

DETAILED CONTENTS

1 Introduction: Biology Today 1

The Scope of Biology 2

Life at Its Many Levels 2

Life in Its Diverse Forms 6

Evolution: Biology's Unifying Theme 8

The Darwinian View of Life 9

Natural Selection 10

The Process of Science 13

Discovery Science 13

Hypothesis-Driven Science 14

A Case Study in the Process of Science 15

The Culture of Science 16

Theories in Science 16

Science, Technology, and Society 18



Unit One CELLS

2 Essential Chemistry for Biology 20

Biology and Society: Fluoride in the Water 21

Tracing Life Down to the Chemical Level 21

Some Basic Chemistry 22

Matter: Elements and Compounds 22

Atoms 23

Chemical Bonding and Molecules 25

Chemical Reactions 27

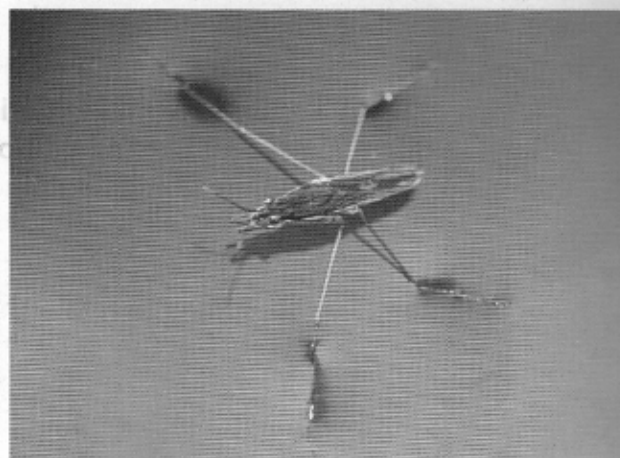
Water and Life 28

The Structure of Water 28

Water's Life-Supporting Properties 29

Acids, Bases, and pH 21

Evolution Connection: Earth Before Life 32





3 The Molecules of Life 35

Biology and Society: Got Lactose? 36

Organic Molecules 36

Carbon Chemistry 36

Giant Molecules from Smaller Building Blocks 38

Biological Molecules 39

Carbohydrates 39

Lipids 42

Proteins 44

Nucleic Acids 47

Evolution Connection: DNA and Proteins as Evolutionary Tape Measures 49

4 A Tour of the Cell 52

Biology and Society: Drugs That Target Cells 53

The Microscopic World of Cells 53

Microscopes as Windows to Cells 54

The Two Major Categories of Cells 55

A Panoramic View of Eukaryotic Cells 57

Membrane Structure and Function 58

A Fluid Mosaic of Lipids and Proteins 58

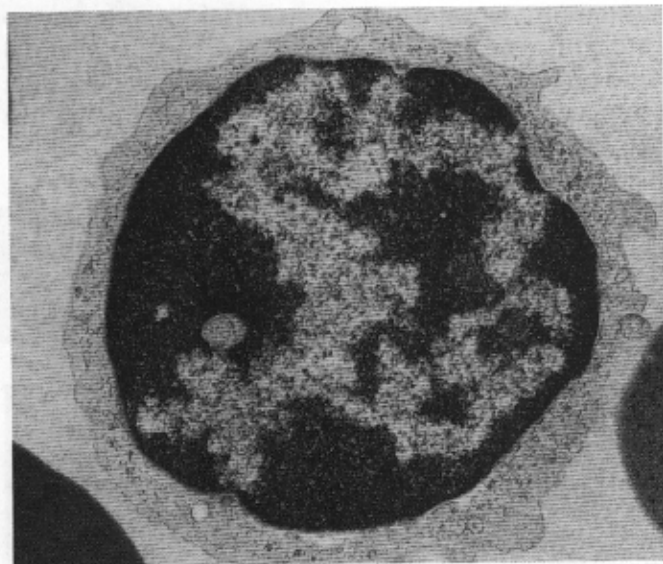
