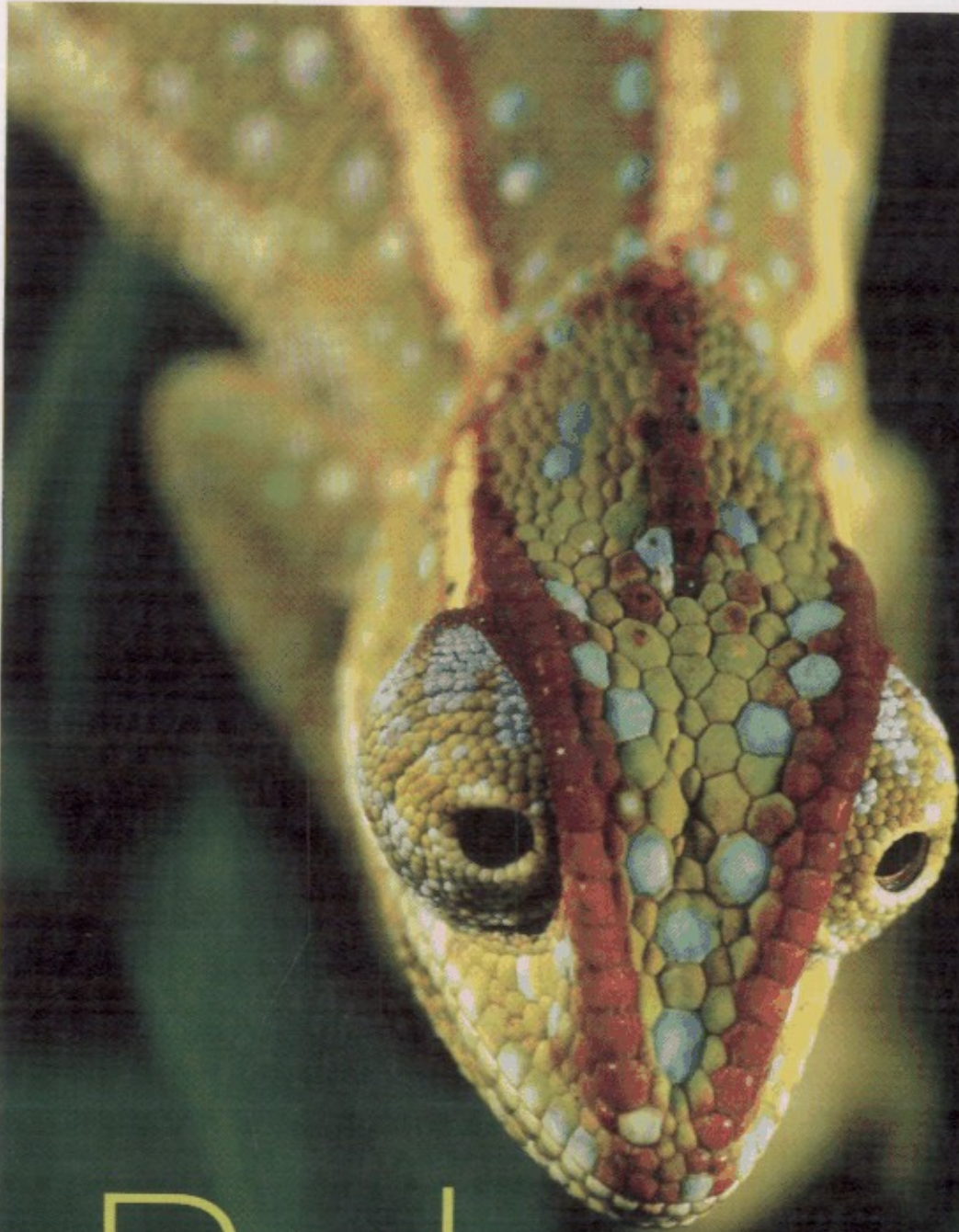


INTERNATIONAL STUDENT EDITION



Solomon  
Berg  
Martin

# Biology

8TH EDITION

Not for Sale in the  
United States

# Contents

## Part 1 THE ORGANIZATION OF LIFE 1

### 1 A VIEW OF LIFE 1

#### Three Basic Themes 2

#### Characteristics of Life 2

Organisms are composed of cells 2

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

#### Levels of Biological Organization 6

Organisms have several levels of organization 6

Several levels of ecological organization can be identified 6

#### Information Transfer 6

DNA transmits information from one generation  
to the next 6

Information is transmitted by chemical and electrical  
signals 8

#### Evolution: The Basic Unifying Concept of Biology 9

Biologists use a binomial system for naming organisms 9

Taxonomic classification is hierarchical 9

The tree of life includes three domains and six kingdoms 11

Species adapt in response to changes in their environment 11

Natural selection is an important mechanism by which  
evolution proceeds 11

Populations evolve as a result of selective pressures from  
changes in their environment 13

#### The Energy for Life 14

#### 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 16

A hypothesis is a testable statement 17

Many predictions can be tested by experiment 17

Researchers must avoid bias 18

Scientists interpret the results of experiments and make  
conclusions 18

A theory is supported by tested hypotheses 20

Many hypotheses cannot be tested by direct experiment 20

Paradigm shifts allow new discoveries 21

Systems biology integrates different levels of information 21

Science has ethical dimensions 21

## 2 ATOMS AND MOLECULES: THE CHEMICAL BASIS OF LIFE 25

### Elements and Atoms 26

An atom is uniquely identified by its number of protons 27

Protons plus neutrons determine atomic mass 28

Isotopes of an element differ in number of neutrons 28

Electrons move in orbitals corresponding to energy levels 29

### Chemical Reactions 29

Atoms form compounds and molecules 29

Simplest, molecular, and structural chemical formulas  
give different information 30

