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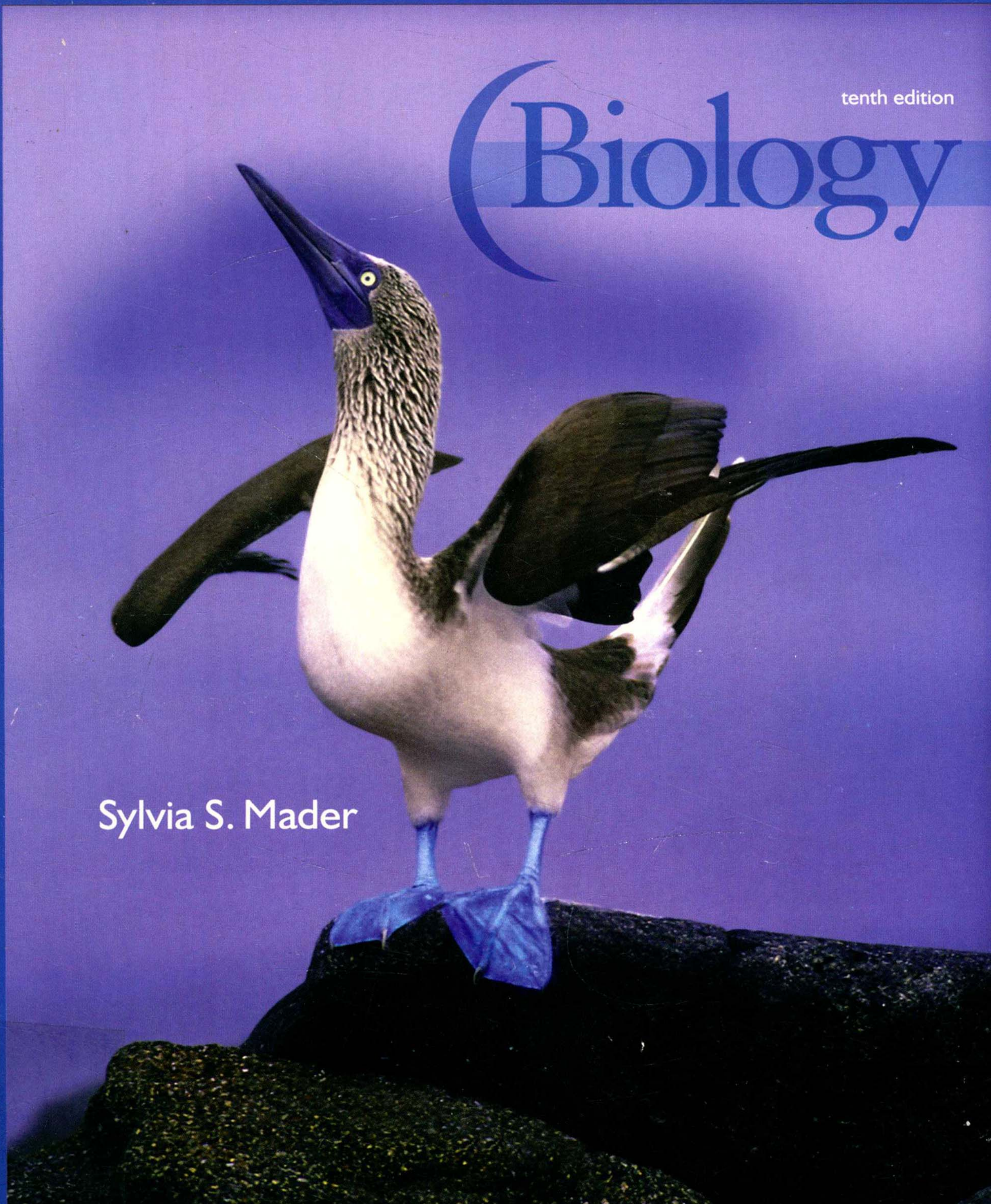
Biology

Sylvia S. Mader



Armstrong Atlantic State University Edition for BIOL 1108

BIOL 1108

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Biology

tenth edition

Armstrong Atlantic State University Edition for

BIOL 1108

Sylvia S. Mader

with significant contributions by

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PREFACE

The mission of my text, *Biology*, has always been to give students an understanding of biological concepts and a working knowledge of the scientific process. If one understands the concepts of biology and the methodology of science, they can be used to understand the particulars of new ideas or a system on any scale from the cell to the biosphere. By now, we are well into the twenty-first century, and the field of biology has been flooded with exciting new discoveries and insights way beyond our predictions even a few short years ago. It is our task, as instructors, to make these findings available to our students so they will have the background to keep up with the many discoveries still to come. At the same time, we must provide students with a firm foundation in those core principles on which biology is founded. This means that the tenth edition of *Biology* is both new and old at the same time. With this edition, instructors will be confident that they are "up to date," while still teaching the fundamental concepts of biology in a way that allows students to apply them in new and different ways. In this edition you will find:

- *Increased Evolutionary Coverage*
- *Currency of Coverage*
- *Media Integration*

Birth of *Biology*

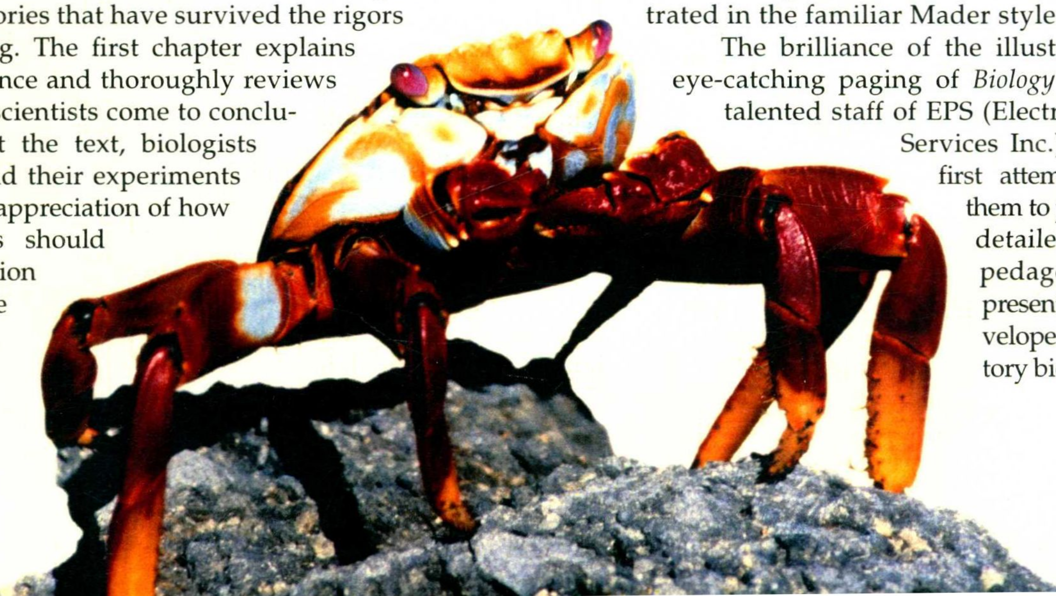
I am an instructor of biology as are the contributors that have lent their several talents to this edition of *Biology*. Collectively, we have taught students for many years from the community college to the university level. We are all dedicated to the desire that students develop a particular view of the world—a biological view. When I wrote the first edition of *Biology,* it seemed to me that a thorough grounding in biological principles would lead to an appreciation of the structure and function of individual organisms, how they evolved, and how they interact in the biosphere. This caused me to use the levels of biological organization as my guide—thus, this edition, like the previous editions, begins with chemistry and ends with the biosphere.

Students need to be aware that our knowledge of biology is built on theories that have survived the rigors of scientific testing. The first chapter explains the process of science and thoroughly reviews examples of how scientists come to conclusions. Throughout the text, biologists are introduced, and their experiments are explained. An appreciation of how science progresses should lead to the perception that, without the scientific process, biology could not exist.

Evolution of *Biology*

While I have always guided the development of each new edition of *Biology*, many instructors have lent their talents to ensuring its increasing success. I give my utmost thanks to all the reviewers and contributors that have been so generous with their time and expertise. This edition, I want to particularly thank Andrew Baldwin, of Mesa Community College, who revised the ecology chapters; Rebecca Roush, of Sandhills Community College, for her work on Part VI; Michael Thompson, of Middle Tennessee State University, who did the first chapter and the genetics chapters; and Stephanie Songer, of North Georgia College and State University, who revised Part IV and many chapters in Part V. My involvement ensured that each of these chapters, along with the chapters I revised, are written and illustrated in the familiar Mader style.

The brilliance of the illustrations and the eye-catching paging of *Biology* are due to the talented staff of EPS (Electronic Publishing Services Inc.), who took my first attempts and altered them to produce the most detailed, refined, and pedagogically sound presentations ever developed for an introductory biology book.



The Learning System

Mader books excel in pedagogy, and *Biology* is consistent with the usual high standard. Pages xii–xv of this preface review "The Learning System" of *Biology*. As explained, each part opening page introduces that part in a new engaging way that explains the rationale of that part. The chapter opening page lists the key concepts under the major sections for that chapter. In this way, students are given an overview of the chapter and its concepts. The opening vignette captures student interest and encourages them to begin their study of the chapter. New to this edition, major sections end with "Check Your Progress" questions designed to foster confidence as they proceed through the chapter. "Connecting the Concepts" at the end of the chapter ties the concepts of this chapter to those in other chapters. The end matter gives students an opportunity to review the chapter and test themselves on how well they understand the concepts.

The Mader writing style is well known for its clarity and a simplicity of style that appeals to students because it meets them where they are and assists them in achieving mastery of the concept. Concepts are only grasped if a student comes away with "take-home messages." Once students have internalized the fundamental concepts of biology, they will have developed a biological view of the world that is essential in the twenty-first century.

