

BIOLOGY

today and tomorrow

WITH PHYSIOLOGY



STARR EVERS STARR

SECOND EDITION

BIOLOGY

today and tomorrow

WITH PHYSIOLOGY

SECOND EDITION

OU-828-B

C H

ALL LIBRARY MATERIALS MUST
BE RETURNED AFTER TWO WEEKS
USE IF NEEDED BY ANOTHER
PATRON

THE UNIVERSITY OF OKLAHOMA LIBRARY

THOMSON
★
BROOKS/COLE

Australia • Canada • Mexico • Singapore
Spain • United Kingdom • United States



PUBLISHER Jack C. Carey

VICE-PRESIDENT, EDITOR-IN-CHIEF Michelle Julet

SENIOR DEVELOPMENT EDITOR Peggy Williams

ASSOCIATE DEVELOPMENT EDITOR Suzannah Alexander

EDITORIAL ASSISTANT Kristina Razmara

TECHNOLOGY PROJECT MANAGER Keli Amann

MARKETING MANAGER Stacy Best, Kara Kindstrom

MARKETING ASSISTANT Brian Smith

MARKETING COMMUNICATIONS MANAGER Nathaniel
Bergson-Michelson

PROJECT MANAGER, EDITORIAL PRODUCTION Andy Marinkovich

CREATIVE DIRECTOR Rob Hugel

PRINT BUYER Karen Hunt

PERMISSIONS EDITOR Joohee Lee, Sarah Harkrader

PRODUCTION SERVICE Grace Davidson & Associates

TEXT AND COVER DESIGN Gary Head

PHOTO RESEARCHER Myrna Engler

COPY EDITOR Christy Goldfinch

ILLUSTRATORS Gary Head, ScEYence Studios, Lisa Starr

COMPOSITOR Lachina Publishing Services

TEXT AND COVER PRINTER QuebecorWorld—Versailles

COVER PHOTOGRAPHER Jay Barnes

A female crab flower spider (Misumena vatia) raises its legs and shows its fangs in a defensive posture. Such spiders exploit the mutually beneficial relationship between flowers and their pollinators. A bee or fly that is lured into range by the flower's color and scent is snatched by the spider's elongated front legs and subdued by a venomous bite from the fangs.

© 2007 Thomson Brooks/Cole, a part of The Thomson Corporation. Thomson, the Star logo, and Brooks/Cole are trademarks used herein under license.

ALL RIGHTS RESERVED. No part of this work covered by the copyright hereon may be reproduced or used in any form or by any means—graphic, electronic, or mechanical, including photocopying, recording, taping, web distribution, information storage and retrieval systems, or in any other manner—without the written permission of the publisher.

Printed in the United States of America
3 4 5 6 7 09 08 07

Library of Congress Control Number: 2005936176

ISBN-13: 978-0-495-01654-0

ISBN-13: 978-0-495-10285-4

ISBN-10: 0-495-01654-3 (softcover)

ISBN-10: 0-495-10285-7 (softcover)

ISBN-13: 978-0-495-10919-8

ISBN-10: 0-495-10919-3 (hardcover)

For more information about our products, contact us at:
Thomson Learning Academic Resource Center

1-800-423-0563

For permission to use material from this text or product, submit
a request online at <http://www.thomsonrights.com>.
Any additional questions about permissions can be submitted
by e-mail to thomsonrights@thomson.com.

BOOKS IN THE BROOKS/COLE BIOLOGY SERIES

Biology: The Unity and Diversity of Life, Eleventh, Starr/Taggart
Engage Online for Biology: The Unity and Diversity of Life
Biology: Concepts and Applications, Sixth, Starr
Basic Concepts in Biology, Sixth, Starr
Biology Today and Tomorrow, Second, Starr
Biology, Seventh, Solomon/Berg/Martin
Human Biology, Sixth, Starr/McMillan
Biology: A Human Emphasis, Sixth, Starr
Human Physiology, Fifth, Sherwood
Fundamentals of Physiology, Second, Sherwood
Human Physiology, Fourth, Rhoades/Pflanzer
Laboratory Manual for Biology, Fourth, Perry/Morton/Perry
Laboratory Manual for Human Biology, Morton/Perry/Perry
Photo Atlas for Biology, Perry/Morton
Photo Atlas for Anatomy and Physiology, Morton/Perry
Photo Atlas for Botany, Perry/Morton
Virtual Biology Laboratory, Beneski/Waber
Introduction to Cell and Molecular Biology, Wolfe
Molecular and Cellular Biology, Wolfe
Biotechnology: An Introduction, Second, Barnum
Introduction to Microbiology, Third, Ingraham/Ingraham
Microbiology: An Introduction, Batzing
Genetics: The Continuity of Life, Fairbanks/Anderson
Human Heredity, Seventh, Cummings
Current Perspectives in Genetics, Second, Cummings
Gene Discovery Lab, Benfey
Animal Physiology, Sherwood, Kleindorf, Yarcey
Invertebrate Zoology, Seventh, Ruppert/Fox/Barnes
Mammalogy, Fourth, Vaughan/Ryan/Czaplewski
Biology of Fishes, Second, Bond
Vertebrate Dissection, Ninth, Homburger/Walker
Plant Biology, Second, Rost/Barbour/Stocking/Murphy
Plant Physiology, Fourth, Salisbury/Ross
Introductory Botany, Berg
General Ecology, Second, Krohne
Essentials of Ecology, Third, Miller
Terrestrial Ecosystems, Second, Aber/Melillo
Living in the Environment, Fourteenth, Miller
Environmental Science, Tenth, Miller
Sustaining the Earth, Seventh, Miller
Case Studies in Environmental Science, Second, Underwood
Environmental Ethics, Third, Des Jardins
Watersheds 3—Ten Cases in Environmental Ethics, Third, Newton/Dillingham
Problem-Based Learning Activities for General Biology, Allen/Duch
The Pocket Guide to Critical Thinking, Second, Epstein

WebTutor™ © 2006 Thomson Learning, Inc. All Rights Reserved. Thomson Learning WebTutor™ is a trademark of Thomson Learning, Inc.

Due to contractual restrictions, Thomson can offer vMentor only to institutions of higher education (including post-secondary, proprietary schools) within the United States. We are unable to offer it outside the US or to any other US domestic customers.

Thomson Higher Education
10 Davis Drive
Belmont, CA 94002-3098
USA

Canada
Thomson Nelson
1120 Birchmount Road
Toronto, Ontario M1K 5G4

Asia (including India)
Thomson Learning
5 Shenton Way
#01-01 UIC Building
Singapore 068808

UK/Europe/Middle East/Africa
Thomson Learning
High Holborn House
50/51 Bedford Row
London WC1R 4LR
United Kingdom

Australia/New Zealand
Thomson Learning Australia
102 Dodds Street
Southbank, Victoria 3006
Australia

Preface

Biology opens a window on processes of nature that are so familiar that we might not even think about them. It reveals connections, sometimes subtle and sometimes not, between us and everything else on Earth. This is profound stuff that many nonmajors students are ill-prepared to grasp. Many enter college without adequate preparation in science, and often with the mistaken belief that they are not smart enough to learn biology. Should textbook writers reinforce their apprehension by squeezing all the juice out of a story, by producing a pedagogical husk? We think not. We find biology fascinating and eagerly devour news of recent discoveries. We believe that, with the proper guidance, students too can become lifelong learners who understand and are excited by the science of life.

This book is briefer than our other titles, but in it we strive to share our enthusiasm for biology with easy-to-follow writing on relevant topics. For this edition, we have shortened and streamlined many sections. We did not water down the science, but instead emphasize processes and relationships over detail.

