Brief Contents

Preface xxiii

To the Student xxx

PART ONE: The Organization of Life

- 1 A View of Life 1
- 2 Atoms and Molecules: The Chemical Basis of Life **26**
- 3 The Chemistry of Life: Organic Compounds 46
- 4 Organization of the Cell 73
- 5 Biological Membranes 106
- 6 Cell Communication 131

PART TWO: Energy Transfer through Living Systems

- 7 Energy and Metabolism 150
- 8 How Cells Make ATP: Energy-Releasing Pathways **167**
- 9 Photosynthesis: Capturing Light Energy 187

PART THREE: The Continuity of Life: Genetics

- 10 Chromosomes, Mitosis, and Meiosis 206
- 11 The Basic Principles of Heredity 228
- 12 DNA: The Carrier of Genetic Information 253
- 13 Gene Expression 272
- 14 Gene Regulation 297
- 15 DNA Technology and Genomics 315
- 16 Human Genetics and the Human Genome **340**
- 17 Developmental Genetics 362

PART FOUR: The Continuity of Life: Evolution

- 18 Introduction to Darwinian Evolution 385
- 19 Evolutionary Change in Populations 406
- 20 Speciation and Macroevolution 421
- 21 The Origin and Evolutionary History of Life **442**
- 22 The Evolution of Primates 461

PART FIVE: The Diversity of Life

- 23 Understanding Diversity: Systematics 478
- 24 Viruses and Subviral Agents 499
- 25 Bacteria and Archaea 517
- 26 Protists 539
- 27 Seedless Plants 563

28 Seed Plants 584

- 29 The Fungi 603
- 30 An Introduction to Animal Diversity 628
- 31 Sponges, Cnidarians, Ctenophores, and Protostomes 641
- 32 The Deuterostomes 676

PART SIX: Structure and Life Processes in Plants

- 33 Plant Structure, Growth, and Development 710
- 34 Leaf Structure and Function 729
- 35 Stem Structure and Transport 745
- 36 Roots and Mineral Nutrition 762
- 37 Reproduction in Flowering Plants 782
- 38 Plant Developmental Responses to External and Internal Signals **803**

PART SEVEN: Structure and Life Processes in Animals

- 39 Animal Structure and Function: An Introduction 821
- 40 Protection, Support, and Movement 842
- 41 Neural Signaling 860
- 42 Neural Regulation 882
- 43 Sensory Systems 911
- 44 Internal Transport 936
- 45 The Immune System: Internal Defense 962
- 46 Gas Exchange 991
- 47 Processing Food and Nutrition 1010
- 48 Osmoregulation and Disposal of Metabolic Wastes **1032**
- 49 Endocrine Regulation 1050
- 50 Reproduction 1074
- 51 Animal Development 1104
- 52 Animal Behavior 1124

PART EIGHT: The Interactions of Life: Ecology

- 53 Introduction to Ecology: Population Ecology 1151
- 54 Community Ecology 1171
- 55 Ecosystems and the Biosphere **1194**
- 56 Ecology and the Geography of Life 1216
- 57 Biological Diversity and Conservation Biology 1241

Glossary G-1 Index I-1

Steroids contain foer rings of reaction atoms seends entrosomes are realistical are right of the seen is and the chemical mediation are right on the seen and the seen of the

PART ONE: THE ORGANIZATION OF LIFE

1 A View of Life 1

1.1 Major Themes of Biology 2
1.2 Characteristics of Life 2
Organisms are composed of cells 3
Organisms grow and develop 3
Organisms regulate their metabolic processes 3
Organisms respond to stimuli 4
Organisms reproduce 5
Populations evolve and become adapted to the environment 5
1.3 Levels of Biological Organization 6
Organisms have several levels of organization 6

Several levels of ecological organization can be identified **6 1.4 Information Transfer 6**

DNA transmits information from one generation to the next Information is transmitted by chemical and electrical signals Organisms also communicate information to one another **1.5 The Energy of Life 9**

1.5 The Energy of Life 9

1.6 Evolution: The Basic Unifying Concept of Biology 10 Biologists use a binomial system for naming organisms **11** Taxonomic classification is hierarchical **11**

Systematists classify organisms in three domains **11** Species adapt in response to changes in their environment **14** Natural selection is an important mechanism by which

evolution proceeds 14

Populations evolve as a result of selective pressures from changes in their environment **15**

1.7 The Process of Science 15

Science requires systematic thought processes **16** Scientists make careful observations and ask critical

questions 16

Chance often plays a role in scientific discovery 17

A hypothesis is a testable statement **17**

Researchers must avoid bias 18

Scientists interpret the results of experiments and draw conclusions **18**

A scientific theory is supported by tested hypotheses Many hypotheses cannot be tested by direct experiment Paradigm shifts accommodate new discoveries Systems biology integrates different levels of information Science has ethical dimensions Science, technology, and society interact

Atoms and Molecules: The Chemical Basis of Life 26

2.1 Elements and Atoms 27

An atom is uniquely identified by its number of protons Protons plus neutrons determine atomic mass Isotopes of an element differ in number of neutrons Electrons move in orbitals corresponding to energy levels

2.2 Chemical Reactions 31

Atoms form compounds and molecules 31
Simplest, molecular, and structural chemical formulas give different information 31
One mole of any substance contains the same number of units 31
Chemical equations describe chemical reactions 32
2.3 Chemical Bonds 32
In covalent bonds electrons are shared 32
The function of a molecule is related to its shape 34
Covalent bonds can be nonpolar or polar 34
Ionic bonds form between cations and anions 34
Hydrogen bonds are weak attractions 36

van der Waals interactions are weak forces 37

2.4 Redox Reactions 37

2.5 Water 38

Hydrogen bonds form between water molecules **38** Water molecules interact with hydrophilic substances by hydrogen bonding **38**

Water helps maintain a stable temperature **2.6 Acids, Bases, and Salts 41** pH is a convenient measure of acidity Buffers minimize pH change An acid and a base react to form a salt

3.1 Carbon Atoms and Organic Molecules 47

3 The Chemistry of Life: Organic Compounds 46

Isomers have the same molecular formula but different structures 48 Functional groups change the properties of organic molecules 49 Many biological molecules are polymers 50 3.2 Carbohydrates 51 Monosaccharides are simple sugars 51 Disaccharides consist of two monosaccharide units 52 Polysaccharides can store energy or provide structure 53 Some modified and complex carbohydrates have special roles 55 3.3 Lipids 56 Triacylglycerol is formed from glycerol and three fatty acids 56 Saturated and unsaturated fatty acids differ in physical properties 57 Phospholipids are components of cell membranes 57 Carotenoids and many other pigments are derived from isoprene units 57

Steroids contain four rings of carbon atoms **58** Some chemical mediators are lipids **59**

2

3.4 Proteins 59

Amino acids are the subunits of proteins 60 Peptide bonds join amino acids 61 Proteins have four levels of organization 61 The amino acid sequence of a protein determines its conformation 65

3.5 Nucleic Acids 68

Some nucleotides are important in energy transfers and other cell functions 68

3.6 Identifying Biological Molecules 69

Organization of the Cell 73 4

4.1 The Cell: Basic Unit of Life 74

The cell theory is a unifying concept in biology 74 The organization and basic functions of all cells are similar 74

Cell size is limited 74

Cell size and shape are adapted to function 76

4.2 Methods for Studying Cells 76

Light microscopes are used to study stained or living cells 76 Electron microscopes provide a high-resolution image that can

be greatly magnified 78

Biologists use biochemical and genetic methods to connect cell structures with their functions 79

4.3 Prokaryotic and Eukaryotic Cells 82

Organelles of prokaryotic cells are not surrounded by membranes 82

Membranes divide the eukaryotic cell into compartments 83 The unique properties of biological membranes allow

eukaryotic cells to carry on many diverse functions 83 4.4 The Cell Nucleus 84

Ribosomes manufacture proteins in the cytoplasm 87

4.5 Membranous Organelles in the Cytoplasm 88

The endoplasmic reticulum is a multifunctional network of membranes 88

The ER is the primary site of membrane assembly for components of the endomembrane system 91