Changes in *Biology*, Tenth Edition

The tenth edition builds on the visual appeal of the previous edition. New illustrations have been developed that are just as stunning as those prepared for the ninth edition, and many new photographs and micrographs have been added.

Biology has a new table of contents that consolidates chapters so that the book is shorter by some forty pages compared to the last edition. No individual chapter is overly long, however. In Part II, certain material from Chapter 12 was moved into Chapter 10, *Meiosis and Sexual Reproduction* and Chapter 11, *Mendelian Patterns of Inheritance*. In Part III, *Speciation and Macroevolution* is a much needed new chapter. In Part VI, the two invertebrate evolution chapters from the previous edition have become Chapter 28, *Invertebrates*. In Part VIII, Chapter 45, *Community and Ecosystem Ecology* is a consolidation of two chapters from the previous edition.

I believe you will be interested in knowing about these chapters that demonstrate the quality of *Biology*, Tenth Edition:

- Chapter 1, *A View of Life*, was revised to have a new section: "Evolution, the Unifying Concept of *Biology*." This section presents basic evolutionary principles and contains a depiction of the Tree of Life, which introduces the three domains of life and the various types of eukaryotes. Prokaryotes and eukaryotes are also pictorially displayed.

Part I The Cell

- Chapter 5, *Membrane Structure and Function*, introduces the concept of cell signaling. New to this edition, the plasma membrane art now depicts the extracellular matrix (see Fig. 5.1), which has a role in cell signaling—a topic that is further explored in the Science Focus, "How Cells Talk to One Another."
- Chapter 8, *Cellular Respiration*, begins with a new section that now emphasizes that cellular respiration is the reason we eat and breathe (see Figure 8.1). The fermentation section in this edition precedes the events that occur in mitochondria and is enhanced by a new Science Focus box, "Fermentation Helps Produce Numerous Food Products." The chapter now ends with a comparison of photosynthesis to cellular respiration (see Fig. 8.12).

Overview of Changes to *Biology*, Tenth Edition

VISUALS

The brilliant visuals program of the previous edition is enhanced even more by the addition of many new micrographs and innovative page layouts.

CELLULAR BIOLOGY

Cell signaling receives expanded coverage as a mechanism of cellular metabolism and cell division control.

GENETICS

Reorganization of the genetics chapters results in increased genome coverage, including the role of small RNA molecules in regulation.

SYSTEMATICS

Cladistics is better explained, and new evolutionary trees are presented for protists, plants, and animals.

EVOLUTION

A new chapter, *Speciation and Macroevolution*, points to the possible role of Hox genes in punctuated evolution.

PLANT EVOLUTION

A reorganization of Chapter 23 better describes the evolution of plants from an aquatic green algal ancestor.

ANIMAL EVOLUTION

Reorganization of Part VI results in two new animal diversity chapters: the invertebrates and the vertebrates.

Part II Genetic Basis of Life

- Chapter 9, *The Cell Cycle and Cellular Reproduction*, builds on the topic of cell signaling that was introduced in Chapter 5. Cell signaling is the means by which the cell cycle, and, therefore, cell division is regulated. A new Science Focus box shows how the G_1 checkpoint is highly regulated by cell signaling, and Figure 9.8 dramatically illustrates how a breakdown in cell cycle regulation may contribute to cancer.
- Chapter 13, *Regulation of Gene Activity*, is an excellent chapter that instructors will not want to overlook because it explains how humans can make do with far fewer protein-coding genes than have been discovered by DNA sequencing of our genome. The chapter is updated by continued emphasis on chromatin structure, many references to the regulatory role of RNA molecules including a new Science Focus box, "Alternative mRNA Splicing in Disease."
- Chapter 14, *Biotechnology and Genomics*, has an expanded section on genomics. Much of chromatin consists of introns and intergenic sequences which may have important functions still to be discovered (see Fig. 14.8). Molecular geneticists are seeking a new definition of a gene that can apply to both protein-coding and non-protein-coding sequences. The chapter also discusses genomic diversity. The new Science Focus box, "DNA Microarray Technology," explains how this technique is now being applied to identify genes involved in health and disease. Another new Science Focus box, "Copy Number Variations," gives another example of genetic diversity within the population and its relationship to health and disease.

Part III Evolution

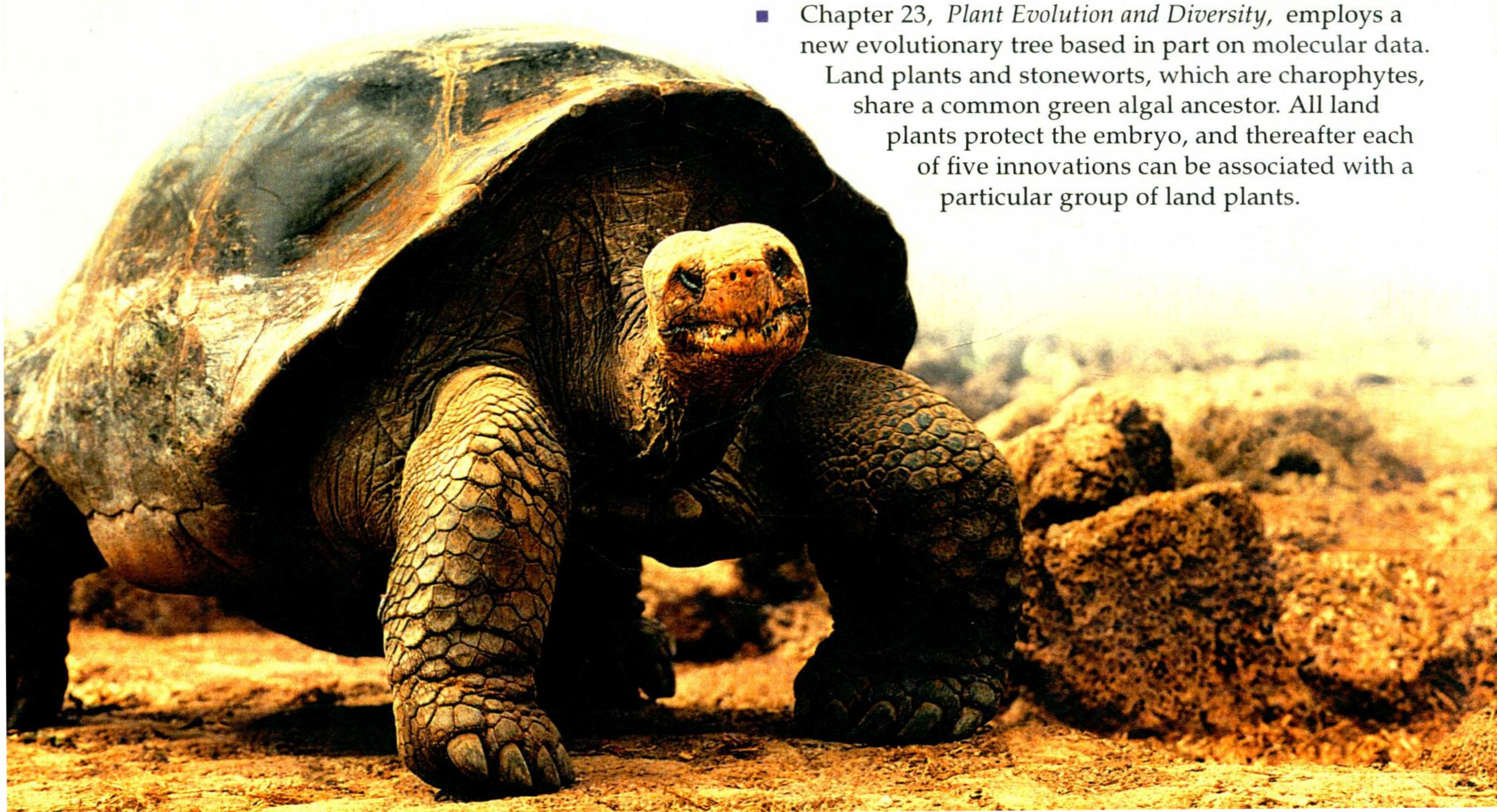
- Chapter 16, *How Populations Evolve*, is an exciting new chapter that begins with an introduction based on community acquired MRSA. This chapter is also enhanced by new figures: an example of genetic diversity (see Fig. 16.1), the gene pool (see Fig. 16.2), microevolution (see Fig. 16.3), and a natural selection experiment (see Fig. 16.10) are included. Also, sexual selection is now included in this chapter.
- Chapter 17, *Speciation and Macroevolution*, is new to this edition. This chapter begins by describing species concepts, and examples of both allopatric and sympatric speciation are given. The concepts of gradualistic and punctuated equilibrium are discussed with reference to the Burgess Shale as an example of rapid evolution to produce many species, and Hox genes are offered as a possible mechanism to bring it about.

Part IV Microbiology and Evolution

- Chapter 21, *Protist Evolution and Diversity*, has been revised because protist classification has undergone dramatic changes in recent years. This chapter is reorganized accordingly, but the biological and ecological relevance of each type of protist is still discussed.

Part V Plant Evolution and Biology

- Chapter 23, *Plant Evolution and Diversity*, employs a new evolutionary tree based in part on molecular data. Land plants and stoneworts, which are charophytes, share a common green algal ancestor. All land plants protect the embryo, and thereafter each of five innovations can be associated with a particular group of land plants.



Part VI Animal Evolution and Diversity

- Chapter 28, *Invertebrates*, has been thoroughly updated and revised in this edition. The chapter better defines an animal and explains the colonial flagellate hypothesis on the origin of animals. The organization of this chapter follows a new evolutionary tree based on molecular and developmental data; the biology of each group is discussed as before.
- Chapter 29, *Vertebrates*, has been reorganized, and each vertebrate group is now a major section. In keeping with modern findings, birds are considered reptiles. Each section begins with a listing of characteristics for that group and is followed by a discussion of the evolution and then the diversity of that group.

