

Contents

1 Biology, the Study of Life 2

LOOKING AT LIFE Fire Ants Protect Their Own 2

The Process of Science 4

- 1.1 Scientists use a preferred method 4
- **1.2** Many experiments have test and control groups 6

The Cell Theory 9

1.3 Cells are the fundamental unit of living things 9

The Gene Theory 10

1.4 Organisms have a genetic inheritance 10

The Theory of Homeostasis 11

1.5 Organisms regulate their internal environment 11

The Theory of Ecosystems 12

1.6 The biosphere is divided into ecosystems 12

The Theory of Evolution 13

- **1.7** The ancestry of species can be determined 13
- **1.8** Evolutionary relationships help biologists group organisms 14
- **1.9** Evolution through natural selection results in adaptation to the environment 16
- **1.10** Evolution from a common ancestor accounts for the characteristics of life 18

UNIT 1

Organisms Are Composed of Cells 22

2 Basic Chemistry of Cells 22

LOOKING AT LIFE: Life Depends on Water 22

The Atoms of Cells 24

2.1 Six types of atoms are basic to life 24

Atoms Form Molecules 27

- **2.2** After atoms react, they have a completed outer shell 27
- 2.3 Ionic bonds and covalent bonds are common 28
- 2.4 A covalent bond can be nonpolar or polar 30

The Properties of Water 31

2.5 Water molecules stick together and to other materials 31

- 2.6 Both frozen and liquid water help organisms maintain a normal temperature 32
- 2.7 Water dissolves other polar substances 33

Acids, Bases, and pH 34

- 2.8 Acids and bases affect cells and organisms 34
- 2.9 The pH scale measures acidity and basicity 35

3 Organic Molecules of Cells 40

LOOKING AT LIFE: Plants and Animals Are the Same but Different 40

Fundamentals of Organic Chemistry 42

- **3.1** The chemistry of carbon makes diverse molecules possible 42
- **3.2** Molecular subunits can be linked to form varied large biomolecules 44

Carbohydrates 45

- 3.3 Simple carbohydrates provide quick energy 45
- **3.4** Complex carbohydrates store energy and provide structural support 46

Lipids 47

- 3.5 Fats and oils are rich energy-storage molecules 47
- **3.6** Other lipids have structural, hormonal, or protective functions 48

Proteins 50

- **3.7** Proteins are the most versatile of life's molecules 50
- 3.8 The shape of a protein is necessary to its function 51

Nucleic Acids 54

- 3.9 DNA stores coded information 54
- 3.10 The nucleotide ATP is the cell's energy carrier 56

4 Structure and Function of Cells 60

LOOKING AT LIFE: Cells: What Are They? 60

The Cellular Level of Organization 62

- 4.1 All organisms are composed of cells 62
- 4.2 Prokaryotic cells evolved first 65
- **4.3** Eukaryotic cells contain specialized organelles: An overview 66

The Nucleus and Endomembrane System 68

4.4 The nucleus is a control center 68

- **4.5** The ER produces and transports proteins and lipids to the Golgi apparatus 70
- **4.6** The organelles of the endomembrane system work together 72

Vacuoles and Vesicles 73

- **4.7** Vacuoles are common in plant cells 73
- 4.8 Peroxisomes have many different functions 73

Chloroplasts and Mitochondria 74

4.9 Chloroplasts and mitochondria have opposite functions 74

The Cytoskeleton and Cell Movement 76

- **4.10** The cytoskeleton maintains cell shape and assists movement 76
- The Eukaryotic Cell in Review 78

5 Dynamic Activities of Cells 82

LOOKING AT LIFE: Life Is Organized 82

The Plasma Membrane Structure and Function 84

5.1 The plasma membrane is a phospholipid bilayer with embedded proteins 84

The Passage of Molecules Into and Out of Cells 86

- **5.2** Diffusion across a membrane requires no energy input 86
- **5.3** Active transport and bulk transport require energy input 88

