

Brief Table of Contents

Unit 1—The Diversity of Life

Chapter 1: The Nature of Science and the Characteristics of Life 2

Chapter 2: Organizing the Diversity of Life 22

Chapter 3: Major Groups of Living Organisms 38

INTERLUDE A—Applying What We Learned: Biodiversity and People A1

Unit 2—Cells: The Basic Units of Life

Chapter 4: Chemical Building Blocks 68

Chapter 5: Cell Structure and Compartments 96

Chapter 6: Cell Membranes, Transport, and Communication 116

Chapter 7: Energy and Enzymes 134

Chapter 8: Photosynthesis and Respiration 152

Chapter 9: Cell Division 170

INTERLUDE B—Applying What We Learned: Cancer: Cell Division Out of Control B1

Unit 3—Genetics

Chapter 10: Patterns of Inheritance 186

Chapter 11: Chromosomes and Human Genetics 206

Chapter 12: DNA 226

Chapter 13: From Gene to Protein 244

Chapter 14: Control of Gene Expression 262

Chapter 15: DNA Technology 278

INTERLUDE C—Applying What We Learned: Harnessing the Human Genome C1

Unit 4—Evolution

Chapter 16: How Evolution Works 298

Chapter 17: Evolution of Populations 318

Chapter 18: Adaptation and Speciation 338

Chapter 19: The Evolutionary History of Life 356

INTERLUDE D—Applying What We Learned: Humans and Evolution D1

Unit 5—Interactions with the Environment

Chapter 20: The Biosphere 378

Chapter 21: Growth of Populations 396

Chapter 22: Interactions among Organisms 414

Chapter 23: Communities of Organisms 430

Chapter 24: Ecosystems 448

Chapter 25: Global Change 468

INTERLUDE E—Applying What We Learned: Building a Sustainable Ecosystem E1

Table of Contents

STUDENT WEB SITE AND CD FEATURES i

MEDIA AND SUPPLEMENTS OVERVIEW iv

ABOUT THE AUTHORS xii

PREFACE xiii

GUIDED TOUR FOR STUDENTS xxi

LIST OF BOXES xxix

Unit 1—The Diversity of Life

Chapter 1: The Nature of Science and the Characteristics of Life 2

They're Alive! Or Are They? 3

1.1 Asking Questions, Testing Answers: The Work of Science 4

Scientists use the scientific method 5

The scientific method has limits 7

1.2 The Characteristics That All Living Organisms Share 7

Living organisms are built of cells 7

Science Toolkit: Thinking Outside the Box: Thinking Inside the Soup 8

Living organisms reproduce themselves via DNA 9

Living organisms develop 10

Living organisms capture energy from their environment 10

Living organisms sense their environment and respond to it 10

Living organisms show a high level of organization 11

Biology Matters: How Much to Eat of What? 12

Living organisms evolve 13

1.3 Viruses—A Gray Zone Between Life and Nonlife? 13

1.4 The Biological Hierarchy 14

Levels in the biological hierarchy provide biologists with a framework for studying living organisms 14

Knowing the biological hierarchy can be useful in everyday life 14

1.5 Energy Flow Through Biological Systems 16

Are Nanobes Indeed the Smallest Form of Life? 17

Chapter Review 18

Biology in the News: "Baby's Fate in Summit Court" 21

Chapter 2: Organizing the Diversity of Life 22

The Iceman Cometh 23

2.1 Building Evolutionary Trees 24

Groups are related through their most recent common ancestor 24

Examining shared derived features helps determine the most recent common ancestor 25

Convergent features are similarities that do not indicate relatedness 26

DNA comparisons are a powerful new way to study evolutionary relationships 26

2.2 Using Evolutionary Trees to Predict the Biology of Organisms 27

Science Toolkit: The Guilty Dentist 28

2.3 A Classification System for Organizing Life: The Linnaean Hierarchy and Beyond 29

2.4 Branches on the Tree of Life 31

Unexpected evolutionary relationships exist between the plant, fungus, and animal kingdoms 31

