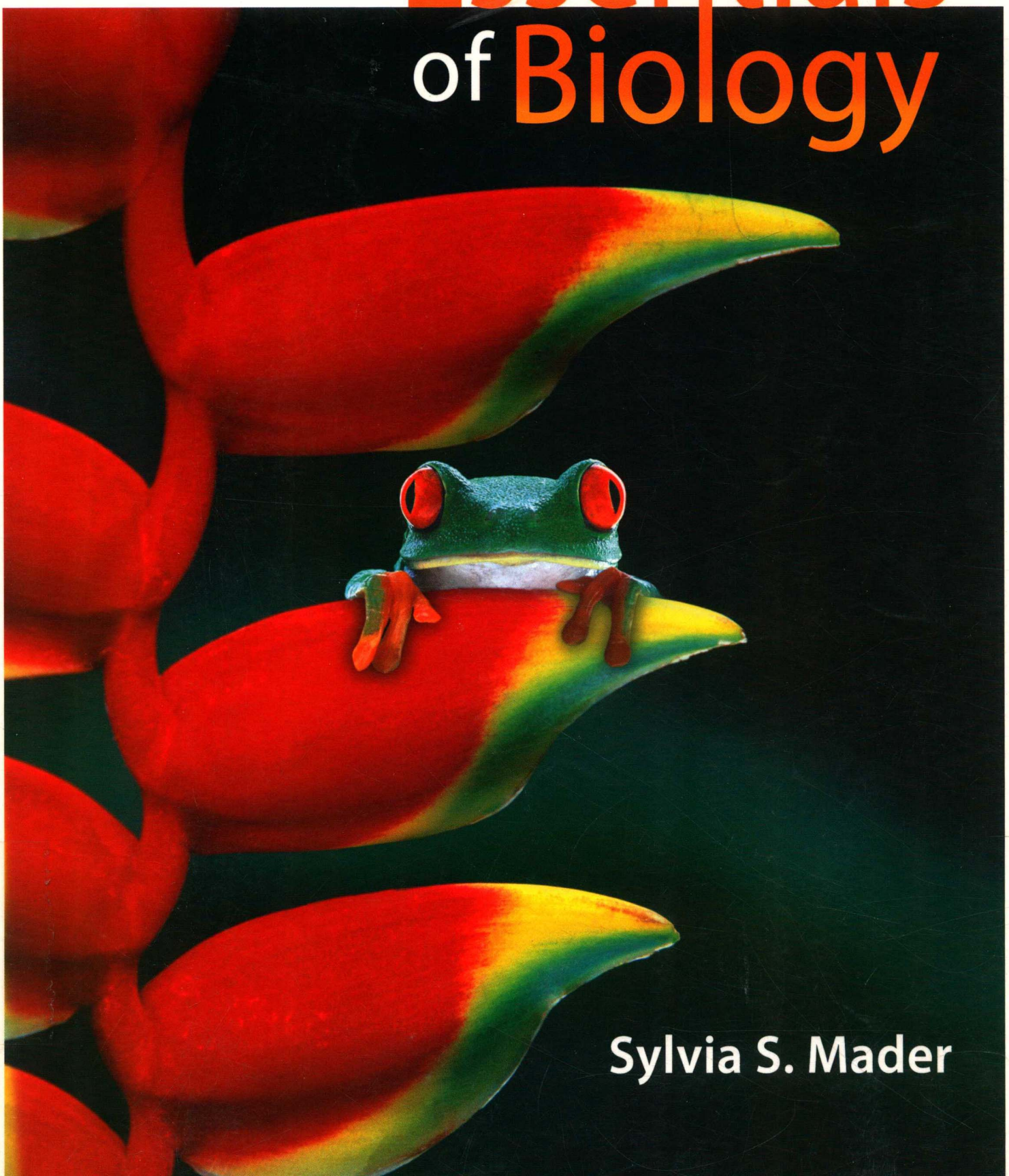
Second Edition

Essentials of Biology



Sylvia S. Mader

Second Edition

Essentials of Biology

Sylvia S. Mader

with significant contributions by

Andrew Baldwin
Mesa Community College

Rebecca Roush
Sandhills Community College

Stephanie Songer
North Georgia College and State University

Michael Thompson
Middle Tennessee State University

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Preface

Essentials of Biology was written to engage non-major students in the study of biology and inspire them to learn more. It continues to be traditional in its approach and organized around the major concepts of biology. However, the book is succinct enough to be appropriate for a one semester course.

Three primary goals guided the revision of *Essentials of Biology,* Second Edition:

1. build upon the strengths of the first edition,
2. increase student awareness of evolution and why it is a central concept of biology,
3. add more applications to enhance the relevancy of the content for students.

Strengths of *Essentials of Biology*

Content Organization Writing Style Illustrations Pedagogy

The content and organization of *Essentials of Biology* continues to be solid—accurate and up-to-date, and logical. Equally important, the text reaches out to the student because it has a conversational writing style and an exciting illustration program. The design and illustration program of the book is appropriate for those who are accustomed to being visually stimulated, and instructors can easily use these same great illustrations in lecture or as part of assignments.

> "***Essentials of Biology*** is an outstanding textbook for the non-major. The material is clear and specific, but not intimidating. The text contains numerous graphics, diagrams, etc. to enhance student-learning. This text invites students to open it and read!"
>
> *Barbara J. Salvo*
> *Carthage College*

The *Essentials of Biology* Learning System also helps beginning biology students by guiding them through each chapter. The chapter-opening page lists the key concepts to give students an overview of the chapter. The opening vignette captures students' interest and encourages them to begin their study of the chapter. Distributed throughout each chapter are *Check Your Progress* questions designed to foster confidence as readers proceed through the chapter. The chapter end matter gives students an opportunity to review the chapter and test themselves on how well they understand the concepts. *Thinking Scientifically* questions allow students to apply their knowledge to concrete scientific explorations. Most chapters now end with a *Bioethical Issue* that can be used as a basis for class discussion.

Four contributors joined me in revising *Essentials of Biology,* and their varied backgrounds and extensive teaching experience further enhanced the strengths of the book. Andrew Baldwin, *Mesa Community College,* revised the evolution and ecology chapters. Rebecca Roush, *Sandhills Community College,* revised Chapters 22-26 of the animal structure and function chapters. Stephanie Songer, *North Georgia College and State University*, revised the diversity of life and several animal structure and function chapters. Michael Thompson, *Middle Tennessee State University,* revised the cell, genetics, and plant chapters.

We worked collaboratively to improve this new edition, and through my review of every chapter, the book retains the hallmark features of a Mader text: accurate and current content, logical organization of chapters, clear writing, well-developed visuals, and a strong pedagogical system. For more information on the features of this book, see the Guided Tour on pages vii-xi.

Increased Evolution Coverage

For several years now, biology has been undergoing a revolutionary change. Molecular biology is indeed wedded to evolution and the binding together of these two fields of biology has opened up a vista into the evolutionary relationships of organisms never before possible. With the help of nucleic acid sequencing, we can now more confidently reconstruct the evolutionary history of life. *Essentials of Biology* makes full use of our newfound knowledge and relates the evolutionary consequences for the broadest categories, the domains, and for each of the kingdoms.

Being good educators we realized that students need a firm foundation in the principles of evolution in order to fully appreciate the phylogenic data now available to biologists. Reviewers will find a renewed emphasis on evolution that begins in the first chapter with a new section devoted to evolutionary principles and a generalized tree of life. The evolution chapters in Part III, *Evolution,* received special attention before Part IV, *Diversity of Life,* specifically discusses the evolution of various groups and presents new evolutionary trees for protists, plants, fungi, and animals. Increased evolution coverage is also weaved throughout this edition, and a *Thinking Scientifically* question that pertains to evolution is presented at the end of each chapter (identified with an icon, *left*) to help students realize that evolution is pertinent to all aspects of biology.

> "This text clearly presents topics in biology in such an interesting fashion that it is sure to intrigue and fascinate students. The text is also written in such as way as to be quite understandable by the non-science student."
>
> *Kathleen Pelkki,*
> *Saginaw Valley State University*

Additional examples of the increased evolution coverage are noted below in the overview of changes.

Relevancy of Biology

More applications have been added to the second edition of *Essentials of Biology* to increase the relevancy of the text. In reviews, instructors emphasize the need to relate the concepts of biology to students' lives. Such relevant examples help students understand the concepts, and increase their chances of remembering the concepts.

Each chapter opens with a brief story that relates the biological concepts of that chapter to something of interest to students. For example, Chapter 2 introduces chemistry by discussing how exposure to extreme levels of radiation can cause sunburn, hair loss, or cancer. Chapter 25 discusses saturated, unsaturated, and trans fats to open the nutrition chapter.

> "I really like this book because it is student friendly. Content has real world application and is easy to read and understand. [It] has beautiful illustrations that stimulate interest and excellent end of chapter materials."
> *Mary Ruth Hood, Tomball College*

Most chapters also end with a Bioethical Issue; a brief reading about an ethical issue related to biology that confronts our society. Examples of topics covered include cloning, global climate change, water pollution, health risks associated with certain plastics, gene therapy, and blood doping.

Additional examples of relevancy are given below in the overview of changes.

Overview of Changes to *Essentials of Biology*, Second Edition

Chapter 1 *A View of Life*

This chapter previews the text by discussing the characteristics of life, principles of evolution, organization of the biosphere, and the scientific process. An expanded section on evolution including a generalized tree of life, is new to this edition. The scientific process includes a new example of a controlled experiment that is more applicable to students' lives.