The Plasma Membrane and Cell Communication 90

5.4 Extracellular material allows cells to join together and communicate 90

Energy Transformations in Organisms and Cells 92

- 5.5 Energy makes things happen 92
- 5.6 Cellular work is powered by ATP 94

Enzyme Function and Metabolic Pathways 96

5.7 Enzymes speed reactions 96

6 Pathways of Photosynthesis 102

LOOKING AT LIFE: The Sun Drives Photosynthesis 102

Overview of Photosynthesis 104

- **6.1** Photosynthesizers are autotrophs that produce their own food 104
- **6.2** Photosynthesis involves two sets of reactions: The light reactions and the Calvin cycle reactions 106

The Light Reactions—Harvesting Energy 107

- 6.3 Solar energy is absorbed by pigments 107
- 6.4 Solar energy boosts electrons to a higher energy level 108
- **6.5** Solar energy is converted to the chemical energy of ATP 108
- **6.6** The noncyclic flow of electrons produces ATP and NADPH 109
- 6.7 A thylakoid is highly organized for its task 111

The Calvin Cycle Reactions—Making Sugars 112

- **6.8** ATP and NADPH from the light-dependent reactions are needed to produce a carbohydrate 112
- **6.9** In photosynthesizers, a carbohydrate is the starting point for other molecules 113

Types of Photosynthesis 114

6.10 C3, C4, and CAM photosynthesis thrive under different conditions 114

7 Pathways of Cellular Respiration 120

LOOKING AT LIFE: ATP Is Universal 120

Overview of Cellular Respiration 122

7.1 Cellular respiration is a redox reaction that requires O₂ 122

Outside the Mitochondria: Glycolysis 124

7.2 Glycolysis: Glucose breakdown begins 124

Inside the Mitochondria 126

- **7.3** The preparatory reaction occurs before the Krebs cycle 126
- 7.4 The Krebs cycle generates much NADH 127
- **7.5** The electron transport chain captures energy and ATP synthase produces ATP 128
- **7.6** The ATP payoff can be calculated 130

Fermentation 131

7.7 When oxygen is in short supply, the cell switches to fermentation 131

Intersections of Metabolic Pathways 133

7.8 Organic molecules can be broken down and synthesized as needed 133

UNIT 2

Genes Control the Traits of Organisms 138

8 Cellular Reproduction 138

LOOKING AT LIFE: Cancer Is a Genetic Disorder 138

The Cell Cycle 140

8.1 Cellular reproduction depends on the cell cycle 140

Mitosis: Division of Nucleus 142

- **8.2** Following mitosis, daughter cells have the same chromosome count as the parent cell 142
- **8.3** Mitosis has a set series of phases 144

Cytokinesis: Division of Cytoplasm 146

8.4 Cytokinesis follows mitosis 146

Cell Cycle Control and Cancer 148

- 8.5 Cell cycle control depends on checkpoints 148
- 8.6 Cancer cells are distinctly abnormal 149

9 Sexual Reproduction 154

LOOKING AT LIFE: Sex—What is it? 154

The Basics of Meiosis 156

- 9.1 Chromosomes come in pairs 156
- 9.2 Homologues separate during meiosis 157

The Phases of Meiosis 158

- **9.3** Events of meiosis l increase genetic variation among the gametes 158
- 9.4 Both meiosis I and meiosis II have four phases 160
- 9.5 Meiosis can be compared to mitosis 163

Chromosome Number Anomalies 164

- **9.6** Nondisjunction causes chromosome number anomalies 164
- **9.7** Chromosome number anomalies cause syndromes 165

10 Patterns of Genetic Inheritance 170

LOOKING AT LIFE: Troubles with Dog Breeding 170

Mendel's Laws 172

- **10.1** Mendel developed a particulate model of inheritance 172
- 10.2 Mendel's law of segregation describes how gametes pass on traits 174
- 10.3 Mendel's law of independent assortment describes inheritance of multiple traits 176
- 10.4 Support for Mendel's laws is various 178

Mendel's Laws Apply to Humans 180

- 10.5 Pedigrees can reveal the patterns of inheritance 180
- **10.6** Some human genetic disorders are autosomal recessive and some are autosomal dominant 182

Beyond Mendel's Laws 184

- 10.7 Variations in the recessive/dominant allele relationship occur 184
- **10.8** Variations in the one gene–one trait relationship occur 185