One mole of any substance contains the same number  
of units 31

Chemical equations describe chemical reactions 31

### Chemical Bonds 31

In covalent bonds electrons are shared 31

Ionic bonds form between cations and anions 33

Hydrogen bonds are weak attractions 35

van der Waals interactions are weak forces 36

### Redox Reactions 36

### Water 36

Hydrogen bonds form between water molecules 37

Water molecules interact with hydrophilic substances  
by hydrogen bonding 37

Water helps maintain a stable temperature 38

### Acids, Bases, and Salts 39

pH is a convenient measure of acidity 40

Buffers minimize pH change 40

An acid and a base react to form a salt 41

<b>3</b>	<b>THE CHEMISTRY OF LIFE: ORGANIC COMPOUNDS</b>	<b>45</b>
	Carbon Atoms and Molecules	46
	Isomers have the same molecular formula but different structures	47
	Functional groups change the properties of organic molecules	48
	Many biological molecules are polymers	50
	<b>Carbohydrates</b>	<b>50</b>
	Monosaccharides are simple sugars	51
	Disaccharides consist of two monosaccharide units	52
	Polysaccharides can store energy or provide structure	52
	Some modified and complex carbohydrates have special roles	54
	<b>Lipids</b>	<b>56</b>
	Triacylglycerol is formed from glycerol and three fatty acids	56
	Saturated and unsaturated fatty acids differ in physical properties	56
	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	57
	Some chemical mediators are lipids	58
	<b>Proteins</b>	<b>59</b>
	Amino acids are the subunits of proteins	62
	Proteins have four levels of organization	63
	The amino acid sequence of a protein determines its conformation	66
	<b>Nucleic Acids</b>	<b>67</b>
	Some nucleotides are important in energy transfers and other cell functions	68
	<b>Identifying Biological Molecules</b>	<b>70</b>
<b>4</b>	<b>ORGANIZATION OF THE CELL</b>	<b>73</b>
	The Cell Theory	74
	Cell Organization and Size	74
	The organization of all cells is basically similar	74
	Cell size is limited	74
	Cell size and shape are related to function	76
	<b>Methods for Studying Cells</b>	<b>76</b>
	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 techniques to study cell components	78
	<b>Prokaryotic and Eukaryotic Cells</b>	<b>80</b>
	Cell Membranes	81
	The Cell Nucleus	84

<b>Focus On:</b>	<i>Acetabularia</i> and the Control of Cell Activities	86
	<b>Organelles in the Cytoplasm</b>	<b>88</b>
	Ribosomes manufacture proteins	89
	The endoplasmic reticulum is a network of internal membranes	90
	The Golgi complex processes, sorts, and modifies proteins	91
	Lysosomes are compartments for digestion	92
	Vacuoles are large, fluid-filled sacs with a variety of functions	93
	Peroxisomes metabolize small organic compounds	94
	Mitochondria and chloroplasts are energy-converting organelles	94
	Mitochondria make ATP through cellular respiration	94
	Chloroplasts convert light energy to chemical energy through photosynthesis	96
	<b>The Cytoskeleton</b>	<b>97</b>
	Microtubules are hollow cylinders	97
	Microfilaments consist of intertwined strings of actin	99
	Intermediate filaments help stabilize cell shape	101
	<b>Cell Coverings</b>	<b>102</b>

<b>5</b>	<b>BIOLOGICAL MEMBRANES</b>	<b>106</b>
	The Structure of Biological Membranes	107
	Phospholipids form bilayers in water	107
	Current data support a fluid mosaic model of 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	110
	Proteins are oriented asymmetrically across the bilayer	111
	Membrane proteins function in transport, in information transfer, and as enzymes	113
	<b>Passage of Materials through Cell Membranes</b>	<b>114</b>
	Biological membranes present a barrier to polar molecules	115
	Transport proteins transfer molecules across membranes	115
	<b>Passive Transport</b>	<b>115</b>
	Diffusion occurs down a concentration gradient	116
	Osmosis is diffusion of water across a selectively permeable membrane	116
	Facilitated diffusion occurs down a concentration gradient	118
	<b>Active Transport</b>	<b>120</b>
	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

**Exocytosis and Endocytosis** 123  
In exocytosis, vesicles export large molecules 123  
In endocytosis, the cell imports materials 123  
**Cell Junctions** 127  
Anchoring junctions connect cells of an epithelial sheet 127  
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 129

## **6 CELL COMMUNICATION 134**

**Cell Signaling: An Overview** 135  
**Sending Signals** 136  
**Reception** 137  
Cells regulate reception 138  
Three types of receptors occur on the cell surface 138  
Some receptors are intracellular 140  
**Signal Transduction** 140  
Ion channel-linked receptors open or close channels 140  
G protein-linked receptors initiate signal transduction 141  
Second messengers are intracellular signaling agents 141  
Enzyme-linked receptors function directly 144  
Many activated intracellular receptors are transcription factors 144  
Scaffolding proteins increase efficiency 145  
Signals can be transmitted in more than one direction 145  
**Responses to Signals** 145  
The response to a signal is amplified 146  
Signals must be terminated 147  
**Evolution of Cell Communication** 147

---

## **Part 2 ENERGY TRANSFER THROUGH LIVING SYSTEMS 152**

### **7 ENERGY AND METABOLISM 152**

**Biological Work** 153  
Organisms carry out conversions between potential energy and kinetic energy 153  
**The Laws of Thermodynamics** 154  
The total energy in the universe does not change 154  
The entropy of the universe is increasing 154  
**Energy and Metabolism** 155  
Enthalpy is the total potential energy of a system 155  
Free energy is available to do cell work 155  
Chemical reactions involve changes in free energy 155

Free energy decreases during an exergonic reaction 155  
Free energy increases during an endergonic reaction 156  
Diffusion is an exergonic process 156  
Free-energy changes depend on the concentrations of reactants and products 156  
Cells drive endergonic reactions by coupling them to exergonic reactions 157

### **ATP, the Energy Currency of the Cell 157**

ATP donates energy through the transfer of a phosphate group 158  
ATP links exergonic and endergonic reactions 158  
The cell maintains a very high ratio of ATP to ADP 159

### **Energy Transfer in Redox Reactions 159**

Most electron carriers transfer hydrogen atoms 159

### **Enzymes 160**

All reactions have a required energy of activation 161  
An enzyme lowers a reaction's activation energy 162  
An enzyme works by forming an enzyme-substrate complex 162  
Enzymes are specific 163  
Many enzymes require cofactors 163  
Enzymes are most effective at optimal conditions 163  
Enzymes are organized into teams in metabolic pathways 164  
The cell regulates enzymatic activity 165  
Enzymes are inhibited by certain chemical agents 166  
Some drugs are enzyme inhibitors 167

### **8 HOW CELLS MAKE ATP: ENERGY-RELEASING PATHWAYS 171**

#### **Redox Reactions 172**

#### **The Four Stages of Aerobic Respiration 173**

In glycolysis, glucose yields two pyruvates 174  
Pyruvate is converted to acetyl CoA 175  
The citric acid cycle oxidizes acetyl CoA 178  
The electron transport chain is coupled to ATP synthesis 179  
Aerobic respiration of one glucose yields a maximum of 36 to 38 ATPs 183  
Cells regulate aerobic respiration 185

#### **Energy Yield of Nutrients Other Than Glucose 185**

#### **Anaerobic Respiration and Fermentation 186**

Alcohol fermentation and lactate fermentation are inefficient 187

### **9 PHOTOSYNTHESIS: CAPTURING ENERGY 191**

#### **Light 192**

#### **Chloroplasts 193**

Chlorophyll is found in the thylakoid membrane 193  
Chlorophyll is the main photosynthetic pigment 194

