

Contents

About the Author iii | Brief Contents v | Preface vi | Visual Tour viii | Acknowledgments xx

UNIT 1 Science, Chemistry, and Cells



1 The Scientific Study of Life 2

- 1.1 What Is Life? 4
 - A. Life Is Organized 4
 - B. Life Requires Energy 6
 - C. Life Maintains Internal Constancy 6
 - D. Life Reproduces Itself, Grows, and Develops 7
 - E. Life Evolves 7
- 1.2 The Tree of Life Includes Three Main Branches 9
- 1.3 Scientists Study the Natural World 10
 - A. The Scientific Method Has Multiple Interrelated Parts 10
 - B. An Experimental Design Is a Careful Plan 11
 - C. Theories Are Comprehensive Explanations 12
 - D. Scientific Inquiry Has Limitations 13
- 1.4 Investigating Life: The Orchid and the Moth 15

2 The Chemistry of Life 18

- 2.1 Atoms Make Up All Matter 20
 - A. Elements Are Fundamental Types of Matter 20
 - B. Atoms Are Particles of Elements 21
 - C. Isotopes Have Different Numbers of Neutrons 21
- 2.2 Chemical Bonds Link Atoms 23
 - A. Electrons Determine Bonding 23
 - B. In a Covalent Bond, Atoms Share Electrons 24

- C. In an Ionic Bond, One Atom Transfers Electrons to Another Atom 25
- D. Partial Charges on Polar Molecules Create Hydrogen Bonds 26

- 2.3 Water Is Essential to Life 27
 - A. Water Is Cohesive and Adhesive 27
 - B. Many Substances Dissolve in Water 27
 - C. Water Regulates Temperature 28
 - D. Water Expands as It Freezes 28
 - E. Water Participates in Life's Chemical Reactions 29
- 2.4 Organisms Balance Acids and Bases 29
 - A. The pH Scale Expresses Acidity or Alkalinity 30
 - B. Buffer Systems Regulate pH in Organisms 30
- 2.5 Organic Molecules Generate Life's Form and Function 31
 - A. Carbohydrates Include Simple Sugars and Polysaccharides 32
 - B. Lipids Are Hydrophobic and Energy-Rich 34
 - C. Proteins Are Complex and Highly Versatile 36
 - D. Nucleic Acids Store and Transmit Genetic Information 40
- 2.6 Investigating Life: E. T. and the Origin of Life 41

3 Cells 44

- 3.1 Cells Are the Units of Life 46
 - A. Simple Lenses Revealed the Cellular Basis of Life 46
 - B. The Cell Theory Emerges 46
 - C. Microscopes Magnify Cell Structures 47
 - D. All Cells Have Features in Common 48
- 3.2 Different Cell Types Characterize Life's Three Domains 50
 - A. Domain Bacteria Contains Earth's Most Abundant Organisms 50
 - B. Domain Archaea Includes Prokaryotes with Unique Biochemistry 50
 - C. Domain Eukarya Contains Organisms with Complex Cells 51

- 3.3 A Membrane Separates Each Cell from Its Surroundings 54**
- 3.4 Eukaryotic Organelles Divide Labor 56**
 - A. The Nucleus, Endoplasmic Reticulum, and Golgi Interact to Secrete Substances 56
 - B. Lysosomes, Vacuoles, and Peroxisomes Are Cellular Digestion Centers 58
 - C. Photosynthesis Occurs in Chloroplasts 60
 - D. Mitochondria Extract Energy from Nutrients 61
- 3.5 The Cytoskeleton Supports Eukaryotic Cells 62**
- 3.6 Cells Stick Together and Communicate with One Another 64**
 - A. Cell Walls Are Strong, Flexible, and Porous 64
 - B. Animal Cell Junctions Occur in Several Forms 65
- 3.7 Investigating Life: Did the Cytoskeleton Begin in Bacteria? 67**

4 The Energy of Life 70

- 4.1 All Cells Capture and Use Energy 72**
 - A. Energy Allows Cells to Do Life's Work 72
 - B. The Laws of Thermodynamics Describe Energy Transfer 72
- 4.2 Networks of Chemical Reactions Sustain Life 74**
 - A. Chemical Reactions Absorb or Release Energy 74
 - B. At Chemical Equilibrium, Reaction Rates Are in Balance 75
 - C. Linked Oxidation and Reduction Reactions Form Electron Transport Chains 75
- 4.3 ATP Is Cellular Energy Currency 76**
 - A. Coupled Reactions Release and Store Energy in ATP 76
 - B. Transfer of Phosphate Completes the Energy Transaction 76
 - C. ATP Represents Short-Term Energy Storage 77
- 4.4 Enzymes Speed Biochemical Reactions 78**
 - A. Enzymes Bring Reactants Together 78
 - B. Enzymes Have Partners 78
 - C. Cells Control Reaction Rates in Metabolic Pathways 78
 - D. Many Factors Affect Enzyme Activity 79
- 4.5 Membrane Transport May Release Energy or Cost Energy 80**
 - A. Passive Transport Does Not Require Energy Input 80
 - B. Active Transport Requires Energy Input 82
 - C. Endocytosis and Exocytosis Use Vesicles to Transport Substances 83
- 4.6 Investigating Life: Does Natural Selection Maintain Some Genetic Illnesses? 85**

5 Photosynthesis 88

- 5.1 Life Depends on Photosynthesis 90**
 - A. Photosynthesis Builds Carbohydrates Out of Carbon Dioxide and Water 90
 - B. The Evolution of Photosynthesis Changed Planet Earth 91
- 5.2 Sunlight Is the Energy Source for Photosynthesis 92**
 - A. What Is Light? 92
 - B. Photosynthetic Pigments Capture Light Energy 92
 - C. Chloroplasts Are the Sites of Photosynthesis 93
- 5.3 Photosynthesis Occurs in Two Stages 95**
- 5.4 The Light Reactions Begin Photosynthesis 96**
 - A. Photosystem II Produces ATP 96
 - B. Photosystem I Produces NADPH 97
- 5.5 The Carbon Reactions Produce Carbohydrates 98**
- 5.6 C₃ Plants Use Only the Calvin Cycle to Fix Carbon 99**
- 5.7 The C₄ and CAM Pathways Save Carbon and Water 99**
- 5.8 Investigating Life: Solar-Powered Sea Slugs 101**

