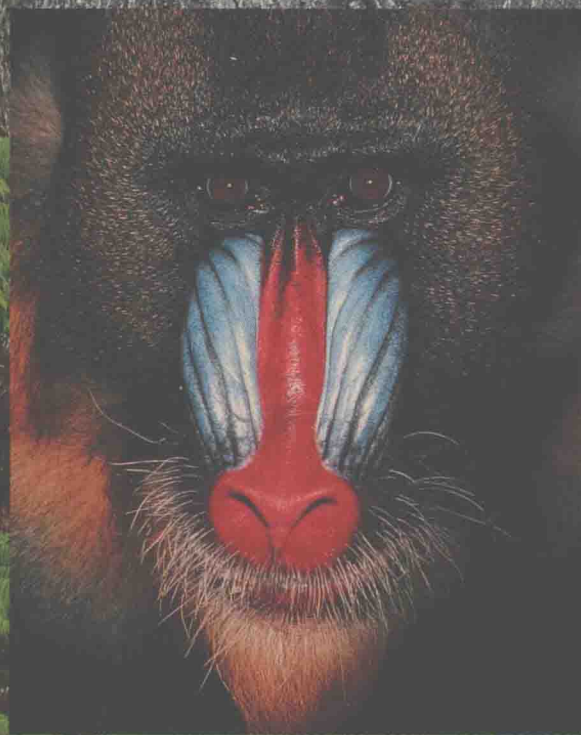


# Exploring Life

THE PRINCIPLES OF BIOLOGY

John Blamire



# Exploring Life

T H E P R I N C I P L E S O F B I O L O G Y

**John Blamire**

*City University of New York,  
Brooklyn College*



**Wm. C. Brown Publishers**

Dubuque, Iowa • Melbourne, Australia • Oxford, England

## **Book Team**

Editor *Kevin Kane*  
Development Editor *Margaret J. Kemp*  
Production Editor *Jane Matthews*  
Designer *Jeff Storm*  
Art Editor *Joseph P. O'Connell*  
Photo Editor *Lori Gockel*  
Permissions Coordinator *Gail I. Wheatley*



### **Wm. C. Brown Publishers**

A Division of Wm. C. Brown Communications, Inc.

Vice President and General Manager *Beverly Kolz*  
Vice President, Director of Sales and Marketing *Ginny Moffat*  
Marketing Manager *Carol J. Mills*  
Advertising Manager *Janelle Keefer*  
Director of Production *Colleen A. Yonda*  
Publishing Services Manager *Karen J. Slaght*



### **Wm. C. Brown Communications, Inc.**

President and Chief Executive Officer *G. Franklin Lewis*  
Corporate Vice President, President of WCB Manufacturing *Roger Meyer*  
Vice President and Chief Financial Officer *Robert Chesterman*

Unless otherwise credited, all photographs © John Blamire.

Copyedited by Kathy Massimini

Cover photos:  
(Background) © Greg Vaughn/Tom Stack and Associates  
(Inset) © Toni Angermayer/Photo Researchers, Inc.

The credits section for this book begins on page 490 and is considered an extension of the copyright page.

Copyright © 1994 by Wm. C. Brown Communications, Inc.  
All rights reserved

A Times Mirror Company

Library of Congress Catalog Card Number: 92-75102

ISBN 0-697-14537-9

No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the publisher.

Printed in the United States of America by Wm. C. Brown Communications, Inc.,  
2460 Kerper Boulevard, Dubuque, IA 52001

10 9 8 7 6 5 4 3 2 1

---

# Preface

This book is intended for use in introductory level courses, in short general biology courses (one quarter or one semester), and possibly in those courses that require an overview of biology before specializing in other majors.

Biology is the *science of life*, but for many students, the principles of science are so mysterious and threatening, they never get past their fears and on to the fascinating realm of living creatures that inhabit every good biology course. Between the pages of this book, therefore, the two themes of *science* and of *life* are brought together in a way that makes the biology accessible and the science much less intimidating. Any student who is interested in biology, but who has little experience with the process of science, will find it possible to learn the principles of biology by following this text. Science is presented as a living process carried out by living scientists in a true context. We see how *their* work reveals a little more each day about how *life* works.

## The Student and the Author

As you will learn in Chapter 1, I am a scientist who carries out research and teaches introductory biology. The dual nature of my work has given me an insight into how people approach the study of biology. Almost without exception, I have found that students come to their first college biology class wanting to know more about this phenomenon we call life. They ask questions like: "How does it work?" and "How do we know?" But they are quickly turned off by vague answers or by answers filled with jargon and assumptions. From my experience introducing these students to the world of biological science, and from my many attempts to answer their questions (without having their eyes glaze over), I have written this book.

More than any other factor, I have tried to keep the vision of my very first biology class in mind as I prepared each chapter. As a freshly minted Ph.D.

with several published research papers to my credit, I stood before my first class and plunged right into the latest findings and awesome significance of DNA replication. My very polite audience waited half an hour before one student had the courage to raise her hand and ask me the first question. To my surprise, the question concerned a point I thought I had made abundantly clear in the second sentence. I spent the rest of that class going backward through my presentation trying to make each point clear *in reverse order*. With this in mind, whenever I sat before my word processor and began a new chapter, I always pictured that class and was careful to think of their needs as I laid down my sequence of ideas.

I hope you find that I have succeeded. Although there are many ways to use a textbook like this one, remember the advice the Queen of Hearts gave to Alice in Wonderland. Alice asked, "How shall I tell my story?" and she was told, "Begin at the beginning, go on to the end, and then stop." If you read this book in the order it is written, you will find that the ideas and themes of biology flow easily and that the concepts are explained and illustrated in a logical sequence that makes them easier to understand. For example, in Chapter 3 the property of atoms is explained. With this knowledge, you can follow the structure and function of DNA in Chapter 4. . . . Knowing about the role of DNA makes the understanding of genetics much simpler in Chapters 9 and 10. A grounding in genetic principles makes it a snap to follow the mechanisms of evolution found in Chapters 20 and 21 and the arrival of humans in Chapter 22. You can even learn how a small change in a DNA molecule was instrumental in bringing about the Russian Revolution!

