

BIOLOGY

The Unity and Diversity of Life

SIXTH EDITION

CECIE STARR

RALPH TAGGART



B I O L O G Y

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Belmont, California

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PREFACE

Ask people at random to comment on the photograph on the cover of this book and you might hear something like, *What sweet little birds!* (as we did).

Those “sweet little birds” are highly specialized predators, the African bee-eaters of the family Meropidae. They swoop preferentially after bees and wasps in midair, using their long bill to catch safely, hold onto, and crush the stinging types. Then they *WHAP WHAP WHAP* the crushed body against the side of a branch or some other hard surface until the stinger protrudes and its venom drips out. After tossing the body several times in the air, the bee-eater gulps it down, head first, stinger last.

All textbooks for survey courses in biology include such descriptions of events in the natural world. All put on a parade of representatives from the five great kingdoms of organisms. They all describe the structure and function of those organisms at different levels of biological organization. The descriptions are useful, in that they help students build a working vocabulary about the parts and processes of life.

And yet, if textbooks are to convey accurately the nature of biological science, they must be more than a collection of observations. They must help students become familiar with the approach that biologists take to answering questions about what it is they see. With this approach, for example, the photograph of bee-eaters may open a door of inquiry, with all sorts of questions tumbling out.

. . . I've read about the aggressive African bees and what happened after they were introduced to South America. If the bees are so aggressive, why don't they defend themselves? Are they color-blind? How else could such brilliant-blue birds sneak up on them in midair? Maybe bees don't see blue. (Come to think of it, they must not be color-blind—I see them all the time on yellow flowers.) How could I test this idea? If it's true, then bees should pass up blue flowers in favor of yellow ones. How might I set up an experiment to test this prediction? For one thing, I'd better use odorless plastic flowers . . .

Biologists ask questions, make educated guesses (hypotheses) about possible answers, then devise ways to rigorously test predictions that will hold true if the hypotheses are correct. In broad outline, their approach is that simple. Yet it has proved to be one of the most useful of all tools for explaining the world

around us. Students can use the biological approach to satisfy curiosity about bees and bee-eaters. They can use this approach to pick their way logically through today's environmental, medical, and social landmines. Finally, they can use it to understand the past and predict possible futures for ourselves and all other organisms.

OBJECTIVES FOR THIS EDITION

Biology: The Unity and Diversity of Life has been evolving for eighteen years. More than 2 million students have used this book, and each revision becomes more refined in response to their experience with it. More than 1,500 dedicated teachers and researchers have shared insights with us during the years of refinements. They are our guardians of reading level and depth of coverage, of currency and accuracy.

As with previous editions, we mapped out major objectives to guide us in our approach to the sixth edition: First, write in a clear, engaging style, without being patronizing. Second, give enough examples of problem solving and experiments to provide familiarity with a scientific approach to interpreting the world. Third, identify the key concepts and select topics that reflect current research in all major fields, then present this material in light of two major themes in biology—evolution and energy flow. Fourth, use interesting, informative applications to stimulate student interest. Fifth, create easy-to-follow line art and select informative photographs.

REVISION HIGHLIGHTS

Writing Style

Years ago, we thought students could be enticed into the biological sciences with lively writing, memorable analogies, and engaging bits of natural history. However, the prevailing view was that such an approach somehow would be inappropriate for a textbook dealing with biological science. And so, for the past fifteen years, we focused primarily on making the writing clear and the science accurate.

Today, students often pick up biology textbooks with apprehension. If the words do not engage them, they sometimes end up hating the book *and* the subject. Instructors still ask for a scientifically accurate book—but now they also ask for one that puts the life back in.

We could not be more pleased. Because we devoted so many years to writing about biology with confidence, precision, and objectivity, we knew where the writing in this new edition *could* be loosened up. Inter-

rupting a description of, say, the mechanisms of mitosis with a dithering of words will do the struggling student no good. Plunking humorous anecdotes into a chapter on the correlation between geologic and organismic evolution trivializes a magnificent story. Taking up valuable reading time with bits of natural history is pointless—unless those bits lead students to the big concepts.

By contrast, it certainly is appropriate to liven up a paragraph on, say, the structure of the nuclear envelope (page 61), the role of mitosis in growth and development (page 146), and the functions of skin (page 621). When you look through this new edition, you will see stunning line art and photographs. Don't let them distract you from the line-by-line judgment calls made with respect to the writing in every chapter. Improving and livening up the writing was our major objective.

Vignettes

What authors say in a preface sometimes bears no apparent resemblance to what they did in the book. As corroboration of what we did with the writing, look at the chapter introductions, each a short story that leads into the chapter's key concepts. Some provide glimpses into the natural history of an organism, others show how biological science applies to human affairs, and many do both.

If the Chapter 9 vignette rings true, it is because Beverly McMillan sat quietly beside the Alagnak at dawn, watching life end for a female salmon. If the body language of a bulldog making his contribution to cardiology provides a light touch (Chapter 38), this is Margaret Warner's offering. Remembering a journal article from her graduate school days, she rummaged through her university's archives and found those photographs for us. If you wonder whether a confrontation with a tornado will work in class, this is Fred Delcomyn's story (the Chapter 32 vignette) and it works for him. If the Chapter 24 vignette on daisies as supermarkets seems accurate yet refreshing, Edward Ross has been thinking about this for a long time.

Applications

This new edition features a greatly increased number of applications, all indexed on the back endpapers for easy reference. Some examples enrich the text. Others are boxed illustrations or *Commentaries* that provide in-depth information for the interested student but do not interrupt the text flow.