6 How Cells Release Energy 105

- 6.1 Cells Use Energy in Food to Make ATP 106**
- 6.2 Cellular Respiration Includes Three Main Processes 107**
- 6.3 In Eukaryotic Cells, Mitochondria Produce Most ATP 108**
- 6.4 Glycolysis Breaks Down Glucose to Pyruvate 109**
- 6.5 Aerobic Respiration Yields Much More ATP than Glycolysis Alone 110**
 - A. Pyruvate Is Oxidized to Acetyl CoA 110
 - B. The Krebs Cycle Produces ATP and Electron Carriers 110
 - C. The Electron Transport Chain Drives ATP Formation 110
- 6.6 How Many ATPs Can One Glucose Molecule Yield? 112**
- 6.7 Other Food Molecules Enter the Energy-Extracting Pathways 113**
- 6.8 Some Energy Pathways Do Not Require Oxygen 114**
 - A. Anaerobic Respiration Uses an Electron Acceptor Other than O₂ 114
 - B. Fermenters Acquire ATP Only from Glycolysis 115
- 6.9 Photosynthesis and Respiration Are Ancient Pathways 116**
- 6.10 Investigating Life: Plants' "Alternative" Lifestyles Yield Hot Sex 117**

UNIT 2

Biotechnology, Genetics, and Inheritance



7 DNA Structure and Gene Function 120

- 7.1 Experiments Identified the Genetic Material 122**
 - A. Bacteria Can Transfer Genetic Information 122
 - B. Hershey and Chase Confirmed the Genetic Role of DNA 123
- 7.2 DNA Is a Double Helix of Nucleotides 124**
- 7.3 DNA Contains the “Recipes” for a Cell’s Proteins 126**
 - A. Protein Synthesis Requires Transcription and Translation 126
 - B. RNA Is an Intermediary Between DNA and a Polypeptide Chain 127
- 7.4 Transcription Uses a DNA Template to Create RNA 128**
 - A. Transcription Occurs in Three Steps 128
 - B. mRNA Is Altered in the Nucleus of Eukaryotic Cells 129
- 7.5 Translation Builds the Protein 130**
 - A. The Genetic Code Links mRNA to Protein 130
 - B. Translation Requires mRNA, tRNA, and Ribosomes 131
 - C. Translation Occurs in Three Steps 131
 - D. Proteins Must Fold Correctly After Translation 132
- 7.6 Cells Regulate Gene Expression 134**
 - A. Operons Are Groups of Bacterial Genes That Share One Promoter 134
 - B. Eukaryotic Organisms Use Transcription Factors 135
 - C. Eukaryotic Cells Also Use Additional Regulatory Mechanisms 136
- 7.7 Mutations Change DNA Sequences 138**
 - A. Mutations Range from Silent to Devastating 138
 - B. What Causes Mutations? 139
 - C. Mutations May Pass to Future Generations 140
 - D. Mutations Are Important 140
- 7.8 The Human Genome Is Surprisingly Complex 141**
- 7.9 Genetic Engineering Moves Genes Among Species 141**
 - A. Transgenic Organisms Contain DNA from Multiple Species 141
 - B. Creating Transgenic Organisms Requires Cutting and Pasting DNA 142
- 7.10 Researchers Can Fix, Block, or Monitor Genes 144**
 - A. Gene Therapy Repairs Faulty Genes 144
 - B. Antisense RNA and Gene Knockouts Block Gene Expression 144
 - C. DNA Microarrays Help Monitor Gene Expression 144
- 7.11 Investigating Life: Clues to the Origin of Language 145**

8 DNA Replication, Mitosis, and the Cell Cycle 150

- 8.1 Cells Divide and Cells Die 152**
 - A. Sexual Life Cycles Include Mitosis, Meiosis, and Fertilization 152
 - B. Cell Death Is Part of Life 152
- 8.2 DNA Replication Precedes Cell Division 154**
- 8.3 Replicated Chromosomes Condense as a Cell Prepares to Divide 156**
- 8.4 Mitotic Division Generates Exact Cell Copies 157**
 - A. Interphase Is a Time of Great Activity 158
 - B. Chromosomes Divide During Mitosis 159
 - C. The Cytoplasm Splits in Cytokinesis 160
- 8.5 Cancer Arises When Cells Divide out of Control 162**
 - A. Chemical Signals Regulate Cell Division 162
 - B. Cancer Cells Break Through Cell Cycle Controls 162
 - C. Cancer Cells Differ from Normal Cells in Many Ways 163
 - D. Inheritance and Environment Both Can Cause Cancer 164
 - E. Cancer Treatments Remove or Kill Abnormal Cells 165
- 8.6 Apoptosis Is Programmed Cell Death 167**
- 8.7 Stem Cells and Cloning Present Ethical Dilemmas 167**
 - A. Stem Cells Divide to Form Multiple Cell Types 167
 - B. Cloning Creates Identical Copies of an Organism 169
- 8.8 Several Technologies Use DNA Replication Enzymes 170**
 - A. DNA Sequencing Reveals the Order of Bases 170
 - B. PCR Replicates DNA in a Test Tube 171
 - C. DNA Profiling Has Many Applications 172
- 8.9 Investigating Life: Cutting Off a Tumor’s Supply Lines in the War on Cancer 174**

9 Sexual Reproduction and Meiosis 178

- 9.1 Why Sex? 180**
- 9.2 Diploid Cells Contain Two Homologous Sets of Chromosomes 181**
- 9.3 Meiosis Is Essential in Sexual Reproduction 182**
 - A. Gametes Are Haploid Sex Cells 182
 - B. Specialized Germ Cells Undergo Meiosis 182
 - C. Meiosis Halves the Chromosome Number and Scrambles Alleles 183
- 9.4 In Meiosis, DNA Replicates Once, but the Nucleus Divides Twice 184**
 - A. In Meiosis I, Homologous Chromosomes Pair Up and Separate 184
 - B. Meiosis II Yields Four Haploid Cells 185

- 9.5 **Meiosis Generates Enormous Variability 186**
 - A. Crossing Over Shuffles Genes 186
 - B. Chromosome Pairs Align Randomly During Metaphase I 186
 - C. Random Fertilization Multiplies the Diversity 187
- 9.6 **Mitosis and Meiosis Have Different Functions: A Summary 188**
- 9.7 **Errors Sometimes Occur in Meiosis 189**
 - A. Polyploidy Means Extra Chromosome Sets 189
 - B. Nondisjunction Results in Extra or Missing Chromosomes 189
 - C. Smaller-Scale Chromosome Abnormalities Also Occur 190
- 9.8 **Haploid Nuclei Are Packaged into Gametes 192**
 - A. In Humans, Gametes Form in Testes and Ovaries 192
 - B. In Plants, Gametophytes Produce Gametes 193
- 9.9 **Investigating Life: A New Species Is Born, but Who's the Daddy? 194**