The Golgi complex processes, sorts, and routes proteins from the ER to different parts of the endomembrane system 91

Lysosomes are compartments for digestion 93 Vacuoles are large, fluid-filled sacs with a variety of

functions 94

Peroxisomes metabolize small organic compounds 94 Mitochondria and chloroplasts are energy-converting

organelles 95

Mitochondria make ATP through aerobic respiration 95 Chloroplasts convert light energy to chemical energy through photosynthesis 97

4.6 The Cytoskeleton 98

Microtubules are hollow cylinders 98

Centrosomes and centrioles function in cell division 99 Cilia and flagella are composed of microtubules 99

Microfilaments consist of intertwined strings of actin 100 Intermediate filaments help stabilize cell shape 102 4.7 Cell Coverings 103

5 **Biological Membranes 106**

5.1 The Structure of Biological Membranes 107

Phospholipids form bilayers in water 107 The fluid mosaic model explains membrane structure 108 Biological membranes are two-dimensional fluids 109 Biological membranes fuse and form closed vesicles 110 Membrane proteins include integral and peripheral proteins 111

Proteins are oriented asymmetrically across the bilayer 111 5.2 Overview of Membrane Protein Functions 113 5.3 Cell Membrane Structure and Permeability 114 Biological membranes present a barrier to polar

molecules 114

Transport proteins transfer molecules across membranes 115 5.4 Passive Transport 115

Diffusion occurs down a concentration gradient 115

Osmosis is diffusion of water across a selectively permeable membrane 116

Facilitated diffusion occurs down a concentration gradient 118 5.5 Active Transport 120

Active transport systems "pump" substances against their concentration gradients 120

Carrier proteins can transport one or two solutes 122

Cotransport systems indirectly provide energy for active transport 122

5.6 Exocytosis and Endocytosis 123

In exocytosis, vesicles export large molecules 123 In endocytosis, the cell imports materials 123

5.7 Cell Junctions 125

Anchoring junctions connect cells of an epithelial sheet 125 Tight junctions seal off intercellular spaces between some animal cells 127

Gap junctions allow the transfer of small molecules and ions 128 Plasmodesmata allow certain molecules and ions to move between plant cells 128

6 Cell Communication 131

6.1 Cell Communication: An Overview 132 6.2 Sending Signals 133 6.3 Reception 134 Cells regulate reception 135 Three types of receptors occur on the cell surface 135 Some receptors are located inside the cell **137**

6.4 Signal Transduction 138

Signaling molecules can act as molecular switches 138 Ion channel-linked receptors open or close channels 139 G protein–linked receptors initiate signal transduction 139 Second messengers are intracellular signaling agents 139

Many activated intracellular receptors are transcription factors **142** Scaffold proteins increase efficiency **143**

Signals can be transmitted in more than one direction 143 6.5 Responses to Signals 143

PART TWO: ENERGY TRANSFER THROUGH LIVING SYSTEMS

7 Energy and Metabolism 150

7.1 Biological Work 151

Organisms carry out conversions between potential energy and kinetic energy **151**

7.2 The Laws of Thermodynamics 151

The total energy in the universe does not change **151** The entropy of the universe is increasing **152**

7.3 Energy and Metabolism 152

Enthalpy is the total potential energy of a system **153** Free energy is available to do cell work **153**

Chemical reactions involve changes in free energy Free energy decreases during an exergonic reaction Free energy increases during an endergonic reaction Diffusion is an exergonic process

Free-energy changes depend on the concentrations of reactants and products **154**

Cells drive endergonic reactions by coupling them to exergonic reactions **154**

7.4 ATP, the Energy Currency of the Cell 155

ATP donates energy through the transfer of a phosphate group **155**

ATP links exergonic and endergonic reactions **156** The cell maintains a very high ratio of ATP to ADP **156**

7.5 Energy Transfer in Redox Reactions 157

Most electron carriers transfer hydrogen atoms **157 7.6 Enzymes 158**

All reactions have a required energy of activation 158
An enzyme lowers a reaction's activation energy 159
An enzyme works by forming an enzyme–substrate complex 159

Enzymes are specific 160

Many enzymes require cofactors Enzymes are most effective at optimal conditions Enzymes are organized into teams in metabolic pathways The cell regulates enzymatic activity Enzymes are inhibited by certain chemical agents Some drugs are enzyme inhibitors

How Cells Make ATP: Energy-Releasing Pathways 167

8.1 Redox Reactions 168

8.2 The Four Stages of Aerobic Respiration 168 In glycolysis, glucose yields two pyruvates **170**

viii / Contents

8

Ras pathways involve tyrosine kinase receptors and G proteins 144
The response to a signal is amplified 144
Signals must be terminated 145
6.6 Evolution of Cell Communication 146

Pyruvate is converted to acetyl CoA **171** The citric acid cycle oxidizes acetyl groups derived from acetyl CoA **171**

The electron transport chain is coupled to ATP synthesis **176**

Aerobic respiration of one glucose yields a maximum of 36 to 38 ATPs **180**

Cells regulate aerobic respiration 181

8.3 Energy Yield of Nutrients Other Than Glucose 182

 8.4 Anaerobic Respiration and Fermentation 182
 Alcohol fermentation and lactate fermentation are inefficient 183

9 Photosynthesis: Capturing Light Energy 187

9.1 Light and Photosynthesis 188 9.2 Chloroplasts 189 Chlorophyll is found in the thylakoid membrane 190 Chlorophyll is the main photosynthetic pigment 191 9.3 Overview of Photosynthesis 192 ATP and NADPH are the products of the light-dependent reactions: An overview 192 Carbohydrates are produced during the carbon fixation reactions: An overview 193 9.4 The Light-Dependent Reactions 193 Photosystems I and II each consist of a reaction center and multiple antenna complexes 194 Noncyclic electron transport produces ATP and NADPH 194 Cyclic electron transport produces ATP but no NADPH 196 ATP synthesis occurs by chemiosmosis 196 9.5 The Carbon Fixation Reactions 198 Most plants use the Calvin cycle to fix carbon 198 Photorespiration reduces photosynthetic efficiency 200 The initial carbon fixation step differs in C₄ plants and in

CAM plants 200

CAM plants fix CO₂ at night **202**

9.6 Metabolic Diversity 202

9.7 Photosynthesis in Plants and in the Environment 203

PART THREE: THE CONTINUITY OF LIFE: GENETICS

10 Chromosomes, Mitosis, and Meiosis 206

10.1 Eukaryotic Chromosomes 207

DNA is organized into informational units called genes **207** DNA is packaged in a highly organized way in

chromosomes 207

Chromosome number and informational content differ among species 208

10.2 The Cell Cycle and Mitosis 210

Chromosomes duplicate during interphase **210** During prophase, duplicated chromosomes become visible with the microscope **211**

Prometaphase begins when the nuclear envelope breaks down **211**

Duplicated chromosomes line up on the midplane during metaphase 212

During anaphase, chromosomes move toward the poles **213**

During telophase, two separate nuclei form **215**

Cytokinesis forms two separate daughter cells 215

Mitosis produces two cells genetically identical to the parent cell **215**

Lacking nuclei, prokaryotes divide by binary fission **216 10.3 Regulation of the Cell Cycle 217**

10.4 Sexual Reproduction and Meiosis 219

Meiosis produces haploid cells with unique gene combinations **220**

Prophase I includes synapsis and crossing-over 221 During meiosis I, homologous chromosomes separate 221 Chromatids separate in meiosis II 222 Mitosis and meiosis lead to contrasting outcomes 223

10.5 Sexual Life Cycles 224

11 The Basic Principles of Heredity 228

11.1 Mendel's Principles of Inheritance 229

Alleles separate before gametes are formed: the principle of segregation **231** Alleles occupy corresponding loci on homologous

chromosomes **232** A monohybrid cross involves individuals with different alleles

of a given locus 233

A dihybrid cross involves individuals that have different alleles at two loci **235**

Alleles on nonhomologous chromosomes are randomly distributed into gametes: the principle of independent assortment **236**

Recognition of Mendel's work came during the early 20th century 236

11.2 Using Probability to Predict Mendelian Inheritance 238 The rules of probability can be applied to a variety of calculations **238**