Sex-Linked Inheritance 187

- **10.9** Traits transmitted via the X chromosome have a unique pattern of inheritance 187
- 10.10 Humans have X-linked recessive disorders 188

11 Molecular Biology of Inheritance 192

LOOKING AT LIFE: Arabidopsis Is a Model Organism 192

DNA and RNA Structure and Function 194

- **11.1** DNA and RNA are polymers of nucleotides 194
- **11.2** DNA is a double helix 196

DNA Replication 198

11.3 DNA replication is semiconservative 198

Gene Expression 200

- **11.4** Transcription is the first step in gene expression 200
- **11.5** Translation is the second step in gene expression: An overview 202
- **11.6** During translation, polypeptide synthesis occurs one amino acid at a time 204
- 11.7 Let's review gene expression 205

Mutations: Altered Gene Expression 206

- 11.8 Genetic mutations affect a single allele 206
- 11.9 Chromosomal mutations affect several alleles 208

12 Regulation of Gene Activity 214

LOOKING AT LIFE: Moth and Butterfly Wings Tell a Story 214

Transcriptional Control 216

- **12.1** DNA-binding proteins usually turn genes off in prokaryotes 216
- **12.2** DNA-binding proteins usually turn genes on in eukaryotes 217
- **12.3** Histones regulate accessibility of DNA for transcription 218
- **12.4** Hox proteins are DNA-binding proteins active during development 220

Posttranscriptional Control 222

- **12.5** Alternative mRNA splicing results in varied gene products 222
- **12.6** Small RNA (sRNA) molecules fine-tune gene expression 222

Translational and Posttranslational Control 224

12.7 Both the activity of mRNA and the protein product are regulated 224

Cancer: Lack of Cell Cycle Control 226

12.8 Two types of genes ordinarily control the cell cycle 226

13 Biotechnology and Genomics 232

LOOKING AT LIFE: Witnessing Genetic Engineering 232

- Cloning of Organisms, Genes, and DNA Segments 234
- 13.1 Animals can be cloned using surrogate mothers 234
- 13.2 Genes can be cloned in bacteria 235
- 13.3 DNA segments can be cloned in a test tube 236

Biotechnology Products and Genetically

Modified Organisms 237

- **13.4** Genetically modified bacteria produce useful products 237
- **13.5** Plants can be genetically modified 238
- 13.6 Animals can be genetically modified 240
- **13.7** A person's genome can be modified 241

The Human Genome and How It Functions 242

- 13.8 The human genome has been sequenced 242
- **13.9** The genome contains coding and noncoding DNA 243
- **13.10** Functional and comparative genomics analyze the human genome 244

- 13.11 Proteomics analyzes the proteins in human cells 246
- **13.12** Bioinformatics assists the study of genomics and proteomics 249

UNIT 3

Organisms Are Related and Adapted to Their Environment 254

14 Evidence of Evolution 254

LOOKING AT LIFE: The "Vice Versa" of Animals and Plants 000

Darwin Collected Evidence of Evolution 254

- **14.1** Observations support and give evidence for evolution 256
- 14.2 Natural selection is a mechanism for evolution 258

More Evidence of Evolution 260

- **14.3** Fossils provide powerful evidence for common descent 260
- 14.4 Anatomic evidence supports common descent 262
- **14.5** Biogeographic evidence supports common descent 264
- 14.6 Molecular evidence supports common descent 265

Evidence Through Study of Populations 266

- 14.7 Gene pool frequency changes determine evolution 266
- **14.8** Both mutations and sexual recombination produce variations 267
- **14.9** Nonrandom mating and gene flow change gene pool frequencies 267
- **14.10** Genetic drift is more likely to alter gene pool frequencies in small populations 269
- **14.11** Natural selection can be stabilizing, directional, or disruptive 270
- 14.12 Sexual selection influences who reproduces 272
- 14.13 How variations are maintained in a population 274

15 Speciation and Evolution 278

LOOKING AT LIFE: Hybrid Animals Do Exist 278

Diversity Requires Speciation 280

- **15.1** Species have been defined in more than one way 280
- **15.2** Reproductive barriers maintain genetic differences between species 282

Speciation Due to Geographic Separation 284

- **15.3** Allopatric speciation utilizes a geographic barrier 284
- 15.4 Adaptive radiation produces many related species 286