Many examples convey the importance of biological science in general, as when basic concepts in population ecology are applied to the prospects and problems of 5.4 billion of us now living on this planet (pages

797 and 875). Others bring home the impact of biological research on individual lives, as when students are asked to think about the effects of crack cocaine (page 562), anabolic steroids (page 637) or the implications of human gene therapy (page 257), which to a limited extent is already under way.

Starting in February, 1992, Wadsworth will be publishing an *Annual Newsletter* on important new applications that may be used to supplement those already incorporated into the sixth edition.

Doing Science

Earlier editions included many examples of biologists at work as a way to help students develop their own understanding of critical thinking. The entire chapter on DNA structure and function has been especially successful in this respect. So have the descriptions of experimental evidence for the concepts being discussed, as in the chapter on plant growth and development. (See also the index entry, Experiments.) This edition builds on our base of science in action.

At John Alcock's suggestion, we added *Doing Science* essays. In one, students will follow Molly Lutcavage's line of questioning in her studies of the leatherback turtle, a species on the brink of extinction (page 712). In one of the essays that John drafted himself, they will see how DNA fingerprinting was used to help explain self-sacrificing behavior—not among insects, but among a fascinating group of mammals (page 918).

Illustrations

One of us (Cecie Starr) has for eighteen years been obsessed with writing and creating illustrations simultaneously. It takes her almost as much time to research, develop, and integrate art with the text as to write and rewrite manuscripts. The obsession extends to positioning art and text references on the same two-page spread, no page-flipping required. Chapter 8, an obvious example, shows how layouts make it easier to study glycolysis, the Krebs cycle, electron transport phosphorylation, and anaerobic pathways.

Icons (pictorial representations) next to the main art show students where pathways or structures occur in a cell, multicelled body, or some other system. Zoom-sequence illustrations, from the macroscopic to microscopic, serve a similar purpose. Simple color-coded diagrams help students interpret micrographs.

Careful use of color helps students track information on hard-to-visualize topics. Throughout the book, for instance, proteins are color-coded green, carbohydrates pink, lipids yellow and gold, DNA blue, and RNA orange. Full-color anatomical paintings help give students a sense of the splendid internal complexity of organisms.

Often we incorporated written summaries *within* diagrams to make concepts easier to grasp. Where possible, we broke down information into a series of steps that are far less threatening than one large, complex diagram. Students find this approach useful, particularly with respect to art on mitosis, meiosis, and protein synthesis. It works just as effectively for such topics as antibody-mediated immunity and neural functioning.

Consider also the pedagogical impact of illustration size, as Starr did for every page. One photograph (page 885) conveys the magnitude of tropical rain forest destruction; a small photograph of a patch of burning trees could never do this. Probably few students gasp in wonder over a diagram of biomes—but ask them to use that diagram to interpret the spectacular photograph preceding Chapter 1. Pieced together from thousands of satellite images, it reveals the sweep of the Sahara, the collective green of boreal forests, and other features of the earth's surface.

STUDY AIDS

New to this edition is a *list of key concepts* following the vignette for each chapter. We increased the number of summary statements of concepts within the text itself to help keep readers on track. Several end-of-chapter study aids reinforce the key concepts. Each chapter has a *summary* in list form, *review questions*, a *self-quiz*, *selected key terms*, and *recommended readings*. Page numbers tie each review question and key term to the relevant text page.

Numerous *genetics problems* help students grasp the principles of inheritance. The *glossary* includes pronunciation guides and origins of words, when such information will make formidable words less so. The *index* is comprehensive; students find a door to the text more quickly through finer divisions of topics. The first appendix has *metric-English conversion charts*. The second is a *classification scheme* that students can use for reference purposes. The third has *detailed answers* to the genetics problems; and the fourth, *answers* to self-quizzes. The final appendix shows structural formulas for *major metabolic pathways* for interested students and instructors who prefer the added detail.

The appendixes and glossary are printed on paper of different tints to preclude frustrating searches for where one ends and the next starts.

SUPPLEMENTS

Twenty supplements are available. *Full-color transparencies* and *35mm slides* of almost all illustrations from the

book are labeled with large, boldface type. A *Test Items* booklet has 5,000 questions by outstanding test writers. Questions are available in electronic form on IBM, Apple IIe, and Macintosh.

An *Instructor's Resource Manual* has, for each chapter, an outline, objectives, list of boldface or italic terms, and a detailed lecture outline. It also includes suggestions for lecture presentations, classroom and laboratory demonstrations, suggested discussion questions, research paper topics, and annotations for filmstrips and videos. *Lecture outlines* in the *Instructor's Resource Manual* are available on a data disk for those who wish to modify the material. A *Videodisc Correlation Directory and Barcode Guide* correlates the text with popular videodiscs. Software—*HyperCard Stacks for Videodiscs*—correlates the text with the same videodiscs.

A new, active-oriented *Study Guide and Workbook* asks students to respond to almost all questions by writing in the guide. Questions are arranged by chapter section. Each chapter also has a set of critical thinking questions. The *chapter objectives* of the Study Guide are available on disk as part of the testing file for those who wish to modify or select portions of the material. An *electronic study guide* consists of multiple-choice questions different from those in the test-item booklet. Students get feedback on why their answer is correct or incorrect. A 100-page *Answer Booklet* has answers to the book's end-of-chapter review questions.

A special version of STELLA II, a software tool for developing critical thinking skills, is available to users of the book, together with a workbook.

Approximately 400 *flashcards* with 1,000 glossary items are available. There are four anthologies. *Contemporary Readings in Biology* has articles on applications of interest to students. *Science and the Human Spirit: Contexts for Writing and Learning* helps students learn to write effectively about biology. *Ethical Issues in the New Reproductive Technologies* discusses some major issues of our time. *The Game of Science* gives students a realistic view of what science is and what scientists do.