Part I *The Cell*

This part was revised to emphasize the dynamic nature of cells. Chapter 3, *The Organic Molecules of Life,* has been enriched with new references to health concerns including high-fructose drinks, trans fats in processed foods and the abuse of steroids to gain muscle mass. Chapter 5, *The Dynamic Cell,* has been reorganized to place enzymatic reactions next to the discussion of metabolic pathways. In Chapter 6, *Energy for Life,* the diversity of photosynthetic process is explained as adaptations to different environments.

New bioethical issues occur in this part including *Human Cloning, Arsenic in Drinking Water,* and *Are Carbon Offset Credits Effective?*

Part II *Genetics*

This part has been updated to be more applicable to students' everyday lives. In Chapter 9, *Sexual Reproduction,* the importance of meiosis for the generation of variations so necessary to evolution is stressed. Chapter 11, *DNA Biology and Technology,* now contains a new illustration (Fig. 11.9) to introduce the topic of protein synthesis. The discussion of genomics and bioinformatics has been moved from Chapter 13 to this chapter. The Human Genome Project is reviewed, and the current emphasis on genomic variation between individuals is also addressed. Further, the contributions of genomics to our knowledge of evolutionary ties between species is discussed. In Chapter 12, *Gene Regulation and Cancer,* an improved section on the genetics of cancer is supported by new Figure 12.15.

New bioethical issues occur in this part including *Selecting the Sex of Your Child, Should BPA be Banned?,* and *Gene Therapy Trials.*

Part III *Evolution*

This part is much improved by current examples of the evolutionary process. In Chapter 14, *Darwin and Evolution,* Alfred Russell Wallace's contribution to Darwin's theory is emphasized, and Darwin's theory is better explained. In Chapter 15, *Evolution on a Small Scale,* an improved discussion of a Hardy-Weinberg equilibrium is supported by a new figure. Examples of genetic mutations have been updated by a discussion of SNPs (single nucleotide polymorphisms). Figures 15.10-15.11, which describe the different types of natural selection, have been clarified and revised. Chapter 16, *Evolution on a Large Scale,* contains two new sections: 16.2 is now a discussion of the fossil record, and 16.3 now gives a review of systematics that includes an improved discussion of cladistics and its relationship to Linnaean classification.

> "I think the revisions made so far and the process of updating this textbook will continue to make it one of the sought after texts for general biology."
> *Bo Sosnicki, Piedmont Virginia Community College*

Part IV *Diversity of Life*

This part has been updated to include a more comprehensive look at the evolutionary relationships of organisms. In Chapter 17, *The First Forms of Life,* both the origin of the first cell and the origin of the eukaryotic cell are now included. Chapter 18, *Land Environment: Plants and Fungi,* has been thoroughly revised to include a new evolutionary tree of plants, and a discussion that traces their evolution from an algal ancestor and emphasizes five significant events as they became fully adapted to land. Chapter 19, *Both Water and Land: Animals,* now includes a new evolutionary tree of animals and a discussion that traces their evolution from an ancestral protist. The tree emphasizes number of germ layers, type of symmetry, and type of embryonic development. Human evolution, which is in this chapter, was updated to include the new designation, hominins, which also includes the chimpanzees.

Part V *Plant Structure and Function*

Chapter 20, *Plant Anatomy and Growth,* and Chapter 21, *Plant Responses and Reproduction,* were revised to make the material more student friendly and to emphasize the specific adaptations of flowering plants that have resulted in their great success on land.

Part VI *Animal Structure and Function*

Various applications and analogies have been inserted and more material was added to selected topics. For example, in Chapter 24, *The Maintenance Systems,* digestive enzymes are reviewed in a new section. In Chapter 26, *Defenses Against Disease,* the new terms "acquired immunity" and "innate immunity" are introduced. The emphasis on homeostasis is maintained in this part, and new applications have been provided to enliven the discussion. The bioethical issues have been updated and expanded.

Part VII Ecology

The principles of ecology are more thoroughly reviewed in this section. The interplay between ecology and evolution is emphasized because adaptations are often a response to ecological factors. In Chapter 32, *Human Impact on the Biosphere,* the negative human impacts on the environment are counter balanced by an expanded section that shows how humans can foster sustainability.

What's New to This Edition

Increased Evolution Coverage

- Chapter 1 now introduces students to the principles of evolution and includes a generalized tree of life. The process of science contains a more applicable example of a controlled study.
- Plant and animal biology now begin with evolutionary trees based on nucleic acid sequencing and emphasizing the innovations that have occurred since they evolved from protistan ancestors.
- Thinking Scientifically questions that pertain to all aspects of evolution have been added and are identified with an icon.

Improved Genetics

The relationship between genetics and cancer is highlighted and a reorganization has resulted in expanded coverage of genomics and bioinformatics as they apply to student lives.

Expanded Ecology

The negative impact of human activities on the environment is balanced by a new section on sustainability that gives examples of ways humans can and do contribute to the sustainability of the planet.

Additional Applications

Many new and/or improved applications and analogies have been added to the text. They will help students relate all aspects of biology to their lives and the world around them.

CONNECT

McGraw-Hill CONNECT Biology is a web-based assignment and assessment platform. Instructors can deliver assignments, quizzes, and tests easily online. Students can practice important skills at their own pace and on their own schedule.

Enhanced Instructor Presentation Tools

All line art figures in *Essentials of Biology,* Second Edition are available to instructors for presentation purposes in an easy-to-use table of assets. Included are enhanced image PowerPoints, (including editable art, tables, and photos), lecture PowerPoints with animations, animation PowerPoints, as well as labeled and unlabeled JPEG images. With the help of a content expert, figures have been split or stepped out as necessary to ensure optimal quality during presentations.

Electronic Books

If you or your students are ready for an alternative version of the traditional textbook, an innovative and inexpensive electronic textbook is available for *Essentials of Biology,* Second Edition. Smart, interactive, searchable, and portable, the electronic book comes with a powerful suite of built-in tools that allow detailed searching, highlighting, note taking, and student-to-student or instructor-to-student note sharing. In addition, relevant animations and videos are integrated into the textbook content for a true multimedia learning experience.

Guided Tour

Increased Evolution Coverage

Provides a firm foundation in the principles of evolution

Chapter 1

introduces you to the principles of evolution and a generalized tree of life.

Part IV Diversity of Life

includes a more comprehensive look at the evolutionary relationships of organisms.

Thinking Scientifically Question

related to evolution is presented at the end of each chapter (and identified with an icon) to help you understand how evolution is pertinent to all aspects of biology.

Thinking Scientifically

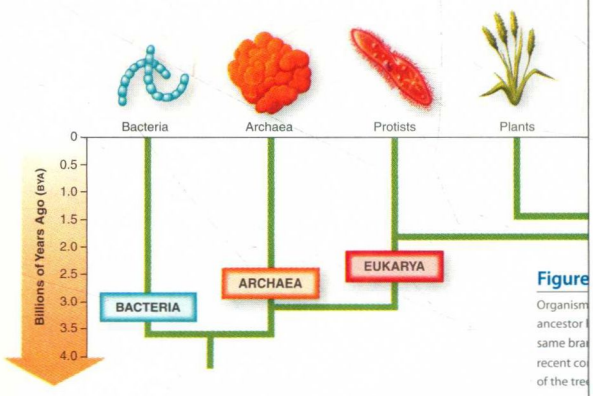
1. Recently, three fossil skulls of *Homo sapiens*, dating to about 160,000 years BP, were discovered in eastern Africa. These skulls fill a gap between the 100,000-year-old *H. sapiens* skulls found in Africa and Israel and 500,000-year-old skulls of archaic *H. sapiens* found in Ethiopia. Supporters of the replacement model (out-of-Africa hypothesis) argue that this discovery strengthens their position by documenting the succession of human ancestors from 6 MYA through this most recent group. Does this finding prove that the replacement model is correct? If not, what fossil evidence might yet be found to support the multiregional continuity hypothesis?
2. Think of the animals in this chapter that are radially symmetrical (cnidarians, many adult echinoderms). How is their lifestyle different from that of bilaterally symmetrical animals? How does their body plan complement their lifestyle?

1.2 | Evolution: The Core Concept of Biology

From bacteria to bats, toadstools to trees, whip-poor-wills to whales—the diversity of the living world boggles the mind. Yet all organisms are united by a common heritage that began during the early years of our planet. Just as you are descended from your parents, grandparents, and so forth from generation to generation back in time, all species can trace their history to the original living thing. **Evolution**, the process by which species have changed and diversified since life arose, explains the unity—all living things share the same characteristics—and the diversity of life. If you have ever studied a family tree, then you know it is a diagram used to show how individuals are related to one another and descended from common ancestors. An evolutionary tree is very much like a family tree, only it depicts relationships between groups of organisms. The evolutionary tree in **Figure 1.4** illustrates the lineages of the major groups of living things. The tree summarizes the history of life on Earth over the approximately 3.5 billion years that have passed since the first, ancestral cell. All the different groups of organisms on our planet are related to one another, and are represented by branches on the same "family tree of life."

The Diversity of Life

Think of an enormous department store, offering thousands of different items for sale. The various items are grouped in departments—electronics, apparel, furniture, and so on—to make them easy for customers to find. Because life is so diverse, it is helpful to have a system that groups organisms into categories (see Appendix B). **Taxonomy** is the discipline of identifying and classifying organisms according to certain rules. Taxonomy makes sense out of the bewildering variety of life on Earth by classifying organisms according to their presumed evolutionary relationship. As more is learned about evolutionary



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17.4 | The Protists

Like ancient creatures from another planet, the **protists** inhabit the oceans and other watery environments of the world. Their morphological diversity is their most outstanding feature—unicellular diatoms are encrusted in silica "petri dishes"; dinoflagellates have plates of armor; and ciliates shaped like slippers have complex structures.