Promote Critical Thinking Like all textbooks at this level, we walk students through examples of problem solving and experiments throughout the book. Many historical and theoretical experiments have been integrated into the text. Each chapter ends with several *Critical Thinking* questions, some illustrated. Some are more challenging than others, but all invite students to think outside the memorization box. We return again and again in chapter introductions and in the text to examples of how science is carried out. Introductory students are not scientists, however, so we do not expect them to learn the language and processes of science by intuition alone; we help them build these skills in a paced way.

Make It Brief, With Clear Explanations To keep the book length manageable, we were selective about which topics to include but were not stingy with clear explanations. If something is worth reading, why reduce it to a factoid? Factoids invite mind-numbing memorization, which does not promote critical thinking about the world and our place in it.

For instance, you can safely bet that most nonmajors simply do not want to memorize each catalytic step of crassulacean acid metabolism. They *do* want to learn about the biological basis of sex, and many female students want to know what will be going on inside them if and when they get pregnant. Good explanations can help them make their own informed decisions on many biology-related issues, including STDs, fertility drugs, prenatal diagnoses of genetic disorders, gene therapies, and abortions.

Our choices for which topics to condense, expand, or delete were not arbitrary. They reflect three decades of feedback from teachers throughout the world.

Make It Relevant Most students taking this course will not become biologists, but biological research will affect their lives in direct and often controversial ways. *What they learn today will have impact on how they make decisions tomorrow*—in the voting booth as well as in their personal lives.

Each chapter starts with an **IMPACTS/ISSUES** essay on a topic of current interest related to its content. For instance, the microevolution chapter opens with how the use of warfarin has favored “super rats.” Essays are expanded in custom videoclips and in sidebars on relevant pages within chapters, as shown on the facing page. We return to the essay topics in exercises on the student website and in the PowerLecture, an all-in-one PowerPoint tool for instructors. We also ask the students, **HOW WOULD YOU VOTE?** on an application related to the essay’s topic. The exercise invites them to read a selection of articles, pro and con, before voting.

12

PROCESSES OF EVOLUTION

Rise of the Super Rats

Slipping in and out of the pages of human history are rats—*Rattus*—the most notorious of mammalian pests. One kind of rat or another has distributed pathogens and parasites that cause bubonic plague, typhus, and other deadly infectious diseases. The death toll from fleas that bit infected rats and then bit people has exceeded the death toll in all wars combined.

The rats themselves are far more successful. By one estimate, there is one rat for every person in urban and suburban centers of the United States. In addition to spreading diseases, rats chew their way through walls and wires of homes and cities. In any given year, they cause economic losses approaching 19 billion dollars.

For years, people have been fighting back with traps, ratproof storage facilities, and various poisons. During the 1950s, they started using baits laced with warfarin. This compound interferes with blood clotting. Rats ate the baits, then died within days after bleeding internally or losing blood through cuts or scrapes. Warfarin was extremely effective. Compared with other rat poisons, it had a lot less impact on harmless species.

In 1958, however, a Scottish researcher reported that warfarin did not work against some rats. Similar reports from other European countries followed. About twenty years later, 10 percent of the urban rats caught in the United States were warfarin resistant. *What happened?*

To find out, researchers compared warfarin-resistant rat populations with still-vulnerable rats. They traced the difference to a gene on one of the rat chromosomes. At that gene locus, a dominant allele was common in warfarin-resistant rat populations but very rare among

the vulnerable ones. “What happened?” was evolution by natural selection. Warfarin was exerting selective pressure on populations of rats. The previously rare dominant allele proved to be adaptive. The lucky rats that inherited the allele survived and produced more offspring. The unlucky ones that inherited the recessive allele had no built-in defense, and died. Over time, the dominant allele’s frequency increased in all rat populations exposed to the poison.

Of course, selection pressures can and often do change. When warfarin resistance increased in rat populations, people stopped using warfarin. And guess what: The dominant allele’s frequency declined. Now the latest worry is the evolution of “super rats,” which even more potent rodenticides can’t seem to kill.

When you hear someone question whether life evolves, remember this: With respect to life, **evolution** simply means that heritable change is occurring in some line of descent. The actual mechanisms that can bring about such change are the focus of this chapter. Later chapters highlight how these mechanisms have contributed to the evolution of new species.

How Would You Vote? Antibiotic-resistant strains of bacteria are becoming dangerously pervasive. Standard animal husbandry practice includes the repeated dosing of healthy animals with antibiotics—the same ones prescribed to people. Should this practice stop? See *BiologyNow* for details, then vote online.

IMPACTS, ISSUES



Key Concepts

EVOLUTIONARY VIEWS EMERGE

The world distribution of species, similarities and differences in body form, and the fossil record gave early evidence of evolution—of changes in lines of descent. Charles Darwin and Alfred Wallace had an idea of how those changes occur.

VARIATION AND ADAPTATION

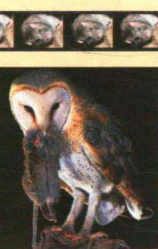
An adaptation is a heritable aspect of form, function, behavior, or development that promotes survival and reproduction. It enhances the fit between the individual and prevailing conditions in its environment.

MICROEVOLUTIONARY PROCESSES

An individual does not evolve. A *population* evolves, which means its shared pool of alleles changes. Over generations, any allele may increase in its frequency among individuals, or it may become rare or lost. Mutation, genetic drift, natural selection, and gene flow change allele frequencies in a population. These processes of microevolution change the observable characteristics that define a population and, more broadly, a species.

Links to Earlier Concepts

Section 1.4 sketched out the key premises of the theory of natural selection. Here you will read about evidence that led to its formulation. You may wish to refresh your memory of protein structure (2.6), basic terms of genetics (8.1), chromosomes and crossing over (8.4, 8.5), DNA replication and repair (9.3), and gene mutation (10.5). This chapter puts the chromosomal basis of inheritance (8.4, 8.7) and continuous variation in populations (8.3) into the broader context of evolution.



Warfarin-resistant rats led to the development of anticoagulants that are more toxic and that persist longer in the environment. They are weakening and killing owls, hawks, coyotes, and other predators that have eaten poisoned rats. Between 1985 and 1999, for example, the number of barn owls with anticoagulants in their blood rose from 5 to 36 percent. And that was just one study in Great Britain.

Students throughout the country are already voting online, and they are accessing campuswide, statewide, and nationwide tallies. This interactive approach to issues reinforces the premise that an individual's actions can make a difference.

Make It Easy To Follow On each chapter's opening page is a preview of key concepts, each with a simple title. We repeat these titles at the bottom of appropriate pages as reminders of the chapter's conceptual organization.

New to this edition are **LINKS TO EARLIER CONCEPTS** that can help students follow the big connections within and between the chapters. The opening page lists the key sections in

earlier chapters that students should be familiar with before they start the chapter. For instance, before reading about neural function, a student may wish to scan an earlier chapter's section on active transport. We repeat linking icons in the chapter's page margins as reminders of these and other relevant sections. This feature demonstrates how the concepts in the book are not separate topics, but are as closely interconnected as biology itself.

A conversational writing style eases students into the story. They can stay focused on that story without worrying about highlighting something they might be tested on. Why? We already highlight key points for them, in blue boxes at the end of each section. These **HIGHLIGHTED KEY POINTS** function as a *running in-text summary*. All chapters end with a *section-by-section summary* that reinforces what they have learned.

Students also can stay on track with **ANIMATED DIAGRAMS**. They can walk through the text's step-by-step art as a preview of major concepts, then check out the steps online. These visual learning devices are available in narrated, animated form, on *BiologyNow* and on the PowerLecture DVD. Exposing students to the material in a variety of modalities accommodates diverse learning styles and reinforces understanding.