10 | Patterns of Inheritance 198

- 10.1 **Chromosomes Are Packets of Genetic Information: A Review 200**
- 10.2 **Mendel's Experiments Uncovered Basic Laws of Inheritance 201**
 - A. Why Peas? 201
 - B. Dominant Alleles Appear to Mask Recessive Alleles 201
 - C. For Each Gene, a Cell's Two Alleles May Be Identical or Different 202
 - D. Every Generation Has a Name 202
- 10.3 **The Two Alleles of Each Gene End Up in Different Gametes 204**
 - A. Monohybrid Crosses Track the Inheritance of One Gene 204
 - B. Meiosis Explains Mendel's Law of Segregation 205
- 10.4 **Genes on Different Chromosomes Are Inherited Independently 206**
 - A. Dihybrid Crosses Track the Inheritance of Two Genes at Once 206
 - B. Meiosis Explains Mendel's Law of Independent Assortment 206
- 10.5 **Genes on the Same Chromosome May Be Inherited Together 208**
 - A. Genes on the Same Chromosome Are Linked 208
 - B. Studies of Linked Genes Have Yielded Chromosome Maps 210
- 10.6 **Gene Expression Can Appear to Alter Mendelian Ratios 211**
 - A. Incomplete Dominance and Codominance Add Phenotype Classes 211
 - B. Some Inheritance Patterns Are Especially Difficult to Interpret 212

- 10.7 **Sex-Linked Genes Have Unique Inheritance Patterns 213**
 - A. X and Y Chromosomes Determine Sex in Humans 213
 - B. X-Linked Recessive Disorders Affect More Males Than Females 214
 - C. X Inactivation Prevents "Double Dosing" of Proteins 215
- 10.8 **Pedigrees Show Modes of Inheritance 217**
- 10.9 **Most Traits Are Influenced by the Environment and Multiple Genes 219**
 - A. The Environment Can Alter the Phenotype 219
 - B. Polygenic Traits Depend on More Than One Gene 219
- 10.10 **Investigating Life: Heredity and the Hungry Hordes 221**

UNIT 3 | The Evolution of Life



11 | The Forces of Evolutionary Change 228

- 11.1 **Evolutionary Thought Has Evolved for Centuries 230**
 - A. Many Explanations Have Been Proposed for Life's Diversity 230
 - B. Charles Darwin's Voyage Provided a Wealth of Evidence 231
 - C. *On the Origin of Species* Proposed Natural Selection as an Evolutionary Mechanism 232
 - D. Evolutionary Theory Continues to Expand 235
- 11.2 **Natural Selection Molds Evolution 236**
 - A. Adaptations Enhance Reproductive Success 236
 - B. Natural Selection Eliminates Phenotypes 237
 - C. Natural Selection Does Not Have a Goal 237
 - D. What Does "Survival of the Fittest" Really Mean? 239
- 11.3 **Evolution Is Inevitable in Real Populations 240**
 - A. At Hardy-Weinberg Equilibrium, Allele Frequencies Do Not Change 240
 - B. In Reality, Allele Frequencies Always Change 240
- 11.4 **Natural Selection Can Shape a Population in Many Ways 242**
- 11.5 **Sexual Selection Directly Influences Reproductive Success 244**
- 11.6 **Evolution Occurs in Several Additional Ways 245**
 - A. Mutation Fuels Evolution 245
 - B. Genetic Drift Occurs by Chance 245
 - C. Nonrandom Mating Concentrates Alleles Locally 247
 - D. Gene Flow Moves Alleles Between Populations 247
- 11.7 **Investigating Life: Size Matters in Fishing Frenzy 249**

12 Evidence of Evolution 252

- 12.1 Clues to Evolution Lie in the Earth, Body Structures, and Molecules 254
- 12.2 Fossils Record Evolution 256
 - A. Fossils Form in Many Ways 256
 - B. The Fossil Record Is Often Incomplete 256
 - C. The Age of a Fossil Can Be Estimated in Two Ways 258
- 12.3 Biogeography Considers Species' Geographical Locations 260
 - A. The Theory of Plate Tectonics Explains Earth's Shifting Continents 260
 - B. Species Distributions Reveal Evolutionary Events 260
- 12.4 Anatomical Comparisons May Reveal Common Descent 262
 - A. Homologous Structures Have a Shared Evolutionary Origin 262
 - B. Vestigial Structures Have Lost Their Functions 262
 - C. Convergent Evolution Produces Superficial Similarities 263
- 12.5 Embryonic Development Patterns Provide Evolutionary Clues 264
- 12.6 Molecules Reveal Relatedness 266
 - A. Comparing DNA and Protein Sequences May Reveal Close Relationships 266
 - B. Molecular Clocks Help Assign Dates to Evolutionary Events 266
- 12.7 Investigating Life: Darwin's Finches Reveal Ongoing Evolution 268

13 Speciation and Extinction 272

- 13.1 The Definition of "Species" Has Evolved over Time 274
 - A. Linnaeus Devised the Binomial Naming System 274
 - B. Ernst Mayr Developed the Biological Species Concept 275
- 13.2 Reproductive Barriers Cause Species to Diverge 276
 - A. Prezygotic Barriers Prevent Fertilization 276
 - B. Postzygotic Barriers Prevent Viable or Fertile Offspring 276
- 13.3 Spatial Patterns Define Three Types of Speciation 278
 - A. Allopatric Speciation Reflects a Geographic Barrier 278
 - B. Parapatric Speciation Occurs in Neighboring Regions 279
 - C. Sympatric Speciation Occurs in a Shared Habitat 280
 - D. Determining the Type of Speciation May Be Difficult 281
- 13.4 Speciation May Be Gradual or Occur in Bursts 282
 - A. Gradualism and Punctuated Equilibrium Are Two Models of Speciation 282
 - B. Bursts of Speciation Occur During Adaptive Radiation 282

- 13.5 Extinction Marks the End of the Line 284
 - A. Many Factors Can Combine to Put a Species at Risk 284
 - B. Extinction Rates Have Varied over Time 284
- 13.6 Biological Classification Systems Are Based on Common Descent 286
 - A. The Taxonomic Hierarchy Organizes Species into Groups 286
 - B. A Cladistics Approach Is Based on Shared Derived Traits 287
 - C. Cladograms Depict Hypothesized Evolutionary Relationships 288
 - D. Many Traditional Groups Are Not Monophyletic 290
- 13.7 Investigating Life: Birds Do It, Bees Do It 292