Many protists are unicellular, but all are eukaryotes with a nucleus and a wide range of organelles. It is widely held that the organelles of eukaryotic cells arose from close symbiotic associations between bacteria and primitive eukaryotes (**Fig. 17.19**). This so-called *endosymbiotic hypothesis* is supported by the presence of double membranes around mitochondria and chloroplasts. Also, these organelles have their own genomes, although incomplete, and their ribosomal genes point to bacterial origins. The mitochondria appear closely related to certain bacteria, and the chloroplasts are most closely related to cyanobacteria.

To explain the diversity of protists, we can well imagine that once the eukaryotic cell arose, it provided the opportunity for many different lineages to begin. Some unicellular protists have organelles not seen in other eukaryotes. For example, food is digested in food vacuoles, and excess water is expelled when contractile vacuoles discharge their contents.

Protists also possibly give us insight into the evolution of a multicellular organism with differentiated tissues. Some protists are a colony of single cells, with certain cells specialized to produce eggs and sperm, and others are multicellular, with tissues specialized for various purposes. Perhaps the first type of organization preceded the second in a progression toward multicellular organisms.

General Biology of Protists

The complexity and diversity of protists make it difficult to classify them. The variety of protists is so great that it's been suggested they could be split into more than a dozen kingdoms. Due to limited space, this text groups the protists according to modes of nutrition.

Traditionally, the term **algae** means aquatic photosynthesizer. At one time, botanists classified algae as plants because they contain chlorophyll *a* and carry on photosynthesis. In aquatic environments, algae are a part of the phytoplankton, photosynthesizers that lie suspended in the water. They are producers, which serve as a source of food for other organisms and pour oxygen into the environment. In terrestrial systems, algae are found in soils, on rocks, and in trees. One type of alga is a symbiote of animals called corals, which depend on them for food as they build the coral reefs of the world. Others partner with fungi in lichens capable of living in harsh terrestrial environments.

The definition of a **protozoan** as a unicellular chemoheterotroph explains why protozoans were originally classified with the animals. Often a protozoan has some form of locomotion, either by flagella, pseudopods, or cilia. In aquatic environments, protozoans are a part of the zooplankton, suspended microscopic heterotrophs that serve as a food source for animals. While most are free-living, some protozoans are human pathogens, often causing diseases of the blood or intestines. In many cases, their complex life cycles inhibit the development of suitable treatments.

There is still one other group of protists: the slime molds and water molds. These microrganisms are chemoheterotrophs, but the slime molds

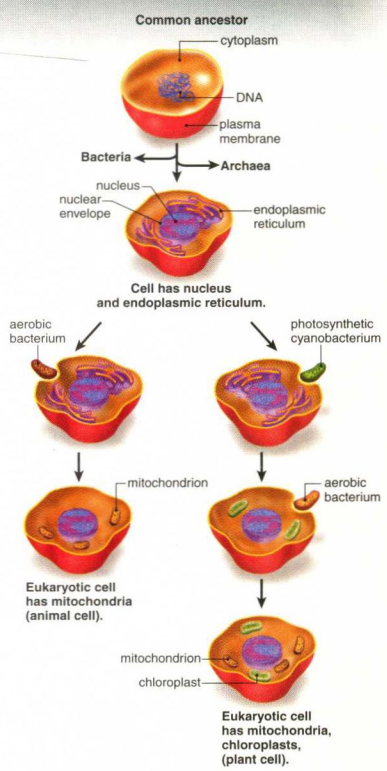


Figure 17.19 Evolution of the eukaryotic cell.

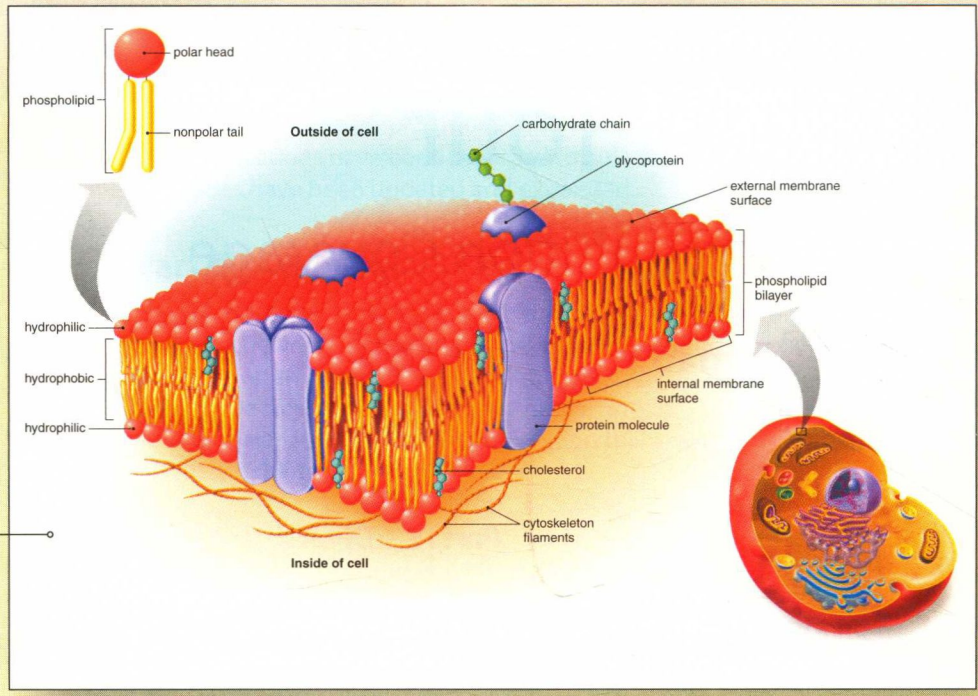
Invagination of the plasma membrane could account for the formation of the nucleus and certain other organelles. The endosymbiotic hypothesis suggests that mitochondria and chloroplasts are derived from prokaryotes that were taken up by a much larger eukaryotic cell.

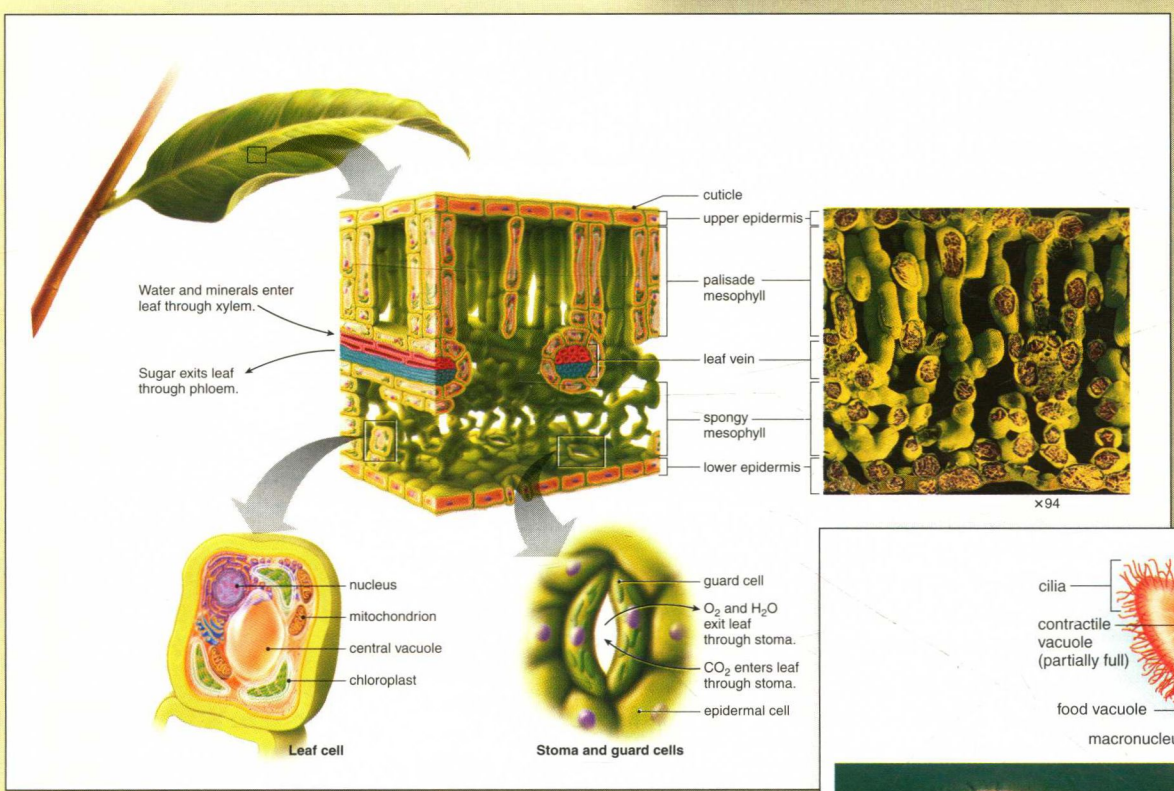
The Visuals

A brilliant visuals program brings biology to life!