Selective Permeability 58

The Nucleus and Ribosomes: Genetic Control of the Cell 59

Structure and Function of the Nucleus 60

Ribosomes 60

How DNA Controls the Cell 60



The Endomembrane System: Manufacturing and Distributing Cellular Products 61

The Endoplasmic Reticulum 61

The Golgi Apparatus 62

Lysosomes 62

Vacuoles 63

Chloroplasts and Mitochondria: Energy Conversion 64

Chloroplasts 64

Mitochondria 65

The Cytoskeleton: Cell Shape and Movement 65

Maintaining Cell Shape 65

Cilia and Flagella 66

Cell Surfaces: Protection, Support, and Cell-Cell Interactions 67

Plant Cell Walls and Cell Junctions 68

Animal Cell Surfaces and Cell Junctions 68

Evolution Connection: The Origin of Membranes 69

5 The Working Cell 72

Biology and Society: Stonewashing Without the Stones 73

Some Basic Energy Concepts 73

Conservation of Energy 73

Entropy 74

Chemical Energy 74

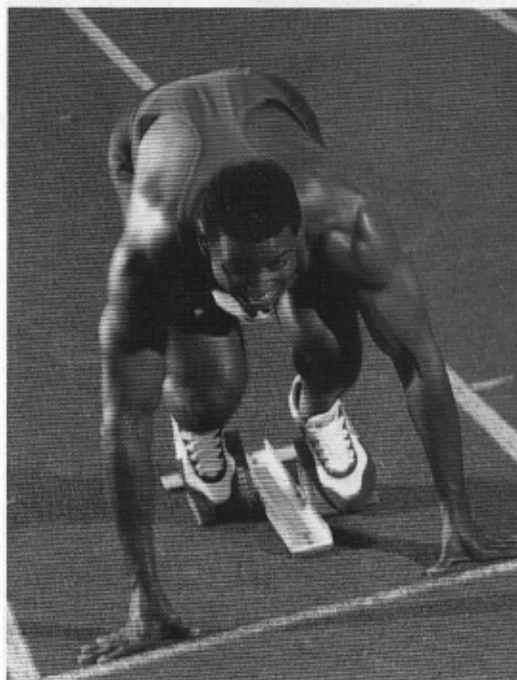
Food Calories 75

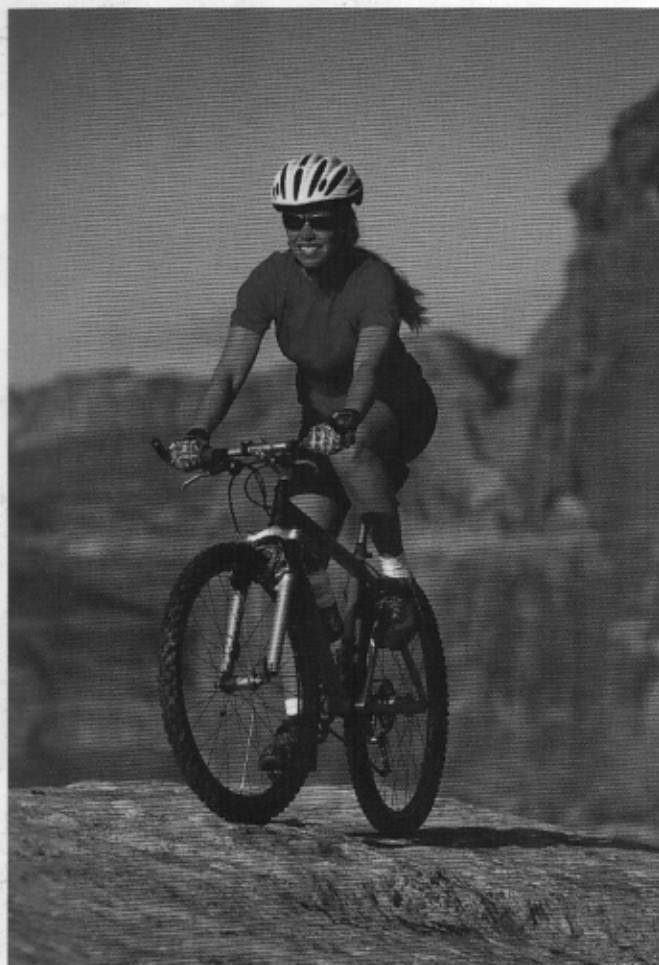
ATP and Cellular Work 76

The Structure of ATP 76

Phosphate Transfer 77

The ATP Cycle 77





Enzymes 78

Activation Energy 78

Induced Fit 78

Enzyme Inhibitors 78

Membrane Transport 80

Passive Transport: Diffusion Across Membranes 80

Osmosis and Water Balance in Cells 81

Active Transport: The Pumping of Molecules Across Membranes 82

Exocytosis and Endocytosis: Traffic of Large Molecules

The Role of Membranes in Cell Signaling 83

Evolution Connection: Evolving Enzymes 84

6 Cellular Respiration: Harvesting Chemical Energy 87