14 The Origin and History of Life 296

- 14.1 Life's Origin Remains Mysterious 298
 - A. The First Organic Molecules May Have Formed in a Chemical "Soup" 299
 - B. Some Investigators Suggest an "RNA World" 300
 - C. Membranes Enclosed the Molecules 301
 - D. The Origin of Metabolism Would Have Involved Early Enzymes 302
 - E. Early Life Changed Earth Forever 302
- 14.2 Complex Cells and Multicellularity Arose over a Billion Years Ago 304
 - A. Endosymbiosis Explains the Origin of Mitochondria and Chloroplasts 304
 - B. Multicellularity May Also Have Its Origin in Cooperation 305
- 14.3 Life's Diversity Exploded in the Past 500 Million Years 306
 - A. The Strange Ediacarans Flourished Late in the Precambrian 306
 - B. Paleozoic Plants and Animals Emerged onto Land 306
 - C. Reptiles and Flowering Plants Thrived During the Mesozoic Era 309
 - D. Mammals Diversified During the Cenozoic Era 310
- 14.4 Fossils and DNA Tell the Human Evolution Story 312
 - A. Humans Are Primates 312
 - B. Molecular Evidence Documents Primate Relationships 313
 - C. Hominine Evolution Is Partially Recorded in Fossils 315
 - D. Environmental Changes Have Spurred Hominine Evolution 316
 - E. Migration and Culture Have Changed *Homo sapiens* 317
- 14.5 Investigating Life: What Makes Us Human? 318

UNIT 4 | The Diversity of Life



15 | Viruses 322

- 15.1 Viruses Are Infectious Particles of Genetic Information and Protein 324**
 - A. Viruses Are Smaller and Simpler Than Cells 324
 - B. A Virus's Host Range Consists of the Organisms It Infects 324
 - C. Are Viruses Alive? 325
- 15.2 Viral Replication Occurs in Five Stages 326**
- 15.3 Cell Death May Be Immediate or Delayed 327**
 - A. Some Viruses Kill Cells Immediately 327
 - B. Viral DNA Can “Hide” in a Cell 327
- 15.4 Effects of a Viral Infection May Be Mild or Severe 328**
 - A. Symptoms Result from Cell Death and the Immune Response 328
 - B. Some Animal Viruses Linger for Years 328
 - C. Drugs and Vaccines Help Fight Viral Infections 329
- 15.5 Viruses Cause Diseases in Plants 331**
- 15.6 Viroids and Prions Are Other Noncellular Infectious Agents 332**
 - A. A Viroid Is an Infectious RNA Molecule 332
 - B. A Prion Is an Infectious Protein 332
- 15.7 Investigating Life: Scientific Detectives Follow HIV's Trail 333**

16 | Bacteria and Archaea 336

- 16.1 Prokaryotes Are a Biological Success Story 338**
- 16.2 Prokaryote Classification Traditionally Relies on Visible Features 339**
 - A. Microscopes Reveal Cell Structures 339
 - B. Metabolic Pathways May Be Useful in Classification 341
 - C. Molecular Data Reveal Evolutionary Relationships 342
- 16.3 Prokaryotes Transmit DNA Vertically and Horizontally 343**
- 16.4 Prokaryotes Include Two Domains with Enormous Diversity 344**
 - A. Domain Bacteria Includes Many Familiar Groups 344
 - B. Many, But Not All, Archaea Are “Extremophiles” 345
- 16.5 Bacteria and Archaea Are Important to Human Life 346**
 - A. Microbes Form Vital Links in Ecosystems 346
 - B. Bacteria and Archaea Live in and on Us 347
 - C. Humans Put Many Prokaryotes to Work 348

- 16.6 Investigating Life: A Bacterial Genome Solves Two Mysteries 348**

17 | Protists 352

- 17.1 Protists Lie at the Crossroads Between Simple and Complex Organisms 354**
 - A. What Is a Protist? 354
 - B. Protists Are Important in Many Ways 354
 - C. Protists Have a Lengthy Evolutionary History 354
- 17.2 Many Protists Are Photosynthetic 356**
 - A. Euglenoids Are Heterotrophs and Autotrophs 356
 - B. Dinoflagellates Are “Whirling Cells” 356
 - C. Golden Algae, Diatoms, and Brown Algae Contain Yellowish Pigments 357
 - D. Red Algae Can Live in Deep Water 358
 - E. Green Algae Are the Closest Relatives of Plants 358
- 17.3 Some Heterotrophic Protists Were Once Classified as Fungi 360**
 - A. Slime Molds Are Unicellular and Multicellular 360
 - B. Water Molds Are Decomposers and Parasites 360
- 17.4 Protozoa Are Diverse Heterotrophic Protists 362**
 - A. Several Flagellated Protozoa Cause Disease 362
 - B. Amoeboid Protozoa Produce Pseudopodia 362
 - C. Ciliates Are Common Protozoa with Complex Cells 363
 - D. Apicomplexans Include Nonmotile Animal Parasites 364
- 17.5 Protist Classification Is Changing Rapidly 366**
- 17.6 Investigating Life: Glassy Fossils Reveal the Birth of a Species 367**

18 | Plants 370

- 18.1 Plants Have Changed the World 372**
 - A. Green Algae Are the Closest Relatives of Plants 372
 - B. Plants Are Adapted to Life on Land 374
- 18.2 Bryophytes Are the Simplest Plants 376**
 - A. Bryophytes Are Small and Lack Vascular Tissue 376
 - B. Bryophytes Have a Conspicuous Gametophyte 377
- 18.3 Seedless Vascular Plants Have Xylem and Phloem but No Seeds 378**
 - A. Seedless Vascular Plants Include Ferns and Their Close Relatives 378
 - B. Seedless Vascular Plants Have a Conspicuous Sporophyte 379
- 18.4 Gymnosperms Are “Naked Seed” Plants 380**
 - A. Gymnosperms Include Conifers and Three Related Groups 380
 - B. Conifers Produce Pollen and Seeds in Cones 381

- 18.5 Angiosperms Produce Seeds in Fruits 382**
 A. Most Angiosperms Are Eudicots or Monocots 382
 B. Flowers and Fruits Are Unique to the Angiosperm Life Cycle 383
 C. Animals Often Participate in Angiosperm Reproduction 384
- 18.6 Investigating Life: Genetic Messages from the Dead Tell Tales of Ancient Ecosystems 386**

19 Fungi 390

- 19.1 Fungi Are Essential Decomposers 392**
 A. Fungi Are Eukaryotic Heterotrophs That Digest Food Externally 392
 B. Fungal Classification Is Traditionally Based on Reproductive Structures 394
- 19.2 Chytridiomycetes Produce Swimming Spores 395**
- 19.3 Zygomycetes Are Fast Growing and Prolific 396**
- 19.4 Glomeromycetes Colonize Living Plant Roots 397**
- 19.5 Ascomycetes Are the Sac Fungi 398**
- 19.6 Basidiomycetes Are the Familiar Club Fungi 400**
- 19.7 Fungi Interact with Other Organisms 402**
 A. Endophytes Live in Aerial Plant Parts 402
 B. Mycorrhizal Fungi Live on or in Roots 402
 C. Some Ants Cultivate Fungi 402
 D. Lichens Are Distinctive Dual Organisms 403
- 19.8 Investigating Life: The Battle for Position in Cacao Tree Leaves 404**