Multi-Level Perspective

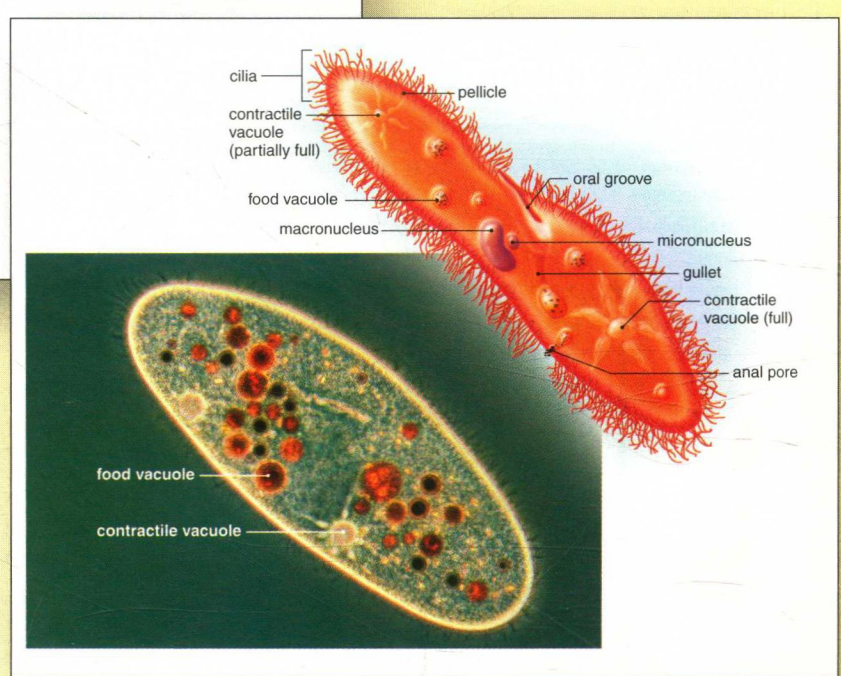
Illustrations depicting complex structures show macroscopic and microscopic views to help you see the relationships between increasingly detailed drawings.





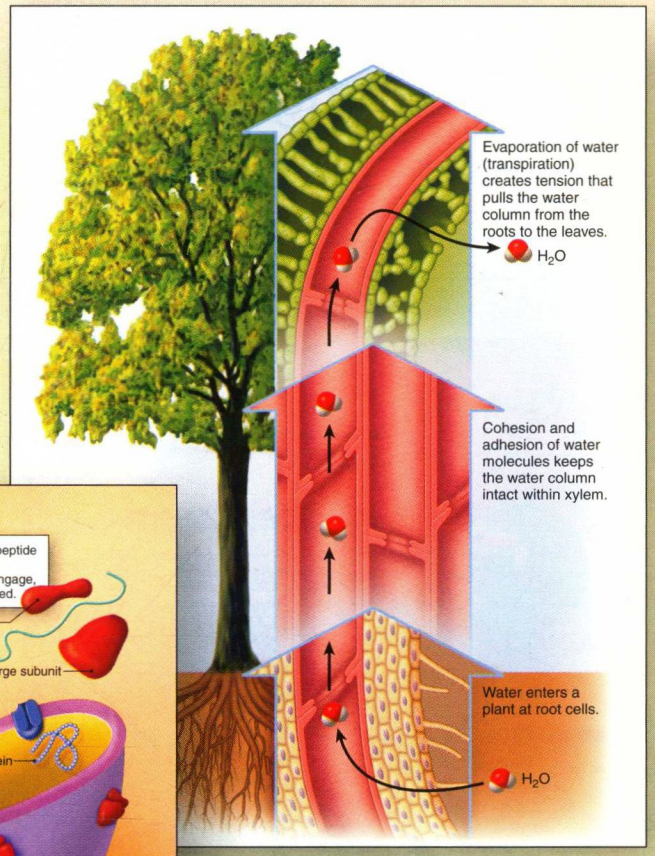
Combination Art

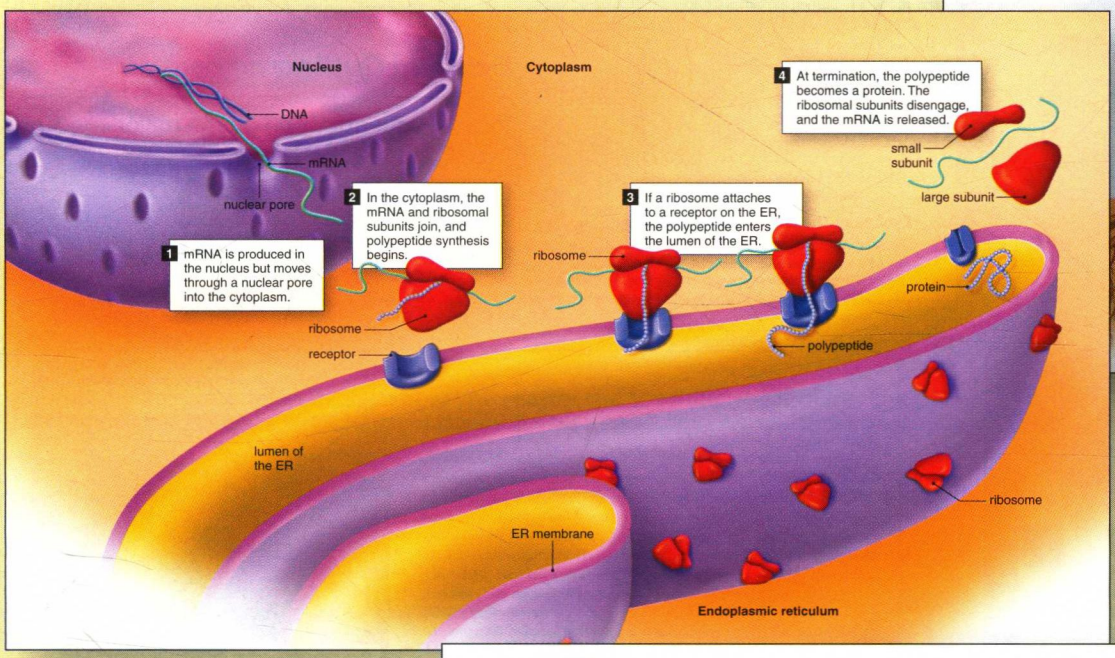
Drawings of structures are paired with micrographs to give you the best of both perspectives: the realism of photos and the explanatory clarity of line drawings.

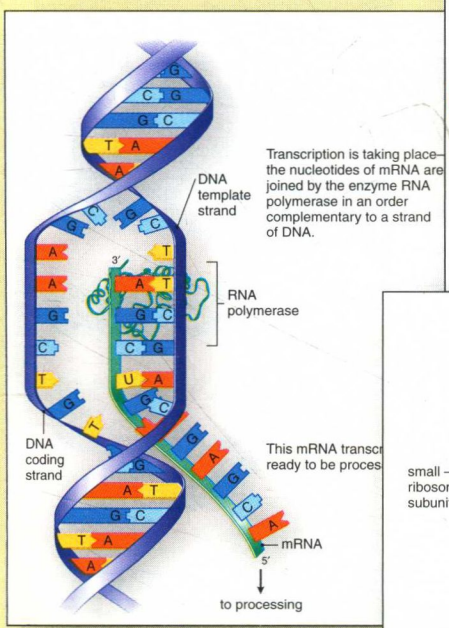


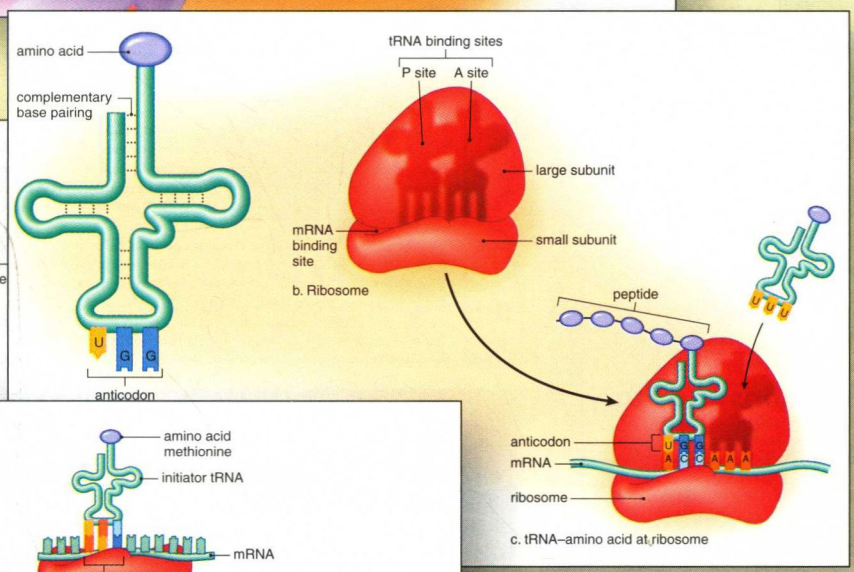
Process Figures

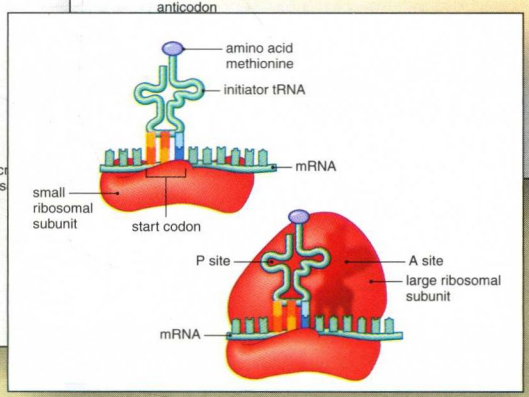
Complex processes are broken down into a series of smaller steps that are easy-to-follow. Numbers guide you through the process.