11.3 Inheritance and Chromosomes 240

Linked genes do not assort independently **240** Calculating the frequency of crossing-over reveals the linear

order of linked genes on a chromosome **240** Sex is generally determined by sex chromosomes **241**

11.4 Extensions of Mendelian Genetics 246

Dominance is not always complete **246** Multiple alleles for a locus may exist in a population **248**

A single gene may affect multiple aspects of the phenotype **248** Alleles of different loci may interact to produce a

phenotype 248

In polygenic inheritance, the offspring exhibit a continuous variation in phenotypes **249**

Genes interact with the environment to shape phenotype 250

12 DNA: The Carrier of Genetic Information 253

12.1 Evidence of DNA as the Hereditary Material 254
DNA is the transforming factor in bacteria 254
DNA is the genetic material in certain viruses 254
12.2 The Structure of DNA 257
Nucleotides can be covalently linked in any order to form long polymers 257
DNA is made of two polynucleotide chains intertwined to form a double helix 258

In double-stranded DNA, hydrogen bonds form between A and T and between G and C **261**

12.3 DNA Replication 261

Meselson and Stahl verified the mechanism of semiconservative replication **262**

Semiconservative replication explains the perpetuation of mutations **262**

DNA replication requires protein "machinery" **263** Enzymes proofread and repair errors in DNA **268** Telomeres cap eukaryotic chromosome ends **268**

13 Gene Expression 272

13.1 Discovery of the Gene–Protein Relationship 273 Beadle and Tatum proposed the one-gene, one-enzyme hypothesis 273

13.2 Information Flow from DNA to Protein: An Overview 275

DNA is transcribed to form RNA RNA is translated to form a polypeptide Biologists cracked the genetic code in the 1960s The genetic code is virtually universal The genetic code is redundant

13.3 Transcription 279

The synthesis of mRNA includes initiation, elongation, and termination **280**

Messenger RNA contains base sequences that do not directly code for protein **281**

Eukaryotic mRNA is modified after transcription and before translation **282**

Biologists debate the evolution of eukaryotic gene

structure 282

13.4 Translation 284

An amino acid is attached to tRNA before incorporation into a polypeptide **284**

The components of the translational machinery come together at the ribosomes **285**

Translation begins with the formation of an initiation complex **285**

During elongation, amino acids are added to the growing polypeptide chain **286**

One of three stop codons signals the termination of translation **288**

Transcription and translation are coupled in bacteria **288 13.5 Mutations 290**

Base-pair substitution mutations result from the replacement of one base pair by another **290**

Frameshift mutations result from the insertion or deletion of base pairs **290**

Some mutations involve mobile genetic elements **290** Mutations have various causes **292**

13.6 Variations in Gene Expression 292

Many eukaryotic genes produce "non-coding" RNAs with catalytic, regulatory, or other cellular functions **292**

The definition of a gene has evolved **293**

The usual direction of information flow has exceptions 293

14 Gene Regulation 297

14.1 Gene Regulation in Bacteria and Eukaryotes: An Overview 298

14.2 Gene Regulation in Bacteria 299

Operons in bacteria facilitate the coordinated control of functionally related genes **299**

Some posttranscriptional regulation occurs in bacteria **303**

14.3 Gene Regulation in Eukaryotic Cells 304

Eukaryotic transcription is controlled at many sites and by many regulatory molecules **305**

Chromosome organization affects the expression of some genes **307**

Long non-coding RNAs (IncRNAs) regulate transcription over long distances within the genome **309**

The mRNAs of eukaryotes are subject to many types of posttranscriptional control **309**

Posttranslational chemical modifications may alter the activity of eukaryotic proteins **312**

15 DNA Technology and Genomics 315

15.1 DNA Cloning 316 Restriction enzymes are "molecular scissors" used to construct recombinant DNA molecules 316 Recombinant DNA is formed when DNA is spliced into a vector 317 Scientists use restriction enzymes and gel electrophoresis to examine cloned DNA fragments 318 The polymerase chain reaction amplifies DNA in vitro 318 cDNA clones do not contain introns 319 15.2 CRISPR-Based Technologies 321 CRISPR-based technologies can be used to edit genes in growing cells 321 CRISPR-based tools exploit host DNA repair systems to perform many types of recombinant DNA functions 322 Engineered CRISPR systems are used for specialized research applications 322 15.3 Tools for Studying DNA 323 DNA, RNA, and protein blots detect differences in related molecules separated by gel electrophoresis 324 Automated DNA sequencing methods have been developed 324 Gene databases are powerful research tools 325 Reverse transcription of mRNA to cDNA is used to measure gene expression in numerous ways 326 15.4 Genomics 328 Collaborative genome-wide association studies have radically changed our view of the human genome 328 Comparative genomic databases are tools for uncovering gene functions 328 RNA interference is used to study gene functions 329 15.5 Applications of DNA Technologies 330 DNA technology has revolutionized medicine 330 DNA fingerprinting has numerous applications 331 Transgenic organisms have many research and technological applications 331 15.6 CRISPR-Based Gene Drives 334 15.7 DNA Technology and Safety Concerns 336

16 Human Genetics and the Human Genome 340

16.1 Studying Human Genetics 341 Human chromosomes are studied by karyotyping **341**

Family pedigrees help identify certain inherited conditions **342**

Human gene databases allow geneticists to map the locations of genes on chromosomes **342**

16.2 Abnormalities in Chromosome Number and Structure 344

Down syndrome is usually caused by trisomy 21 **345** Most sex chromosome aneuploidies are less severe than autosomal aneuploidies **347** Abnormalities in chromosome structure cause certain disorders **348**

Genomic imprinting may determine whether inheritance is from the male or female parent **349**

16.3 Genetic Diseases Caused by Single-Gene Mutations 351

Many genetic diseases are inherited as autosomal recessive traits **351**

Some genetic diseases are inherited as autosomal dominant traits **353**

Some genetic diseases are inherited as X-linked recessive traits **353**

16.4 Gene Therapy 354

Performing clinical trials on humans always has inherent risks **354**

16.5 Genetic Testing and Counseling 355

Prenatal diagnosis detects chromosome abnormalities and gene defects **355**

Preimplanation genetic diagnosis is used to screen embryos produced by in vitro fertilization **356**

Genetic screening searches for genotypes or karyotypes **356** Genetic counselors educate people about genetic

diseases 357

16.6 Human Genetics, Society, and Ethics 357

Genetic discrimination provokes heated debate **358** Many ethical issues related to human genetics must be addressed **358**

PART FOUR: THE CONTINUITY OF LIFE: EVOLUTION

18 Introduction to Darwinian Evolution 385

18.1 What Is Evolution? 386 18.2 Pre-Darwinian Ideas about Evolution 386 18.3 Darwin and Evolution 387 Darwin proposed that evolution occurs by natural selection 389 The modern synthesis combines Darwin's scientific theory of evolution with genetics 390 Biologists study the effect of chance on evolution 390 18.4 Evidence for Evolution 391 The fossil record provides strong evidence for evolution 391 The distribution of plants and animals supports evolution 395 Comparative anatomy of related species demonstrates similarities in their structures 396 Molecular comparisons among organisms provide evidence for evolution 399 Developmental biology helps unravel evolutionary patterns 400

Evolutionary hypotheses are tested experimentally 401

17 Developmental Genetics 362

17.1 Cell Differentiation and Nuclear Equivalence 363

- Most cell differences are due to differential gene expression **363**
- A totipotent nucleus contains all the instructions for development **364**

The first cloned mammal was a sheep 366

Stem cells divide and give rise to differentiated cells **367**

17.2 The Genetic Control of Development 369

- A variety of model organisms provide insights into basic biological processes **369**
- Many genes that control development have been identified in the fruit fly **369**
- Caenorhabditis elegans has a relatively rigid developmental pattern **374**

The mouse is a model for mammalian development **377** *Arabidopsis* is a model for studying plant development,

including transcription factors 379

17.3 Cancer and Cell Development 380

Oncogenes are usually altered components of cell signaling pathways that control growth and differentiation **381**