However, because there is no one way of learning biology, you are certainly at liberty to turn to page 366, find out about the evolution of the human species, and then work your way back to the atoms on page 31; but just remember my first biology class.

## A Picture Is Worth a Thousand Words

Publishers like words. As any prospective author quickly learns, editors who are responsible for producing expensive textbooks like to see a “manuscript.” These written words are sent out for review, and after all the necessary changes are made, the errors eliminated, and the final revisions completed, then a publisher begins to discuss the art program for a textbook. As a result, the two most important parts of the work, the words and the pictures, are created separately and, very often, independently of one another. No matter how dedicated and clever the artist or the art director, the final book often looks like the work of two different sets of people, and the student may be left wondering if the author and the artist ever talked with one another. As a teacher, I found this very frustrating because the image that accompanies an idea in life science is often better at explaining a concept than 1,000 words.

Wm. C. Brown Publishers are probably unique in that they have allowed me to develop the art program that accompanies this textbook *as the manuscript was produced*. Not only that, *all* the drawings in this book were produced by the same artist. Art and words are woven together in a way that is additive, not independent. As you read about plant structure on page 223, you meet the “up and down” nature of basic plant shapes. Then, as you turn the page to find out about plant cells and tissues, exactly the same drawing is seen again, but with some extra added features. On the next page, you learn about roots, and once again the drawing is consistent and the new information is added seamlessly to the old. You will not have to reinterpret each drawing every time you meet a new fact or face a new concept.

Such an art program is expensive and labor intensive. It requires close collaboration between the author and the artist. With considerable patience, the artist on this project revised and revised a figure until it was just what was needed. Sometimes a figure was simplified because the original tried to do too much. Other times, when something more dramatic was needed, a simple drawing grew until the message it carried was unavoidable. In just one or two places, a touch of humor escapes, like Redi’s flies on page 10, all to enhance the ability of the book to transfer knowledge and understanding to its reader.

## The Hook

Any good story, and the story of life is certainly one of the best stories, needs a hook. This is a literary device in which authors “hook” your interest in what they have to say. Very often, they do this using a dramatic, unusual, or especially intriguing opening

sentence, paragraph, or page. Once you are hooked, you want to read on.

Throughout this book, you will find a similar concept at work. Complex ideas, such as the evidence for the beginning of life or the time scale for evolution, are presented within a context familiar from everyday life. This makes the science readily accessible and much more comprehensible. A famous detective helps us unravel the mystery of how life got started on this planet in Chapter 3, and in Chapter 22 a very boring movie helps us understand the amount of time it took for the various forms of life to evolve on earth. Each of these themes gently moves the reader from an easily recognizable concept (such as a detective story) to the scientific principle (such as atomic structure).

Long after you have closed this book, finished the biology course, and moved on to other phases of your education, you will remember the peccaries and their gene pool on page 350. This is important because science is *not* just a collection of facts that you have to learn to pass exams, it is also a way of understanding.

Science is a process of discovery and understanding of the world around us. In learning about biology, therefore, it is just as critical to understand *why* living cells use ribosomes as it is to memorize the component parts of a ribosome itself. Consequently, much effort has gone into showing you how biological facts fit together. Carried along by the themes, the art work, and the “hooks,” the facts of life become less intimidating and easier to learn as you begin to understand the important overarching principles at work.

For me, as a scientist, a teacher, and an author, this is the ultimate reward. I enjoy biology very much and I want to pass some of that pleasure on to you. From the understanding of biology that you take away from this course, you will find that the many important decisions you make every day become easier, more reasoned, and, hopefully, more correct. You will be able to read the list of ingredients on a food packet with more comprehension. In the voting booth, you will be able to cast your ballot on environmental issues from an informed position rather than from a hunch or “gut feeling.” Your conversations with your doctor about what medicines to take will have more depth, and you will certainly know why you should avoid certain types of pollution. This is real empowerment in your life—and all from one biology course!

John Blamire  
Brooklyn, N.Y. 1993

## Ancillaries

A *Student Study Guide* is available in which the key elements in each chapter are laid out in an easy to follow sequence. “Along-the-way” tests help students to see how far their comprehension of each topic has progressed, and key concepts are highlighted.

An *Instructor’s Manual* puts together some ideas from one teacher to another as well as provides outlines, chapter to chapter interleaving, concepts, pivot points, and suggested use of the visuals within this book. The manual also includes a Test Item File, which the instructor can receive in Apple, IBM, and Macintosh disk format.

Instructors and adopters may also request a pack of “clean” images selected from the unique art work within this book that they may customize and use for overhead transparencies.

## Acknowledgments

The list of people to thank on a project like this one is long, but the space available is short, so I hope that anyone who feels that I have left out their names will forgive me. I have listed a few of the absolutely key people who at one time or another played vital roles in either the moral, physical, or intellectual production of this book, but special thanks should also go to my parents, who gave me my first spark of interest in science (that is another story for another time), and to my first science teachers who fanned that spark into a flame.

No doubt one or two errors will have persisted and made it into the final version of this manuscript, but that will not be the fault of the following excellent reviewers who helped me in more ways than they will never know.