The primate evolutionary tree reveals the closest relative of humans 33

A surprising tangle can be found at the roots of the tree of life 33

The evolutionary tree of life is a work in progress 34

And the True Identity of the Iceman Is . . . 34

Chapter Review 35

Biology in the News: "Irish Potato Famine Caused by Unidentified Fungus" 37

Chapter 3: Major Groups of Living Organisms 38

Here, There, and Everywhere 39

3.1 The Major Groups in Context 40

There are three major systems for classifying all of life 40

Organisms can also be identified as prokaryotes and eukaryotes 41

3.2 The Bacteria and Archaea: Tiny, Successful, and Abundant 42

Prokaryotes represent simplicity translated into success 42

Prokaryotes exhibit unmatched diversity in methods of obtaining nutrition 42

Biology on the Job: A Passion for Life 45

Prokaryotes can thrive in extreme environments 46

Prokaryotes play important roles in the biosphere and in human society 46
Bacteria and Archaea exhibit key differences 46

3.3 The Protista: A Window into the Early Evolution of the Eukarya 46

Protists represent early stages in the evolution of the eukaryotic cell 48
Protists provide insight into the early evolution of multicellularity 48
Protists had sex first 48
Protists are well known for their disease-causing abilities 48

3.4 The Plantae: Pioneers of Life on Land 49

Life on land requires special structures 49
Vascular systems allowed ferns and their allies to grow to great heights 49
Gymnosperms evolved seeds as a way to protect their young 51
Angiosperms produced the world's first flowers 51
Plants are the basis of land ecosystems and provide many valuable products 53

3.5 The Fungi: A World of Decomposers 53

Fungi have evolved a structure that makes them highly efficient decomposers 55
Reproduction also sets fungi apart from other organisms 55
The same characteristics that make fungi good decomposers make them dangerous parasites 55
Some fungi live in beneficial associations with other species 56

3.6 The Animalia: Complex, Diverse, and Mobile 56

Animals evolved true tissues 57
Animals evolved organs and organ systems 57
Animals evolved complete body cavities 57
Animal body forms exhibit variations on a few themes 60
Animals exhibit an astounding variety of behaviors 61
Animals play key roles in ecosystems and provide products for humans 61
Biology Matters: What's on Your Plate? 62

3.7 The Difficulty of Viruses 62

An Overflowing Cornucopia of Life 63

Chapter Review 63

Biology in the News: "Bizarre Giant Virus Rewrites the Record Books" 66

Interlude A—Applying What We Learned: Biodiversity and People A1

Where Have All the Frogs Gone? A1

How Many Species Are There on Earth? A3

Scientists use indirect methods to estimate total species numbers A3
Some groups are well known and others are poorly studied A4

The Beginnings of a Present-Day Mass Extinction A5

The current mass extinction probably began with early humans A6
Scientists have made estimates of species losses occurring today A6

The Many Threats to Biodiversity A7

Habitat loss and deterioration are the biggest threats to biodiversity A7

Introduced foreign species can wipe out native species A7

Climate changes also threaten species A9

Some threats are difficult to identify or define A9

Human population growth underlies many, if not all, of the major threats to biodiversity A9

Biology Matters: Does What I Do Matter? A10

Mass Extinctions of the Past A11

The Importance of Biodiversity A11

Biodiversity can improve the function of ecosystems A11

Biodiversity provides people with goods and services A12

Review and Discussion A14

Unit 2—Cells: The Basic Units of Life

Chapter 4: Chemical Building Blocks 68

Looking for Life among the Stars 69

4.1 Atoms Make Up the Physical World 70

Atoms can be described by numbers 71

Some elements can exist as isotopes with different atomic mass numbers 71

4.2 Covalent Bonds: The Strongest Linkages in Nature 72

4.3 Noncovalent Bonds: Dynamic Linkages Between Molecules 73

Biology Matters: Elements 'R Us 75

Hydrogen bonds are important temporary bonds 75

Ionic bonds form between atoms of opposite charge 76

4.4 Chemical Reactions Rearrange Atoms Within Molecules 77

Acids and bases affect the pH of water 77

Buffers prevent large changes in pH 78

4.5 The Chemical Building Blocks of Living Systems 78

Biology on the Job: At the Chattanooga Nature Center 80

Carbohydrates provide energy and structural support for living organisms 81

Nucleotides store information and energy 81

Amino acids are the building blocks of proteins 84

Fatty acids store energy and form membranes 87

Steroids are lipids that play vital roles in cell membranes and in development 89

