

Brief Contents

- 1 An Introduction to Life on Earth 1

UNIT 1 The Life of a Cell 19

- 2 Atoms, Molecules, and Life 20
- 3 Biological Molecules 36
- 4 Cell Structure and Function 56
- 5 Cell Membrane Structure and Function 80
- 6 Energy Flow in the Life of a Cell 100
- 7 Capturing Solar Energy: Photosynthesis 116
- 8 Harvesting Energy: Glycolysis and Cellular Respiration 132

UNIT 2 Inheritance 147

- 9 DNA: The Molecule of Heredity 148
- 10 Gene Expression and Regulation 166
- 11 The Continuity of Life: Cellular Reproduction 190
- 12 Patterns of Inheritance 220
- 13 Biotechnology 250

UNIT 3 Evolution and Diversity of Life 275

- 14 Principles of Evolution 276
- 15 How Organisms Evolve 294
- 16 The Origin of Species 314
- 17 The History of Life 330
- 18 Systematics: Seeking Order Amidst Diversity 356
- 19 The Diversity of Prokaryotes and Viruses 370
- 20 The Diversity of Protists 386
- 21 The Diversity of Plants 402
- 22 The Diversity of Fungi 422
- 23 Animal Diversity I: Invertebrates 440
- 24 Animal Diversity II: Vertebrates 468

UNIT 4 Behavior and Ecology 487

- 25 Animal Behavior 488
- 26 Population Growth and Regulation 512
- 27 Community Interactions 536
- 28 How Do Ecosystems Work? 558
- 29 Earth's Diverse Ecosystems 580
- 30 Conserving Life on Earth 610

UNIT 5 Animal Anatomy and Physiology 633

- 31 Homeostasis and the Organization of the Animal Body 634
- 32 Circulation 648
- 33 Respiration 668
- 34 Nutrition and Digestion 684
- 35 The Urinary System 706
- 36 Immunity: Defenses Against Disease 720
- 37 Chemical Control of the Animal Body: The Endocrine System 740
- 38 The Nervous System and the Senses 760
- 39 Action and Support: The Muscles and Skeleton 796
- 40 Animal Reproduction 814
- 41 Animal Development 836

UNIT 6 Plant Anatomy and Physiology 857

- 42 Plant Anatomy and Nutrient Transport 858
- 43 Plant Reproduction and Development 886
- 44 Plant Responses to the Environment 908

This textbook is available in two versions:

Biology: Life on Earth (0-13-238061-7) consists of chapters 1–30, which provide biology students with a thorough overview of cell biology, genetics, evolution, diversity, and ecology.

Biology: Life on Earth with Physiology (0-13-195766-X), an expanded version of the text, contains chapters 1–44: the thirty chapters noted above, plus fourteen chapters covering plant and animal anatomy and physiology.

Contents

Preface xxiii

1 An Introduction to Life on Earth 1

CASE STUDY: Life on Earth—and Elsewhere? 1

1.1 How Do Scientists Study Life? 2

Life Can Be Studied at Different Levels of Organization 2

Scientific Principles Underlie All Scientific Inquiry 3

The Scientific Method Is the Basis for Scientific Inquiry 4

Communication Is Crucial to Science 5

Science Is a Human Endeavor 5

SCIENTIFIC INQUIRY: Controlled Experiments, Then and Now 6

Scientific Theories Have Been Thoroughly Tested 8

1.2 Evolution: The Unifying Theory of Biology 9

Three Natural Processes Underlie Evolution 9

1.3 What Are the Characteristics of Living Things? 10

Living Things Are Complex, Organized, and Composed of Cells 11

Living Things Maintain Relatively Constant Internal Conditions Through Homeostasis 11

EARTH WATCH: Why Preserve Biodiversity? 12

Living Things Respond to Stimuli 13

Living Things Acquire and Use Materials and Energy 13

LINKS TO LIFE: The Life Around Us 14

Living Things Grow 14

Living Things Reproduce Themselves 14

Living Things, Collectively, Have the Capacity to Evolve 14

1.4 How Do Scientists Categorize the Diversity of Life? 14

The Domains Bacteria and Archaea Consist of Prokaryotic Cells; the Domain Eukarya Is Composed of Eukaryotic Cells 14

Bacteria, Archaea, and Protists Are Mostly Unicellular; Members of the Kingdoms Fungi, Plantae, and Animalia Are Primarily Multicellular 15

Members of the Different Kingdoms Have Different Ways of Acquiring Energy 15

1.5 How Does Knowledge of Biology Illuminate Everyday Life? 15

CASE STUDY REVISITED: Life on Earth—and Elsewhere? 17

UNIT 1

The Life of a Cell 19

2 Atoms, Molecules, and Life 20

CASE STUDY: Walking on Water 21

2.1 What Are Atoms? 22

Atoms, the Basic Structural Units of Matter, Are Composed of Still Smaller Particles 22

2.2 How Do Atoms Interact to Form Molecules? 23

Atoms Interact with Other Atoms When There Are Vacancies in Their Outermost Electron Shells 23

SCIENTIFIC INQUIRY: Radioactivity in Research 24

Charged Atoms Called Ions Interact to Form Ionic Bonds 25

Uncharged Atoms Can Become Stable by Sharing Electrons, Forming Covalent Bonds 26

Hydrogen Bonds Are Electrical Attractions Between or Within Molecules with Polar Covalent Bonds 28

2.3 Why Is Water So Important to Life? 28

Water Interacts with Many Other Molecules 28

LINKS TO LIFE: Health Food? 29

Water Molecules Tend to Stick Together 30

Water-Based Solutions Can Be Acidic, Basic, or Neutral 31

Water Moderates the Effects of Temperature Changes 32

Water Forms an Unusual Solid: Ice 32

CASE STUDY REVISITED: Walking on Water 33

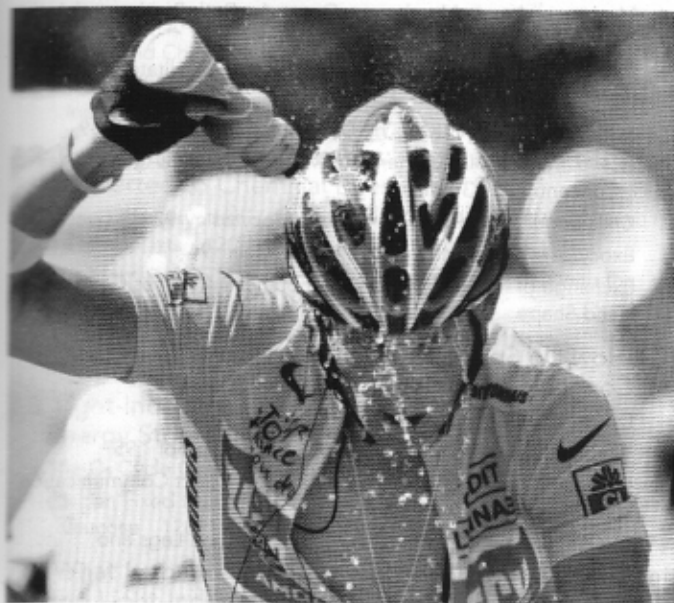
3 Biological Molecules 36

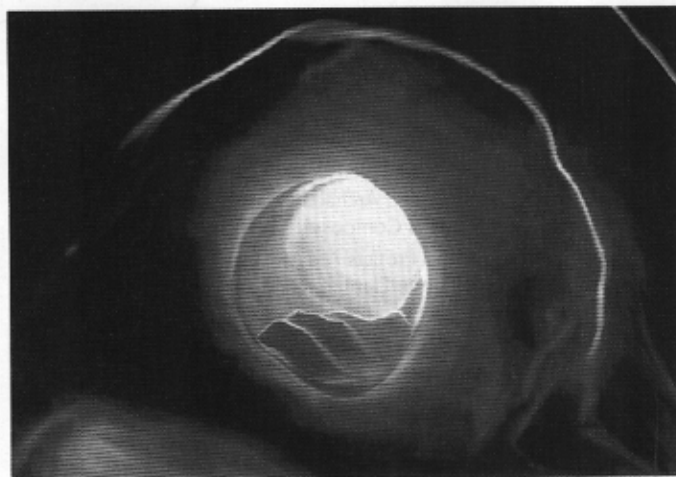
CASE STUDY: Puzzling Proteins 37

3.1 Why Is Carbon So Important in Biological Molecules? 38

3.2 How Are Organic Molecules Synthesized? 38

Biological Molecules Are Joined Together or Broken Apart by Removing or Adding Water 39





3.3 What Are Carbohydrates? 39

There Are Several Monosaccharides with Slightly Different Structures 39

LINKS TO LIFE: Fake Food? 41

Disaccharides Consist of Two Single Sugars Linked by Dehydration Synthesis 41

Polysaccharides Are Chains of Single Sugars 42

3.4 What Are Lipids? 44

Oils, Fats, and Waxes Are Lipids Containing Only Carbon, Hydrogen, and Oxygen 44

Phospholipids Have Water-Soluble "Heads" and Water-Insoluble "Tails" 46

Steroids Consist of Four Carbon Rings Fused Together 46

HEALTH WATCH: Cholesterol—Friend and Foe 47

3.5 What Are Proteins? 47

Proteins Are Formed from Chains of Amino Acids 48

Amino Acids Are Joined to Form Chains by Dehydration Synthesis 49

A Protein Can Have Up to Four Levels of Structure 49

The Functions of Proteins Are Linked to Their Three-Dimensional Structures 51

A CLOSER LOOK: A Hairy Subject 52

3.6 What Are Nucleic Acids? 53

DNA and RNA, the Molecules of Heredity, Are Nucleic Acids 53

Other Nucleotides Act as Intracellular Messengers and Energy Carriers 53

CASE STUDY REVISITED: Puzzling Proteins 54

4 Cell Structure and Function 56

CASE STUDY: Spare Parts for Human Bodies 57

4.1 What Is the Cell Theory? 59

4.2 What Are the Basic Attributes of Cells? 59

Cell Function Limits Cell Size 59

All Cells Share Common Features 59

There Are Two Basic Types of Cells: Prokaryotic and Eukaryotic 62

4.3 What Are the Major Features of Eukaryotic Cells? 63

Some Eukaryotic Cells Are Supported by Cell Walls 63

The Cytoskeleton Provides Shape, Support, and Movement 63

SCIENTIFIC INQUIRY: The Search for the Cell 64

Cilia and Flagella Move the Cell Through Fluid or Move Fluid Past the Cell 67

The Nucleus Is the Control Center of the Eukaryotic Cell 67

Eukaryotic Cytoplasm Includes an Elaborate System of Membranes 70

Vacuoles Serve Many Functions, Including Water Regulation, Support, and Storage 72