A new *Laboratory Manual* has 38 experiments and exercises. It now contains hundreds of labeled photographs, and all illustrations are in full color. Many experiments are divided into distinct parts that can be assigned individually, depending on time available. All have objectives, discussion (introduction, background, and relevance), a list of materials for each part of an experiment, procedural steps, pre-lab questions, and post-lab questions. An *Instructor's Manual* accompanies the Laboratory Manual. It covers quantities, procedures for preparing reagents, time requirements for each portion of the exercise, hints to make the lab a success, and vendors of materials with item numbers.

IMPROVEMENTS IN CONTENT AND ORGANIZATION

Although the following paragraphs are by no means inclusive, they convey the magnitude of the revision.

INTRODUCTION We streamlined the first two chapters of the preceding edition. Now one chapter provides an overview of key biological concepts and a revised treatment of scientific methods, livened up by John Alcock. Simple examples introduce the pertinent points of evolution by natural selection, but the history of evolutionary thought now is the stage-setting chapter for the evolution unit (III).

UNIT I. CELLULAR BASIS OF LIFE More concise writing and greatly improved art make the chapters on cell structure and biochemistry more accessible. Chapter 2 has a new *Commentary* on radioisotopes. Chapter 3 includes an improved discussion of carbohydrates, a new *Commentary* on cholesterol and atherosclerosis, and a better diagram of hemoglobin structure. Chapter 4 has a simpler description of the cytomembrane system. Notice the cell icons in the illustrations of organelles. We updated the classification of membrane proteins (Chapter 5). Better diagrams of freeze-fracturing accompany the *Doing Science* essay (page 78). Chapter 6 presents a simpler overview of basic metabolism.

The plant in the zoom-sequence of chloroplast structure (Chapter 7) is now the same species used in Chapter 28, which continues the story by showing translocation. David Fisher helped develop these illustrations. Chapter 8 is reorganized—first the aerobic pathway, then anaerobic pathways. To keep text concepts uncluttered, details of ATP formation in Chapters 7 and 8 are presented in boxed illustrations.

UNIT II. PRINCIPLES OF INHERITANCE Chapters 9 through 11 already are effective in the classroom. We sharpened the writing, included new examples (such as Labrador coat color), but left the organization much the same. Robert Robbins suggested the vignette for Chapter 10 and the *Commentary* on HeLa cells (page 147). Chromosomal inheritance and human genetics are combined in one chapter (12). Morgan's fruit fly experiments are in an optional, boxed illustration. Students should enjoy the new *Commentary* on sex determination (page 186).

The Chapter 13 vignette provides background for the Watson-Crick story and reminds students that

science proceeds as a community effort (more or less). The organization of DNA in chromosomes is now described and illustrated in this chapter (page 212). The Chapter 14 vignette actually makes the idea of reading about protein synthesis nonthreatening. A simple overview and improved art make the chapter easier to follow. Early studies of gene function are described in an optional boxed illustration. Gene mutation is now introduced in this chapter, with a *Commentary* on its role in evolution.

Chapter 15 (gene regulation) is updated, with better delineation between prokaryotic and eukaryotic mechanisms. The vignette on control of cell division sets the stage for the *Commentary* on cancer. Daniel Fairbanks and Lisa Starr made solid contributions to Chapter 16, which provides a reorganized, updated, and more accurate picture of recombinant DNA technology and genetic engineering. The *Doing Science* essay gives interested students simple descriptions of gel electrophoresis of DNA and DNA sequencing methods.

UNIT III. PRINCIPLES OF EVOLUTION The evolution and diversity units now immediately follow the genetics unit. We overhauled the content and added spectacular illustrations (see page 312). Chapter 17 provides the historical background. We polished the chapter on microevolution (18) and added an in-depth look at a current study of speciation (page 288).

Chapter 19 has crisper descriptions of the evidence for the origin of the earth and life. Events and mechanisms underlying large-scale evolutionary patterns and rates of change are described succinctly. Macroevolutionary patterns dominating each major geologic era are sketched out. Figure 19.16 graphically emphasizes a central concept—that changes in the environment have been a profound force in the evolution of life.

Aaron Bauer wrote a new chapter on systematics (20) and, amazingly, made cladistics understandable (page 324). We moved the case study on human evolution (Chapter 21) here to make the unit self-contained. It includes a *Doing Science* essay on mitochondrial DNA and recent human ancestry. A section on classification outlines the five-kingdom scheme.

In Chapter 20 and elsewhere, we remind students that boundaries between taxa are not real; we impose them on a continuum of evolutionary lines. Taxonomists take the impositions seriously, and possibly our

decision to classify the red, brown, and green algae as plants will make some of them cranky. However, we did not make the decision lightly. It reflects the overwhelming preference of hundreds of teachers who responded to a questionnaire on this issue.

UNIT IV. EVOLUTION AND DIVERSITY We reworked the diversity unit extensively. Introductory texts (our earlier editions included) tend to slight the microbial world. Notice the expanded, richly illustrated coverage of viruses, bacteria, and protists in Chapter 22. The chapter also has *Commentaries* on infectious diseases (page 352), eukaryotic origins (page 361), and the beginnings of multicellularity (page 369). Fungi now have their own chapter (23) that conveys the diversity in this often-ignored kingdom.

We clarified the Chapter 24 survey of evolutionary trends among plants. More applications are woven into descriptions of the major divisions, as on page 388. Once again, Eugene Kozloff guided us through the maze of invertebrates and helped refine the chapter (25). Vertebrates are described in a separate chapter (26). In both chapters, icons serve as effective roadmaps.

UNIT V. PLANT STRUCTURE AND FUNCTION We made the writing easier to follow, added applications, and improved the art and page layouts. Chapter 28 has better coverage of root nodules (page 489) and superior diagrams for absorption (491), transpiration (492), and translocation (496).