Offer Easy-to-Use Media Tools Integrated into each end-of-chapter summary are associated media tools that will help students focus their study and understand the key concepts. With this new edition, taking advantage of these online assets is easier than ever. Students register their **1PASS ACCESS CODE** at <http://1pass.thomson.com>, then log in to access all resources outlined below. An access code is packaged in each new copy of the book.

BIOLOGYNOW™ tests

which topics students have not yet mastered and creates customized learning plans to focus their study and review. Responses to the diagnostic pretest questions activate a personalized learning plan. Answer incorrectly, and the plan lists the relevant text sections, figures, chapter videos, and animations that the student may review.

A *Post-Test* can be used as a self-assessment tool or submitted to an instructor. Because *BiologyNow* is built into iLrn, Thomson Learning's course management system, the answers and results can be fed directly into an electronic gradebook. *BiologyNow* can be integrated with WebCT and Blackboard, so students may log in through these systems as well.

Interactive flashcards with audio pronunciation use the definitions from this edition's highly revised glossary. All the boldface terms within the text are presented in this resource.

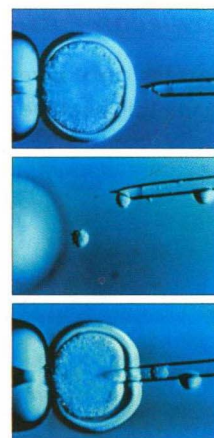
The *How Do I Prepare?* section of *BiologyNow* has tutorials in math, chemistry, and graphing, as well as a review of basic study skills.

1PASS grants access to **INFOTRAC COLLEGE EDITION™**, an exclusive online searchable database of more than 5,000 periodicals and close to 18 million articles. The articles are in full-text form and can be located easily and quickly with a key word search. For each chapter, the *How Would You Vote* exercise in *BiologyNow* references specific InfoTrac articles and websites. As students vote on each issue, the website provides a running tally by campus, state, and the country. Instructors can assign the exercises from iLrn, or students can access them through the website at <http://biology.brookscole.com/btt2>.

An online **ISSUES AND RESOURCES INTEGRATOR** correlates chapter sections with applications, videos, InfoTrac articles, and websites. This guide is updated each semester.

VMENTOR is an online tutorial service available from 6 AM to 12 PM Monday through Saturday. Students may interact with a live tutor in a virtual classroom by voice communication, whiteboard, and text messaging.

New college editions of the book can also include access to the **AUDIOBOOK**. Students can either listen to narration online or download MP3 files for use on a portable MP3 player.



1 Removal of the nucleus from a sheep egg during a cloning. At the center is an unfertilized sheep egg. A pipette has positioned the egg, which a microneedle is about to penetrate.

2 The microneedle has now emptied the sheep egg of its own nucleus, which holds the cell's DNA.

3 A nucleus from a donor cell is about to enter the enucleated egg. An electric spark will stimulate the egg to enter mitotic cell divisions. At an early stage, the ball of cells will be implanted in the womb of a surrogate mother sheep.

Figure 9.8 Animated! Nuclear transfer of sheep cells. In this series of photos, a microneedle replaces the nucleus of a sheep egg with a nucleus from an adult sheep cell. Newer methods involve direct transfer of nuclear DNA that has been treated with mitotic cell extracts to condense the chromosomes.

Acknowledgments

No short list can convey our thanks to the extended team that made this book not only possible, but also excellent. John Jackson and Walt Judd deserve special thanks for their detailed evaluations, perspective, and continued commitment to excellence. Dave Rintoul and his students helped us fine-tune some important last-minute details. Through focus-group participation, reviews, and class testing, he and the other instructors listed below helped us transform our first edition into the polished, cohesive textbook you see here, one that particularly addresses the needs of students who have been previously underserved.

With Jack Carey, Susan Badger, Sean Wakely, Kathie Head, Michelle Julet, and Michael Johnson, Thomson Learning proved why it is one of the world's foremost publishers; we doubt that any authors get finer support anywhere. Keli Amann managed production of all student and instructor media tools. Peggy Williams again brought her tenacity, intelligence, and humor to the developmental editing. Andy Marinkovich calmly kept us on track, and Grace Davidson made this book happen despite several hurricanes, both literal and figurative. Gary Head created great designs and graphics; Steve Bolinger did so for the media tools. Myrna Engler, Suzannah Alexander, Kristina Razmara, Karen Hunt, Stacy Best—the list goes on. Thank you to each one of you; this book would not exist without your help.

CECIE STARR, CHRIS EVERS, AND LISA STARR *November 2005*

General Advisors

DANIEL J. FAIRBANKS *Brigham Young University*
JOHN D. JACKSON *North Hennipin Community College*
WALTER JUDD *University of Florida*
E. WILLIAM WISCHUSEN *Louisiana State University*

Focus Groups, Reviewers, and Class Testing

JO DALE H. ALES *Baton Rouge Community College*
DIANNE ANDERSON *San Diego City College*
KENNETH D. ANDREWS *East Central University*
BERT ATSMAN *Union County College*
ANDREW STEPHEN BALDWIN *Mesa Community College*
GREGORIO B. BEGONIA *Jackson State University*
DAVID BELT *Johnson County Community College*
PAUL A. BILLETER *College of Southern Maryland*
ANDREW BLAUSTEIN *Oregon State University*
JUDY BLUEMER *Morton College*
MARK G. BOLLONE *Tallahassee Community College*
SUSAN BOWER *Pasadena City College*
WILLIAM BROWER *Del Mar College*
STEVEN G. BRUMBAUGH *Greenriver Community College*
WILBERT BUTLER, JR. *Tallahassee Community College*
THOMAS R. CAMPBELL *Los Angeles Pierce College*
J. MICHELLE CAWTHORN *Georgia Southern University*
THOMAS T. CHEN *Santa Monica College*
THOMAS F. CHUBB *Villanova University*
JAY L. COMEAUX *Louisiana State University*
EDWARD A. DEGRAUW *Portland Community College*
JEAN DESAIX *University of North Carolina*
BRIAN DINGMANN *University of Minnesota, Crookston*