Mitochondria Extract Energy from Food Molecules, and Chloroplasts Capture Solar Energy 73

Plants Use Plastids for Storage 74

4.4 What Are the Major Features of Prokaryotic Cells? 75

Prokaryotic Cells Are Small and Possess Specialized Surface Features 75

Prokaryotic Cells Have Fewer Specialized Structures Within Their Cytoplasm 76

LINKS TO LIFE: Unwanted Guests 77

CASE STUDY REVISITED: Spare Parts for Human Bodies 77

5 Cell Membrane Structure and Function 80

CASE STUDY: Vicious Venoms 81

5.1 How Is the Structure of a Membrane Related to Its Function? 82

Cell Membranes Isolate the Cell Contents While Allowing Communication with the Environment 82

Membranes Are "Fluid Mosaics" in Which Proteins Move Within Layers of Lipids 82

The Phospholipid Bilayer Is the Fluid Portion of the Membrane 83

A Variety of Proteins Form a Mosaic Within the Membrane 84

5.2 How Do Substances Move Across Membranes? 85

Molecules in Fluids Move in Response to Gradients 85

Movement Across Membranes Occurs by Both Passive and Active Transport 86

Passive Transport Includes Simple Diffusion, Facilitated Diffusion, and Osmosis 86

SCIENTIFIC INQUIRY: The Discovery of Aquaporins 89

Active Transport Uses Energy to Move Molecules Against Their Concentration Gradients 92

Cells Engulf Particles or Fluids by Endocytosis 92

Exocytosis Moves Material Out of the Cell 94

Exchange of Materials Across Membranes Influences Cell Size and Shape 94

5.3 How Do Specialized Junctions Allow Cells to Connect and Communicate? 95

Desmosomes Attach Cells Together 95

Tight Junctions Make Cell Attachments Leakproof 95

Gap Junctions and Plasmodesmata Allow Direct Communication Between Cells 96

EVOLUTIONARY CONNECTIONS: Caribou Legs and Membrane Diversity 96

CASE STUDY REVISITED: Vicious Venoms 97

6 Energy Flow in the Life of a Cell 100

CASE STUDY: Energy Unleashed 101

6.1 What Is Energy? 102

The Laws of Thermodynamics Describe the Basic Properties of Energy 102

Living Things Use the Energy of Sunlight to Create the Low-Entropy Conditions of Life 103

6.2 How Does Energy Flow in Chemical Reactions? 103

Exergonic Reactions Release Energy 104

Endergonic Reactions Require a Net Input of Energy 105

Coupled Reactions Link Exergonic with Endergonic Reactions 105

6.3 How Is Cellular Energy Carried Between Coupled Reactions? 105

ATP Is the Principal Energy Carrier in Cells 105

Electron Carriers Also Transport Energy Within Cells 107

6.4 How Do Cells Control Their Metabolic Reactions? 108

At Body Temperatures, Spontaneous Reactions Proceed Too Slowly to Sustain Life 108

Catalysts Reduce Activation Energy 108

Enzymes Are Biological Catalysts 108

Cells Regulate Metabolism by Controlling Enzymes 110

Poisons, Drugs, and Environmental Conditions Influence Enzyme Activity 111

LINKS TO LIFE: Lack of an Enzyme Leads to Lactose Intolerance 113

CASE STUDY REVISITED: Energy Unleashed 113

7 Capturing Solar Energy: Photosynthesis 116

CASE STUDY: Did the Dinosaurs Die from Lack of Sunlight? 117

7.1 What Is Photosynthesis? 118

Leaves and Chloroplasts Are Adaptations for Photosynthesis 118

Photosynthesis Consists of Light-Dependent and Light-Independent Reactions 119

7.2 Light-Dependent Reactions: How Is Light Energy Converted to Chemical Energy? 120

During Photosynthesis, Light Is First Captured by Pigments in Chloroplasts 120

The Light-Dependent Reactions Occur in Association with the Thylakoid Membranes 121

A CLOSER LOOK: Chemiosmosis—ATP Synthesis in Chloroplasts 124

7.3 Light-Independent Reactions: How Is Chemical Energy Stored in Glucose Molecules? 125

The C_3 Cycle Captures Carbon Dioxide 125

Carbon Fixed During the C_3 Cycle Is Used to Synthesize Glucose 126

7.4 What Is the Relationship Between Light-Dependent and Light-Independent Reactions? 127

7.5 Water, CO_2 , and the C_4 Pathway 127

When Stomata Are Closed to Conserve Water, Wasteful Photorespiration Occurs 127

C_4 Plants Reduce Photorespiration by Means of a Two-Stage Carbon-Fixation Process 129

C_3 and C_4 Plants Are Each Adapted to Different Environmental Conditions 129

LINKS TO LIFE: You Owe Your Life to Plants 129

CASE STUDY REVISITED: Did the Dinosaurs Die from Lack of Sunlight? 130

8 Harvesting Energy: Glycolysis and Cellular Respiration 132

CASE STUDY: When Athletes Boost Their Blood Counts: Do Cheaters Prosper? 133

8.1 How Do Cells Obtain Energy? 134

Photosynthesis Is the Ultimate Source of Cellular Energy 134

Glucose Is a Key Energy-Storage Molecule 134

An Overview of Glucose Breakdown 134

8.2 How Is the Energy in Glucose Captured During Glycolysis? 135

Glycolysis Breaks Down Glucose to Pyruvate, Releasing Chemical Energy 135

In the Absence of Oxygen, Fermentation Follows Glycolysis 135

A CLOSER LOOK: Glycolysis 136

8.3 How Does Cellular Respiration Capture Additional Energy from Glucose? 138

Cellular Respiration in Eukaryotic Cells Occurs in Mitochondria 138

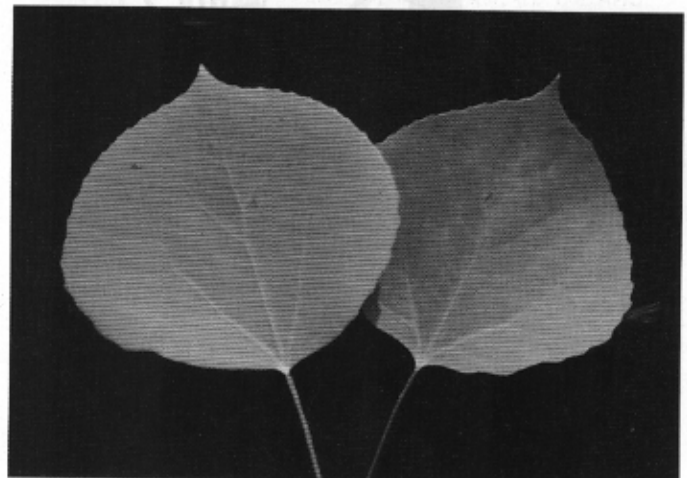
LINKS TO LIFE: A Jug of Wine, a Loaf of Bread, and a Nice Bowl of Sauerkraut 139

Pyruvate Is Broken Down in the Mitochondrial Matrix, Releasing More Energy 139

High-Energy Electrons Travel Through the Electron Transport Chain 140

A CLOSER LOOK: The Mitochondrial Matrix Reactions 141

Chemiosmosis Captures Energy Stored in a Hydrogen Ion Gradient and Produces ATP 141



8.4 Putting It All Together 142

A Summary of Glucose Breakdown in Eukaryotic Cells 142

Glycolysis and Cellular Respiration Influence the Way Organisms Function 143

HEALTH WATCH: Why Can You Get Fat by Eating Sugar? 144**CASE STUDY REVISITED:** When Athletes Boost Their Blood Counts: Do Cheaters Prosper? 145**UNIT 2****Inheritance 147****9 DNA: The Molecule of Heredity 148****CASE STUDY:** Muscles, Mutations, and Myostatin 149**9.1 How Did Scientists Discover That Genes Are Made of DNA? 150**

Transformed Bacteria Revealed the Link Between Genes and DNA 150

9.2 What Is the Structure of DNA? 151**SCIENTIFIC INQUIRY:** DNA Is the Hereditary Molecule of Bacteriophages 152

DNA Is Composed of Four Nucleotides 154

DNA Is a Double Helix of Two Nucleotide Strands 154

Hydrogen Bonds Between Complementary Bases Hold the Two DNA Strands Together 154

SCIENTIFIC INQUIRY: The Discovery of the Double Helix 156**9.3 How Does DNA Encode Information? 157****9.4 How Does DNA Replication Ensure Genetic Constancy During Cell Division? 157**

Replication of DNA Is a Critical Event in a Cell's Life 157

DNA Replication Produces Two DNA Double Helices, Each with One Original Strand and One New Strand 157

9.5 How Do Mutations Occur? 158**A CLOSER LOOK:** DNA Structure and Replication 159

Accurate Replication and Proofreading Produce Almost Error-Free DNA 163

Mistakes Do Happen 163

Mutations Range from Changes in Single Nucleotide Pairs to Movements of Large Pieces of Chromosomes 163

Mutations May Have Varying Effects on Function 163

CASE STUDY REVISITED: Muscles, Mutations, and Myostatin 163**10 Gene Expression and Regulation 166****CASE STUDY:** Vive la Différence! 167**10.1 How Are Genes and Proteins Related? 168**

Most Genes Contain the Information for the Synthesis of a Single Protein 168

DNA Provides Instructions for Protein Synthesis via RNA Intermediaries 169

Overview: Genetic Information Is Transcribed into RNA and Then Translated into Protein 170

The Genetic Code Uses Three Bases to Specify an Amino Acid 171

10.2 How Is Information in a Gene Transcribed into RNA? 172

Initiation of Transcription Occurs When RNA Polymerase Binds to the Promoter of a Gene 172