20 Animals 408

- 20.1 Animals Live Nearly Everywhere 410**
 A. The First Animals Likely Evolved from Protists 410
 B. Animals Share Several Characteristics 410
 C. Biologists Classify Animals Based on Organization, Morphology, and Development 411
 D. Biologists Also Consider Additional Characteristics 413
- 20.2 Sponges Are Simple Animals That Lack Differentiated Tissues 415**
- 20.3 Cnidarians Are Radially Symmetrical, Aquatic Animals 416**
- 20.4 Flatworms Have Bilateral Symmetry and Incomplete Digestive Tracts 418**
- 20.5 Mollusks Are Soft, Unsegmented Bodies 420**
- 20.6 Annelids Are Segmented Worms 422**
- 20.7 Nematodes Are Unsegmented, Cylindrical Worms 424**
- 20.8 Arthropods Have Exoskeletons and Jointed Appendages 426**

- A. Arthropods Have Complex Organ Systems 426
 B. Arthropods Are the Most Diverse Animals 427
- 20.9 Echinoderms Have Five-Part, Radial Symmetry 430**
- 20.10 Most Chordates Are Vertebrates 432**
 A. Four Features Distinguish Chordates 432
 B. Biologists Use Many Features to Classify Chordates 433
- 20.11 Tunicates and Lancelets Have Neither Cranium nor Backbone 436**
- 20.12 Hagfishes Have a Cranium but Lack a Backbone 437**
- 20.13 Fishes Are Aquatic Vertebrates with Gills and Fins 438**
 A. Fishes Changed the Course of Vertebrate Evolution 438
 B. Fishes May or May Not Have Jaws 438
- 20.14 Amphibians Lead a Double Life on Land and in Water 440**
 A. Amphibians Were the First Tetrapods 440
 B. Amphibians Include Three Main Lineages 440
- 20.15 Reptiles Were the First Vertebrates to Thrive on Dry Land 442**
 A. Nonavian Reptiles Include Four Main Groups 443
 B. Birds Are Warm, Feathered Reptiles 443
- 20.16 Mammals Are Warm, Furry Milk-Drinkers 445**
 A. Mammals Share a Common Ancestor with Reptiles 445
 B. Mammals Lay Eggs or Bear Live Young 446
- 20.17 Investigating Life: Limbs Gained and Limbs Lost 447**

UNIT 5 Plant Life



21 Plant Form and Function 454

- 21.1 Vegetative Plant Parts Include Stems, Leaves, and Roots 456**
- 21.2 Plants Have Flexible Growth Patterns, Thanks to Meristems 458**
 A. Plants Grow by Adding New Modules 458
 B. Plant Growth Occurs at Meristems 458
- 21.3 Plant Cells Build Tissues 459**
 A. Plants Have Several Cell Types 459
 B. Plant Cells Form Three Main Tissue Systems 461
- 21.4 Tissues Build Stems, Leaves, and Roots 463**
 A. Stems Support Leaves 463
 B. Leaves Are the Primary Organs of Photosynthesis 464
 C. Roots Absorb Water and Minerals, and Anchor the Plant 464
- 21.5 Lateral Meristems Produce Wood and Bark 468**
 A. The Vascular Cambium Produces Xylem and Phloem in Woody Plants 468

- B. The Cork Cambium Produces the Outer Layer of a Woody Stem or Root 468
 - C. Wood Is Durable and Useful 469
- 21.6 Investigating Life: An Army of Tiny Watchdogs 470**

22 | Plant Nutrition and Transport 474

- 22.1 Soil and Air Provide Water and Nutrients 476**
- A. Plants Require 16 Essential Elements 476
 - B. Soils Have Distinct Layers 476
 - C. Leaves and Roots Absorb Essential Elements 477
- 22.2 Water and Dissolved Minerals Are Pulled Up to Leaves 479**
- A. Water Vapor Is Lost from Leaves Through Transpiration 479
 - B. Xylem Transport Relies on Cohesion 480
 - C. The Cuticle and Stomata Help Conserve Water 481
- 22.3 Organic Compounds Are Pushed to Nonphotosynthetic Cells 482**
- A. Phloem Sap Contains Sugars and Other Organic Compounds 482
 - B. The Pressure Flow Theory Explains Phloem Function 482
- 22.4 Parasitic Plants Tap into Another Plant's Vascular Tissue 484**
- 22.5 Investigating Life: The Hidden Cost of Traps 484**

23 | Reproduction and Development of Flowering Plants 488

- 23.1 Angiosperms Reproduce Asexually and Sexually 490**
- A. Asexual Reproduction Yields Clones 490
 - B. Sexual Reproduction Generates Variability 490
- 23.2 The Angiosperm Life Cycle Includes Flowers, Fruits, and Seeds 492**
- A. Flowers Are Reproductive Organs 492
 - B. The Pollen Grain and Embryo Sac Are Gametophytes 493
 - C. Pollination Brings Pollen to the Stigma 493
 - D. Double Fertilization Yields Zygote and Endosperm 494
 - E. A Seed Is an Embryo and Its Food Supply Inside a Seed Coat 495
 - F. The Fruit Develops from the Ovary 496
 - G. Fruits Protect and Disperse Seeds 497
- 23.3 Plant Growth Begins with Seed Germination 498**
- 23.4 Hormones Regulate Plant Growth and Development 499**
- A. Auxins and Cytokinins Are Essential for Plant Growth 500
 - B. Gibberellins, Ethylene, and Abscisic Acid Influence Plant Development in Many Ways 500
 - C. Biologists Continue to Discover Additional Plant Hormones 501
- 23.5 Light Is a Powerful Influence on Plant Life 502**
- A. Phototropism Is Growth Toward Light 502
 - B. Phytochrome Regulates Seed Germination, Daily Rhythms, and Flowering 503

- 23.6 Plants Respond to Gravity and Touch 505**
- 23.7 Plant Parts Die or Become Dormant 506**
- 23.8 Investigating Life: A Red Hot Chili Pepper Paradox 507**