Speciation Without Geographic Separation 287

15.5 Speciation occasionally occurs without a geographic barrier 287

Principles of Macroevolution 289

- 15.6 Speciation occurs at different tempos 289
- **15.7** Development plays a role in speciation 292
- 15.8 Speciation is not goal-oriented 294

16 The Evolutionary History of Life on Earth 298

LOOKING AT LIFE: Motherhood Among Dinosaurs 298

Fossils Tell a Story 300

- **16.1** The geologic timescale is based on the fossil record 300
- **16.2** Continental drift has affected the history of life 302
- 16.3 Mass extinctions have affected the history of life 303

Linnaean Systematics 304

- 16.4 Organisms can be classified into categories 304
- **16.5** The three-domain system divides all organisms into three large groups 306

Modern Systematics: Cladistics 308

- 16.6 Cladograms reflect evolutionary history 308
- 16.7 Certain types of data are used to trace phylogeny 311

17 Evolution of Microbial Life 316

LOOKING AT LIFE: At Your Service: Viruses and Bacteria 316

Viruses, Viroids, and Prions 318

- 17.1 Viruses have a simple structure 318
- 17.2 Some viruses reproduce inside bacteria 319
- **17.3** Viruses are responsible for a number of plant diseases 320
- **17.4** Viruses also reproduce inside animal cells and cause animal diseases 322

Origin of Life 328

- **17.5** Experiments show how small organic molecules may have first formed 325
- 17.6 RNA may have been the first macromolecule 326

The Prokaryotes 000

- 17.7 Prokaryotes have unique structural features 328
- 17.8 Prokaryotes reproduce by binary fission 329
- 17.9 How genes are transferred between bacteria 330
- 17.10 Prokaryotes have various means of nutrition 332
- 17.11 Some archaea live in extreme environments 334
- **17.12** Prokaryotes have medical and environmental importance 335

18 Evolution of Protists 340

LOOKING AT LIFE: Protists Cause Disease Too 340

Diversity of Protists 342

- 18.1 Eukaryotic organelles arose by endosymbiosis 342
- 18.2 Protists differ in many ways 343

Protozoan Protists 346

- 18.3 Protozoans called flagellates move by flagella 346
- 18.4 Protozoans called amoeboids move by pseudopods 347
- **18.5** Protozoans called ciliates move by cilia 348
- 18.6 Some protozoans are not motile 349

Protists Called "Molds" 350

18.7 The diversity of protists includes slime molds and water molds 350

Algal Protists 351

- **18.8** The diatoms and dinoflagellates are significant algae in the oceans 351
- 18.9 Red algae and brown algae are multicellular 352
- 18.10 Green algae are ancestral to plants 353

19 Evolution of Plants and Fungi 358

LOOKING AT LIFE: Some Plants Are Carnivorous 358

Evolution of Plants 360

- 19.1 Plants have a green algal ancestor 360
- 19.2 Plants have an alternation-of-generations life cycle 362

Diversity of Plants 364

- **19.3** Bryophytes protect the embryo and have apical growth 364
- 19.4 Lycophytes have vacular tissue for transport 366
- 19.5 Ferns have large leaves called megaphylls 367
- **19.6** Most gymnosperms bear cones on which the seeds are "naked" 370
- **19.7** Angiosperms have flowers in which the seeds are "covered" 373

Evolution and Diversity of Fungi 378

- 19.8 Fungi differ from plants and animals 378
- **19.9** Land fungi occur in three main groups 380

20 Evolution of Animals 386

LOOKING AT LIFE: The Secret Life of Bats 386

Animals and How They Evolved 388

- 20.1 Animals have distinctive characteristics 388
- **20.2** The phylogenetic tree of animals is based on molecular and anatomic data 390

The Invertebrates 392

- 20.3 Sponges are multicellular animals 393
- **20.4** Cnidarians are radially symmetrical with two tissue layers 394
- 20.5 Flatworms are trochozoans without a coelom 395
- **20.6** A coelom gives complex animals certain advantages 398
- 20.7 Molluscs have a three-part body plan 399
- 20.8 Annelids are the segmented worms 400
- 20.9 Roundworms are nonsegmented and plentiful 401
- 20.10 Arthropods have jointed appendages 402
- **20.11** Echinoderms are radially symmetrical as adults 405