ERNEST F. DUBRUL *University of Toledo*
PARAMJIT DUGGAL *Metropolitan Community College, Maple Woods*
PAMELA K. ELF *University of Minnesota, Crookston*
ROBERT C. EVANS *Rutgers University-Camden*
W. LOGAN FINK *Pensacola Junior College*
APRIL A. FONG *Portland Community College*
EDISON R. FOWLKS *Hampton University*
TERESA LANE FULCHER *Pellissippi State Technical Community College*
RIC A. GARCIA *Clemson University*
MICHELLE GEARY *West Valley College*
MARY GOBBETT *University of Indianapolis*
MELVIN H. GREEN *University of California, San Diego*
CARLA GUTHRIDGE *Cameron University*
GALE HAIGH *McNeese State University*
JERRIE R. HANIBLE *Southeastern Louisiana University*
LINDA HARRIS-YOUNG *Motlow State Community College*
DAVID J. HENSON *Eastern Arizona College*
JULIANA HINTON *McNeese State University*
SONGQIAO (SARA) HUANG *Los Angeles Valley College*
DONNA HUFFMAN *Calhoun Community College*
KIMBERLY HURD *Bakersfield College*
DESIRÉE JACKSON *Texas Southern University*
ROSS S. JOHNSON *Virginia State University*
GLENN H. KAGEYAMA *California State Polytechnic University, Pomona*
RITA A. KARPIE *Brevard Community College*
JUDITH KELLY *Henry Ford Community College*
PAULINE LIZOTTE *Valencia Community College*
JUAN LOPEZ-BAUTISTA *University of Alabama, Tuscaloosa*
DAVID LORING *Johnson County Community College*
DANIEL MARK *Metropolitan Community College, Maple Woods*
LINDA MARTIN-MORRIS *University of Washington*
DENNIS McDERMOT *Lake Erie College*
RON MOLICK *Christopher Newport University*
JILL NISSEN *Montgomery College*
ALEXANDER E. OLVIDO *Virginia State University*
JOSHUA M. PARKER *Community College of Southern Nevada*
ROBERT P. PATTERSON *North Carolina State University*
JOHN S. PETERS *College of Charleston*
HAROLD PLETT *Fullerton College*
JENNIE M. PLUNKETT *San Jacinto College*
JAMES V. PRICE *Utah Valley State College*
JERRY W. PURCELL *San Antonio College*
KIRSTEN RAINES *San Jacinto College*
WENDA RIBEIRO *Thomas Nelson Community College*
PELE EVE RICH *Mt. San Jacinto College*
DAVID A. RINTOUL *Kansas State University*
FRANK A. ROMANO III *Jacksonville State University*
DAVID ROSEN *Diablo Valley College*
ETTA V. RUPPERT *Clemson University*
ERIK P. SCULLY *Towson University*
MIKE SHIFFLER *University of Alabama*
MARCIA SHOFNER *University of Maryland*
GREG A. SIEVERT *Emporia State University*
LINDA D. SMITH-STATON *Pellissippi State Technical Community College*
LARRY L. ST. CLAIR *Brigham Young University*
JACQUELINE J. STEVENS *Jackson State University*
JUDY STEWART *Community College of Southern Nevada*
ALICE B. TEMPLET *Nicholls State University*
MICHAEL T. TOLIVER *Eureka College*
JEANETTE H. TUCKER *Northern Virginia Community College*
HEATHER D. VANCE-CHALCRAFT *East Carolina University*
PATRICIA M. WALSH *University of Delaware*
JENNIFER WARNER *University of North Carolina at Charlotte*
MICHAEL WENZEL *California State University, Sacramento*
LISA A. WERNER *Pima Community College*
EMILY C. WHITELEY *Catawba Valley Community College*
MICHAEL WINDELSPECHT *Appalachian State University*
MARK WITMER *Ithaca College*
MARK WYGODA *McNeese State University*
MARTIN D. ZAHN *Thomas Nelson Community College*
ROSEMARY ZARAGOZA *University of Chicago*



Current configurations of the Earth's oceans and land masses—the geologic stage upon which life's drama continues to unfold. This composite satellite image reveals global energy use at night by the human population. Just as biological science does, it invites you to think more deeply about the world of life—and about our impact upon it.

CONTENTS IN BRIEF

- 1 Invitation to Biology

Unit One Cells

- 2 Molecules of Life
- 3 How Cells Are Put Together
- 4 How Cells Work
- 5 Where It Starts—Photosynthesis
- 6 How Cells Release Chemical Energy

Unit Two Genetics

- 7 How Cells Reproduce
- 8 Observing Patterns in Inherited Traits
- 9 DNA Structure and Function
- 10 Gene Expression and Control
- 11 Studying and Manipulating Genomes

Unit Three Evolution and Diversity

- 12 Processes of Evolution
- 13 Evolutionary Patterns, Rates, and Trends
- 14 Early Life
- 15 Plant Evolution
- 16 Animal Evolution
- 17 Plants and Animals: Common Challenges

Unit Four How Plants Work

- 18 Plant Form and Function
- 19 Plant Reproduction and Development

Unit Five How Animals Work

- 20 Animal Tissues and Organ Systems
- 21 How Animals Move
- 22 Circulation and Respiration
- 23 Immunity
- 24 Digestion, Nutrition, and Excretion
- 25 Neural Control and the Senses
- 26 Endocrine Controls
- 27 Reproduction and Development

Unit Six Ecology

- 28 Population Ecology
- 29 Community Structure and Biodiversity
- 30 Ecosystems
- 31 The Biosphere
- 32 Behavioral Ecology

Epilogue

DETAILED CONTENTS

1 Invitation to Biology

IMPACTS, ISSUES *What Am I Doing Here?* 1

- 1.1 LIFE'S LEVELS OF ORGANIZATION 2
 - From Small to Smaller 2
 - From Smaller to Vast 2
- 1.2 OVERVIEW OF LIFE'S UNITY 4
 - DNA, The Basis of Inheritance 4
 - Energy, The Basis of Metabolism 4
 - Energy and Life's Organization 4
 - Life's Responsiveness to Change 5
- 1.3 IF SO MUCH UNITY, WHY SO MANY SPECIES? 6
- 1.4 AN EVOLUTIONARY VIEW OF DIVERSITY 8
- 1.5 THE NATURE OF BIOLOGICAL INQUIRY 9
 - Observations, Hypotheses, and Tests 9
 - About the Word "Theory" 9
- 1.6 THE POWER OF EXPERIMENTAL TESTS 10
 - An Assumption of Cause and Effect 10
 - Example of an Experimental Design 10
 - Example of a Field Experiment 10
 - Bias in Reporting Results 11
- 1.7 THE SCOPE AND LIMITS OF SCIENCE 12

Unit One Cells

2 Molecules of Life

IMPACTS, ISSUES *Science or Supernatural?* 15

- 2.1 ATOMS AND THEIR INTERACTIONS 16
 - Atoms and Isotopes 16
 - Electrons and Energy Levels 16
- 2.2 BONDS IN BIOLOGICAL MOLECULES 18
 - Ion Formation and Ionic Bonding 18
 - Covalent Bonding 18
 - Hydrogen Bonding 19
- 2.3 WATER'S LIFE-GIVING PROPERTIES 20
 - Polarity of the Water Molecule 20
 - Water's Temperature-Stabilizing Effects 20
 - Water's Solvent Properties 21
 - Water's Cohesion 21

2.4 ACIDS AND BASES 22

- The pH Scale 22
- Salts and Water 22
- Buffers Against Shifts in pH 23

2.5 MOLECULES OF LIFE—FROM STRUCTURE TO FUNCTION 23

- What Is an Organic Compound? 23
- It All Starts With Carbon's Bonding Behavior 23
- Functional Groups 24
- How Do Cells Build Organic Compounds? 25

2.6 THE TRULY ABUNDANT CARBOHYDRATES 26

- The Simple Sugars 26
- Short-Chain Carbohydrates 26
- Complex Carbohydrates 26

2.7 GREASY, FATTY—MUST BE LIPIDS 28

- Fats and Fatty Acids 28
- Phospholipids 29
- Cholesterol and Other Sterols 29
- Waxes 29

2.8 PROTEINS—DIVERSITY IN STRUCTURE AND FUNCTION 30

- What Is an Amino Acid? 30
- Levels of Protein Structure 30

2.9 WHY IS PROTEIN STRUCTURE SO IMPORTANT? 32

- Just One Wrong Amino Acid ... 32
- Proteins Undone—Denaturation 32

2.10 NUCLEOTIDES AND THE NUCLEIC ACIDS 34

3 How Cells Are Put Together

IMPACTS, ISSUES *Animalcules and Cells Fill'd With Juices* 38

3.1 WHAT IS "A CELL"? 39

3.2 MOST CELLS ARE REALLY SMALL 40

- Types of Microscopes 40
- Why Aren't All Cells Big? 41

3.3 THE STRUCTURE OF CELL MEMBRANES 42

3.4 A CLOSER LOOK AT PROKARYOTIC CELLS 44

3.5 A CLOSER LOOK AT EUKARYOTIC CELLS 45

- The Nucleus 46
- The Endomembrane System 46
- Mitochondria 48
- Chloroplasts 48
- Summary of Major Organelles 48

3.6 WHERE DID ORGANELLES COME FROM? 50

- Origin of the Nucleus and ER 50
- Theory of Endosymbiosis 50
- Evidence of Endosymbiosis 51