My thanks and deepest appreciation to:

Dean A. Adkins  
*Marshall University*

Frank T. Awbrey  
*San Diego State University*

Rosemarie L. Becker  
*Springfield Technical Community College*

Robert Elgart  
*State University of New York—Farmingdale*

Glenn A. Gorelick  
*Citrus College*

G. A. Griffith  
*South Suburban College*

Chris Kellner  
*Arkansas Tech University*

Robert Klose  
*University of Maine*

Samuel J. Levine  
*Borough of Manhattan Community College*

Satish Mahajan  
*Lane College*

Terry Martin  
*Kishwaukee College*

Jack D. McConnell  
*Seward County Community College*

Donald J. McGraw  
*University of San Diego*

Mary Lou McReynolds  
*University of Kentucky—Hopkinsville Community College*

Dwight Meyer  
*City University of New York—Queensborough  
Community College*

Glendon R. Miller  
*Wichita State University*

Neil A. Miller  
*Memphis State University*

Pamela Moehring  
*Mount Mary College*

Carol E. Morris  
*Tompkins Cortland Community College*

Haig H. Najarian  
*University of Southern Maine*

Lloyd Ohl  
*University of Wisconsin—Eau Claire*

William J. Radke  
*University of Central Oklahoma*

Ralph E. Reiner  
*College of the Redwoods*

Martin Roedor  
*The Florida State University*

Michael D. Rourke  
*Bakersfield College*

Dr. M. Shopper  
*Johnson County Community College*

Bruce N. Smith  
*Brigham Young University*

Margaret W. Smith  
*Butler University*

F. Lee St. John  
*The Ohio State University at Newark*

Kathleen M. Steinert  
*Bellevue Community College*

William F. Towne  
*Kutztown University of Pennsylvania*

Terry N. Trobec  
*Oakton Community College*

Sandra B. Wilson  
*Manatee Community College*

N. Yarlett  
*Pace University*

Dorothy D. Zinsmeister  
*Kennesaw State College*

---

**Author's Personal Word of Thanks**

A textbook such as this one is influenced by many people. I would like to thank a few of them personally.

Peter Prescott—*who got me started*

Ann Vinecomb—*who kept me going*

Ray Carlucci—*who persuaded me to continue*

Ed Jaffe—*who convinced me it was possible*

Jane Matthews—*who put it all together*

Marge Kemp—*who says "no" better than anyone*

Kathy Massimini—*who banned the word "very"*

Kevin Kane—*who listened*

Carol Mills—*to whom I could listen forever*

# Brief Contents

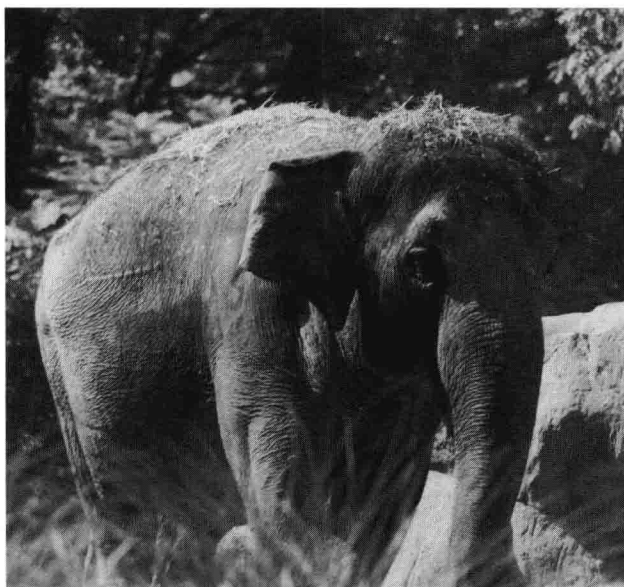
---

## **Part One**

---

### From Molecules to Cells

- Chapter 1 The Science of Life 2
- Chapter 2 The Signs of Life 14
- Chapter 3 The Beginning of Life 26
- Chapter 4 The Components of Cells:  
The Macromolecules 42
- Chapter 5 The World of Cells 56
- Chapter 6 Eukaryotic Cell Structure 72
- Chapter 7 Biological Energy 84
- Chapter 8 Energy Storage and Utilization 96



## **Part Two**

---

### From Cells to Humans

- Chapter 9 Biological Information 112
- Chapter 10 Mendel and Diploid Genetics 130
- Chapter 11 Animal Reproduction and Development 152
- Chapter 12 Human Reproduction and Development 166

## **Part Three**

---

### The Diversity of Life

- Chapter 13 Protistans and the Animal Form 188
- Chapter 14 Fungi and the Plant Form: Decomposers and  
Producers 212
- Chapter 15 Plant Reproduction and Growth 236

## **Part Four**

---

### Integration of the Parts

- Chapter 16 System I: Digestion and Respiration 254
- Chapter 17 System II: Circulation and Exchange 274
- Chapter 18 System III: Hormones and Nerves 292
- Chapter 19 System IV: Support and Movement 312

## **Part Five**

---

### Life on the Biosphere

- Chapter 20 Darwinism and Natural Selection 328
- Chapter 21 Evolution in Action 348
- Chapter 22 The Evolution of Humans 366
- Chapter 23 Animal Behavior 400
- Chapter 24 Ecosystems 426
- Chapter 25 Ecosystems and the Passage of Time 448