The Vertebrates 406

- 20.12 Four features characterize chordates 406
- **20.13** Jaws, a bony skeleton, and lungs evolved among the fishes 408
- 20.14 Amphibians are tetrapods that can move on land 409

- **20.15** Reptiles have an amniotic egg and can reproduce on land 410
- 20.16 Mammals have hair and mammary glands 412

21 Evolution of Humans 418

LOOKING AT LIFE: Meet Ardi 418

Evolution of Primates 420

- 21.1 Primates are adapted to live in trees 420
- 21.2 All primates evolved from a common ancestor 423

Evolution of Humans 424

- **21.3** The early humanlike hominins could walk upright 424
- **21.4** Mosaic evolution continues and produces the first humans 426

Evolution of Modern Humans 429

- 21.5 Cro-Magnons replaced the other Homo species 429
- **21.6** Cro-Magnons were socially advanced 430
- 21.7 Humans belong to one species 432

UNIT 4

Plants Are Homeostatic 436

22 Plant Organization and Homeostasis 436

LOOKING AT LIFE: Plants Fuel You (and Soon Your Car) 436

Organs and Tissues of Flowering Plants 438

- **22.1** Flowering plants typically have roots, stems, and leaves 438
- 22.2 Flowering plants are either monocots or eudicots 440
- **22.3** Plants have specialized cells and tissues 442
- **22.4** The three types of plant tissues are present in each organ 444

Growth of Roots and Stems 446

- **22.5** Primary growth lengthens the root and shoot systems 446
- 22.6 Secondary growth widens roots and stems 448

Homeostatic Mechanisms of Plants 450

22.7 Leaves carry on photosynthesis and help maintain homeostasis 450

23 Transport and Nutrition in Plants 456

LOOKING AT LIFE: Reach for the Stars 456

Xylem and Phloem Structure 458

23.1 Transport begins in both the roots and the leaves of a plant 458

Water Transport in Xylem 460

- **23.2** Water is pulled up in xylem by evaporation from leaves 460
- 23.3 Guard cells regulate water loss at leaves 462

XX CONTENTS

Organic Nutrient Transport in Phloem 464

23.4 Pressure flow explains phloem transport 464

Plant Nutrition and Soil 466

- 23.5 Certain nutrients are essential to plants 466
- **23.6** Roots are specialized for the uptake of water and minerals 468
- 23.7 Adaptations of plants help them acquire nutrients 470

24 Control of Growth Responses in Plants 474

LOOKING AT LIFE: Plastic Trees 474

Plant Hormones 476

- **24.1** Plant hormones act by utilizing signal transduction pathways 476
- 24.2 Auxins promote growth and cell elongation 477
- 24.3 Gibberellins control stem elongation 478
- **24.4** Cytokinins stimulate cell division and differentiation 479
- **24.5** Abscisic acid suppresses growth of buds and closes stomata 480
- 24.6 Ethylene stimulates the ripening of fruits 481

Plant Responses to the Abiotic Environment 482

- 24.7 Tropisms occur when plants respond to stimuli 482
- **24.8** Turgor and sleep movements are complex responses 484
- **24.9** Response to the photoperiod requires phytochrome 486
- **24.10** Flowering is a response to the photoperiod in some plants 487

Plant Responses to the Biotic Environment 488

24.11 Plants respond to other organisms in the environment 488

25 Reproduction in Plants 494

LOOKING AT LIFE: With a Little Help 494

Sexual Reproductive Strategies 496

- **25.1** Plants have a sexual life cycle called alternation of generations 496
- **25.2** Pollination and fertilization bring gametes together during sexual reproduction 500

Seed Development and Growth 502

- **25.3** A sporophyte embryo and its cotyledons develop as a seed matures 502
- **25.4** The ovary becomes a fruit, which assists in sporophyte dispersal 503
- 25.5 With seed germination, the life cycle is complete 504

Asexual Reproductive Strategies 505

- 25.6 Plants have various ways of reproducing asexually 505
- **25.7** Cloning of plants in tissue culture assists agriculture 506