In many familial cancers, tumor suppressor genes must be inactivated before cells progress to cancer **382** Cancer cells evolve by accumulating new mutations **382**

19 Evolutionary Change in Populations 406

19.1 Genotype, Phenotype, and Allele Frequencies 407

19.2 The Hardy–Weinberg Principle 407

Genetic equilibrium occurs if certain conditions are met **409** Human MN blood groups are a valuable illustration of the

Hardy-Weinberg principle 409

19.3 Microevolution 410

Nonrandom mating changes genotype frequencies Mutation increases variation within a population In genetic drift, random events change allele frequencies Gene flow generally increases variation within a population Natural selection changes allele frequencies in a way that increases adaptation

19.4 Genetic Variation in Populations 415

Genetic polymorphism can be studied in several ways **415** Balanced polymorphism exists for long periods **416** Neutral variation may give no selective advantage or

disadvantage 418

Populations in different geographic areas often exhibit genetic adaptations to local environments **418**

20 Speciation and Macroevolution 421

20.1 What Is a Species? 422

The biological species concept is based on reproductive isolation **422**

The phylogenetic species concept defines species based on such evidence as molecular sequencing **422**

20.2 Reproductive Isolation 423

Prezygotic barriers interfere with fertilization 423

Postzygotic barriers prevent gene flow when fertilization occurs **425**

Biologists are discovering genes responsible for reproductive isolating mechanisms **425**

20.3 Speciation 425

Long physical isolation and different selective pressures result in allopatric speciation **427**

The evolutionary importance of hybridization is being re-evaluated **432**

20.4 The Rate of Evolutionary Change 434

20.5 Macroevolution 435

Evolutionary novelties originate through modifications of pre-existing structures **435**

Adaptive radiation is the diversification of an ancestral species into many species **436**

Extinction is an important aspect of evolution **438** Is microevolution related to speciation and

macroevolution? 439

21 The Origin and Evolutionary History of Life 442

21.1 Chemical Evolution on Early Earth 443 Organic molecules formed on primitive Earth 443 21.2 The First Cells 445

The origin of a simple metabolism within a membrane boundary may have occurred early in the evolution of cells **445**

Molecular reproduction was a crucial step in the origin of cells **445**

PART FIVE: THE DIVERSITY OF LIFE

23 Understanding Diversity: Systematics 478

23.1 Classifying Organisms 479

Organisms are named using a binomial system **479** Each taxonomic level is more general than the one below it **480**

23.2 Determining the Major Branches in the Tree of Life 480

Systematics is an evolving science 480

The three domains form the three main branches of the tree of life **482**

Biological evolution began with the first cells 447

Photosynthesis was a further step in the evolution of cells **448**

Aerobes appeared after oxygen increased in the atmosphere **449**

Eukaryotic cells descended from prokaryotic cells **450 21.3 The History of Life 451**

Rocks from the Ediacaran period contain fossils of cells and simple animals **451**

A diversity of organisms evolved during the Paleozoic era **451** Dinosaurs and other reptiles dominated the Mesozoic era **454** The Cenozoic era is the Age of Mammals **457**

22 The Evolution of Primates 461

22.1 Primate Adaptations 462

22.2 Primate Classification 462

- Suborder Anthropoidea includes monkeys, apes, and humans **463**
- Apes are our closest living relatives 465

22.3 Hominin Evolution 467

The earliest hominins may have lived 6 mya to 7 mya **468** *Ardipithecus, Australopithecus,* and *Paranthropus* are

australopithecines, or "southern man apes" **468** *Homo habilis* is considered the oldest member of genus *Homo* **470**

Homo ergaster may have arisen from H. habilis **471** Homo erectus probably evolved from H. ergaster **471** Archaic humans date from about 1.2 mya to 200,000 years

ago **471** Neandertals appeared approximately 250,000 years ago **472**

Scientists have reached a near consensus on the origin of modern *H. sapiens* **473**

22.4 Cultural Change 474

Development of agriculture resulted in a more dependable food supply **475**

Human culture has had a profound effect on the biosphere **475**

Some biologists are moving away from Linnaean categories **482**

Phylogenetic trees show hypothesized evolutionary relationships **483**

Systematists continue to consider other hypotheses **484 23.3 Reconstructing Evolutionary History 485**

Homologous structures are important in determining evolutionary relationships **485**

Shared derived characters provide clues about phylogeny **486** Systematists base taxonomic decisions on recent shared ancestry **487** Molecular homologies help clarify phylogeny **487** Taxa are grouped based on their evolutionary relationships **488**

23.4 Constructing Phylogenetic Trees 490

Outgroup analysis is used in constructing and interpreting cladograms **490**

A cladogram is constructed by considering shared derived characters **491**

Each branch point represents a major evolutionary step **491** Systematists use the principles of parsimony and maximum likelihood to make decisions **494**

23.5 Applying Phylogenetic Information 495

24 Viruses and Subviral Agents 499

24.1 The Status and Structure of Viruses 500 Viruses are very small 500

A virus consists of nucleic acid surrounded by a protein coat **500**

The capsid is a protective protein coat **501** Some viruses are surrounded by an envelope **502**

24.2 Classification of Viruses 502 24.3 Viral Replication 503

Bacteriophages infect bacteria **503** Viruses replicate inside host cells **503**

24.4 Viral Diseases 504

Viruses cause serious plant diseases **505** Viruses cause serious diseases in animals **505**

24.5 Evolution of Viruses 511 24.6 Subviral Agents 512

Satellites depend on helper viruses Viroids are short, single strands of naked RNA Prions are protein particles Defective interfering particles are virus mutants

25 Bacteria and Archaea 517

25.1 The Structure of Bacteria and Archaea 518 Prokaryotes have several common shapes **518** Prokaryotic cells do not have membrane-enclosed

organelles 518

A cell wall protects most prokaryotes Some bacteria produce capsules or slime layers Some prokaryotes have fimbriae or pili Some bacteria survive unfavorable conditions by forming endospores

Many types of prokaryotes are motile **25.2 Prokaryote Reproduction and Evolution 522** Rapid reproduction contributes to prokaryote success Prokaryotes transfer genetic information Evolution proceeds rapidly in prokaryote populations **25.3 Nutritional and Metabolic Adaptations 524** Most prokaryotes require oxygen Some prokaryotes fix and metabolize nitrogen

25.4 The Phylogeny of the Two Prokaryote Domains 525

Key characters distinguish the three domains **526** Taxonomy of archaea and bacteria continuously changes **526** Most archaea live in marine and soil habitats, and many

thrive in harsh environments **527** Bacteria are the most familiar prokaryotes **528**

25.5 Impact on Ecology, Technology, and Commerce 528

Prokaryotes form intimate relationships with other organisms **529**

Prokaryotes play key ecological roles 529

Prokaryotes are important in many commercial processes and in technology **532**

25.6 Bacteria and Disease 533

26.1 Diversity in the Protists 540

Many scientists have contributed to our understanding of infectious disease **533**

Many adaptations contribute to pathogen success **533** Antibiotic resistance is a major public health problem **535**

26 Protists 539

26.2 How Did Eukaryotes Evolve? 541 Mitochondria and chloroplasts probably originated from endosymbionts 541 A consensus in eukaryote classification is beginning to emerge 541 26.3 Excavates 544 Diplomonads are small, mostly parasitic flagellates 544 Parabasilids are anaerobic endosymbionts that live in animals 544 Euglenoids and trypanosomes include both free-living species and parasites 545 26.4 Chromalveolates 546 Most dinoflagellates are a part of marine plankton 546 Apicomplexans are spore-forming parasites of animals 547 Ciliates use cilia for locomotion 548 Water molds produce biflagellate reproductive cells 549 Diatoms are stramenopiles with shells composed of two parts 551 Brown algae are multicellular stramenopiles 551 Most golden algae are unicellular biflagellates 552 26.5 Rhizarians 553 Forams extend cytoplasmic projections that form a threadlike, interconnected net 553 Actinopods project slender axopods 553 26.6 Archaeplastids 554 Red algae do not produce motile cells 554 Green algae share many similarities with land plants 555 26.7 Unikonts 555 Amoebozoa are unikonts with lobose pseudopodia 556