## Overview of Photosynthesis 196

ATP and NADPH are the products of the light-dependent reactions: An overview 197

Carbohydrates are produced during the carbon fixation reactions: An overview 197

## The Light-Dependent Reactions 198

Photosystems I and II each consist of a reaction center and multiple antenna complexes 198

Noncyclic electron transport produces ATP and NADPH 198

Cyclic electron transport produces ATP but no NADPH 200

ATP synthesis occurs by chemiosmosis 200

## The Carbon Fixation Reactions 202

Most plants use the Calvin cycle to fix carbon 202

Photorespiration reduces photosynthetic efficiency 204

The initial carbon fixation step differs in  $C_4$  plants and in CAM plants 204

## Metabolic Diversity 206

## Photosynthesis in Plants and in the Environment 207

Prophase I includes synapsis and crossing-over 224

During meiosis I, homologous chromosomes separate 225

Chromatids separate in meiosis II 225

Mitosis and meiosis lead to contrasting outcomes 225

The timing of meiosis in the life cycle varies among species 228

## 11 THE BASIC PRINCIPLES OF HEREDITY 234

### Mendel's Principles of Inheritance 235

Alleles separate before gametes are formed: the principle of segregation 236

Alleles occupy corresponding loci on homologous chromosomes 238

A monohybrid cross involves individuals with different alleles of a given locus 238

A dihybrid cross involves individuals that have different alleles at two loci 240

Alleles on nonhomologous chromosomes are randomly distributed into gametes: the principle of independent assortment 241

Recognition of Mendel's work came during the early 20th century 242

### Using Probability to Predict Mendelian Inheritance 243

The rules of probability can be applied to a variety of calculations 244

### Focus On: Solving Genetics Problems 245

### Inheritance and Chromosomes 246

Linked genes do not assort independently 246

Calculating the frequency of crossing-over reveals the linear order of linked genes on a chromosome 247

Sex is generally determined by sex chromosomes 248

### Extensions of Mendelian Genetics 252

Dominance is not always complete 252

Multiple alleles for a locus may exist in a population 253

A single gene may affect multiple aspects of the phenotype 253

Alleles of different loci may interact to produce a phenotype 254

Polygenes act additively to produce a phenotype 255

Genes interact with the environment to shape phenotype 256

## 12 DNA: THE CARRIER OF GENETIC INFORMATION 260

### Evidence of DNA as the Hereditary Material 261

DNA is the transforming principle in bacteria 261

DNA is the genetic material in certain viruses 263

## Part 3 THE CONTINUITY OF LIFE: GENETICS 211

## 10 CHROMOSOMES, MITOSIS, AND MEIOSIS 211

### Eukaryotic Chromosomes 212

DNA is organized into informational units called genes 212

DNA is packaged in a highly organized way in chromosomes 212

Chromosome number and informational content differ among species 214

### The Cell Cycle and Mitosis 215

Chromosomes duplicate during interphase 215

During prophase, duplicated chromosomes become visible with the microscope 216

Prometaphase begins when the nuclear envelope breaks down 218

Duplicated chromosomes line up on the midplane during metaphase 218

During anaphase, chromosomes move toward the poles 219

During telophase, two separate nuclei form 220

Cytokinesis forms two separate daughter cells 220

Mitosis produces two cells genetically identical to the parent cell 221

Lacking nuclei, prokaryotes divide by binary fission 221

### Regulation of the Cell Cycle 221

### Sexual Reproduction and Meiosis 223

Meiosis produces haploid cells with unique gene combinations 224

## The Structure of DNA 263

Nucleotides can be covalently linked in any order to form long polymers 263

DNA is made of two polynucleotide chains intertwined to form a double helix 264

In double-stranded DNA, hydrogen bonds form between A and T and between G and C 265

## DNA Replication 266

Meselson and Stahl verified the mechanism of semiconservative replication 266

Semiconservative replication explains the perpetuation of mutations 268

DNA replication requires protein “machinery” 270

Enzymes proofread and repair errors in DNA 274

Telomeres cap eukaryotic chromosome ends 275

## 13 GENE EXPRESSION 279

### Discovery of the Gene–Protein Relationship 280

Beadle and Tatum proposed the one-gene, one-enzyme hypothesis 280

### Information Flow from DNA to Protein: An Overview 282

DNA is transcribed to form RNA 282

RNA is translated to form a polypeptide 282

Biologists cracked the genetic code in the 1960s 283

### Transcription 285

The synthesis of mRNA includes initiation, elongation, and termination 286

Messenger RNA contains base sequences that do not directly code for protein 288

### Translation 288

An amino acid is attached to tRNA before incorporation into a polypeptide 288

The components of the translational machinery come together at the ribosomes 289

### Variations in Gene Expression in Different Organisms 292

Transcription and translation are coupled in prokaryotes 293

Eukaryotic mRNA is modified after transcription and before translation 293

Both noncoding and coding sequences are transcribed from eukaryotic genes 294

Several kinds of eukaryotic RNA have a role in gene expression 296

The definition of a gene has evolved as biologists have learned more about genes 297

The usual direction of information flow has exceptions 297

### Mutations 298

Base-substitution mutations result from the replacement of one base pair by another 298

Frameshift mutations result from the insertion or deletion of base pairs 298

Some mutations involve larger DNA segments 298

Mutations have various causes 300

## 14 GENE REGULATION 304

### Gene Regulation in Bacteria and Eukaryotes: An Overview 305

### Gene Regulation in Bacteria 306

Operons in bacteria facilitate the coordinated control of functionally related genes 306

Some posttranscriptional regulation occurs in bacteria 309

### Gene Regulation in Eukaryotic Cells 312

Eukaryotic transcription is controlled at many sites and by many different regulatory molecules 313

The mRNAs of eukaryotes have many types of posttranscriptional control 317

Posttranslational chemical modifications may alter the activity of eukaryotic proteins 318

## 15 DNA TECHNOLOGY AND GENOMICS 322

### DNA Cloning 323

Restriction enzymes are “molecular scissors” 323

Recombinant DNA forms when DNA is spliced into a vector 324

DNA can be cloned inside cells 324

The polymerase chain reaction is a technique for amplifying DNA in vitro 328

### DNA Analysis 330

Gel electrophoresis is used for separating macromolecules 330

DNA, RNA, and protein blots detect specific fragments 331

Restriction fragment length polymorphisms are a measure of genetic relationships 331

One way to characterize DNA is to determine its sequence of nucleotides 331

### Genomics 333

Identifying protein-coding genes is useful for research and for medical applications 334