UNIT 6 | Animal Life



24 | Animal Tissues and Organ Systems 510

- 24.1 Specialized Cells Build Animal Bodies 512**
- 24.2 Animals Consist of Four Tissue Types 514**
- A. Epithelial Tissue Covers Surfaces 514
 - B. Most Connective Tissues Bind Other Tissues Together 515
 - C. Muscle Tissue Provides Movement 516
 - D. Nervous Tissue Forms a Rapid Communication Network 517
- 24.3 Organ Systems Are Interconnected 518**
- A. The Nervous and Endocrine Systems Coordinate Communication 518
 - B. The Skeletal and Muscular Systems Support and Move the Body 518
 - C. The Digestive, Circulatory, and Respiratory Systems Work Together to Acquire Energy 518
 - D. The Urinary, Integumentary, Immune, and Lymphatic Systems Protect the Body 519
 - E. The Reproductive System Produces the Next Generation 519
- 24.4 Organ System Interactions Promote Homeostasis 520**
- 24.5 The Integumentary System Regulates Temperature and Conserves Moisture 521**
- 24.6 Investigating Life: Vitamins and the Evolution of Human Skin Pigmentation 523**

25 | The Nervous System 526

- 25.1 The Nervous System Forms a Rapid Communication Network 528**
- A. Invertebrates Have Nerve Nets, Nerve Ladders, or Nerve Cords 528
 - B. Vertebrate Nervous Systems Are Highly Centralized 529
- 25.2 Neurons Are Functional Units of a Nervous System 530**
- A. A Typical Neuron Consists of a Cell Body, Dendrites, and an Axon 530
 - B. The Nervous System Includes Three Classes of Neurons 530

- 25.3 Action Potentials Convey Messages 532**
 - A. A Neuron at Rest Has a Negative Charge 532
 - B. A Neuron Transmitting an Impulse Undergoes a Wave of Depolarization 532
 - C. The Myelin Sheath Speeds Impulse Conduction 534
- 25.4 Neurotransmitters Pass the Message from Cell to Cell 536**
 - A. Neurons Communicate at Synapses 536
 - B. The Postsynaptic Cell Integrates Signals from Multiple Synapses 537
- 25.5 The Peripheral Nervous System Consists of Nerve Cells Outside the Central Nervous System 538**
- 25.6 The Central Nervous System Consists of the Spinal Cord and Brain 540**
 - A. The Spinal Cord Transmits Information Between Body and Brain 540
 - B. The Human Brain Is Divided into Several Regions 541
 - C. Many Brain Regions Participate in Memory Formation 543
 - D. Damage to the Central Nervous System Can Be Devastating 544
- 25.7 Investigating Life: The Nerve of Those Clams! 546**

26 | The Senses 550

- 26.1 Diverse Senses Operate by the Same Principles 552**
 - A. Sensory Receptors Respond to Stimuli by Generating Action Potentials 552
 - B. Continuous Stimulation May Cause Sensory Adaptation 553
- 26.2 The General Senses Detect Touch, Temperature, Pain, and Position 554**
- 26.3 The Senses of Smell and Taste Detect Chemicals 555**
 - A. Chemoreceptors in the Nose Detect Odor Molecules 555
 - B. Chemoreceptors in the Mouth Detect Taste 556
- 26.4 Vision Depends on Light-Sensitive Cells 557**
 - A. Invertebrate Eyes Take Many Forms 557
 - B. In the Vertebrate Eye, Light Is Focused on the Retina 557
 - C. Signals Travel from the Retina to the Optic Nerve and Brain 558
- 26.5 The Senses of Hearing and Equilibrium Begin in the Ears 560**
 - A. Mechanoreceptors in the Inner Ear Detect Sound Waves 560
 - B. The Inner Ear Also Provides the Sense of Equilibrium 561
- 26.6 Investigating Life: Unraveling the Mystery of the Origin of the Eye 562**

27 | The Endocrine System 566

- 27.1 The Endocrine System Uses Hormones to Communicate 568**
 - A. Endocrine Glands Secrete Hormones That Interact with Target Cells 568
 - B. The Nervous and Endocrine Systems Work Together 569

- 27.2 Hormones Stimulate Responses in Target Cells 570**
 - A. Water-Soluble Hormones Trigger Second Messenger Systems 570
 - B. Lipid-Soluble Hormones Directly Alter Gene Expression 571
- 27.3 The Hypothalamus and Pituitary Gland Oversee Endocrine Control 573**
 - A. The Posterior Pituitary Stores and Releases Two Hormones 573
 - B. The Anterior Pituitary Produces and Secretes Six Hormones 573
- 27.4 Hormones from Many Glands Regulate Metabolism 574**
 - A. The Thyroid Gland Sets the Metabolic Pace 574
 - B. The Parathyroid Glands Control Calcium Level 575
 - C. The Adrenal Glands Coordinate the Body's Stress Responses 575
 - D. The Pancreas Regulates Nutrient Use 576
 - E. The Pineal Gland Secretes Melatonin 577
- 27.5 Hormones from the Ovaries and Testes Control Reproduction 578**
- 27.6 Investigating Life: Something's Fishy in Evolution—The Origin of the Parathyroid Gland 578**

28 | The Skeletal and Muscular Systems 582

- 28.1 Skeletons Take Many Forms 584**
- 28.2 The Vertebrate Skeleton Features a Central Backbone 585**
- 28.3 Bones Provide Support, Protect Internal Organs, and Supply Calcium 586**
 - A. Bones Consist Mostly of Bone Tissue and Cartilage 586
 - B. Bones Are Constantly Built and Degraded 588
 - C. Bones Help Regulate Calcium Homeostasis 588
 - D. Bone Meets Bone at a Joint 588
- 28.4 Muscle Movement Requires Contractile Proteins, Calcium, and ATP 590**
 - A. Actin and Myosin Filaments Fill Muscle Cells 590
 - B. Sliding Filaments Are the Basis of Muscle Fiber Contraction 591
 - C. Motor Neurons Stimulate Muscle Fiber Contraction 592
- 28.5 Muscle Fibers Generate ATP in Many Ways 594**
- 28.6 Many Muscle Fibers Combine to Form One Muscle 595**
 - A. Each Muscle May Contract with Variable Force 595
 - C. Muscles Contain Slow-Twitch and Fast-Twitch Fibers 595
 - D. Exercise Strengthens Muscles 596
- 28.7 Investigating Life: Did a Myosin Gene Mutation Make Humans Brainier? 596**