# Contents

---

Another View xv  
Preface xvi

---

## Part One: From Molecules to Cells

### **Chapter 1**

---

The Science of Life 2

The Gay Yeast 2

Science and the Scientific Method 2

Theories Can Change 4

Quantitative Observations and Scientific Experiments 5

*Experiments* 5

Another View: Setting a Standard 6

*Taking Control* 8

Science and Biology 8

Appearances Can Be Deceptive 9

Spontaneous Generation: A Theory That Died Twice 10

Author's Afterword 12

Summary 13

Quick Quiz 13

Questions 13

### **Chapter 2**

---

The Signs of Life 14

What Are We Looking For? 14

The Signs of Life 15

Response to Stimuli 15

Growth and Reproduction 16

Heredity 17

Homeostasis 17

Adaptation 18

Levels of Organization 19

Another View: A Burp from Eating Dust 19

Atoms 20

Molecules and Compounds 20

Monomers 20

Polymers or Macromolecules 21

The Cell 21

Energy, Entropy, and the Laws of Thermodynamics 22

The First Law of Thermodynamics 22

The Second Law of Thermodynamics 23

Life and Energy 23

Summary 24

Quick Quiz 25

Questions 25



**Chapter 3****The Beginning of Life 26****A Detective Story 26****Solving the Mystery of Life 27**

Deducing Conditions on the Primitive Earth 27

*Clue number one 27**Clue number two 28**Clue number three 28*

A Reconstruction 29

*Stanley Miller 29*

Another View: In the Beginning 30

**Atomic Structure 31**

Electron Energy 32

Physical Properties of Atoms 32

Chemical Properties of Atoms 33

Bonding 34

*Ionic Bonds 34**Covalent Bonds 35*

Spontaneous and Nonspontaneous Reactions 36

*Activation Energy 36***Properties of Water 37**

Water Is a Liquid 37

Water Is a Solvent 38

Water Can Ionize 39

**Summary 40****Quick Quiz 41****Questions 41****Chapter 4****The Components of Cells:  
The Macromolecules 42****From Monomers to Polymers 42****Waxes, Fatty Acids, and Lipids 44**

Waxes 44

Neutral Lipids 45

Phospholipids 46

Another View: The Importance of Carbon 46

Steroids 47

**Monosaccharides and Polysaccharides 47**

Starch 48

Glycogen 48

Cellulose 48

**Amino Acids, Polypeptides, and Proteins 49**

Amino Acids 49

Polypeptides 49

Structure of Proteins 50

Function of Proteins 51

**Nucleic Acids: DNA and RNA 51**

Another View: Types of Polymers 53

**The Components of the System 53****Summary 54****Quick Quiz 55****Questions 55****Chapter 5****The World of Cells 56****The Cell Theory 56**

Another View: The Size of Things 57

**The First Cells 59**

Prokaryotic Cells 60

Eukaryotic Cells 61

Another View: Microscopes 62

**The Problem of Size 64****Getting Substances into and out of Cells 65**

Diffusion 65

Osmosis 65

Transport 66

*Passive Transport 66**Active Transport 67*

Another View: The Missing Link? 67

Endocytosis and Exocytosis 68

Another View: Viruses: The Boundary of Life 69

**Now and Then 70****Summary 70****Quick Quiz 71****Questions 71****Chapter 6****Eukaryotic Cell Structure 72****Methods of Study 72****The Component Parts: The Organelles 74**