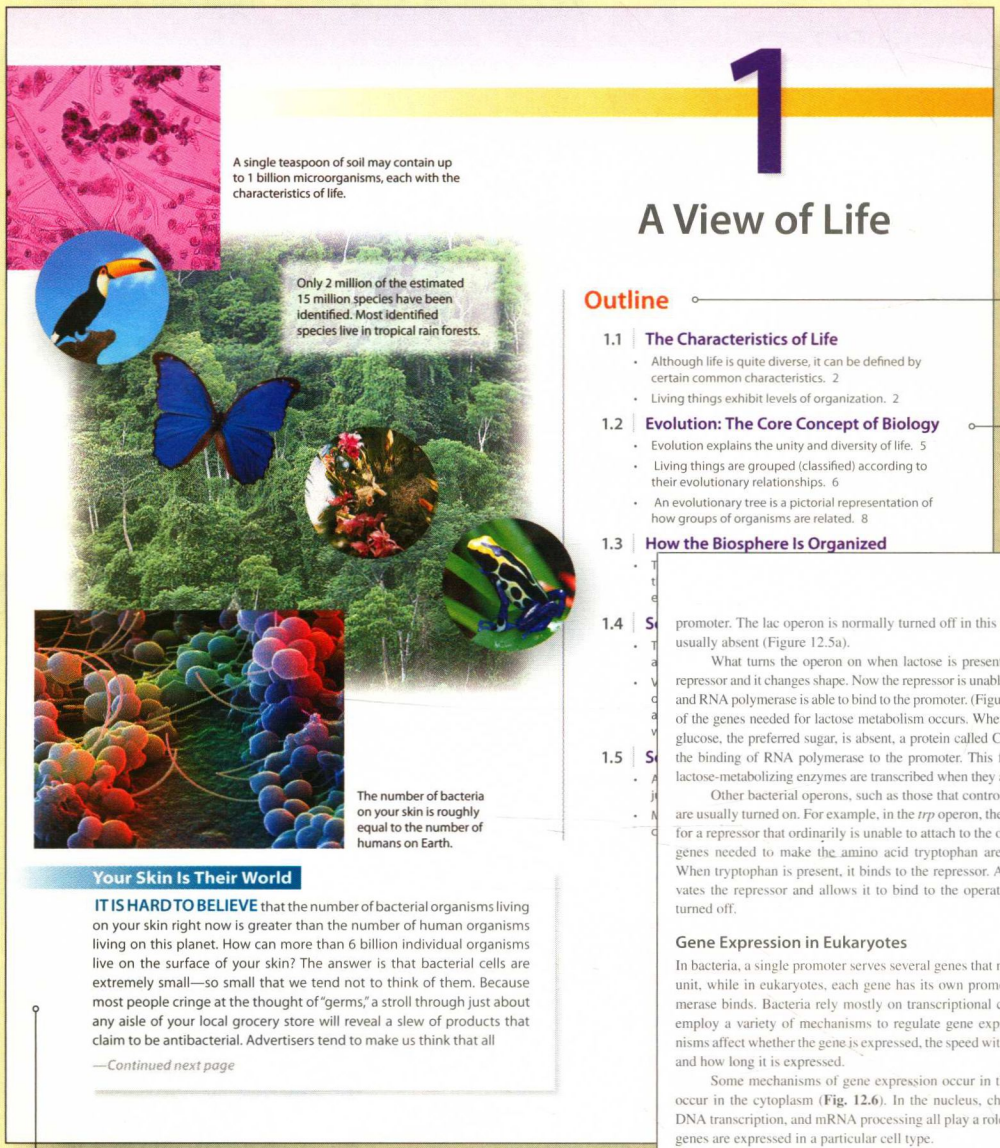


Color Consistency

Consistent use of color organizes information and clarifies concepts.

The Learning System

Pedagogical features facilitate your understanding of biology



1

A View of Life

A single teaspoon of soil may contain up to 1 billion microorganisms, each with the characteristics of life.

Only 2 million of the estimated 15 million species have been identified. Most identified species live in tropical rain forests.

The number of bacteria on your skin is roughly equal to the number of humans on Earth.

Outline

1.1 The Characteristics of Life
- Although life is quite diverse, it can be defined by certain common characteristics. 2
- Living things exhibit levels of organization. 2

1.2 Evolution: The Core Concept of Biology
- Evolution explains the unity and diversity of life. 5
- Living things are grouped (classified) according to their evolutionary relationships. 6
- An evolutionary tree is a pictorial representation of how groups of organisms are related. 8

1.3 How the Biosphere Is Organized

1.4 S

1.5 S

Your Skin Is Their World

IT IS HARD TO BELIEVE that the number of bacterial organisms living on your skin right now is greater than the number of human organisms living on this planet. How can more than 6 billion individual organisms live on the surface of your skin? The answer is that bacterial cells are extremely small—so small that we tend not to think of them. Because most people cringe at the thought of "germs," a stroll through just about any aisle of your local grocery store will reveal a slew of products that claim to be antibacterial. Advertisers tend to make us think that all

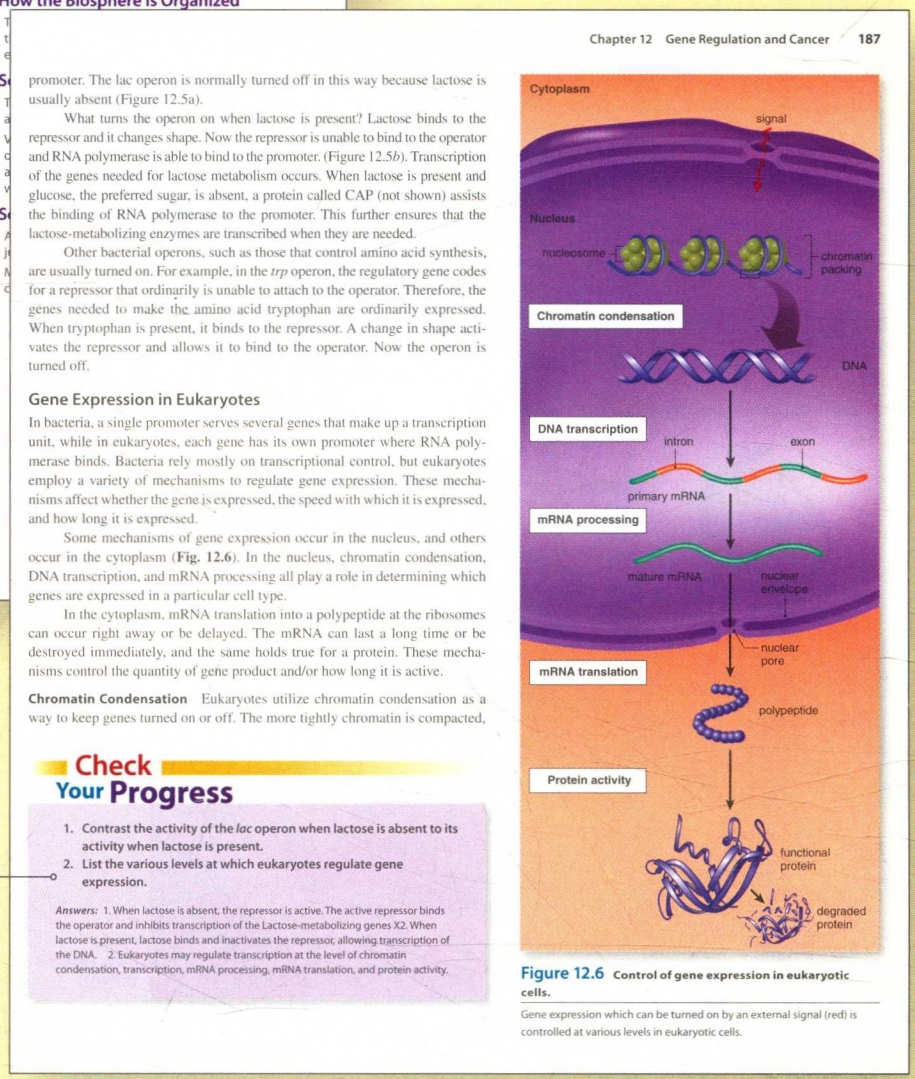
—Continued next page

Detailed Outline

focuses your attention on the major concepts.

Numbered Sections

help you organize the content.



promoter. The lac operon is normally turned off in this way because lactose is usually absent (Figure 12.5a).

What turns the operon on when lactose is present? Lactose binds to the repressor and it changes shape. Now the repressor is unable to bind to the operator and RNA polymerase is able to bind to the promoter. (Figure 12.5*b*). Transcription of the genes needed for lactose metabolism occurs. When lactose is present and glucose, the preferred sugar, is absent, a protein called CAP (not shown) assists the binding of RNA polymerase to the promoter. This further ensures that the lactose-metabolizing enzymes are transcribed when they are needed.

Other bacterial operons, such as those that control amino acid synthesis, are usually turned on. For example, in the *trp* operon, the regulatory gene codes for a repressor that ordinarily is unable to attach to the operator. Therefore, the genes needed to make the amino acid tryptophan are ordinarily expressed. When tryptophan is present, it binds to the repressor. A change in shape activates the repressor and allows it to bind to the operator. Now the operon is turned off.

Gene Expression in Eukaryotes

In bacteria, a single promoter serves several genes that make up a transcription unit, while in eukaryotes, each gene has its own promoter where RNA polymerase binds. Bacteria rely mostly on transcriptional control, but eukaryotes employ a variety of mechanisms to regulate gene expression. These mechanisms affect whether the gene is expressed, the speed with which it is expressed, and how long it is expressed.

Some mechanisms of gene expression occur in the nucleus, and others occur in the cytoplasm (**Fig. 12.6**). In the nucleus, chromatin condensation, DNA transcription, and mRNA processing all play a role in determining which genes are expressed in a particular cell type.

In the cytoplasm, mRNA translation into a polypeptide at the ribosomes can occur right away or be delayed. The mRNA can last a long time or be destroyed immediately, and the same holds true for a protein. These mechanisms control the quantity of gene product and/or how long it is active.

Chromatin Condensation Eukaryotes utilize chromatin condensation as a way to keep genes turned on or off. The more tightly chromatin is compacted,

Check Your Progress

1. Contrast the activity of the *lac* operon when lactose is absent to its activity when lactose is present.
2. List the various levels at which eukaryotes regulate gene expression.