29 | The Circulatory System 600

- 29.1 Circulatory Systems Deliver Nutrients and Remove Wastes 602**
 - A. Circulatory Systems Are Open or Closed 602
 - B. Vertebrate Circulatory Systems Have Become Increasingly Complex 603
- 29.2 Blood Is a Complex Mixture 604**
 - A. Plasma Carries Many Dissolved Substances 604
 - B. Red Blood Cells Transport Oxygen 605
 - C. White Blood Cells Fight Infection 605
 - D. Blood Clotting Requires Platelets and Plasma Proteins 606
- 29.3 Blood Circulates Through the Heart and Blood Vessels 607**
- 29.4 The Human Heart Is a Muscular Pump 608**
 - A. The Heart Has Four Chambers 608
 - B. The Right and Left Halves of the Heart Deliver Blood Along Different Paths 608
 - C. Cardiac Muscle Cells Produce the Heartbeat 609
 - D. Exercise Strengthens the Heart 609
- 29.5 Blood Vessels Form the Circulation Pathway 611**
 - A. Arteries, Capillaries, and Veins Have Different Structures 611
 - B. Blood Pressure and Velocity Differ Among Vessel Types 612
- 29.6 The Lymphatic System Maintains Circulation and Protects Against Infection 615**
- 29.7 Investigating Life: In (Extremely) Cold Blood 616**

30 | The Respiratory System 620

- 30.1 Gases Diffuse Across Respiratory Surfaces 622**
 - A. Some Invertebrates Exchange Gases Across the Body Wall or in Internal Tubules 623
 - B. Gills Exchange Gases with Water 623
 - C. Terrestrial Vertebrates Exchange Gases in Lungs 624
- 30.2 The Human Respiratory System Delivers Air to the Lungs 626**
 - A. The Nose, Pharynx, and Larynx Form the Upper Respiratory Tract 626
 - B. The Lower Respiratory Tract Consists of the Trachea and Lungs 627
- 30.3 Breathing Requires Pressure Changes in the Lungs 628**
- 30.4 Blood Delivers Oxygen and Removes Carbon Dioxide 630**
 - A. Blood Carries Gases in Several Forms 630
 - B. Blood Gas Levels Help Regulate the Breathing Rate 630
- 30.5 Investigating Life: Why Do Bugs Hold Their Breath? 632**

31 | Digestion and Nutrition 636

- 31.1 Digestive Systems Derive Nutrients from Food 638**
 - A. Animals Eat to Obtain Energy and Building Blocks 638
 - B. How Much Food Does an Animal Need? 638
 - C. Animals Process Food in Four Stages 638
 - D. Animal Diets and Feeding Strategies Vary Greatly 639
- 31.2 Animal Digestive Tracts Take Many Forms 640**
- 31.3 The Human Digestive System Consists of Several Organs 642**
 - A. Digestion Begins in the Mouth and Esophagus 642
 - B. The Stomach Stores, Digests, and Pushes Food 643
 - C. The Small Intestine Digests and Absorbs Nutrients 644
 - D. The Large Intestine Completes Nutrient and Water Absorption 646
- 31.4 A Healthy Diet Includes Essential Nutrients and the Right Number of Calories 648**
 - A. A Varied Diet Is Essential to Good Health 648
 - B. Body Weight Reflects Food Intake and Activity Level 650
 - C. Starvation: Too Few Calories to Meet the Body's Needs 651
 - D. Obesity: More Calories Than the Body Needs 651
- 31.5 Investigating Life: The Ultimate Sacrifice 652**

32 | Regulation of Temperature and Body Fluids 656

- 32.1 Animals Regulate Their Internal Temperature 658**
 - A. Heat Gains and Losses Determine an Animal's Body Temperature 658
 - B. Several Adaptations Help an Animal to Adjust Its Temperature 659
- 32.2 Animals Regulate Water and Ions in Body Fluids 661**
- 32.3 Nitrogenous Wastes Include Ammonia, Urea, and Uric Acid 662**
- 32.4 The Urinary System Produces, Stores, and Eliminates Urine 663**
- 32.5 The Nephron Is the Functional Unit of the Kidney 664**
 - A. Nephrons Interact Closely with Blood Vessels 664
 - B. Urine Formation Includes Filtration, Reabsorption, and Secretion 664
 - C. The Glomerular Capsule Filters Blood 665
 - D. Reabsorption and Secretion Occur in the Renal Tubule 665
 - E. The Collecting Duct Conserves More Water 666
 - F. Hormones Regulate Kidney Function 666
- 32.6 Investigating Life: Sniffing Out the Origin of Fur and Feathers 668**

33 | The Immune System 672

- 33.1 Many Cells, Tissues, and Organs Defend the Body 674**
- A. White Blood Cells and Macrophages Play Major Roles in the Immune System 674
 - B. The Lymphatic System Consists of Several Tissues and Organs 675
 - C. The Immune System Has Two Main Subdivisions 675
- 33.2 Innate Defenses Are Nonspecific and Act Early 676**
- A. Barriers Form the First Line of Defense 676
 - B. White Blood Cells and Macrophages Destroy Invaders 676
 - C. Redness and Swelling Indicate Inflammation 676
 - D. Complement Proteins and Cytokines Are Chemical Defenses 677
 - E. Fever Helps Fight Infection 677
- 33.3 Adaptive Immunity Defends Against Specific Pathogens 678**
- A. Macrophages Trigger Both Cell-Mediated and Humoral Immunity 678
 - B. T Cells Coordinate Cell-Mediated Immunity 679
 - C. B Cells Direct the Humoral Immune Response 680
 - D. The Immune Response Turns Off Once the Threat Is Gone 682
 - E. The Secondary Immune Response Is Stronger Than the Primary Response 683
- 33.4 Vaccines Jump-Start Immunity 684**
- 33.5 Several Disorders Affect the Immune System 685**
- A. Autoimmune Disorders Are Devastating and Mysterious 685
 - B. Immunodeficiencies Lead to Opportunistic Infections 685
 - C. Allergies Misdirect the Immune Response 686
 - D. A Pregnant Woman's Immune System May Attack Her Fetus 687
- 33.6 Investigating Life: The Hidden Cost of Hygiene 688**

34 | Animal Reproduction and Development 692

- 34.1 Animal Development Begins with Reproduction 694**
- A. Reproduction Is Asexual or Sexual 694
 - B. Gene Expression Dictates Animal Development 694
 - C. Development Is Indirect or Direct 695
- 34.2 Males Produce Sperm Cells 696**
- A. Male Reproductive Organs Are Inside and Outside the Body 696
 - B. Spermatogenesis Yields Sperm Cells 697
 - C. Hormones Influence Male Reproductive Function 698
- 34.3 Females Produce Egg Cells 699**
- A. Female Reproductive Organs Are Inside the Body 699
 - B. Oogenesis Yields Egg Cells 700
 - C. Hormones Influence Female Reproductive Function 702

- D. Hormonal Fluctuations Can Cause Discomfort 703
- E. Contraceptives Prevent Pregnancy 703

34.4 Sexual Activity May Transmit Disease 705

34.5 The Human Infant Begins Life as a Zygote 706

- A. Fertilization Joins Genetic Packages and Initiates Pregnancy 706
- B. Preembryonic Events Include Cleavage, Implantation, and Gastrulation 706
- C. Organs Take Shape During the Embryonic Stage 708
- D. Organ Systems Become Functional in the Fetal Stage 711
- E. Muscle Contractions in the Uterus Drive Labor and Childbirth 713

34.6 Birth Defects Have Many Causes 714

34.7 Investigating Life: The “Cross-Dressers” of the Reef 715

UNIT 7 | Behavior and Ecology



35 | Animal Behavior 720

- 35.1 Animal Behaviors Have Proximate and Ultimate Causes 722**
- 35.2 Animal Behaviors Combine Innate and Learned Components 723**
- A. Innate Behaviors Do Not Require Experience 723
 - B. Learning Requires Experience 723
 - C. Genes and Environment Interact to Determine Behavior 725
- 35.3 Many Behaviors Improve Survival 726**
- A. Some Animals Can Find Specific Locations 726
 - B. Animals Balance the Energy Content and Costs of Acquiring Food 726
 - C. Avoiding Predation Is Another Key to Survival 728
- 35.4 Many Behaviors Promote Reproductive Success 730**
- A. Courtship Sets the Stage for Mating 730
 - B. Sexual Selection Leads to Differences Between the Sexes 730
 - C. Animals Differ in Mating Systems and Degrees of Parental Care 731
 - D. Human Reproductive Choices May Reflect Natural Selection 732
- 35.5 Social Behaviors Often Occur in Groups 733**
- A. Group Living Has Costs and Benefits 733
 - B. Dominance Hierarchies and Territoriality Reduce Competition 733
 - C. Kin Selection and Reciprocal Altruism Explain Some Acts of Cooperation 734
 - D. Eusocial Animals Have Highly Developed Societies 735
- 35.6 Investigating Life: Addicted to Affection 736**

36 | Population Ecology 740

- 36.1 A Population Consists of Individuals of One Species 742**
 - A. Density and Distribution Patterns Are Static Measures of a Population 742
 - B. Isolated Subpopulations May Evolve into New Species 742
- 36.2 Births and Deaths Help Determine Population Size 744**
 - A. Births Add Individuals to a Population 744
 - B. Survivorship Curves Show the Probability of Dying at a Given Age 745
- 36.3 Population Growth May Be Exponential or Logistic 746**
 - A. Growth Is Exponential When Resources Are Unlimited 746
 - B. Population Growth Eventually Slows 747
 - C. Many Conditions Limit Population Size 748
- 36.4 Natural Selection Influences Life Histories 750**
 - A. Organisms Balance Reproduction Against Other Requirements 750
 - B. *r*- and *K*-Selected Species Differ in the Trade-Off Between Quantity and Quality 750
 - C. Guppies Illustrate the Importance of Natural Selection 751
- 36.5 The Human Population Continues to Grow 752**
 - A. Population Dynamics Reflect the Demographic Transition 752
 - B. The Ecological Footprint Is an Estimate of Resource Use 754
- 36.6 Investigating Life: Let Your Love Light Shine 756**

37 | Communities and Ecosystems 760

- 37.1 Multiple Species Interact in Communities 762**
 - A. Populations Interact in Many Ways 762
 - B. A Keystone Species Has a Pivotal Role in the Community 765
 - C. Closely Interacting Species May Coevolve 765
- 37.2 Communities Change over Time 766**
- 37.3 Ecosystems Require Continuous Energy Input 767**
 - A. Food Webs Depict the Transfer of Energy and Atoms 768
 - B. Every Trophic Level Loses Energy 769
 - C. Harmful Chemicals May Accumulate in the Highest Trophic Levels 770
- 37.4 Chemicals Cycle Within Ecosystems 772**
 - A. Water Circulates Between the Land and the Atmosphere 772
 - B. Autotrophs Obtain Carbon as CO₂ 774
 - C. The Nitrogen Cycle Relies on Bacteria 775
 - D. The Phosphorus Cycle Begins with the Weathering of Rocks 776
 - E. Terrestrial and Aquatic Ecosystems Are Linked in Surprising Ways 777
- 37.5 Investigating Life: Two Kingdoms and a Virus Team Up to Beat the Heat 777**

38 | Biomes 782

- 38.1 The Physical Environment Determines Where Life Exists 784**
- 38.2 Earth Has Diverse Climates 786**
- 38.3 Terrestrial Biomes Range from the Lush Tropics to the Frozen Tundra 788**
 - A. Towering Trees Dominate the Forests 789
 - B. Grasslands Occur in Tropical and Temperate Regions 790
 - C. Whether Hot or Cold, All Deserts Are Dry 791
 - D. Fire- and Drought-Adapted Plants Dominate Mediterranean Shrublands (Chaparral) 792
 - E. Tundras Occupy High Latitudes and High Elevations 793
 - F. The Polar Ice Caps House Cold-Adapted Species 793
- 38.4 Freshwater Biomes Include Lakes, Ponds, and Streams 794**
 - A. Lakes and Ponds Contain Standing Water 794
 - B. Streams Carry Running Water 795
- 38.5 Oceans Make Up Earth's Largest Ecosystem 796**
 - A. Land Meets Sea at the Coast 796
 - B. The Open Ocean Remains Mysterious 797
- 38.6 Investigating Life: Some Like It Hot 798**

39 | Preserving Biodiversity 802

- 39.1 Earth's Biodiversity Is Dwindling 804**
- 39.2 Human Activities Destroy Habitats 805**
- 39.3 Pollution Degrades Habitats 807**
 - A. Water Pollution Threatens Aquatic Life 807
 - B. Air Pollution Causes Many Types of Damage 808
 - C. Global Climate Change Alters and Shifts Habitats 809
- 39.4 Exotic Invaders and Overexploitation Devastate Many Species 812**
 - A. Invasive Species Displace Native Organisms 812
 - B. Overexploitation Can Drive Species to Extinction 813
- 39.5 Some Biodiversity May Be Recoverable 814**
- 39.6 Investigating Life: The Case of the Missing Frogs: Is Climate the Culprit? 816**

- Appendix A** Answers to Multiple Choice Questions A-1
- Appendix B** A Brief Guide to Statistical Significance A-2
- Appendix C** Metric Units and Conversions A-5
- Appendix D** Periodic Table of Elements A-6
- Appendix E** Amino Acid Structures A-7

Glossary G-1 | Credits C-1 | Index I-1