Cilia and Flagella 74

The Plasma Membrane 75

The Cytoskeleton: Microtubules and Microfilaments 76

*Microtubules 76**Centrioles 77*

The Cytoplasm 77

The Endoplasmic Reticulum and Golgi Apparatus 77

The Mitochondria: Energy Conversion 79

The Lysosome 79

The Nucleus 80

*Chromosomes 80**Nucleolus 81**Transcription 81***Organelles in Plant Cells 81**

Cell Walls 81

Plastids 82

**Summary 82****Quick Quiz 83****Questions 83**

## Chapter 7

### Biological Energy 84

*Saccharum officinarum* 84

The Study of Energy 85

Spontaneous and Nonspontaneous Reactions 86

Energy and Electrons 88

Catalysts and Enzymes 89

Synthesis: Linking Reactions Together 91

A Problem and a Solution 92

Adenosine Triphosphate—Short Term Energy Currency 93

Obeying All the Laws 94

Summary 94

Quick Quiz 95

Questions 95

## Chapter 8

### Energy Storage and Utilization 96

Liquid Sunshine 96

Photosynthesis: Light and Energy 97

Chlorophyll and the Light-dependent Reactions of

Photosynthesis 98

*Splitting Water for Electrons* 99

*Electron Transport and ATP Synthesis* 99

*Chemiosmosis* 100

*Photosystem I and NADP* 100

The Light-independent Reactions of Photosynthesis 101

*Step 1: Fixing Carbon Dioxide* 102

*Step 2: Moving Electrons* 102

*Step 3: Bookkeeping and the Calvin Cycle* 102

Aerobic Respiration: Mobilizing Reserves 103

Glycolysis 104

The Krebs Cycle 105

Regenerating NAD 106

Chemiosmotic Phosphorylation 106

Alcoholic and Lactic Acid Fermentations 107

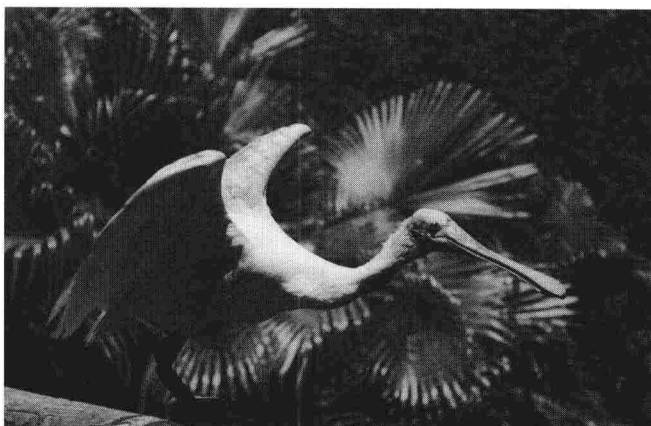
Other Foods 108

Two Organelles at Work 108

Summary 109

Quick Quiz 110

Questions 110



## Part Two: From Cells to Humans

## Chapter 9

### Biological Information 112

The Language of Heredity 112

A Genetic Trait 113

The Flow of Information 114

Mutations 116

Mechanisms of Inheritance 117

DNA Replication 118

Organization of DNA within Cells 118

Asexual Reproduction: Mitosis 119

*Interphase* 119

*Gap One: G1* 119

*Synthesis: S Phase* 119

*Gap Two: G2* 119

*Nuclear Division* 119

*Cytoplasmic Division* 120

Sexual Reproduction and Meiosis 121

*Alternation between Haploid and Diploid* 121

*Stages in Meiosis* 121

*Meiosis I* 122

*Meiosis II* 122

The Two Roles of DNA 123

Genetic Engineering 123

Cutting up DNA 124

Separating by Size 124

Putting the Pieces back Together 125

Cloning the Genes 125

Future Promises 126

*Protein Production* 127

*Plant and Animal Husbandry* 127

Summary 128

Quick Quiz 129

Questions 129

## Chapter 10

### Mendel and Diploid Genetics 130

A Monastery Garden 130

What Mendel Did and What He Saw 131

Phenotype and Genotype 133

A Typical Cross 134

How Mendel Explained His Results 135

*The First Round: F1 Generation* 135

*The Second Round: F2 Generation* 136

*Two-factor Crosses and Independent Assortment* 138

Exceptions to the Rule 139

*Linked Genes* 139

*Incomplete Dominance* 140

Another View: Trophim, Triticale, and Genetics 140

*Polygenic Traits* 141

**Sex Determination and Sex-linked Traits 141**

- Lover of Dew 141
- Sex-linked Traits 143

**Inherited Characteristics in Humans 145**

- Mendelian Traits 145
  - Blood Groups 145*
- Sex-linked Traits 146
  - Queen Victoria and Hemophilia 146*
  - Nondisjunction: Down's syndrome 147*
- Another View: Looking at Chromosomes: Karyotype 148
  - Nondisjunctions of Sex Chromosomes 149*

**Back in the Garden 149****Summary 149****Quick Quiz 150****Genetic Problems 151****Questions 151****Chapter 11****Animal Reproduction and Development 152****From Egg to Adult 152**

- Production of Gametes 153
  - Spermatogenesis in Animals 153*
  - Oogenesis in Animals 154*
- Reproductive Strategy 154
- Mating Behavior 155
  - Fertilization 156*
- Survival of the Zygote 158

**Development of the Zygote 159**

- Cleavage 160*
- Gastrulation 160*
- Organogenesis 160*
- From Egg to Frog 161
- Another View: Control of Development 162

**Summary 164****Quick Quiz 165****Questions 165****Chapter 12****Human Reproduction and Development 166****Six o'clock One Morning 166****Human Reproduction 167**

- Male Reproductive Organs 167
- Female Reproductive Organs 168
  - Estrus and the Human Menstrual Cycle 168*
- Sexual Intercourse: Phases in the Male Response 170
- Sexual Intercourse: Phases in the Female Response 171

**Human Development 172**

- The First Three Months 172
- The Second Three Months 174
- The Third Three Months 174
- Birth 175

**Human Reproductive Strategy 176**

- Choosing a Mate 176
- Planning a Family 178
  - Increasing the Number of Pregnancies 179*
    - Artificial Insemination 180*
    - In Vitro Fertilization 180*
    - In Vivo Fertilization 180*
    - Adoption 181*
  - Decreasing the Number of Pregnancies 181*
    - Abstinence 181*
    - Rhythm Methods 181*
    - Coitus Interruptus 182*
    - Physical Barriers to Contraception 182*
    - Barriers to Zygote Formation and Implantation 183*
    - Termination of Pregnancy 184*

**Summary 185****Quick Quiz 186****Questions 186****Part Three: The Diversity of Life****Chapter 13****Protistans and the Animal Form 188****The Ladder of Life 188**

- Another View: Taxonomy and the Chaos of Diversity 190

**Protistans 192**

- Protozoa: Mainly Heterotrophic "Animal" Protists 192
- Slime Molds: Decomposer "Fungal" Protists 193
- Protophyta: Mainly Autotrophic "Plant" Protists 193

**Animals 194**

- Sponges: The Simplest Form 195
- Hydra: The Radial Form 196
- Flatworms: The Bilateral Form 197
- Roundworms: A Cavity and a Gut 198
- True Worms: The Segmented Form 199
- Arthropods: The Specialized Segment Form 200
- Mollusks: The Soft Body Form 202
- Sea Urchins: The Internal Skeleton 203
- A Stiff Rod up the Back 204
  - Fish: The First Vertebrate Form 205*
  - Amphibians: The First Land Vertebrates 206*
  - Reptiles: The Dry Land Form 206*
  - Birds: Warm Blood and Hard-shelled Eggs 207*
  - Mammals: The Milk Givers 207*

**The Tree of Life 208**

- Another View: Soft Fossils and Hard Classification 209

**Summary 210****Quick Quiz 211****Questions 211**

## Chapter 14

### Fungi and the Plant Form: Decomposers and Producers 212

#### The Flow of Energy and Building Materials 212

##### Fungi 213

- The Fungal Body Form 213
- Fungal Life-Styles 214
- Fungal Reproduction 215
- The Fungal Family 215

##### Plants 216

- Algae: Aquatic Body Form 217
- Bryophytes: The First Land Plants 218
- Tracheophytes: Diploids are Dominant 219
  - Lower Vascular Plants* 220
  - The Seed Bearers* 220
  - Naked Seeds and Vessel Seeds* 221