Answers: 1. When lactose is absent, the repressor is active. The active repressor binds the operator and inhibits transcription of the Lactose-metabolizing genes X2. When lactose is present, lactose binds and inactivates the repressor, allowing transcription of the DNA. 2. Eukaryotes may regulate transcription at the level of chromatin condensation, transcription, mRNA processing, mRNA translation, and protein activity.

Figure 12.6 Control of gene expression in eukaryotic cells.

Gene expression which can be turned on by an external signal (red) is controlled at various levels in eukaryotic cells.

Captivating Illustrations and Story

show how the concepts relate to your life.

Check Your Progress

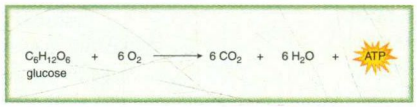
as you read the chapter. Maximize your study time by identifying concepts that you don't understand before you move on.

The Chapter in Review

Summary

7.1 | Cellular Respiration

During cellular respiration, glucose from food is oxidized to CO_2, which we exhale. Oxygen (O_2), which we breathe in, is reduced to H_2O. When glucose is oxidized, energy is released. Cellular respiration captures the energy of oxidation and uses it to produce ATP molecules. The following equation gives an overview of these events:



7.2 | Outside the Mitochondria: Glycolysis

Glycolysis, the breakdown of glucose to 2 molecules of pyruvate, is a series of enzymatic reactions that occur in the cytoplasm. During glycolysis:

- Glucose is oxidized by removal of hydrogen atoms ($H^+ + e^-$).
- When NAD^+ accepts electrons, NADH results.

Breakdown releases enough energy to immediately give a net gain of 2 ATP by substrate-level ATP synthesis. The inputs and outputs of glycolysis are summarized here:

Glycolysis	
inputs	outputs
glucose	2 pyruvate
2 NAD^+	2 NADH
2 ATP	2 ADP
4 ADP + 4 P	4 ATP
	2 ATP net

The Citric Acid Cycle

Acetyl groups enter the citric acid cycle, a series of reactions occurring in the mitochondrial matrix. During one turn of the cycle, oxidation results in 2 CO_2, 3 NADH, and 1 $FADH_2$. One turn also produces 1 ATP. The cycle turns twice and doubles these amounts per glucose.

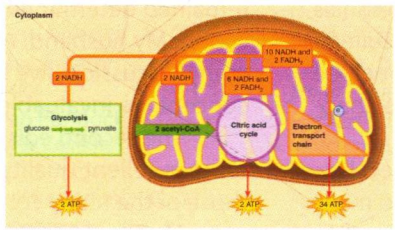
The Electron Transport Chain

The final stage of cellular respiration involves the electron transport chain located in the cristae of the mitochondria. The chain is a series of electron carriers that accept high-energy electrons (e^-) from NADH and $FADH_2$ and pass electrons along until they are finally low-energy electrons received by oxygen, which combines with H^+ to produce water.

The carriers of the electron transport chain are located in molecular complexes on the cristae of mitochondria. These carriers capture energy from the passage of electrons and use it to pump H^+ into the intermembrane space of the mitochondrion. When H^+ flows down its gradient into the matrix through ATP synthase complexes, energy is released and used to form ATP molecules from ADP and P.

Energy Yield from Glucose Metabolism

Of the maximum 38 ATP formed by complete glucose breakdown, 4 are the result of substrate-level ATP synthesis, and the rest are produced as a result of the electron transport chain and ATP synthase:



Alternative Metabolic Pathways

Besides carbohydrates, glycerol and fatty acids from fats, and amino acids from proteins can undergo cellular respiration by entering glycolysis and/or the citric acid cycle. These metabolic pathways also provide substrates for the synthesis of fats and proteins.

The Chapter in Review

provides an excellent overview of the chapter concepts using concise, bulleted summaries and key illustrations.

Thinking Scientifically

questions give you an opportunity to reason as a scientist. An icon identifies questions that are related to evolution. (See Appendix A for answers.)

Key Terms

are page-referenced to help you master the scientific vocabulary.

Key Terms

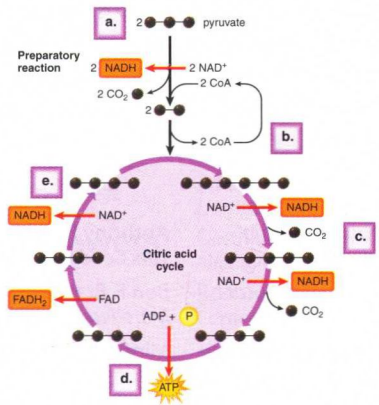
acetyl-CoA 104
citric acid cycle 101
coenzyme 101
coenzyme A (CoA) 101
electron transport chain 101
fermentation 109
glycolysis 101
intermembrane space 107
oxygen deficit 109
preparatory (prep) reaction 101

Testing Yourself

Choose the best answer for each question.

1. During cellular respiration, _____ is oxidized and _____ is reduced.
   a. glucose, oxygen
   b. glucose, water
   c. oxygen, water
   d. water, oxygen
   e. oxygen, carbon dioxide
2. Cellular respiration requires _____ and _____ are produced.
   a. water and carbon dioxide; oxygen and glucose
   b. oxygen and carbon dioxide; glucose and water
   c. oxygen and glucose; carbon dioxide and water
   d. water and glucose; oxygen and carbon dioxide
   e. ATP and glucose; oxygen and water
3. During the energy-harvesting steps of glycolysis, which are produced?
   a. ATP and NADH
   b. ADP and NADH
   c. ATP and NAD^+
   d. ADP and NAD^+

Oxidation results in NADH and CO_2.
ATP is produced by substrate-level ATP synthesis.
Oxidation produces more NADH and $FADH_2$.



11. The strongest and final electron acceptor in the electron trans chain is

Testing Yourself

questions help you review material and prepare for tests. (See Appendix A for answers.)

Thinking Scientifically

1. The compound malonate, a substrate of the citric acid cycle, can be poisonous at high concentrations because it can block cellular respiration. How might a substrate of the citric acid cycle block respiration when it is present in great excess?
2. Insulin resistance can lead to diabetes. Insulin normally causes cells to take in glucose from the blood, but insulin resistance causes cells to not respond properly to this signal. The pancreas then compensates by secreting even more insulin into the body. Researchers have found a connection between a high-fat diet, decreased mitochondrial function, and insulin resistance in some elderly patients. What might be the connection between these three events?
3. You observe that prokaryotic cells sometimes have invaginations of the plasma membrane where metabolic pathways take place. How could this observation be used to support your hypothesis that mitochondria evolved when a prokaryote cell was engulfed by a nucleated cell?

Bioethical Issue

Regulating Dietary Supplements

Americans spend millions of dollars every year on products and diets that claim to boost metabolic rates and assist in weight loss. These and other supplements are available in supermarkets, by mail order, and through the Internet. Drug makers are required to prove that a drug is safe and effective before it can be sold to the public. But the Food and Drug Administration (FDA) cannot legally supervise the supplement industry because their products are not defined as drugs. Thus, regulators must prove that a supplement is dangerous before it can be removed from the market. Although some of the more dangerous supplements, such as ephedra, have been banned, many questionable and dangerous products remain freely available to anyone who wants them. Since the FDA does not have the time or resources to perform the necessary research, most dietary supplements receive scant supervision.

Many scientists and other concerned individuals contend that FDA regulation of the supplement industry is needed to protect public safety. They argue that FDA regulation would protect the public from potentially dangerous products and ensure the efficacy of dietary supplements and diet products. However, some are concerned that regulation of the supplement industry would undermine the public interest by reducing choices in the marketplace. Furthermore, they argue that FDA regulation of supplements would create the need for additional taxes and divert resources that would be better spent regulating prescription and over-the-counter drugs.

Do you believe that the government should increase scrutiny of dietary and weight-loss supplements? Or do you believe that FDA regulation of these products would be a waste of time and money?

Bioethical Issue

readings discuss a variety of controversial topics that confront our society so you can begin to understand those issues in the context of biology.

Essentials of Biology Website

The companion website for *Essentials of Biology* provides a wealth of information organized and integrated by chapter. You will find practice tests, animations, videos, and much more that will complement your learning and understanding of general biology.

http://www.mhhe.com/maderessentials2

Essentials of Biology Website

provides practice tests, animations, and videos organized and integrated by chapter to help you succeed in your study of biology.

Acknowledgments

While I guided the development of both editions of *Essentials of Biology,* many instructors have lent their talents to ensuring its increasing success. This edition, I want to particularly thank Andrew Baldwin of Mesa Community College, Rebecca Roush of Sandhills Community College, Stephanie Songer of North Georgia College and State University, and Michael Thompson of Middle Tennessee State University. My involvement ensured that each of these chapters was written and illustrated in the familiar Mader style.

Many dedicated and talented individuals assisted in the development of *Essentials of Biology.* I am very grateful for the help of so many professionals at McGraw-Hill who were involved in bringing this book to fruition. In particular, let me thank Rose Koos, the developmental editor who lent her talents and advice to all those who worked on this text. The biology publisher and editor are Janice Roerig-Blong and Michael Hackett, who steadfastly encouraged and supported this project. The project manager, Jayne Klein, faithfully and carefully steered the book through the publication process. Tamara Maury, the marketing manager, tirelessly promoted the text and educated the sales reps on its message.

The design of the book is the result of the creative talents of Laurie Janssen and many others who assisted in deciding the appearance of each element in the text. Electronic Publishing Services followed their guidelines as they created and reworked each illustration, emphasizing pedagogy and beauty to arrive at the best presentation on the page. Lori Hancock and Evelyn Jo Johnson did a superb job of finding just the right photographs and micrographs.