One way to study gene function is to silence genes one at a time 335

DNA microarrays are a powerful tool for studying how genes interact 335

The Human Genome Project stimulated studies on the genome sequences of other species 337

### Applications of DNA Technologies 338

DNA technology has revolutionized medicine and pharmacology 338

DNA fingerprinting has numerous applications 339

Transgenic organisms have incorporated foreign DNA into their cells 340

### DNA Technology Has Raised Safety Concerns 342

## 16 THE HUMAN GENOME 346

### Studying Human Genetics 347

Human chromosomes are studied by karyotyping 347

Family pedigrees help identify certain inherited conditions 348

The Human Genome Project sequenced the DNA on all human chromosomes 349

Comparative genomics has revealed several hundred DNA segments that are identical in both mouse and human genomes 350

Researchers use mouse models to study human genetic diseases 350

### Abnormalities in Chromosome Number and Structure 351

Down syndrome is usually caused by trisomy 21 353

Most sex chromosome aneuploidies are less severe than autosomal aneuploidies 354

Abnormalities in chromosome structure cause certain disorders 354

### Genetic Diseases Caused by Single-Gene Mutations 356

Many genetic diseases are inherited as autosomal recessive traits 356

Some genetic diseases are inherited as autosomal dominant traits 358

Some genetic diseases are inherited as X-linked recessive traits 359

### Gene Therapy 360

Gene therapy programs are carefully scrutinized 360

### Genetic Testing and Counseling 361

Prenatal diagnosis detects chromosome abnormalities and gene defects 361

Genetic screening searches for genotypes or karyotypes 362

Genetic counselors educate people about genetic diseases 363

### Human Genetics, Society, and Ethics 363

Genetic discrimination provokes heated debate 364

Many ethical issues related to human genetics must be addressed 364

## 17 DEVELOPMENTAL GENETICS 368

### Cell Differentiation and Nuclear Equivalence 369

Most cell differences are due to differential gene expression 369

A totipotent nucleus contains all the instructions for development 370

The first cloned mammal was a sheep 371

Stem cells divide and give rise to differentiated cells 372

### The Genetic Control of Development 374

A variety of model organisms provide insights into basic biological processes 374

Many examples of genes that control development have been identified in the fruit fly *Drosophila* 375

*Caenorhabditis elegans* has a relatively rigid developmental pattern 380

The mouse is a model for mammalian development 383

*Arabidopsis* is a model for studying plant development, including transcription factors 385

### Cancer and Cell Development 386

---

## Part 4 THE CONTINUITY OF LIFE: EVOLUTION 390

## 18 INTRODUCTION TO DARWINIAN EVOLUTION 390

### What Is Evolution? 391

### Pre-Darwinian Ideas about Evolution 391

### Darwin and Evolution 392

Darwin proposed that evolution occurs by natural selection 394

The modern synthesis combines Darwin's theory with genetics 394

Biologists study the effect of chance on evolution 395

### Evidence for Evolution 396

The fossil record provides strong evidence for evolution 396

Comparative anatomy of related species demonstrates similarities in their structures 400

The distribution of plants and animals supports evolution 402

Developmental biology helps unravel evolutionary patterns 404

Molecular comparisons among organisms provide evidence for evolution 405

Evolutionary hypotheses are tested experimentally 408

## 19 EVOLUTIONARY CHANGE IN POPULATIONS 412

### Genotype, Phenotype, and Allele Frequencies 413

### The Hardy-Weinberg Principle 413

Genetic equilibrium occurs if certain conditions are met 415

Human MN blood groups are a valuable illustration of the Hardy-Weinberg principle 415

**Microevolution 416**  
Nonrandom mating changes genotype frequencies 416  
Mutation increases variation within a population 417  
In genetic drift, random events change allele frequencies 417  
Gene flow generally increases variation within a population 418  
Natural selection changes allele frequencies in a way that increases adaptation 418

**Genetic Variation in Populations 421**  
Genetic polymorphism exists among alleles and the proteins for which they code 421  
Balanced polymorphism exists for long periods 422  
Neutral variation may give no selective advantage or disadvantage 424  
Populations in different geographic areas often exhibit genetic adaptations to local environments 425

## 20 SPECIATION AND MACROEVOLUTION 428

**What Is a Species? 429**  
**Reproductive Isolation 430**  
Prezygotic barriers interfere with fertilization 430  
Postzygotic barriers prevent gene flow when fertilization occurs 431  
Biologists are discovering the genetic basis of isolating mechanisms 432  
**Speciation 432**  
Long physical isolation and different selective pressures result in allopatric speciation 433  
Two populations diverge in the same physical location by sympatric speciation 434  
Reproductive isolation breaks down in hybrid zones 437  
**The Rate of Evolutionary Change 438**  
**Macroevolution 439**  
Evolutionary novelties originate through modifications of pre-existing structures 439  
Adaptive radiation is the diversification of an ancestral species into many species 440  
Extinction is an important aspect of evolution 442  
Is microevolution related to speciation and macroevolution? 444

## 21 THE ORIGIN AND EVOLUTIONARY HISTORY OF LIFE 447

**Chemical Evolution on Early Earth 448**  
Organic molecules formed on primitive Earth 449  
**The First Cells 450**  
Molecular reproduction was a crucial step in the origin of cells 450

Biological evolution began with the first cells 452  
The first cells were probably heterotrophic 452  
Aerobes appeared after oxygen increased in the atmosphere 453  
Eukaryotic cells descended from prokaryotic cells 453  
**The History of Life 455**  
Rocks from the Ediacaran period contain fossils of cells and simple animals 455  
A diversity of organisms evolved during the Paleozoic era 455  
Dinosaurs and other reptiles dominated the Mesozoic era 459  
The Cenozoic era is the Age of Mammals 461

**Focus On: The Origin of Flight in Birds 462**

## 22 THE EVOLUTION OF PRIMATES 466

**Primate Adaptations 467**  
**Primate Classification 468**  
Suborder Anthropoidea includes monkeys, apes, and humans 469  
Apes are our closest living relatives 469  
**Hominid Evolution 471**  
The earliest hominids may have lived 6 mya to 7 mya 473  
Australopithecines are the immediate ancestors of genus *Homo* 474  
*Homo habilis* is the oldest member of genus *Homo* 474  
*Homo erectus* apparently evolved from *Homo habilis* 475  
Archaic *Homo sapiens* appeared between 400,000 and 200,000 years ago 475  
Neandertals appeared approximately 230,000 years ago 475

**Focus On: The Smallest Humans 476**  
Biologists debate the origin of modern *Homo sapiens* 477  
**Cultural Change 478**  
Development of agriculture resulted in a more dependable food supply 478  
Cultural evolution has had a profound impact on the biosphere 479