Proteins That Can Take the Heat 90

Chapter Review 91

Biology in the News: "Canada Looks Likely to Ban Trans Fatty Acids in Foods" 94

Chapter 5: Cell Structure and Compartments 96

Traveling with Hijackers 97

- 5.1 Cells: The Simplest Units of Life 98**
- 5.2 The Plasma Membrane: Separating Cells from Their Environment 98**
Science Toolkit: Exploring Cells under the Microscope 99
- 5.3 Comparing Prokaryotes and Eukaryotes 101**
- 5.4 The Specialized Internal Compartments of Eukaryotic Cells 101**
The nucleus is the repository for genetic material 103
The endoplasmic reticulum is the site of manufacture for lipids and many proteins 103
The Golgi apparatus sends proteins and lipids to their final destinations in the cell 104
Lysosomes and vacuoles are specialized compartments for recycling, storage, and structural support 105
Mitochondria are the power stations of the eukaryotic cell 105
Chloroplasts capture energy from sunlight 106
- 5.5 The Cytoskeleton: Providing Shape and Movement 107**
Microtubules support movement inside the cell 108
Intermediate filaments strengthen the connections between cells 109
Microfilaments are involved in cell movement 109
Cilia and flagella act like oars and propellers 109

The Evolution of Organelles 111

Chapter Review 113

Biology in the News: "High Doses of Vitamin E Supplements Do More Harm Than Good" 115

Chapter 6: Cell Membranes, Transport, and Communication 116

Pollution Detectives 117

- 6.1 The Plasma Membrane Is Both Gate and Gatekeeper 118**
Cells can move materials across the plasma membrane with or without the expenditure of energy 119
Small molecules can diffuse through the phospholipid bilayer 119
Channel proteins and passive carrier proteins allow molecules to cross the plasma membrane passively 120
Only active carrier proteins can move materials up a concentration gradient 120
Active and passive transport often work together 120
- 6.2 Water Requires a Cellular Balancing Act 121**
- 6.3 Cell Membranes as Transport Luggage 121**
Biology Matters: Water, Water Everywhere—But Not a Drop to Drink 122
- 6.4 Cooperation among Cells in Multicellular Organisms 123**
- 6.5 Connections Between Neighboring Cells 124**
- 6.6 Signaling Molecules in Cell Communication 125**
Hormones are long-range signaling molecules 125

Science Toolkit: Tagging Proteins 127
Steroid hormones can cross cell membranes 128

Why Are Lichens So Sensitive to Air Pollution? 129

Chapter Review 130

Biology in the News: "Reclamation Techniques at Sudbury, Canada" 132

Chapter 7: Energy and Enzymes 134

"Take Two Aspirin and Call Me in the Morning" 135

7.1 The Role of Energy in Living Systems 136

The laws of thermodynamics apply to living systems 136
The flow of energy and the cycling of carbon connect living things with the environment 137

7.2 Using Energy from the Controlled Combustion of Food 138

Capturing energy from foods requires the transfer of electrons 138
Science Toolkit: Counting Calories with a Bomb 139
Chemical reactions are governed by simple transformations of energy 141

7.3 How Cells Speed Up Chemical Reactions 142

Enzymes speed up chemical reactions 142
The hydration of carbon dioxide requires catalysis 142
The shape of an enzyme directly determines its activity 143
Sequences of reactions have energetic advantages 143

7.4 Enzymes and Energy in Use: The Building of DNA 144

7.5 Metabolic Rates and Life Span 145

Biology Matters: Energy Is a Weighty Subject 146

Making a Wonder Drug Even Better 147

Chapter Review 148

Biology in the News: "More Heart Risks Found for COX-2 Inhibitors" 150

Chapter 8: Photosynthesis and Respiration 152

Food for Thought 153

8.1 Energy Carriers: Powering All Activities of the Cell 154

8.2 Photosynthesis: Capturing Energy from Sunlight 154

Chloroplasts are the sites of photosynthesis 155
The light reactions capture energy from sunlight 156
The dark reactions manufacture sugars 158