My office assistant, Beth Butler, worked faithfully as she helped proof the chapters and made sure all was well before the book went to press. As always, my family was extremely patient with me as I remained determined to meet every deadline on the road to publication. My husband, Arthur Cohen, is also a teacher of biology. The many discussions we have about the minutest detail to the gravest concept are invaluable to me.

The second edition of *Essentials of Biology* would not have the same excellent quality without the input of these contributors and those of the many contributors and reviewers listed below.

McGraw-Hill's 360° Development Process is an ongoing, never-ending, market-oriented approach to building accurate and innovative print and digital products. It is dedicated to continual large-scale and incremental improvement driven by multiple customer feedback loops and checkpoints. This is initiated during the early planning stages of our new products, and intensifies during the development and production stages, then begins again upon publication in anticipation of the next edition.

This process is designed to provide a broad, comprehensive spectrum of feedback for refinement and innovation of our learning tools, for both student and instructor. The 360° Development Process includes market research, content reviews, course- and product-specific symposia, accuracy checks, and art reviews. We appreciate the expertise of the many individuals involved in this process.

Ancillary Authors

Instructor's Manual

Farshad Tamari, *Kean University*

Practice Tests

Josh Dobkins and Denise Slayback-Barry, *Keiser University*

Media Asset Correlations

Jennifer Burtwistle, *Northeast Community College*

Test Bank

Andrew Baldwin, *Mesa Community College*

Laurie Faber-Foster, *Grand Rapids Community College*

Sarah Krajewski, *Grand Rapids Community College*

Rebecca Roush, *Sandhills Community College*

Cara Schillington, *Eastern Michigan University*

Stephanie Songer, *North Georgia College and State University*

Michael Thompson, *Tennessee State University*

Lecture Outlines/Image PowerPoints

Brenda Leady, *University of Toledo*

BioInteractive Questions

Jennifer Herzog, Herkimer County Community College

Second Edition Reviewers

Eugene L. Bass
University of Maryland Eastern Shore

Bill Radley Bassman
Stern College

Loren A. Bertocci
Salem International University

Barbara Boss
Keiser University

Patty Bostwick Taylor
Florence Darlington Technical College

Anthony Botyrius
York College of Pennsylvania

Ben F. Brammell
Morehead State University

Mimi Bres
Prince George's Community College

Carol Britson
University of Mississippi

Nikolle L. Brown
State Center Community College District, Madera Center

Matthew Burnham
Jones County Junior College

Claire M. Carpenter
Yakima Valley Community College

Steven Christenson
Brigham Young University Idaho

Julie Clements
Keiser University

Anthony Cooper
Albany State University

Laurie-Ann Crawford
Hawkeye Community College

Peter A. Daempfle
SUNY College of Technology at Delhi

Debbie Dalrymple
Thomas Nelson Community College

Chris Davison
Long Beach City College

Jean DeSaix
University of North Carolina at Chapel Hill

Josh Dobkins
Keiser University

Li'anne Drysdale
Ozarks Technical Community College, Richwood Valley Facility

Pamela Faber, D.A.
Heidelberg College

Farshad Tamari
Kean University

Jeffry Fasick
Kean University

Lynn Firestone
Brigham Young University, Idaho

Diane Fritz
Northern Kentucky University

Wendy Garrison
University of Mississippi

Norma Golovoy
Schoolcraft College

David M. Gordman
Pittsburg State

Tamar Goulet
University of Mississippi

Colleen Hatfield
California State University, Chico

Jennifer A. Herzog
Herkimer County Community College

Elizabeth Hodgson
York College of Pennsylvania

Mary Ruth Hood
Tomball College

George A. Jacob
Xavier University

Ashok Jain
Albany State University

Scott Johnson
Wake Technical Community College

Gregory A. Jones
Santa Fe Community College

Mary King Kananen
Penn State Altoona

Brenda Kelley
Alpena Community College

David Knowles
East Carolina University

Eliot Krause
Seton Hall University

Ruhul H. Kuddus
Utah Valley University

Brenda Leady
University of Toledo

Debabrata Majumdar
Norfolk State University

Lisa Maranto
Prince George's Community College

Rob McCandless
Methodist University

Michael McCarthy
Eastern Arizona College

Quintece M. McCrary
University of Maryland–Eastern Shore

John Mishler
Delaware Valley College

Sarah E. Myer
Oral Roberts University

Joanna Padolina
Virginia Commonwealth University

Kathleen Pelkki
Saginaw Valley State University

Mary Perry
Keiser University

Patrick K. Pfaffle
Carthage College

Megan Pickering Stringer
Jones County Junior College

Rongsun Pu
Kean University

Denice Robertson
Northern Kentucky University

Carolina Ross
Laramie County Community College

Barbara J. Salvo
Carthage College

Susan Sawyer
Kellogg Community College

John Richard Schrock
Emporia State University

James M. Schwartz
Front Range Community College

Marilyn Shopper
Johnson County Community College

William Simcik
Tomball College, NHMCCD

Robert Singer
New Jersey City University

Denise Slayback-Barry
Keiser University

Kathryn Sloan Ponnock
Delaware Valley College

Bo Sosnicki
Piedmont Virginia Community College

Chebium Subrahmanyam
Florida A & M University

Marshall D. Sundberg
Emporia State University

Karen S. Teitelbaum
State University of NY College of Technology at Delhi

Kip R. Thompson
Ozarks Technical Community College

Kevin R. Toal
St. Louis Community College at Florissant Valley

Kate Warpeha
University of Illinois at Chicago

Stan Willenbring
Dabney S Lancaster Community College

Heather Wilson-Ashworth
Utah Valley University

W. Brooke Yeager III
Luzerne County Community College

First Edition Reviewers

Sylvester Allred
Northern Arizona University

Paul E. Arriola
Elmhurst College

Tammy Atchison
Pitt Community College

James S. Backer
Daytona Beach Community College

Gail F. Baker
LaGuardia Community College

Sirakaya Beatrice
Pennsylvania State University

Carla Bundrick Benejam
California State University–Monterey Bay

Charles L. Biles
East Central University

Donna H. Bivans
Pitt Community College

Steven G. Brumbaugh
Greenriver Community College

Neil Buckley
SUNY–Plattsburgh

Nancy Butler
Kutztown University

Michelle Cawthorn
Georgia Southern University

Van D. Christman
Brigham Young University

Genevieve C. Chung
Broward Community College

Kimberly Cline-Brown
University of Northern Iowa

Mary C. Colavito
Santa Monica College

Mark A. Coykendall
College of Lake County

Don C. Dailey
Austin Peay State University

Cathy A. Davison
Empire State College

Bonnie L. Dean
West Virginia State University

William R. DeMott
Indiana-Purdue University–Fort Wayne

Amy Stinnett Dewald
Eureka College

Lee C. Drickamer
Northern Arizona University

Marie D. Dugan
Broward Community College

James W. DuMond, Jr.
Texas State University

Kathryn A. Durham
Lorain County Community College

Andrew R. Dyer
University of South Carolina–Aiken

Steven E. Fields
Winthrop University

Lynn Firestone
Brigham Young University–Idaho

Susan Fisher
Ohio State University

Edison R. Fowlks
Hampton University

Dennis W. Fulbright
Michigan State University

Ron Gaines
Cameron University

John R. Geiser
Western Michigan University

Beatriz Gonzalez
Santa Fe Community College

Andrew Goyke
Northland College

Richard Gringer
Augusta State University

Lonnie J. Guralnick
Western Oregon University

William F. Hanna
Massasoit Community College

Lisa K. Johansen
University of Colorado at Denver

Ragupathy Kannan
University of Arkansas–Fort Smith

Arnold Karpoff
University of Louisville

Darla E. Kelly
Orange Coast College

Elaine B. Kent
California State University–Sacramento

Scott L. Kight
Montclair State University

Kristin Lenertz
Black Hawk College

Melanie Loo
California State University–Sacramento

Michelle Malott
Minnesota State University–Moorhead

Paul Mangum
Midland College

Mara Manis
Hillsborough Community College

Karen Benn Marshall
Montgomery College–Takoma Park

Cynthia Conaway Mauroidis
Northwest State Community College

Elizabeth McPartlan
De Anza College

Dwight Meyer
Queensborough Community College

Rod Nelson
University of Arkansas–Fort Smith

Donald J. Padgett
Bridgewater State College

Tricia L. Paramore
Hutchinson Community College

Brian K. Paulson
California University of Pennsylvania

Debra K. Pearce
Northern Kentucky University

Lisa Rapp
Springfield Technical Community College

Jill Raymond
Rock Valley Community College

Cara Shillington
Eastern Michigan University

Lee Sola
Glendale Community College

John D. Sollinger
Southern Oregon University

Andrew Storfer
Washington State University

Janis G. Thompson
Lorain County Community College

Briana Timmerman
University of South Carolina

James R. Triplett
Pittsburg State University

Paul Twigg
University of Nebraska–Kearney

Garland Rudolph Upchurch, Jr.
Texas State University, San Marcos

James A. Wallis II
St. Petersburg College, Tarpon Springs Campus

Cosima B. Wiese
College Misericordia

Melissa Zwick
Longwood University

General Biology Symposia

Every year McGraw-Hill conducts several General Biology Symposia, which are attended by instructors from across the country. These events are an opportunity for editors from McGraw-Hill to gather information about the needs and challenges of instructors teaching non-majors level biology courses. They also offer a forum for the attendees to exchange ideas and experiences with colleagues they might not have otherwise met. The feedback we have received has been invaluable, and has contributed to the development of *Essentials of Biology,* Second Edition and its ancillaries.