Choanoflagellates are opisthokonts closely related to animals 558

27 Seedless Plants 563

27.1 Adaptations of Plants to Life on Land 564
The plant life cycle alternates between haploid and diploid generations 564
Four major groups of plants exist today 565

27.2 Bryophytes 568

Moss gametophytes are differentiated into "leaves and "stems" 568

Liverwort gametophytes are either thalloid or leafy **571** Hornwort gametophytes are inconspicuous thalloid

plants 572

Bryophytes are used for experimental studies **572** Recap: details of bryophyte evolution are based on fossils and on structural and molecular evidence **573**

27.3 Seedless Vascular Plants 574

Club mosses are small plants with rhizomes and short, erect branches **574**

Ferns are a diverse group of spore-forming vascular plants **575**

Whisk ferns are classified as reduced ferns Horsetails are an evolutionary line of ferns Some ferns and club mosses are heterosporous Seedless vascular plants are used for experimental studies Seedless vascular plants arose more than 420 mya

28 Seed Plants 584

28.1 An Introduction to Seed Plants 585

28.2 Gymnosperms 586

Conifers are woody plants that produce seeds in cones **586**

Pines represent a typical conifer life cycle **588** Cycads have seed cones and compound leaves **589** *Ginkgo biloba* is the only living species in its

phylum 590

Gnetophytes include three unusual genera 591

28.3 Flowering Plants 591

Monocots and eudicots are the two largest classes of flowering plants **592**

Sexual reproduction takes place in flowers 593

The life cycle of flowering plants includes double fertilization **594**

Seeds and fruits develop after fertilization 596

Flowering plants have many adaptations that account for their success **596**

Floral structure provides insights into the evolutionary process **596**

28.4 The Evolution of Seed Plants 597

Our understanding of the evolution of flowering plants has made great progress in recent years **597**

The basal angiosperms comprise three clades 599

The core angiosperms comprise magnoliids, monocots, and eudicots **600**

29 The Fungi 603

29.1 Characteristics of Fungi 604 Fungi absorb food from the environment 604 Fungi have cell walls that contain chitin 604 Most fungi consist of a network of filaments 604 29.2 Fungal Reproduction 605 Many fungi reproduce asexually 605 Most fungi reproduce sexually 605 29.3 Fungal Diversity 607 Fungi are assigned to the opisthokont clade 607 Diverse groups of fungi have evolved 607 Chytrids have flagellate spores 608 Zygomycetes reproduce sexually by forming zygospores 609 Microsporidia have been a taxonomic mystery 610 Glomeromycetes have a symbiotic relationship with plant roots 611 Ascomycetes reproduce sexually by forming ascospores 612 Basidiomycetes reproduce sexually by forming basidiospores 615 29.4 Ecological Importance of Fungi 618 Fungi form symbiotic relationships with some animals 618 Mycorrhizae are symbiotic associations between fungi and plant roots 618 A lichen consists of one or more fungi and a photoautotroph 619 29.5 Economic, Biological, and Medical Impact of Fungi 621 Fungi provide beverages and food 621 Fungi are important to modern biology and medicine 622 Fungi are used in bioremediation and to biologically control pests 623 Some fungi cause diseases in humans and other animals 623 Fungi cause many important plant diseases 623

30 An Introduction to Animal Diversity 628

of development 631

30.1 Animal Characteristics 629
30.2 Adaptations to Ocean, Freshwater, and Terrestrial Habitats 630
Marine habitats offer many advantages 630
Some animals are adapted to freshwater habitats 630
Terrestrial living requires major adaptations 630
30.3 Animal Evolution 631
Molecular systematics helps biologists interpret the fossil record 631
Biologists develop hypotheses about the evolution

xiv / Contents

30.4 Reconstructing Animal Phylogeny 632

Animals exhibit two main types of body symmetry **632** Animal body plans are linked to the level of tissue

development 633

- Most bilateral animals have a body cavity lined with mesoderm **634**
- Bilateral animals form two main clades based on differences in development 635

Biologists have identified major animal clades based on structure, development, and molecular data 635

Segmentation apparently evolved three times **636**

31 Sponges, Cnidarians, Ctenophores, and Protostomes 641

31.1 Sponges, Cnidarians, and Ctenophores 642 Sponges have collar cells and other specialized cells **642**

Cnidarians have unique stinging cells 644

Comb jellies have adhesive glue cells that trap prey **648**

31.2 The Lophotrochozoa 649

Flatworms are bilateral acoelomates Nemerteans are characterized by their proboscis Mollusks have a muscular foot, visceral mass, and mantle Annelids are segmented worms

The lophophorates are distinguished by a ciliated ring of tentacles **659**

Rotifers have a crown of cilia 661

31.3 The Ecdysozoa 662

Roundworms are of great ecological importance **662** Arthropods are characterized by jointed appendages and an exoskeleton of chitin **662**

an exoskeleton of chitin bo

32 The Deuterostomes 676

32.1 What are Deuterostomes? 67732.2 Echinoderms 677Feather stars and sea lilies are suspension feeders 678

Abscisic add promotes seed dormancy 812 29132011

PART SIX: STRUCTURE AND LIFE PROCESSES IN PLANTS

33 Plant Structure, Growth, and Development 710 33.1 The Plant Body 711

The plant body consists of cells and tissues The ground tissue system is composed of three simple tissues The vascular tissue system consists of two complex tissues The dermal tissue system consists of two complex tissues

33.2 Plant Meristems 720

Primary growth takes place at apical meristems **721** Secondary growth takes place at lateral meristems **721 33.3 Development of Form 722**

The plane and symmetry of cell division affect plant form 723

Many sea stars capture prey **678** Basket stars and brittle stars make up the largest group

of echinoderms 680

Sea urchins and sand dollars have movable spines **680** Sea cucumbers are elongated, sluggish animals **680**

32.3 The Chordates: Major Characteristics 681

32.4 Invertebrate Chordates 682

Tunicates are common marine animals **682** Lancelets clearly exhibit chordate characteristics **682** Systematists debate chordate phylogeny **683**

32.5 Introducing the Vertebrates 684

The vertebral column is a derived vertebrate character **684** Vertebrate taxonomy is a work in progress **686**

- 32.6 Jawless Fishes 686
- 32.7 Evolution of Jaws and Limbs: Jawed Fishes and Tetrapods 688

Most cartilaginous fishes inhabit marine environments Ray-finned fishes gave rise to modern bony fishes Tetrapods evolved from sarcopterygian ancestors Amphibians were the first successful land vertebrates

32.8 Amniotes: Terrestrial Vertebrates 694

Our understanding of amniote phylogeny is changing Reptiles have many terrestrial adaptations Biologists assign reptiles to two major lineages Lizards and snakes are common modern reptiles Tuataras superficially resemble lizards Turtles have protective shells Crocodilians have an elongated skull How do we know that birds are really dinosaurs? Early birds were transitional forms Modern birds are adapted for flight Mammals (class Mammalia) have many unique characters New fossil discoveries are changing our understanding of

the early evolution of mammals **702** Modern mammals are assigned to three subclasses **703**

The orientation of cellulose microfibrils affects the direction of cell expansion **724**

Cell differentiation depends in part on a cell's location **724** Morphogenesis occurs through pattern formation **725**

34 Leaf Structure and Function 729

34.1 Leaf Form and Structure 730
Leaf structure is adapted for maximum light absorption 730
34.2 Stomatal Opening and Closing 736
Blue light triggers stomatal opening 736
Additional factors affect stomatal opening and closing 737

Some plants exude liquid water 738 34.4 Leaf Abscission 739 In many leaves, abscission occurs at an abscission zone near the base of the petiole 739 34.5 Modified Leaves 740 Modified leaves of carnivorous plants capture insects 742 Stem Structure and Transport 745 35.1 Stem Growth and Structure 746 Herbaceous eudicot and monocot stems differ in internal structure 746 Woody plants have stems with secondary growth 748 35.2 Water Transport 754 Water and minerals are transported in xylem 754 Water movement can be explained by a difference in water potential 755 According to the tension-cohesion model, water is pulled up a stem 755 Root pressure pushes water from the root up a stem 756 35.3 Translocation of Sugar in Solution 757