Biology and Society: Feeling the "Burn" 88

Energy Flow and Chemical Cycling in the Biosphere 88

Producers and Consumers 89

Chemical Cycling Between Photosynthesis and Cellular Respiration 89

Cellular Respiration: Aerobic Harvest of Food Energy 90

The Relationship Between Cellular Respiration and Breathing 90

The Overall Equation for Cellular Respiration 91

The Role of Oxygen in Cellular Respiration 91

The Metabolic Pathway of Cellular Respiration 93

Fermentation: Anaerobic Harvest of Food Energy 98

Fermentation in Human Muscle Cells 98

Fermentation in Microorganisms 99

Evolution Connection: Life on an Anaerobic Earth 99

7 Photosynthesis: Converting Light Energy to Chemical Energy 102

Biology and Society: Plant Power 103

The Basics of Photosynthesis 103

Chloroplasts: Sites of Photosynthesis 103

The Overall Equation for Photosynthesis 105

A Photosynthesis Road Map 105

The Light Reactions: Converting Solar Energy to Chemical Energy 106

The Nature of Sunlight 106

Chloroplast Pigments 107

How Photosystems Harvest Light Energy 107

How the Light Reactions Generate ATP and NADPH 109

The Calvin Cycle: Making Sugar from Carbon Dioxide 111

Water-Saving Adaptations of C₄ and CAM Plants 112

The Environmental Impact of Photosynthesis 113

How Photosynthesis Moderates the Greenhouse Effect 112

Evolution Connection: The Oxygen Revolution 114



Unit Two GENETICS

8 The Cellular Basis of Reproduction and Inheritance 118

Biology and Society: A \$50,000 Egg! 119

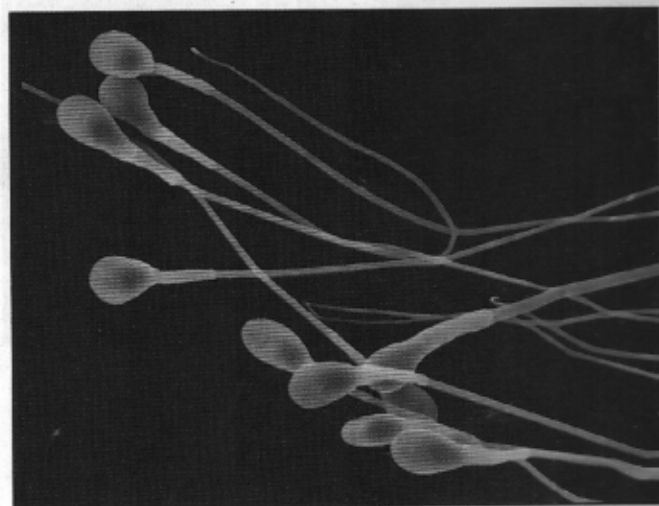
What Cell Reproduction Accomplishes 119