Part VII Comparative Animal Biology

- Chapter 33, *Lymph Transport and Immunity*, has been reorganized and revised so that both nonspecific defense (innate immunity) and specific defense (acquired immunity) have their own major section. All concepts regarding antibodies have been brought together in the specific defense section. Immunity side effects has new illustrations; Cytokines and Cancer Therapy is a new subsection.
- Chapter 35, *Respiratory Systems*, is much improved in this edition from an increased emphasis on diversity to a better description of the human respiratory tract and transport of gases (see Figs. 35.3, 35.6, and 35.12). This chapter now ends with a dramatic photo of emphysema and lung cancer (see Fig. 35.15). "Connecting the Concepts" emphasizes the contribution of the respiratory system to homeostasis by description and art.
- Chapter 41, *Reproductive Systems*, now begins with a revised comparative section that includes more photos. An illustration depicting contraceptives replaces a table, and there is a new Health Focus, "Preimplantation Genetic Diagnosis." Sexually transmitted diseases have been updated to reflect current statistics. A new bioethical issue concerns the use of fertility drugs.

Part VIII Behavior and Ecology

- Chapter 43, *Behavioral Ecology*, has an evolutionary emphasis culminating in a new section entitled "Behaviors that Increase Fitness" in which several types of societal interactions are explored as a means to increase representation of genes in the next generation. Orientation and migratory behavior and cognitive learning are ways of learning not discussed previously.
- Chapter 45, *Community and Ecosystem Ecology*, is a combined chapter that allows instructors to cover the basics of ecology in one chapter. A discussion of symbiotic relationships and ecological succession precede the concepts of chemical cycling and energy flow in ecosystems.

About the Author

Dr. Sylvia S. Mader has authored several nationally recognized biology texts published by McGraw-Hill. Educated at Bryn Mawr College, Harvard University, Tufts University, and Nova Southeastern University, she holds degrees in both Biology and Education. Over the years, she has taught at the University of Massachusetts–Lowell, Massachusetts Bay Community College, Suffolk University, and Nathan Matthew Seminars. Her ability to reach out to science-shy students led to the writing of her first text, *Inquiry into Life*, which is now in its twelfth edition. Highly acclaimed for her crisp and entertaining writing style, her books have become models for others who write in the field of biology.

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

For My Children

Sylvia Mader

Guided Tour

Increased Evolutionary Coverage

NEW CHAPTERS

16 (*How Populations Evolve*) and 17 (*Speciation and Macroevolution*) highlight new evolutionary coverage.

Early observation

Later observation

36% dark-colored phenotype

64% dark-colored phenotype

FIGURE 16.3 Microevolution.

Microevolution has occurred when there is a change in gene pool frequencies—in this case, due to natural selection. On the left, birds cannot see light-colored peppered moths, *Biston betularia*, against light-colored vegetation—and, therefore, light-colored moths are more frequent in the population. On the right, after vegetation has been darkened due to pollution, birds are less likely to see dark-colored moths against dark vegetation, and dark moths are more frequent in the population.

The **Hardy-Weinberg principle** states that an equilibrium of gene pool frequencies, calculated by using the bi-
ession, will remain in effect in each succeeding
f a sexually reproducing population, as long as
ns are met:

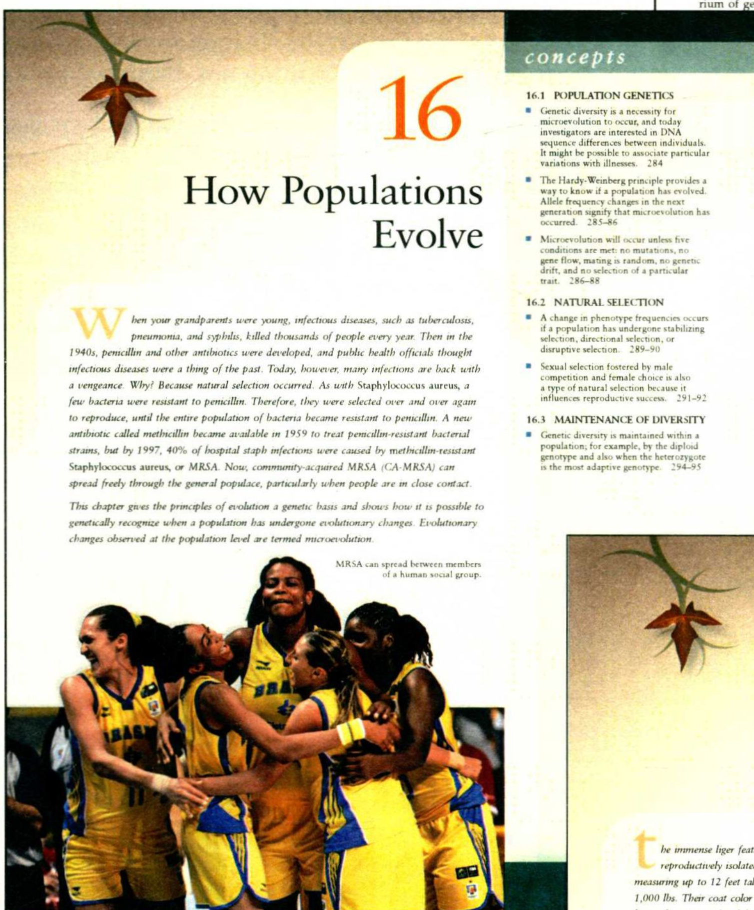
tations: Allele changes do not occur, or changes
direction are balanced by changes in the
te direction.
e flow: Migration of alleles into or out of the
tion does not occur.
m mating: Individuals pair by chance, not
ing to their genotypes or phenotypes.
etic drift: The population is very large, and
s in allele frequencies due to chance alone are
ficant.
ection: Selective forces do not favor one
pe over another.

life, these conditions are rarely, if ever, met,
requencies in the gene pool of a population
from one generation to the next. Therefore,
as occurred. The significance of the Hardy-
rinciple is that it tells us what factors cause
those that violate the conditions listed. Micro-
n be detected by noting any deviation from a
berg equilibrium of allele frequencies in the
f a population.
ge in allele frequencies may result in a change
e frequencies. Our calculation of gene pool frequencies in Figure 16.3 assumes that industrial melanism may have started but was not fully in force yet. **Industrial melanism** refers to a darkening of moths once industrialization has begun in a country. Prior to the Industrial Revolution in Great Britain, light-colored peppered moths living on the light-colored, unpolluted vegetation, were more common than dark-colored peppered moths. When dark-colored moths landed on light vegetation, they were seen and eaten by predators. In Figure 16.3, *left*, we suppose that only 36% of the population were dark-colored, while 64% were light-colored. With the advent of industry and an increase in pollution, the vegetation was stained darker. Now, light-colored moths were easy prey for predators. Figure 16.3, *right*, assumes that the gene pool frequencies switched, and now the dark-colored moths are 64% of the population. Can you calculate the change in gene pool frequencies using Figure 16.2 as a guide?

Just before the Clean Air legislation in the mid-1950s, the numbers of dark-colored moths exceeded a frequency of 80% in some populations. After the legislation, a dramatic reversal in the ratio of light-colored moths to dark-colored moths occurred once again as light-colored moths became more and more frequent. Aside from showing that natural selection can occur within a short period of time, our example shows that a change in gene pool frequencies does occur as microevolution occurs. Recall that microevolution occurs below the species level.

Causes of Microevolution

The list of conditions for a Hardy-Weinberg equilibrium implies that the opposite conditions can cause evolutionary



16

How Populations Evolve

When your grandparents were young, infectious diseases, such as tuberculosis, pneumonia, and syphilis, killed thousands of people every year. Then in the 1940s, penicillin and other antibiotics were developed, and public health officials thought infectious diseases were a thing of the past. Today, however, many infections are back with a vengeance. Why? Because natural selection occurred. As with Staphylococcus aureus, *a few bacteria were resistant to penicillin. Therefore, they were selected over and over again to reproduce, until the entire population of bacteria became resistant to penicillin. A new antibiotic called methicillin became available in 1959 to treat penicillin-resistant bacterial strains, but by 1997, 40% of hospital staph infections were caused by methicillin-resistant* Staphylococcus aureus, *or MRSA. Now, community-acquired MRSA (CA-MRSA) can spread freely through the general populace, particularly when people are in close contact.*

This chapter gives the principles of evolution a genetic basis and shows how it is possible to genetically recognize when a population has undergone evolutionary changes. Evolutionary changes observed at the population level are termed microevolution.

MRSA can spread between members of a human social group.

concepts

16.1 POPULATION GENETICS

- Genetic diversity is a necessity for microevolution to occur, and today investigators are interested in DNA sequence differences between individuals. It might be possible to associate particular variations with illnesses. 284
- The Hardy-Weinberg principle provides a way to know if a population has evolved. Allele frequency changes in the next generation signify that microevolution has occurred. 285–86
- Microevolution will occur unless five conditions are met: no mutations, no gene flow, mating is random, no genetic drift, and no selection of a particular trait. 286–88

16.2 NATURAL SELECTION

- A change in phenotype frequencies occurs if a population has undergone stabilizing selection, directional selection, or disruptive selection. 289–90
- Sexual selection fostered by male competition and female choice is also a type of natural selection because it influences reproductive success. 291–92

16.3 MAINTENANCE OF DIVERSITY

- Genetic diversity is maintained within a population; for example, by the diploid genotype and also when the heterozygote is the most adaptive genotype. 294–95

17

Speciation and Macroevolution

The immense liger featured here is an offspring of a lion and a tiger, two normally reproductively isolated animal species. Ligers are the largest of all known cats, measuring up to 12 feet tall when standing on their hind legs and weighing as much as 1,000 lbs. Their coat color is usually tan with tiger stripes on the back and hindquarters and lion cub spots on the abdomen. A liger can produce both the "chuff" sound of a tiger and the roar of a lion. Male ligers may have a modest lion mane or no mane at all. Most ligers like to be near water and love to swim. Generally, ligers have a gentle disposition; however, considering their size and heritage, handlers should be extremely careful. By what criteria could a liger be considered a new species? Only if they, in turn, were reproductively isolated and only mated with ligers. In this chapter, we will explore the definition of a species and how species arise. In so doing, we will begin our discussion of macroevolution, which we continue in the next chapter.