8.3 Catabolism: Breaking Down Molecules for Energy 160

Glycolysis is the first stage in the cellular breakdown of sugars 160
Fermentation sidesteps the need for oxygen 161
Biology on the Job: A Baker's Tale 162
Most of the ATP in eukaryotes is produced by aerobic respiration 163
The Krebs cycle produces NADH and carbon dioxide 163

Oxidative phosphorylation uses oxygen and NADH to produce ATP in quantity 163

Biology Matters: Our Fondness for Fermentation 166

Solving the Brain Drain 166

Chapter Review 167

Biology in the News: "Biodiesel Boom Well-Timed" 169

Chapter 9: Cell Division 170

An Army Turned Against Itself 171

9.1 Stages of the Cell Cycle 172

9.2 Interphase: Preparing the Cell for Division 173

9.3 Mitosis and Cytokinesis: From One Cell to Two Identical Cells 174

The DNA of each species is organized into a distinctive karyotype 174

Chromosomes become visible during prophase 175

Chromosomes are attached to the spindle during prometaphase 175

Chromosomes line up in the middle of the cell during metaphase 176

Chromatids separate during anaphase 176

New nuclei form during telophase 177

Cell division occurs during cytokinesis 178

9.4 Meiosis: Halving the Chromosome Number 178

Gametes contain half the number of chromosomes as other cells 178

Biology on the Job: Wildlife Curator: Saving the Red Wolf 179

Meiosis I is the reduction division 181

Meiosis II is similar to mitosis 181

Immune Cell Proliferation and Lyme Disease 182

Chapter Review 183

Biology in the News: "It's Time to Play the Music, It's Time to Light the Lights" 185

Interlude B—Applying What We Learned: Cancer: Cell Division Out of Control B1

Enlisting a Virus to Fight Cancer B1

What Is Cancer? B3

Positive Growth Regulators: Promoting Cell Division B3

Some viruses can cause cancer B4

Oncogenes play an important role in cancer development B5

Negative Growth Regulators: Inhibiting Cell Division B5

Tumor suppressors block specific steps of growth factor signal cascades B6

Both copies of a tumor suppressor gene must be mutated to cause cancer B7

An Interplay of Factors Can Cause Cancer B7

Cancer is a multi-step process B8

Cancer is often related to lifestyle choices B9

Biology Matters: The Truth about Cigarettes in School B11

Making the Most of Losing p53 B11

The p53 protein helps to maintain normal cell division B11

The absence of p53 may be useful in cancer therapies involving adenoviruses B12

Review and Discussion B12

Unit 3—Genetics

Chapter 10: Patterns of Inheritance 186

The Lost Princess 187

10.1 Essential Terms in Genetics 188

10.2 Gene Mutations: The Source of New Alleles 190

10.3 Basic Patterns of Inheritance 191

Mendel conducted genetic experiments on pea plants 191

Inherited traits are determined by genes 191

10.4 Mendel's Laws 192

Mendel's first law: Segregation 192

Mendel's second law: Independent assortment 193

10.5 Extensions of Mendel's Laws 195

Many alleles do not show complete dominance 195

Science Toolkit: Tossing Coins and Crossing Plants: Probability and the Design of Experiments 196