UNIT 5

Animals Are Homeostatic 510

26 Animal Organization and Homeostasis 510

LOOKING AT LIFE: Staying Warm, Staying Cool 510

Types of Tissues 000

- **26.1** Levels of biological organization are evident in animals 512
- **26.2** Epithelial tissue covers organs and lines body cavities 512
- **26.3** Connective tissue connects and supports other tissues 512
- **26.4** Muscular tissue is contractile and moves body parts 516
- **26.5** Nervous tissue communicates with and regulates the functions of the body's organs 517

Organs and Organ Systems 518

- **26.6** Each organ has a specific structure and function 518
- **26.7** Several organs work together to carry out the functions of an organ system 520

Homeostasis 522

- 26.8 Body systems contribute to homeostasis 522
- **26.9** Homeostasis is achieved through negative feedback mechanisms 523

27 Coordination by Neural Signaling 528

LOOKING AT LIFE: Getting a Head 528

Nervous Systems 530

- **27.1** Vertebrates have well-developed central and peripheral nervous systems 530
- 27.2 Axons conduct nerve impulses 532
- **27.3** Communication between neurons occurs at synapses 534

The Central Nervous System (CNS) 538

- 27.4 The spinal cord communicates with the brain 538
- **27.5** The other parts of the brain have specialized functions 540
- **27.6** The limbic system is involved in memory and learning as well as in emotions 542

The Peripheral Nervous System (PNS) 543

- **27.7** The peripheral nervous system contains cranial and spinal nerves 543
- 27.8 The somatic system can respond quickly to stimuli 544
- **27.9** The autonomic system controls the actions of internal organs 545

Drug Abuse 546

27.10 Certain neurotransmitters are known to affect behavior and emotional attributes 546

28 Sense Organs 552

LOOKING AT LIFE: The Eyes Have It 552

Sensory Receptors 554

28.1 Sensory receptors differ but function similarly 554

Chemical Senses 556

28.2 Chemoreceptors are exemplified by taste buds and olfactory cells 556

Sense of Vision 558

- 28.3 The vertebrate eye is a camera-type eye 558
- 28.4 The retina sends information to the visual cortex 560

Sense of Hearing and Balance 562

- **28.5** The mammalian ear has three well-developed regions 562
- **28.6** Mammalian balance receptors are in the inner ear 566

Somatic Senses 568

28.7 Mammalian proprioceptors are located in skeletal muscles 568

29 Locomotion and Support Systems 572

LOOKING AT LIFE: Skeletal Remains Reveal All 572

Diversity of Skeletons 574

- **29.1** Animal skeletons can be hydrostatic, external, or internal 574
- 29.2 A skeleton serves many functions 575

Mammalian Skeleton 576

- **29.3** The bones of the axial skeleton lie in the midline of the body 576
- **29.4** The appendicular skeleton consists of bones in the girdles and limbs 578
- 29.5 Bones and joints are composed of living tissues 580

Vertebrate Skeletal Muscles 583

- 29.6 Skeletal muscles primarily cause bones to move 583
- 29.7 Muscles contract at the cellular level 586

30 Circulation and Cardiovascular Systems 592

LOOKING AT LIFE: Not All Animals Have Red Blood 592

Invertebrate Circulatory Systems 594

30.1 A circulatory system serves the needs of cells 594

Vertebrate Cardiovascular Systems 596

- **30.2** The mammalian heart is a double pump 596
- **30.3** The structure of blood vessels is suited to their function 600
- **30.4** Blood vessels form two circuits in mammals 602

Blood 604

- 30.5 Blood is a liquid tissue 604
- **30.6** Exchanges between blood and tissue fluid occur at capillaries 606
- **30.7** Blood types must be matched for transfusions 607

31 Lymph Transport and Immunity 612

LOOKING AT LIFE: HIV/AIDS: A Global Disaster 612

The Lymphatic System 614

31.1 Lymphatic vessels transport lymph 614

Innate Immunity 616

- **31.2** Barriers to entry, protective proteins, and white blood cells are first responders 616
- **31.3** The inflammatory response is a localized response to invasion 618