34.3 Transpiration and Guttation 737

35

Many plants have mechanisms that prevent self-pollination **786**

Flowering plants and their animal pollinators have coevolved **786**

Some flowering plants depend on wind to disperse pollen **788**

37.3 Fertilization and Seed and Fruit Development 789

A unique double fertilization process occurs in flowering plants **790**

Embryonic development in seeds is orderly and predictable **790**

The mature seed contains an embryonic plant and storage materials **791**

Fruits are mature, ripened ovaries **792** Seed dispersal is highly varied **794**

37.4 Germination and Early Growth 796
Some seeds do not germinate immediately 797
Eudicots and monocots exhibit characteristic patterns of early growth 797

37.5 Asexual Reproduction in Flowering Plants 797 Apomixis is the production of seeds without the sexual process **799**

37.6 A Comparison of Sexual and Asexual Reproduction 800

Sexual reproduction has some disadvantages 800

38 Plant Developmental Responses to External and Internal Signals 803 38.1 Tropisms 804

38.2 Plant Hormones and Development 805 Plant hormones act by signal transduction 805 Auxins promote cell elongation 807 Gibberellins promote stem elongation 809 Cytokinins promote cell division 810 Ethylene promotes abscission and fruit ripening 811 Abscisic acid promotes seed dormancy 812 Brassinosteroids are plant steroid hormones 812 Identification of a universal flower-promoting signal remains elusive 813 38.3 Light Signals and Plant Development 813 Phytochrome detects day length 814 Competition for sunlight among shade-avoiding plants involves phytochrome 815 Phytochrome is involved in other responses to light, including germination 816 Phytochrome acts by signal transduction **816** Light influences circadian rhythms 816 38.4 Responses to Herbivores and Pathogens 817 Jasmonic acid activates several plant defenses 818

Methyl salicylate may induce systemic acquired

resistance 818

36 Roots and Mineral Nutrition 762

The pressure-flow model explains translocation in

36.1 Root Structure and Function 763 Roots have root caps and root hairs **763**

phloem 757

The arrangement of vascular tissues distinguishes the roots of herbaceous eudicots and monocots **764**

Woody plants have roots with secondary growth **767** Some roots are specialized for unusual functions **768**

36.2 Root Associations and Interactions 769

Mycorrhizae facilitate the uptake of essential minerals by roots **771**

Rhizobial bacteria fix nitrogen in the roots of leguminous plants **772**

36.3 The Soil Environment 773

Soil comprises inorganic minerals, organic matter, air, and water **773**

About 50% of soil volume is composed of pore spaces Soil organisms form a complex ecosystem Soil pH affects soil characteristics and plant growth Soil provides most of the minerals found in plants

Soil can be damaged by human mismanagement 778

37 Reproduction in Flowering Plants 782

37.1 The Flowering Plant Life Cycle 783
Flowers develop at apical meristems 783
Each part of a flower has a specific function 783
37.2 Pollination 786

PART SEVEN: STRUCTURE AND LIFE PROCESSES IN ANIMALS

39 Animal Structure and Function: An Introduction 821

39.1 Tissues, Organs, and Organ Systems 822
Epithelial tissues cover the body and line its cavities 822
Glands are made of epithelial cells 823
Epithelial cells form membranes 823
Connective tissues support other body structures 823

Muscle tissue is specialized to contract **828** Nervous tissue controls muscles and glands **829** Tissues and organs make up the organ systems of the body **830**

39.2 Regulating the Internal Environment 834
Negative feedback systems restore homeostasis 834
A few positive feedback systems operate in the body 835
39.3 Regulating Body Temperature 836
Ectotherms absorb heat from their surroundings 836
Endotherms derive heat from metabolic processes 836
Many animals adjust to challenging temperature changes 839

40 Protection, Support, and Movement 842

40.1 Epithelial Coverings 843

Invertebrate epithelium may secrete a cuticle **843** Vertebrate skin functions in protection and temperature

regulation 843

40.2 Skeletal Systems 844

In hydrostatic skeletons body fluids transmit force Mollusks and arthropods have nonliving exoskeletons Internal skeletons are capable of growth The vertebrate skeleton has two main divisions A typical long bone amplifies the motion generated by muscles **846**

Bones are remodeled throughout life **847** Joints are junctions between bones **847**

40.3 Muscle Contraction 848

Invertebrate muscle varies among groups 848

- Vertebrate skeletal muscles act antagonistically to one another 849
- A vertebrate muscle may consist of thousands of muscle fibers **849**
- Contraction occurs when actin and myosin filaments move past one another **850**

ATP powers muscle contraction 853

- The type of muscle fibers determines strength and endurance **855**
- Several factors influence the strength of muscle contraction **855**

Smooth muscle and cardiac muscle are involuntary 856

41 Neural Signaling 860

41.1 Neural Signaling: An Overview 861 41.2 Neurons and Glial Cells 862

Neurons receive stimuli and transmit neural signals Certain regions of the CNS produce new neurons Axons aggregate to form nerves and tracts Glial cells play critical roles in neural function

41.3 Transmitting Information along the Neuron 865

Ion channels and pumps maintain the resting potential of the neuron **865**

- lons cross the plasma membrane by diffusion through ion channels **866**
- Ion pumping maintains the gradients that determine the resting potential **867**

Graded local signals vary in magnitude 867

Axons transmit signals called action potentials 867

An action potential is generated when the voltage reaches threshold level **867**

The neuron repolarizes and returns to a resting state **868** The action potential is an all-or-none response **869** An action potential is self-propagating **870**

Several factors determine the velocity of an action potential **871**

41.4 Transmitting Information across Synapses 872
Signals across synapses can be electrical or chemical 872
Neurons use neurotransmitters to signal other cells 873
Neurotransmitters bind with receptors on postsynaptic cells 873

Activated receptors can send excitatory or inhibitory signals 874

41.5 Neural Integration 877

Postsynaptic potentials are summed over time and space **877** Where does neural integration take place? **877**

41.6 Neural Circuits: Complex Information Signaling 877

42 Neural Regulation 882

42.1 Invertebrate Nervous Systems: Trends in Evolution 883

42.2 Overview of the Vertebrate Nervous System 884

42.3 Evolution of the Vertebrate Brain 885

The hindbrain develops into the medulla, pons, and cerebellum **886**

The midbrain is prominent in fishes and amphibians **886** The forebrain gives rise to the thalamus, hypothalamus, and cerebrum **887**

42.4 The Human Central Nervous System 888
The spinal cord transmits impulses to and from the brain 888
The most prominent part of the human brain is the cerebrum 889

Axons in the white matter of the cerebrum connect parts of the brain 892 The body follows a circadian rhythm of sleep and wakefulness 892 The limbic system affects emotional aspects of behavior 896 Learning and memory involve long-term changes at synapses 897 Language involves comprehension and expression 901 42.5 The Peripheral Nervous System 901 The somatic division helps the body adjust to the external environment 901 The autonomic division regulates the internal environment 901 42.6 Effects of Drugs on the Nervous System 903 Drug addiction is a serious issue 904 Opioid overdose is an epidemic 904

43 Sensory Systems 911

43.1 How Sensory Systems Work 912
Sensory receptors receive information 912
Sensory receptors transduce energy 912
Sensory input is integrated at many levels 912
We can classify sensory receptors based on location

of stimuli or on the type of energy they transduce 914

43.2 Thermoreceptors 915

43.3 Electroreceptors and Magnetic Reception 916 43.4 Nociceptors 916

43.5 Mechanoreceptors 916

Tactile receptors are located in the skin Proprioceptors help coordinate muscle movement Many invertebrates have gravity receptors called statocysts Hair cells are characterized by stereocilia Lateral line organs supplement vision in fishes The vestibular apparatus maintains equilibrium Auditory receptors are located in the cochlea **43.6 Chemoreceptors 924**

Taste receptors detect dissolved food molecules **925** The olfactory epithelium is responsible for the sense of smell **925** Many animals communicate with pheromones **926**