Alleles for one gene can alter the effects of another gene 197

The environment can alter the effects of a gene 198

Most traits are determined by two or more genes 198

10.6 Putting It All Together: Genes and Inheritance 198

Biology Matters: How to Avoid Life-Threatening Diseases 200

Solving the Mystery of the Lost Princess 200

Chapter Review 201

Biology in the News: "DNA Tweak Turns Vole Mates into Soul Mates" 204

Chapter 11: Chromosomes and Human Genetics 206

A Horrible Dance 207

11.1 The Role of Chromosomes in Inheritance 208

Genes are located on chromosomes 208

11.2 Autosomes and Sex Chromosomes 208

In humans, sex is determined by males 209

Biology Matters: Know Your Type 210

11.3 Linkage and Crossing-Over 211

Linked genes violate Mendel's law of independent assortment 211

	Crossing-over reduces genetic linkage	211
1.4	Origins of Genetic Differences among Individuals	213
1.5	Human Genetic Disorders	214
	Pedigrees are a useful way to study human genetic disorders	214
	Genetic disorders may or may not be inherited	214
1.6	Autosomal Inheritance of Single-Gene Mutations	216
	There are many autosomal recessive genetic disorders	216
	Science Toolkit: Prenatal Genetic Screening	217
	Dominant genetic disorders are less common	218
1.7	Sex-Linked Inheritance of Single-Gene Mutations	218
1.8	Inherited Chromosomal Abnormalities	219
	The structure of chromosomes can change in several ways	219
	Changes in chromosome number are often fatal	219
	<i>Uncovering the Genetics of Huntington Disease</i>	220
	Chapter Review	221
	Biology in the News: "Heart Tumor Discovery"	225

Chapter 12: DNA 226

The Library of Life 227

12.1	The Search for the Genetic Material	228
	Harmless bacteria can be transformed into deadly bacteria	228
	DNA can transform bacteria	229
	The genetic instructions of a virus are contained in its DNA	229
12.2	The Three-Dimensional Structure of DNA	230
	DNA is a double helix	230
12.3	How DNA Is Replicated	232
	Biology on the Job: Helping People Cope with Genetic Disorders	234
12.4	Repairing Replication Errors and Damaged DNA	235
	Few mistakes are made in DNA replication	236
	Normal gene function depends on DNA repair	236
	Biology Matters: Cancer in Children	237

Errors in the Library of Life 239

Chapter Review 240

Biology in the News: "Aral Catastrophe Recorded in DNA" 242

Chapter 13: From Gene to Protein 244

Finding the Messenger and Breaking the Code 245

13.1	How Genes Work	246
	Genes contain information for the synthesis of RNA molecules	246
	Three types of RNA are involved in the production of proteins	247
13.2	How Genes Control the Production of Proteins	247
13.3	Transcription: Information Flow from DNA to RNA	248
13.4	The Genetic Code	250
13.5	Translation: Information Flow from mRNA to Protein	251
13.6	The Effect of Mutations on Protein Synthesis	252

Mutations can alter one or many bases in a gene's DNA sequence 252

Mutations can cause a change in protein function 253

Biology on the Job: Investing in Biotech 254

13.7 **Putting It All Together: From Gene to Phenotype** 255

From Gene to Protein, to New Hope for Huntington Disease 257

Chapter Review 258

Biology in the News: "Injections Temporarily Turn Slacker Monkeys into Model Workers" 261

Chapter 14: Control of Gene Expression 262

Greek Myths and One-Eyed Lambs 263

14.1	The Structural and Functional Organization of DNA	265
	Eukaryotes have much more DNA per cell than prokaryotes	265
	Genes constitute only a small percentage of the DNA in eukaryotes	265
14.2	DNA Packing in Eukaryotes	266
14.3	Patterns of Gene Expression	267
	Organisms turn genes on and off in response to short-term environmental changes	267
	Different cells in eukaryotes express different genes	268
	Development in eukaryotes relies on gene cascades and homeotic genes	268
14.4	How Cells Control Gene Expression	270
	Cells control the expression of most genes by controlling transcription	270
	Cells also control gene expression in other ways	271
14.5	The Consequences of Controlling Gene Expression	271

From Gene Expression to Cancer Treatment 272

Science Toolkit: Using DNA Chips to Monitor Gene Expression 274

Chapter Review 275

Biology in the News: "RNA Treatment Lowers Cholesterol" 277

Chapter 15: DNA Technology 278

Glowing Bunnies and Food for Millions 279

15.1	Working with DNA: Basic Techniques	280
	Several key enzymes are used in DNA technology	280
	Gel electrophoresis sorts DNA fragments by size	281
	DNA probes can test for the presence of an allele or gene	282
	DNA sequencing and DNA synthesis are used in basic research and practical applications of modern genetics	283
15.2	Working with DNA: DNA Cloning	283
	Cloning can be done by constructing a DNA library	284
	The polymerase chain reaction can clone DNA very rapidly	285
15.3	Applications of DNA Technology	286
	DNA fingerprinting can distinguish one individual from another	286
	Science Toolkit: Human Cloning	287