---

## Part 5 THE DIVERSITY OF LIFE 482

## 23 UNDERSTANDING DIVERSITY: SYSTEMATICS 482

**Classifying Organisms 483**  
Organisms are named using a binomial system 483  
Each taxonomic level is more general than the one below it 484  
Biologists are moving away from Linnaean categories 484



**Determining the Major Branches in the Tree of Life** 484

**Reconstructing Phylogeny** 487

Homologous structures are important in determining evolutionary relationships 489

Shared derived characters provide clues about phylogeny 489

Biologists carefully choose taxonomic criteria 490

Molecular homologies help clarify phylogeny 491

Taxa are grouped based on their evolutionary relationships 492

**Constructing Phylogenetic Trees** 493

Outgroup analysis is used in constructing and interpreting cladograms 493

A cladogram is constructed by considering shared derived characters 494

In a cladogram each branch point represents a major evolutionary step 496

Systematists use the principle of parsimony to make decisions 497

## **24 VIRUSES AND PROKARYOTES** 500

**Viruses** 501

A virus consists of nucleic acid surrounded by a protein coat 501

Viruses may have evolved from cells 502

The International Committee on Taxonomy of Viruses classifies viruses 502

Bacteriophages are viruses that attack bacteria 503

Viruses reproduce only inside host cells 503

Lytic reproductive cycles destroy host cells 503

Temperate viruses integrate their DNA into the host DNA 503

Many viruses infect vertebrates 505

**Focus On:** Influenza and Other Emerging and Re-emerging Diseases 506

Some viruses infect plant cells 510

**Viroids and Prions** 510

Viroids are the smallest known pathogens 510

Prions are protein particles 511

**Prokaryotes** 512

Prokaryotes have several common shapes 512

Prokaryotic cells lack membrane-enclosed organelles 512

A cell wall typically covers the cell surface 512

Many types of prokaryotes are motile 513

Prokaryotes have a circular DNA molecule 514

Most prokaryotes reproduce by binary fission 514

Bacteria transfer genetic information 514

Evolution proceeds rapidly in bacterial populations 516

Some bacteria form endospores 516

Many bacteria form biofilms 516

Metabolic diversity has evolved among prokaryotes 517

Most prokaryotes require oxygen 517

**The Two Prokaryote Domains** 518

Some archaea survive in harsh environments 519

Bacteria are the most familiar prokaryotes 520

**Impact of Prokaryotes** 520

Some prokaryotes cause disease 523

Prokaryotes are used in many commercial processes 526

## **25 PROTISTS** 530

**Introduction to the Protists** 531

**Evolution of the Eukaryotes** 531

Mitochondria and chloroplasts probably originated from endosymbionts 532

A consensus is emerging in eukaryote classification 532

**Representative Protists** 534

Excavates are anaerobic zooflagellates 534

Discicristates include euglenoids and trypanosomes 536

Alveolates have flattened vesicles under the plasma membrane 537

Motile cells of heterokonts are biflagellate 540

Red algae, green algae, and land plants are collectively classified as plants 545

Cercozoa are amoeboid cells enclosed in shells 546

Amoebozoa have lobose pseudopodia 547

Opisthokonts include choanoflagellates, fungi, and animals 551

## **26 KINGDOM FUNGI** 555

**Characteristics of Fungi** 556

Fungi absorb food from the environment 556

Fungi have cell walls that contain chitin 556

Most fungi have a filamentous body plan 556

Fungi reproduce by spores 556

**Fungal Diversity** 558

Fungi are assigned to the opisthokont clade 558

Diverse groups of fungi have evolved 560

Chytrids have flagellate spores 560

Zygomycetes reproduce sexually by forming zygospores 561

Glomeromycetes are symbionts with plant roots 565

Ascomycetes reproduce sexually by forming ascospores 566

Basidiomycetes reproduce sexually by forming basidiospores 568

**Ecological Importance of Fungi** 570

Fungi form symbiotic relationships with some animals 570

Mycorrhizae are symbiotic relationships between fungi and plant roots 570

Lichens are symbiotic relationships between a fungus and a photoautotroph 572

**Economic, Biological, and Medical Impact of Fungi** 574

Fungi provide beverages and food 574

Fungi are important to modern biology and medicine 574

Some fungi cause animal diseases 576

Fungi cause many important plant diseases 576

## 27 THE PLANT KINGDOM: SEEDLESS PLANTS 581

Adaptations of Plants 582

The plant life cycle alternates haploid and diploid generations 582

Four major groups of plants evolved 583

**Bryophytes 584**

Moss gametophytes are differentiated into “leaves” and “stems” 585

Liverwort gametophytes are either thalloid or leafy 587

Hornwort gametophytes are inconspicuous thalloid plants 587

Bryophytes are used for experimental studies 588

Details of bryophyte evolution are based on fossils and on structural and molecular evidence 589

**Seedless Vascular Plants 589**

**Focus On:** Ancient Plants and Coal Formation 590

Club mosses are small plants with rhizomes and short, erect branches 591

Ferns are a diverse group of spore-forming vascular plants 591

Some ferns and club mosses are heterosporous 595

Seedless vascular plants are used for experimental studies 595

Seedless vascular plants arose more than 420 mya 595

## 28 THE PLANT KINGDOM: SEED PLANTS 600

An Introduction to Seed Plants 601

**Gymnosperms 601**

Conifers are woody plants that produce seeds in cones 602

Cycads have seed cones and compound leaves 605

*Ginkgo biloba* is the only living species in its phylum 606

Gnetophytes include three unusual genera 606

**Flowering Plants 607**

Monocots and eudicots are the two largest classes of flowering plants 608

Flowers are involved in sexual reproduction 608

The life cycle of flowering plants includes double fertilization 610

Seeds and fruits develop after fertilization 611

Flowering plants have many adaptations that account for their success 611

Studying how flowers evolved provides insights into the evolutionary process 613

**The Evolution of Seed Plants 614**

Our understanding of the evolution of flowering plants has made great progress in recent years 614