Elongation Proceeds Until RNA Polymerase Reaches a Termination Signal 172

10.3 How Is the Base Sequence of a Messenger RNA Molecule Translated into Protein? 174

Messenger RNA Carries the Code for Protein Synthesis from DNA to Ribosomes 174

Ribosomes Consist of Two Subunits, Each Composed of Ribosomal RNA and Protein 176

Transfer RNA Molecules Decode the Sequence of Bases in mRNA into the Amino Acid Sequence of a Protein 176

During Translation, mRNA, tRNA, and Ribosomes Cooperate to Synthesize Proteins 176

LINKS TO LIFE: Genetics, Evolution, and Medicine 178**A CLOSER LOOK AT PROTEIN SYNTHESIS:** A High-Energy Business 180

Recap: Decoding the Sequence of Bases in DNA into the Sequence of Amino Acids in Protein Requires Transcription and Translation 178

10.4 How Do Mutations in DNA Affect the Function of Genes? 179

Mutations May Have a Variety of Effects on Protein Structure and Function 179

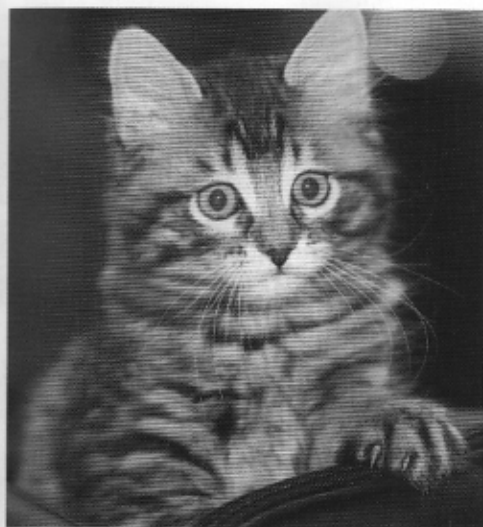
Mutations Provide the Raw Material for Evolution 180

10.5 How Are Genes Regulated? 180

Gene Regulation in Prokaryotes 181

Gene Regulation in Eukaryotes 182





SCIENTIFIC INQUIRY: RNA—It's Not Just a Messenger Any More 183

Eukaryotic Cells May Regulate the Transcription of Individual Genes, Regions of Chromosomes, or Entire Chromosomes 183

HEALTH WATCH: Sex, Aging, and Mutations 184

CASE STUDY REVISITED: Vive la Différence! 186

11 The Continuity of Life: Cellular Reproduction 190

CASE STUDY: How Much Is a Great Tan Worth? 191

11.1 What Is the Role of Cellular Reproduction in the Lives of Individual Cells and Entire Organisms? 192

The Prokaryotic Cell Cycle Consists of Growth and Binary Fission 193

The Eukaryotic Cell Cycle Consists of Interphase and Cell Division 194

11.2 How Is DNA in Eukaryotic Cells Organized into Chromosomes? 195

The Eukaryotic Chromosome Consists of a Linear DNA Double Helix Bound to Proteins 195

Eukaryotic Chromosomes Usually Occur in Homologous Pairs with Similar Genetic Information 197

11.3 How Do Cells Reproduce by Mitotic Cell Division? 199

During Prophase, the Chromosomes Condense and the Spindle Microtubules Form and Attach to the Chromosomes 200

During Metaphase, the Chromosomes Align Along the Equator of the Cell 200

During Anaphase, Sister Chromatids Separate and Are Pulled to Opposite Poles of the Cell 200

During Telophase, Nuclear Envelopes Form Around Both Groups of Chromosomes 200

During Cytokinesis, the Cytoplasm Is Divided Between Two Daughter Cells 200

11.4 How Is the Cell Cycle Controlled? 201

SCIENTIFIC INQUIRY: Carbon Copies—Cloning in Nature and the Lab 202

Checkpoints Regulate Progress Through the Cell Cycle 204

The Activities of Specific Enzymes Drive the Cell Cycle 204

Controls over the Checkpoints 206

11.5 Why Do So Many Organisms Reproduce Sexually? 206

Mutations in DNA Are the Ultimate Source of Genetic Variability 207

Sexual Reproduction May Combine Different Parental Alleles in a Single Offspring 207

11.6 How Does Meiotic Cell Division Produce Haploid Cells? 207

Meiosis Separates Homologous Chromosomes, Producing Haploid Daughter Nuclei 207

HEALTH WATCH: Cancer—Mitotic Cell Division Run Amok 208

Meiotic Cell Division Followed by Fusion of Gametes Keeps the Chromosome Number Constant from Generation to Generation 209

Meiosis I Separates Homologous Chromosomes into Two Haploid Daughter Nuclei 209

Meiosis II Separates Sister Chromatids into Four Daughter Nuclei 213

11.7 When Do Mitotic and Meiotic Cell Division Occur in the Life Cycles of Eukaryotes? 213

In Haploid Life Cycles, the Majority of the Cycle Consists of Haploid Cells 215

In Diploid Life Cycles, the Majority of the Cycle Consists of Diploid Cells 215

In Alternation of Generations Life Cycles, There Are Both Diploid and Haploid Multicellular Stages 215

11.8 How Do Meiosis and Sexual Reproduction Produce Genetic Variability? 216

Shuffling of Homologues Creates Novel Combinations of Chromosomes 216

Crossing Over Creates Chromosomes with Novel Combinations of Genes 217

Fusion of Gametes Adds Further Genetic Variability to the Offspring 217

CASE STUDY REVISITED: How Much Is a Great Tan Worth? 217

12 Patterns of Inheritance 220

CASE STUDY: Sudden Death on the Court 221

12.1 What Is the Physical Basis of Inheritance? 222

Genes Are Sequences of Nucleotides at Specific Locations on Chromosomes 222

An Organism's Two Alleles May Be the Same or Different 222

12.2 How Did Gregor Mendel Lay the Foundations for Modern Genetics? 222

Doing It Right: The Secrets of Mendel's Success 222

12.3 How Are Single Traits Inherited? 223

The Inheritance of Dominant and Recessive Alleles on Homologous Chromosomes Can Explain the Results of Mendel's Crosses 224

Simple "Genetic Bookkeeping" Can Predict Genotypes and Phenotypes of Offspring 225

- Mendel's Hypothesis Can Be Used to Predict the Outcome of New Types of Single-Trait Crosses 226
- 12.4 How Are Multiple Traits Inherited? 227
Mendel Hypothesized That Traits Are Inherited Independently 227
In an Unprepared World, Genius May Go Unrecognized 228
- 12.5 How Are Genes Located on the Same Chromosome Inherited? 229
Genes on the Same Chromosome Tend to Be Inherited Together 229
Recombination Can Create New Combinations of Linked Alleles 230
- 12.6 How Is Sex Determined, and How Are Sex-Linked Genes Inherited? 231
Sex-Linked Genes Are Found Only on the X or Only on the Y Chromosome 231
- 12.7 Do the Mendelian Rules of Inheritance Apply to All Traits? 233
Incomplete Dominance: The Phenotype of Heterozygotes Is Intermediate Between the Phenotypes of the Homozygotes 233
A Single Gene May Have Multiple Alleles 233
SCIENTIFIC INQUIRY: Cystic Fibrosis 234
Many Traits Are Influenced by Several Genes 235
Single Genes Typically Have Multiple Effects on Phenotype 235
The Environment Influences the Expression of Genes 237
- 12.8 How Are Human Genetic Disorders Investigated? 237
- 12.9 How Are Human Disorders Caused by Single Genes Inherited? 238
Some Human Genetic Disorders Are Caused by Recessive Alleles 238
Some Human Genetic Disorders Are Caused by Dominant Alleles 239
Some Human Genetic Disorders Are Sex-Linked 240
- 12.10 How Do Errors in Chromosome Number Affect Humans? 240
Some Genetic Disorders Are Caused by Abnormal Numbers of Sex Chromosomes 240
Some Genetic Disorders Are Caused by Abnormal Numbers of Autosomes 243
- CASE STUDY REVISITED: Sudden Death on the Court 244

13 Biotechnology 250

CASE STUDY: Guilty or Innocent? 251

- 13.1 What Is Biotechnology? 252
- 13.2 How Does DNA Recombine in Nature? 252
Sexual Reproduction Recombines DNA 252
Transformation May Combine DNA from Different Bacterial Species 252
Viruses May Transfer DNA Between Species 253



- 13.3 How Is Biotechnology Used in Forensic Science? 254
The Polymerase Chain Reaction Amplifies DNA 255
SCIENTIFIC INQUIRY: Hot Springs and Hot Science 256
Gel Electrophoresis Separates DNA Segments 256
DNA Probes Are Used to Label Specific Nucleotide Sequences 257
Every Person Has a Unique DNA Profile 258
- 13.4 How Is Biotechnology Used in Agriculture? 258
Many Crops Are Genetically Modified 258
Genetically Modified Plants May Be Used to Produce Medicines 261
Genetically Modified Animals May Be Useful in Agriculture and Medicine 261
- 13.5 How Is Biotechnology Used to Learn About the Human Genome? 261
- 13.6 How Is Biotechnology Used for Medical Diagnosis and Treatment? 262
DNA Technology Can Be Used to Diagnose Inherited Disorders 262
DNA Technology Can Help to Treat Disease 264
- 13.7 What Are the Major Ethical Issues of Modern Biotechnology? 265
LINKS TO LIFE: Biotechnology—from the Sublime to the Ridiculous 266
Should Genetically Modified Organisms Be Permitted in Agriculture? 266
BIOTECHNOLOGY WATCH: Golden Rice 267
HEALTH WATCH: Prenatal Genetic Screening 268
Should the Genome of Humans Be Changed by Biotechnology? 270
CASE STUDY REVISITED: Guilty or Innocent? 271

UNIT 3

Evolution and Diversity of Life 275

14 Principles of Evolution 276

CASE STUDY: What Good Are Wisdom Teeth? 277

14.1 How Did Evolutionary Thought Evolve? 278

Early Biological Thought Did Not Include the Concept of Evolution 278

Exploration of New Lands Revealed a Staggering Diversity of Life 279

A Few Scientists Speculated That Life Had Evolved 279

Fossil Discoveries Showed That Life Has Changed over Time 279

Some Scientists Devised Nonevolutionary Explanations for Fossils 280

Geology Provided Evidence That Earth Is Exceedingly Old 280

Some Pre-Darwin Biologists Proposed Mechanisms for Evolution 281

Darwin and Wallace Proposed a Mechanism of Evolution 281

SCIENTIFIC INQUIRY: Charles Darwin—Nature Was His Laboratory 282

14.2 How Do We Know That Evolution Has Occurred? 282

Fossils Provide Evidence of Evolutionary Change over Time 283

Comparative Anatomy Gives Evidence of Descent with Modification 283

Embryological Similarity Suggests Common Ancestry 286

Modern Biochemical and Genetic Analyses Reveal Relatedness Among Diverse Organisms 286

14.3 How Does Natural Selection Work? 288

Darwin and Wallace's Theory Rests on Four Postulates 288

Postulate 1: Populations Vary 288

Postulate 2: Traits Are Inherited 289

Postulate 3: Some Individuals Fail to Survive and Reproduce 289

Postulate 4: Reproductive Success Is Not Random 289

Natural Selection Modifies Populations over Time 289

14.4 What Is the Evidence That Populations Evolve by Natural Selection? 289

Controlled Breeding Modifies Organisms 289

Evolution by Natural Selection Occurs Today 290

14.5 A Postscript by Charles Darwin 292

CASE STUDY REVISITED: What Good Are Wisdom Teeth? 292

15 How Organisms Evolve 294

CASE STUDY: Evolution of a Menace 295

15.1 How Are Populations, Genes, and Evolution Related? 296

Genes and the Environment Interact to Determine Traits 296

The Gene Pool Is the Sum of the Genes in a Population 297

Evolution Is the Change of Allele Frequencies Within a Population 297

The Equilibrium Population Is a Hypothetical Population in Which Evolution Does Not Occur 297

A CLOSER LOOK: The Hardy-Weinberg Principle 298

15.2 What Causes Evolution? 298

Mutations Are the Original Source of Genetic Variability 298

Gene Flow Between Populations Changes Allele Frequencies 300

Allele Frequencies May Drift in Small Populations 300

Mating Within a Population Is Almost Never Random 304

All Genotypes Are Not Equally Beneficial 304

15.3 How Does Natural Selection Work? 306

Natural Selection Stems from Unequal Reproduction 306

Natural Selection Acts on Phenotypes 306

Some Phenotypes Reproduce More Successfully Than Others 306

EARTH WATCH: Endangered Species—From Gene Pools to Gene Puddles 308

Selection Can Influence Populations in Three Ways 309

CASE STUDY REVISITED: Evolution of a Menace 311

16 The Origin of Species 314

CASE STUDY: Lost World 315

16.1 What Is a Species? 316

Biologists Need a Clear Definition of Species 316

Species Are Groups of Interbreeding Populations 316

Appearance Can Be Misleading 316

16.2 How Is Reproductive Isolation Between Species Maintained? 317

Premating Isolating Mechanisms Prevent Mating Between Species 317

Postmating Isolating Mechanisms Limit Hybrid Offspring 319

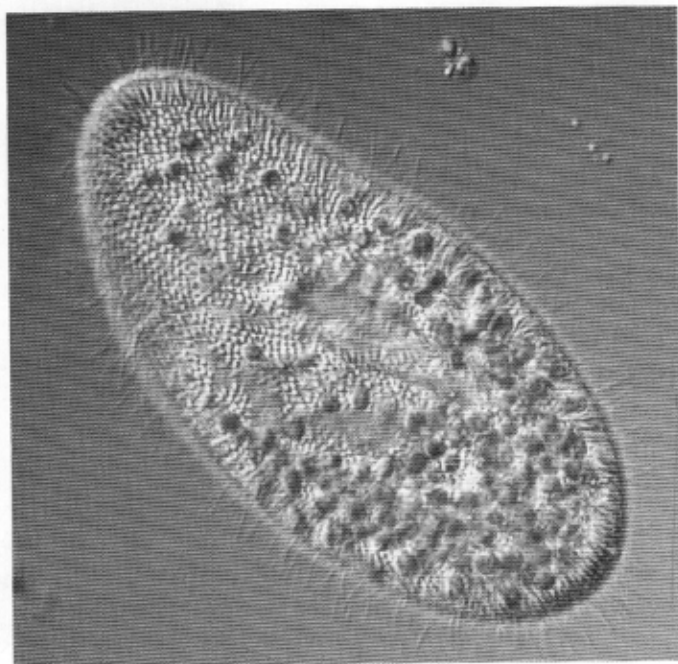
16.3 How Do New Species Form? 320

Geographical Separation of a Population Can Lead to Allopatric Speciation 321

EARTH WATCH: Hybridization and Extinction 322

Ecological Isolation of a Population Can Lead to Sympatric Speciation 322





Under Some Conditions, Many New Species May Arise 324

16.4 What Causes Extinction? 324

Localized Distribution and Overspecialization Make Species Vulnerable in Changing Environments 324

Interactions with Other Organisms May Drive a Species to Extinction 325

A CLOSER LOOK: Speciation by Mutation 326

Habitat Change and Destruction Are the Leading Causes of Extinction 326

EVOLUTIONARY CONNECTIONS: Scientists Don't Doubt Evolution 326

LINKS TO LIFE: Biological Vanity Plates 328

CASE STUDY REVISITED: Lost World 328

17 The History of Life 330

CASE STUDY: Little People, Big Story 331

17.1 How Did Life Begin? 332

Experiments Refuted Spontaneous Generation 332

The First Living Things Arose from Nonliving Ones 332

RNA May Have Been the First Self-Reproducing Molecule 334

Membrane-Like Vesicles May Have Enclosed Ribozymes 334

But Did All This Happen? 334

17.2 What Were the Earliest Organisms Like? 335

The First Organisms Were Anaerobic Prokaryotes 335

Some Organisms Evolved the Ability to Capture the Sun's Energy 337

Photosynthesis Increased the Amount of Oxygen in the Atmosphere 337

Aerobic Metabolism Arose in Response to the Oxygen Crisis 337

Some Organisms Acquired Membrane-Enclosed Organelles 337

SCIENTIFIC INQUIRY: How Do We Know How Old a Fossil Is? 338

17.3 What Were the Earliest Multicellular Organisms Like? 339

Some Algae Became Multicellular 340

Animal Diversity Arose in the Precambrian Era 340

17.4 How Did Life Invade the Land? 340

Some Plants Became Adapted to Life on Dry Land 340

Some Animals Became Adapted to Life on Dry Land 342

17.5 What Role Has Extinction Played in the History of Life? 344

Evolutionary History Has Been Marked by Periodic Mass Extinctions 345

Climate Change Contributed to Mass Extinctions 345

Catastrophic Events May Have Caused the Worst Mass Extinctions 346

17.6 How Did Humans Evolve? 346

Humans Inherited Some Early Primate Adaptations for Life in Trees 346

The Oldest Hominid Fossils Are from Africa 347

The Earliest Hominids Could Stand and Walk Upright 347

Several Species of *Australopithecus* Emerged in Africa 349

The Genus *Homo* Diverged from the *Australopithecines* 2.5 Million Years Ago 349

The Evolution of *Homo* Was Accompanied by Advances in Tool Technology 349

Neanderthals Had Large Brains and Excellent Tools 350

Modern Humans Emerged Less than 200,000 Years Ago 350

Several Waves of Hominids Emigrated from Africa 351

The Evolutionary Origin of Large Brains May Be Related to Meat Consumption 351

The Evolutionary Origin of Human Behavior Is Highly Speculative 353

The Cultural Evolution of Humans Now Far Outpaces Biological Evolution 353

CASE STUDY REVISITED: Little People, Big Story 353

18 Systematics: Seeking Order Amidst Diversity 356

CASE STUDY: Origin of a Killer 357

18.1 How Are Organisms Named and Classified? 358

Each Species Has a Unique, Two-Part Name 358

Classification Originated as a Hierarchy of Categories 358

Systematists Identify Features That Reveal Evolutionary Relationships 358

Anatomy Plays a Key Role in Systematics 359

Molecular Similarities Are Also Useful for Reconstructing Phylogeny 360

18.2 What Are the Domains of Life? 360

The Five-Kingdom System Improved Classification 360

A Three-Domain System More Accurately Reflects Life's History 360

Kingdom-Level Classification Remains Unsettled 361

A CLOSER LOOK: Reconstructing Phylogenetic Trees 362

18.3 Why Do Classifications Change? 364

Species Designations Change When New Information Is Discovered 364

The Biological Species Definition Can Be Difficult or Impossible to Apply 364

SCIENTIFIC INQUIRY: Molecular Genetics Reveals Evolutionary Relationships 365

18.4 How Many Species Exist? 366

LINKS TO LIFE: Small World 367

CASE STUDY REVISITED: Origin of a Killer 367

19 The Diversity of Prokaryotes and Viruses 370

CASE STUDY: Agents of Death 371

19.1 Which Organisms Make Up the Prokaryotic Domains—Bacteria and Archaea? 372

Bacteria and Archaea Are Fundamentally Different 372

Classification of Prokaryotes Within Each Domain Is Difficult 372

Prokaryotes Differ in Size and Shape 373

19.2 How Do Prokaryotes Survive and Reproduce? 373

Some Prokaryotes Are Mobile 373

Many Bacteria Form Films on Surfaces 373

Protective Endospores Allow Some Bacteria to Withstand Adverse Conditions 374

Prokaryotes Are Specialized for Specific Habitats 374

Prokaryotes Exhibit Diverse Metabolisms 375

Prokaryotes Reproduce by Binary Fission 375

Prokaryotes May Exchange Genetic Material Without Reproducing 376

19.3 How Do Prokaryotes Affect Humans and Other Eukaryotes? 376

Prokaryotes Play Important Roles in Animal Nutrition 376

Prokaryotes Capture the Nitrogen Needed by Plants 376

Prokaryotes Are Nature's Recyclers 377

Prokaryotes Can Clean Up Pollution 377

Some Bacteria Pose a Threat to Human Health 377—

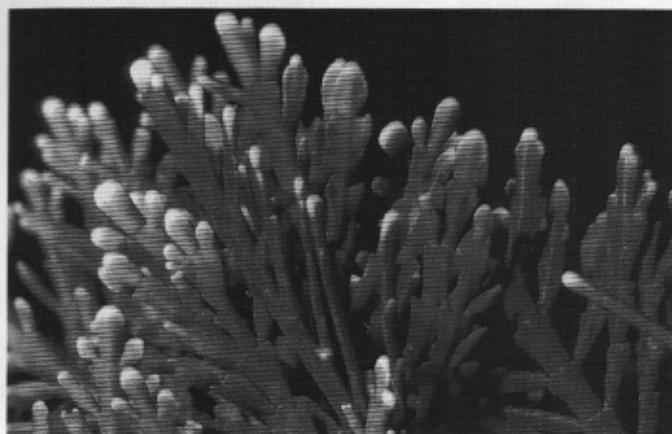
LINKS TO LIFE: Unwelcome Dinner Guests 378

19.4 What Are Viruses, Viroids, and Prions? 379

A Virus Consists of a Molecule of DNA or RNA Surrounded by a Protein Coat 379

A CLOSER LOOK: Viruses—How the Nonliving Replicate 382

Viruses Are Parasites 380



Some Infectious Agents Are Even Simpler Than Viruses 381

No One Is Certain How These Infectious Particles Originated 384

CASE STUDY REVISITED: Agents of Death 384

20 The Diversity of Protists 386

CASE STUDY: Green Monster 387

20.1 What Are Protists? 388

Most Protists Are Single-Celled 389

Protists Use Diverse Modes of Nutrition 389

Protists Use Diverse Modes of Reproduction 389

Protists Have Significant Effects on Humans 390

20.2 What Are the Major Groups of Protists? 390

Excavates Lack Mitochondria 390

Euglenozoans Have Distinctive Mitochondria 391

Stramenopiles Include Photosynthetic and Non-Photosynthetic Organisms 392

Alveolates Include Parasites, Predators, and Phytoplankton 393

Cercozoans Have Thin Pseudopods and Elaborate Shells 395

Amoebozoans Inhabit Aquatic and Terrestrial Environments 397

Red Algae Live Primarily in Clear Tropical Oceans 398

Green Algae Live Mostly in Ponds and Lakes 399

EVOLUTIONARY CONNECTIONS: Our Unicellular Ancestors 400

CASE STUDY REVISITED: Green Monster 400

21 The Diversity of Plants 402

CASE STUDY: Queen of the Parasites 403

21.1 What Are the Key Features of Plants? 404

Plants Have Alternating Multicellular Haploid and Diploid Generations 404

Plants Have Multicellular, Dependent Embryos 404

Plants Play a Crucial Ecological Role 404

Plants Provide Humans with Necessities and Luxuries 405

21.2 What Is the Evolutionary Origin of Plants? 405

Green Algae Gave Rise to Plants 405

The Ancestors of Plants Lived in Fresh Water 405

21.3 How Have Plants Adapted to Life on Land? 406

Plant Bodies Resist Gravity and Drying 406

Plant Embryos Are Protected, and Plant Sex Cells May Disperse Without Water 406

21.4 What Are the Major Groups of Plants? 407

Bryophytes Lack Conducting Structures 407

Vascular Plants Have Conducting Vessels That Also Provide Support 410

The Seedless Vascular Plants Include the Club Mosses, Horsetails, and Ferns 410

The Seed Plants Dominate the Land, Aided by Two Important Adaptations: Pollen and Seeds 410

Gymnosperms Are Nonflowering Seed Plants 410

Angiosperms Are Flowering Seed Plants 416

More Recently Evolved Plants Have Smaller Gametophytes 416

CASE STUDY REVISITED: Queen of the Parasites 419

22 The Diversity of Fungi 422

CASE STUDY: Humongous Fungus 423

22.1 What Are the Key Features of Fungi? 424

- Fungal Bodies Consist of Slender Threads 424
- Fungi Obtain Their Nutrients from Other Organisms 424
- Fungi Propagate by Spores 424
- Most Fungi Can Reproduce Both Sexually and Asexually 425

22.2 What Are the Major Groups of Fungi? 425

- Chytrids Produce Swimming Spores 425
- Zygomycetes Can Reproduce by Forming Diploid Spores 426
- Ascomycetes Form Spores in a Saclike Case 429
- Basidiomycetes Produce Club-Shaped Reproductive Structures 429

22.3 How Do Fungi Interact with Other Species? 430

- Lichens Are Formed by Fungi That Live with Photosynthetic Algae or Bacteria 430
- Mycorrhizae Are Fungi Associated with Plant Roots 432
- Endophytes Are Fungi That Live Inside Plant Stems and Leaves 432
- Some Fungi Are Important Recyclers 432

22.4 How Do Fungi Affect Humans? 433

- Fungi Attack Plants That Are Important to People 433
- Fungi Cause Human Diseases 434
- Fungi Can Produce Toxins 434
- Many Antibiotics Are Derived from Fungi 434
- Fungi Make Important Contributions to Gastronomy 435
- EARTH WATCH: The Case of the Disappearing Mushrooms 435
- EVOLUTIONARY CONNECTIONS: Fungal Ingenuity—Pigs, Shotguns, and Nooses 435
- LINKS TO LIFE: Collect Carefully 436

CASE STUDY REVISITED: Humongous Fungus 437

23 Animal Diversity I: Invertebrates 440

CASE STUDY: The Search for a Sea Monster 441

23.1 What Are the Key Features of Animals? 442

23.2 Which Anatomical Features Mark Branch Points on the Animal Evolutionary Tree? 442

- Lack of Tissues Separates Sponges from All Other Animals 443
- Animals with Tissues Exhibit Either Radial or Bilateral Symmetry 443
- Most Bilateral Animals Have Body Cavities 444
- Bilateral Organisms Develop in One of Two Ways 445
- Protostomes Include Two Distinct Evolutionary Lines 445

23.3 What Are the Major Animal Phyla? 445

- Sponges Have a Simple Body Plan 445
- Cnidarians Are Well-Armed Predators 447
- Flatworms Have Organs but Lack Respiratory and Circulatory Systems 450
- Annelids Are Composed of Identical Segments 451
- Most Mollusks Have Shells 453
- LINKS TO LIFE: Physicians' Assistants 454

- Arthropods Are the Dominant Animals on Earth 456
- Roundworms Are Abundant and Mostly Tiny 462
- Echinoderms Have a Calcium Carbonate Skeleton 463
- The Chordates Include the Vertebrates 464

CASE STUDY REVISITED: The Search for a Sea Monster 464

24 Animal Diversity II: Vertebrates 468

CASE STUDY: Fish Story 468

24.1 What Are the Key Features of Chordates? 470

- All Chordates Share Four Distinctive Features 470
- The Invertebrate Chordates Live in the Seas 471
- Vertebrates Have a Backbone 471

24.2 What Are the Major Groups of Vertebrates? 472

- Some Vertebrates Lack Jaws 472
- Jawed Fishes Rule Earth's Waters 473
- Amphibians Live a Double Life 475
- EARTH WATCH: Frogs in Peril 476
- Reptiles and Birds Are Adapted for Life on Land 477
- Mammals Provide Milk to Their Offspring 480
- EVOLUTIONARY CONNECTIONS: Are Humans a Biological Success? 482
- LINKS TO LIFE: Do Animals Belong in Laboratories? 482

CASE STUDY REVISITED: Fish Story 484

UNIT 4

Behavior and Ecology 487

25 Animal Behavior 488

CASE STUDY: Sex and Symmetry 489

25.1 How Do Innate and Learned Behaviors Differ? 489

- Innate Behaviors Can Be Performed Without Prior Experience 489
- Learned Behaviors Are Modified by Experience 490



There Is No Sharp Distinction Between Innate and Learned Behaviors 492

25.2 How Do Animals Communicate? 495

Visual Communication Is Most Effective over Short Distances 495
 Communication by Sound Is Effective over Longer Distances 496
 Chemical Messages Persist Longer but Are Hard to Vary 496
 Communication by Touch Helps Establish Social Bonds 497

25.3 How Do Animals Compete for Resources? 497

Aggressive Behavior Helps Secure Resources 497
 Dominance Hierarchies Help Manage Aggressive Interactions 498
 Animals May Defend Territories That Contain Resources 499

25.4 How Do Animals Find Mates? 501

Signals Encode Sex, Species, and Individual Quality 501

25.5 What Kinds of Societies Do Animals Form? 502

Group Living Has Advantages and Disadvantages 502
 The Extent of Sociality Varies Among Species 502
 Forming Groups with Relatives Fosters the Evolution of Altruism 503
 Honeybees Live Together in Rigidly Structured Societies 504
 Naked Mole Rats Form a Complex Vertebrate Society 505

25.6 Can Biology Explain Human Behavior? 506

The Behavior of Newborn Infants Has a Large Innate Component 506
 Young Humans Acquire Language Easily 506
 Behaviors Shared by Diverse Cultures May Be Innate 507
 Humans May Respond to Pheromones 507
 Studies of Twins Reveal Genetic Components of Behavior 508
 Biological Investigation of Human Behavior Is Controversial 508
 EVOLUTIONARY CONNECTIONS: Why Do Animals Play? 508

CASE STUDY REVISITED: Sex and Symmetry 509

26 Population Growth and Regulation 512

CASE STUDY: The Mystery of Easter Island 513

26.1 How Does Population Size Change? 514

Biotic Potential Can Produce Exponential Growth 514

26.2 How Is Population Growth Regulated? 515

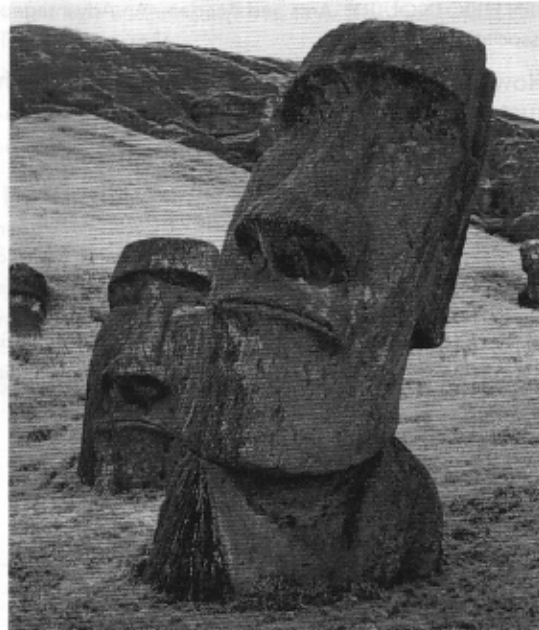
Exponential Growth Occurs Only Under Special Conditions 515
 Environmental Resistance Limits Population Growth 518
 SCIENTIFIC INQUIRY: Cycles in Predator and Prey Population 519

26.3 How Are Populations Distributed in Space and Time? 524

Populations Exhibit Different Spatial Distributions 524
 Survivorship in Populations Follows Three Basic Patterns 525

26.4 How Is the Human Population Changing? 526

Demographers Track Changes in Human Populations 526
 The Human Population Continues to Grow Rapidly 526
 Technological Advances Have Increased Earth's Capacity to Support People 526
 The Demographic Transition Helps Stabilize Populations 527
 EARTH WATCH: Have We Exceeded Earth's Carrying Capacity? 528



Population Growth Is Unevenly Distributed 528

The Current Age Structure of a Population Predicts Its Future Growth 529

Fertility in Europe Is Below Replacement Level 530

The U.S. Population Is Growing Rapidly 532

LINKS TO LIFE: Treading Lightly—How Big Is Your "Footprint"? 533

CASE STUDY REVISITED: The Mystery of Easter Island 532

27 Community Interactions 536

CASE STUDY: Invasion of the Zebra Mussels 537

27.1 Why Are Community Interactions Important? 538

27.2 What Is the Relationship Between Ecological Niche and Competition? 538

The Ecological Niche Defines the Place and Role of Each Species in Its Ecosystem 538
 Competition Occurs Whenever Two Organisms Attempt to Use the Same, Limited Resources 538
 Adaptations Reduce the Overlap of Ecological Niches Among Coexisting Species 539
 Interspecific Competition May Reduce the Population Size and Distribution of Each Species 540
 Competition Within a Species Is a Major Factor Controlling Population Size 540

27.3 What Are the Results of Interactions Between Predators and Their Prey? 540

EARTH WATCH: Invasive Species Disrupt Community Interactions 541
 Predator-Prey Interactions Shape Evolutionary Adaptations 543

27.4 What Is Symbiosis? 547

Parasitism Harms, but Does Not Immediately Kill, the Host 547
 In Mutualistic Interactions, Both Species Benefit 547

SCIENTIFIC INQUIRY: Ants and Acacias—An Advantageous Association 549

27.5 How Do Keystone Species Influence Community Structure? 549

27.6 Succession: How Do Community Interactions Cause Change over Time? 550

There Are Two Major Forms of Succession: Primary and Secondary 550

Succession Also Occurs in Ponds and Lakes 553

Succession Culminates in the Climax Community 553

Some Ecosystems Are Maintained in a Subclimax State 553

EVOLUTIONARY CONNECTIONS: Is Camouflage Splitting a Species? 554

CASE STUDY REVISITED: Invasion of the Zebra Mussels 555

28 How Do Ecosystems Work? 558

CASE STUDY: When the Salmon Return 559

28.1 What Are the Pathways of Energy and Nutrients? 560

28.2 How Does Energy Flow Through Communities? 561

Energy Enters Communities Through Photosynthesis 561

Energy Is Passed from One Trophic Level to Another 562

Energy Transfer Through Trophic Levels Is Inefficient 564

EARTH WATCH: Food Chains Magnify Toxic Substances 566

28.3 How Do Nutrients Move Within and Among Ecosystems? 567

Carbon Cycles Through the Atmosphere, Oceans, and Communities 567

The Major Reservoir for Nitrogen Is the Atmosphere 568

The Phosphorus Cycle Has No Atmospheric Component 569

Most Water Remains Chemically Unchanged During the Hydrologic Cycle 570



28.4 What Causes "Acid Rain"? 571

Overloading the Nitrogen and Sulfur Cycles Causes Acid Deposition 571

Acid Deposition Damages Life in Lakes and Forests 572

The Clean Air Act Has Significantly Reduced Sulfur, but Not Nitrogen, Emissions 572

28.5 What Causes Global Warming? 572

Interfering with the Carbon Cycle Contributes to Global Warming 572

Greenhouse Gases Trap Heat in the Atmosphere 573

Global Warming Will Have Severe Consequences 574

How Are People Responding to the Threat? 575

EARTH WATCH: Poles in Peril 576

LINKS TO LIFE: Making a Difference 577

CASE STUDY REVISITED: When the Salmon Return 577

29 Earth's Diverse Ecosystems 580

CASE STUDY: Wings of Hope 581

29.1 What Factors Influence Earth's Climate? 582

Both Climate and Weather Are Driven by the Sun 582

Earth's Physical Features Also Influence Climate 582

29.2 What Conditions Does Life Require? 585

EARTH WATCH: The Ozone Hole—A Puncture in Our Protective Shield 586

29.3 How Is Life on Land Distributed? 585

Terrestrial Biomes Support Characteristic Plant Communities 587

LINKS TO LIFE: Crave Chocolate and Save Rain Forests? 591

Rainfall and Temperature Limit the Plant Life of a Biome 598

29.4 How Is Life in Water Distributed? 598

Freshwater Ecosystems Include Lakes, Streams, and Rivers 598

Marine Ecosystems Cover Much of Earth 601

CASE STUDY REVISITED: Wings of Hope 607

30 Conserving Life on Earth 610

CASE STUDY: Back from Extinction 611

30.1 What Is Biodiversity, and Why Should We Care About It? 612

Ecosystem Services: Practical Uses for Biodiversity 612

Ecological Economics Recognizes the Monetary Value of Ecosystem Services 614

30.2 Is Earth's Biodiversity Diminishing? 615

Extinction Is a Natural Process, but Rates Have Risen Dramatically 615

EARTH WATCH: Restoring the Everglades 616

Increasing Numbers of Species Are Threatened with Extinction 616

30.3 What Are The Major Threats to Biodiversity? 617

Humanity Is Depleting Earth's "Ecological Capital" 617

Human Activities Threaten Biodiversity in Several Important Ways 618

EARTH WATCH: Tangled Troubles—Logging, Fishing, and Bushmeat 618

EARTH WATCH: Saving Sea Turtles 621

30.4 How Can Conservation Biology Help to Preserve Biodiversity? 623

The Foundations of Conservation Biology 623

Conservation Biology Is an Integrated Science 623

Conserving Wild Ecosystems 623

EARTH WATCH: Restoring a Keystone Predator 624

30.5 Why Is Sustainability the Key to Conservation? 625

Sustainable Living and Sustainable Development Promote Long-Term Ecological and Human Well-Being 625

Biosphere Reserves Provide Models for Conservation and Sustainable Development 626

Sustainable Agriculture Helps Preserve Natural Communities 627

The Future Is in Your Hands 627

EARTH WATCH: Preserving Biodiversity with Shade-Grown Coffee 629

LINKS TO LIFE: What Can Individuals Do? 630

CASE STUDY REVISITED: Back from Extinction 629

UNIT 5

Animal Anatomy and Physiology 633

31 Homeostasis and the Organization of the Animal Body 634

CASE STUDY: Life on Hold? 635

31.1 Homeostasis: How Do Animals Regulate Their Internal Environment? 636

The Internal Environment Is Maintained in a State of Dynamic Constancy 636



Animals May Be Categorized by How They Regulate Body Temperature 636

LINKS TO LIFE: Heat or Humidity? 637

Feedback Systems Regulate Internal Conditions 638

The Body's Internal Systems Act in Concert 639

31.2 How Is the Animal Body Organized? 639

Animal Tissues Are Composed of Similar Cells That Perform a Specific Function 639

Organs Include Two or More Interacting Tissue Types 643

Organ Systems Consist of Two or More Interacting Organs 644

CASE STUDY REVISITED: Life on Hold? 646

32 Circulation 648

CASE STUDY: Sudden Death 649

32.1 What Are the Major Features and Functions of Circulatory Systems? 650

Animals Have Two Types of Circulatory Systems 650

The Vertebrate Circulatory System Has Diverse Functions 651

32.2 How Does the Vertebrate Heart Work? 651

Increasingly Complex and Efficient Hearts Have Arisen During Vertebrate Evolution 651

The Vertebrate Heart Consists of Muscular Chambers That Form Two Separate Pumps 652

HEALTH WATCH: Repairing Broken Hearts 654

32.3 What Is Blood? 657

Plasma Is Primarily Water in Which Proteins, Salts, Nutrients, and Wastes Are Dissolved 658

Red Blood Cells Carry Oxygen from the Lungs to the Tissues 658

White Blood Cells Help Defend the Body Against Disease 659

Platelets Are Cell Fragments That Aid in Blood Clotting 659

32.4 What Are the Types and Functions of Blood Vessels? 661

Arteries and Arterioles Are Thick-Walled Vessels That Carry Blood Away from the Heart 661

Capillaries Are Microscopic Vessels That Allow the Blood and Body Cells to Exchange Nutrients and Wastes 661

Veins and Venules Carry Blood Back to the Heart 662

Arterioles Control the Distribution of Blood Flow 662

32.5 How Does the Lymphatic System Work with the Circulatory System? 663

Lymphatic Vessels Resemble the Veins and Capillaries of the Circulatory System 664

The Lymphatic System Returns Fluids to the Blood 664

The Lymphatic System Transports Fats from the Small Intestine to the Blood 665

The Lymphatic System Helps Defend the Body Against Disease 665

CASE STUDY REVISITED: Sudden Death 666

33 Respiration 668

CASE STUDY: Lives Up in Smoke 669

33.1 Why Exchange Gases? 670

33.2 What Are Some Evolutionary Adaptations for Gas Exchange? 670

Some Animals in Moist Environments Lack Specialized Respiratory Structures 671

Respiratory Systems Facilitate Gas Exchange by Diffusion 671

Gills Facilitate Gas Exchange in Aquatic Environments 672

Terrestrial Animals Have Internal Respiratory Structures 672

A CLOSER LOOK: Gills and Gases—Countercurrent Exchange 674

33.3 How Does the Human Respiratory System Work? 675

The Conducting Portion of the Respiratory System Carries Air to the Lungs 675

Gas Exchange Occurs in the Alveoli 676

Carbon Dioxide and Oxygen Are Transported Using Different Mechanisms 677

HEALTH WATCH: Smoking—A Life and Breath Decision 678

LINKS TO LIFE: Quitters Are Winners 680

Air Is Inhaled Actively and Exhaled Passively 680

Breathing Rate Is Controlled by the Respiratory Center of the Brain 680

CASE STUDY REVISITED: Lives Up in Smoke 681

34 Nutrition and Digestion 684

CASE STUDY: Dieting to Death? 685

34.1 What Nutrients Do Animals Need? 686

Energy Is Derived from Nutrients and Measured in Calories 686

Lipids Include Fats, Phospholipids, and Cholesterol 686

HEALTH WATCH: Dying for a Cheeseburger 687

Carbohydrates Are a Source of Quick Energy 688

Amino Acids Form the Building Blocks of Proteins 688

Minerals Are Elements Required by the Body 688

Vitamins Play Many Roles in Metabolism 688

The Human Body Is About Two-Thirds Water 688

Nutritional Guidelines Help People Obtain a Balanced Diet 691

34.2 How Is Digestion Accomplished? 692

An Overview of Digestion 692

In Sponges, Digestion Occurs Within Single Cells 693

A Sac with One Opening Forms the Simplest Digestive System 693

Digestion in a Tube Allows Animals to Feed More Frequently 693

Digestive Specializations 693

34.3 How Do Humans Digest Food? 695

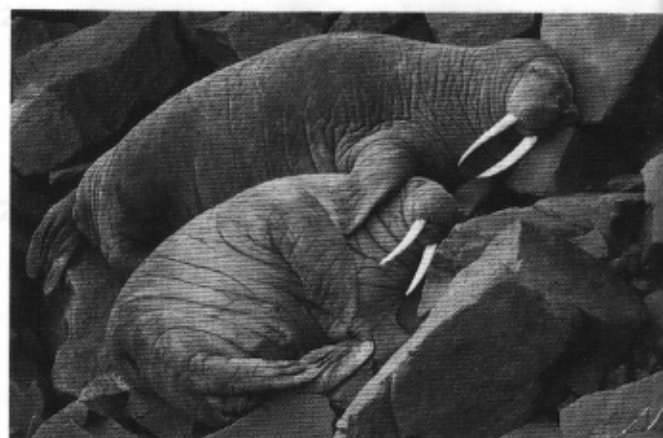
Mechanical and Chemical Breakdown of Food Begins in the Mouth 695

The Esophagus Conducts Food to the Stomach 697

Most Digestion Occurs in the Small Intestine 698

HEALTH WATCH: Ulcers: Digesting the Digestive Tract 699

Most Absorption Occurs in the Small Intestine 700



Water Is Absorbed and Feces Are Formed in the Large Intestine 701

Digestion Is Controlled by the Nervous System and Hormones 702

CASE STUDY REVISITED: Dieting to Death? 702

35 The Urinary System 706

CASE STUDY: A Perfect Match 707

35.1 What Are the Basic Functions of Urinary Systems? 708

35.2 What Are Some Examples of Invertebrate Excretory Systems? 708

Protonephridia Filter Interstitial Fluid in Flatworms 708

Malpighian Tubules Filter the Blood of Insects 708

Nephridia Filter Coelomic Fluid in Earthworms 709

35.3 What Are the Functions of Vertebrate Urinary Systems? 709

Vertebrate Kidneys Filter the Blood 709

Excretion of Nitrogenous Wastes Is Adapted to the Environment 709

35.4 What Are the Structures and Functions of the Human Urinary System? 710

The Urinary System Consists of the Kidneys, Ureters, Bladder, and Urethra 710

Urine Is Formed in the Nephrons of the Kidneys 710

A CLOSER LOOK: The Nephron and Urine Formation 712

The Filtrate Is Converted to Urine in the Tubule of the Nephron 712

HEALTH WATCH: When the Kidneys Collapse 714

The Loop of Henle Allows Urine to Become Concentrated 714

35.5 How Do Mammalian Kidneys Help Maintain Homeostasis? 715

The Kidneys Regulate the Water Content of the Blood 715

Kidneys Release Hormones That Help Regulate Blood Pressure and Oxygen Levels 715

Kidneys Monitor and Regulate Dissolved Substances in the Blood 716

Vertebrate Kidneys Are Adapted to Diverse Environments 716

LINKS TO LIFE: Too Much to Drink? 717

CASE STUDY REVISITED: A Perfect Match 717

36 Immunity: Defenses Against Disease 720

CASE STUDY: Fighting the Flu 721

36.1 What Are the Basic Mechanisms of Defense Against Disease? 722

- Vertebrate Animals Have Three Major Lines of Defense 722
- Invertebrate Animals Possess the First Two Lines of Defense 722

36.2 How Do Nonspecific Defenses Function? 723

- Skin and Mucous Membranes Form External Barriers to Invasion 723
- Nonspecific Internal Defenses Combat Disease 723

36.3 What Are the Key Characteristics of the Immune Response? 725

- Cells of the Immune System Recognize the Invader 726
- Cells of the Immune System Launch an Attack 729
- Cells of the Immune System Remember Past Victories 730

36.4 How Does Medical Care Augment the Immune Response? 731

- Vaccinations Stimulate the Development of Memory Cells 731
- SCIENTIFIC INQUIRY: The Discovery of Vaccines 732
- Antibiotics Slow Down Microbial Reproduction 733

36.5 What Happens When the Immune System Malfunctions? 733

- Allergies Are Misdirected Immune Responses 733
- HEALTH WATCH: Fighting Influenza—Is a Bird Flu Pandemic Imminent? 734
- An Autoimmune Disease Is an Immune Response Against the Body's Own Molecules 734
- An Immune Deficiency Disease Disables the Immune System 735
- Cancer Can Evade or Overwhelm the Immune Response 736

CASE STUDY REVISITED: Fighting the Flu 738

37 Chemical Control of the Animal Body: The Endocrine System 740

CASE STUDY: Losing on Artificial Hormones 741

37.1 How Do Animal Cells Communicate? 742

37.2 What Are the Characteristics of Animal Hormones? 742

- Local Hormones Diffuse to Nearby Target Cells 742
- Hormones of the Endocrine System Are Transported by the Circulatory System 742
- Hormones Bind Specific Receptors on Target Cells 743
- Hormone Release Is Regulated by Feedback Mechanisms 744
- Vertebrate and Invertebrate Endocrine Hormones Show Striking Similarities 746

37.3 What Are the Structures and Hormones of the Mammalian Endocrine System? 746

- Mammals Have Both Exocrine and Endocrine Glands 746
- The Hypothalamus Controls Secretions of the Pituitary Gland 748

The Thyroid and Parathyroid Glands Influence Metabolism and Calcium Levels 750

The Pancreas Is Both an Exocrine and an Endocrine Gland 752

The Sex Organs Secrete Steroid Hormones 753

The Adrenal Glands Have Two Parts That Secrete Different Hormones 753

EARTH WATCH: Endocrine Deception 754

Hormones Are Produced by the Pineal Gland, Thymus, Kidneys, Heart, Digestive Tract, and Fat Cells 755

LINKS TO LIFE: Closer to a Cure for Diabetes 756

EVOLUTIONARY CONNECTIONS: The Evolution of Hormones 756

CASE STUDY REVISITED: Losing on Artificial Hormones 757

38 The Nervous System and the Senses 760

CASE STUDY: How Do I Love Thee? 761

38.1 What Are the Structures and Functions of Neurons? 762

38.2 How Is Neural Activity Produced and Transmitted? 762

- Neurons Produce Electrical Voltages Across Their Membranes 762
- Neurons Communicate at Synapses 764

38.3 How Are Nervous Systems Organized? 764

- Information Processing in the Nervous System Requires Four Basic Operations 764

A CLOSER LOOK: Ions and Electrical Signaling in Neurons 766

HEALTH WATCH: Drugs, Diseases, and Neurotransmitters 769

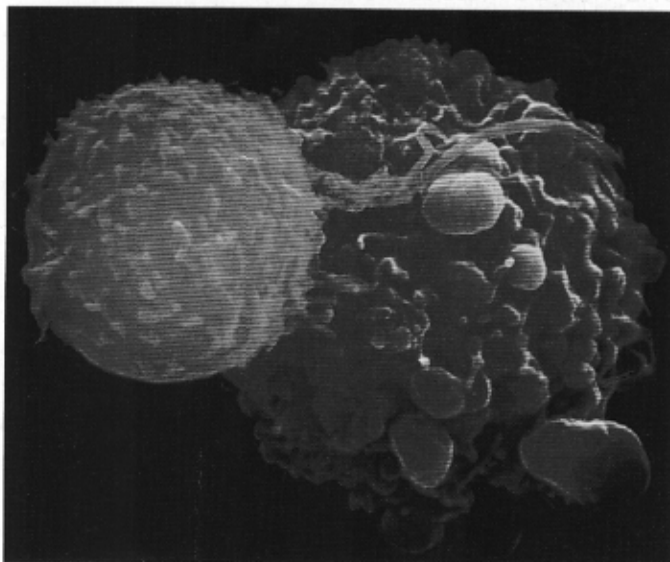
Neural Pathways Direct Behavior 770

Complex Nervous Systems Are Centralized 770

38.4 What Is the Structure of the Human Nervous System? 770

The Peripheral Nervous System Links the Central Nervous System to the Rest of the Body 771

The Central Nervous System Consists of the Spinal Cord and Brain 773



The Spinal Cord Is a Cable of Axons Protected by the Backbone 773

The Brain Consists of Many Parts Specialized for Specific Functions 774

38.5 How Does the Brain Produce the Mind? 778

The "Left Brain" and "Right Brain" Are Specialized for Different Functions 778

The Mechanisms of Learning and Memory Are Subjects of Intensive Research 778

Insights About How the Brain Creates the Mind Come from Diverse Sources 779

SCIENTIFIC INQUIRY: Neuroimaging—Peering into the "Black Box" 780

38.6 How Do Sensory Receptors Work? 781

38.7 How Are Mechanical Stimuli Detected? 782

38.8 How Is Sound Sensed? 782

The Ear Converts Sound Waves into Electrical Signals 782

38.9 How Is Light Sensed? 785

The Compound Eyes of Arthropods Produce a Mosaic Image 785

The Mammalian Eye Collects and Focuses Light, Converting It into Electrical Signals 785

38.10 How Are Chemicals Sensed? 788

Olfactory Receptors Detect Airborne Chemicals 788

Taste Receptors Detect Chemicals That Contact the Tongue 789

Pain Is a Specialized Chemical Sense 790

EVOLUTIONARY CONNECTIONS: Uncommon Senses 790

CASE STUDY REVISITED: How Do I Love Thee? 792

39 Action and Support: The Muscles and Skeleton 796

CASE STUDY: Hidden Hazards of Space Travel 797

39.1 An Introduction to the Muscular and Skeletal Systems 798

39.2 How Do Muscles Work? 798

Skeletal Muscle Cell Structure and Function Are Closely Linked 800

Muscle Contraction Results from Thick and Thin Filaments Sliding Past One Another 800

Cardiac Muscle Powers the Heart 804

Smooth Muscle Produces Slow, Involuntary Contractions 804

39.3 What Does the Skeleton Do? 804

Three Types of Skeletons Are Found in Animals 804

The Vertebrate Skeleton Serves Many Functions 805

39.4 Which Tissues Comprise the Vertebrate Skeleton? 806

Cartilage Provides Flexible Support and Connections 806

Bone Provides a Strong, Rigid Framework for the Body 806

Bone Remodeling Allows Skeletal Repair and Adaptation to Stresses 807

HEALTH WATCH: How Bones Heal 808

39.5 How Does the Body Move? 808

Muscles Move the Skeleton Around Flexible Joints 808

HEALTH WATCH: Osteoporosis—When Bones Become Brittle 810

LINKS TO LIFE: Walk with a Dog 811

CASE STUDY REVISITED: Hidden Hazards of Space Travel 810

40 Animal Reproduction 814

CASE STUDY: The Frozen Zoo 815

40.1 How Do Animals Reproduce? 816

Asexual Reproduction Does Not Involve the Fusion of Sperm and Egg 816

Sexual Reproduction Requires the Union of Sperm and Egg 817

40.2 How Does the Human Reproductive System Work? 820

The Ability to Reproduce Begins at Puberty 820

The Male Reproductive Tract Includes the Testes and Accessory Structures 820

The Female Reproductive Tract Includes the Ovaries and Accessory Structures 823

Copulation Allows Internal Fertilization 825

A CLOSER LOOK: Hormonal Control of the Menstrual Cycle 826

HEALTH WATCH: Sexually Transmitted Diseases 828

40.3 How Can People Limit Fertility? 829

Permanent Contraception Can Be Achieved Through Sterilization 829

Temporary Contraception and Abortion Prevent or Terminate Pregnancy 829

HEALTH WATCH: High-Tech Reproduction 831

SCIENTIFIC INQUIRY: Seeking a Male Contraceptive 832

CASE STUDY REVISITED: The Frozen Zoo 832

41 Animal Development 836

CASE STUDY: Faces of FAS 837

41.1 How Do Indirect and Direct Development Differ? 838

During Indirect Development, Animals Undergo a Radical Change in Body Form 838



Newborn Animals That Undergo Direct Development Resemble Miniature Adults 839

41.2 How Does Animal Development Proceed? 840

Cleavage of the Zygote Begins Development 841

Gastrulation Forms Three Tissue Layers 841

Adult Structures Develop During Organogenesis 841

41.3 How Is Development Controlled? 842

Each Cell Contains the Entire Genetic Blueprint for the Organism 842

SCIENTIFIC INQUIRY: The Promise of Stem Cells 843

Gene Transcription Is Precisely Regulated During Development 844

41.4 How Do Humans Develop? 845

During the First Two Months, Rapid Differentiation and Growth Occur 845

The Placenta Secretes Hormones and Exchanges Materials Between Mother and Embryo 848

Growth and Development Continue During the Last Seven Months 850

Development Culminates in Labor and Delivery 850

HEALTH WATCH: The Placenta Provides Only Partial Protection 852

Milk Secretion Is Stimulated by Hormones of Pregnancy 851

Aging Is Inevitable 852

LINKS TO LIFE: Why Is Human Childbirth So Difficult? 854

CASE STUDY REVISITED: Faces of FAS 854

UNIT 6

Plant Anatomy and Physiology 857

42 Plant Anatomy and Nutrient Transport 858

CASE STUDY: Why Do Leaves Turn Red in the Fall? 859

42.1 How Are Plant Bodies Organized, and How Do They Grow? 860

Flowering Plants Consist of a Root System and a Shoot System 860

As Plants Grow, Meristem Cells Give Rise to Differentiated Cells 861

42.2 What Are the Tissues and Cell Types of Plants? 862

The Dermal Tissue System Covers the Plant Body 862

The Ground Tissue System Comprises Most of the Young Plant Body 862

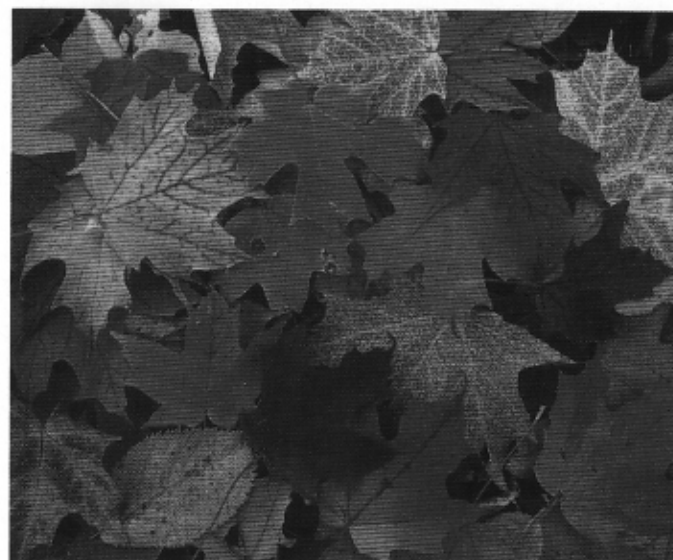
The Vascular Tissue System Transports Water and Nutrients 864

42.3 What Are the Structures and Functions of Leaves, Roots, and Stems? 865

Leaves Are Nature's Solar Cells 865

Stems Elevate and Support the Plant Body 866

Roots Anchor the Plant, Absorb Nutrients, and Store Food 870



42.4 How Do Plants Acquire Mineral Nutrients? 873

Roots Absorb Mineral Nutrients from Soil 873

Symbiotic Relationships Help Plants Acquire Nutrients 873

A CLOSER LOOK: How Roots Absorb Water and Minerals 874

42.5 How Do Plants Move Water Upward from Roots to Leaves? 876

Water Movement in Xylem Is Explained by the Cohesion-Tension Theory 876

Adjustable Stomata Control the Rate of Transpiration 877

EARTH WATCH: Plants Help Regulate the Distribution of Water 878

42.6 How Do Plants Transport Sugars? 879

The Pressure-Flow Theory Explains Sugar Movement in Phloem 879

EVOLUTIONARY CONNECTIONS: Interesting Adaptations of Roots, Stems, and Leaves 880

CASE STUDY REVISITED: Why Do Leaves Turn Red in the Fall? 883

43 Plant Reproduction and Development 886

CASE STUDY: Gorgeous? Sure! But Hot? 887

43.1 What Are the Basic Features of Plant Life Cycles? 888

Plants Engage in Sex 888

Alternation of Generations Is Clearly Evident in Ferns and Mosses 889

43.2 How Is Reproduction in Seed Plants Adapted to Drier Environments? 889

43.3 What Is the Function and Structure of the Flower? 889

Most Flowers Lure Animals That Pollinate Them 889

HEALTH WATCH: Are You Allergic to Pollen? 890

Flowers Are the Reproductive Structure of Angiosperms 891

Complete Flowers Have Four Major Parts 892
 Pollens Contains the Male Gametophyte 892
 The Female Gametophyte Forms Within the Ovule of the
 Ovary 895
 Pollination of the Flower Leads to Fertilization 895

43.4 How Do Fruits and Seeds Develop? 896

The Fruit Develops from the Ovary 896
 The Seed Develops from the Ovule 896
 EARTH WATCH: On Dodos, Bats, and Disrupted
 Ecosystems 898

43.5 How Do Seeds Germinate and Grow? 899

Seed Dormancy Helps Ensure Germination at an Appropriate
 Time 899
 Upon Germination, the Root Emerges First, Followed by the
 Shoot 899
 Cotyledons Nourish the Sprouting Seed 899

43.6 What Are Some Adaptations for Pollination and Seed Dispersal? 900

Coevolution Matches Plants and Pollinators 900
 Fruits Help Disperse Seeds 903

CASE STUDY REVISITED: Gorgeous? Sure! But Hot? 904



44 Plant Responses to the Environment 908

CASE STUDY: Predacious Plants 909

44.1 What Are Plant Hormones, and How Do They Act? 910

SCIENTIFIC INQUIRY: How Were Plant Hormones
 Discovered? 912

44.2 How Do Hormones Regulate the Plant Life Cycle? 911

The Plant Life Cycle Begins with a Seed 911
 Auxin Controls the Orientation of the Sprouting Seedling 913
 The Genetically Determined Shape of the Mature Plant
 Is the Result of Interactions Among Hormones 915
 Day Length Controls Flowering 916
 Hormones Coordinate the Development of Seeds
 and Fruit 918
 Senescence and Dormancy Prepare the Plant for Winter 919

44.3 Can Plants Communicate and Move Rapidly? 920

Plants May Summon "Bodyguards" When Attacked 920
 Plants May Warn Their Neighbors and Offspring
 of Attacks 920
 Some Plants Move Rapidly 921

CASE STUDY REVISITED: Predacious Plants 922

Appendix I: Metric System Conversions 925

Appendix II: Classification of Major Groups of Organisms 926

Appendix III: Biological Vocabulary: Common Roots, Prefixes, and Suffixes 927

Glossary G1

Answers to Figure Caption Questions A1

Photo Credits P1

Index I1