Genetic engineering is used to transfer genes from one species to another 288

15.4 Ethical Issues and Risks of DNA Technology 289

Biology Matters: Think Before You Drink 291

Human Gene Therapy 292

Chapter Review 294

Biology in the News: "Biotech Grass Found Far Afield" 296

Interlude C—Applying What We Learned: Harnessing the Human Genome C1

A Crystal Ball for Your Health C1

The Quest for the Human Genome C3

A Preview of Our Blueprint C3

Complexity in organisms is determined by more than just the number of genes C4

Comparing the genomes of different organisms yields valuable insights C7

Health Care for You Alone C8

SNPs are a powerful means of characterizing individual genomes C9

SNP profiling will help identify the risk of getting certain diseases C9

SNP profiling may help provide individuals with tailored drug therapies C10

Genetic Testing Raises Ethical Issues C10

New prenatal genetic screening methods provide added choices—and dilemmas—for parents C10

Prenatal genetic screening combined with other technologies may encourage parents to choose embryos with the right genetics C11

SNP profiling may affect individual privacy and freedom in new ways C12

Review and Discussion C12

Unit 4—Evolution

Chapter 16: How Evolution Works 298

A Journey Begins 299

16.1 Biological Evolution: The Sum of Genetic Changes 300

16.2 Mechanisms of Evolution 301

Biology Matters: You Can't Live with 'Em, You Can't Live Without 'Em 302

16.3 Consequences of Evolution for Life on Earth 303

Adaptations result from natural selection 303

The diversity of life results from the splitting of one species into two or more species 303

Organisms share characteristics due to common descent 304

16.4 Strong Evidence Shows That Evolution Happens 305

Evolution is strongly supported by the fossil record 306

Organisms contain evidence of their evolutionary history 307

Continental drift and evolution explain the geographic locations of fossils 307

Direct observation reveals genetic changes within species 308

New species can be produced experimentally and their formation can be observed in nature 308

16.5 The Impact of Evolutionary Thought 309

Biology on the Job: Evolution's Champion 310

Evolution in Action 311

Chapter Review 314

Biology in the News: "What a Story Lice Can Tell" 317

Chapter 17: Evolution of Populations 318

Evolution of Resistance 319

17.1 Key Definitions: Allele and Genotype Frequencies 320

17.2 Genetic Variation: The Raw Material of Evolution 321

Mutation is one source of genetic variation 321

Recombination provides another source of genetic variation 321

17.3 Four Mechanisms Can Cause Populations to Evolve 321

17.4 Mutation: The Source of Genetic Variation 322

17.5 Gene Flow: Exchanging Alleles Between Populations 323

17.6 Genetic Drift: The Effects of Chance 323

Genetic drift affects small populations 323

Science Toolkit: Testing Whether Evolution Is Occurring in Natural Populations 324

Genetic bottlenecks can threaten the survival of populations 326

17.7 Natural Selection: The Effects of Advantageous Alleles 326

Even natural selection does not always lead to evolutionary change 326

There are three types of natural selection 328

17.8 Sexual Selection: Where Sex and Natural Selection Meet 329

17.9 Putting It All Together: How Evolution in Populations Works 331

Halting the Spread of Antibiotic Resistance 332

Biology Matters: You'll Just Have to Tough It Out 334

Chapter Review 335

Biology in the News: "WHO Urges End to Use of Antibiotics for Animal Growth" 337

Chapter 18: Adaptation and Speciation 338

Cichlid Mysteries 339

18.1 Adaptation: Adjusting to Environmental Challenges 340

There are many different kinds of adaptations 340

All adaptations share certain key characteristics 340

Populations can adjust rapidly to environmental change 341

Biology on the Job: Dog Show Judge Extraordinaire 342

- 18.2 Adaptation Does Not Craft Perfect Organisms 343**
 Lack of genetic variation can limit adaptation 343
 The multiple effects of developmental genes can limit adaptation 343
 Ecological trade-offs can limit adaptation 344
- 18.3 What Are Species? 344**
 Species are often morphologically distinct 344
 Species are reproductively isolated from one another 345
- 18.4 Speciation: Generating Biodiversity 346**
 Speciation can be explained by the same mechanisms that cause the evolution of populations 346
 Speciation often results from geographic isolation 348
 Speciation can occur without geographic isolation 348
- 18.5 Rates of Speciation 350**
- 18.6 Implications of Adaptation and Speciation 350**