##### Plant Structure 223

- Up and Down 223
- Angiosperm Plant Types 223
- Cell and Tissue Types 224
- Root Structure 225
  - The Dermal System* 225
  - The Ground System* 225
  - The Vascular System* 226
- Stem Structure 226
  - The Dermal System* 227
  - The Ground System* 227
  - The Vascular System* 227
- Leaf Structure 228
  - The Dermal System* 228
  - The Ground System* 229
  - The Vascular System* 229
- Transpiration 229
- Another View: Getting and Storing 230
- Translocation 232

##### Summary 234

##### Quick Quiz 235

##### Questions 235

## Chapter 15

### Plant Reproduction and Growth 236

#### Sex and the Saguaro 236

- Pollen and Ovaries 237
  - Pollen Production* 238
  - Megagametophyte Production* 238
- Pollination 239
  - Wind Pollination* 239
  - Beetle Pollination* 239
  - Bee Pollination* 240
  - Moths, Birds, Mice, and Bats* 240

Fertilization and Zygote Formation 240

Seeds 240

Seed Dispersal 241

*Air and Wind Dispersal* 241

*Water Dispersal* 242

*Animal Dispersal* 242

Seed Germination 242

#### Plant Growth 243

Becoming a Seedling 244

Auxin and the Response to Light 245

Cytokinins and Cell Division 246

Gibberellin and Stem Elongation 246

Ethylene, Buds, Roots, Flowers, Fruits, and Leaves 247

Flowering and Photoperiodism 248

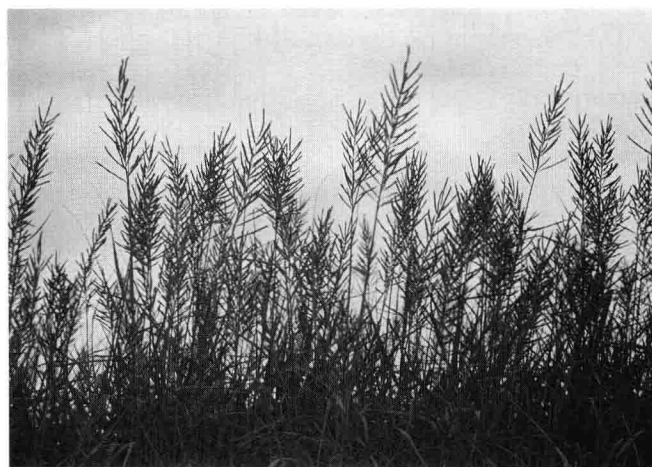
*How Plants Measure the Critical Period of Darkness* 249

Is There a Flowering Hormone? 250

#### Summary 251

#### Quick Quiz 252

#### Questions 252



## Part Four: Integration of the Parts

### Chapter 16

#### System I: Digestion and Respiration 254

##### The Body City 254

##### Animal Nutrition and Digestion 256

Food Requirements 257

*Energy* 257

*Building Materials* 257

*Helpers* 258

Getting the Meal Inside 258

*Single-Celled Creatures* 258

*Flatworms* 259

*Earthworms* 260

- The Human Gastrointestinal System 260
  - Enjoying the Meal: The Mouth* 260
  - I'm Hungry: The Stomach* 261
  - Getting the Most from a Meal: The Small Intestine* 263
  - The End of the Journey: The Large Intestine and Rectum* 264

### The Air We Breathe: Respiration 265

- Properties of Gases 265
- Surface Area 266
  - Exchange Surfaces* 267
    - Across the Cell Membrane Directly* 267
    - Across the Body Surface Directly* 267
    - Across Extensions of the Body Surface* 267
    - Across the Walls of Tubes* 267
    - Across Invaginations Using a Distribution System* 268
- The Human Respiratory Network 268
  - Air Flow within the System* 269
  - The Mechanics of Breathing* 269
  - Pigments and Transport* 270
- Another View: Alveoli and the Law of Laplace 270
  - The Hemoglobin Pigment* 279
  - Carbon Dioxide* 279

### Summary 272

### Quick Quiz 273

### Questions 273

## Chapter 17

### System II: Circulation and Exchange 274

#### The Internal Sea 274

- Interstitial Fluid 275
- Balancing the Internal Sea 276

#### Fluids in Motion 277

- Circulation in Animals 277
  - Composition of the Blood* 277
  - Erythrocytes* 277
  - Leukocytes* 278
- Fluid Systems 278
  - The Lymphatic System* 278
  - The Cardiovascular System* 279
    - Heartbeat and Blood Pressure* 280
    - Visiting the Organs* 281

#### The Liquid Balance 281

- Marine, Freshwater, and Terrestrial Fluid Balance 282
- Ions and Nitrogen 282
- The Human Kidney 283
  - The Renal Process* 283
  - The Case of Glucose* 284
  - The Case of Urea* 284
  - The Case of Potassium* 284
  - The Special Case of Sodium and Water* 285

#### Homeostasis: Staying the Same 285

- Temperature Regulation 286
  - Poikilotherms: Cold-blooded Animals* 287
  - Homeotherms: Warm-blooded Animals* 288
- Regulation of Blood Flow 289

*Loss of Blood* 289

### Summary 290

### Quick Quiz 291

### Questions 291

## Chapter 18

### System III: Hormones and Nerves 292

#### Two Crimes 292

- Burglary 292
- Assault 293

#### The Nervous System 294

- Neurons: The Wires 294
- The Nerve Impulse: Propagation of the Message 295
- The Synapse: Getting the Message Across 297
- The Senses and Receptors: Primary Stimulation 299
- Subdivisions of the Nervous System:
  - The Wiring Diagram 300
  - Central Nervous System* 301
  - Peripheral Nervous System* 302
- Another View: Nerve Net to Brain: Evolution of the Nervous System 302
  - Afferent or Sensory Nerves* 302
  - Efferent or Motor Nerves* 303
- The Reflex Arc: Direct Action 305

