

BIOLOGY

A GUIDE TO THE NATURAL WORLD



David Krogh

Second Edition

W / 1 CD

STUDENT CD-ROM INCLUDED

Library of Congress Cataloging-in-Publication Data

Krogh, David.

Biology: a guide to the natural world / David Krogh—[2nd ed.].

p. cm

ISBN 0-13-090726-X—ISBN 0-13-092178-5 (pbk.)

1. Biology. I. Title.

QH308.2 .K76 2002

570—dc21

00-066580

CIP

Executive Editor: *Gary Carlson*

Editor-in-Chief, Life and Geosciences: *Sheri L. Snively*

Project Manager: *Karen Horton*

Art Development Editor: *Kim Quillin*

Text Development Editor: *Annie Reid*

MediaLabs Development Editor: *Peggy Brickman*

Editorial Assistant: *Lisa Tarabokjia*

Vice President of Production and Manufacturing: *David W. Riccardi*

Executive Managing Editor: *Kathleen Schiaparelli*

Senior Production Editor: *Nicole M. Bush*

Production Support: *Susan Fisher, Ed Thomas*

Assistant Managing Editor, Science Media: *Elizabeth Wright, Nicole M. Bush*

Executive Marketing Manager, Biology and Geosciences: *Jennifer Welchans*

Marketing Manager: *Shari Meffert*

Marketing Assistant: *Anke Braun*

Manufacturing Manager: *Trudy Pisciotto*

Assistant Manufacturing Manager: *Michael Bell*

Director of Creative Services: *Paul Belfanti*

Manager of Electronic Composition and Digital Content: *Jim Sullivan*

Electronic Composition/Production Specialist: *Donna Marie Paukovits*

Managing Editor, Audio/Visual Assets: *Grace Hazeldine*

A/V Editor: *Adam Velthaus*

Art Support: *Julita Nazario, Shannon Sims*

Director of Design: *Carole Anson*

Art Director: *Jonathan Boylan*

Cover Designer: *Luke Daigle*

Interior Designers: *Lynn Stiles, Jonathan Boylan*

Media Developer: *Mike Guidry/Lightcone Interactive*

Media Editor: *Andrew Stull*

Media Production Editors: *Anthony Maffia, Nicole M. Bush*

Photo Research Administrator: *Melinda Reo*

Photo Researcher: *Diane Austin*

Copy Editor: *Chris Thillen*

Image Permission Coordinator: *Tony Arabia*

Art Studio/Illustrator: *Imagineering*

Cover Photo Credits: *Front, from left:* Butterfly *Cethosia Biblis* (J. Y. Grospas/Peter Arnold, Inc); Na'v flower (Middleton/Liittschwager); Great egret (SuperStock, Inc.). *Spine:* Zebras at Etosha National Park, Namibia (Wolfgang Kaehler Photography). *Rear, from left:* Pine forest in Landes, France (SuperStock, Inc.); Mushrooms in tree trunk, Amazon rain forest (Wolfgang Kaehler Photography); Wood fern *Thelypteridaceae* in Swamp Sanctuary, Florida (Fritz Polking/Peter Arnold, Inc.)

Prentice
Hall

© 2002, 2000 by Prentice-Hall, Inc.
Upper Saddle River, New Jersey 07458

All rights reserved. No part of this book may be reproduced, in any form or by any means, without permission in writing from the Publisher.

Printed in the United States of America

10 9 8 7 6 5 4 3 2

ISBN 0-13-090726-X (case)/0-13-092178-5 (paper)/
0-13-093685-5 (Instructor's Edition)

Pearson Education LTD., London

Pearson Education Australia PTY, Limited, Sydney

Pearson Education Singapore, Pte. Ltd

Pearson Education North Asia Ltd, Hong Kong

Pearson Education Canada, Ltd., Toronto

Pearson Educación de Mexico, S.A. de C.V.

Pearson Education—Japan, Tokyo

Pearson Education Malaysia, Pte. Ltd.

- A new chapter on animal behavior
- Increased coverage of human evolution
- Coverage of many of the new developments in biotechnology: stem-cell research, the possibility of human cloning and xenotransplantation, the results of the sequencing of the human genome, and the controversy surrounding genetically modified foods
- Expanded coverage of the issue of global warming
- Updated or new information on such issues as Mad Cow disease, acid rain, and fad diets

Some detail on these additions probably is in order. Anyone who writes a textbook has to carry out a balancing act between putting in too much and putting in too little. Following publication of the first edition, faculty convinced us that we had erred on the side of too little in connection with two topics: the diversity of life and animal behavior. Therefore, with this edition, readers will see expanded coverage of both topics. Where once we covered diversity in a single chapter, we now cover it in two, the second of which is devoted to animals. The diversity coverage has also been rearranged, so that faculty who want to review plants without going into the details of their anatomy and physiology can do so with the help of the book's first diversity chapter. Meanwhile, animal behavior got its own chapter in the second edition. Students seem to find this a fascinating subject, and their author did too, after diving into it. The *Guide's* diversity coverage begins with Chapter 20, while its animal behavior Chapter is 31.

Faculty and students also wanted more coverage of human evolution in the book, and to that end, we have substantially expanded our coverage of this subject. The long, last module of Chapter 19 is given over to it. I'm happy to say that we are as up-to-date as a textbook can be on this fast-moving field. Faculty who wanted to see coverage of the senses will find, in Chapter 25, a long section on vision as an example of our sensory capabilities.

Apart from expanding into new areas, the second edition of the *Guide* also needed to take account of new developments in biology.

There has been plenty to take account of. As one who has followed perhaps a score of research areas for several years now, I can attest that there is no grass growing under the feet of biologists. The sequencing of the human genome has brought with it a tidal wave of new findings—new fields of biology, even. (It would be interesting to pinpoint the first published use of such terms as bioinformatics.) As a result, this book's biotechnology coverage, in Chapter 15, has changed greatly. It wasn't just the sequencing of the human genome that necessitated this change, however. Reproductive cloning has raised the possibility of human cloning and xenotransplantation. Meanwhile, the fight over genetically modified foods has greatly intensified in the past couple of years. Readers will find expanded coverage of all these issues in Chapter 15. Another fast-emerging and controversial field in biology is that of stem-cell research. This topic seemed a natural fit with the book's Chapter 27, which covers development.

With each passing month since the first edition was published, biology seems to have figured ever more prominently in other societal issues as well. Accordingly, the second edition of the *Guide* has retained and updated its coverage of such subjects as DNA fingerprinting, cancer, and acid rain, while adding new essays on such subjects as Mad Cow disease (Chapter 20), fad diets (Chapter 3), and human sexuality (Chapter 31). Global warming has emerged in the past two years as perhaps the planet's single most worrisome environmental issue. Readers will find updated and expanded coverage of it in Chapter 30.