Norris Armstrong
University of Georgia

David Bachoon
Georgia College and State University

Sarah Bales
Moraine Valley Community College

Lisa Bellows
North Central Texas College

Joressia Beyer
John Tyler Community College

James Bidlack
University of Central Oklahoma

Mark Bloom
Texas Christian University

Paul Bologna
Montclair University

Linda Brandt
Henry Ford Community College

Marguerite Brickman
University of Georgia

Bradford Boyer
Suffolk County Community College

Art Buikema
Virginia Polytechnic Institute

Sharon Bullock
Virginia Commonwealth University

Raymond Burton
Germanna Community College

Nancy Butler
Kutztown University of Pennsylvania

Jane Caldwell
West Virginia University

Carol Carr
John Tyler Community College

Kelly Cartwright
College of Lake County

Rex Cates
Brigham Young University

Sandra Caudle
Calhoun Community College

Genevieve Chung
Broward Community College

Jan Coles
Kansas State University

Marian Wilson Comer
Chicago State University

Renee Dawson
University of Utah

Lewis Deaton
University of Louisiana at Lafayette

Jody DeCamilo
St. Louis Community College

Jean DeSaix
University of North Carolina at Chapel Hill

JodyLee Estrada-Duek
Pima Community College, Desert Vista

Laurie Faber-Foster
Grand Rapids Community College

Susan Finazzo
Broward Community College

Theresa Fischer
Indian River Community College

Theresa Fulcher
Pellissippi State Technical College

Dennis Fulbright
Michigan State University

Steven Gabrey
Northwestern State University

Cheryl Garett
Henry Ford Community College

Farooka Gauhari
University of Nebraska–Omaha

John Geiser
Western Michigan University

Cindy Ghent
Towson University

Julie Gibbs
College of DuPage

William Glider
University of Nebraska, Lincoln

Christopher Gregg
Louisiana State University

Carla Guthridge
Cameron University

Bob Harms
St. Louis Community College, Meramec

Wendy Hartman
Palm Beach Community College

Tina Hartney
California State Polytechnic University

Kelly Hogan
University of North Carolina, Chapel Hill

Eva Horne
Kansas State University

David Huffman
Texas State University, San Marcos

Shelley Jansky
University of Wisconsin, Stevens Point

Sandra Johnson
Middle Tennessee State University

Tina Jones
Shelton State Community College

Arnold Karpoff
University of Louisville

Jeff Kaufmann
Irvine Valley College

Kyoungtae Kim
Missouri State University

Michael Koban
Morgan State University

Todd Kostman
University of Wisconsin Oshkosh

Steven Kudravi
Georgia State University

Nicki Locascio
Marshall University

Dave Loring
Johnson County Community College

Janice Lynn
Alabama State University

Phil Mathis
Middle Tennessee State University

Mary Victoria McDonald
University of Central Arkansas

Susan Meiers
Western Illinois University

Daryl Miller
Broward Community College, South Campus

Marjorie Miller
Greenville Technical College

Meredith Norris
University of North Carolina at Charlotte

Mured Odeh
South Texas College

Nathan Olia
Auburn University, Montgomery

Rodney Olsen
Fresno City College

Alexander Olvido
Virginia State University

Clark Ovrebo
University of Central Oklahoma

Forrest Payne
University of Arkansas at Little Rock

Nancy Pencoe
University of West Georgia

Murray P. "Pat" Pendarvis
Southeastern Louisiana University

Jennie Plunkett
San Jacinto College

Scott Porteous
Fresno City College

David Pylant
Wallace State Community College

Fiona Qualls
Jones County Junior College

Eric Rabitoy
Citrus College

Karen Raines
Colorado State University

Kirsten Raines
San Jacinto College

Jill Reid
Virginia Commonwealth University

Darryl Ritter
Okaloosa-Walton College

Chris Robinson
Bronx Community College

Robin Robison
Northwest Mississippi Community College

Vickie Roettger
Missouri Southern State University

Bill Rogers
Ball State University

Vicki Rosen
Utah State University

Kim Sadler
Middle Tennessee State University

Cara Shillington
Eastern Michigan University

Greg Sievert
Emporia State University

Jimmie Sorrels
Itawamba Community College

Judy Stewart
Community College of Southern Nevada

Julie Sutherland
College of DuPage

Bill Trayler
California State University–Fresno

Linda Tyson
Santa Fe Community College

Eileen Underwood
Bowling Green State University

Heather Vance-Chalcraft
East Carolina University

Marty Vaughan
IUPUI, Indianapolis

Paul Verrell
Washington State University

Thomas Vogel
Western Illinois University

Brian Wainscott
Community College of Southern Nevada

Jennifer Warner
University of North Carolina, Charlotte

Scott Wells
Missouri Southern State University

Lan Xu
South Dakota State University

Robin Whitekiller
University of Central Arkansas

Allison Wiedemeier
University of Illinois, Columbia

Michael Windelspecht
Appalachian State University

Mary Wisgirda
San Jacinto College, South Campus

Tom Worcester
Mount Hood Community College

Frank Zhang
Kean University

Michelle Zjhra
Georgia Southern University

Victoria Zusman
Miami Dade College

Supplements

Dedicated to providing high-quality and effective supplements for instructors and students, the following supplements were developed for *Essentials of Biology,* Second Edition.

For Instructors

Laboratory Manual

The ***Essentials of Biology Laboratory Manual*** is written by Dr. Sylvia Mader. With few exceptions, each chapter in the text has an accompanying laboratory exercise in the manual. 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, and to gain a better understanding of the scientific method.

Connect

McGraw-Hill Connect Biology is a web-based assignment and assessment platform that gives students the means to better connect with their coursework, with their instructors, and with the important concepts that they will need to know for success now and in the future. With Connect Biology, instructors can deliver assignments, quizzes and tests easily online. Students can practice important skills at their own pace and on their own schedule. With Connect Biology Plus, students also get 24/7 online access to an eBook—an online edition of the text—to aid them in successfully completing their work, wherever and whenever they choose.

Companion Website

www.mhhe.com/maderessentials2

The companion website contains the following resources for instructors:

- ***Presentation Tools*** Everything you need for outstanding presentations in one place! This easy-to-use table of assets includes
  - *Enhanced Image PowerPoints*—including every piece of art that has been sized and cropped specifically for superior presentations as well as labels that you can edit. Also included are tables, photographs, and unlabeled art pieces.
  - *Animation PowerPoints*—Numerous full-color animations illustrating important processes are also provided. Harness the visual impact of concepts in motion by importing these files into classroom presentations or online course materials.
  - *Lecture PowerPoints*—with animations fully embedded
  - *Labeled and Unlabeled JPEG Images*—Full-color digital files of all illustrations that can be readily incorporated into presentations, exams, or custom-made classroom materials.
- ***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 that can be used to create customized lectures, visually enhanced tests and quizzes, compelling course websites, or attractive printed support materials. All assets are copyrighted by McGraw-Hill Higher Education, but can be used by instructors for classroom purposes.
- ***Instructor's Manual*** The instructor's manual contains chapter outlines, lecture enrichment ideas, and critical thinking questions.
- ***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. EZ Test Online allows you to create paper and online tests or quizzes in this easy to use program! A new tagging scheme allows you to sort questions by difficulty level, topic, and section. Imagine being able to create and access your test or quiz anywhere, at any time, without installing the testing software. Now, 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.

Test Creation

- Author/edit questions online using the 14 different question type templates
- Create question pools to offer multiple versions online— great for practice
- Export your tests for use in WebCT, Blackboard, PageOut, and Apple's iQuiz
- Sharing tests with colleagues, adjuncts, TAs is easy

Online Test Management

- Set availability dates and time limits for your quiz or test
- Assign points by question or question type with dropdown menu
- Provide immediate feedback to students or delay feedback until all finish the test
- Create practice tests online to enable student mastery
- Your roster can be uploaded to enable student self-registration

Online Scoring and Reporting

- Automated scoring for most of EZ Test's numerous question types
- Allows manual scoring for essay and other open-response questions
- Manual rescoring and feedback are also available
- EZ Test's grade book is designed to easily export to your grade book
- View basic statistical reports

Support and Help

- Flash tutorials for getting started on the support site
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McGraw-Hill: Biology Digitized Video Clips

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McGraw-Hill is pleased to offer an outstanding presentation tool to text adopting instructors—digitized biology video clips on DVD! Licensed from some of the highest-quality science video producers in the world, these brief segments range from about five seconds to just under three minutes in length and cover all areas of general biology from cells to ecosystems. Engaging and informative, McGraw-Hill's digitized videos will help capture students' interest while illustrating key biological concepts and processes such as mitosis, how cilia and flagella work, and how some plants have evolved into carnivores.

Student Response System

Wireless technology brings interactivity into the classroom or lecture hall. Instructors and students receive immediate feedback through wireless response pads that are easy to use and engage students. This system can be used by instructors to take attendance, administer quizzes and tests, create a lecture with intermittent questions, manage lectures and student comprehension through the use of the grade book, and integrate interactivity into their PowerPoint presentations.

For Students

Companion Website

www.mhhe.com/maderessentials2

The Mader: *Essentials of Biology* companion website is an electronic study system that offers students a digital portal of knowledge. Students can readily access a variety of digital learning objects that include:

- Chapter-level quizzing with pretest and posttest
- Bio Tutorial animations with quizzing
- Vocabulary flashcards
- Virtual Labs

Biology Prep, also available on the companion website, helps students to prepare for their upcoming coursework in biology. This website enables students to perform self assessments, conduct self-study sessions with tutorials, and perform a post-assessment of their knowledge in the following areas:

- Introductory Biology Skills
- Basic Math Review I and II
- Chemistry
- Metric System
- Lab Reports and Referencing

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Brief Contents