3.7 THE DYNAMIC CYTOSKELETON 52

- Moving Along With Motor Proteins 52
- Cilia, Flagella, and False Feet 53

3.8 CELL SURFACE SPECIALIZATIONS 54

- Eukaryotic Cell Walls 54
- Matrixes Between Animal Cells 55
- Cell Junctions 55

4 How Cells Work

IMPACTS, ISSUES *Beer, Enzymes, and Your Liver* 58

4.1 INPUTS AND OUTPUTS OF ENERGY 59

- The One-Way Flow of Energy 59
- ATP—The Cell's Energy Currency 59
- Up and Down the Energy Hills 60

4.2 INPUTS AND OUTPUTS OF SUBSTANCES 61

- What Are Metabolic Pathways? 61
- The Nature of Metabolic Reactions 61

4.3 HOW ENZYMES MAKE SUBSTANCES REACT 62

- Lowering the Energy Hill 62
- Help From Cofactors 63
- How Is Enzyme Activity Controlled? 64
- Effects of Temperature, pH, and Salinity 64

4.4 DIFFUSION AND METABOLISM 65

- What Is a Concentration Gradient? 65
- What Determines Diffusion Rates? 66

4.5 WORKING WITH AND AGAINST DIFFUSION 66

- Passive Transport 66
- Active Transport 67

4.6 WHICH WAY WILL WATER MOVE? 68

- Osmosis 68

Effects of Tonicity 68

Effects of Fluid Pressure 68

4.7 CELL BURPS AND GULPS 70

5 Where It Starts— Photosynthesis

IMPACTS, ISSUES *Sunlight and Survival* 73

5.1 THE RAINBOW CATCHERS 74

- Light and Pigments 74
- Two Stages of Reactions 75

5.2 LIGHT-DEPENDENT REACTIONS 76

5.3 LIGHT-INDEPENDENT REACTIONS 78

- The Sugar Factory 78
- Different Plants, Different Pathways 79

5.4 PASTURES OF THE SEAS 80

6 How Cells Release Chemical Energy

IMPACTS, ISSUES *When Mitochondria Spin
Their Wheels* 82

6.1 OVERVIEW OF ENERGY-RELEASING PATHWAYS 83

6.2 GLYCOLYSIS—GLUCOSE BREAKDOWN STARTS 84

6.3 SECOND AND THIRD STAGES OF AEROBIC RESPIRATION 86

- Acetyl-CoA Formation and the Krebs Cycle 86
- Electron Transfer Phosphorylation 87

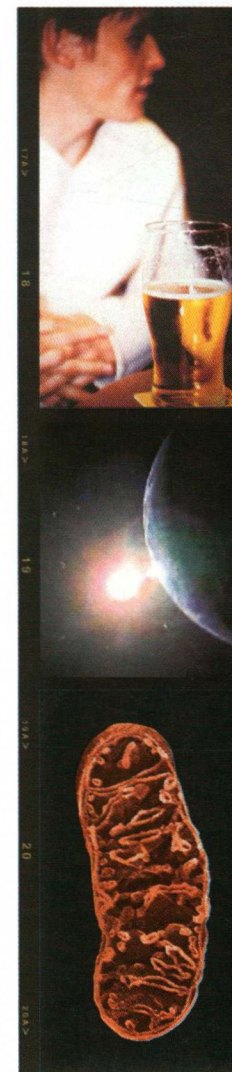
6.4 ANAEROBIC ENERGY-RELEASING PATHWAYS 88

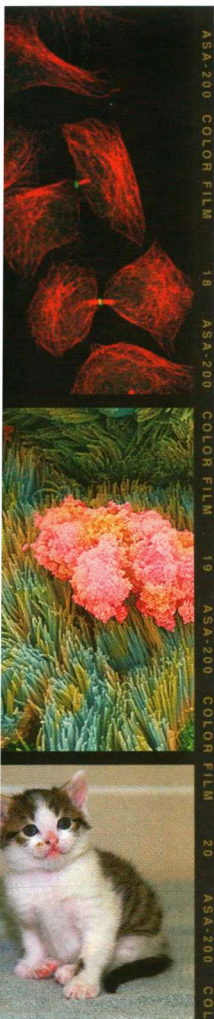
- Alcoholic Fermentation 89
- Lactate Fermentation 89

6.5 ALTERNATIVE ENERGY SOURCES IN THE BODY 89

- The Fate of Glucose at Mealtime
and in Between Meals 89
- Energy From Fats 91
- Energy From Proteins 91

6.6 CONNECTIONS WITH PHOTOSYNTHESIS 91





Unit Two Genetics

7 How Cells Reproduce

IMPACTS, ISSUES *Henrietta's Immortal Cells* 94

- 7.1 OVERVIEW OF CELL DIVISION MECHANISMS 95
 - Mitosis and Meiosis 95
 - Key Points About Chromosome Structure 95
- 7.2 INTRODUCING THE CELL CYCLE 96
- 7.3 MITOSIS MAINTAINS THE CHROMOSOME NUMBER 97
 - Prophase: Mitosis Begins 98
 - Transition to Metaphase 98
 - From Anaphase Through Telophase 98
- 7.4 DIVISION OF THE CYTOPLASM 100
- 7.5 MEIOSIS AND SEXUAL REPRODUCTION 101
 - Asexual Versus Sexual Reproduction 101
 - Two Divisions, Not One 102
- 7.6 HOW MEIOSIS PUTS VARIATION IN TRAITS 104
 - Crossing Over in Prophase I 104
 - Metaphase I Alignments 105
- 7.7 FROM GAMETES TO OFFSPRING 106
 - Gamete Formation in Plants 106
 - Gamete Formation in Animals 106
 - More Shufflings at Fertilization 106
- 7.8 THE CELL CYCLE AND CANCER 108
 - The Cell Cycle Revisited 108
 - Characteristics of Cancer 109

8 Observing Patterns in Inherited Traits

IMPACTS, ISSUES *Menacing Mucus* 112

- 8.1 TRACKING TRAITS WITH HYBRID CROSSES 113
 - Terms Used in Modern Genetics 113
 - Mendel's Experimental Approach 113
 - Mendel's Theory of Segregation 114
 - Mendel's Theory of Independent Assortment 116

- 8.2 NOT-SO-STRAIGHTFORWARD PHENOTYPES 117
 - ABO Blood Types—A Case of Codominance 117
 - Incomplete Dominance 118
 - When Products of Two or More Gene Pairs Interact 118
 - Single Genes With a Wide Reach 119
- 8.3 COMPLEX VARIATIONS IN TRAITS 120
 - Regarding the Unexpected Phenotype 120
 - Continuous Variation in Populations 120
 - Environmental Effects on Phenotype 121
- 8.4 THE CHROMOSOMAL BASIS OF INHERITANCE 123
 - A Rest Stop on Our Conceptual Road 123
 - Karyotyping 123
 - Autosomes and Sex Chromosomes 123
- 8.5 IMPACT OF CROSSING OVER ON INHERITANCE 125
- 8.6 HUMAN GENETIC ANALYSIS 126
- 8.7 EXAMPLES OF HUMAN INHERITANCE PATTERNS 127
 - Autosomal Dominant Inheritance 127
 - Autosomal Recessive Inheritance 128
 - X-Linked Recessive Inheritance 128
- 8.8 STRUCTURAL CHANGES IN CHROMOSOMES 130
 - Major Categories of Structural Change 130
 - Does Chromosome Structure Evolve? 130
- 8.9 CHANGE IN THE NUMBER OF CHROMOSOMES 131
 - An Autosomal Change and Down Syndrome 131
 - Changes in the Sex Chromosome Number 132
- 8.10 SOME PROSPECTS IN HUMAN GENETICS 133
 - Bioethical Questions 133
 - Choices Available 133