Rapid Speciation in Lake Victoria Cichlids 350

Chapter Review 352

Biology in the News: "Humans' Ancestral Tree Adds a Twig" 354

Chapter 19: The Evolutionary History of Life 356

Puzzling Fossils in a Frozen Wasteland 357

- 19.1 The Fossil Record: A Guide to the Past 358**
 The fossil record is not complete 358
 Fossils reveal that whales are closely related to a group of hoofed mammals 360
- 19.2 The History of Life on Earth 361**
 The first single-celled organisms arose at least 3.5 billion years ago 361
 Multicellular life evolved about 650 million years ago 361
 Colonization of land followed the Cambrian explosion 362
- 19.3 The Effects of Continental Drift 364**
- 19.4 Mass Extinctions: Worldwide Losses of Species 365**
Biology Matters: Is a Mass Extinction Underway? 367
- 19.5 Adaptive Radiations: Increases in the Diversity of Life 368**
- 19.6 The Origin and Adaptive Radiation of Mammals 368**
 The mammalian jaw and teeth evolved from reptilian forms in three stages 368
 Mammals increased in size after the extinction of the dinosaurs 370
- 19.7 An Overview of the Evolutionary History of Life 370**
 Major new groups of organisms evolve from existing groups 370
 Macroevolution differs from the evolution of populations 371
Biology on the Job: Geerat Vermeij: A Hands-On Approach to Evolution 372

When Antarctica Was Green 373

Chapter Review 374

Biology in the News: "When Bats and Humans Were One and the Same" 376

Interlude D—Applying What We Learned: Humans and Evolution D1

Who Are We? Where Do We Come From? D1

We Are Apes D2

Hominid Evolution: From Climbing Trees to Walking Upright D3

Evolution in the Genus *Homo* D4

The Origin and Spread of Modern Humans D6

The Evolutionary Future of Humans D8

The Effects of Humans on Evolution D9

People have profound effects on microevolution in other species D9

People also alter macroevolutionary patterns D10

Biology Matters: Humans: The World's Dominant Evolutionary Force? D11

People sometimes attempt to control human evolution D11

Review and Discussion D13

Unit 5—Interactions with the Environment

Chapter 20: The Biosphere 378

The Tapestry of Life 379

- 20.1 Why Is Ecology Important? 380**
Biology Matters: The Costs of Introduced Species 381
- 20.2 Interactions with the Environment 382**
- 20.3 Climate Has a Large Effect on the Biosphere 383**
 Incoming solar radiation shapes climate 383
 Global movements of air and water shape climate 383
 The major features of Earth's surface also shape climate 385
- 20.4 Life on Land 385**
 The biosphere can be divided into biomes 385
 The location of terrestrial biomes is determined by climate and human actions 388
- 20.5 Life in Water 388**
 Aquatic biomes are influenced by terrestrial biomes and climate 389
 Aquatic biomes are also influenced by human activity 389
Science Toolkit: The Interplay of Science, Philosophy, and Ethics 391

The Human Impact on the Biosphere 392

Chapter Review 393

Biology in the News: "Cuban Tree Frogs Moving Toward South Carolina" 395

Chapter 21: Growth of Populations 396

The Tragedy of Easter Island 397

21.1 What Are Populations? 398

21.2 Changes in Population Size 398

21.3 Exponential Growth 400

Exponential growth results in rapid population increases 400

Biology Matters: How Fast Can Populations Grow? 400

Exponential growth often occurs when a species moves into a new area 401

21.4 Limits to Population Growth 401

Growth is limited by essential resources and other environmental factors 402

Some growth-limiting factors depend on population density; others do not 404

21.5 Patterns of Population Growth 404

Science Toolkit: Population Counts Help Save Endangered Species 406

21.6 Human Population Growth: Surpassing the Limits? 407

What Does the Future Hold? 408

Chapter Review 410

Biology in the News: "Desert City a Pool of West Nile Cases" 412

Chapter 22: Interactions among Organisms 414

Lumbering Mantises and Gruesome Parasites 415

22.1 Mutualisms 416

There are many types of mutualisms 416

Mutualists are in it for themselves 417

Mutualisms are everywhere 418

Mutualisms can determine the distribution and abundance of species 418

22.2 Exploitation 418

Consumers and their food organisms can exert strong selection pressure on each other 419