Adaptive Immunity 619

- 31.4 Adaptive immunity targets a specific antigen 619
- **31.5** Lymphocytes are directly responsible for adaptive immunity 620
- 31.6 Antibody-mediated immunity involves B cells 621
- **31.7** Cell-mediated immunity involves several types of T cells 622

Immune System Failures 625

31.8 Autoimmune disorders can result in long-term illnesses 625

32 Digestive Systems and Nutrition 630

LOOKING AT LIFE: How to Tell a Carnivore from an Herbivore 630

How Animals Acquire and Process Food 632

32.1 Animals have various ways to obtain food before processing occurs 632

Mammalian Organs of Digestion 636

- **32.2** Some digestion occurs before food reaches the stomach 636
- **32.3** Digestion mainly takes place in the stomach and small intestine 638
- **32.4** The large intestine absorbs water and prepares wastes for elimination 640

Pancreas and Liver Are Vital Organs 642

32.5 Pancreas and liver contribute to chemical digestion 642

Nutrition 643

- **32.6** Carbohydrates, lipids, and proteins supply nutrients 643
- **32.7** Minerals and vitamins have various roles in the body 645

33 Gas Exchange and Transport in Animals 652

LOOKING AT LIFE: Free-Diving Is Dangerous 652

Gas-Exchange Surfaces 654

- 33.1 Respiration involves several steps 654
- 33.2 Gills are an efficient gas-exchange surface in water 656
- **33.3** The tracheal system in insects permits direct gas exchange 657
- **33.4** The human ventilation system utilizes lungs as a gasexchange surface 658

Ventilation and Transport of Gases 660

- 33.5 Breathing brings air into and out of the lungs 660
- 33.6 External and internal respiration require no energy 662

34 Osmoregulation and Excretion 668

LOOKING AT LIFE: Do Coral Reef Animals Regulate? 668

Comparative Excretory Organs 67

- **34.1** The nitrogenous waste product of animals varies according to the environment 670
- 34.2 Many invertebrates have organs of excretion 671

Mammalian Urinary System 674

- **33.3** The urinary system includes kidneys that contain tubules 674
- 33.4 The kidney tubules produce urine 676

Kidneys and Homeostasis 678

- **34.5** The kidneys can concentrate urine to maintain water-salt balance 678
- 34.6 Lungs and kidneys maintain acid-base balance 679

35 Coordination by Hormone Signaling 684

LOOKING AT LIFE: Pheromones Among Us 684

The Endocrine System 686

- **35.1** The endocrine and nervous systems work together 686
- 35.2 Hormones affect cellular metabolism 688

The Hypothalamus and the Pituitary Gland 690

35.3 The hypothalamus is a part of the nervous and endocrine systems 690

Hormones and Homeostasis 692

- **35.4** Growth hormone controls the height of an individual 692
- **35.5** The thyroid and the parathyroids regulate metabolism 693
- 35.6 The adrenal glands respond to stress 694
- 35.7 The pancreas regulates the blood sugar level 696
- **35.8** The pineal gland is involved in biorhythms 697

36 Reproduction and Development 702

LOOKING AT LIFE: How to Do It on Land 702

How Animals Reproduce 704

36.1 Both asexual and sexual reproduction occur among animals 704

Human Reproductive Systems 706

- **36.2** Testes are the male gonads 706
- 36.3 Ovaries are the female gonads 708
- 36.4 The ovarian cycle drives the uterine cycle 710

Early Developmental Stages and Processes 714

- **36.5** Cellular stages of development precede tissue stages 714
- **36.6** Tissue stages of development precede organ stages 715
- **36.7** Organ stages of development occur after tissue stages 716
- **36.8** Cellular differentiation begins with cytoplasmic segregation 717
- 36.9 Morphogenesis involves induction also 718

Human Embryonic and Fetal Development 719

- **36.10** Extraembryonic membranes are critical to human development 719
- **36.11** Embryonic development involves tissue and organ formation 720
- **36.12** Fetal development involves refinement and weight gain 722
- 36.13 Pregnancy ends with the birth of the newborn 724