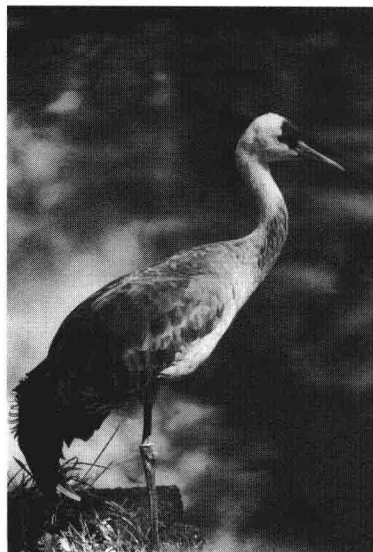
#### Hormones and the Endocrine System 306

- Production and Response 307
- Master Control: The Hypothalamus and Pituitary 308
  - Anterior Lobe* 308
  - Posterior Lobe* 309
  - Working Together* 309
- Other Endocrine Glands 310

### Summary 310

### Quick Quiz 311

### Questions 311



## Chapter 19

### System IV: Support and Movement 312

#### Old Bones and Muscles in Action 312

Locomotion 313

#### Bones, Joints, and Cartilage 315

Bone Structure 315

*Cartilage* 316

Joints 316

Making the Connection: Ligaments and Tendons 317

#### Muscles 317

Types of Muscle 317

Muscle Structure 318

*Ultrastructure of the Myofibril* 319

Excitation and Contraction 319

Another View: Water Beds and Armored Knights:  
Other Kinds of Support 321

Response and Control 322

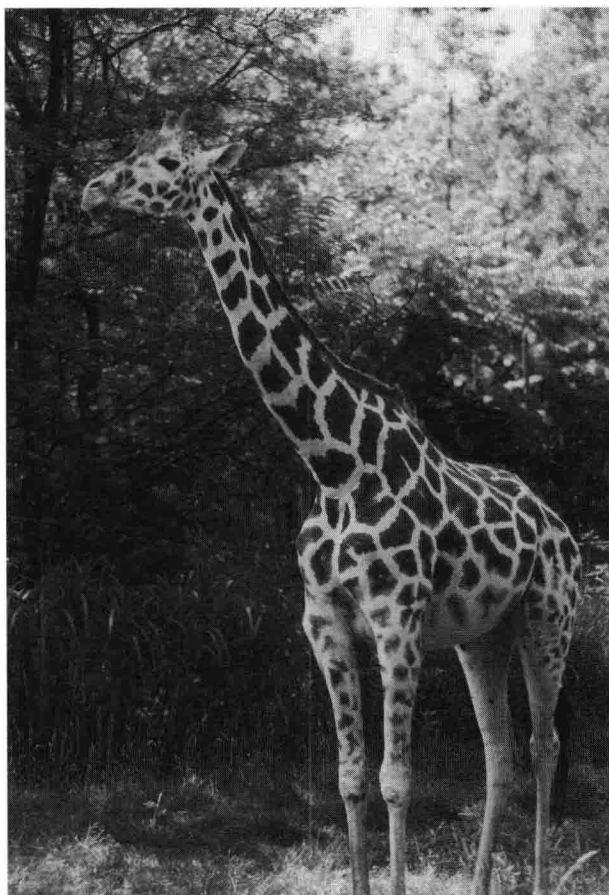
Levers and Antagonists 323

Another View: The Human Skeleton 324

#### Summary 324

#### Quick Quiz 326

#### Questions 326



## Part Five: Life on the Biosphere

### Chapter 20

#### Darwinism and Natural Selection 328

#### The Three Dimensions of Biology 328

#### The Dimension of Time 330

The Goldfish and the Eagle 330

Adaptations 333

*Animal Defensive Adaptations* 333

*Stings and Poisons* 333

*Warning Signals* 334

*Mimics* 334

*Blending into the Background* 334

#### Variation and Natural Selection 335

Darwin's Observations 335

The Raw Material: Sources of Variation 336

Another View: The History of an Idea 337

*Sources of Increased Variation* 338

*Mutation* 338

*Rates of Mutation* 338

*Recombination* 339

*Gene Flow* 340

*Sources of Decreased Variation* 340

*Selection* 340

*Genetic Drift: The Element of Chance* 340

Experiments in Natural Selection: Bacteria, Budworms,  
and Butterflies 341

*Resistance to Antibiotics* 342

*Tobacco Budworm* 343

Another View: Molecular Evolution 344

*Biston betularia in Birmingham* 345

#### Summary 346

#### Quick Quiz 347

#### Questions 347

### Chapter 21

#### Evolution in Action 348

#### Peccaries 348

Measuring Evolution: The Hardy-Weinberg Law and  
Genetic Equilibrium 349

#### Evolution in Action: Agents of Change 353

Large Populations 353

*Directional Selection* 353

*Stabilizing Selection* 355

*Disruptive Selection* 355

Small Populations 356

*Population Size* 356

*Genetic Drift* 357

*The Founder Effect* 357

Speciation 358

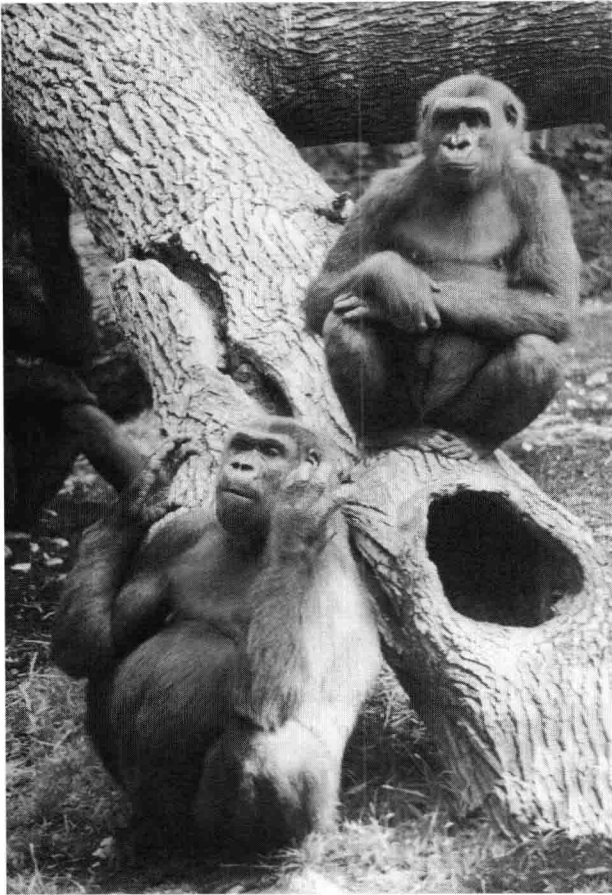
*Isolation* 359

*What Is a Species* 359

*What Are the Origins of New Species?* 359

- A Natural Diversity 360
- Adaptive Radiation and Character Displacement 361
- There Is No Going Back 362

- Summary 364**
- Quick Quiz 365**
- Questions 365**



## **Chapter 22**

### **The Evolution of Humans 366**

- A Very Boring Movie 366**
- Hominid Evolution: From the Takeover to the Moon 369**
  - Into the Darkness 371
  - Southern Ape of Africa 373
  - Another View: Continents Adrift 374
  - Handyman 378
  - Homo sapiens* 381
  - Three Branches 384
  - Lessons from the Garbage Dump 387
  - Sumer and Surplus 390
    - Sumer* 392
  - To the Moon 393
- Summary 396**
- Quick Quiz 398**
- Questions 398**

## **Chapter 23**

### **Animal Behavior 400**

- A Simple Smile 400**
- What Is Behavior? 401**
  - Taxes 402
  - The Potential for Learning 402
- Innate Behaviors 404**
  - Reflexes 404
  - Fixed-Action Patterns 405
  - Appetitive and Consummatory Behavior 406