## 29 THE ANIMAL KINGDOM: AN INTRODUCTION TO ANIMAL DIVERSITY 619

Animal Characters 620

**Adaptations to Habitats 620**

Marine habitats offer many advantages 620

Some animals are adapted to freshwater habitats 621

Terrestrial living requires major adaptations 621

**Animal Origins 621**

Molecular systematics helps biologists interpret the fossil record 622

Biologists develop hypotheses about the evolution of development 622

**Reconstructing Animal Phylogeny 622**

Animals exhibit two main types of body symmetry 622

Animal body plans are linked to the level of tissue development 624

Biologists group animals according to type of body cavity 624

Bilateral animals form two main groups based on differences in development 625

Biologists have identified major animal groups based on structure 625

Molecular data contribute to our understanding of animal relationships 626

**The Parazoa: Sponges 630**

Collar cells characterize sponges 630

**The Radiata: Animals with Radial Symmetry and Two Cell Layers 631**

Cnidarians have unique stinging cells 631

Comb jellies have adhesive glue cells that trap prey 636

## 30 THE ANIMAL KINGDOM: THE PROTOSTOMES 640

**Importance of the Coelom 641**

**The Lophotrochozoa 641**

Flatworms are bilateral acoelomates 641

Phylum Nemertea is characterized by the proboscis 643

Mollusks have a muscular foot, visceral mass, and mantle 644

Annelids are segmented worms 649

The lophophorate phyla are distinguished by a ciliated ring of tentacles 652

Rotifers have a crown of cilia 653

**The Ecdysozoa 654**

Roundworms are of great ecological importance 654

Arthropods are characterized by jointed appendages and an exoskeleton of chitin 655

**31 THE ANIMAL KINGDOM:  
THE DEUTEROSTOMES 667**

What Are Deuterostomes? 668

Echinoderms 668

Members of class Crinoidea are suspension feeders 668

Many members of class Asteroidea capture prey 669

Class Ophiuroidea is the largest class of echinoderms 670

Members of class Echinoidea have movable spines 670

Members of class Holothuroidea are elongated, sluggish animals 671

Chordate Characters 671

Invertebrate Chordates 672

Tunicates are common marine animals 672

Lancelets may be closely related to vertebrates 673

Systematists are making progress in understanding chordate phylogeny 674

Introducing the Vertebrates 674

The vertebral column is a key vertebrate character 674

Vertebrate taxonomy is a work in progress 676

Jawless Fishes 677

Evolution of Jaws and Limbs: Jawed Fishes and Amphibians 678

Members of class Chondrichthyes are cartilaginous fishes 678

The ray-finned fishes gave rise to modern bony fishes 680

Descendants of the lungfishes moved onto the land 680

Amphibians were the first successful land vertebrates 682

Amniotes 683

Our understanding of amniote phylogeny is changing 684

Reptiles have many terrestrial adaptations 686

We can assign extant reptiles to four groups 686

Are birds really dinosaurs? 687

Some dinosaurs had feathers 688

Modern birds are adapted for flight 689

Mammals are characterized by hair and mammary glands 690

The vascular tissue system consists of two complex tissues 706

The dermal tissue system consists of two complex tissues 708

Plant Meristems 710

Primary growth takes place at apical meristems 711

Secondary growth takes place at lateral meristems 712

**33 LEAF STRUCTURE AND FUNCTION 715**

Leaf Form and Structure 716

Leaf structure consists of an epidermis, photosynthetic ground tissue, and vascular tissue 716

Leaf structure is related to function 720

**Focus On: Air Pollution and Leaves 721**

Stomatal Opening and Closing 722

Blue light triggers stomatal opening 722

Additional factors affect stomatal opening and closing 724

Transpiration and Guttation 724

Some plants exude liquid water 725

Leaf Abscission 725

In many leaves, abscission occurs at an abscission zone near the base of the petiole 726

Modified Leaves 726

Modified leaves of carnivorous plants capture insects 728

**34 STEMS AND TRANSPORT  
IN VASCULAR PLANTS 731**

External Stem Structure in Woody Twigs 732

Stem Growth and Structure 732

Herbaceous eudicot and monocot stems differ in internal structure 733

Woody plants have stems with secondary growth 734

**Focus On: Tree-Ring Analysis 738**

Transport in the Plant Body 739

Water and minerals are transported in xylem 740

Sugar in solution is translocated in phloem 742

**Part 6 STRUCTURE AND LIFE PROCESSES  
IN PLANTS 698**

**32 PLANT STRUCTURE, GROWTH,  
AND DIFFERENTIATION 698**

Plant Structure and Life Span 699

Plants have different life history strategies 700

The Plant Body 700

The plant body consists of cells and tissues 700

The ground tissue system is composed of three simple tissues 702

**35 ROOTS AND MINERAL NUTRITION 748**

Root Structure and Function 749

Roots have root caps and root hairs 749

The arrangement of vascular tissues distinguishes the roots of herbaceous eudicots and monocots 749

Woody plants have roots with secondary growth 753

Some roots are specialized for unusual functions 754

Root Associations with Fungi and Bacteria 756

Mycorrhizae facilitate the uptake of essential minerals by roots 756

Rhizobial bacteria fix nitrogen in the roots of leguminous plants 756

### The Soil Environment 757

Soil is composed of inorganic minerals, organic matter, air, and water 758

The organisms living in the soil form a complex ecosystem 760

Soil pH affects soil characteristics and plant growth 760

Soil provides most of the minerals found in plants 761

Soil can be damaged by human mismanagement 762

## 36 REPRODUCTION IN FLOWERING PLANTS 767

### The Flowering Plant Life Cycle 768

Flowers develop at apical meristems 769

Each part of a flower has a specific function 769

Female gametophytes are produced in the ovary, male gametophytes in the anther 769

### Pollination 771

Many plants have mechanisms to prevent self-pollination 771

Flowering plants and their animal pollinators have coevolved 771

Some flowering plants depend on wind to disperse pollen 774

### Fertilization and Seed/Fruit Development 775

A unique double fertilization process occurs in flowering plants 776

Embryonic development in seeds is orderly and predictable 776

The mature seed contains an embryonic plant and storage materials 777

Fruits are mature, ripened ovaries 777

Seed dispersal is highly varied 780

### Germination and Early Growth 782

Some seeds do not germinate immediately 782

Eudicots and monocots exhibit characteristic patterns of early growth 782

### Asexual Reproduction in Flowering Plants 783

Apomixis is the production of seeds without the sexual process 784

### A Comparison of Sexual and Asexual Reproduction 785

Sexual reproduction has some disadvantages 785

## 37 PLANT GROWTH AND DEVELOPMENT 789

Tropisms 790

### Plant Hormones and Development 791

Plant hormones act by signal transduction 791

Auxins promote cell elongation 792

Gibberellins promote stem elongation 794

Cytokinins promote cell division 795

### Focus On: Cell and Tissue Culture 796

Ethylene promotes abscission and fruit ripening 797

Abscisic acid promotes seed dormancy 797

Additional signaling molecules affect growth and development, including plant defenses 798