Consumers can alter the behavior of the organisms they eat 420

Consumers can restrict the distribution and abundance of their food organisms 420

Consumers can drive their food organisms to extinction 421

Science Toolkit: Answering Ecological Questions with Experiments 422

22.3 Competition 423

Competition can limit the distribution and abundance of species 423

Competition can increase the differences between species 424

22.4 Interactions among Organisms Shape Communities and Ecosystems 424

Parasites Often Alter Host Behavior 426

Chapter Review 427

Biology in the News: "At the Old Swimming Hole, a Vicious Cycle Thrives" 429

Chapter 23: Communities of Organisms 430

The Formation of a New Community 431

23.1 The Effects of Species Interactions on Communities 433

Food webs consist of multiple food chains 433

Keystone species have profound effects on communities 434

23.2 Communities Change over Time 434

Succession establishes new communities and replaces disturbed communities 435

Communities change as climate changes 437

23.3 Recovery from Disturbances 438

Communities can recover from some human-caused disturbances 438

People can cause long-term damage to communities 439

Changes in communities affect their value to humans 441

Biology on the Job: Designing with Nature 442

Introduced Species: Taking Island Communities by Stealth 443

Chapter Review 444

Biology in the News: "Linking Rivers, With Happy Results" 446

Chapter 24: Ecosystems 448

Is There a Free Lunch? 449

24.1 How Ecosystems Function: An Overview 450

24.2 Energy Capture in Ecosystems 451

The rate of energy capture varies across the globe 452

Human activities can increase or decrease NPP 453

24.3 Energy Flow Through Ecosystems 454

An energy pyramid shows the amount of energy transferred up a food chain 454

Secondary productivity is highest in areas of high NPP 455

24.4 Nutrient Cycles 455

Biology on the Job: From Corn to Cars 456

Sulfur is one of several important nutrients with an atmospheric cycle 457

Phosphorus is the only major nutrient with a sedimentary cycle 458

Human activities can alter nutrient cycles 458

24.5 Ecosystem Design 459

The Economic Value of Ecosystem Services 461

Biology Matters: How Much Are Lakes and Rivers Worth? 463

Chapter Review 463

Biology in the News: "Marvel Chemicals Pop Up in Animals All Over World" 466

Chapter 25: Global Change 468

Devastation on the High Seas 469

25.1 Land and Water Transformation 470

There is ample evidence of land and water transformation 470
Land and water transformation have important consequences 471

25.2 Changes in the Chemistry of Earth 472

25.3 Changes in the Global Nitrogen Cycle 473

25.4 Changes in the Global Carbon Cycle 473

Science Toolkit: From Science to Public Policy and Back: Repairing the
Ozone Layer 474

Atmospheric carbon dioxide levels have risen dramatically 475
Increased carbon dioxide concentrations have many biological effects 476

25.5 Global Warming 477

Global temperatures appear to be rising 477
What will the future bring? 478

A Message of Ecology 479

Biology Matters: What's the Size of Your Footprint? 480

Chapter Review 480

Biology in the News: "Risk to State Dire in Climate Study" 482

APPENDIX: THE HARDY-WEINBERG EQUILIBRIUM APP1

SUGGESTED READINGS SR1

TABLE OF METRIC-ENGLISH CONVERSION T1

ANSWERS TO SELF-QUIZ QUESTIONS AS1

ANSWERS TO REVIEW QUESTIONS AR1

GLOSSARY GL1

CREDITS CR1

INDEX I1

Interlude E—Applying What We Learned: Building a Sustainable Society E1

The State of the World E1

The Current Human Impact Is Not Sustainable E2

Declining water resources are a serious problem E3
Global deforestation continues at an alarming rate E3

Sources of Hope for the Future E5

Awareness and understanding are the first steps to solving environmental
problems E5
Individual actions can have a ripple effect E6
New research tools are being used to measure human impacts E7
Government has an important role to play E10
Business participation is crucial E11

Review and Discussion E12