43.7 Photoreceptors 926

Invertebrates have several types of light-sensing organs **926** Vertebrate eyes form sharp images **927**

The retina contains light-sensitive rods and cones **929** Light activates rhodopsin **930**

Color vision depends on three types of cones **931** Integration of visual information begins in the retina **931**

44 Internal Transport 936

44.1 Types of Circulatory Systems 937

Many invertebrates have an open circulatory system **937** Some invertebrates have a closed circulatory system **938** Vertebrates have a closed circulatory system **938**

44.2 Vertebrate Blood 939 Plasma is the fluid component of blood 939 Red blood cells transport oxygen 939 White blood cells defend the body against disease organisms 940 Platelets function in blood clotting 941 44.3 Vertebrate Blood Vessels 942 44.4 Evolution of the Vertebrate Circulatory System 944 44.5 The Human Heart 946 Each heartbeat is initiated by a pacemaker 947 The cardiac cycle consists of alternating periods of contraction and relaxation 948 The nervous system regulates heart rate 949 Stroke volume depends on venous return 950 Cardiac output varies with the body's need 950 44.6 Blood Pressure 950 Blood pressure varies in different blood vessels 952 Blood pressure is carefully regulated 952 44.7 The Pattern of Circulation 953 The pulmonary circulation oxygenates the blood 954 The systemic circulation delivers blood to the tissues 954 44.8 The Lymphatic System 955 The lymphatic system consists of lymphatic vessels and lymph tissue 955 The lymphatic system plays an important role in fluid homeostasis 956 44.9 Cardiovascular Disease 956 Atherosclerosis develops progressively 957 Atherosclerosis has many effects 958

Cardiovascular disease can be treated **958** The risk of cardiovascular disease can be lowered **959**

45 The Immune System: Internal Defense 962

45.1 Evolution of Immune Responses 963
Invertebrates launch innate immune responses 963
Vertebrates launch both innate and adaptive immune responses 964

45.2 Innate Immune Responses in Vertebrates 965 Physical barriers and chemical weapons stop most pathogens **965**

Cells of the innate immune system destroy pathogens **965** Cytokines are important signaling molecules **966**

Complement promotes destruction of pathogens and enhances inflammation **967**

Inflammation is a protective response 967

45.3 Adaptive Immune Responses in Vertebrates 969

Many types of cells are involved in adaptive immune responses **969**

The major histocompatibility complex is responsible for recognition of self **971**

45.4 Cell-Mediated Immunity 972

45.5 Antibody-Mediated Immunity 973

- A typical antibody consists of four polypeptide chains **974**
- Antibodies are grouped in five classes **976** Antigen–antibody binding activates other defenses **977** The immune system responds to millions of different
- antigens **977** Monoclonal antibodies are highly specific **978**
- Immunological memory is responsible for long-term immunity **979**
- 45.6 Response to Disease, Immune Failures, and Harmful Reactions 980
- Cancer cells evade the immune system **981** Immunodeficiency disease can be acquired or
- inherited 982
- HIV is the major cause of acquired immunodeficiency in adults **982**
- In an autoimmune disease, the body attacks its own tissues **984**
- Rh incompatibility can result in hypersensitivity **985** Allergic reactions are directed against ordinary environmental antigens **985**
- Graft rejection is an immune response against transplanted tissue **987**

46 Gas Exchange 991

46.1 Adaptations for Gas Exchange in Air or Water 992

46.2 Types of Respiratory Surfaces 992

The body surface may be adapted for gas exchange **992** Tracheal tube systems deliver air directly to the cells **992** Gills are the respiratory surfaces in many aquatic

animals 994

Terrestrial vertebrates exchange gases through lungs 994

46.3 The Mammalian Respiratory System 997 The airway conducts air into the lungs Gas exchange occurs in the alveoli of the lungs Ventilation is accomplished by breathing The quantity of respired air can be measured Gas exchange takes place in the alveoli Gas exchange takes place in the tissues

- Respiratory pigments increase capacity for oxygen transport **1001**
- Carbon dioxide is transported mainly as bicarbonate ions **1002**
- Breathing is regulated by respiratory centers in the brain **1002** Hyperventilation reduces carbon dioxide
- concentration 1004

High flying or deep diving can disrupt homeostasis **1004** Some mammals are adapted for diving **1004 46.4 Breathing Polluted Air 1005** 47 Processing Food and Nutrition 1010 47.1 Nutritional Styles and Adaptations 1011 Animals are adapted to their mode of nutrition 1011 Some invertebrates have a digestive cavity with a single opening 1012 Most animal digestive systems have two openings 1013 47.2 The Vertebrate Digestive System 1013 Food processing begins in the mouth 1015 The pharynx and esophagus conduct food to the stomach 1016 Food is mechanically and enzymatically digested in the stomach 1016 Most enzymatic digestion takes place in the small intestine 1017 The liver secretes bile 1019 The pancreas secretes digestive enzymes **1019** Nutrients are digested as they move through the digestive tract 1019 Nerves and hormones regulate digestion **1020** Absorption takes place mainly through the villi of the small intestine 1021 The large intestine eliminates waste 1021 47.3 Required Nutrients 1022 Carbohydrates provide energy **1022** Lipids provide energy and are used to make biological molecules 1023 Proteins serve as enzymes and as structural components of cells 1024 Vitamins are organic compounds essential for normal metabolism 1024 Minerals are inorganic nutrients 1026 Antioxidants inactivate reactive molecules 1026 Phytochemicals play important roles in maintaining health 1027 47.4 Energy Metabolism 1027 Energy metabolism is regulated by complex signaling 1028 Obesity is a serious nutritional problem 1028 Undernutrition can cause serious health problems 1029

48 Osmoregulation and Disposal of Metabolic Wastes 1032

- 48.1 Maintaining Fluid and Electrolyte Balance 1033 48.2 Metabolic Waste Products 1033
- 48.3 Osmoregulation and Excretion in
- Invertebrates 1034 Nephridial organs are specialized for osmoregulation and/or
- excretion **1034** Malpighian tubules conserve water **1035**
- 48.4 Osmoregulation and Excretion in

Vertebrates 1036

- Freshwater vertebrates must rid themselves of excess water **1036**
- Marine vertebrates must replace lost fluid 1036

Terrestrial vertebrates must conserve water 1037 48.5 The Urinary System of Mammals 1038 The nephron is the functional unit of the kidney 1040

Urine is produced by glomerular filtration, tubular reabsorption, and tubular secretion **1041**

Glomerular filtration is not selective with regard to ions and small molecules **1041**

Urine becomes concentrated as it passes through the renal tubule **1043**

Urine consists of water, nitrogenous wastes, and salts **1044**

Hormones regulate kidney function 1044

49 Endocrine Regulation 1050

49.1 An Overview of Endocrine Regulation 1051

The endocrine system and nervous system interact to regulate the body **1051**

Negative feedback systems regulate endocrine activity **1051** Hormones are assigned to four chemical groups **1052**

49.2 Types of Endocrine Signaling 1053

Neurohormones are transported in the blood **1053** Some local regulators are considered hormones **1053 49.3 Mechanisms of Hormone Action 1055**

Lipid-soluble hormones enter target cells and activate genes **1055**

Water-soluble hormones bind to cell-surface receptors **1056 49.4 Neuroendocrine Regulation in Invertebrates 1058 49.5 Endocrine Regulation in Vertebrates 1058** Homeostasis depends on normal concentrations of

hormones 1058

The hypothalamus regulates the pituitary gland **1058** The posterior pituitary gland releases hormones produced

by the hypothalamus 1059

The anterior pituitary gland regulates growth and other endocrine glands **1059**

Thyroid hormones increase metabolic rate Negative feedback systems regulate thyroid secretion The parathyroid glands regulate calcium concentration The islets of the pancreas regulate blood glucose

concentration 1065

The adrenal glands help the body respond to stress **1068** Many other hormones help regulate life processes **1071**

50 Reproduction 1074

50.1 Asexual and Sexual Reproduction 1075
Asexual reproduction is an efficient strategy 1075
Most animals reproduce sexually 1075
Sexual reproduction increases genetic variability 1076
50.2 Human Reproduction: The Male 1077
The testes produce gametes and hormones 1077
A series of ducts store and transport sperm 1079