Progress is being made in identifying the elusive flower-promoting signal 799

### Light Signals and Plant Development 800

Phytochrome detects day length 801

Competition for sunlight among shade-avoiding plants involves phytochrome 802

Phytochrome is involved in other responses to light, including germination 802

Phytochrome acts by signal transduction 802

Light influences circadian rhythms 803

---

## Part 7 STRUCTURE AND LIFE PROCESSES IN ANIMALS 807

## 38 ANIMAL STRUCTURE AND FUNCTION: AN INTRODUCTION 807

### Tissues 808

Epithelial tissues cover the body and line its cavities 808

Connective tissues support other body structures 809

Muscle tissue is specialized to contract 815

### Focus On: Unwelcome Tissues: Cancers 816

Nervous tissue controls muscles and glands 817

### Organs and Organ Systems 817

The body maintains homeostasis 817

### Regulating Body Temperature 822

Ectotherms absorb heat from their surroundings 823

Endotherms derive heat from metabolic processes 823

Many animals adjust to challenging temperature changes 824

## 39 PROTECTION, SUPPORT, AND MOVEMENT 827

### Epithelial Coverings 828

Invertebrate epithelium may function in secretion or gas exchange 828

Vertebrate skin functions in protection and temperature regulation 828

### Skeletal Systems 829

In hydrostatic skeletons, body fluids transmit force 829

Mollusks and arthropods have nonliving exoskeletons 830  
Internal skeletons are capable of growth 830  
The vertebrate skeleton has two main divisions 831

### **Muscle Contraction 833**

Invertebrate muscle varies among groups 834  
Insect flight muscles are adapted for rapid contraction 834  
Vertebrate skeletal muscles act antagonistically to one another 834  
A vertebrate muscle may consist of thousands of muscle fibers 835  
Contraction occurs when actin and myosin filaments slide past one another 837  
ATP powers muscle contraction 840  
The strength of muscle contraction varies 840  
Muscle fibers may be specialized for slow or quick responses 841  
Smooth muscle and cardiac muscle are involuntary 842

## **40 NEURAL SIGNALING 845**

### **Information Flow through the Nervous System 846**

#### **Neurons and Glial Cells 847**

A typical neuron consists of a cell body, dendrites, and an axon 847  
Glial cells provide metabolic and structural support 848

#### **Transmitting Information along the Neuron 849**

The neuron membrane has a resting potential 849  
Graded local signals vary in magnitude 851  
An action potential is generated by an influx of  $\text{Na}^+$  and an efflux of  $\text{K}^+$  851

#### **Neural Signaling across Synapses 855**

Signals across synapses can be electrical or chemical 855  
Neurons use neurotransmitters to signal other cells 855

### **Focus On: Alzheimer's Disease 857**

Neurotransmitters bind with receptors on postsynaptic cells 859  
Activated receptors can send excitatory or inhibitory signals 859

#### **Neural Integration 860**

#### **Neural Circuits 861**

## **41 NEURAL REGULATION 865**

### **Invertebrate Nervous Systems 866**

#### **Organization of the Vertebrate Nervous System 867**

#### **Evolution of the Vertebrate Brain 868**

The hindbrain develops into the medulla, pons, and cerebellum 868

The midbrain is prominent in fishes and amphibians 869  
The forebrain gives rise to the thalamus, hypothalamus, and cerebrum 869

### **The Human Central Nervous System 871**

The spinal cord transmits impulses to and from the brain 871  
The most prominent part of the human brain is the cerebrum 872  
Brain activity cycles in a sleep-wake pattern 873  
The limbic system affects emotional aspects of behavior 876

### **Focus On: The Neurobiology of Traumatic Experience 879**

#### **Information Processing 880**

Learning involves the storage of information and its retrieval 881  
Language involves comprehension and expression 883

#### **The Peripheral Nervous System 883**

The somatic division helps the body adjust to the external environment 884  
The autonomic division regulates the internal environment 884

#### **Effects of Drugs on the Nervous System 886**

### **Focus On: Alcohol: The Most Abused Drug 887**

## **42 SENSORY SYSTEMS 893**

### **How Sensory Systems Work 894**

Sensory receptors receive information 894  
Sensory receptors transduce energy 894  
Sensory input is integrated at many levels 894

#### **Types of Sensory Receptors 896**

##### **Thermoreceptors 897**

##### **Electroreceptors and Electromagnetic Receptors 898**

##### **Nociceptors 898**

##### **Mechanoreceptors 898**

Touch receptors are located in the skin 899  
Proprioceptors help coordinate muscle movement 899  
Many invertebrates have gravity receptors called statocysts 900