- Learned Behaviors 407**
  - Classical Conditioning or Associative Learning 408
  - Habituation 410
  - Operant Conditioning or Trial-and-Error Learning 410
- Interactive Behavior 411**
  - Communication 412
    - Visual Communication* 412
    - Communication through Sound* 413
    - Smell* 413
    - Touch* 414
    - Integrated Communication* 414
  - Rituals 415
    - Courtship* 415
    - Territorial Defense* 415
  - Social Behavior 416
    - Invertebrate Societies* 416
    - Vertebrate Societies* 418
      - Advantages and Disadvantages* 419
  - Sociobiology 421
- That Not So Simple Smile 422**
- Summary 424**
- Quick Quiz 425**
- Questions 425**

## **Chapter 24**

### **Ecosystems 426**

- The Fragile Film 426**
- Ecosystem 428**
  - The Flow of Energy in an Ecosystem 429
  - Transfers and Trophic Levels 430
    - Producers, Consumers, and Decomposers* 431
  - Another View: The Web and the Computer 432
  - Material Resource Cycles 434
- Communities and Niches 435**
  - Ranges of Tolerance 436
  - Roles 437
  - The Niche 437
  - Interspecies Interactions 438
    - Competition* 440
    - Predation* 441
    - Mutualism* 444
- Summary 446**
- Quick Quiz 447**
- Questions 447**



## Chapter 25

### Ecosystems and the Passage of Time 448

#### Trouvelot and Two Types of Change 448

#### Populations and the Passage of Time: Quantitative Changes 449

Growth 450

*Case Number 1: Bacteria and Exponential Growth* 450

*Case Number 2: Bacteria in a Bottle, and Limits to Growth* 451

Death 453

*Aging* 453

Carrying Capacity 454

Reproductive Strategies 455

#### Ecosystems and the Passage of Time: Qualitative Changes 456

Ecological Succession 457

#### The Biosphere 458

The Biomes 461

*Deserts* 461

*Tundra* 462

*Rain Forests* 463

#### Summary 464

#### Quick Quiz 465

#### Questions 465

#### Appendix A 467

#### Glossary 468

#### Credits 490

#### Index 492

## Another View

- |   |  |
|---|--|
| <b>1.1</b> Setting A Standard 6                   | <b>13.1</b> Taxonomy and the Chaos of Diversity 190                    |
| <b>2.1</b> A Burp from Eating Dust 19             | <b>13.2</b> Soft Fossils and Hard Classification 209                   |
| <b>3.1</b> In the Beginning 30                    | <b>14.1</b> Getting and Storing 230                                    |
| <b>4.1</b> The Importance of Carbon 46            | <b>16.1</b> Alveoli and the Law of Laplace 270                         |
| <b>4.2</b> Types of Polymers 53                   | <b>18.1</b> Nerve Net to Brain: Evolution of the Nervous System 302    |
| <b>5.1</b> The Size of Things 57                  | <b>19.1</b> Water Beds and Armored Knights: Other Kinds of Support 321 |
| <b>5.2</b> Microscopes 62                         | <b>19.2</b> The Human Skeleton 324                                     |
| <b>5.3</b> The Missing Link? 67                   | <b>20.1</b> The History of an Idea 337                                 |
| <b>5.4</b> Viruses: The Boundary of Life 69       | <b>20.2</b> Molecular Evolution 344                                    |
| <b>10.1</b> Trophim, Triticale and Genetics 140   | <b>22.1</b> Continents Adrift 374                                      |
| <b>10.2</b> Looking at Chromosomes: Karyotype 148 | <b>24.1</b> The Web and the Computer 432                               |
| <b>11.1</b> Control of Development 162            |  |