The accessory glands produce the fluid portion of semen **1079**

The penis transfers sperm to the female Testosterone has multiple effects The hypothalamus, pituitary gland, and testes regulate male reproduction

50.3 Human Reproduction: The Female 1082 The ovaries produce gametes and sex hormones 1083 The oviducts transport the secondary oocyte 1084 The uterus incubates the embryo **1084** The vagina receives sperm 1085 The vulva are external genital structures 1085 Breasts function in lactation 1086 The hypothalamus, pituitary gland, and ovaries regulate female reproduction 1086 Menstrual cycles stop at menopause 1089 Most mammals have estrous cycles 1091 50.4 Fertilization, Pregnancy, and Birth 1091 Fertilization is the fusion of sperm and egg 1091 Hormones are necessary to maintain pregnancy 1093 The birth process depends on a positive feedback system 1093 50,5 Human Sexual Response 1094 50.6 Birth Control Methods and Abortion 1096 Many birth control methods are available 1096

Most hormonal contraceptives prevent ovulation Intrauterine devices are widely used Barrier methods of contraception include the diaphragm and condom

Emergency contraception is available **1098** Sterilization renders an individual incapable of producing offspring **1098**

Future contraceptives may control regulatory peptides **1099**

Abortions can be spontaneous or induced 1099 50.7 Sexually Transmitted Infections 1099

51 Animal Development 1104

51.1 Development of Form 1105

51.2 Fertilization 1105

The first step in fertilization involves contact and recognition **1105**

Sperm entry is regulated 1106

Fertilization activates the egg 1107

Sperm and egg pronuclei fuse, restoring the diploid state **1107**

51.3 Cleavage 1107

The pattern of cleavage is affected by yolk Cleavage may distribute developmental determinants Cleavage provides building blocks for development **51.4 Gastrulation 1110**

The amount of yolk affects the pattern of gastrulation 1111

51.5 Organogenesis 1113

51.6 Extraembryonic Membranes 1115

51.7 Human Development 1115

The placenta is an organ of exchange Organ development begins during the first trimester Development continues during the second and third trimesters

More than one mechanism can lead to a multiple birth Environmental factors affect the embryo The neonate must adapt to its new environment Aging is not a uniform process

52 Animal Behavior 1124

52.1 Behavior and Adaptation 1125

Behaviors have benefits and costs 1125
Genes interact with environment 1125
Behavior depends on physiological readiness 1126
Many behavior patterns depend on motor programs 1127
52.2 Learning: Changing Behavior as a Result

of Experience 1127

An animal habituates to irrelevant stimuli Imprinting occurs during an early critical period In classical conditioning, a reflex becomes associated with a new stimulus

In operant conditioning, spontaneous behavior is reinforced 1129

Play may be practice behavior 1131 52.3 Behavioral Responses to Environmental Stimuli 1131 Biological rhythms regulate many behaviors 1131 Environmental signals trigger physiological responses that lead to migration 1132 52.4 Foraging Behavior 1133 52.5 Costs and Benefits of Social Behavior 1134 Communication is necessary for social behavior 1135 Dominance hierarchies establish social status 1136 Many animals defend a territory 1137 Some insect societies are highly organized 1138 52.6 Sexual Selection 1140 Animals of the same sex compete for mates 1140 Animals select quality mates 1140 Sexual selection favors polygynous mating systems 1141 Some animals care for their young 1142 52.7 Helping Behavior 1143 Altruistic behavior can be explained by inclusive fitness 1145 Helping behavior may have alternative explanations 1145 Some animals help nonrelatives 1145 52.8 Culture in Vertebrate Societies 1146 Some vertebrates transmit culture 1146 Sociobiology explains human social behavior in terms

Animal cognition is controversial 1130

of adaptation 1147

PART EIGHT: THE INTERACTIONS OF LIFE: ECOLOGY

53 Introduction to Ecology: Population Ecology 1151 53.1 Features of Populations 1152

Density and dispersion are important features of populations **1152 53.2 Changes in Population Size 1154**

Dispersal affects the growth rate in some populations **1154** Each population has a characteristic intrinsic rate of

increase 1154

No population can increase exponentially indefinitely 1155 53.3 Factors Influencing Population Size 1156

Density-dependent factors regulate population size **1156** Density-independent factors are generally abiotic **1159**

53.4 Life History Traits 1160

Life tables and survivorship curves indicate mortality and survival **1161**

53.5 Metapopulations 1163

53.6 Human Populations 1164

Not all countries have the same growth rate 1165

The age structure of a country helps predict future population growth **1166**

Environmental degradation is related to population growth and resource consumption **1167**

54 Community Ecology 1171

54.1 Community Structure and Functioning 1172 Community interactions are complex and often not readily apparent 1173 The niche is a species' ecological role in the community 1173 Competition is intraspecific or interspecific 1175 Natural selection shapes the bodies and behaviors of both predator and prey 1178 Symbiosis involves a close association between species 1180 54.2 Strength and Direction of Community Interactions 1183 Other species of a community depend on or are greatly affected by keystone species 1183 Dominant species influence a community as a result of their greater size or abundance 1184 Ecosystem regulation occurs from the bottom up and top down 1184

54.3 Community Biodiversity 1185

Ecologists seek to explain why some communities have more species than others **1186**

Species richness may promote community stability **1187 54.4 Community Development 1189**

Disturbance influences succession and species richness **1190** Ecologists continue to study community structure **1190**

55 Ecosystems and the Biosphere 1194

55.1 Energy Flow through Ecosystems 1195

Ecological pyramids illustrate how ecosystems work **1196**

Ecosystems vary in productivity **1197**

Some toxins persist in the environment **1199**

55.2 Cycles of Matter in Ecosystems 1201

Carbon dioxide is the pivotal molecule in the carbon cycle **1201**

Bacteria and archaea are essential to the nitrogen cycle **1202**

The phosphorus cycle lacks a gaseous component **1204** Water moves among the ocean, land, and atmosphere in

the hydrologic cycle 1205

55.3 Abiotic Factors in Ecosystems 1206 The sun warms Earth 1206

The atmosphere contains several gases essential to organisms **1208**

The global ocean covers most of Earth's surface Climate profoundly affects organisms Fires are a common disturbance in some ecosystems **55.4 Studying Ecosystem Processes 1212**

56 Ecology and the Geography of Life 1216

56.1 Biomes 1217

Tundra is the cold, boggy plains of the far north **1217**

Boreal forest is the evergreen forest of the north **1219**

Temperate rain forest has cool weather, dense fog, and high precipitation **1219**

Temperate deciduous forest has a canopy of broad-leaf trees **1220**

Temperate grasslands occur in areas of moderate precipitation **1220**

Chaparral is a thicket of evergreen shrubs and small trees 1221 Deserts are arid ecosystems 1222 Savanna is a tropical grassland with scattered trees 1223 There are two basic types of tropical forests 1224 56.2 Aquatic Ecosystems 1226 Freshwater ecosystems are linked to land and marine ecosystems 1226 Estuaries occur where fresh water and salt water meet 1230 Marine ecosystems dominate Earth's surface 1231 56.3 Ecotones 1235 56.4 Biogeography 1235

Land areas are divided into biogeographic realms 1236

57 Biological Diversity and Conservation Biology 1241

57.1 The Biodiversity Crisis 1242 Endangered species have certain characteristics in common 1243

Human activities contribute to declining biological diversity **1245**

57.2 Conservation Biology 1248

In situ conservation is the best way to preserve biological diversity **1249**

Ex situ conservation attempts to save species on the brink of extinction **1252**

The Endangered Species Act provides some legal protection for species and habitats **1252**

International agreements provide some protection for species and habitats **1253**

57.3 Deforestation 1253

Why are tropical rain forests continuing to disappear? **1254** Why are boreal forests disappearing? **1255**

57.4 Climate Change 1255

Greenhouse gases cause climate change **1256** What are the probable effects of climate change? **1257 The Future? 1260**

Glossary G-1 Index I-1