Hair cells are characterized by stereocilia 901

Lateral line organs supplement vision in fishes 901

The vestibular apparatus maintains equilibrium 901

Auditory receptors are located in the cochlea 903

##### **Chemoreceptors 906**

Taste receptors detect dissolved food molecules 906

The olfactory epithelium is responsible for the sense of smell 908

Many animals communicate with pheromones 909

## Photoreceptors 909

Invertebrate photoreceptors include eyespots, simple eyes, and compound eyes 909

Vertebrate eyes form sharp images 910

The retina contains light-sensitive rods and cones 912

## 43 INTERNAL TRANSPORT 919

### Types of Circulatory Systems 920

Many invertebrates have an open circulatory system 920

Some invertebrates have a closed circulatory system 921

Vertebrates have a closed circulatory system 922

### Vertebrate Blood 922

Plasma is the fluid component of blood 922

Red blood cells transport oxygen 923

White blood cells defend the body against disease organisms 924

Platelets function in blood clotting 925

### Vertebrate Blood Vessels 925

#### Evolution of the Vertebrate Cardiovascular System 927

#### The Human Heart 928

Each heartbeat is initiated by a pacemaker 930

The nervous system regulates heart rate 932

Stroke volume depends on venous return 932

Cardiac output varies with the body's need 932

#### Blood Pressure 933

### **Focus On:** Cardiovascular Disease 934

Blood pressure varies in different blood vessels 934

Blood pressure is carefully regulated 935

#### The Pattern of Circulation 937

The pulmonary circulation oxygenates the blood 937

The systemic circulation delivers blood to the tissues 937

#### The Lymphatic System 938

The lymphatic system consists of lymphatic vessels and lymph tissue 939

The lymphatic system plays an important role in fluid homeostasis 940

## 44 THE IMMUNE SYSTEM: INTERNAL DEFENSE 944

### Nonspecific and Specific Immunity: An Overview 945

The immune system responds to danger signals 945

Invertebrates launch nonspecific immune responses 946

Vertebrates launch nonspecific and specific immune responses 946

### Nonspecific Immune Responses 946

Phagocytes and natural killer cells destroy pathogens 947

Cytokines and complement mediate immune responses 948

Inflammation is a protective response 949

### Specific Immune Responses 950

Many types of cells are involved in specific immune responses 950

The major histocompatibility complex is responsible for recognition of self 952

### Cell-Mediated Immunity 952

#### Antibody-Mediated Immunity 952

A typical antibody consists of four polypeptide chains 953

Antibodies are grouped in five classes 954

Antigen-antibody binding activates other defenses 955

The immune system responds to millions of different antigens 956

Monoclonal antibodies are highly specific 958

#### Immunological Memory 958

A secondary immune response is more effective than a primary response 958

Immunization induces active immunity 959

Passive immunity is borrowed immunity 960

#### The Immune System and Disease 960

Cancer cells evade the immune system 960

Immunodeficiency disease can be inherited or acquired 961

HIV is the major cause of acquired immunodeficiency in adults 961

#### Harmful Immune Responses 964

Graft rejection is an immune response against transplanted tissue 964

Rh incompatibility can result in hypersensitivity 965

Allergic reactions are directed against ordinary environmental antigens 965

In an autoimmune disease, the body attacks its own tissues 966

## 45 GAS EXCHANGE 970

### Adaptations for Gas Exchange in Air or Water 971

#### Types of Respiratory Surfaces 971

The body surface may be adapted for gas exchange 971

Tracheal tube systems deliver air directly to the cells 971

Gills are the respiratory surfaces in many aquatic animals 972

Terrestrial vertebrates exchange gases through lungs 973

#### The Mammalian Respiratory System 975

The airway conducts air into the lungs 975

Gas exchange occurs in the alveoli of the lungs 976

Ventilation is accomplished by breathing 976

The quantity of respired air can be measured 978

Gas exchange takes place in the alveoli 978

Gas exchange takes place in the tissues 979

Respiratory pigments increase capacity for oxygen transport 979

Carbon dioxide is transported mainly as bicarbonate ions 980  
Breathing is regulated by respiratory centers in the brain 981  
Hyperventilation reduces carbon dioxide concentration 982  
High flying or deep diving can disrupt homeostasis 982  
Some mammals are adapted for diving 982  
Breathing Polluted Air 983

**Focus On:** The Effects of Smoking 984

## 46 PROCESSING FOOD AND NUTRITION 989

**Nutritional Styles and Adaptations 990**  
Animals are adapted to their mode of nutrition 990  
Some invertebrates have a digestive cavity with a single opening 991  
Most animal digestive systems have two openings 992  
**The Vertebrate Digestive System 992**  
Food processing begins in the mouth 993  
The pharynx and esophagus conduct food to the stomach 994  
Food is mechanically and enzymatically digested in the stomach 994  
Most enzymatic digestion takes place in the small intestine 995  
The liver secretes bile 996  
The pancreas secretes digestive enzymes 996  
Nutrients are digested as they move through the digestive tract 997  
Nerves and hormones regulate digestion 998  
Absorption takes place mainly through the villi of the small intestine 999  
The large intestine eliminates waste 1000  
**Required Nutrients 1000**  
Carbohydrates provide energy 1001  
Lipids provide energy and are used to make biological molecules 1001  
Proteins serve as enzymes and as structural components of cells 1002  
Vitamins are organic compounds essential for normal metabolism 1002  
Minerals are inorganic nutrients 1003  
Antioxidants protect against oxidants 1003  
Phytochemicals play important roles in maintaining health 1003  
**Energy Metabolism 1005**  
Undernutrition can cause serious health problems 1006  
Obesity is a serious nutritional problem 1006

## 47 OSMOREGULATION AND DISPOSAL OF METABOLIC WASTES 1011

Maintaining Fluid and Electrolyte Balance 1012  
Metabolic Waste Products 1012

## Osmoregulation and Excretion in Invertebrates 1013

Nephridial organs are specialized for osmoregulation and/or excretion 1013  
Malpighian tubules conserve water 1014

## Osmoregulation and Excretion in Vertebrates 1015

Freshwater vertebrates must rid themselves of excess water 1015  
Marine vertebrates must replace lost fluid 1016  
Terrestrial vertebrates must conserve water 1016  
**The Urinary System 1017**  
The nephron is the functional unit of the kidney 1018  
Urine is produced by filtration, reabsorption, and secretion 1019  
Urine becomes concentrated as it passes through the renal tubule 1021  
Urine consists of water, nitrogenous wastes, and salts 1022  
Hormones regulate kidney function 1023

## 48 ENDOCRINE REGULATION 1028

**An Overview of Endocrine Regulation 1029**  
The endocrine system and nervous system interact to regulate the body 1029  
Negative feedback systems regulate endocrine activity 1029  
Hormones are assigned to four chemical groups 1030  
**Types of Endocrine Signaling 1031**  
Neurohormones are transported in the blood 1031  
Some local regulators are considered hormones 1031

**Focus On:** Anabolic Steroids and Other Abused Hormones 1032

**Mechanisms of Hormone Action 1033**  
Some hormones enter target cells and activate genes 1033  
Many hormones bind to cell-surface receptors 1033

## Invertebrate Neuroendocrine Systems 1035

**The Vertebrate Endocrine System 1036**  
Homeostasis depends on normal concentrations of hormones 1036  
The hypothalamus regulates the pituitary gland 1037  
The posterior lobe of the pituitary gland releases hormones produced by the hypothalamus 1038  
The anterior lobe of the pituitary gland regulates growth and other endocrine glands 1038  
Thyroid hormones increase metabolic rate 1041  
The parathyroid glands regulate calcium concentration 1042  
The islets of the pancreas regulate glucose concentration 1043  
The adrenal glands help the body respond to stress 1045  
Many other hormones are known 1047

## 49 REPRODUCTION 1051

### Asexual and Sexual Reproduction 1052

Asexual reproduction is an efficient strategy 1052

Most animals reproduce sexually 1052

Sexual reproduction increases genetic variability 1053

### Human Reproduction: The Male 1054

The testes produce gametes and hormones 1054

A series of ducts store and transport sperm 1056

The accessory glands produce the fluid portion of semen 1056

The penis transfers sperm to the female 1057

Testosterone has multiple effects 1057

The hypothalamus, pituitary gland, and testes regulate male reproduction 1058

### Human Reproduction: The Female 1058

The ovaries produce gametes and sex hormones 1059

The oviducts transport the secondary oocyte 1060

The uterus incubates the embryo 1061

The vagina receives sperm 1061

The vulva are external genital structures 1061

The breasts function in lactation 1062

### **Focus On:** Breast Cancer 1063

The hypothalamus, pituitary gland, and ovaries regulate female reproduction 1063

Menstrual cycles stop at menopause 1067

Most mammals have estrous cycles 1067

### