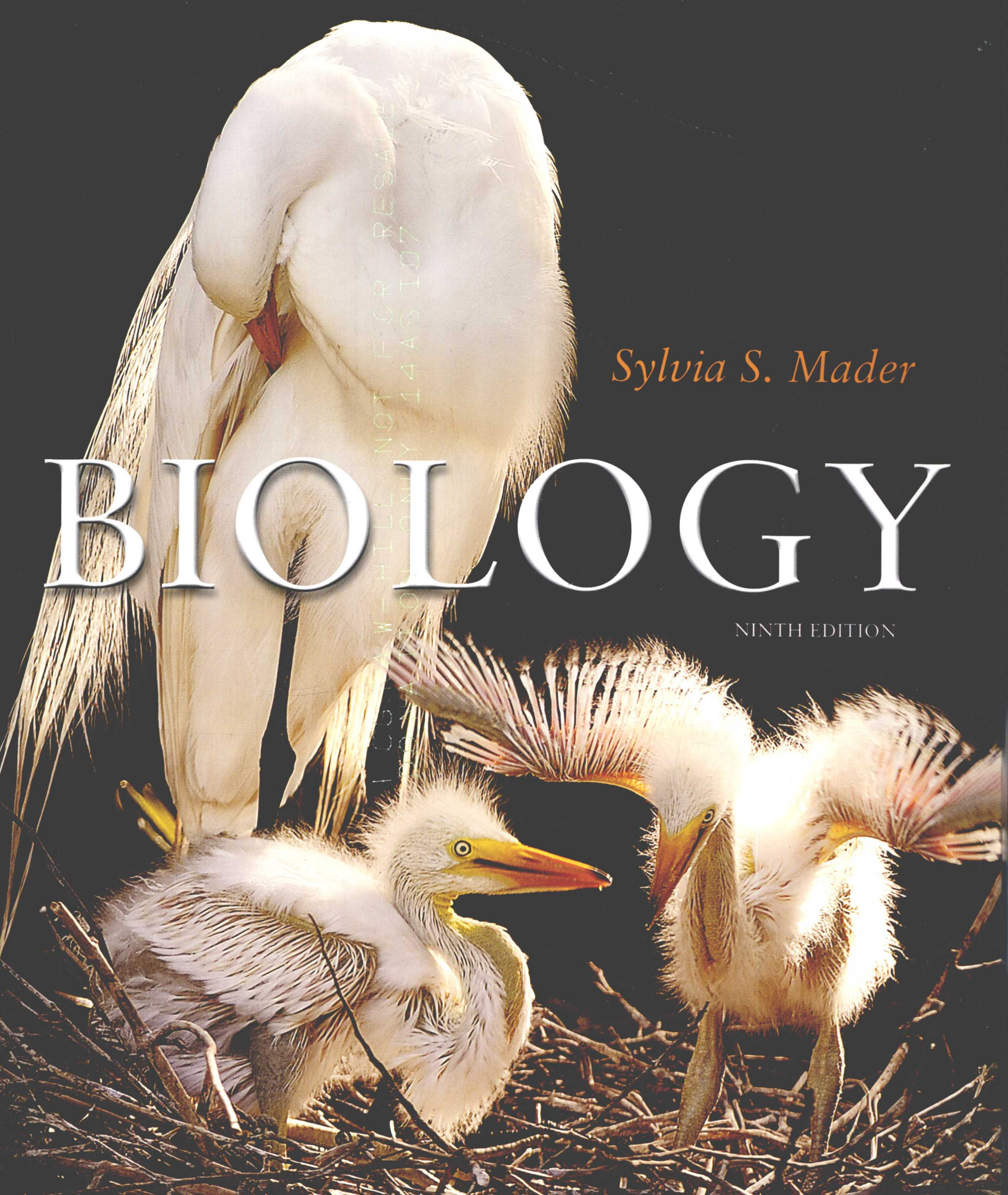

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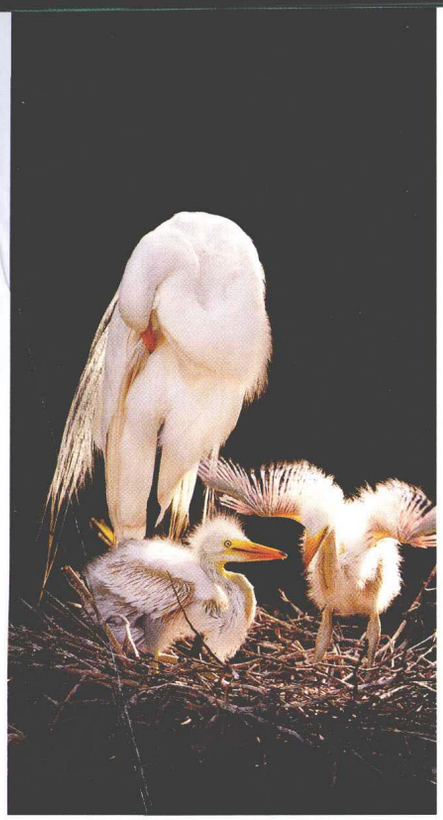
BIOLOGY

NINTH EDITION



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NINTH EDITION

with significant contributions by

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Southeastern Louisiana University

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PREFACE

Biology was born out of my desire for students to develop a particular view of the world—a biological view. It seemed to me that a thorough grounding in biological principles would bring about an appreciation of the structure and function of individual organisms, how they have evolved, and how they interact in the biosphere. This led me to use the levels of biological organization as my guide; thus, the book begins with chemistry and ends with the biosphere.

Students need to be aware that our knowledge of biology is built on scientific discovery. The first chapter explains the process of science and thoroughly reviews examples of how this process works. Throughout the text, biologists are introduced and their experiments are explained. An appreciation of the scientific process should include the perception that without it, the study of biology would not exist.

Evolution of *Biology*

The ninth edition of *Biology* is the result of a dramatic evolutionary change. Previously, the text gradually improved with each edition; in comparison, this edition represents a giant leap forward. As soon as the eighth edition left the presses, we started working on the next edition. Murray P. "Pat" Pendarvis, a talented biology professor much beloved by his students, assisted in updating the text and improving the illustrations. Pat's many additions to the text and choice of photographs increased its beauty and, in particular, its relevancy. I, too, worked diligently from cover to cover refining all that went before and making additions to improve content and pedagogy. My work was greatly assisted by the talented staff of EPS (Electronic Publishing Services Inc.) who laid out the pages and reworked every illustration to produce the most detailed, refined, and pedagogically sound figures ever developed for an introductory biology book.

Pedagogy

Pages xxi-xxiii of this preface review "The Learning System" of *Biology*. As explained, each chapter opening page provides an outline and lists the concepts that are discussed and reinforced within the chapter. Opening vignettes capture the interest of students, and at the close of each chapter, "Connecting the Concepts" discusses the relationships between various biological principles. The end matter of the chapter gives students an opportunity to test themselves on their progress.

It has been my privilege to develop a style and methodology that appeals to students because it meets them where they are and brings them along to a thorough understanding of the concept being presented. Concepts are only grasped if a student comes away with "take-home messages." The interweaving of concepts allows the student to develop a biological view of the world that is essential in the twenty-first century.

Overview of Changes to *Biology*, Ninth Editon

VISUALS

A brilliant new visuals program combined with innovative page layouts enhances the pedagogical value and visual appeal.

GENETICS

Reproductive and therapeutic cloning are illustrated. There is an improved emphasis on regulation of gene activity, expansion of genomics to include proteomics and bioinformatics, and much more.

EVOLUTION AND CLASSIFICATION

Micro- and macroevolution are better explained and illustrated. Fungal and animal classifications are reorganized based on molecular data.

BOTANY

Discussion now centers on a generalized flowering plant, and plant anatomy is more expansive.

ANIMAL PHYSIOLOGY

New homeostasis art, contrast of nervous system with hormone system, reorganization of the development chapter, and the importance of chronic inflammatory response to general health are now included.

ECOLOGY

Population ecology is more comprehensive and understandable.

Changes in *Biology*, Ninth Edition

Perhaps the first significant enhancement that readers will notice in the ninth edition of *Biology* is the brilliant new visuals program. Virtually every illustration is either completely new or significantly revised to convey basic concepts and processes as effectively as possible. In addition to new artwork, hundreds of new photos grace the pages of *Biology*. Finally, we employed an innovative page layout process that combines text, art, and photos in a seamless manner to enhance pedagogical value and visual appeal.

Other significant content updates of special interest include:

- *Chapter 9, The Cell Cycle and Cellular Reproduction*, was reorganized and updated. The descriptions of stages now applies to both plant and animal cells, with differences still clearly designated. A new section, "The Functions of Mitosis," includes a Science Focus reading on Reproductive and Therapeutic Cloning. The cancer section has been completely rewritten to include the origin of cancer and how it relates to the regulation of the cell cycle. The action of oncogenes and tumor repressor genes is stressed.
- *Chapter 15, Regulation of Gene Activity and Gene Mutations*, has taken on new significance because we now know that humans have far fewer genes than was estimated before the sequencing of the human genome. This chapter was revised to reflect the importance of chromatin organization, transcription factors, and activators to the control of gene activity within the nucleus. Translational control within the cytoplasm, including the possible role of RNA to expand each gene's functions, is discussed, as is the importance of gene mutations to the development of cancer.
- *Chapter 16, Biotechnology and Genomics.* This chapter was updated and the topic of genomics was expanded to include a discussion of a genomic profile, proteomics, and bioinformatics. The importance of all these advances for improved health care is explored.
- *Chapter 18, Process of Evolution*, was reorganized to include a section on microevolution and macroevolution. Under macroevolution a more thorough discussion of speciation due to reproductive isolating mechanisms precedes real-life examples of allopatric speciation.
- *Chapter 20, Classification of Living Things*, was rewritten and now includes a better explanation of the phylogenetic tree and its connection to the classification and evolutionary relationships between organisms. The utilization of molecular data to guide classification from domain to species is stressed. A new Science Focus reading describes the proposal to use DNA differences as a basis to develop bar codes for all living species.
- *Chapter 23, The Fungi*, was reorganized to reflect the classification of fungi based on DNA sequencing. Fungi previously classified as imperfect fungi have been incorporated into the ascomycetes, and this chapter now has an expanded discussion of the sac fungi and their relationship to human beings.
- *Chapter 25, Structure and Organization of Plants.* A generalized flowering plant has been developed to present the basics of plant anatomy. New additional structural information permeates this chapter, which seeks to have students understand the overall functioning of a flowering plant. The discussion of primary versus secondary growth has been expanded to provide a better explanation for plant growth.
- *Part VI, Animal Evolution.* This part has been reorganized to be consistent with molecular data regarding the relationship of groups of animals. Traditional classification is the backbone of this part, but new hypotheses regarding the classification of animals are introduced. To accommodate the new hypotheses, Chapter 30 now includes molluscs, annelids, arthropods and echinoderms. Chapter 31 is devoted exclusively to the vertebrates.
- *Chapter 33, Animal Organization and Homeostasis*, has been reorganized to lead students to a better understanding of tissues, organs, and organ systems. Professors will particularly appreciate the improved homeostasis diagrams that explain negative feedback mechanisms. A new Health Focus regarding nerve regeneration stresses advances in this field and touches on the possible use of stem cells to cure paralysis.
- *Chapter 35, Lymph Transport and Immunity*, has been revised to include updated explanations of nonspecific and specific defenses. New data regarding the role of chronic inflammatory response to human illnesses is included. This chapter also has a new Health Focus reading regarding Opportunistic Infections and HIV.
- *Chapter 42, Hormones and Endocrine Systems*, now begins with an overview of the endocrine system, which includes a contrast between hormone and nervous signaling. An in-depth look at hormone signaling follows. The review of endocrine glands and their hormones includes an updated discussion of diabetes mellitus.
- *Chapter 44, Animal Development*, has been reorganized to present a more logical progression of animal developmental stages before developmental processes are explained. The discussion of developmental processes places an emphasis on experimental data to explain the orderliness of development. As before, the chapter ends with a look at the stages of human development.
- *Chapter 46, Ecology of Populations*, was reorganized and rewritten to better present the modern principles of population ecology. The sections now include demographics of populations, population growth models, and regulation of population size before life history patterns and human population growth are considered.

ACKNOWLEDGMENTS

The hard work of many dedicated and talented individuals helped to vastly improve this edition of *Biology*. Let me begin by thanking the people who guided this revision at McGraw-Hill. I am very grateful for the help of so many professionals who were involved in bringing this book to fruition. In particular, let me thank Margaret Horn, the developmental editor who lent her talents and advice to all those who worked on this edition of *Biology*. The biology editor was Thomas Lyon, who was also intimately involved in putting *Biology* through its paces. 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 Wayne Harms and many others who assisted in deciding the appearance of each element in the text. EPS 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 Connie Mueller did a superb job of finding just the right photographs and micrographs.

My staff, consisting of Evelyn Jo Hebert and Beth Butler, worked faithfully as they 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 make 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.

As stated previously, the content of the ninth edition of *Biology* is not due to my efforts alone. I want to thank the many specialists who were willing to share their knowledge to improve *Biology*. Also, this edition was enriched by Pat Pendarvis, who went through every chapter improving the presentation, making relevant additions, and helping to seek and/or select photographs to enhance the text. I am extremely grateful to Pat for his dedicated efforts. The ninth edition of *Biology* would not have the same excellent quality without his suggested changes and those of the many reviewers who are listed here.

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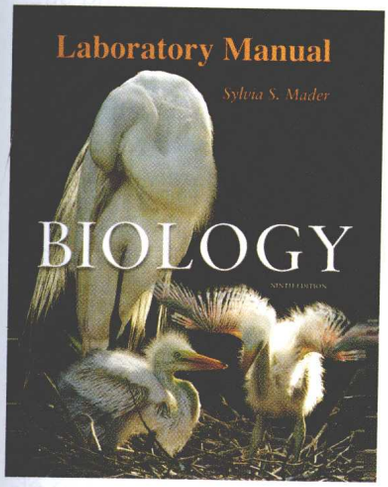
Biology Laboratory Manual



The *Biology Laboratory Manual*, Ninth Edition, 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, as well as gain a better understanding of the scientific method.

ISBN-13: 978-0-07-298955-7 (ISBN-10: 0-07-298955-6)

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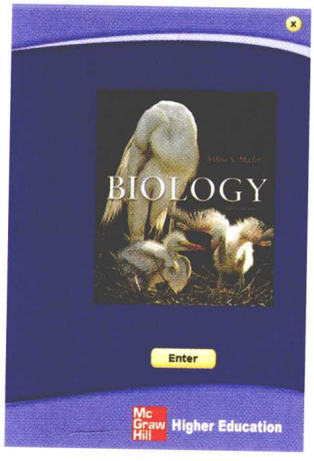
This collection of multimedia resources provides tools for rich visual support of your lectures. You can utilize artwork from the text in multiple formats to create customized classroom presentations, visually based tests and quizzes, dynamic course website content, or attractive printed support materials. The following digital assets are available either on a cross-platform CD-ROM or on a DVD and are grouped by chapters:



Art Libraries. Full-color digital files of all illustrations in the book, plus the same art saved in unlabeled and grayscale version, can be readily incorporated into lecture presentations, exams, or custom-made classroom materials.

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This set of overhead transparencies includes every piece of line art in the textbook plus every table. The images are printed with better visibility and contrast than ever before, and labels are large and bold for clear projection.
ISBN-13: 978-0-07-296752-4 (ISBN-10: 0-07-296752-8)

ARIS

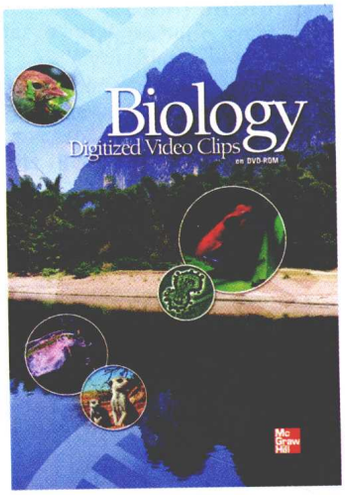
McGraw-Hill's ARIS—Assessment, Review, and Instruction System—for *Biology* Ninth Edition is a complete online tutorial, electronic homework, and course management system designed for greater ease of use than any other system available. Instructors can create and share course materials and assignments with colleagues with a few clicks of the mouse. All PowerPoint® lectures, assignments, quizzes, tutorials, and interactives are directly tied to text-specific materials in *Biology*, but instructors can also edit questions, import their own content, and create announcements and due dates for assignments. ARIS has automatic grading and reporting of easy-to-assign homework, quizzing, and testing. All student activity within McGraw-Hill's ARIS is automatically recorded and available to the instructor through a fully integrated grade book that can be downloaded to Excel.

The *Biology* Ninth Edition ARIS site at www.mhhe.com/maderbiology9 offers access to a vast array of premium online content to fortify the learning and teaching experience for students and instructors.

Instructor Edition. In addition to all of the resources for students, the Instructor Edition of ARIS has these assets:

- ***eInstruction Classroom Performance System (CPS) Question Bank*** A set of questions for use with the CPS is provided for every textbook chapter to assist instructors in quickly assessing student comprehension of the concepts.
- ***Animations*** The next generation of biology animations is available with the ninth edition of *Biology*. Key biological processes in full color have been brought to life via animation. These animations offer flexibility for instructors. Designed to be used in lectures, you can pause, rewind, fast-forward, and turn the audio on or off. Many of the animations are also available with Spanish narration and audio.
- ***Laboratory Resource Guide*** A preparation guide that provides set-up instructions, sources for materials and supplies, time estimates, special requirements, and suggested answers to all questions in the *Biology Laboratory Manual*, Ninth Edition.
- ***PageOut*** McGraw-Hill's exclusive tool for creating your own website for your general biology course. It requires no knowledge of coding and is hosted by McGraw-Hill.
- ***Active Art Demo*** Teaches you how to use the Active Art that is on the Digital Content Manager CD-ROM.
- ***Case Studies*** Offers suggestions on how to use Case Studies in your classroom.

McGraw-Hill: Biology Digitized Video Clips



McGraw-Hill is pleased to offer adopting instructors a new presentation tool—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 Biology Digitized Video Clips 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.
ISBN-13: 978-0-07-312155-0 (ISBN-10: 0-07-312155-X)

Mader Micrograph Slides

This set contains one hundred 35mm slides of many of the photomicrographs and electron micrographs in the text.
ISBN-13: 978-0-07-239977-6 (ISBN-10: 0-07-239977-5)

LEARNING SUPPLEMENTS FOR THE STUDENT

Student Study Guide

Dr. Sylvia Mader has written the *Student Study Guide* that accompanies *Biology,* thereby ensuring close coordination with the text. Each text chapter has a corresponding study guide chapter that includes a chapter review, learning objectives and study questions for each section of the chapter, and a chapter test. Answers to all questions are provided to give students immediate feedback. Students who make use of the *Student Study Guide* should find that performance increases dramatically.

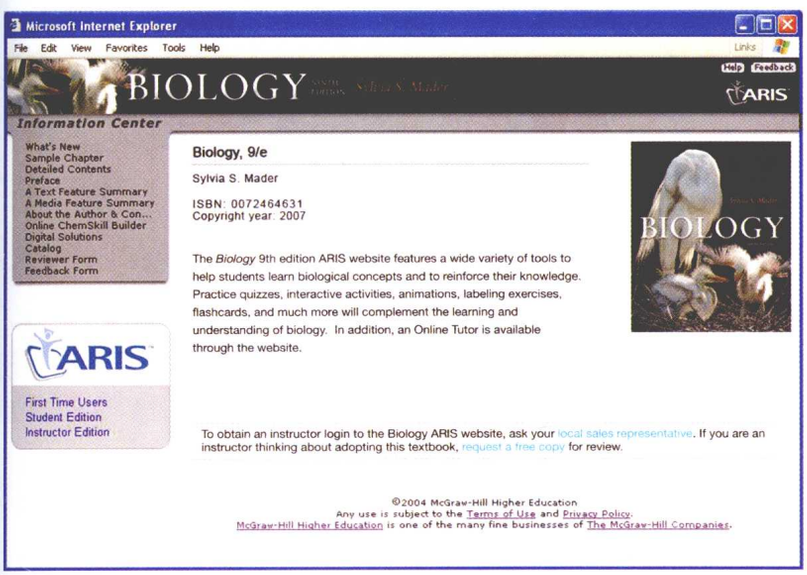
ISBN-13: 978-0-07-297671-7 (ISBN-10: 0-07-297671-3)

ARIS

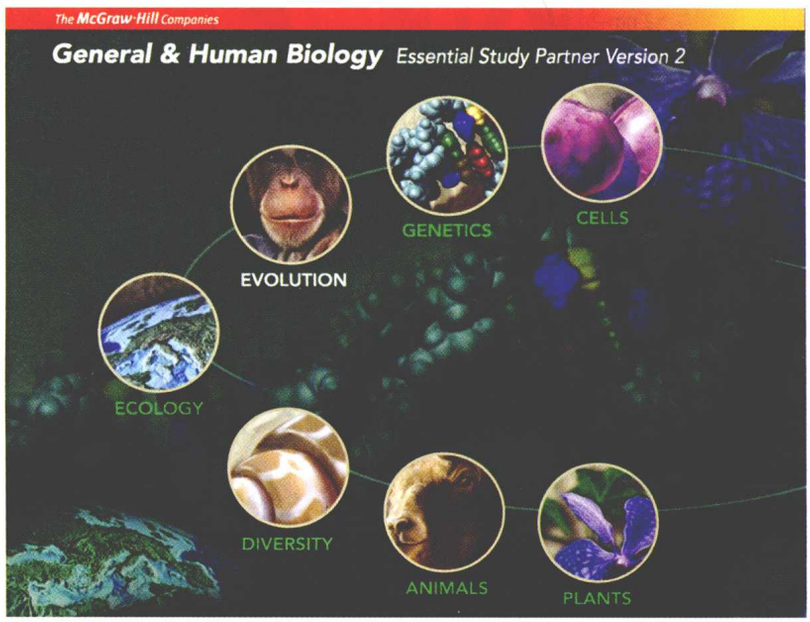
McGraw-Hill's ARIS—Assessment, Review, and Instruction System—for *Biology,* Ninth Edition at www.mhhe.com/maderbiology9 offers access to a vast array of premium online content to fortify the learning experience.

Student Edition. The Student Edition of ARIS features a wide variety of tools to help students learn biological concepts and to reinforce their knowledge:

- *Interactive Activities* These online study aids, organized by chapter, include **practice quizzes, animations, labeling exercises, flashcards,** and much more.
- *Online Tutoring* The tutorial service is moderated by qualified instructors. Help with difficult concepts is only an email away!



- *Essential Study Partner* This collection of interactive study modules contains hundreds of animations, learning activities, and quizzes designed to help students grasp complex concepts.



- *Animations* Full-color presentations of key biological processes have been brought to life via animation. You can pause, rewind, fast-forward, and turn the audio on or off. Many of the animations are also available with Spanish narration and audio.
- *Animation Quizzes* Quizzes based on the new animations will help you assess your understanding of the concepts.

Student Interactive CD-ROM

This interactive CD-ROM is an indispensable resource for studying topics covered in the text. It includes chapter outlines, chapter-based quizzes, animations of complex processes, flashcards, PowerPoint® lecture outlines, and PowerPoint® slides of all art and photos found in the textbook. All of the material is organized chapter-by-chapter. Direct links to the text's ARIS website and to the Essential Study Partner are also provided.

ISBN-13: 978-0-07-326525-4 (ISBN-10: 0-07-326525-X)

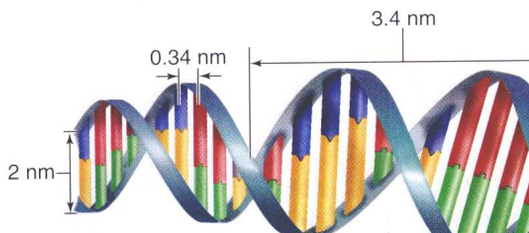
BIOLOGY, Ninth Edition

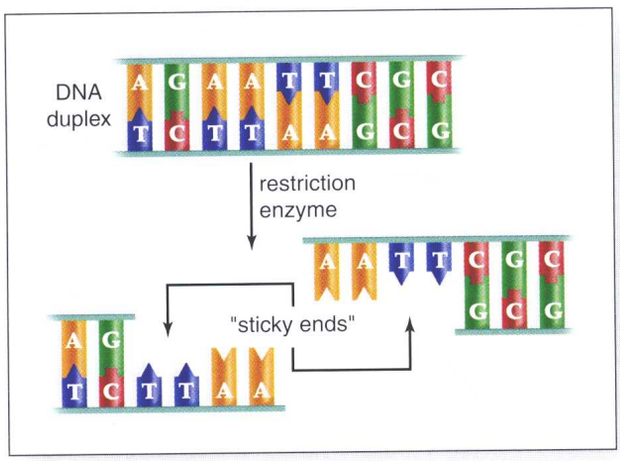
Guided Tour

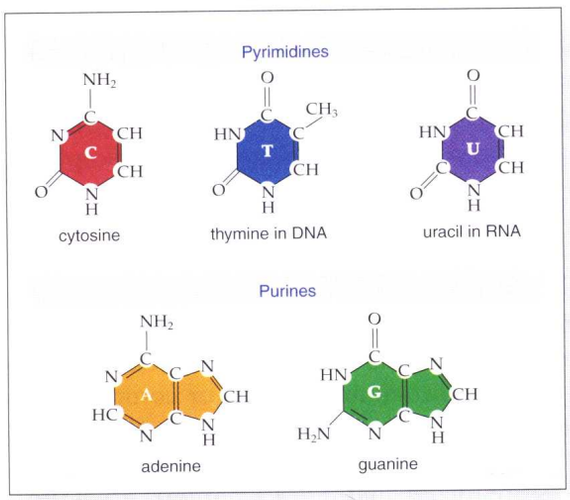
A brilliant new visuals program brings* Biology *to life!

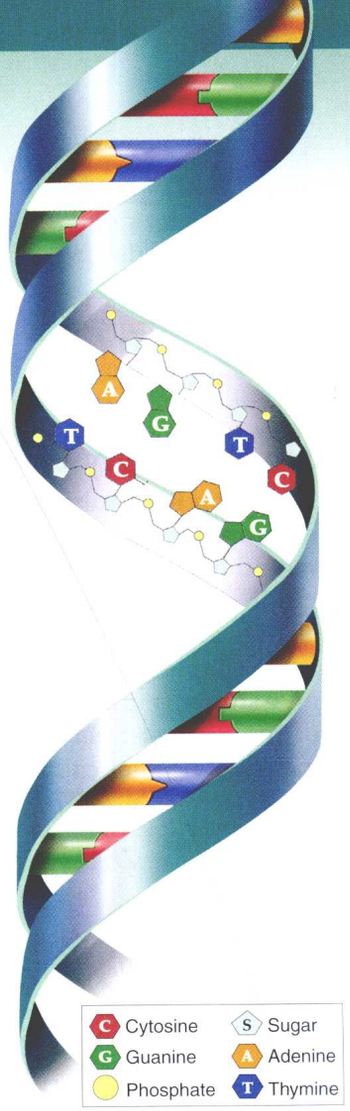
Color Consistency

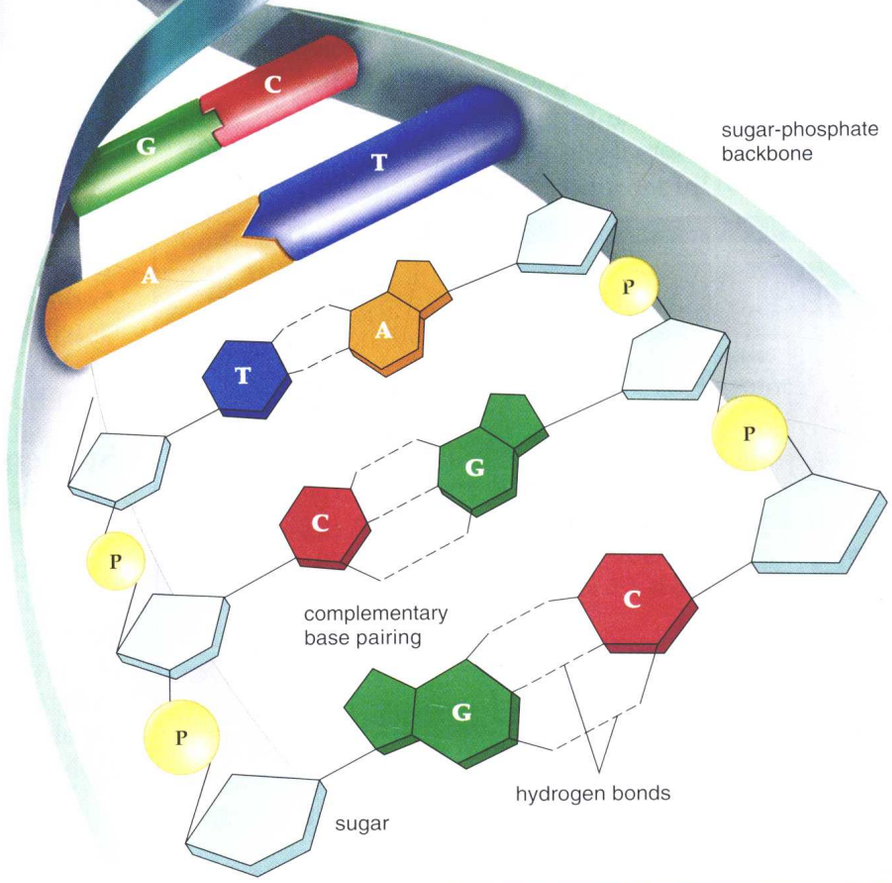
Color consistency organizes information and clarifies concepts for visual learners.





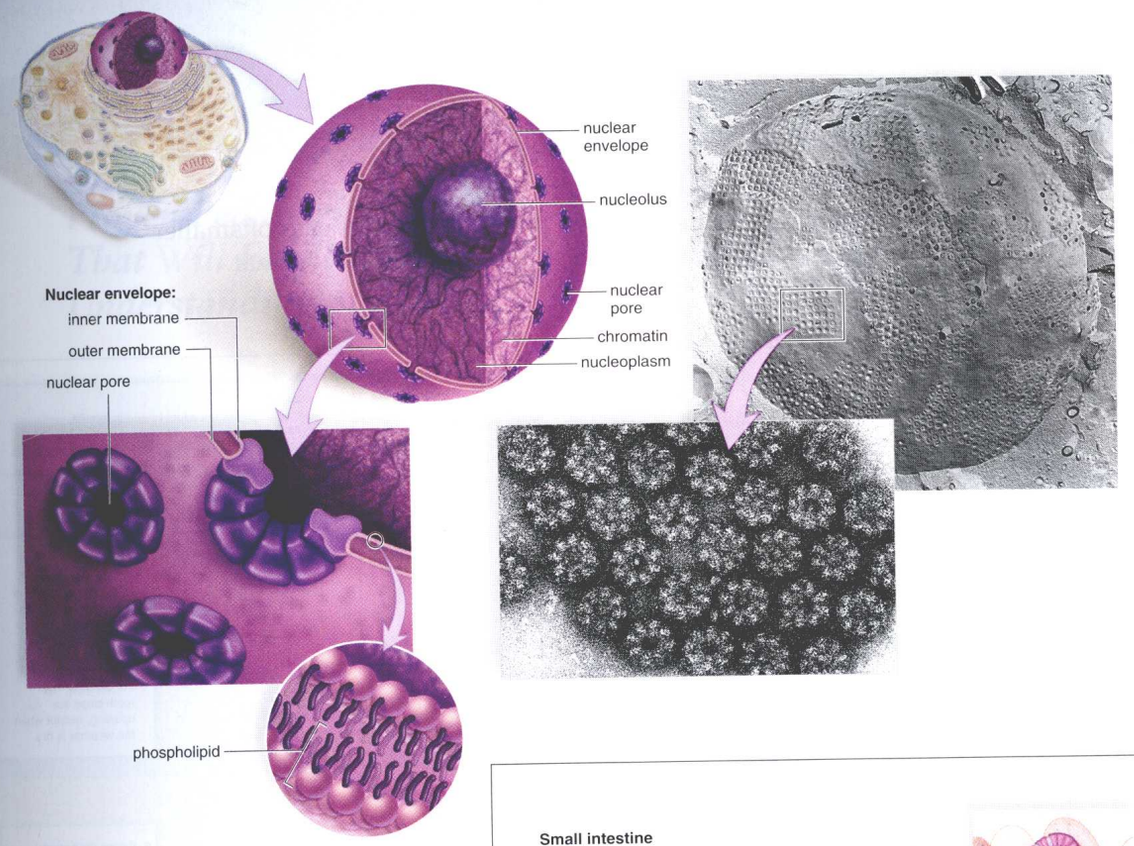


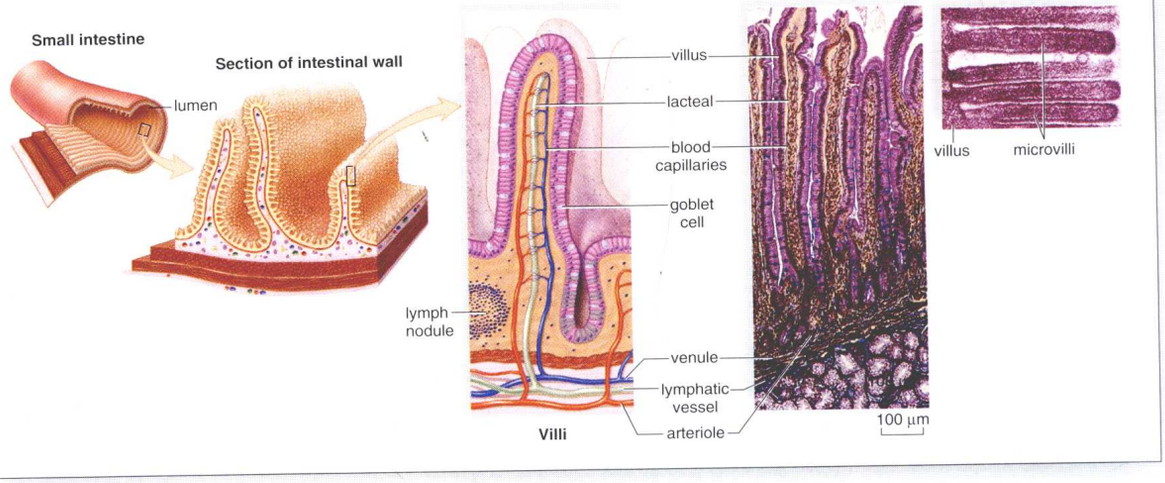




Multi-Level Perspective

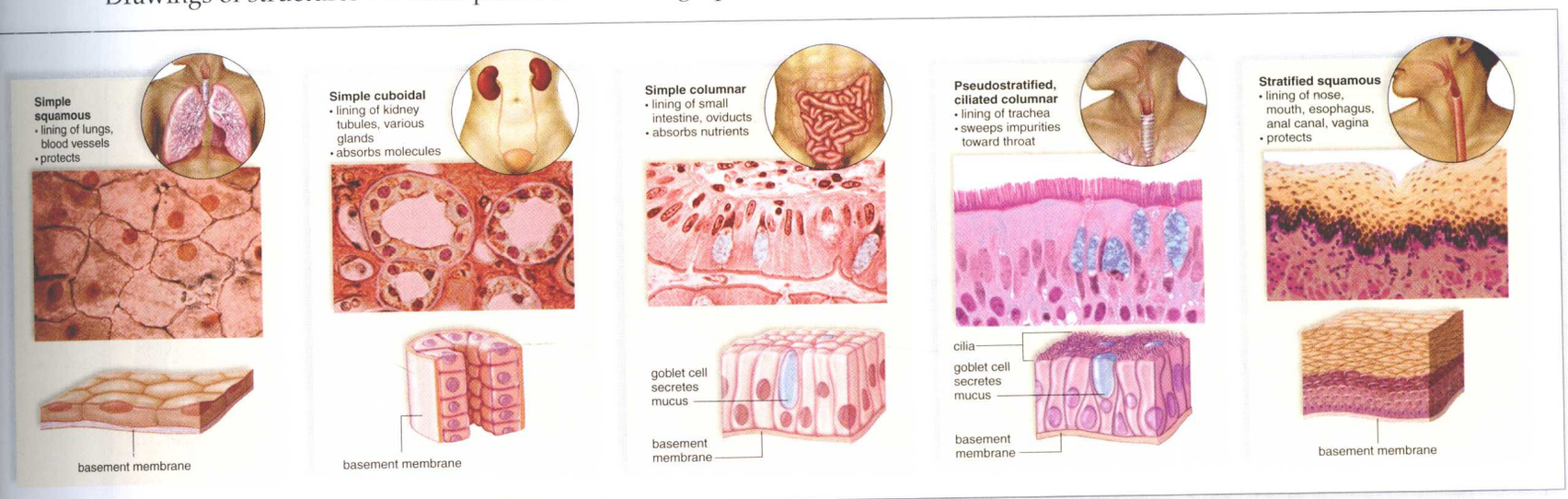
Illustrations depicting complex structures connect macroscopic and microscopic views to help students connect the two levels.

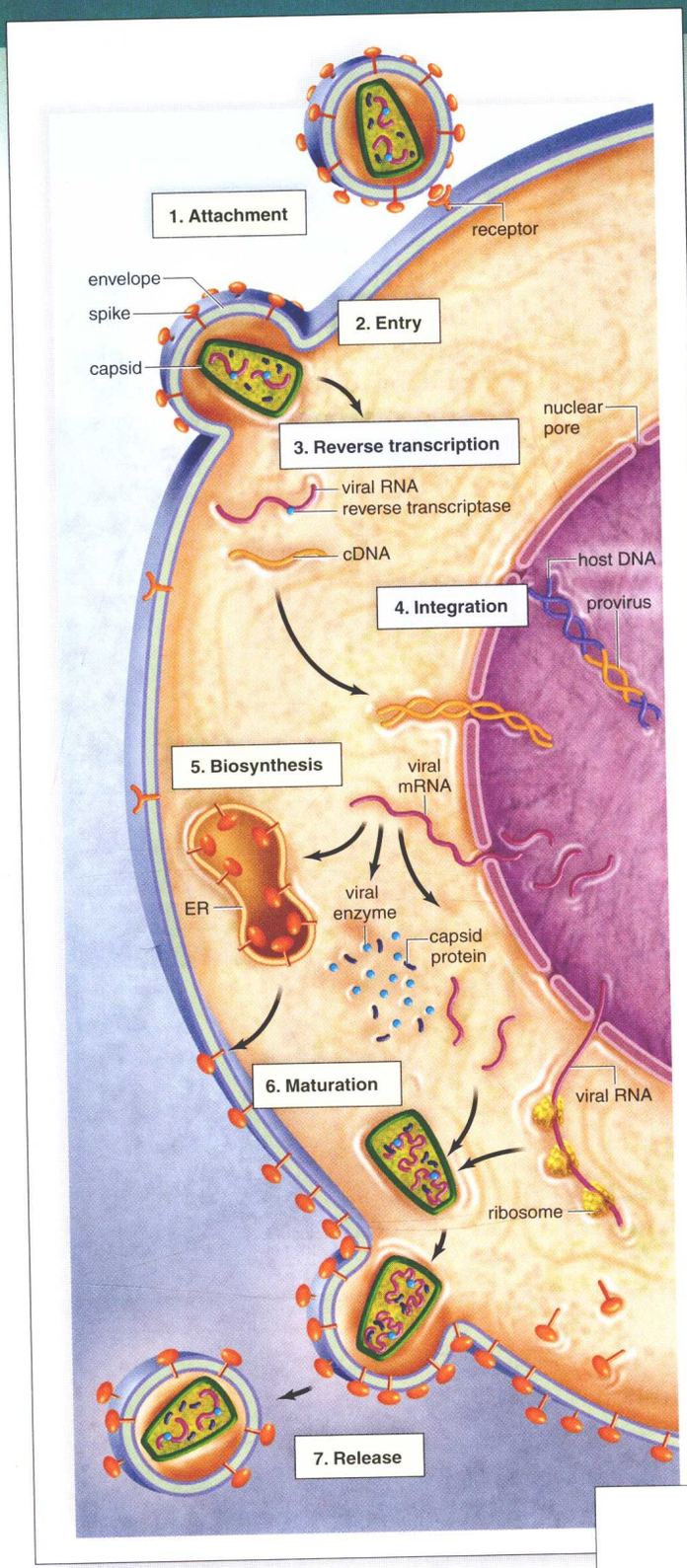




Combination Art

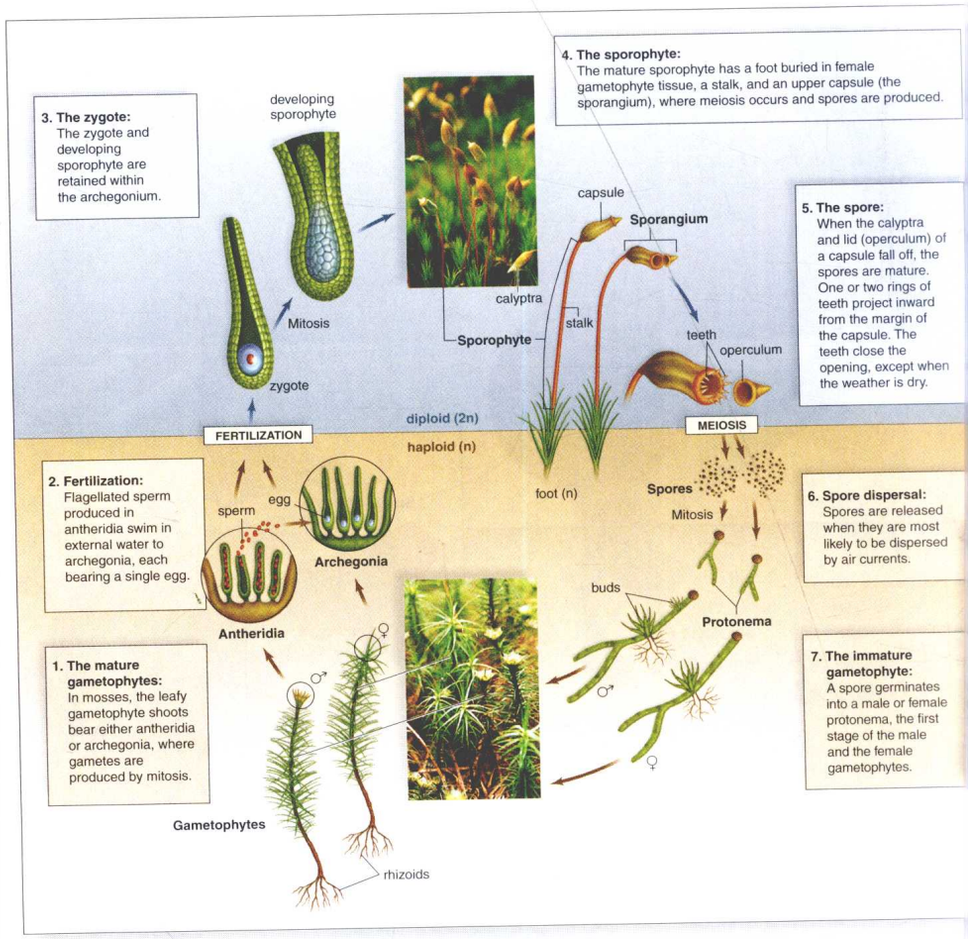
Drawings of structures are often paired with micrographs to enhance visualization.





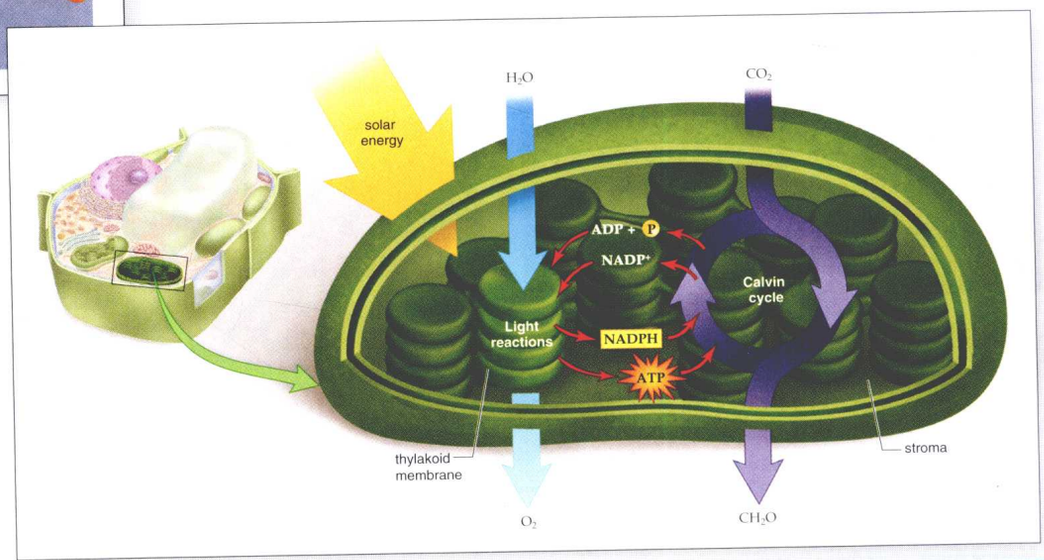
Process Figures

These figures break down processes into a series of smaller steps and organize them in an easy-to-follow format.



Icons

Icons help orient the student.



The Learning System

Proven Pedagogical Features That Will Facilitate Your Understanding of Biology

Chapter Concepts

The chapter begins with an integrated outline that numbers the major topics of the chapter and lists the concepts for each topic.

7

PHOTOSYNTHESIS

The fate of life on Earth literally hinges on a star 93 million miles away because this star provides photosynthesizers with solar energy. Only 42% of the solar energy directed towards Earth reaches the planet; the remainder is absorbed by or reflected into the atmosphere and becomes heat. Of this, only 1–2% is captured by photosynthesizers and, only a portion of this is incorporated into plant materials.

Yet all living things are dependent on the amount of solar energy that photosynthesizers transform into chemical energy. Exceptions do exist. In rare hydrothermal environments, some prokaryotes acquire energy by oxidizing inorganic molecules and are the producers of food for others. In the majority of ecosystems, photosynthesizers are the producers that take in inorganic molecules and produce food by using solar energy.

When photosynthesis occurs, carbon dioxide is absorbed and oxygen is released. Oxygen is required by organisms when they carry on cellular respiration. The collective action of algae and plants is responsible for placing copious amounts of oxygen into the atmosphere. It rises high into the atmosphere and forms an ozone layer that makes terrestrial life possible. Accordingly, this layer that protects us against damaging ultraviolet rays of the sun is called the ozone shield.

The products of photosynthesis are critical to humankind in a number of ways. They provide our food, to be sure, but they also are a source of building materials, fabrics, paper, fuel, and pharmaceuticals. Even plants that existed hundreds of millions of years ago are important as a source of fossil fuels. And while we are thanking green plants for their many services, let's not forget the simple beauty of a magnolia blossom or the majesty of the Earth's forests.

Photosynthesizers use solar energy to produce organic nutrients for themselves and all other organisms.

CONCEPTS

Phases of Cellular Respiration

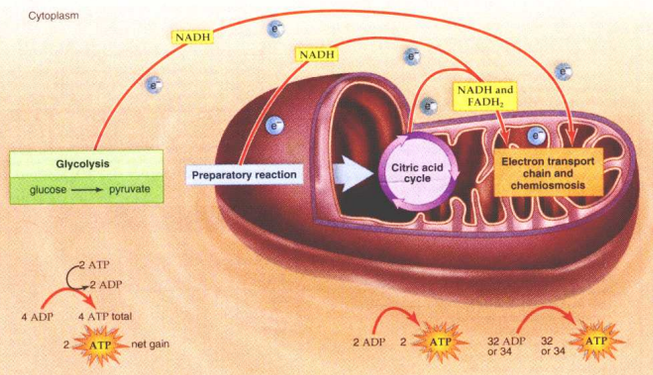
The oxidation of glucose by removal of hydrogen atoms involves four phases (Fig. 8.2). Glycolysis takes place outside the mitochondria and does not require the presence of oxygen. Therefore, glycolysis is **anaerobic.** The other phases of cellular respiration take place inside the mitochondria, where oxygen is the final acceptor of electrons.

- During **glycolysis** [Gk. *glycos,* sugar, and *lysis,* splitting], glucose is broken down in the cytoplasm to two molecules of pyruvate. Oxidation by removal of hydrogen atoms results in NADH and provides enough energy for the net yield of two molecules of ATP.
- During the **preparatory (prep) reaction,** pyruvate enters a mitochondrion and is oxidized to a 2-carbon acetyl group carried by CoA; NADH is formed; and the waste product CO_2 is removed. Since glycolysis ends with two molecules of pyruvate, the prep reaction occurs twice per glucose molecule.
- The **citric acid cycle** is a cyclical series of oxidation reactions in the matrix of a mitochondrion that result in NADH and $FADH_2$. CO_2 is given off and one ATP is produced. The citric acid cycle turns twice because two acetyl CoA molecules enter the cycle per glucose molecule. Altogether, the citric acid cycle accounts for two immediate ATP molecules per glucose molecule.
- The **electron transport chain** is a series of carriers in the inner mitochondrial membrane that accept the electrons removed from glucose and pass them along from one carrier to the next until they are finally received by O_2, which then combines with hydrogen ions and becomes water. As the electrons pass from a higher-energy to a lower-energy state, energy is released and later used for ATP synthesis by chemiosmosis. The electrons from one glucose result in 32 or 34 ATP, depending on certain conditions.

Pyruvate is a pivotal metabolite in cellular respiration. If oxygen is not available to the cell, fermentation occurs in the cytoplasm (see Fig. 8.10). During **fermentation,** glucose is incompletely metabolized to lactate or to carbon dioxide and alcohol, depending on the organism. As we shall see on page 142, fermentation results in a net gain of only two ATP per glucose molecule.

Cellular respiration involves the oxidation of glucose to carbon dioxide and water. As glucose breaks down, energy is made available for ATP synthesis. A total of 36 or 38 ATP molecules are produced per glucose molecule in cellular respiration (2 from glycolysis, 2 from the citric acid cycle, and 32 or 34 from the electron transport chain).

FIGURE 8.2 The four phases of complete glucose breakdown.
The complete breakdown of glucose consists of four phases. Glycolysis in the cytoplasm produces pyruvate, which enters mitochondria if oxygen is available. The preparatory reaction and the citric acid cycle that follow occur inside the mitochondria. Also, inside mitochondria, the electron transport chain receives the electrons that were removed from glucose breakdown products. The result of glucose breakdown is 36 or 38 ATP, depending on the particular cell.



Internal Summary Statements

A summary statement appears at the end of each major section of the chapter to help students focus on the key concepts.

science focus

Viewing the Chromosomes

ecology focus

Plants: Could We Do Without Them?

health focus

Nerve Regeneration

Readings

Biology offers three types of boxed readings:

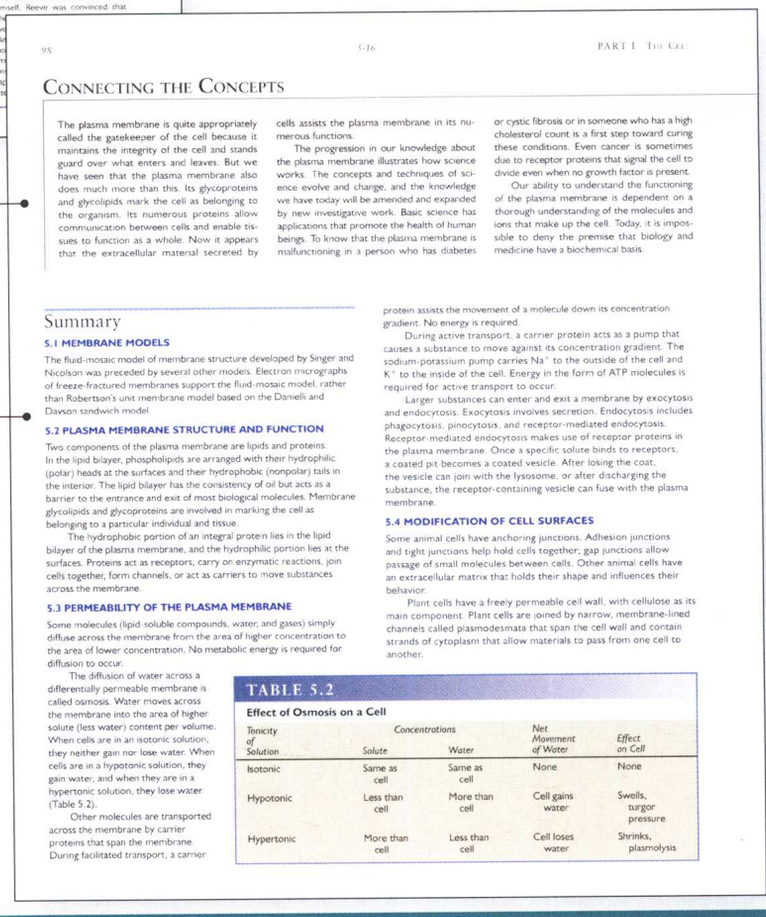
- Science Focus readings describe how experimentation and observations have contributed to our knowledge about the living world.
- Ecology Focus readings show how the concepts of the chapter can be applied to ecological concerns.
- Health Focus readings review procedures and technology that can contribute to our well-being.

Connecting the Concepts

These appear at the close of the text portion of the chapter, and they stimulate critical thinking by showing how the concepts of the chapter are related to other concepts in the text.

Chapter Summary

The summary is organized according to the major sections in the chapter and helps students review the important topics and concepts.



CONNECTING THE CONCEPTS

Summary

TABLE 5.2

Effect of Osmosis on a Cell

End-of-Chapter Study Tools

Reviewing the Chapter

These page-referenced study questions follow the sequence of the chapter.

Testing Yourself

These objective questions allow you to test your ability to answer recall-based questions. Answers to *Testing Yourself* questions are given in Appendix A.

Thinking Scientifically

Critical thinking questions give you an opportunity to reason as a scientist. Detailed answers to these questions are found on ARIS, the *Biology*, Ninth Edition website.

Bioethical Issue

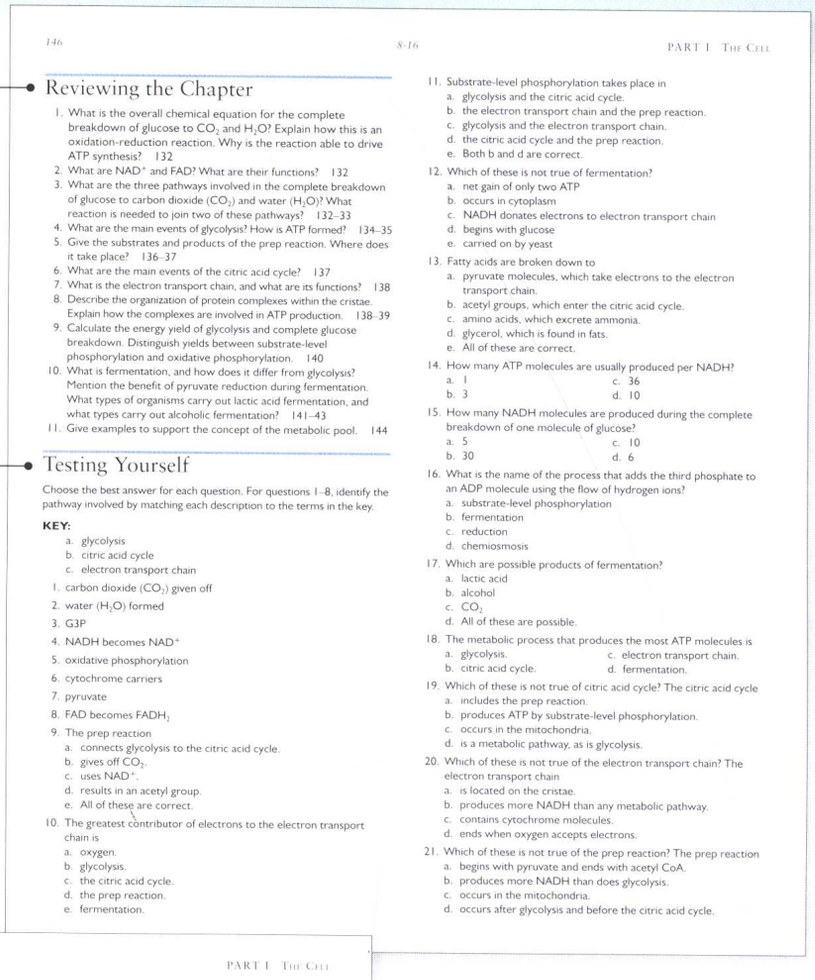
A *Bioethical Issue* is found at the end of most chapters. These short readings discuss a variety of controversial topics that confront our society. Each reading ends with appropriate questions to help you fully consider the issue and arrive at an opinion.

Understanding the Terms

The boldface terms in the chapter are page referenced, and a matching exercise allows you to test your knowledge of the terms.

Website Reminder

Located at the end of the chapter is this reminder that additional study questions and other learning activities are on ARIS, the *Biology*, Ninth Edition website.



146 8-16 PART I The Cell

Reviewing the Chapter

1. What is the overall chemical equation for the complete breakdown of glucose to CO_2 and H_2O? Explain how this is an oxidation-reduction reaction. Why is the reaction able to drive ATP synthesis? 132
2. What are NAD^+ and FAD? What are their functions? 132
3. What are the three pathways involved in the complete breakdown of glucose to carbon dioxide (CO_2) and water (H_2O)? What reaction is needed to join two of these pathways? 132–33
4. What are the main events of glycolysis? How is ATP formed? 134–35
5. Give the substrates and products of the prep reaction. Where does it take place? 136–37
6. What are the main events of the citric acid cycle? 137
7. What is the electron transport chain, and what are its functions? 138
8. Describe the organization of protein complexes within the cristae. Explain how the complexes are involved in ATP production. 138–39
9. Calculate the energy yield of glycolysis and complete glucose breakdown. Distinguish yields between substrate-level phosphorylation and oxidative phosphorylation. 140
10. What is fermentation, and how does it differ from glycolysis? Mention the benefit of pyruvate reduction during fermentation. What types of organisms carry out lactic acid fermentation, and what types carry out alcoholic fermentation? 141–43
11. Give examples to support the concept of the metabolic pool. 144

Testing Yourself

Choose the best answer for each question. For questions 1–8, identify the pathway involved by matching each description to the terms in the key.

KEY:

a. glycolysis
b. citric acid cycle
c. electron transport chain

1. carbon dioxide (CO_2) given off
2. water (H_2O) formed
3. G3P
4. NADH becomes NAD^+
5. oxidative phosphorylation
6. cytochrome carriers
7. pyruvate
8. FAD becomes $FADH_2$
9. The prep reaction
   a. connects glycolysis to the citric acid cycle.
   b. gives off CO_2.
   c. uses NAD^+.
   d. results in an acetyl group.
   e. All of these are correct.
10. The greatest contributor of electrons to the electron transport chain is
    a. oxygen.
    b. glycolysis.
    c. the citric acid cycle.
    d. the prep reaction.
    e. fermentation.
11. Substrate-level phosphorylation takes place in
    a. glycolysis and the citric acid cycle.
    b. the electron transport chain and the prep reaction.
    c. glycolysis and the electron transport chain.
    d. the citric acid cycle and the prep reaction.
    e. Both b and d are correct.
12. Which of these is not true of fermentation?
    a. net gain of only two ATP
    b. occurs in cytoplasm
    c. NADH donates electrons to electron transport chain
    d. begins with glucose
    e. carried on by yeast
13. Fatty acids are broken down to
    a. pyruvate molecules, which take electrons to the electron transport chain.
    b. acetyl groups, which enter the citric acid cycle.
    c. amino acids, which excrete ammonia.
    d. glycerol, which is found in fats.
    e. All of these are correct.
14. How many ATP molecules are usually produced per NADH?
    a. 1 c. 36
    b. 3 d. 10
15. How many NADH molecules are produced during the complete breakdown of one molecule of glucose?
    a. 5 c. 10
    b. 30 d. 6
16. What is the name of the process that adds the third phosphate to an ADP molecule using the flow of hydrogen ions?
    a. substrate-level phosphorylation
    b. fermentation
    c. reduction
    d. chemiosmosis
17. Which are possible products of fermentation?
    a. lactic acid
    b. alcohol
    c. CO_2
    d. All of these are possible.
18. The metabolic process that produces the most ATP molecules is
    a. glycolysis. c. electron transport chain.
    b. citric acid cycle. d. fermentation.
19. Which of these is not true of citric acid cycle? The citric acid cycle
    a. includes the prep reaction.
    b. produces ATP by substrate-level phosphorylation.
    c. occurs in the mitochondria.
    d. is a metabolic pathway, as is glycolysis.
20. Which of these is not true of the electron transport chain? The electron transport chain
    a. is located on the cristae.
    b. produces more NADH than any metabolic pathway.
    c. contains cytochrome molecules.
    d. ends when oxygen accepts electrons.
21. Which of these is not true of the prep reaction? The prep reaction
    a. begins with pyruvate and ends with acetyl CoA.
    b. produces more NADH than does glycolysis.
    c. occurs in the mitochondria.
    d. occurs after glycolysis and before the citric acid cycle.

114 6-14 PART I The Cell

Thinking Scientifically

1. A certain flower generates heat. This heat attracts pollinating insects to the flower. While the evolutionary benefit of attracting insects is obvious, the metabolic cost of this particular adaptation is high. What metabolic mechanism(s) might a plant use to generate heat, and under what circumstances would the metabolic cost be high?
2. The free energy of carbon dioxide and water is considerably less than the free energy of sucrose (table sugar). However, the conversion of sucrose to carbon dioxide and water is never spontaneous under normal conditions. How would you explain this observation?

Bioethical Issue: Greenhouse Effect and Emerging Diseases

Today, we are very much concerned about emerging diseases caused by pathogens. Examples of emerging diseases are AIDS and Ebola, which emerge from their natural hosts to cause illness in humans. In 1993, the hantavirus strain emerged from the common deer mouse and killed about 60 young people in the Southwest. In the case of hantavirus, we know that climate was involved. An unusually mild winter and wet spring caused piñon trees to bloom well and provide pine nuts to the mice. The increasing deer mouse population came into contact with humans, and the hantavirus leaped easily from mice to humans.

The prediction is that global warming, caused in large part by the burning of fossil fuels, will upset normal weather cycles and result in outbreaks of hantavirus as well as malaria, dengue and yellow fevers, filariasis, encephalitis, schistosomiasis, and cholera. Clearly, any connection between global warming and emerging diseases offers another reason that greenhouse gases should be curtailed when fossil fuels such as gasoline are consumed. Examples of greenhouse gases are carbon dioxide and methane, which allow the sun's rays to pass through but then trap the heat from escaping.

In December 1997, 159 countries met in Kyoto, Japan, to work out a protocol that would reduce greenhouse gases worldwide. This protocol, called the Kyoto Protocol, entered into force February 16, 2005. It is believed that the emission of greenhouse gases, especially from power plants, will cause Earth's temperature to rise 1.5°–4.5° by 2060. The U.S. Senate still does not want to ratify the agreement because it does not include a binding emissions commitment from the developing countries, which are only now becoming industrialized. While the United States presently emits a large proportion of the greenhouse gases, China is expected to surpass that amount in about 2020 to become the biggest source of greenhouse emissions.

Negotiations with the developing countries are still going on, and some creative ideas have been put forward. Why not have a trading program that allows companies to buy and sell emission credits across international boundaries? Accompanying that would be a market in greenhouse reduction techniques. If it became monetarily worth their while, companies in developed countries would have an incentive to reduce greenhouse emissions. If you were a CEO, would you be willing to reduce greenhouse emissions simply because they cause a deterioration of the environment and probably cause human illness? Why or why not? Instead, would you approve of giving companies monetary incentives to reduce greenhouse emissions? Why or why not?

Understanding the Terms

active site 106
ADP (adenosine diphosphate) 104
ATP (adenosine triphosphate) 104
ATP synthase complex 111
chemical energy 102
chemiosmosis 111
coenzyme 108
cofactor 108
competitive inhibition 109
coupled reactions 105
denatured 108
electron transport chain 110
endergonic reaction 104
energy 102
energy of activation 106
entropy 103
enzyme 106
enzyme inhibition 109
exergonic reaction 104
feedback inhibition 109
free energy 104
heat 102
induced fit model 106
kinetic energy 102
laws of thermodynamics 102
mechanical energy 102
metabolic pathway 106
metabolism 104
NAD (nicotinamide adenine dinucleotide) 110
NADP (nicotinamide adenine dinucleotide phosphate) 110
noncompetitive inhibition 109
oxidation 110
phosphorylation 109
potential energy 102
product 104
reactant 104
reduction 110
substrate 106
vitamin 109

Match the terms to these definitions:

a. _____ All of the chemical reactions that occur in a cell during growth and repair.
b. _____ Stored energy as a result of location or spatial arrangement.
c. _____ Essential requirement in the diet, needed in small amounts. They are often part of coenzymes.
d. _____ Measure of disorder or randomness.
e. _____ Nonprotein organic molecule that aids the action of the enzyme to which it is loosely bound.
f. _____ Loss of one or more electrons from an atom or molecule; in biological systems, generally the loss of hydrogen atoms.

ARIS, the *Biology* Website

ARIS, the website for *Biology*, provides a wealth of information organized and integrated by chapter. You will find practice quizzes, interactive activities, labeling exercises, flashcards, and much more that will complement your learning and understanding of general biology.

www.mhhe.com/maderbiology9