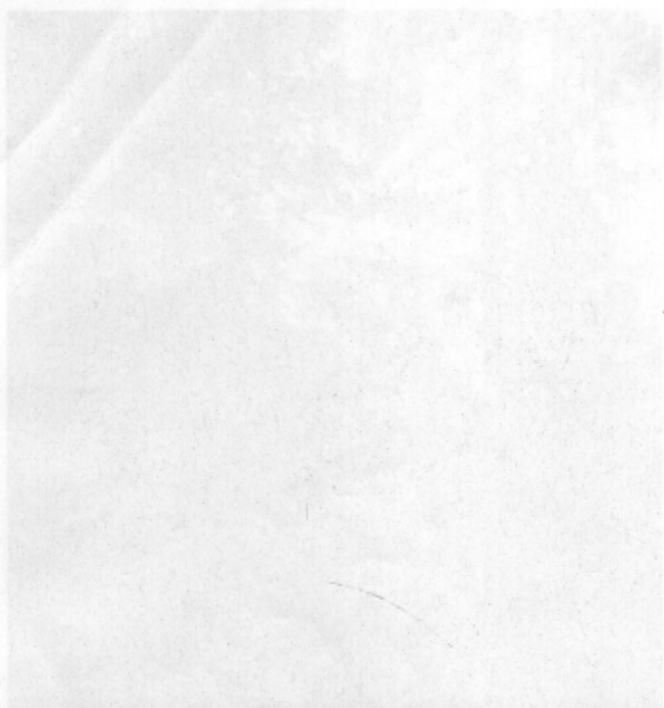
Passing On the Genes from Cell to Cell 120

The Reproduction of Organisms 120

The Cell Cycle and Mitosis 121

Eukaryotic Chromosomes 121





- The Cell Cycle* 122
- Mitosis and Cytokinesis* 124
- Cancer Cells: Growing Out of Control* 126

Meiosis, the Basis of Sexual Reproduction 128

- Homologous Chromosomes* 128
- Gametes and the Life Cycle of a Sexual Organism* 129
- The Process of Meiosis* 130
- Review: Comparing Mitosis and Meiosis* 133
- The Origins of Genetic Variation* 133
- When Meiosis Goes Awry* 134

Evolution Connection: New Species from Errors in Cell Division 137

9 Patterns of Inheritance 141

Biology and Society: Testing Your Baby 142

Heritable Variation and Patterns of Inheritance 142

- In an Abbey Garden* 143
- Mendel's Principle of Segregation* 144
- Mendel's Principle of Independent Assortment* 147
- Using a Testcross to Determine an Unknown Genotype*
- The Rules of Probability* 149
- Family Pedigrees* 150
- Human Disorders Controlled by a Single Gene* 151

Beyond Mendel 154

- Incomplete Dominance in Plants and People* 155
- Multiple Alleles and Blood Type* 156
- Pleiotropy and Sickle-Cell Disease* 157
- Polygenic Inheritance* 158
- The Role of Environment* 158

The Chromosomal Basis of Inheritance 159

- Gene Linkage* 160
- Genetic Recombination: Crossing Over and Linkage Maps* 162

Sex Chromosomes and Sex-Linked Genes 163

Sex Determination in Humans and Fruit Flies 163

Sex-Linked Genes 163

Sex-Linked Disorders in Humans 165

Evolution Connection:

The Telltale Y Chromosome 166

10 Molecular Biology of the Gene 170

Biology and Society: Sabotaging HIV 171

The Structure and Replication of DNA 171

DNA and RNA: Polymers of Nucleotides 172

Watson and Crick's Discovery of the Double Helix 173

DNA Replication 175

**The Flow of Genetic Information from
DNA to RNA to Protein 176**

*How an Organism's DNA Genotype Produces
Its Phenotype* 177

*From Nucleotide Sequence to Amino Acid
Sequence: An Overview* 178

The Genetic Code 179

Transcription: From DNA to RNA 180

The Processing of Eukaryotic RNA 181

Translation: The Players 182

Translation: The Process 183

Review: DNA → RNA → Protein 184

Mutations 186

Viruses: Genes in Packages 188

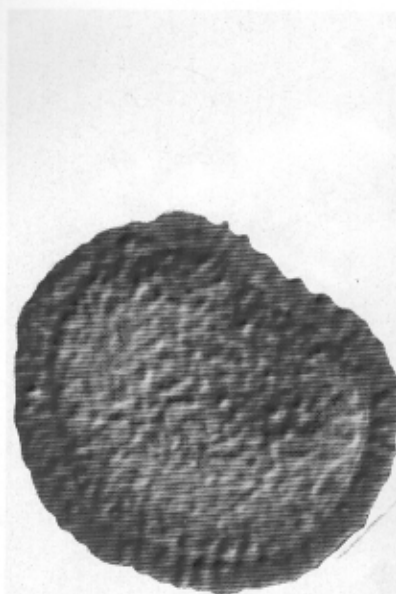
Bacteriophages 188

Plant Viruses 189

Animal Viruses 190

HIV, the AIDS Virus 190

Evolution Connection: Emerging Viruses 192



11 Gene Regulation 196

Biology and Society: Baby's First Bank Account 197

From Egg to Organism: How and Why Genes Are Regulated 197

Patterns of Gene Expression in Differentiated Cells 198

DNA Microarrays: Visualizing Gene Expression 198

The Genetic Potential of Cells 200

Reproductive Cloning of Animals 200

Therapeutic Cloning and Stem Cells 201

The Regulation of Gene Expression 203

Gene Regulation in Bacteria 203

Gene Regulation in the Nucleus of Eukaryotic Cells 204

Regulation in the Cytoplasm 206

Cell Signaling 207

The Genetic Basis of Cancer 208

Genes That Cause Cancer 208

The Effects of Lifestyle on Cancer Risk 211

Evolution Connection: Homeotic Genes 212

12 DNA Technology 216

Biology and Society: Hunting for Genes 217

Recombinant DNA Technology 217

From Humulin to Genetically Modified Foods 218

Recombinant DNA Techniques 220

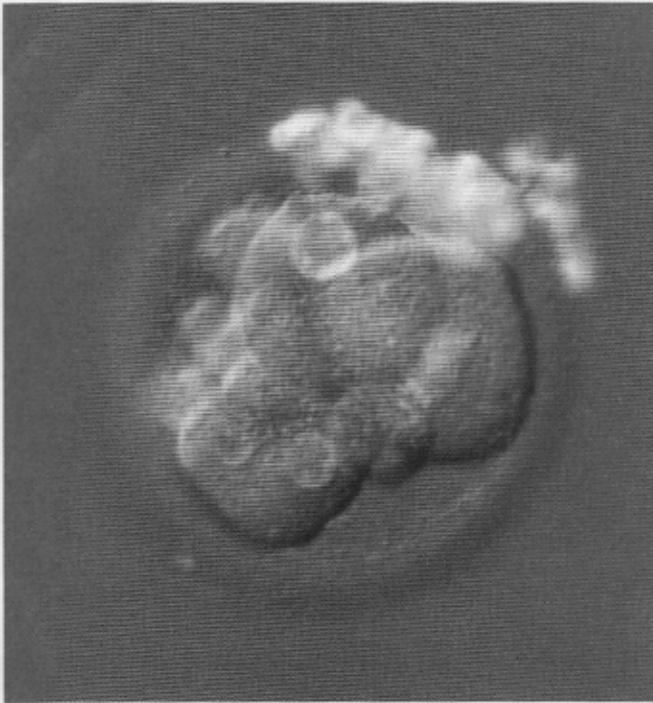
DNA Fingerprinting and Forensic Science 224