The vignette in Chapter 29 gives new meaning to the word chocolate, the *Commentary* (page 506) provides vivid examples of pollination, and a *Doing Science* essay asking why some plants produce so many flowers (page 512) reminds students of what it means to think critically.

UNIT VI. ANIMAL STRUCTURE AND FUNCTION Extensive rewriting and many more applications make this inherently complex unit approachable. The new art speaks for itself.

We updated tissue classification and micrographs and explained homeostasis with tangible examples (Chapter 31). Neurobiologists helped update Chapter 32, and our teacher reviewers helped make it accessible. Chapter 33 better describes the evolution of nervous systems and the neural wiring of vertebrates.

The endocrine chapter (34) has less abstract examples and art. Chapter 35 provides a more accurate picture of sensory function. It has new material on echolocation, pain, and vision, including a *Commentary* on eye disorders (612).

We packed Chapter 36 with applications that should hold student interest. The sections on muscle function and energy metabolism make better sense. An integrative diagram at the start of Chapters 37, 38, and 39 helps students visualize how systems are integrated. We expanded the material on human nutrition and included a *Commentary* on eating disorders (650). Chapters 38 through 42 underwent major reorganization and updating. Whether assigned or not, Chapter 43 on human reproduction and development is one that students read closely, and we took special care to provide them with accurate and current information.

UNIT VII. ECOLOGY AND BEHAVIOR We worked closely with Robert Colwell and George Cox to reorganize and update the ecology chapters. Growth equations in Chapter 44 are described more clearly and the section on human population growth is expanded. Chapter 45 has refined definitions for habitat, niche, and species richness. Charles Krebs suggested an update for the Canadian lynx-hare story (pages 811–812). Jane Lubchenko's study of predation and competition is included (page 817). There is a new *Commentary* on species introduction (page 818).

The Chapter 46 vignette on a major environmental issue may leave students with a sense that things *can* change when we put our minds to it. A new carbon cycle diagram (page 837) leads into the *Commentary* on global warming (838). Chapter 47 provides a tighter overview of factors shaping climate, hence ecosystems. Photographs are large enough to show biome features. The text on lake ecosystems and intertidal zonation is more straightforward. Ernest Benfield provided material on stream ecosystems (864). Tropical reefs are now illustrated in this chapter (868). The Chapter 48 vignette describes tropical rain forests, then the text conveys the magnitude and pace of their destruction (874 and 884). Our friend Tyler Miller, Jr., helped us update this important chapter.

John Alcock's interest in teaching students how to think critically is evident in his two chapters (49 and 50), starting with the vignette on nest-building behavior. He updated and reorganized both.

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A COMMUNITY EFFORT

One, two, or a smattering of authors can write accurately and often very well about their field of interest, but it takes more than this to deal with the full breadth of biological sciences. For us, it takes an educational network that extends through the United States and on into Canada, England, Germany, France, Sweden, Australia, and elsewhere. We continually track down respected researchers, teachers, and photographers. For a few rarified topics, we invite resource manuscripts from specialists who have never turned their back on the call to teach a new generation of students. We integrate such material into our own manuscript, rewriting or graphically shaping it according to our strong convictions about what an introductory book must be.

John Alcock, Aaron Bauer, Rob Colwell, George Cox, Daniel Fairbanks, Eugene Kozloff, Bill Parson, Cleon Ross, and Sam Sweet have been exceptional in their commitment to our efforts. They have responded with grace to phone calls and faxes, to queries concerning the odd fact.

Many reviewers were content specialists, others were diary reviewers who evaluated the fifth edition's effectiveness in their own classrooms. Collectively, their comments helped us shape the revision. Our advisors assisted us in evaluating reviewer comments and in suggesting improvements in the new manuscripts and art. Katherine Denniston, Pamela Hanratty, William Hess, John Jackson, Bernard Frye, Greig Rose, and Nancy Meyer advised us on every chapter for level and clarity. Jackson and Denniston helped us develop new self-quiz questions.

If the writing now seems fresher, this is largely because of our creative interaction with Beverly McMillan, the developmental editor for this edition.

She also researched material and drafted several vignettes, *Doing Science* essays, and *Commentaries*. We treasure her as a friend and gifted writer.

Dick Greenberg, Jack Carey, Kathie Head, Stephen Rapley, and Randy Hurst at Wadsworth never let the users of this book down. This time they assembled the best production team and manufacturers in the business, starting with Mary Douglas, who has our unequivocal respect and friendship. Mary has the talent, toughness, sensitivity, compulsiveness, and oblique sense of humor required to shepherd text and art manuscripts of this complexity.

Because of Jerry Holloway and Kathryn Shea, we kept smiling instead of bashing our head against the wall. Marion Hansen would have liked to bash our head against the wall, but instead she persevered through one more edition and, with Stuart Kenter, collected exquisite photographs. Carolyn McGovern, Gloria Joyce, and Ed Serdziak took care of complicated editorial functions. Todd Armstrong, Karen Culver, and Debbie Dennis have been most supportive. Ryan Carey was the captive student reader. Barbara Odone, John Douglas, and Verbal Clark kept the paper flowing.

Besides designing a memorable cover for the book, Stephen Rapley worked out its interior design in consultations with Gary Head. Raychel Ciemma, Bob Demerest, Darwin Hennings, Vally Hennings, Len Morgan, and Betsy Palay did much of the outstanding new art. Susan Breitbard, Natalie Hill, Carole Lawson, Joan Olson, Jill Turney, and Kathryn Werhane worked directly with us as resident artists. Tom Anderson once again was responsive to picky requests on color separations. G&S is in a league by itself.

Jack Carey, would you have believed eighteen years ago that you would be publisher of such a widely used textbook in biology? You charted our course, and made it happen.

CONTENTS IN BRIEF

INTRODUCTION

- 1 Methods and Concepts in Biology 2

UNIT I THE CELLULAR BASIS OF LIFE

- 2 Chemical Foundations for Cells 18
- 3 Carbon Compounds in Cells 34
- 4 Cell Structure and Function: An Overview 50
- 5 Membrane Structure and Function 74
- 6 Ground Rules of Metabolism 90
- 7 Energy-Acquiring Pathways 104
- 8 Energy-Releasing Pathways 118

UNIT II PRINCIPLES OF INHERITANCE

- 9 Cell Division and Mitosis 136
- 10 A Closer Look at Meiosis 150
- 11 Observable Patterns of Inheritance 164
- 12 Chromosome Variations and Human Genetics 182
- 13 DNA Structure and Function 204
- 14 From DNA to Proteins 216
- 15 Control of Gene Expression 232
- 16 Recombinant DNA and Genetic Engineering 244

UNIT III PRINCIPLES OF EVOLUTION

- 17 Emergence of Evolutionary Thought 260
- 18 Microevolution 272
- 19 Life's Origins and Macroevolutionary Trends 292
- 20 Classification of Life's Diversity 318
- 21 Human Evolution: A Case Study 330

UNIT IV EVOLUTION AND DIVERSITY

- 22 Viruses, Bacteria, and Protistans 346
- 23 Fungi 372
- 24 Plants 384
- 25 Animals: The Invertebrates 404
- 26 Animals: Evolution of Vertebrates 442

UNIT V PLANT STRUCTURE AND FUNCTION

- 27 Plant Tissues 468
- 28 Plant Nutrition and Transport 486
- 29 Plant Reproduction 500
- 30 Plant Growth and Development 516

UNIT VI ANIMAL STRUCTURE AND FUNCTION

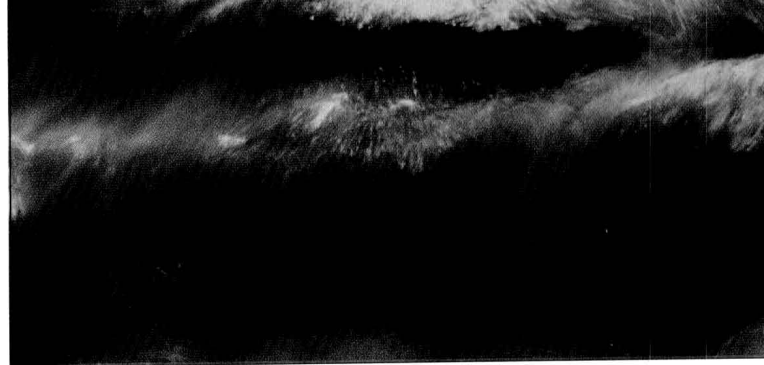
- 31 Tissues, Organ Systems, and Homeostasis 532
- 32 Information Flow and the Neuron 546
- 33 Integration and Control: Nervous Systems 562
- 34 Integration and Control: Endocrine Systems 580
- 35 Sensory Reception 598
- 36 Protection, Support, and Movement 618
- 37 Digestion and Human Nutrition 640
- 38 Circulation 658
- 39 Immunity 680
- 40 Respiration 698
- 41 Salt-Water Balance and Temperature Control 718
- 42 Principles of Reproduction and Development 736
- 43 Human Reproduction and Development 758

UNIT VII ECOLOGY AND BEHAVIOR

- 44 Population Ecology 786
- 45 Community Interactions 804
- 46 Ecosystems 826
- 47 The Biosphere 846
- 48 Human Impact on the Biosphere 874
- 49 Behavioral Responses to the Environment 892
- 50 Social Interactions 906

- Appendix I Units of Measure
- Appendix II Brief Classification Scheme
- Appendix III Answers to Genetics Problems
- Appendix IV Answers to Self-Quizzes
- Appendix V A Closer Look at Some Major Metabolic Pathways

DETAILED TABLE OF CONTENTS



INTRODUCTION

1 METHODS AND CONCEPTS IN BIOLOGY

Biology Revisited 2

Key Concepts 3

Shared Characteristics of Life 3

DNA and Biological Organization 3

Metabolism 4

Interdependency Among Organisms 5

Homeostasis 6

Reproduction 8

Mutation and Adapting to Change 8

Life's Diversity 9

Five Kingdoms, Millions of Species 9

An Evolutionary View of Diversity 10

The Nature of Biological Inquiry 12

On Scientific Methods 12

Testing Alternative Hypotheses 13

The Role of Experiments 13

About the Word "Theory" 14

Uncertainty in Science 14

The Limits of Science 15

Summary 15

UNIT I THE CELLULAR BASIS OF LIFE

2 CHEMICAL FOUNDATIONS FOR CELLS

The Chemistry In and Around You 18

Key Concepts 19

Organization of Matter 19

The Structure of Atoms 20

Isotopes 21

COMMENTARY: Dating Fossils, Tracking Chemicals, and Saving Lives—Some Uses of Radioisotopes 21

Bonds Between Atoms 23

The Nature of Chemical Bonds 23

Ionic Bonding 25

Covalent Bonding 25

Hydrogen Bonding 26

Properties of Water 26

Polarity of the Water Molecule 27

Temperature-Stabilizing Effects 28

Cohesive Properties 28

Solvent Properties 29

Acids, Bases, and Salts 30

Acids and Bases 30

The pH Scale 30

Buffers 30

Dissolved Salts 31

Water and Biological Organization 32

Summary 32

3 CARBON COMPOUNDS IN CELLS

Ancient Carbon Treasures 34

Key Concepts 35

Properties of Carbon Compounds 35

Families of Small Organic Molecules 36

Functional Groups 36

Condensation and Hydrolysis 37

Carbohydrates 38

Monosaccharides 38

Oligosaccharides 38

Polysaccharides 38

Lipids 40

Lipids With Fatty Acids 40

Lipids Without Fatty Acids 41

COMMENTARY: Cholesterol Invasions of Your Arteries 42

Proteins 43

Protein Structure 43

Lipoproteins and Glycoproteins 46

Protein Denaturation 46

Nucleotides and Nucleic Acids 46

Summary 47

4 CELL STRUCTURE AND FUNCTION: AN OVERVIEW

Pastures of the Seas 50

Key Concepts 51

Generalized Picture of the Cell 51

Emergence of the Cell Theory 51

Basic Aspects of Cell Structure and Function 53

Cell Size and Cell Shape 53

Prokaryotic Cells—The Bacteria 57

Eukaryotic Cells 57

Function of Organelles 57

Typical Components of Eukaryotic Cells 58

The Nucleus 61

Nuclear Envelope 61

Nucleolus 62

Chromosomes 62

The Cytoplasmic Membrane System 62

Endoplasmic Reticulum and Ribosomes 63

Golgi Bodies 64

Assorted Vesicles 64

Mitochondria 65

Specialized Plant Organelles 65

Chloroplasts and Other Plastids 65

Central Vacuoles 66

The Cytoskeleton 67

Components of the Cytoskeleton 67

Flagella and Cilia 69

MTOCs and Centrioles 69

Cell Surface Specializations 70

Cell Walls 70

Extracellular Matrix and Cell Junctions 70

Summary 71

5 MEMBRANE STRUCTURE AND FUNCTION

Water, Water Everywhere 74

Key Concepts 75

Fluid Membranes in a Largely Fluid World 75

The Lipid Bilayer 75

Fluid Mosaic Model of Membrane Structure 76

DOING SCIENCE: *Discovering Details About Membrane Structure* 78

Functions of Membrane Proteins 80

Diffusion 81

Gradients Defined 81

Simple Diffusion 81

Bulk Flow 81

Osmosis 82

Osmosis Defined 82

Tonicity 82

Water Potential 83

Movement of Water and Solutes Across

Cell Membranes 84

The Available Routes 84

Facilitated Diffusion 84

Active Transport 85

Exocytosis and Endocytosis 86

Summary 88

6 GROUND RULES OF METABOLISM

The Old Man of the Woods 90

Key Concepts 91

Energy and Life 92

The Nature of Metabolism 93

Energy Changes in Metabolic Reactions 93

Metabolic Pathways 95

Enzymes 96

Characteristics of Enzymes and Their Substrates 96

Enzyme Structure and Function 96

Effects of Temperature and pH on Enzymes 98

Control of Enzyme Activity 98

Cofactors 99

Electron Transfers in Metabolic Pathways 99

ATP: The Universal Energy Carrier 100

Structure and Function of ATP 100

COMMENTARY: *You Light Up My Life—Visible Effects of Electron Transfers* 101

The ATP/ADP Cycle 102

Summary 102

7 ENERGY-ACQUIRING PATHWAYS

Sunlight, Rain, and Cellular Work 104

Key Concepts 105

Photosynthesis 105

Simplified Picture of Photosynthesis 105

Chloroplast Structure and Function 107

Light-Dependent Reactions 107

Light Absorption 108

How ATP and NADPH Form in Chloroplasts 110

A Closer Look at ATP Formation 112

Light-Independent Reactions 112

Calvin-Benson Cycle 113

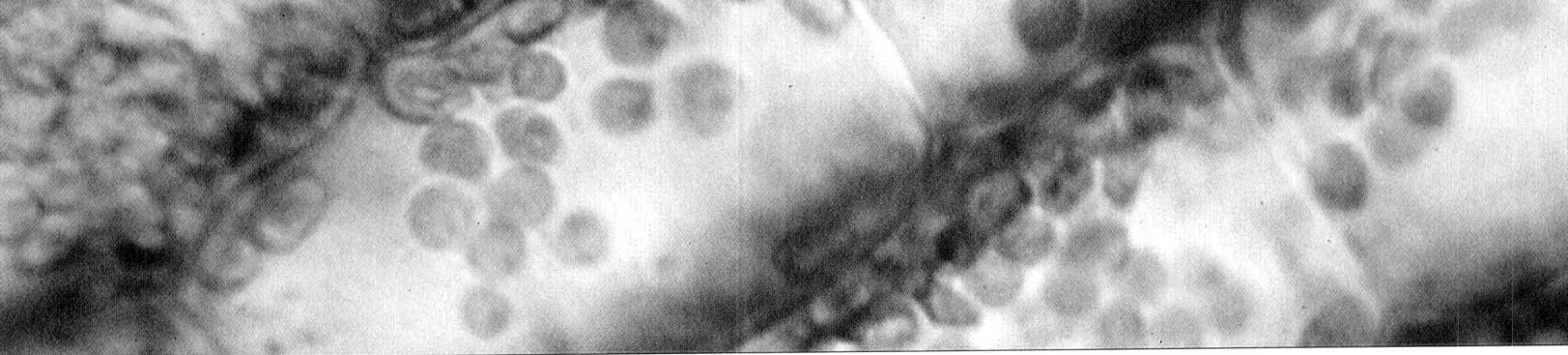
How Autotrophs Use Intermediates and Products of Photosynthesis 114

C4 Plants 114

Chemosynthesis 115

COMMENTARY: *Energy from Artificial Chloroplasts?* 116

Summary 116



8 ENERGY-RELEASING PATHWAYS

The Killers Are Coming! 118

Key Concepts 119

ATP-Producing Pathways 119

Aerobic Respiration 120

Overview of the Reactions 120

Glycolysis 122

Krebs Cycle 124

Electron Transport Phosphorylation 126

Glucose Energy Yield 127

Anaerobic Routes 128

Alcoholic Fermentation 128

Lactate Fermentation 129

Anaerobic Electron Transport 130

Alternative Energy Sources in the Human Body 130

COMMENTARY: *Perspective on Life* 132

Summary 133

UNIT II PRINCIPLES OF INHERITANCE

9 CELL DIVISION AND MITOSIS

Silver in the Stream of Time 136

Key Concepts 137

Dividing Cells: The Bridge Between Generations 137

Overview of Division Mechanisms 137

Some Key Points About Chromosome Structure 138

Mitosis, Meiosis, and the Chromosome Number 139

Mitosis and the Cell Cycle 140

Stages of Mitosis 140

The Microtubular Spindle 141

Prophase: Mitosis Begins 142

Metaphase 143

Anaphase 144

Telophase 145

Cytokinesis 145

COMMENTARY: *Henrietta's Immortal Cells* 147

Summary 148

10 A CLOSER LOOK AT MEIOSIS

Octopus Sex and Other Stories 150

Key Concepts 151

On Asexual and Sexual Reproduction 151

Overview of Meiosis 153

Think "Homologues" 153

Overview of the Two Divisions 153

Stages of Meiosis 154

Prophase I Activities 154

Separating the Homologues 155

Separating the Sister Chromatids 157

Meiosis and the Life Cycles 158

Gamete Formation 158

More Gene Shufflings at Fertilization 158

Meiosis Compared With Mitosis 160

Summary 160

11 OBSERVABLE PATTERNS OF INHERITANCE

Sickled Cells and Garden Peas 164

Key Concepts 165

Mendel's Insights into the Patterns of Inheritance 165

Mendel's Experimental Approach 166

Some Terms Used in Genetics 167

The Concept of Segregation 168

Testcrosses 170

The Concept of Independent Assortment 170

Variations on Mendel's Themes 172

Dominance Relations 172

Interactions Between Different Gene Pairs 173

Multiple Effects of Single Genes 175

Environmental Effects on Phenotype 176

Variable Gene Expression in a Population 177

Summary 179

12 CHROMOSOME VARIATIONS AND HUMAN GENETICS

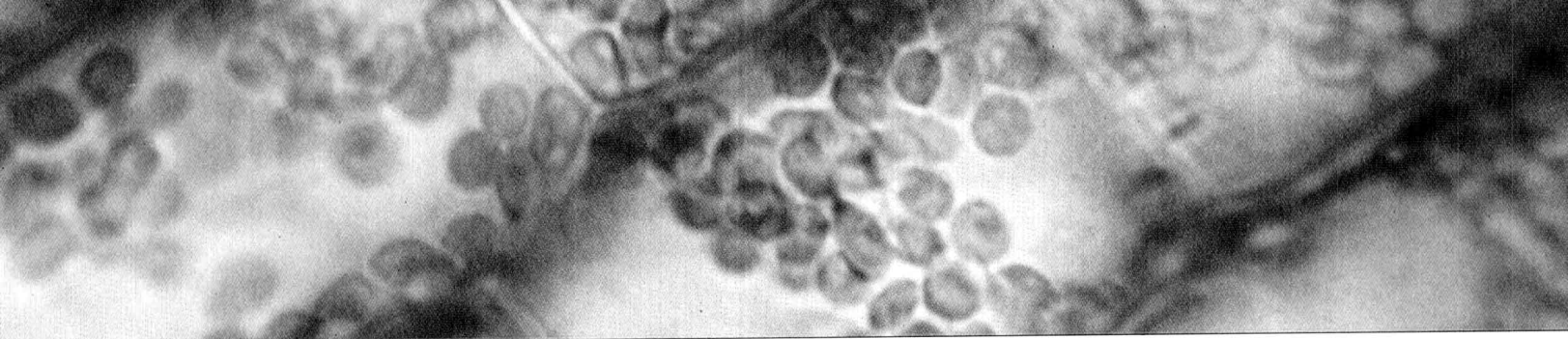
Too Young To Be Old 182

Key Concepts 183

Chromosomal Theory of Inheritance 183

Return of the Pea Plant 183

Autosomes and Sex Chromosomes 185



COMMENTARY: *Girls, Boys, and the Y Chromosome* 186

Linkage and Crossing Over 189

Chromosome Variations in Humans 191

Autosomal Recessive Inheritance 192

Autosomal Dominant Inheritance 192

X-Linked Recessive Inheritance 193

Changes in Chromosome Structure 195

Changes in Chromosome Number 196

COMMENTARY: *Prospects and Problems in Human Genetics* 199

Summary 201

13 DNA STRUCTURE AND FUNCTION

Cardboard Atoms and Bent-Wire Bonds 204

Key Concepts 205

Discovery of DNA Function 205

A Puzzling Transformation 206

Bacteriophage Studies 207

DNA Structure 208

Components of DNA 208

Patterns of Base Pairing 209

DNA Replication 210

Assembly of Nucleotide Strands 210

A Closer Look at Replication 210

Organization of DNA in Chromosomes 213

Summary 214

14 FROM DNA TO PROTEINS

Beyond Byssus 216

Key Concepts 217

Protein Synthesis 217

The Central Dogma 217

Overview of the RNAs 219

Transcription of DNA Into RNA 220

How RNA Is Assembled 220

Messenger-RNA Transcripts 221

Translation 222

The Genetic Code 222

Codon-Anticodon Interactions 223

Ribosome Structure 223

Stages of Translation 224

Mutation and Protein Synthesis 226

COMMENTARY: *Gene Mutation and Evolution* 229

Summary 230

15 CONTROL OF GENE EXPRESSION

A Cascade of Proteins and Cancer 232

Key Concepts 233

The Nature of Gene Control 233

When Controls Come Into Play 234

Control Agents and Where They Operate 234

Gene Control in Prokaryotes 234

Negative Control of Lactose Metabolism 234

Positive Control of Nitrogen Metabolism 235

Gene Control in Eukaryotes 236

Selective Gene Expression 236

Levels of Control in Eukaryotes 236

Evidence of Control Mechanisms 238

When the Controls Break Down 241

COMMENTARY: *Characteristics of Cancer* 241

16 RECOMBINANT DNA AND GENETIC ENGINEERING

Life and Death on the Threshold of a New Technology 244

Key Concepts 245

Recombination in Nature: Some Examples 246

Transfer of Plasmid Genes 246

Transfer of Viral Genes 247

Recombinant DNA Technology 248

Producing Restriction Fragments 248

DNA Amplification 249

Identifying Modified Host Cells 250

Expressing the Gene of Interest 250

Risks and Prospects of the New Technology 251

Uses in Basic Biological Research 251

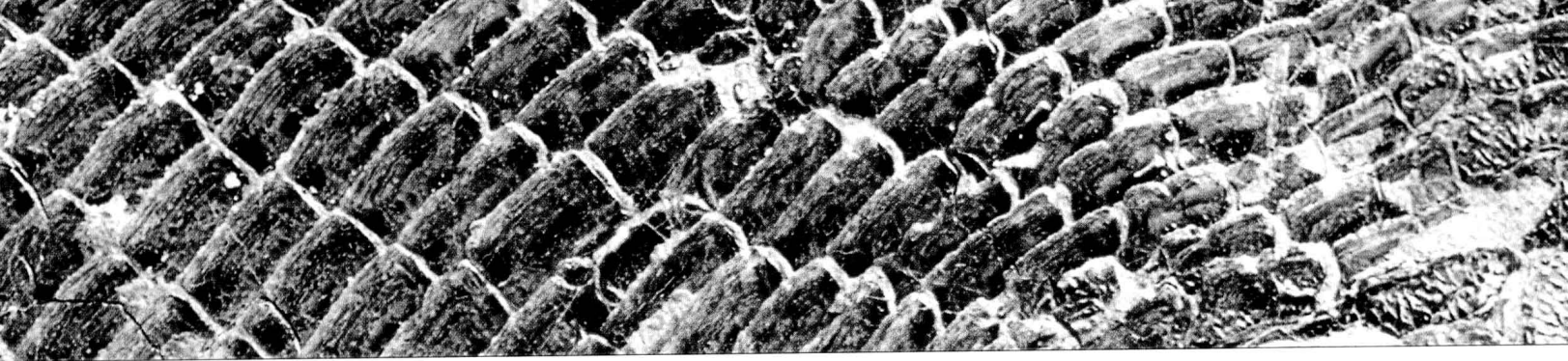
Applications of RFLPs 251

DOING SCIENCE: *Looking for Needles in Molecular Haystacks* 252

Genetic Modification of Organisms: Some Examples 253

COMMENTARY: *Human Gene Therapy* 257

Summary 257



UNIT III PRINCIPLES OF EVOLUTION

17 EMERGENCE OF EVOLUTIONARY THOUGHT

Fire, Brimstone, and Human History 260

Key Concepts 261

Growing Awareness of Change 261

The Great Chain of Being 261

Questions from Biogeography 262

Questions from Comparative Anatomy 263

Questions About Fossils 263

Attempts to Reconcile the Evidence With Prevailing Beliefs 264

Cuvier's Theory of Catastrophism 264

Lamarck's Theory of Desired Evolution 264

Darwin's Journey 264

Voyage of the *Beagle* 265

Evolution by Natural Selection: The Theory Takes Form 266

Evolution: A Study of Process and Pattern 270

Summary 270

18 MICROEVOLUTION

Designer Dogs 272

Key Concepts 273

Microevolutionary Processes 273

Variation in Populations 273

Mutation 276

Genetic Drift 278

Gene Flow 279

Natural Selection 280

Evidence of Natural Selection 280

Stabilizing Selection 280

Directional Selection 283

Disruptive Selection 284

Selection and the Maintenance of Different Phenotypes 284

Balanced Polymorphism 284

COMMENTARY: *Sickle-Cell Anemia—Lesser of Two Evils?* 284

Sexual Dimorphism 285

Speciation 286

Defining the Species 286

Divergence 286

Reproductive Isolating Mechanisms 286

Speciation Routes 288

DOING SCIENCE: *Speciation and the Isthmus of Panama* 288

Summary 290

19 LIFE'S ORIGINS AND MACROEVOLUTIONARY TRENDS

On Floods and Fossils 292

Key Concepts 293

Evidence of Macroevolution 293

The Fossil Record 294

Dating Fossils 295

Comparative Morphology 295

Comparative Biochemistry 298

Macroevolution and Earth History 299

Origin of Life 299

Drifting Continents and Changing Seas 303

Speciation and Rates of Change 303

Extinctions and Adaptive Radiations 304

The Archean and Proterozoic Eras 308

The Paleozoic Era 308

The Mesozoic Era 311

COMMENTARY: *The Dinosaurs—A Tale of Global Impacts, Radiations, and Extinctions* 312

The Cenozoic Era 314

Summary 316

20 CLASSIFICATION OF LIFE'S DIVERSITY

Pandas in the Tree of Life 318

Key Concepts 319

Systematics 319

Taxonomy 320

Recognizing Species 320

The Linnean Scheme 322

Phylogeny 323

Three Interpretive Approaches 323

Portraying Relationships Among Organisms 324

DOING SCIENCE: *Constructing a Family Tree Called a Cladogram* 324