UNIT 6

Organisms Live in Ecosystems 728

37 Population Ecology 728

LOOKING AT LIFE: When a Population Grows Too Large 728

Scope of Ecology 730

37.1 Ecology is studied at various levels 730

How Populations Change Over Time 731

- **37.2** Density and distribution are aspects of population structure 731
- 37.3 The growth rate results in population size changes 732
- **37.4** Patterns of population growth can be described graphically 734

Regulation of Population Size 735

- 37.5 Density-independent factors affect population size 735
- **37.6** Density-dependent factors affect large populations more 736

Life History Patterns 737

37.7 Life history patterns consider several population characteristics 737

Human Population Growth 739

37.8 World population growth is exponential 739

38 Behavioral Ecology 744

LOOKING AT LIFE: For the Benefit of All 744

Inheritance and Learning Influence Behavior 746

- 38.1 Inheritance influences behavior 746
- 38.2 Learning can also influence behavior 748
- 38.3 Associative learning links behavior to stimuli 749

Behaviors That Increase Fitness 750

- 38.4 Behaviors that increase fitness 750
- 38.5 Sexual selection increases fitness 751
- 38.6 Societies increase fitness 752

Animal Communication Suits the Environment 754

38.7 Communication with others involves the senses 754

39 Community and Ecosystem Ecology 760

LOOKING AT LIFE: Ridding the Land of Waste 760

Community Interactions 762

- **39.1** Competition can lead to resource partitioning 762
- **39.2** Predator-prey interactions affect both populations 764
- **39.3** Parasitism benefits one population at another's expense 766
- 39.4 Commensalism benefits only one population 766
- **39.5** Mutualism benefits both populations 768

Community Development 769

39.6 During ecological succession, community composition and diversity change 769

Dynamics of Ecosystems 772

- **39.7** Ecosystems have biotic and abiotic components 772
- **39.8** Energy flow and chemical cycling characterize ecosystems 773
- **39.9** Energy flow involves food webs and food chains 774
- 39.10 Ecological pyramids are based on trophic levels 775
- **39.11** Chemical cycling includes reservoirs, exchange pools, and the biotic community 776
- 39.12 The phosphorus cycle is sedimentary 776
- 39.13 The nitrogen cycle is gaseous 777
- 39.14 The carbon cycle is gaseous 778

40 Major Ecosystems of the Biosphere 782

LOOKING AT LIFE: Life Under Glass 782

Climate and the Biosphere 784

- 40.1 Solar radiation and winds determine climate 784
- **40.2** Topography and other effects also influence climate 785
- 40.3 Ocean currents affect climate 786

Terrestrial Ecosystems 787

- **40.4** Major terrestrial ecosystems are characterized by particular climates 787
- 40.5 The tundra is cold and dark much of the year 788
- **40.6** Coniferous forests are dominated by gymnosperms 788
- 40.7 Temperate deciduous forests have abundant life 790
- 40.8 Temperate grasslands have extreme seasons 790
- 40.9 Savannas have wet-dry seasons 791
- 40.10 Deserts have very low annual rainfall 791
- **40.11** Tropical rain forests are warm with abundant rainfall 792

Aquatic Ecosystems 793

- 40.12 Fresh water flows into salt water 793
- **40.13** Marine ecosystems include those of the coast and the ocean 794

41 Conservation Biology 800

LOOKING AT LIFE: Trouble in Paradise 800

Conservation Biology and Biodiversity 802

- 41.1 Conservation biology is a practical science 802
- **41.2** The direct value of biodiversity is becoming better recognized 804
- 41.3 The indirect value of biodiversity is immense 806

Causes of Species Extinctions 807

- **41.4** Habitat loss is a major cause of wildlife extinctions 807
- **41.5** Introduction of alien species contributes to extinctions 808
- 41.6 Pollution contributes to extinctions 809
- 41.7 Overexploitation contributes to extinctions 811
- 41.8 Disease contributes to extinctions 811

Achieving Species Preservation 812

- **41.9** Habitat preservation is of primary importance 812
- **41.10** Habitat restoration is sometimes necessary 813

Achieving a Sustainable Human Society 815

- 41.11 A sustainable society will preserve resources 815
- 41.12 Energy sources should be renewable 816
- 41.13 Water sources should be conserved 817
- **41.14** Agriculture can be more diverse 818

Appendix A Answer Key A-1

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