Murder, Paternity, and Ancient DNA 225

DNA Fingerprinting Techniques 226

Genomics 229

The Human Genome Project 230



- Tracking the Anthrax Killer* 231
Genome-Mapping Techniques 232

Human Gene Therapy 234

- Treating Severe Combined Immunodeficiency* 2234

Safety and Ethical Issues 235

- The Controversy Over Genetically Modified Foods* 235
Ethical Questions Raised by DNA Technology 236

Evolution Connection: Genomes Hold Clues to Evolution 237

Unit Three EVOLUTION AND DIVERSITY

13 How Populations Evolve 242

Biology and Society: Persistent Pests 243

Charles Darwin and *The Origin of Species* 244

- Darwin's Cultural and Scientific Context* 245
Descent with Modification 248

Evidence of Evolution 249

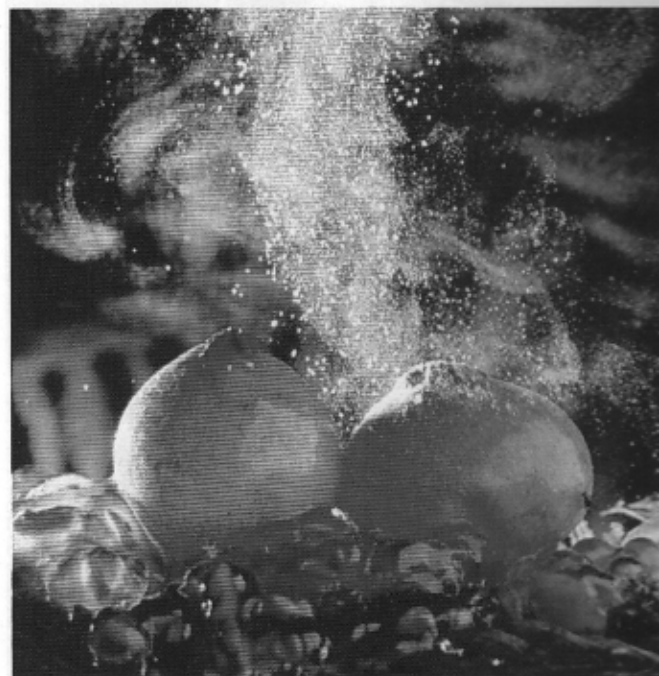
- The Fossil Record* 250
Biogeography 251
Comparative Anatomy 251
Comparative Embryology 252
Molecular Biology 253

Natural Selection and Adaptive Evolution 254

- Darwin's Theory of Natural Selection* 254
Natural Selection in Action 255

The Modern Synthesis: Darwinism Meets Genetics 256

- Populations as the Units of Evolution* 256
Genetic Variation in Populations 257