This liger is a hybrid because it has a lion father and a tiger mother.

concepts

17.1 SEPARATION OF THE SPECIES

- Species can be recognized by their traits, by reproductive isolation, and by DNA differences. 300–301
- Mechanisms that prevent reproduction between species are divided into those that prevent attempts at reproduction and those that prevent development of an offspring or cause the offspring to be infertile. 302–3

17.2 MODES OF SPECIATION

- Allopatric speciation occurs when a new species evolves in geographic isolation from an ancestral species. 304–5
- Adaptive radiation, during which a single species gives rise to a number of different species, is an example of allopatric speciation. 306
- Sympatric speciation occurs when a new species evolves without geographic isolation. 307
- The Burgess Shale gives us a glimpse of marine life some 540 million years ago. 308–9

17.3 PRINCIPLES OF MACROEVOLUTION

- Macroevolution is phenotypic changes at the species and higher levels of taxonomy up to a domain. 310
- The tempo of speciation can be rapid or slow. Developmental genes provide a mechanism for rapid speciation. 311–12
- Macroevolution involves speciation, diversification, and extinction, as observed in the evolution of the horse. Macroevolution is not goal directed and, instead, represents adaptation to varied environments through time. 313–14

1.2 Evolution, the Unifiying Concept of Biology

Despite diversity in form, function, and lifestyle, organisms share the same basic characteristics. As mentioned, they are all composed of cells organized in a similar manner. Their genes are composed of DNA, and they carry out the same metabolic reactions to acquire energy and maintain their organization. The unity of living things suggests that they are descended from a common ancestor—the first cell or cells.

An evolutionary tree is like a family tree (Fig. 1.5). Just as a family tree shows how a group of people have descended from one couple, an evolutionary tree traces the ancestry of life on Earth to a common ancestor. One couple can have diverse children, and likewise a population can be a common ancestor to several other groups, each adapted to a particular set of environmental conditions. In this way, over time, diverse life-forms have arisen. Evolution may be considered the unifying concept of biology because it explains so many aspects of biology, including how living organisms arose from a single ancestor.

Organizing Diversity

Because life is so diverse, it is helpful to group organisms into categories. **Taxonomy** [Gk. *tasso*, arrange, and *nomos*, usage] is the discipline of identifying and grouping organisms according to certain rules. Taxonomy makes sense out of the bewildering variety of life on Earth and is meant to provide valuable insight into evolution. As more is learned about living things, including the evolutionary relationships between species, taxonomy changes. DNA technology is now being used to revise current information and to discover previously unknown relationships between organisms.

Several of the basic classification categories, or *taxa*, going from least inclusive to most inclusive, are **species, genus, family, order, class, phylum, kingdom,** and **domain** (Table 1.1). The least inclusive category, species [L. *species*, model, kind], is defined as a group of interbreeding individuals. Each successive classification category above species contains more types of organisms than the preceding one. Species placed within one genus share many specific characteristics and are the most closely related, while species placed in the same kingdom share only general characteristics with one another. For example, all species in the genus *Pisum* look pretty much the same—that is, like pea plants—but species in the plant kingdom can be quite varied, as is evident when we compare grasses to trees. Species placed in different domains are the most distantly related.

TABLE 1.1

Levels of Classification

Category	*Human*	*Corn*
Domain	**Eukarya**	**Eukarya**
Kingdom	Animalia	Plantae
Phylum	Chordata	Anthophyta
Class	Mammalia	Monocotyledones
Order	Primates	Commelinales
Family	Hominidae	Poaceae
Genus	*Homo*	*Zea*
Species*	*H. sapiens*	*Z. mays*

*To specify an organism, you must use the full binomial name, such as *Homo sapiens*.

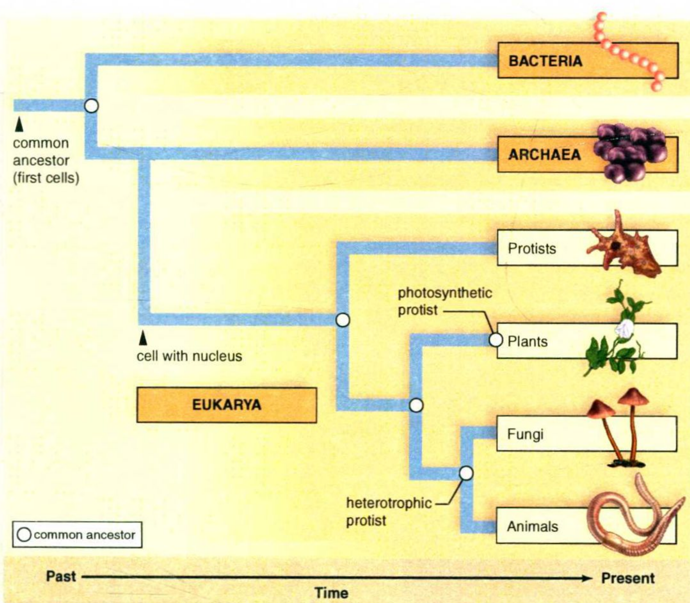


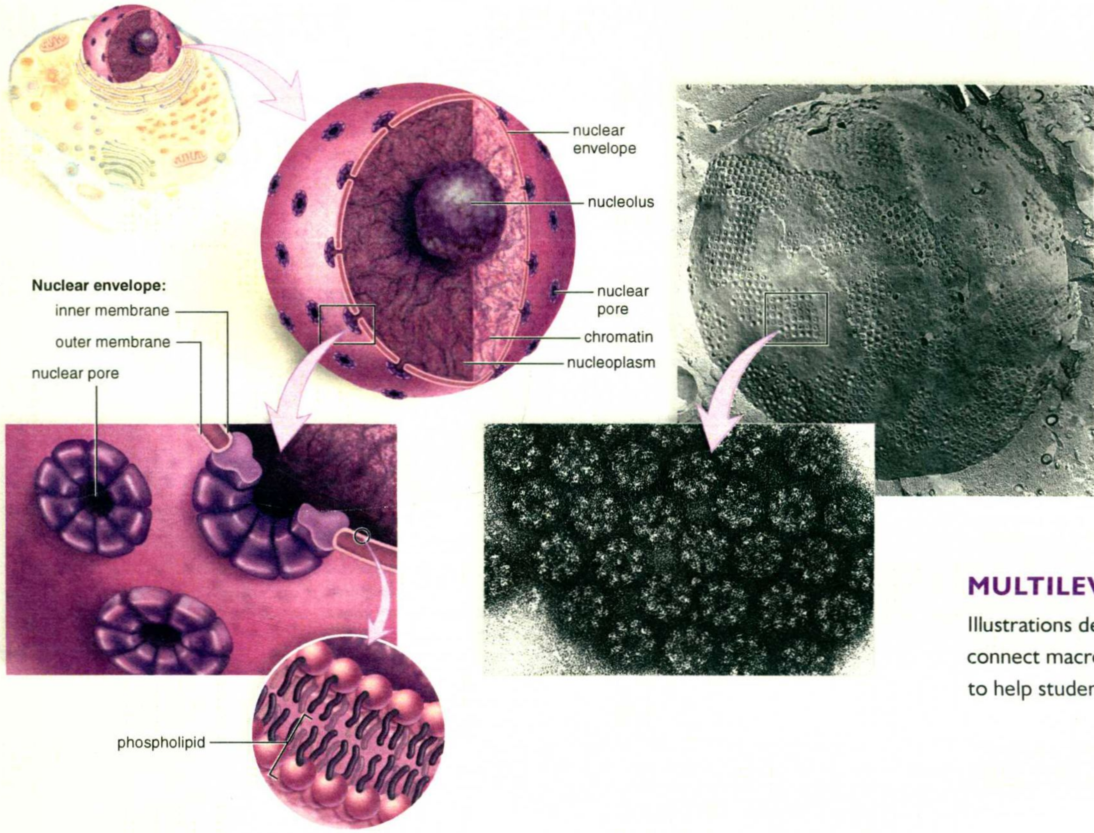
FIGURE 1.5 Evolutionary tree of life.

As existing organisms change over time, they give rise to new species. Evolutionary studies show that all living organisms arose from a common ancestor about 4 billion years ago. Domain Archaea includes prokaryotes capable of surviving in extreme environments, such as those with high salinity and temperature and low pH. Domain Bacteria includes metabolically diverse prokaryotes widely distributed in various environments. The domain Eukarya includes both unicellular and multicellular organisms that possess a membrane-bounded nucleus.

NEW SECTION

Chapter 1 includes a new section that covers basic evolutionary principles and a new depiction of the Tree of Life which introduces the three domains of life.

A Stunning Visuals Program

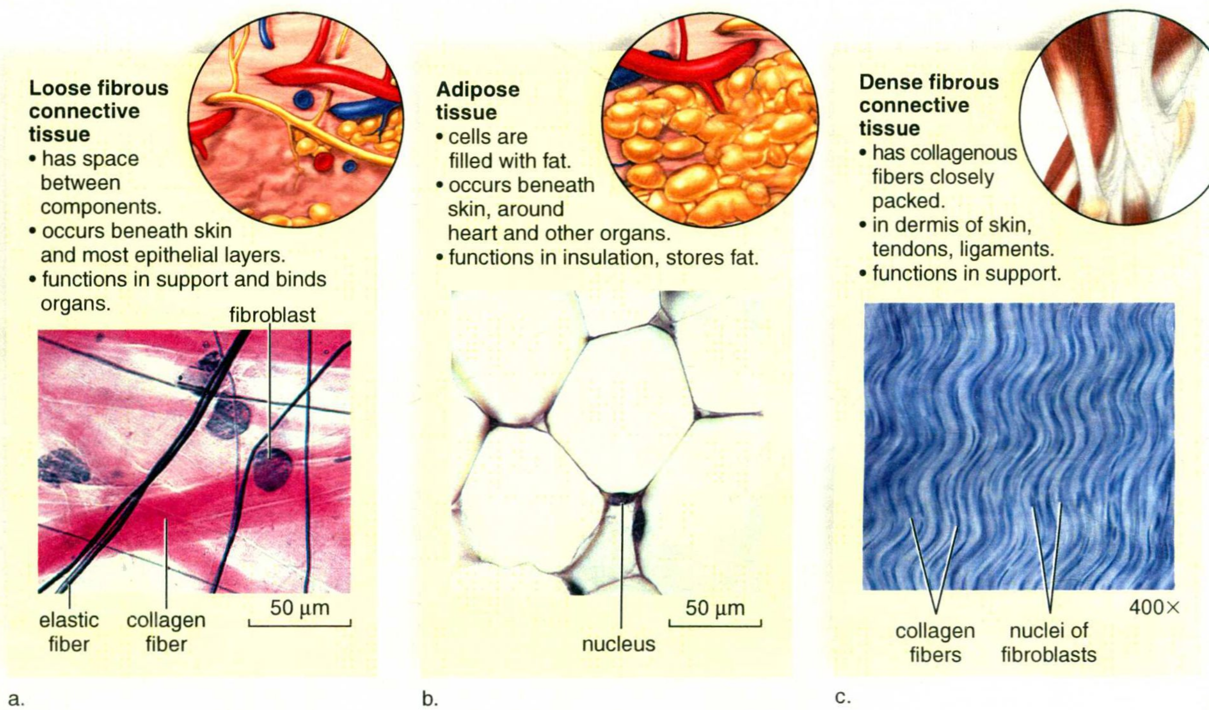


MULTILEVEL PERSPECTIVE

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

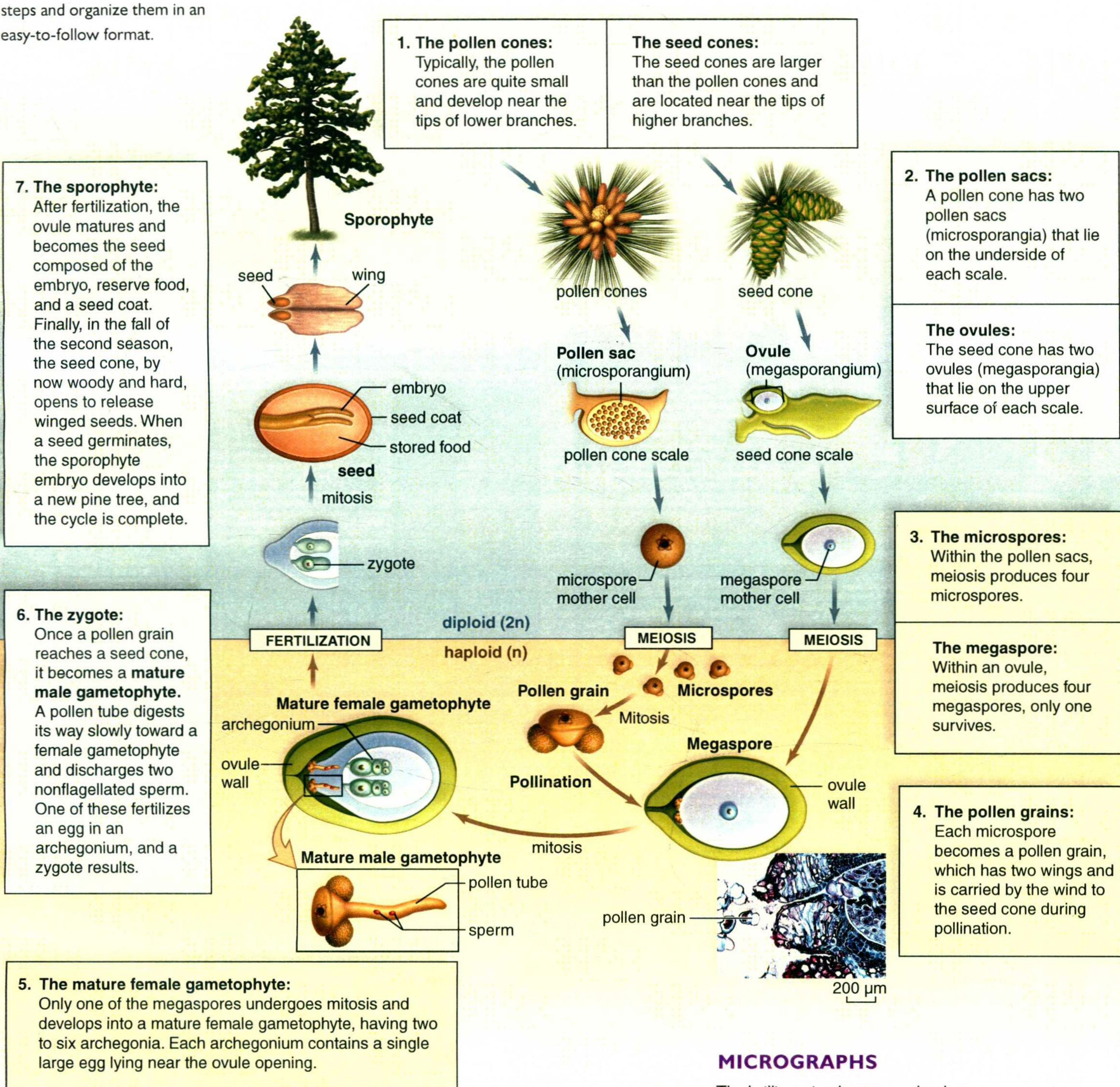
COMBINATION ART

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.



MICROGRAPHS

The brilliant visuals program has been enhanced by many new micrographs.

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.


8

Cellular Respiration

a bacterium with undulating flagella, an ocelot climbing a tree, a snail moving slowly to hide under a rock, or humans marching past a giant cactus—are all making and using ATP—and so is the cactus. ATP is ancient, a molecular fossil, really, and its molecular structure, plus its presence in the first cell or cells that arose on planet Earth, accounts for it being the universal energy currency of cells.

ATP is unique among the cell's storehouse of chemicals; amino acids join to make a protein, and nucleotides join to make DNA or RNA, but ATP is singular and works alone. Whether you go skiing, take an aerobics class, or just hang out, ATP molecules provide the energy needed for nerve conduction, muscle contraction, and any other cellular process that requires energy. Cellular respiration, by which cells harvest the energy of organic compounds and convert it to ATP molecules, is the topic of this chapter. It's
...s that requires many steps and involves the cytoplasm and the mitochondria.
...mitochondria are involved, they are called the powerhouses of the cell.

Tourists marching through a prickly pear cactus grove on the Galápagos Islands.

concepts

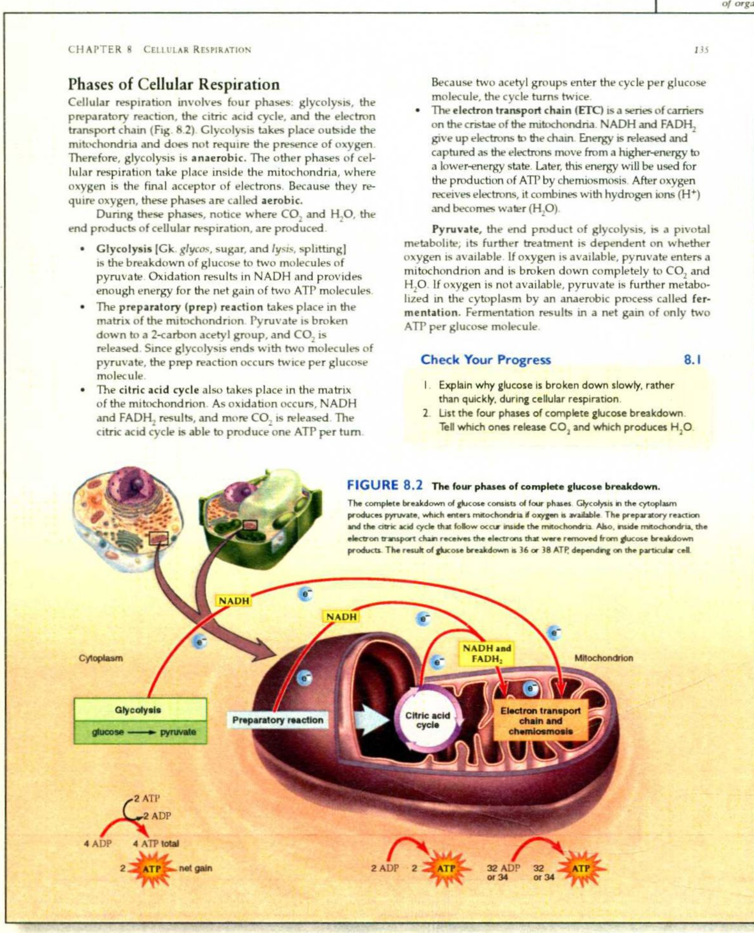
8.1 CELLULAR RESPIRATION
- The energy of nutrients is converted to that of ATP molecules during cellular respiration. The process utilizes the coenzymes NAD^+ and FAD as carriers of electrons. 134
- The complete breakdown of glucose requires four phases, three of which are metabolic pathways. 135

8.2 OUTSIDE THE MITOCHONDRIA: GLYCOLYSIS
- Glycolysis is a metabolic pathway that partially breaks down glucose outside the mitochondria. 136–37

8.3 FERMENTATION
- If oxygen is not available, fermentation partially breaks down glucose under anaerobic conditions. 138–39

8.4 INSIDE THE MITOCHONDRIA
- If oxygen is available, the preparatory (prep) reaction and the citric acid cycle, which occur inside the mitochondria, continue the breakdown of glucose products until carbon dioxide and water result. 140–41
- The electron transport chain, which receives electrons from NADH and $FADH_2$, produces most of the ATP during cellular respiration. 142–44

8.5 METABOLIC POOL
- Cellular respiration is central to metabolism. Its breakdown products are metabolites for synthetic reactions. 145
- An examination of chloroplasts and mitochondria shows that they have a similar anatomy, despite having opposite functions. These functions permit a flow of energy throughout the biosphere. 146


CHAPTER 8 Cellular Respiration 135

Phases of Cellular Respiration

Cellular respiration involves four phases: glycolysis, the preparatory reaction, the citric acid cycle, and the electron transport chain (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. Because they require oxygen, these phases are called **aerobic.**

During these phases, notice where CO_2 and H_2O, the end products of cellular respiration, are produced.

- **Glycolysis** [Gk. *glycos*, sugar, and *lysis*, splitting] is the breakdown of glucose to two molecules of pyruvate. Oxidation results in NADH and provides enough energy for the net gain of two ATP molecules.
- The **preparatory (prep) reaction** takes place in the matrix of the mitochondrion. Pyruvate is broken down to a 2-carbon acetyl group, and CO_2 is released. Since glycolysis ends with two molecules of pyruvate, the prep reaction occurs twice per glucose molecule.
- The **citric acid cycle** also takes place in the matrix of the mitochondrion. As oxidation occurs, NADH and $FADH_2$ results, and more CO_2 is released. The citric acid cycle is able to produce one ATP per turn. Because two acetyl groups enter the cycle per glucose molecule, the cycle turns twice.
- The **electron transport chain (ETC)** is a series of carriers on the cristae of the mitochondria. NADH and $FADH_2$ give up electrons to the chain. Energy is released and captured as the electrons move from a higher-energy to a lower-energy state. Later, this energy will be used for the production of ATP by chemiosmosis. After oxygen receives electrons, it combines with hydrogen ions (H^+) and becomes water (H_2O).

Pyruvate, the end product of glycolysis, is a pivotal metabolite; its further treatment is dependent on whether oxygen is available. If oxygen is available, pyruvate enters a mitochondrion and is broken down completely to CO_2 and H_2O. If oxygen is not available, pyruvate is further metabolized in the cytoplasm by an anaerobic process called **fermentation.** Fermentation results in a net gain of only two ATP per glucose molecule.

Check Your Progress 8.1

1. Explain why glucose is broken down slowly, rather than quickly, during cellular respiration.
2. List the four phases of complete glucose breakdown. Tell which ones release CO_2 and which produces H_2O.

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.

CHECK YOUR PROGRESS

Check Your Progress questions appear at the end of each major section of the chapter to help students focus on the key concepts.

Three Types of Boxed Readings

Science Focus readings describe how experimentation and observations have contributed to our knowledge about the living world.

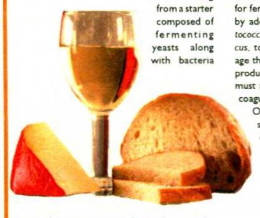
science focus

Fermentation Helps Produce Numerous Food Products

At the grocery store, you will find such items as bread, yogurt, soy sauce, pickles, and maybe even wine (Fig. 8A). These are just a few of the many foods that are produced when microorganisms ferment (break down sugar in the absence of oxygen). Foods produced by fermentation last longer because the fermenting organisms have removed many of the nutrients that would attract other organisms. The products of fermentation can even be dangerous to the very organisms that produced them, as when yeasts are killed by the alcohol they produce.

Yeast Fermentation

Baker's yeast, *Saccharomyces cerevisiae*, is added to bread for the purpose of leavening—the dough rises when the yeasts give off CO_2. The ethyl alcohol produced by the fermenting yeast evaporates during baking. The many different varieties of sourdough breads obtain their leavening from a starter composed of fermenting yeasts along with bacteria from the environment. Depending on the community of microorganisms in the starter, the flavor of the bread may range from sour and tangy, as in San Francisco–style sourdough, to a milder taste, such as that produced by most Amish friendship bread recipes.



Ethyl alcohol is desired when yeasts are used to produce wine and beer. When yeasts ferment the carbohydrates of fruits, the end result is wine. If they ferment grain, beer results. A few specialized varieties of beer, such as traditional wheat beers, have a distinctive sour taste because they are produced with the assistance of lactic acid–producing bacteria, such as those of the genus *Lactobacillus*. Stronger alcoholic drinks (e.g., whiskey and vodka) require distillation to concentrate the alcohol content.

The acetic acid bacteria, including *Acetobacter aceti*, spoil wine. These bacteria convert the alcohol in wine or cider to acetic acid (vinegar). Until the renowned nineteenth-century scientist Louis Pasteur invented the process of pasteurization, acetic acid bacteria commonly caused wine to spoil. Although today we generally associate the process of pasteurization with making milk safe to drink, it was originally developed to reduce bacterial contamination in wine so that limited acetic acid would be produced.

Bacterial Fermentation

Yogurt, sour cream, and cheese are produced through the action of various lactic acid bacteria that cause milk to sour. Milk contains lactose, which these bacteria use as a substrate for fermentation. Yogurt, for example, is made by adding lactic acid bacteria, such as *Streptococcus thermophilus* and *Lactobacillus bulgaricus*, to milk and then incubating it to encourage the bacteria to act on lactose. During the production of cheese, an enzyme called rennin must also be added to the milk to cause it to coagulate and become solid.

Old-fashioned brine cucumber pickles, sauerkraut, and kimchi are pickled vegetables produced by the action of acid-producing, fermenting bacteria that can survive in high-salt environments. Salt is used to draw liquid out of the vegetables and aid in their preservation. The bacteria need not be added to the vegetables, because they are already present on the surfaces of the plants.

Soy Sauce Production

Soy sauce is traditionally made by adding a mold, *Aspergillus*, and a combination of yeasts and fermenting bacteria to soybeans and wheat. The mold breaks down starch, supplying the fermenting microorganisms with sugar they can use to produce alcohol and organic acids.

FIGURE 8A Products from fermentation.
Fermentation helps make the products shown on this page.

ecology focus

Carboniferous Forests

Our industrial society runs on fossil fuels such as coal. The term *fossil fuel* might seem odd at first until one realizes that it refers to the remains of organic material from ancient times. During the Carboniferous period more than 300 million years ago, a great swamp forest (Fig. 23A) encompassed what is now northern Europe, the Ukraine, and the Appalachian Mountains in the United States. The weather was warm and humid, and the trees grew very tall. These are not the trees we know today; instead, they are related to today's seedless vascular plants: the lycophytes, horsetails, and ferns! Lycophytes today may stand as high as 30 cm, but their ancient relatives were 35 m tall and 1 m wide. The stroboli were up to 30 cm long, and some had leaves more than 1 m long. Horsetails too—at 18 m tall—were giants compared to today's specimens. Tree ferns were also taller than tree ferns found in the tropics today. The progymnosperms, including "seed ferns," were significant plants of a Carboniferous swamp. Seed ferns are misnamed because they were actually progymnosperms.

The amount of biomass in a Carboniferous swamp forest was enormous, and occasionally the swampy water rose and the trees fell. Trees under water do not decompose well, and their partially decayed remains became covered by sediment that sometimes changed to sedimentary rock. Exposed to pressure from sedimentary rock, the organic material then became coal, a fossil fuel. This process continued for millions of years, resulting in immense deposits of coal. Geological upheavals raised the deposits to the level where they can be mined today.

With a change of climate, the trees of the Carboniferous period became extinct, and only their herbaceous relatives survived to our time. Without these ancient forests, our life today would be far different because they helped bring about our industrialized society.

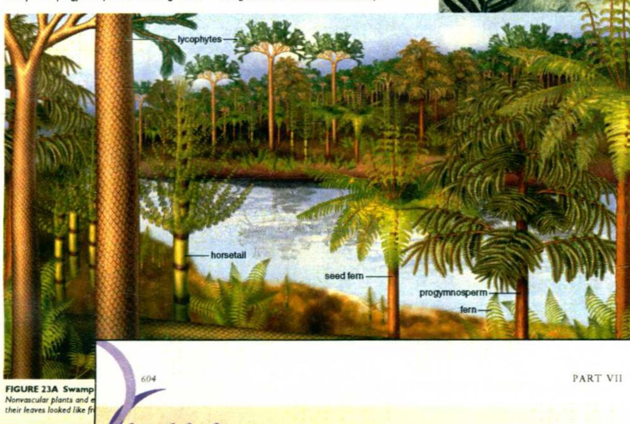


FIGURE 23A Swamp
Nonvascular plants and
their leaves looked like

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.

health focus

Prevention of Cardiovascular Disease

All of us can take steps to prevent cardiovascular disease, the most frequent cause of death in the United States. Certain genetic factors predispose an individual to cardiovascular disease, such as family history of heart attack under age 55, male gender, and ethnicity (African Americans are at greater risk). People with one or more of these risk factors need not despair, however. It means only that they should pay particular attention to the following guidelines for a heart-healthy lifestyle.

The Don'ts

Smoking

Hypertension is well recognized as a major contributor to cardiovascular disease. When a person smokes, the drug nicotine, present in cigarette smoke, enters the bloodstream. Nicotine causes the arterioles to constrict and the blood pressure to rise. Restricted blood flow and cold hands are associated with smoking in most people. More serious is the need for the heart to pump harder to propel the blood through the lungs at a time when the oxygen-carrying capacity of the blood is reduced.

Drug Abuse

Stimulants, such as cocaine and amphetamines, can cause an irregular heartbeat and lead to heart attacks and strokes in people who are using drugs even for the first time. Intravenous drug use may result in a cerebral embolism.

Too much alcohol can destroy just about every organ in the body, the heart included. But investigators have discovered that people who take an occasional drink have a 20% lower risk of heart disease than do teetotalers. Two to four drinks a week is the recommended limit for men; one to three drinks for women.

Weight Gain

Hypertension is prevalent in persons who are more than 20% above the recommended weight for their height. In those who are overweight, more tissues require servicing, and the heart sends the extra blood out under greater pressure. It may be harder to lose weight once it is gained, and therefore it is recommended that weight control be a lifelong endeavor. Even a slight decrease in weight can bring with it a reduction in hypertension. A 4.5-kg weight (about 10 lbs) loss doubles the chance that blood pressure can be normalized without drugs.

The Dos

Healthy Diet

Diet influences the amount of cholesterol in the blood. Cholesterol is ferried by two types of plasma proteins, called LDL (low-density lipoprotein) and HDL (high-density lipoprotein). LDL (called "bad" lipoprotein) takes cholesterol from the liver to the tissues, and HDL (called "good" lipoprotein) transports cholesterol out of the tissues to the liver. When the LDL level in blood is high or the HDL level is abnormally low, plaque, which interferes with circulation, accumulates on arterial walls (Fig. 32A).

Eating foods high in saturated fat (red meat, cream, and butter) and foods containing so-called trans-fats (most margarines, commercially baked goods, and deep-fried foods) raises the LDL-cholesterol level. Replacement of these harmful fats with healthier ones, such as monounsaturated fats (olive and canola oils) and polyunsaturated fats (corn, safflower, and soybean oils), is recommended. Cold water fish (e.g., halibut, sardines, tuna, and salmon) contain polyunsaturated fatty acids and especially omega-3 polyunsaturated fatty acids, which can reduce plaque.

Evidence is mounting to suggest a role for antioxidant vitamins (A, E, and C) in preventing cardiovascular disease. Antioxidants protect the body from free radicals that oxidize cholesterol and damage the lining of an artery, leading to a blood clot that can block blood vessels. Nutritionists believe that consuming at least five servings of fruits and vegetables a day may protect against cardiovascular disease.

Cholesterol Profile

Starting at age 20, all adults are advised to have their cholesterol levels tested at least every five years. Even in healthy individuals, an LDL level above 160 mg/100 ml and an HDL level below 40 mg/100 ml are matters of concern. If a person has heart disease or is at risk for heart disease, an LDL level below 100 mg/100 ml is now recommended. Medications will most likely be prescribed for individuals who do not meet these minimum guidelines.

Exercise

People who exercise are less apt to have cardiovascular disease. One study found that moderately active men who spent an average of 48 minutes a day on a leisure-time activity such as gardening, bowling, or dancing had one-third fewer heart attacks than peers who spent an average of only 16 minutes each day being active. Exercise helps keep weight under control, may help minimize stress, and reduces hypertension. The heart beats faster whe
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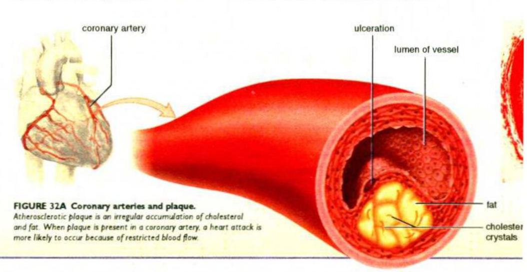


FIGURE 32A Coronary arteries and plaque.
Atherosclerotic plaque is an irregular accumulation of cholesterol and fat. When plaque is present in a coronary artery, a heart attack is more likely to occur because of restricted blood flow.

End of Chapter Study Tools

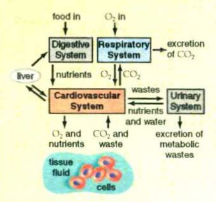
CONNECTING THE CONCEPTS

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



In mammals, the respiratory system consists of the respiratory tract with the nasal passages (or mouth) at one end and the lungs at the other end. Inspired air is 20% O_2 and 0.04% CO_2, while expired air is about 14% O_2 and 6% CO_2. Gas exchange in the lungs accounts for the difference in composition of inspired and expired air.

In the lungs, oxygen is absorbed into the bloodstream and from there it is transported by red blood cells to the capillaries, where it exits and enters tissue fluid. On the other hand, carbon dioxide enters capillaries at the tissues and is transported largely as the bicarbonate ion to the lungs, where it is converted to carbon dioxide and exits the body. Diffusion alone accounts for gas exchange in the lungs, called external respiration, and gas exchange in the tissues, called internal respiration. Energy is not needed, as gases follow their concentration gradients according to their partial pressures.

Internal gas exchange is extremely critical because cells use oxygen and release carbon dioxide as a result of cellular respiration, the process that generates ATP in cells. External gas exchange has the benefit of helping to keep the pH of the blood constant as required for homeostasis. When carbon dioxide exits, the blood pH returns to normal. In Chapter 36, we consider the contribution of the kidneys to homeostasis.

summary

35.1 Gas Exchange Surfaces

Some aquatic animals, such as hydras and planarians, use their entire body surface for gas exchange. Most animals have a specialized gas-exchange area. Large aquatic animals usually pass water through gills. In bony fishes, blood in the capillaries flows in the direction opposite that of the water. Blood takes up almost all of the oxygen in the water as a result of this countercurrent flow. On land, insects use tracheal systems, and vertebrates have lungs. In insects, air enters the tracheae at openings called spiracles. From there, the air moves to ever smaller tracheoles until gas exchange takes place at the cells themselves. Lungs are found inside the body, where water loss is reduced. To ventilate the lungs, some vertebrates use positive pressure, but most inhale, using muscular contraction to produce a negative pressure that causes air to rush into the lungs. When the breathing muscles relax, air is exhaled.

Birds have a series of air sacs attached to the lungs. When a bird inhales, air enters the posterior air sacs, and when a bird exhales, air moves through the lungs to the anterior air sacs before exiting the respiratory tract. The one-way flow of air through the lungs allows more fresh air to be present in the lungs with each breath, and this leads to greater uptake of oxygen from one breath of air.

35.2 Breathing and Transport of Gases

During inspiration, air enters the body at nasal cavities and then passes from the pharynx through the glottis, larynx, trachea, bronchi, and bronchioles to the alveoli of the lungs, where exchange occurs, and during expiration air passes in the opposite direction. Humans breathe by negative pressure, as do other mammals. During inspiration, the rib cage goes up and out, and the diaphragm lowers. The lungs expand ...shing in. During expiration, the rib cage goes down ...iaphragm rises. Therefore, air rushes out. ...f breathing increases when the amount of H^+ and ...in the blood rises, as detected by chemoreceptors ...ic and carotid bodies. ...ge in the lungs and tissues is brought about by diffusion. ...sports oxygen in the blood; carbon dioxide is mainly ...lasma as the bicarbonate ion. Excess hydrogen ions are transported by hemoglobin. The enzyme carbonic anhydrase found in red blood cells speeds the formation of the bicarbonate ion.

35.3 Respiration and Health

The respiratory tract is subject to infections such as pneumonia and pulmonary tuberculosis. New strains of tuberculosis are resistant to the usual antibiotic therapy.

Major lung disorders are usually due to cigarette smoking. In chronic bronchitis the air passages are inflamed, mucus is common, and the cilia that line the respiratory tract are gone. Emphysema and lung cancer are two of the most serious consequences of smoking cigarettes. When the lungs of these patients are removed upon death, they are blackened by smoke.

understanding the terms

alveolus (pl., alveoli) 654	heme 659
aortic body 657	hemoglobin (Hb) 659
bicarbonate ion 659	inspiration 656
bronchiole 655	internal respiration 650
bronchus (pl., bronchi) 655	larynx 654
carbaminohemoglobin 659	lungs 651
carbonic anhydrase 659	oxyhemoglobin 659
carotid body 657	partial pressure 658
countercurrent exchange 652	pharynx 654
diaphragm 656	respiration 650
epiglottis 654	respiratory center 657
expiration 656	trachea (pl., tracheae) 653, 654
external respiration 650	ventilation 650
gills 651	vocal cord 654
glottis 654	

Match the terms to these definitions:

a. ______________ In terrestrial vertebrates, the mechanical act of moving air in and out of the lungs; breathing.

b. ______________ Dome-shaped muscularized sheet separating the thoracic cavity from the abdominal cavity in mammals.

c. ______________ Fold of tissue within the larynx; creates vocal sounds when it vibrates.

d. ______________ Respiratory organ in most aquatic animals; in fish, an outward extension of the pharynx.

e. ______________ Stage during breathing when air is pushed out of the lungs.

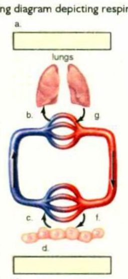
reviewing this chapter

1. Compare the respiratory organs of aquatic animals to those of terrestrial animals. 650–54
2. How does the countercurrent flow of blood within gill capillaries and water passing across the gills assist respiration in fishes? 652
3. Why is it beneficial for the body wall of earthworms to be moist? Why don't insects require circulatory system involvement in air transport? 653
4. Name the parts of the human respiratory system, and list a function for each part. How is the air reaching the lungs cleansed? 654
5. Explain the phrase "breathing by using negative pressure." 656
6. Contrast the tidal ventilation mechanism in humans with the one-way ventilation mechanism in birds, and explain the benefits of the ventilation mechanism in birds. 656–57
7. The concentration of what substances in blood controls the breathing rate in humans? Explain. 658
8. How are oxygen and carbon dioxide transported in blood? What does carbonic anhydrase do? 659
9. Which conditions depicted in Figure 35.14 are due to infection? Which are due to behavioral or environmental factors? Explain. 660–61

testing yourself

Choose the best answer for each question.

1. Label the following diagram depicting respiration.



2. One problem faced by terrestrial animals with lungs, but not by aquatic animals with gills, is that
   a. gas exchange involves water loss.
   b. breathing requires considerable energy.
   c. oxygen diffuses very slowly in air.
   d. the concentration of oxygen in water is greater than that in air.
   e. All of these are correct.
3. In which animal is the circulatory system not involved in gas transport?
   a. mouse
   b. dragonfly
   c. trout
   d. sparrow
   e. human
4. Birds have more efficient lungs than humans because the flow of air
   a. is the same during both inspiration and expiration.
   b. travels in only one direction through the lungs.
   c. never backs up as it does in human lungs.
   d. is not hindered by a larynx.
   e. enters their bones.
5. Which animal breathes by positive pressure?
   a. fish
   b. human
   c. bird
   d. frog
   e. planarian
6. Which of these is a true statement?
   a. In lung capillaries, carbon dioxide combines with water to produce carbonic acid.
   b. In tissue capillaries, carbonic acid breaks down to carbon dioxide and water.
   c. In lung capillaries, carbonic acid breaks down to carbon dioxide and water.
   d. In tissue capillaries, carbonic acid combines with hydrogen ions to form the carbonate ion.
   e. All of these statements are true.
7. Air enters the human lungs because
   a. atmospheric pressure is less than the pressure inside the lungs.
   b. atmospheric pressure is greater than the pressure inside the lungs.
   c. although the pressures are the same inside and outside, the partial pressure of oxygen is lower within the lungs.
   d. the residual air in the lungs causes the partial pressure of oxygen to be less than it is outside.
   e. the process of breathing pushes air into the lungs.
8. If the digestive and respiratory tracts were completely separate in humans, there would be no need for
   a. swallowing.
   b. a nose.
   c. an epiglottis.
   d. a diaphragm.
   e. All of these are correct.
9. In tracing the path of air in humans, you would list the trachea
   a. directly after the nose.
   b. directly before the bronchi.
   c. before the pharynx.
   d. directly before the lungs.
   e. Both a and c are correct.
10. In humans, the respiratory control center
    a. is stimulated by carbon dioxide.
    b. is located in the medulla oblongata.
    c. controls the rate of breathing.
    d. is stimulated by hydrogen ion concentration.
    e. All of these are correct.
11. Carbon dioxide is carried in the plasma
    a. in combination with hemoglobin.
    b. as the bicarbonate ion.
    c. combined with carbonic anhydrase.
    d. only as a part of tissue fluid.
    e. All of these are correct.
12. Which of these is anatomically incorrect?
    a. The nose has two nasal cavities.
    b. The pharynx connects the nasal and oral cavities to the larynx.
    c. The larynx contains the vocal cords.
    d. The trachea enters the lungs.
    e. The lungs contain many alveoli.

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.

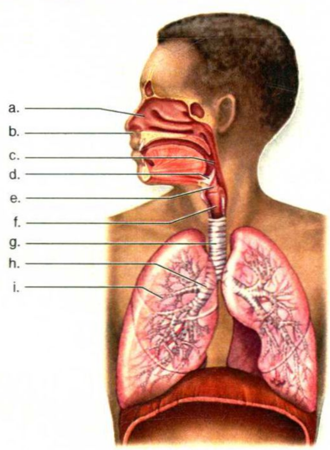
REVIEWING THIS CHAPTER

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 provided in Appendix A.

13. How is inhaled air modified before it reaches the lungs?
    a. It must be humidified.
    b. It must be warmed.
    c. It must be filtered and cleansed.
    d. All of these are correct.
14. Internal respiration refers to
    a. the exchange of gases between the air and the blood in the lungs.
    b. the movement of air into the lungs.
    c. the exchange of gases between the blood and tissue fluid.
    d. cellular respiration, resulting in the production of ATP.
15. The chemical reaction that converts carbon dioxide to a bicarbonate ion takes place in
    a. the blood plasma.
    b. red blood cells.
    c. the alveolus.
    d. the hemoglobin molecule.
16. Which of these would affect hemoglobin's O_2-binding capacity?
    a. pH
    b. partial pressure of oxygen
    c. blood pressure
    d. temperature
    e. All of these except c are correct.
17. The enzyme carbonic anhydrase
    a. causes the blood to be more basic in the tissues.
    b. speeds the conversion of carbonic acid to carbon dioxide and water.
    c. actively transports carbon dioxide out of capillaries.
    d. is active only at high altitudes.
    e. All of these are correct.
18. Which of these is incorrect concerning inspiration?
    a. Rib cage moves up and out.
    b. Diaphragm contracts and moves down.
    c. Pressure in lungs decreases, and air comes rushing in.
    d. The lungs expand because air comes rushing in.
19. Label this diagram of the human respiratory system.



thinking scientifically

1. You are a physician who witnessed Christopher Reeve's riding accident. Why might you immediately use mouth to mouth resuscitation until mechanical ventilation becomes available?
2. Fetal hemoglobin picks up oxygen from the maternal blood. If the oxygen-binding characteristics of hemoglobin in the fetus were identical to the hemoglobin of the mother, oxygen could never be transferred at the placenta to fetal circulation. What hypothesis about the oxygen-binding characteristics of fetal hemoglobin would explain how fetuses get the oxygen they need?

bioethical issue

Antibiotic Therapy

Antibiotics cure respiratory infections, but there are problems associated with antibiotic therapy. Aside from a possible allergic reaction, antibiotics not only kill off disease-causing bacteria, but they also reduce the number of beneficial bacteria in the intestinal tract and other locations. These beneficial bacteria hold in check the growth of other pathogens that now begin to flourish. Diarrhea can result, as can a vaginal yeast infection. The use of antibiotics can also prevent natural immunity from occurring, leading to the need for recurring antibiotic therapy. Especially alarming at this time is the occurrence of resistance. Resistance takes place when vulnerable bacteria are killed off by an antibiotic, and this allows resistant bacteria to become prevalent. The bacteria that cause ear, nose, and throat infections as well as scarlet fever and pneumonia are becoming widely resistant because we have not been using antibiotics properly. Tuberculosis is on the rise, and the new strains are resistant to the usual combined antibiotic therapy.

Every citizen needs to be aware of our present crisis situation. Stuart Levy, a Tufts University School of Medicine microbiologist, says that we should do what is ethical for society and ourselves. What is needed? Antibiotics kill bacteria, not viruses—therefore, we shouldn't take antibiotics unless we know for sure we have a bacterial infection. And we shouldn't take them prophylactically—that is, just in case we might need one. If antibiotics are taken in low dosages and intermittently, resistant strains are bound to take over. Animal and agricultural use should be pared down, and household disinfectants should no longer be spiked with antibacterial agents. Perhaps then, Levy says, vulnerable bacteria will begin to supplant the resistant ones in the population. Are you doing all you can to prevent bacteria from becoming resistant?

Biology website

The companion website for *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/maderbiology10

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, Tenth Edition website. Answers to these questions are found in Appendix A.

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.

WEBSITE REMINDER

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

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 Janice Roerig-Blong, who guided us as we shaped the content and pedagogy of the book. Lisa Bruflodt, the developmental editor, who kept everyone on target as the book was developed. The biology editor was Michael Hackett, who became a member of the team this past year. 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 David Hash 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 Jo Johnson did a superb job of finding just the right photographs and micrographs.

My assistant, Beth Butler, worked faithfully to do a preliminary paging of the book, 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 tenth 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 four contributors: Michael Thompson revised the genetics chapters, Stephanie Songer reworked the microbiology chapters and several animal biology chapters, Rebecca Roush contributed to the animal diversity chapters, and Andy Baldwin oversaw the ecology chapters. The tenth edition of *Biology* would not have the same excellent quality without the input of these contributors and those of the many reviewers who are listed on page xvii.

360 Development

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.

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Lincoln Land Community College

Jason Curtis
Purdue University–Westville

Philip Darby
University of West Florida

Lewis Deaton
University of Louisiana–Lafayette

Domenica Devine
Armstrong Atlantic State University

Waneene Dorsey
Grambling State University

Salman Elawad
Chattahoochee Valley Community College

Eugene Fenster
Longview Community College – Lees Summit

Jennifer Fernandes-Miller
Eastfield College

Julie Fischer
Wallace Community College–Dothan

Paul Florence
Jefferson Community College

Theresa Fulcher
Pellissippi State Technical College

Michelle Geary
West Valley College

Ann Gathers
University of Tennessee–Martin

Melanie Glasscock
Wallace State Community College–Hanceville

Lonnie Guralnick
Western Oregon University

Leslie Hendricks
Southeastern Louisiana University

Jennifer Herzog
Herkimer County Community College

Dagne Hill
Grambling State University

Harold Horn
Lincoln Land Community College

Walter Judd
University of Florida–Gainesville

Laina Karthikeyan
New York City College of Technology

Jenny Knoth
Armstrong Atlantic State University

Yaser Maksoud
Olive Harvey College

Dan Matusiak
St. Charles Community College

Scott Murdoch
Moraine Valley Community College

Necia Nicholas
Calhoun Community College

Joshua Parker
Community College of Southern Nevada

Theresa Poole
Georgia State University

Eric Rabitoy
Citrus College

Jose Ramirez-Domenech
Dillard University

Kathleen Richardson
Portland Community College–Sylvania

David Saunders
Augusta State University

Tanita Shannon-Gragg
Southeast Arkansas College

Linda Smith-Staton
Pellissippi State Technical College

Staria Vanderpool
Arkansas State University

Wendy Vermillion
Columbus State Community College

Heather Wilkins
University of Tennessee–Martin

Albert Wilson
Spokane Falls Community College

Bryant Wright
Jefferson College

Ted Zerucha
Appalachian State University