9 DNA Structure and Function

IMPACTS, ISSUES *Here, Kitty, Kitty, Kitty, Kitty* 137

- 9.1 THE HUNT FOR FAME, FORTUNE, AND DNA 138
 - Early and Puzzling Clues 138
 - Confirmation of DNA Function 138
 - Enter Watson and Crick 139

9.2 DNA STRUCTURE AND FUNCTION 140

DNA's Building Blocks 140

Fame and Glory 140

Patterns of Base Pairing 142

9.3 DNA REPLICATION AND REPAIR 142

How Is a DNA Molecule Duplicated? 142

Monitoring and Fixing DNA 142

9.4 USING DNA TO CLONE MAMMALS 143

10 Gene Expression and Control

IMPACTS, ISSUES *Ricin and Your Ribosomes* 146

10.1 MAKING AND CONTROLLING THE CELL'S PROTEINS 147

10.2 HOW IS RNA TRANSCRIBED FROM DNA? 147

Three Classes of RNA 147

The Nature of Transcription 147

Finishing Up RNA Transcripts 148

10.3 DECIPHERING mRNA 150

10.4 FROM mRNA TO PROTEIN 152

10.5 MUTATED GENES AND THEIR PROTEIN PRODUCTS 154

Common Mutations 154

How Do Mutations Arise? 154

The Proof Is in the Protein 155

10.6 CONTROLS OVER GENE EXPRESSION 156

Common Controls 156

Bacterial Control of the Lactose Operon 156

Eukaryotic Gene Controls 157

11 Studying and Manipulating Genomes

IMPACTS, ISSUES *Golden Rice or Frankenfood?* 162

11.1 A MOLECULAR TOOLKIT 163

The Scissors: Restriction Enzymes 163

Cloning Vectors 163

cDNA Cloning 164

11.2 HAYSTACKS TO NEEDLES 165

Isolating Genes 165

PCR 165

11.3 DNA SEQUENCING 167

11.4 FIRST JUST FINGERPRINTS, NOW DNA FINGERPRINTS 168

11.5 TINKERING WITH THE MOLECULES OF LIFE 169

Emergence of Molecular Biology 169

The Human Genome Project 169

Genomics 170

11.6 PRACTICAL GENETICS 171

Designer Plants 171

Genetically Engineered Bacteria 172

Barnyard Biotech 172

11.7 WEIGHING THE BENEFITS AND RISKS 173

Knockout Cells and Organ Factories 174

Regarding "Frankenfood" 174

Unit Three Evolution and Diversity

12 Processes of Evolution

IMPACTS, ISSUES *Rise of the Super Rats* 176

12.1 EARLY BELIEFS, CONFOUNDING DISCOVERIES 177

Questions From Biogeography 177

Questions From Comparative Morphology 177

Questions About Fossils 178

Squeezing New Evidence Into Old Beliefs 178

Voyage of the *Beagle* 178

Old Bones and Armadillos 179

A Key Insight—Variation in Traits 179

12.2 THE NATURE OF ADAPTATION 181

Salt-Tolerant Tomatoes 181

Adaptation to What? 181

12.3 INDIVIDUALS DON'T EVOLVE, POPULATIONS DO 182

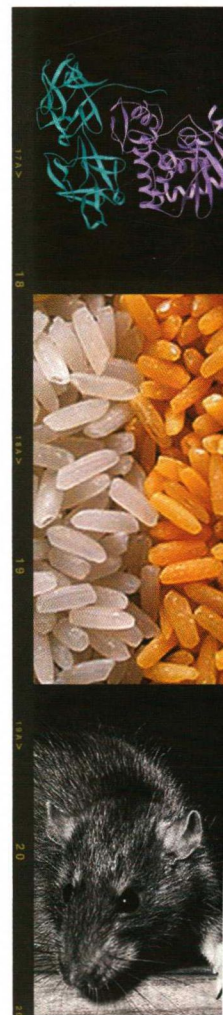
Variation in Populations 182

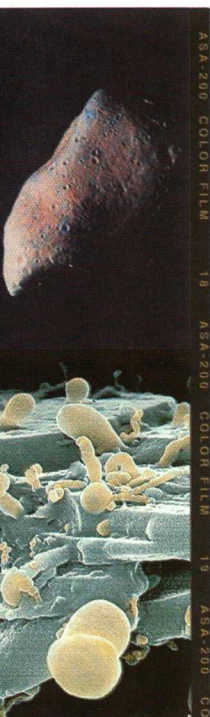
The "Gene Pool" 182

Stability and Change in Allele Frequencies 183

Mutations Revisited 183

12.4 WHEN IS A POPULATION NOT EVOLVING? 184





- 12.5 **NATURAL SELECTION REVISITED** 185
 Directional Selection 185
 Selection Against or in Favor of Extreme Phenotypes 186

- 12.6 **MAINTAINING VARIATION IN A POPULATION** 188
 Sexual Selection 188
 Sickle-Cell Anemia—Lesser of Two Evils? 189

- 12.7 **GENETIC DRIFT—THE CHANCE CHANGES** 190
 Chance Events and Population Size 190
 Bottlenecks and the Founder Effect 191
 Genetic Drift and Inbred Populations 191

- 12.8 **GENE FLOW—KEEPING POPULATIONS ALIKE** 191

13 Evolutionary Patterns, Rates, and Trends

IMPACTS, ISSUES *Measuring Time* 194

- 13.1 **FOSSILS—EVIDENCE OF ANCIENT LIFE** 195
 How Do Fossils Form? 195
 Fossils in Sedimentary Rock Layers 196
 Interpreting the Fossil Record 196
- 13.2 **DATING PIECES OF THE PUZZLE** 196
 Radiometric Dating 196
 Placing Fossils in Geologic Time 197
- 13.3 **EVIDENCE FROM BIOGEOGRAPHY** 199
 An Outrageous Hypothesis 199
 A Big Connection 200
- 13.4 **MORE EVIDENCE FROM COMPARATIVE MORPHOLOGY** 201
 Morphological Divergence 201
 Morphological Convergence 202
- 13.5 **EVIDENCE FROM PATTERNS OF DEVELOPMENT** 203
- 13.6 **EVIDENCE FROM DNA, RNA, AND PROTEINS** 204
 Protein Comparisons 204
 Nucleic Acid Comparisons 204
 Molecular Clocks 205
- 13.7 **REPRODUCTIVE ISOLATION, MAYBE NEW SPECIES** 205
 Reproductive Isolating Mechanisms 206
- 13.8 **INTERPRETING THE EVIDENCE: MODELS FOR SPECIATION** 208

- Geographic Isolation 208
 The Inviting Archipelagos 208
 Sympatric Speciation 210
 Parapatric Speciation 211

- 13.9 **PATTERNS OF SPECIATION AND EXTINCTIONS** 211
 Branching and Unbranched Evolution 211
 Evolutionary Trees and Rates of Change 211
 Adaptive Radiations 212
 Extinctions—End of the Line 212

- 13.10 **ORGANIZING INFORMATION ABOUT SPECIES** 213
 Naming, Identifying, and Classifying Species 213
 What's in a Name? A Cladistic View 214

14 Early Life

IMPACTS, ISSUES *Looking for Life in All the Odd Places* 218

- 14.1 **ORIGIN OF THE FIRST LIVING CELLS** 219
 Conditions On the Early Earth 219
 Origin of Agents of Metabolism 220
 Origin of Self-Replicating Systems 220
 Origin of Cell Membranes 221
 The First Cells and Beyond 222
- 14.2 **WHAT ARE EXISTING PROKARYOTES LIKE?** 224
 General Characteristics 224
 Growth and Reproduction 225
 Prokaryotic Classification 225
 Examples of Archaeal Diversity 226
 Examples of Bacterial Diversity 226
 Bacterial Behavior 228
- 14.3 **THE CURIOUSLY CLASSIFIED PROTISTS** 228
 Flagellated Protozoans and Euglenoids 228
 Radiolarians and Foraminiferans 229
 The Ciliates 230
 Dinoflagellates 230
 Apicomplexans and Malaria 230
 Diatoms, Brown Algae, and Relatives 231
 Red Algae 232
 Green Algae 232
 Amoebozoans 234

14.4 THE FABULOUS FUNGI 234

Characteristics of Fungi 234

Fungal Diversity 234

The Club Fungi 235

Spores and More Spores 236

Fungal Symbionts 237

The Unloved Few 238

14.5 VIRUSES, VIROIDS, AND PRIONS 239

Characteristics of Viruses 239

Viral Multiplication Cycles 240

Viroids and Prions 240

14.6 EVOLUTION AND INFECTIOUS DISEASES 241

15 Plant Evolution

IMPACTS, ISSUES *Beginnings, and Endings* 244

15.1 PIONEERS IN A NEW WORLD 245

Roots, Stems, and Leaves 245

From Haploid to Diploid Dominance 245

Seeds and Pollen Grains 246

15.2 THE BRYOPHYTES—NO VASCULAR TISSUES 247

15.3 SEEDLESS VASCULAR PLANTS 248

Club Mosses 249

Horsetails 249

Ferns 250

15.4 THE RISE OF SEED-BEARING PLANTS 251

15.5 GYMNOSPERMS—PLANTS WITH “NAKED” SEEDS 252

15.6 ANGIOSPERMS—THE FLOWERING PLANTS 254

15.7 DEFORESTATION IN THE TROPICS 256

16 Animal Evolution

IMPACTS, ISSUES *Interpreting and Misinterpreting the Past* 259

16.1 OVERVIEW OF THE ANIMAL KINGDOM 260

Animal Origins 260

A Look at Body Plans 260

16.2 GETTING ALONG WELL WITHOUT ORGANS 262

Sponges 262

Cnidarians 262

16.3 FLATWORMS—INTRODUCING ORGAN SYSTEMS 263

16.4 ANNELIDS—SEGMENTS GALORE 264

16.5 THE EVOLUTIONARILY PLIABLE MOLLUSKS 266

Hiding Out, Or Not 266

On the Cephalopod Need for Speed 266

16.6 AMAZINGLY ABUNDANT ROUNDWORMS 267

16.7 ARTHROPODS—THE MOST SUCCESSFUL ANIMALS 268

Keys to Success 268

Spiders and Their Relatives 269

Crustaceans 269

A Look at Insect Diversity 270

16.8 THE PUZZLING ECHINODERMS 272

16.9 EVOLUTIONARY TRENDS AMONG VERTEBRATES 273

Early Craniates 273

The Key Innovations 274

16.10 MAJOR GROUPS OF JAWED FISHES 275

16.11 EARLY AMPHIBIOUS TETRAPODS 276

16.12 THE RISE OF AMNIOTES 278

The “Reptiles” 278

Birds 279

Mammals 280

16.13 FROM EARLY PRIMATES TO HUMANS 281

Origins and Early Divergences 282

The First Hominids 283

Emergence of Early Humans 284

Emergence of Modern Humans 284

Where Did Modern Humans Originate? 286

17 Plants and Animals: Common Challenges

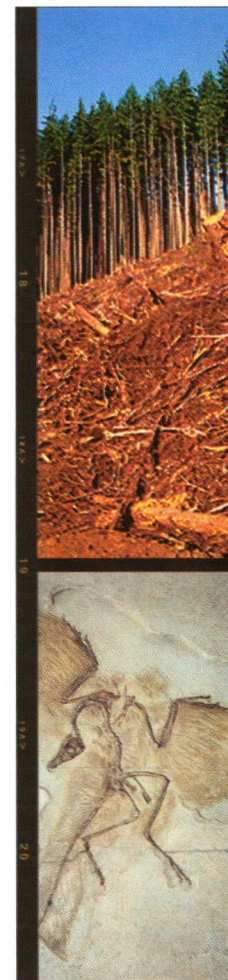
IMPACTS, ISSUES *Too Hot To Handle* 289

17.1 LEVELS OF STRUCTURAL ORGANIZATION 290

From Cells to Multicelled Organisms 290

Growth Versus Development 290

Structural Organization Has a History 290





The Body's Internal Environment 291
How Do Parts Contribute to the Whole? 291

- 17.2 **RECURRING CHALLENGES TO SURVIVAL** 292
Requirements for Gas Exchange 292
Requirements for Internal Transport 292
Maintaining a Solute–Water Balance 293
Requirements for Integration and Control 293
On Variations in Resources and Threats 293

- 17.3 **HOMEOSTASIS IN ANIMALS** 293

Negative Feedback 294
Positive Feedback 295

- 17.4 **DOES HOMEOSTASIS OCCUR IN PLANTS?** 295

Resisting Pathogens 295
Sand, Wind, and the Yellow Bush Lupine 296
About Rhythmic Leaf Folding 296

- 17.5 **HOW CELLS RECEIVE AND RESPOND TO SIGNALS** 297

Unit Four How Plants Work

18 Plant Form and Function

IMPACTS, ISSUES *Drought Versus Civilization* 300

- 18.1 **OVERVIEW OF THE PLANT BODY** 301
Three Plant Tissue Systems 301
Simple Tissues 301
Complex Tissues 302
Eudicots and Monocots—Same Tissues, Different Features 303
- 18.2 **PRIMARY STRUCTURE OF SHOOTS** 304
Inside the Stem 304
Leaf Structure 305
How Do Stems and Leaves Form? 306
- 18.3 **PRIMARY STRUCTURE OF ROOTS** 306
- 18.4 **SECONDARY GROWTH—THE WOODY PLANTS** 308
- 18.5 **PLANT NUTRIENTS AND AVAILABILITY IN SOIL** 310
Properties of Soil 310
Leaching and Erosion 311
- 18.6 **HOW DO ROOTS ABSORB WATER AND MINERAL IONS?** 312

Specialized Absorptive Structures 312
How Roots Control Water Uptake 313

- 18.7 **WATER TRANSPORT THROUGH PLANTS** 314

Transpiration Defined 314
Cohesion–Tension Theory 314

- 18.8 **HOW DO STEMS AND LEAVES CONSERVE WATER?** 316

The Water-Conserving Cuticle 316
Controlled Water Loss at Stomata 316

- 18.9 **HOW ORGANIC COMPOUNDS MOVE THROUGH PLANTS** 317

19 Plant Reproduction and Development

IMPACTS, ISSUES *Imperiled Sexual Partners* 321

- 19.1 **SEXUAL REPRODUCTION IN FLOWERING PLANTS** 322

Regarding the Flowers 322
Regarding the Pollinators 323
From Spores to Zygotes 324

- 19.2 **FROM ZYGOTES TO SEEDS PACKAGED IN FRUIT** 325

- 19.3 **ASEXUAL REPRODUCTION OF FLOWERING PLANTS** 327

Asexual Reproduction in Nature 327
Induced Propagation 327

- 19.4 **PATTERNS OF EARLY GROWTH AND DEVELOPMENT** 328

How Do Seeds Germinate? 328
Genetic Programs, Environmental Cues 328

- 19.5 **CELL COMMUNICATION IN PLANT DEVELOPMENT** 330

Major Types of Plant Hormones 330

- 19.6 **ADJUSTING RATES AND DIRECTIONS OF GROWTH** 332

Responses to Gravity 332
Responses to Light 332
Responses to Contact 333
Responses to Mechanical Stress 333

- 19.7 **MEANWHILE, BACK AT THE FLOWER . . .** 334

How Do Plants Know When To Flower? 334

19.8 LIFE CYCLES END, AND TURN AGAIN 335

19.9 REGARDING THE WORLD'S MOST
NUTRITIOUS PLANT 336

Unit Five How Animals Work

20 Animal Tissues and Organ Systems

IMPACTS, ISSUES *It's All About Potential* 339

20.1 ORGANIZATION AND CONTROL IN
ANIMAL BODIES 340

20.2 FOUR BASIC TYPES OF TISSUES 340

Epithelial Tissues 340

Connective Tissues 341

Muscle Tissues 343

Nervous Tissue 343

20.3 ORGAN SYSTEMS MADE FROM TISSUES 345

Overview of Major Organ Systems 345

Tissue and Organ Formation 345

20.4 SKIN—EXAMPLE OF AN ORGAN SYSTEM 346

21 How Animals Move

IMPACTS, ISSUES *Pumping Up Muscles* 349

21.1 SO WHAT IS A SKELETON? 350

Types of Skeletons 350

Evolution of Vertebrate Skeletons 350

Bone Structure and Function 352

Where Bones Meet—Skeletal Joints 352

21.2 HOW DO BONES AND MUSCLES
INTERACT? 353

21.3 HOW DOES SKELETAL MUSCLE
CONTRACT? 354

Sliding-Filament Model for Contraction 355

Getting Energy for Contraction 355

21.4 PROPERTIES OF WHOLE MUSCLES 356

Muscle Tension 356

A Bad Case of Tetanic Contraction 357

What Is Muscle Fatigue? 357

What Are Muscular Dystrophies? 357

Muscles, Exercise, and Aging 358

22 Circulation and Respiration

IMPACTS, ISSUES *Up In Smoke* 360

22.1 THE NATURE OF BLOOD CIRCULATION 361

The Circulatory and Respiratory Systems
of Vertebrates Evolved Together 361

Links With the Lymphatic System 362

22.2 CHARACTERISTICS OF HUMAN BLOOD 362

22.3 HUMAN CARDIOVASCULAR SYSTEM 364

One Big Circuit and a Special Circuit
to the Lungs 364

The Heart Is a Lonely Pumper 364

How Does Cardiac Muscle Contract? 366

22.4 STRUCTURE AND FUNCTION OF
BLOOD VESSELS 367

Rapid Transport in Arteries 367

Adjusting Resistance at Arterioles 367

Measuring Blood Pressure 368

From Capillaries Back to the Heart 368

Venous Pressure 369

22.5 CARDIOVASCULAR DISORDERS 370

Good Clot, Bad Clot 370

The Silent Killer 370

Atherosclerosis 370

Risk Factors 371

22.6 THE NATURE OF RESPIRATION 371

The Basis of Gas Exchange 371

Which Factors Influence
Gas Exchange? 372

Gills of Fishes and Amphibians 372

Evolution of Paired Lungs 373

22.7 HUMAN RESPIRATORY SYSTEM 374

The System's Many Functions 374

From Airways Into the Lungs 375

22.8 MOVING AIR AND TRANSPORTING GASES 376

The Respiratory Cycle 376

Exchanges at the Respiratory
Membrane 376

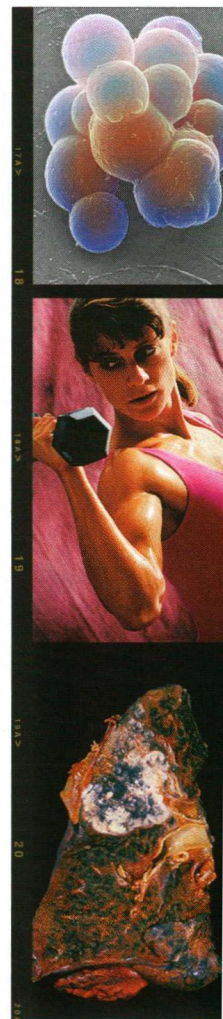
Oxygen and Carbon Dioxide Transport 376

Balancing Air and Blood Flow Rates 378

22.9 WHEN THE LUNGS BREAK DOWN 378

Bronchitis and Emphysema 378

Smoking's Impact 379





23 Immunity

IMPACTS, ISSUES *The Face of AIDS* 382

- 23.1 INTEGRATED RESPONSES TO THREATS 383
 - Evolution of the Body's Defenses 383
 - Three Lines of Defense 383
 - Introducing the Defenders 384
- 23.2 SURFACE BARRIERS 385
 - Intact Skin 385
 - Linings of Tubes and Cavities 385
 - An Uneasy Balance 386
- 23.3 THE INNATE IMMUNE RESPONSE 387
- 23.4 TAILORING RESPONSES TO SPECIFIC ANTIGENS 389
 - Features of Adaptive Immunity 389
 - First Step—The Antigen Alert 389
 - Two Arms of Adaptive Immunity 390
 - So Where Is Antigen Intercepted? 390
- 23.5 ANTIBODIES AND OTHER ANTIGEN RECEPTORS 392
 - B Cell Weapons—The Antibodies 392
 - The Making of Antigen Receptors 393
- 23.6 ANTIBODY-MEDIATED IMMUNE RESPONSE 394
- 23.7 THE CELL-MEDIATED IMMUNE RESPONSE 395
- 23.8 DEFENSES ENHANCED OR COMPROMISED 397
 - Immunization 397
 - Allergies 397
 - Autoimmune Disorders 397
 - Deficient Immune Responses 397
- 23.9 AIDS: IMMUNITY LOST 398
 - HIV Infection—A Titanic Struggle Begins 398
 - How Is HIV Transmitted? 399
 - What About Drugs and Vaccines? 399

24 Digestion, Nutrition, and Excretion

IMPACTS, ISSUES *Hips and Hunger* 402

- 24.1 THE NATURE OF DIGESTIVE SYSTEMS 403
 - Incomplete and Complete Systems 403
 - Correlations With Feeding Behavior 403

- 24.2 HUMAN DIGESTIVE SYSTEM 404
 - Into the Mouth, Down the Tube 404
 - The Stomach 406
 - The Small Intestine 406
 - How Nutrients Are Absorbed 407
 - Controls Over Digestion 408
 - The Large Intestine 409
- 24.3 HUMAN NUTRITIONAL REQUIREMENTS 410
 - Carbohydrates 410
 - Good Fat, Bad Fat 410
 - Body-Building Proteins 411
 - Dietary Recommendations 411
 - Vitamins and Minerals 412
- 24.4 WEIGHTY QUESTIONS, TANTALIZING ANSWERS 413
- 24.5 URINARY SYSTEM OF MAMMALS 415
 - Shifts in Water and Solutes 415
 - Components of the Human Urinary System 415
- 24.6 HOW THE KIDNEYS MAKE URINE 416
 - Nephrons—Functional Units of Kidneys 416
 - Filtration, Reabsorption, and Secretion 416
 - Adjusting Urine Concentration 417
- 24.7 WHEN KIDNEYS BREAK DOWN 419

25 Neural Control and the Senses

IMPACTS, ISSUES *In Pursuit of Ecstasy* 422

- 25.1 NEURONS—THE GREAT COMMUNICATORS 423
 - Neurons and Their Functional Zones 423
 - Resting Membrane Potential 423
 - The Action Potential 424
- 25.2 HOW MESSAGES FLOW FROM CELL TO CELL 426
 - Chemical Synapses 426
 - Synaptic Integration 427
 - A Sampling of Signals 427
- 25.3 THE PATHS OF INFORMATION FLOW 428
 - Blocks and Cables of Neurons 428
 - Reflex Arcs 429
- 25.4 TYPES OF NERVOUS SYSTEMS 430
 - Regarding the Nerve Net 430
 - On the Importance of Having a Head 430
 - Evolution of the Spinal Cord and Brain 430