Analyzing Gene Pools 258

Population Genetics and Health Science 259

Microevolution as Change in a Gene Pool 260

Mechanisms of Microevolution 260

Genetic Drift 261

Gene Flow 263

Mutations 263

Natural Selection: A Closer Look 263

Evolution Connection: Population Genetics of the Sickle-Cell Allele 266

14 How Biological Diversity Evolves 270

Biology and Society: The Impact of Asteroids 271

Macroevolution and the Diversity of Life 271

The Origin of Species 272

What Is a Species? 272

Reproductive Barriers Between Species 274

Mechanisms of Speciation 275

What Is the Tempo of Speciation? 278

The Evolution of Biological Novelty 280

Adaptation of Old Structures for New Functions 280

"Evo-Devo": Development and Evolutionary Novelty 282

Earth History and Macroevolution 282

Geologic Time and the Fossil Record 282

Continental Drift and Macroevolution 285

Mass Extinctions and Explosive Diversifications of Life 288

Classifying the Diversity of Life 287

Some Basics of Taxonomy 287

Classification and Phylogeny 288

Arranging Life into Kingdoms: A Work in Progress 290

Evolution Connection: Just a Theory? 292



15 The Evolution of Microbial Life 296

Biology and Society: Bioterrorism 297

Major Episodes in the History of Life 297

The Origin of Life 300

Resolving the Biogenesis Paradox 300

A Four-Stage Hypothesis for the Origin of Life 300

From Chemical Evolution to Darwinian Evolution 302

Prokaryotes 303

They're Everywhere! 303

The Two Main Branches of Prokaryotic Evolution: Bacteria and Archaea 304

The Structure, Function, and Reproduction of Prokaryotes 304

The Nutritional Diversity of Prokaryotes 307

The Ecological Impact of Prokaryotes 307

Protists 311

The Origin of Eukaryotic Cells 311

The Diversity of Protists 312

Evolution Connection:

The Origin of Multicellular Life 317

16 Plants, Fungi, and the Move onto Land 320

Biology and Society: The Balancing Act of Forest Conservation 321

Colonizing Land 321

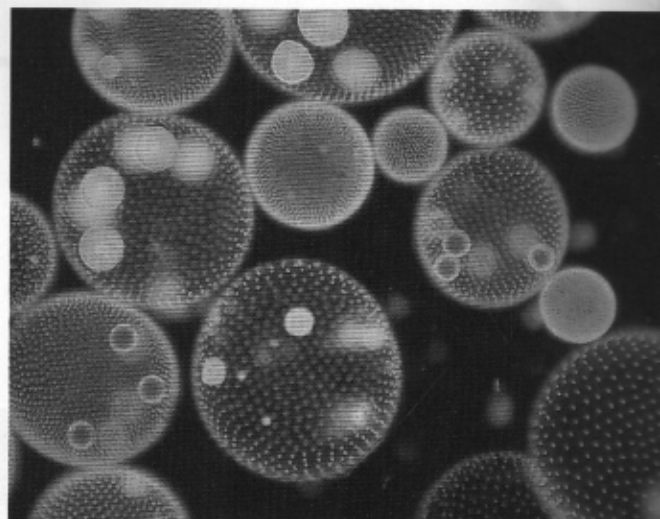
Terrestrial Adaptations of Plants 321

The Origin of Plants from Green Algae 323

Plant Diversity 324

Highlights of Plant Evolution 324

Bryophytes 325



Ferns 327

Gymnosperms 328

Angiosperms 330

Plant Diversity as a Nonrenewable Resource 332

Fungi 334

Characteristics of Fungi 336

The Ecological Impact of Fungi 337

Evolution Connection: Mutual Symbiosis 340

17 The Evolution of Animals 343

Biology and Society: Invasion of the Killer Toads 344

The Origins of Animal Diversity 344

What Is an Animal? 344

Early Animals and the Cambrian Explosion 346

Animal Phylogeny 347

Major Invertebrate Phyla 349

Sponges 350

Cnidarians 350

Flatworms 351

Roundworms 351

Mollusks 353

Annelids 354

Arthropods 356

Echinoderms 359

The Vertebrate Genealogy 360

Characteristics of Chordates 361

Fishes 363

Amphibians 364

Reptiles 365

Birds 366

Mammals 367



The Human Ancestry 368

The Evolution of Primates 368

The Emergence of Humankind 370

Evolution Connection: Earth's New Crisis 376

Unit Four ECOLOGY

18 The Ecology of Organisms and Populations 380

Biology and Society: The Human Population Explosion 381

An Overview of Ecology 381

Ecology as Scientific Study 382

A Hierarchy of Interactions 383

Ecology and Environmentalism 383

Abiotic Factors of the Biosphere 384

The Evolutionary Adaptations of Organisms 387

Physiological Responses 387

Anatomical Responses 388

Behavioral Responses 388

What Is Population Ecology? 388

Population Density 389

Patterns of Dispersion 390

Population Growth Models 390

Regulation of Population Growth 392

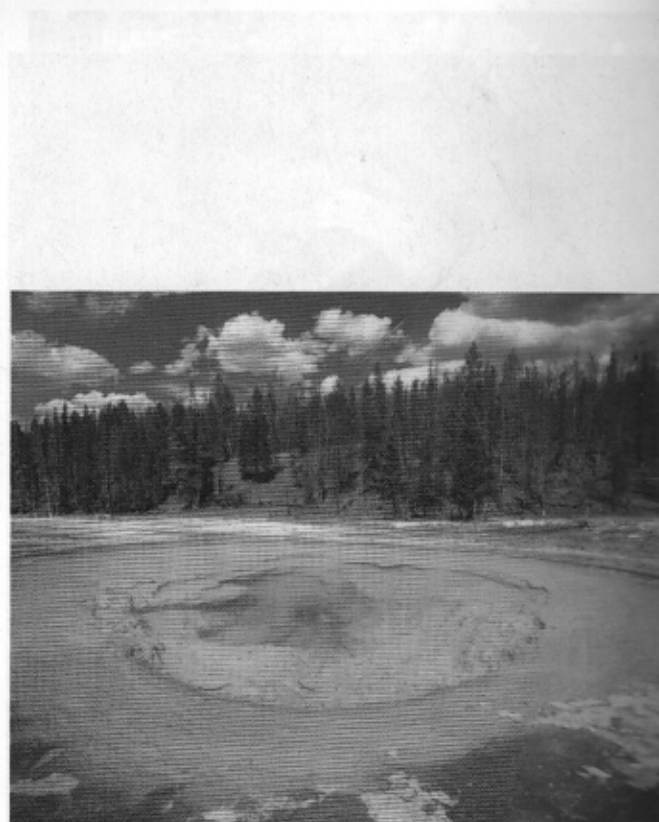
Human Population Growth 395

Life Histories and Their Evolution 398

Life Tables and Survivorship Curves 399

Life History Traits as Evolutionary Adaptations 400

Evolution Connection: Testing a Darwinian Hypothesis 401



19 Communities and Ecosystems 406

Biology and Society: Reefs: Coral and Artificial 407

Key Properties of Communities 407

Diversity 408

Prevalent Form of Vegetation 408

Stability 408

Trophic Structure 409

Interspecific Interactions in Communities 409

Competition Between Species 409

Predation 410

Symbiotic Relationships 414

The Complexity of Community Networks 415

Disturbance of Communities 415

Ecological Succession 416

A Dynamic View of Community Structure 417

An Overview of Ecosystem Dynamics 417

Trophic Levels and Food Chains 419

Food Webs 419

Energy Flow in Ecosystems 421

Productivity and the Energy Budgets of Ecosystems 421

Energy Pyramids 422

Ecosystem Energetics and Human Nutrition 423

Chemical Cycling in Ecosystems 424

The General Scheme of Chemical Cycling 424

Examples of Biogeochemical Cycles 425

Biomes 428

How Climate Affects Biome Distribution 428

Terrestrial Biomes 428

Freshwater Biomes 434

Marine Biomes 435

Evolution Connection: Coevolution in Biological Communities 438



20 Human Impact on the Environment 442

Biology and Society: Aquarium Menaces 443

Human Impact on Biological Communities 443

Human Disturbance of Communities 444

Introduced Species 444

Human Impact on Ecosystems 446

Impact on Chemical Cycles 446

Deforestation and Chemical Cycles: A Case Study 447

The Release of Toxic Chemicals to Ecosystems 448

Human Impact on the Atmosphere and Climate 449

The Biodiversity Crisis 452

The Three Levels of Biodiversity 452

The Loss of Species 452

The Three Main Causes of the Biodiversity Crisis 454

Why Biodiversity Matters 455

Conservation Biology 456

Biodiversity "Hot Spots" 456

Conservation at the Population and Species Levels 457

Conservation at the Ecosystem Level 459

The Goal of Sustainable Development 461

Evolution Connection: Biophilia and an Environmental Ethic 462

Appendix A Metric Conversion Table

Appendix B Answers to Self-Quiz Questions

Appendix C Credits

Glossary

Index

