an article on the use of fungal products as a form of green packaging material. Figure 22.1 now relates the fungi to the other eukaryotic supergroups. Table 22.1 has been enhanced to provide the key features of the fungal phyla.

Unit 5: Plant Evolution and Biology

Chapter 23: Plant Evolution and Diversity starts with a new article on plant diversity. A new Evolution feature on the evolutionary history of maize has been added, and the chapter includes a link to the virtual lab "Classifying Using Biotechnology." In **Chapter 24: Flowering Plants: Structure and Organization,** a new Evolution feature examines the survival mechanisms of plants. A second Nature of Science feature reading explores the many uses of bamboo in society. **Chapter 25: Flowering Plants: Nutrition and Transport** begins with a new article on artificially colored flowers. The 3D animation "Plant Transport" is integrated throughout the chapter. The chapter is linked to the virtual lab "Plant Transpiration." **Chapter 26: Flowering Plants: Control of Growth Responses** contains a new table (26.1) summarizing the major plant hormones. In **Chapter 27: Flowering Plants: Reproduction,** the Evolution feature reading has been enhanced to provide a more evolutionary perspective.

Unit 6: Animal Evolution and Diversity

For **Chapter 28: Invertebrate Evolution,** a new opener examines the fad of tapeworm diets. A new Evolution feature reading examines the genetic basis of the animal body plan. The phylogenetic tree of animals (Fig. 28.4) has been upgraded. Two virtual labs, "Earthworm Dissection" and "Classifying Arthropods," have been linked to the chapter. **Chapter 29: Vertebrate Evolution** includes a revised phylogenetic tree for the chordates (Fig. 29.4). The material on amphibian evolution (Section 29.4) has been updated to reflect recent advances in the field. The evolution of mammals (Section 29.6) now includes a timeline of important events (Fig. 29.19) and a summary table of important characteristics (Table 29.1). A new table (29.2) summarizes the major orders of placental mammals. **Chapter 30: Human Evolution** begins with a new article on the evolutionary relationship of Neandertals and *Homo sapiens*. The chapter and figures (30.4) have been upgraded to reflect changes in classification terminology. The chapter now includes a Nature of Science reading on how scientists are using comparative genomics to study similarities between the chimp and human genomes. The material on the ardipithecines and Cro-magnon *Homo sapiens* has been enhanced to focus on the significance of these groups.

Unit 7: Comparative Animal Biology

Chapter 31: Animal Organization and Homeostasis contains a new Nature of Science feature on regenerative medicine. The chapter is now linked to the virtual lab "Virtual Frog Dissection." **Chapter 32: Circulation and Cardiovascular Systems** now starts with an article on the consequences of aortic dissection. A new Nature of Science feature on the use of horseshoe crabs in cardiovascular medicine is included in the chapter. Two virtual labs, "Earthworm Dissection" and "Virtual Frog Dissection," are now linked to this chapter. **Chapter 33: The Lymphatic and Immune Systems** now begins with an article on severe combined immunodeficiency syndrome. The chapter also features a new section (33.1) on the evolution of immune systems. In addition, a new Nature of Science feature on cancer vaccines has been added to the chapter. **Chapter 34: Digestive Systems and Nutrition** begins with a new article on ruminant mammals. The chapter also includes a new Nature of Science feature on treating obesity and is linked to three virtual labs, "Earthworm Dissection," "Virtual Frog Dissection," and "Nutrition." **Chapter 35: Respiratory Systems** begins with a new article on the evolution of the diving response. The chapter also includes a new Nature of Science feature on artificial lung technology. **Chapter 36: Body Fluid Regulation and Excretory Systems** includes a new Nature of Science feature reading on the misuse of erythropoietin in sports and links to two virtual labs, "Earthworm Dissection" and "Virtual Frog Dissection." **Chapter 37: Neurons and Nervous Systems** includes a new opening article and Nature of Science feature on Parkinson disease. **Chapter 38: Sense Organs** begins with a new article on sensory perception in pit vipers. The chapter has been reorganized to include more details on sensory receptors (Section 38.1) and the somatic senses (Section 38.5). A new Nature of Science feature examines the development of artificial retinas. **Chapter 39: Locomotion and Support Systems** contains a new Nature of Science feature on diluted botulinum toxin and links to the "Muscle Stimulation" virtual lab. **Chapter 40: Hormones and Endocrine Systems** contains new images on Cushing syndrome (Fig. 40.14). **Chapter 41: Reproductive Systems** has been updated to include recent statistics on the prevalence of sexually transmitted diseases. The chapter is linked to the virtual lab "Virtual Frog Dissection." **Chapter 42: Animal Development and Aging** has been revised to include a focus on the aging process (Section 32.4).

Unit 8: Behavior and Ecology

The virtual lab "Mealworm Behavior" has been linked to **Chapter 43: Behavioral Ecology**. In **Chapter 44: Population Ecology**, a new chapter opener has been introduced that focuses on the impact of introduced species. Figure 44.7 has been modified to improve the explanation of the process of exponential growth. The comparison of the environmental impact of developed versus undeveloped countries has been enhanced by changes to Figure 44.17. The chapter is linked to the virtual lab "Population Biology." **Chapter 45: Community and Ecosystem Ecology** now opens with an article on wolves in the Yellowstone National Park, thus providing a link to the cover of the textbook. The chapter includes a new Nature of Science feature reading on global climate change and a link to the "Model Ecosystems" virtual lab. **Chapter 46: Major Ecosystems of the Biosphere** starts with a new article on the migration patterns of Canada geese. The Biological Systems feature "Biomagnification of Mercury" is new to this chapter. **Chapter 47: Conservation of Biodiversity** contains a new Nature of Science feature on floodplain restoration in the Illinois River system.

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