Coverage of the Process of Discovery

One of the priorities for the second edition was to continue to impart to students a sense of *how* research results are arrived at in biology. Most of the book's chapters weave information on the process of discovery into explanations of what has been discovered. See, for example, Chapter 13 on Watson, Crick, and the DNA molecule; or Chapter 31 on proximate and ultimate causes in animal behavior. The first edition of the book also had a series of stand-alone "How Did We

Preface

Learn?” essays, and these have been updated and expanded for the second edition. (See the box on animal navigation in Chapter 31.) We also noted that, while faculty and students like these essays, they didn’t like them interrupting the flow of a chapter’s main text. Thus, “How Did We Learn?” boxes now appear at the end of chapters, rather than in the middle of them.

Electronic Media and the Second Edition

One of the most exciting features of the second edition concerns not what the book covers, but enhancements in its coverage that have been made possible by electronic media. Students and faculty have come to expect sophisticated media components in textbooks, but with the second edition of *A Guide to the Natural World*, I think we will exceed their expectations.

The book’s media offerings for students can be conceptualized as falling into two categories. First, there are the CD-ROM Tutorials—well-named because collectively they function as a kind of book-length tutor. Each of them leads students through a series of related biological concepts with the help of the specialized teaching tool of animation. If, upon reading Chapter 14 on genetic transcription and translation, a student isn’t able to visualize how transfer RNA and messenger RNA work together at ribosomes, he or she can turn to the chapter’s CD-ROM Tutorial and see this process laid out, step by step, with all the kinetics presented in animations. This story, of manufacturing proteins, is a CD-ROM “learning module” for Chapter 14—one of four contained in that chapter’s CD-ROM Tutorial. Each module walks students through a key chapter concept; each contains an interactive activity or exercise; and each ends with its own summary and mini-quiz.

All the CD-ROM Tutorials were developed by Mike Guidry and his colleagues at Light-Cone Interactive. Mike’s team produced a tutorial for every chapter in the book, each one identified in the text with an icon like the one shown at left.

Of course, students can turn to tutorial animations simply to make a given book illustration come to life; but they can also use the tutorials as just that—as learning sessions that employ interactive, step-by-step progressions. The proof here is in the pudding; take a look at some of the tutorials, and I think you’ll agree they are a strong addition to the book.

Apart from the CD-ROM Tutorials, the *Guide* has, in its second edition, an expanded roster of the MediaLabs that proved so popular in the first edition. Produced by Peggy Brickman of the University of Georgia, these MediaLabs are aimed at making plain the linkage between biological concepts and real-world issues, and at fostering critical thinking about this linkage. A given lab starts by having students review, through a CD-ROM Tutorial, certain key concepts in a chapter. Then students are asked to investigate real-world issues connected to these concepts by going to suggested websites. (The cell cycle, covered in Chapter 9, may be intimately involved in the initiation of cancer, but what environmental factors are most important in getting cancer going? A *Scientific American* Web page tells the tale.) Having done this digging, students are then asked to communicate what they have learned by writing brief essays on questions that are put to them. The book now has 15 MediaLabs, each integrated with the content of a specific chapter. Each MediaLab begins within the book itself (at the end of selected chapters), but then broadens out to the CD-ROM and the wide world of the Internet.

Many more digital tools are available to students in this second edition of the *Guide*. The book’s website <http://www.prenhall.com/krogh>, developed by Prentice Hall’s Andrew Stull, provides a host of resources. Students looking at any chapter at the website can click on a “Destinations” hyperlink and be presented with a rich roster of chapter-specific Internet links. Self-quizzes for each chapter also are posted on the website, with quiz questions divided into “basic” and “challenge” sets. (To make things easy for students, the CD-ROM Tutorials contain links to both the Companion Website and the MediaLabs.) Beyond this, there is a set of audio files that can



Tutorial 14.3.4
Protein Translation

Preface

be launched from the website. These are National Public Radio Biocast programs that have been integrated by their author, Bruce Hofkin, into each chapter in the book. Upon launching the *Biocasts* for Chapter 10, for example, a student can listen to a short program on a new technology that helps parents choose the gender of their child. This technology is connected to a basic concept covered in Chapter 10, sex determination in meiosis. Hofkin then brings the basic and applied science together in questions he poses at the end of the program.

All of these digital resources (and more) are available to students in the second edition of the *Guide*, but faculty have additional resources at their disposal. The Instructor's CD-ROM contains all of the key animations in the student CD-ROM; these are in turn part of a bank of images, known as the Media-Portfolio, containing every illustration and most of the photos in the book. The Media-Portfolio makes all the figures available in several formats, including PowerPoint slides that can be mixed and matched as desired, with figure parts, labels, and captions that can be edited. In addition, the *Instructor's Guide* and test-item file are embedded as a Word document in the CD-ROM, so that faculty can cut and paste what they need. Beyond these things, all the traditional media, such as transparencies, are available to faculty.

Notable Features in *A Guide to the Natural World* Design and Illustrations

As in the first edition of the book, each chapter in the second edition is divided into numbered modules (1.1, 1.2, and so forth), so that instructors can easily assign selected parts of a given chapter. The chapter sections are listed at the start of each chapter, and end-of-chapter summaries are indexed by section. On the first page of each chapter is a visual "film-strip" that offers an intriguing preview of what's to come.

Flip through the pages of the *Guide*, and you'll note another useful design element right away: Text almost always occupies the

top left of a page, with illustrations at the bottom. As a result, text continued from one page to the next is almost never broken up by a photo or illustration. Students reading text will not have their concentration broken by graphics when they turn to new pages.

Regarding the book's illustrations, I think *A Guide to the Natural World* is first-rate for reasons of both process and personnel. The process was that illustrations were once again constructed chapter by chapter in a collaboration between myself and artist Kim Quillin. Kim and I now have to communicate through electronic files, whisking them from one coast to the other, whereas in the first edition we communicated at a Berkeley Starbuck's. (Kim moved back to her native coastal Maryland after finishing her Ph.D. in biomechanics at UC Berkeley.) But our method of working has remained the same: We revise chapters at an early stage, based on the illustrations that Kim comes up with, thus ensuring a tight integration between text and illustrations. Put another way, the figures in the book aren't just adjuncts to the text. Rather, figures and text have shaped each other in a back-and-forth process.

The *Guide to the Natural World* Team

Given all the names I've mentioned so far, it may go without saying that production of this book has been a team effort. It is my good fortune to have been given great teams for both editions of *A Guide to the Natural World*. So large is an effort such as this that there are many people I've never met who have put in long hours on the book. I've noted Kim Quillin and her role in the book's art program. Annie Reid served ably as the book's developmental editor—the person who looked over everything Kim and I came up with and said whether it worked, after which she put the revised product together in a package that could be made into a book. Chris Thillen copyedited the manuscript, patiently making sure that the English language was used correctly. Nicole Bush has been a fine production editor, bringing together pieces of art and blocks of text into the nicely laid out

Preface

final product you see before you. Peggy Brickman not only developed the MediaLabs but also contributed greatly to the CD-ROM Tutorials produced by Mike Guidry and his co-workers. Thanks needs to go out in advance to Jennifer Welchans and Shari Meffert, who are just beginning to get the word out about the new edition of the *Guide*. Finally, we had great support at the top from Prentice Hall Editors Gary Carlson and Sheri Snively, who managed the project on its largest scale.

Apart from these team members, more than two-hundred faculty have now carefully critiqued every word and image you see in *A Guide to the Natural World*. (Is any written work more carefully reviewed than a textbook? Peer-reviewed scientific papers are the only other contenders that come to mind.) The names of reviewing faculty can be found beginning on page xxxiv. Of these faculty, I need to make special note of the team of academic advisors who have provided advice not only on the details of the book, but on its overall structure and coverage. These advisors are listed across from the title page.

Finally, my thanks to all the faculty who used the first edition of *A Guide to the Natural World* in their courses and then let us know how it worked. Some of these faculty were reviewers, but some were instructors who sent in comments by e-mail or by old-fashioned letter just because they thought their feedback might be helpful. If they said the book needed some tweaking, we listened—the result being what you see in front of you. The main message from these faculty, however, was gratifying indeed. From them, we learned that we had done what we intended to do with the first edition of *A Guide to the Natural World*: We had created a book that their students could understand. Moreover, they said, we did this not by leaving out the hard parts, but by thinking carefully about how all the parts should be presented. Here's hoping that the second edition works as well.

David Krogh
Berkeley, California

Preface

The Book Team



Kim Quillin received her B.A. in biology at Oberlin College and her Ph.D. in integrative biology from the University of California, Berkeley. Her teaching experience

ranges from elementary school science to undergraduate biology at both Oberlin College and UC, Berkeley. She has studied birds in the Smithsonian Museum of Natural History, howler monkey social behavior in Costa Rica, and restoration ecology of aquatic plants in Ohio. Kim has studied art for over two decades. Her formal art training ranges from the Maryland Summer Center for the Arts to college courses and professional workshops. This book is evidence of her dedicated efforts toward the effective visual communication of biological principles.



Marguerite (Peggy) Brickman received her B.A. from Columbia (College) University and her Ph.D. in genetics from the University of California, Berkeley. In

teaching non-science majors, she focuses on making the material both relevant and entertaining. As an Assistant Professor in the Botany Department at the University of Georgia, she has been ranked number one by student evaluations in the Division of Biology for the past three semesters and is the recipient of an Excellence in Undergraduate Education teaching award. One of the reasons her classes are so popular is her ability to integrate media into her lectures. Peggy teaches her students to view electronic information critically, so that after they finish the class they can approach these same media with intelligence and savvy. As MediaLab editor for the book, Peggy has designed the labs to encourage students to think through the material logically and critically.

We express sincere gratitude to the expert reviewers who worked closely with the author in reviewing final pages to ensure the scientific accuracy of the text and art.

Anthony Ives, *University of Wisconsin, Madison*

Leslie Roldan, *Massachusetts Institute of Technology*

Anu Singh-Cundy, *Western Washington University*

Ellen Smith, *Arizona State University West*

Erica Suchman, *Colorado State University*

Christine Tachibana, *University of Washington*

Sara Via, *University of Maryland*

John Whitmarsh, *University of Illinois*

The end-of-chapter questions were carefully crafted by a team of dedicated instructors, and we wish to acknowledge their contribution.

Ed Bartholomew, *Maui Community College*

David Berrigan, *University of Washington*

Gail E. Gasparich, *Towson University*

Carol A. Hurney, *Virginia Commonwealth University*

Kate Lajtha, *University of Oregon*

Michelle Murphy, *University of Notre Dame*

Rhoda E. Perozzi, *Virginia Commonwealth University*

Heidi Rottschäfer, *University of Notre Dame*

Anu Singh-Cundy, *Western Washington University*

Sara Via, *University of Maryland*

Media Reviewers

Robert S. Boyd, *Auburn University, University of Georgia*

Carolyn Glaubenslee, *University of Southern Colorado*

Gregory J. Podgorski, *Utah State University*

David A. Rintoul, *Kansas State University*

Ron Ruppert, *Cuesta College*

Brian Sailer, *Sam Houston State University*

Rebekah J. Thomas, *Saint Leo University*

Jennifer M. Warner, *University of North Carolina, Charlotte*

Jamie Welling, *South Suburban College*

(continued on the next page)

Second Edition Reviewers

John Alcock, *Arizona State University*
 Sylvester Allred, *Northern Arizona University*
 Gary Anderson, *University of California, Davis*
 Marjay A. Anderson, *Howard University*
 Jessica Baack, *Montgomery College*
 Tania Baker, *Massachusetts Institute of Technology*
 Peter Bednekoff, *Eastern Michigan University*
 David Berrigan, *University of Washington*
 Andrew Blaustein, *Oregon State University*
 Robert S. Boyd, *Auburn University*
 Leon W. Browder, *University of Calgary*
 Warren Burggren, *University of North Texas*
 David Byres, *Florida Central Community College, South Campus*
 Van D. Christman, *Ricks College*
 Deborah C. Clark, *Middle Tennessee State University*
 Patricia Cox, *University of Tennessee, Knoxville*
 Garry Davies, *University of Alaska, Anchorage*
 Paula Dedmon, *Gaston College*
 Miriam del Campo, *Miami Dade Community College*
 Llewellyn Densmore, *Texas Technical University*
 Jean Dickey, *Clemson University*
 Christopher Dobson, *Front Range Community College*
 Deborah Dodson, *Vincennes University*
 Richard H. Falk, *University of California, Davis*
 Christine M. Foreman, *University of Toledo*
 Carl S. Frankel, *Pennsylvania State University*
 Lawrence Friedman, *University of Missouri, St. Louis*
 Matt Geisler, *University of California, Riverside*
 Carolyn Glaubenskle, *University of Southern Colorado*
 Judith Goodenough, *University of Massachusetts, Amherst*
 G. A. Griffith, *South Suburban College*
 Edward Hale, *Ball State University*
 Kelly Hamilton, *Shoreline Community College*
 Steve Heard, *University of Iowa*
 Eva Horne, *Kansas State University*
 Michael Hudecki, *State University of New York, Buffalo*
 Michael Hudspeth, *Northern Illinois University*
 Catherine J. Hurlbut, *Florida Community College*

Anthony Ives, *University of Wisconsin, Green Bay*
 Kevin M. Kelly, *California State University, Long Beach*
 Jeanette J. Kiem, *Guilford Technical Community College*
 Jocelyn Krebs, *University of Alaska, Anchorage*
 Kate Lajtha, *Oregon State University*
 Paul Lurquin, *Washington State University*
 James Manser, *Harvey Mudd College*
 Paul Mason, *Butte Community College*
 Lee H. Mitchell, *Mount Hood Community College*
 Janice Moore, *Colorado State University*
 Jorge A. Moreno, *University of Colorado*
 Michael D. Morgan, *University of Wisconsin, Green Bay*
 David Mork, *Saint Cloud State University*
 Michelle Murphy, *University of Notre Dame*
 Courtney Murren, *University of Tennessee, Knoxville*
 Harry Nickla, *Creighton University*
 Maya Patel, *Ithaca College*
 Carolyn Peters, *Spoon River College*
 Holly C. Pinkart, *Central Washington University*
 Barbara Pleasants, *Iowa State University*
 Gregory J. Podgorski, *Utah State University*
 Lynn Polasek, *Los Angeles Valley College*
 F. Harvey Pough, *Arizona State University West*
 Regina Rector, *William Rainey Harper College*
 Dennis Richardson, *Quinnipiac University*
 David A. Rintoul, *Kansas State University*
 Laurel Roberts, *University of Pittsburgh*
 Rodney A. Rogers, *Drake University*
 Leslie Ann Roldan, *Massachusetts Institute of Technology*
 Ron Ruppert, *Cuesta College*
 Julie Schroer, *Bismarck State College*
 Anu Singh-Cundy, *Western Washington University*
 Peter Slater, *University of St. Andrews, UK*
 Nancy G. Solomon, *Miami University*
 Allan R. Stevens, *Snow College*
 Erica Lynn Suchman, *Colorado State University*
 Christine Tachibana, *University of Washington*
 Rebekah J. Thomas, *Saint Leo University*
 Todd T. Tracy, *Colorado State University*
 Joseph W. Vanable, Jr., *Purdue University*
 Sara Via, *University of Maryland*

Tanya Vickers, *University of Utah*
 Janet Vigna, *Southwest State University*
 Allan Hayes Vogel, *Chemeketa Community College*
 Nicholas Wade, *The New York Times*
 Jyoti R. Wagle, *Houston Community College*
 Timothy S. Wakefield, *John Brown University*
 Charles Walcott, *Cornell University*
 Gene Walton, *Tallahassee Community College*
 Jennifer M. Warner, *University of North Carolina*
 Jamie Welling, *South Suburban College*
 John Whitmarsh, *University of Illinois*
 Susan Whittemore, *Keene State University*
 Mark A. Woelfe, *Vanderbilt University*
 Lorne Wolfe, *Georgia Southern University*

First Edition Reviewers

Dawn Adams, *Baylor University*
 David L. Alles, *Western Washington University*
 Gary Anderson, *University of California, Davis*
 Michael F. Antolin, *Colorado State University*
 Kerri Armstrong, *Community College of Philadelphia*
 Mary Ashley, *University of Illinois, Chicago*
 Kemuel Badger, *Ball State University*
 Michael C. Bell, *Richland College*
 William J. Bell, *University of Kansas*
 David Berrigan, *University of Washington*
 Lois A. Bichler, *Stephens College*
 A. W. Blackler, *Cornell University*
 Robert S. Boyd, *Auburn University*
 Bonnie L. Brenner, *Wilbur Wright College (City College of Chicago)*
 Mimi Bres, *Prince George's Community College*
 Peggy Brickman, *University of Georgia*
 Leon Browder, *University of Calgary*
 Arthur L. Buikema, *Virginia Polytechnic Institute and State University (Allegheny College)*
 Steven K. Burian, *Southern Connecticut State University*
 Janis K. Bush, *University of Texas, San Antonio*
 Linda Butler, *University of Texas, Austin*
 W. Barkley Butler, *Indiana University of Pennsylvania*
 William S. Cohen, *University of Kentucky*

Preface

- Tricia Cooley, *Laredo Community College*
 Karen A. Conzelman, *Glendale Community College*
 Patricia B. Cox, *University of Tennessee*
 John Crane, *Washington State University*
 Brent DeMars, *Lakeland Community College*
 Jean DeSaix, *University of North Carolina, Chapel Hill*
 Matthew M. Douglas, *Grand Rapids Community College (University of Kansas)*
 Lee C. Drickamer, *Southern Illinois University*
 Charles Duggins, Jr., *University of South Carolina*
 Susan A. Dunford, *University of Cincinnati*
 Ron Edwards, *University of Florida*
 Douglas J. Eernisse, *California State University, Fullerton*
 Jamin Eisenbach, *Eastern Michigan University*
 George Ellmore, *Tufts University*
 Patrick E. Elvander, *University of California, Santa Cruz*
 Michael Emsley, *George Mason University*
 David W. Essar, *Winona State University*
 Michael Farabee, *Estrella Mountain Community College*
 Rita Farrar, *Louisiana State University*
 John Philip Fawley, *Westminster College*
 Eugene J. Fenster, *Longview Community College*
 John L. Frola, *University of Akron*
 Larry Fulton, *American River College*
 Gail E. Gasparich, *Towson University*
 Claudette Giscombe, *University of Southern Indiana*
 Jack M. Goldberg, *University of California, Davis*
 Glenn A. Gorelick, *Citrus College*
 Melvin H. Green, *University of California, San Diego*
 Gail Hall, *Trinity College*
 Linnea S. Hall, *California State University, Sacramento*
 Madeline Hall, *Cleveland State University*
 Steven C. Harris, *Clarion University*
 Walter Hewitson, *Bridgewater State College*
 Jane Aloï Horlings, *Saddleback College*
 Eva Horne, *Kansas State University*
 Terry L. Hufford, *The George Washington University*
 Carol A. Hurney, *James Madison University*
 Andrea Huvar, *California Lutheran University*
 Martin Ikkanda, *Los Angeles Pierce College*
 Rose M. Isgrigg, *Ohio University*
 Anthony Ives, *University of Wisconsin, Madison*
 Tom Jurik, *Iowa State University*
 Anne Keddy-Hector, *Austin Community College*
 Kathleen Keeler, *University of Nebraska*
 Nancy Keene, *Pellissippi State Technical Community College*
 Kevin M. Kelley, *California State University, Long Beach*
 Tom Knoedler, *Ohio State University, Lima Campus*
 Don E. Krane, *Wright State University*
 Erika Ann Lawson, *Columbia College*
 Mike Lawson, *Missouri Southern State College*
 Ann Lumsden, *Florida State University*
 Michael M. Martin, *University of Michigan, Ann Arbor*
 Michel Masson, *Santa Barbara City College*
 Mary Colleen McNamara, *Albuquerque T-VI A Community College*
 Scott M. Moody, *Ohio University*
 Joseph Moore, *California State University, Northridge*
 Deborah A. Morris, *Portland State University*
 Allison Morrison-Shetlar, *Georgia Southern University*
 Richard Mortensen, *Albion College*
 Michelle Murphy, *University of Notre Dame*
 Royden Nakamura, *California Polytechnic State University*
 Jane Noble-Harvey, *University of Delaware*
 Marcy P. Osgood, *University of Michigan*
 Andrea Ostrofsky, *University of Maine*
 Patricia A. Peroni, *Davidson College*
 Rhoda E. Perozzi, *Virginia Commonwealth University*
 John S. Peters, *College of Charleston*
 Kim M. Peterson, *University of Alaska, Anchorage*
 Raleigh K. Pettegrew, *Denison University*
 Gary W. Pettibone, *State University of New York, College at Buffalo*
 Barbara Pleasants, *Iowa State University*
 John M. Pleasants, *Iowa State University*
 Don Pribor, *University of Toledo*
 Louis Primavera, *Hawaii Pacific University*
 Paul Ramp, *Pellissippi State and Technical Community College*
 Sonia J. Ringstrom, *Loyola University*
 Leslie Ann Roldan, *Massachusetts Institute of Technology*
 Heidi Rottschafer, *University of Notre Dame*
 John Rueter, *Portland State University*
 Nancy Sanders, *Northeast Missouri State University*
 Gary Sarinsky, *City University of New York, Kingsborough Community College*
 Edna Seaman, *University of Massachusetts, Boston*
 Ralph W. Seelke, *University of Wisconsin, Superior*
 Prem P. Sehgal, *East Carolina University*
 C. Thomas Settlemyre, *Bowdoin College*
 Robert Shetlar, *Georgia Southern University*
 Mark A. Shotwell, *University of Slippery Rock*
 Linda Simpson, *University of North Carolina, Charlotte*
 Anu Singh-Cundy, *Western Washington University*
 Ellen Smith, *Arizona State University West*
 Philip J. Snider, *University of Houston*
 Frederick W. Spiegel, *University of Arkansas*
 Kathleen M. Steinert, *Bellevue Community College*
 Donald P. Streubel, *Idaho State University*
 Erica Suchman, *Colorado State University*
 Gerald Summers, *University of Missouri, Columbia*
 Joanne Tornow, *University of Southern Mississippi*
 Robin W. Tyser, *University of Wisconsin, LaCrosse*
 Sara Via, *University of Maryland*
 Dennis Vrba, *North Iowa Area Community College*
 Nicholas Wade, *The New York Times*
 John H. Wahlert, *Baruch College, The City University of New York*
 Timothy S. Wakefield, *Auburn University*
 Sarah Ward, *Colorado State University*
 R. Barry Welch, *San Antonio College*
 John Whitmarsh, *University of Illinois at Urbana-Champaign*
 Sandra Winicur, *Indiana University, South Bend*
 William Wischusen, *Louisiana State University*
 Deborah Wisti-Peterson, *University of Washington*
 Rachel Witcher, *University of Central Florida*
 Wade B. Worthen, *Furman University*
 Robert Yost, *Indiana University Purdue University Indianapolis*

*For my friends Jerry and Teresa
Far away, but always in my heart*

Essays

Forty-four essays appear in the book, most of them having an applied slant. They deal with such topics as acid rain, fad diets, DNA fingerprinting, osteoporosis and young women, and the nature of human sexuality.

HOW DID WE LEARN? In the How Did We Learn? essays, students can come into understand the inventiveness and the plain hard work that generally are prerequisites to scientific discovery.

Chapter 1

Lung Cancer, Smoking, and Statistics in Science 10

Chapter 2

Notating Chemistry 26
Free Radicals 29

Chapter 3

Acid Rain: When Water Is Trouble 44
Dietary Decisions: Should You Cut Carbohydrates? 54

Chapter 4

The Size of Cells 72
The Stranger within: Lynn Margulis and Endosymbiosis 83
How Did We Learn? First Sightings: Anton van Leeuwenhoek 92

Chapter 5

How Did We Learn? The Fluid-Mosaic Model of the Plasma Membrane 109

Chapter 7

When Energy Harvesting Ends at Glycolysis, Beer Can Be the Result 138
Energy and Exercise 140

Chapter 8

How Did We Learn? Plants Make Their Own Food, But How? 164

Chapter 9

When Cell Division Runs Amok: Cancer 175

Chapter 10

The Revealing Y Chromosome 198

Chapter 11

Proportions and Their Causes: The Rules of Multiplication and Addition 214
Why So Unrecognized? 219

Chapter 12

Testing for Genetic Trouble 238
How Did We Learn? Thomas Hunt Morgan: Using Fruit Flies to Look More Deeply into Genetics 244

Chapter 13

How Did We Learn? Getting Clear about What Genes Do: Beadle and Tatum 264

Chapter 14

Making Sense of "Junk" DNA 280
How Did We Learn? Cracking the Genetic Code 285

Chapter 15

DNA in the Courtroom 305

Chapter 16

Can Darwinian Theory Make Us Healthier? 331

Chapter 17

Lessons from the Cocker Spaniel: The Price of Inbreeding 346

Chapter 18

New Species through Genetic Accidents: Polyploidy 362

Chapter 19

Physical Forces that Have Shaped Evolution: Climate, Extraterrestrial Objects, and Continental Drift 380

Chapter 20

The Unsolvable Taxonomy Problem 407
Not Alive, but Deadly: Prions and 'Mad Cow' Disease 410
Modes of Nutrition: How Organisms Get What They Need to Survive 415

Chapter 22

What Is Plant Food? 477
Keeping Cut Flowers Fresh 483
Ripening Fruit Is a Gas 485

Chapter 23

A Tree's History Can Be Seen in Its Wood 507
The Syrup for our Pancakes Comes from Xylem 510

Chapter 24

Doing Something about Osteoporosis While You Are Young 540

Chapter 28

Hormones and the Female Reproductive Cycle 640
Methods of Contraception 645
Sexually Transmitted Disease 648

Chapter 29

Purring Predators: Housecats and Their Prey 679

Chapter 30

A Cut for the Middleman: Livestock and Food 706
Good News about the Environment 721

Chapter 31

Biological Rhythms and Sports 740
Are Men 'Naturally' Promiscuous and Women Reserved? 744
How Did We Learn? How Do Sea Turtles Find Their Way? 755

MediaLabs

There are fifteen MediaLabs throughout the book. The topics were carefully chosen not only for student interest but also because they highlight issues that students may come across in their daily lives. Each MediaLab takes the reader on a journey of discovery through CD-ROM activities and web investigations.

Chapter 3

You Are What You Eat: Food and the Molecules of Life 66

Chapter 5

Balancing Your Imports and Exports: Membrane Transport 114

Chapter 7

Dietary Fad or Miracle Drug? Using Science to Understand Metabolism 150

Chapter 8

Capturing Sunlight to Make Food: Photosynthesis 168

Chapter 9

Too Much Division: The Cell Cycle and Cancer 188

Chapter 11

Where Did I Get This Nose? Understanding Mendelian Genetics 228

Chapter 12

Do We Know Too Much? Human Genetic Testing 252

Chapter 14

Can We Stop the Cycle? DNA to RNA Protein 290

Chapter 15

Holding Out Promise or Peril? Biotechnology 318

Chapter 17

Are Bacteria Winning the War? Natural Selection in Action 354

Chapter 23

Why Do We Need Plants Anyway? The Importance of Plant Diversity 524

Chapter 25

How Does Your Body Fight the Flu? Understanding the Immune System 588

Chapter 28

Are Test Tube Babies the Solution? Understanding Reproductive Problems 658

Chapter 29

Can Earth Support All of Us? Population Growth Patterns 690

Chapter 30

El Niño and the Greenhouse Effect: How Climate Affects Our Weather, Food, and Water Supplies 730

Brief Contents

- 1 Science as a Way of Learning: A Guide to the Natural World 3

Unit 1 Essential Parts: Atoms, Molecules, and Cells

- 2 The Fundamental Building Blocks: Chemistry and Life 18
3 Water, pH, and Biological Molecules 36
4 Life's Home: The Cell 68
5 Life's Border: The Plasma Membrane 96

Unit 2 Energy and Its Transformations

- 6 Life's Mainspring: An Introduction to Energy 116
7 Vital Harvest: Deriving Energy from Food 130
8 The Green World's Gift: Photosynthesis 152

Unit 3 How Life Goes On: Genetics

- 9 Introduction to Genetics; Mitosis and Cytokinesis 170
10 Preparing for Sexual Reproduction: Meiosis 190
11 The First Geneticist: Mendel and His Discoveries 206
12 Chromosomes and Inheritance 230
13 DNA Structure and Replication 254
14 How Proteins Are Made: Genetic Transcription, Translation, and Regulation 268
15 The Future Isn't What It Used to Be: Biotechnology 292

Unit 4 Life's Organizing Principle: Evolution and the Diversity of Life

- 16 An Introduction to Evolution: Charles Darwin, Evolutionary Thought, and the Evidence for Evolution 320
17 The Means of Evolution: Microevolution 338
18 The Outcomes of Evolution: Macroevolution 356
19 A Slow Unfolding: The History of Life on Earth 376
20 Pond Dwellers, Log Eaters, and Self-Feeders: The Diversity of Life 404
21 Movers and Shakers: The Animal Kingdom 436

Unit 5 A Bounty That Feeds Us All: Plants

- 22 An Introduction to Flowering Plants 472
23 Form and Function in Flowering Plants 494

Unit 6 What Makes the Organism Tick? Animal Anatomy and Physiology

- 24 Introduction to Animal Anatomy and Physiology: The Integumentary, Skeletal, and Muscular Systems 526
25 Control and Defense: The Nervous, Endocrine, and Immune Systems 550
26 Transport, Nutrition, and Exchange: Blood, Breath, Digestion, and Elimination 590
27 An Amazingly Detailed Script: Animal Development 620
28 How the Baby Came to Be: Human Reproduction 634

Unit 7 The Living World as a Whole: Ecology and Animal Behavior

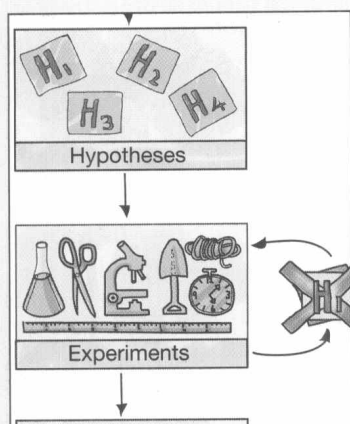
- 29 An Interactive Living World: Populations and Communities in Ecology 660
30 An Interactive Living World: Ecosystems and the Biosphere 692
31 Animal Behavior 732

Contents

HIGHLIGHTS

Essay

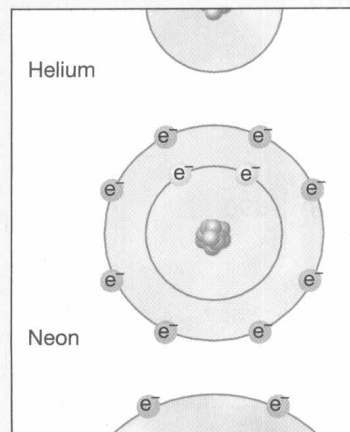
Lung Cancer, Smoking, and
Statistics in Science 10



Scientific Method. 8

Essays

Notating Chemistry 26
Free Radicals 29



Electron configuration. 24

Preface xxviii

Chapter 1 Science as a Way of Learning: A Guide to the Natural World 3

- 1.1 **How Does Science Impact the Everyday World?** 4
A Look at the News 4
- 1.2 **What Does the Public Think, and Know, about Science?** 6
Public Attitudes toward Science 6
Public Knowledge of Science 6
- 1.3 **What Is Science?** 7
Science as a Body of Knowledge 7
Science as a Process: Arriving at Scientific Insights 7
From Hypothesis to Theory 9
- 1.4 **Biology** 12
What Is Life? 12
Life Is Highly Organized, in a Hierarchical Manner 13
- 1.5 **Special Qualities of Biology** 13
Biology's Chief Unifying Principle 15
The Organization of This Book 15
Chapter Review 16

Unit 1 Essential Parts: Atoms, Molecules, and Cells

Chapter 2 The Fundamental Building Blocks: Chemistry and Life 18

- 2.1 **The Nature of Matter: The Atom** 20
Protons, Neutrons, and Electrons 20
Fundamental Forms of Matter: The Element 22
- 2.2 **Matter Is Transformed through Chemical Bonding** 23
Energy Always Seeks Its Lowest State 24
Seeking a Full Outer Shell: Covalent Bonding 24
Reactive and Unreactive Elements 26
Polar and Nonpolar Bonding 26
Ionic Bonding: When Electrons Are Lost or Gained 28
A Third Form of Bonding: Hydrogen Bonding 30
- 2.3 **Some Qualities of Chemical Compounds** 30
Molecules Have a Three-Dimensional Shape 30
Molecular Shape Is Very Important in Biology 31
Solutes, Solvents, and Solutions 31
On to Some Detail Regarding Water 32
Chapter Review 32

Chapter 3 Water, pH, and Biological Molecules 36

3.1 The Importance of Water to Life 37

- Water Is a Major Player in Many of Life's Processes 37
- Water's Structure Gives It Many Unusual Properties 38
- Two Important Terms: Hydrophobic and Hydrophilic 40

3.2 Acids and Bases Are Important to Life 40

- Acids Yield Hydrogen Ions in Solution; Bases Accept Them 41
- Many Common Substances Can Be Ranked According to How Acidic or Basic They Are 42
- The pH Scale Allows Us to Quantify How Acidic or Basic Compounds Are 42
- Some Terms Used When Dealing with pH 42
- Why Does pH Matter? 42

3.3 Carbon Is a Central Element in Life 44

- Carbon as a Starting Ingredient 44
- Carbon's Importance Stems from Its Bonding Capacity 45

3.4 The Molecules of Life: Carbohydrates, Lipids, Proteins, and Nucleic Acids 47

- The Building-Blocks Model of Organic Molecules 47
- Carbohydrates: From Simple Sugars to Cellulose 48
- Lipids: Oils, Fats, Hormones, and the Outer Lining of Cells 50
- Proteins 56
- Lipoproteins and Glycoproteins 60
- Nucleotides and Nucleic Acids 60
- On to Cells 62
- Chapter Review 63

Chapter 4 Life's Home: The Cell 68

4.1 Cells Are the Working Units of Life 69

- Cells Bring Unity and Continuity to Life 69

4.2 All Cells Are Either Prokaryotic or Eukaryotic 70

- Prokaryotic and Eukaryotic Differences 70
- Compartmentalization in Eukaryotic Cells 71

4.3 The Eukaryotic Cell 75

- The Animal Cell 75

4.4 A Tour of the Animal Cell: Along the Protein Production Path 75

- Beginning in the Control Center: The Nucleus 76
- Ribosomes 77
- The Rough Endoplasmic Reticulum 78
- A Pause for the Nucleolus 78
- Elegant Transportation: Transport Vesicles 79
- Downstream from the Rough ER: The Golgi Complex 79
- From the Golgi to the Surface 80

4.5 Outside the Protein Production Path: Other Cell Structures 80

- The Smooth Endoplasmic Reticulum 80
- Tiny Acid Vats: Lysosomes and Cellular Recycling 81
- Extracting Energy from Food: Mitochondria 82

HIGHLIGHTS

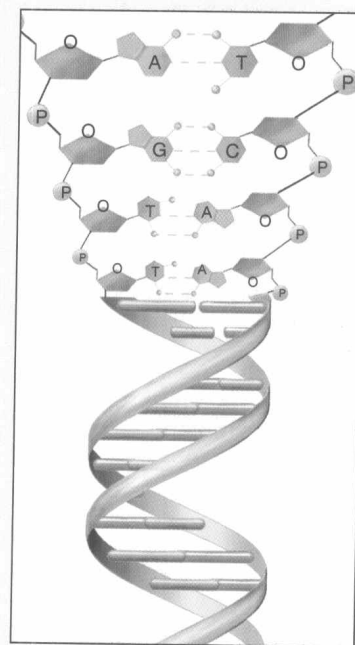
Essays

Acid Rain: When Water Is Trouble 44

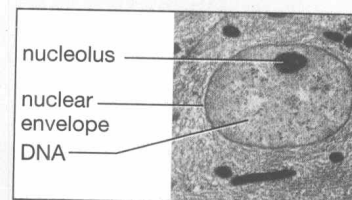
Dietary Decisions: Should You Cut Carbohydrates? 54

MediaLab

You Are What You Eat: Food and the Molecules of Life 66



DNA's structure. 61



The cell's nucleus. 76

Contents

HIGHLIGHTS

Essays

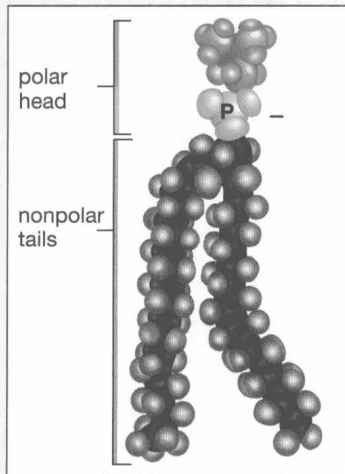
- The Size of Cells 72
- The Stranger Within: Lynn Margulis and Endosymbiosis 83
- How Did We Learn? First Sightings: Anton van Leeuwenhoek 92

Essay

- How Did We Learn? The Fluid-Mosaic Model of the Plasma Membrane 109

MediaLab

- Balancing Your Imports and Exports: Membrane Transport 114



Dual-natured molecule. 98

- 4.6 **The Cytoskeleton: Internal Scaffolding** 82
 - Microfilaments 84
 - Intermediate Filaments 84
 - Microtubules 84
 - In Summary: Structures in the Animal Cell 86
- 4.7 **The Plant Cell** 86
 - The Cell Wall 88
 - The Central Vacuole 89
 - Plastids 90
- 4.8 **Cell Communication: Why Cells Need Not Be Islands** 90
 - Communication among Plant Cells 90
 - Communication among Animal Cells 91
 - On to the Periphery 91
 - Chapter Review** 93

Chapter 5 Life's Border: The Plasma Membrane 96

- 5.1 **The Importance of Activity at the Cell's Periphery** 97
- 5.2 **Why Do We Need the Plasma Membrane?** 98
- 5.3 **Four Components of the Plasma Membrane** 99
 - First Component: The Phospholipid Bilayer 99
 - Second Component: Cholesterol 100
 - Third Component: Proteins 100
 - Fourth Component: The Glycocalyx 100
 - The Fluid-Mosaic Membrane Model 101
- 5.4 **Moving Materials In and Out: Diffusions and Gradients** 101
 - Random Movement and Even Distribution 102
 - Diffusion through Membranes 102
- 5.5 **How Do Materials Get In and Out of the Cell?** 104
 - Passive Transport 104
 - Facilitated Diffusion: Help from Proteins 105
 - Active Transport 105
- 5.6 **Getting the Big Stuff In and Out** 106
 - Movement Out: Exocytosis 107
 - Movement In: Endocytosis 107
 - On to Energy 108
 - Chapter Review** 110

Unit 2 Energy and Its Transformations

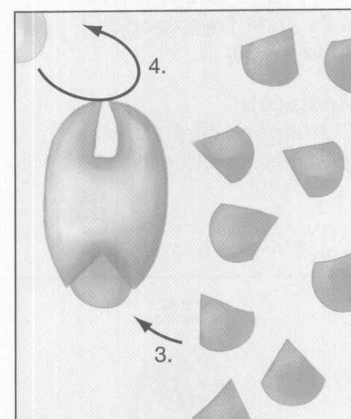
Chapter 6 Life's Mainspring: An Introduction to Energy 116

- 6.1 **Energy Is Central to Life** 117
- 6.2 **What Is Energy?** 118
 - The Forms of Energy 118
 - The Study of Energy: Thermodynamics 118
 - The Consequences of Thermodynamics 119

Contents

- 6.3 How Is Energy Used by Living Things? 120**
 Kinds of Work for Living Things 120
 Up and Down the Great Energy Hill 120
- 6.4 The Energy Currency Molecule: ATP 121**
 How Does ATP Function? 122
 The ATP/ADP Cycle 122
 ATP as Money 122
 Between Food and ATP 123
- 6.5 Efficient Energy Use in Living Things: Enzymes 123**
 Hastening Reactions 123
 Specific Tasks and Metabolic Pathways 123
- 6.6 Lowering the Activation Barrier through Enzymes 124**
 How Do Enzymes Work? 124
 A Case in Point: Chymotrypsin 125
- 6.7 Regulating Enzymatic Activity 126**
 Allosteric Regulation of Enzymes 126
 On to Harvesting Energy from Food 127
 Chapter Review 127
- Chapter 7 Vital Harvest: Deriving Energy from Food 130**
- 7.1 Energizing ATP: Adding a Phosphate Group to ADP 132**
- 7.2 Electrons Fall Down the Energy Hill to Drive the Uphill Production of ATP 133**
 The Great Energy Conveyors: Redox Reactions 133
 Many Molecules Can Oxidize Other Molecules 133
- 7.3 The Three Stages of Cellular Respiration: Glycolysis, the Krebs Cycle, and the Electron Transport Chain 135**
 Glycolysis Is the First Stage in Energy Harvesting 135
 Krebs and the Electron Transport Chain Were Later in Evolving and Are More Efficient 135
 An Overview of the Three Stages 135
- 7.4 First Stage of Respiration: Glycolysis 136**
 The Steps of Glycolysis in Human Beings 138
- 7.5 Second Stage of Respiration: The Krebs Cycle 140**
 Site of Action Moves from the Cytoplasm to the Mitochondria 141
 Between Glycolysis and the Krebs Cycle, an Intermediate Step 142
 Into Krebs: Why Is It a Cycle? 142
- 7.6 Third Stage of Respiration: The Electron Transport Chain 144**
 Visualizing the ETC 145
 Where's the ATP? 145
 Bountiful Harvest: ATP Accounting 145
 Finally, Oxygen Is Reduced, Producing Water 146
- 7.7 Other Foods, Other Respiratory Pathways 146**
 Alternate Respiratory Pathways: Fats as an Example 146
 What Happens When Less Energy Is Needed? 146
 On to Photosynthesis 147
 Chapter Review 147

HIGHLIGHTS



The enzyme changes shape. 127

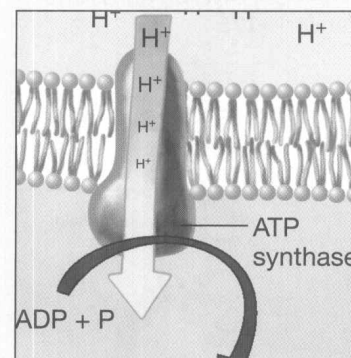
Essays

When Energy Harvesting Ends at Glycolysis, Beer Can Be the Result 138

Energy and Exercise 140

MediaLab

Dietary Fad or Miracle Drug? Using Science to Understand Metabolism 150



ATP synthesis. 144

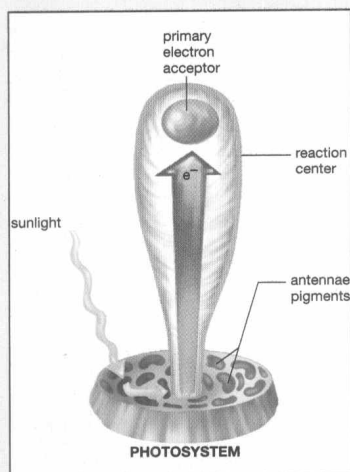
HIGHLIGHTS

Essay

How Did We Learn? Plants Make Their Own Food, But How? **164**

MediaLab

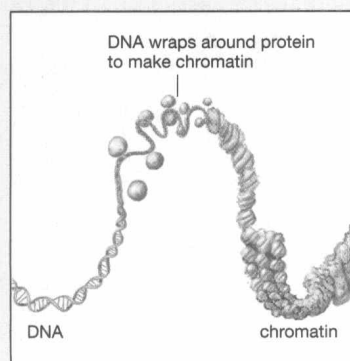
Capturing Sunlight to Make Food: Photosynthesis **168**



Photosystem. **156**

Essay

When Cell Division Runs Amok: Cancer **175**



Chromatin. **177**

Chapter 8 The Green World's Gift: Photosynthesis **152**

- 8.1 Photosynthesis and Energy 153**
 - From Plants, a Great Bounty for Animals 154
 - Up and Down the Energy Hill Again 154
- 8.2 The Components of Photosynthesis 154**
 - What Kind of Light Drives Photosynthesis? 154
 - Where in the Plant Does Photosynthesis Occur? 155
 - Photosynthesis Central: The Chloroplasts 155
 - There Are Two Essential Stages in Photosynthesis 156
 - The Working Unit of Photosynthesis Is Called a Photosystem 156
 - Energy Transfer in Photosynthesis Works through Redox Reactions 157
- 8.3 Stage 1: The Steps of the Light-Dependent Reactions 157**
 - A Chain of Redox Reactions and Another Boost from the Sun 158
 - The Physical Movement of Electrons in the Light-Dependent Reactions 158
- 8.4 What Makes the Light-Dependent Reactions So Important? 158**
 - The Liberation of Oxygen from Water 158
 - The Transformation of Solar Energy to Chemical Energy 158
- 8.5 Stage 2 of Photosynthesis: The Light-Independent Reactions 159**
 - Energized Sugar Comes from a Cycle of Reactions: The Calvin Cycle 160
- 8.6 Photorespiration: Undercutting Photosynthesis 161**
- 8.7 A Different Kind of Photosynthesis: The C₄ Pathway 161**
 - The C₄ Pathway Is Not Always Advantageous 162
- 8.8 Another Photosynthetic Variation: CAM Plants 162**
 - Closing Thoughts on Photosynthesis and Energy 163
 - Chapter Review 166

Unit 3 How Life Goes On: Genetics

Chapter 9 Introduction to Genetics; Mitosis and Cytokinesis **170**

- 9.1 An Introduction to Genetics 171**
 - The Key to Reproduction, Development, and Maintenance Is DNA 171
 - DNA Contains Instructions for Protein Production 172
 - How Do Genes Direct the Production of Proteins? 172
 - Genetics as Information Management 173
 - The Path of Study in Genetics 174
- 9.2 An Introduction to Cell Division 174**
 - The Replication of DNA 176
- 9.3 DNA Is Packaged in Chromosomes 177**
 - Matched Pairs of Chromosomes 178
 - Chromosome Duplication as a Part of Cell Division 179
- 9.4 Mitosis and Cytokinesis 180**
 - The Phases of Mitosis 180
 - Cytokinesis 182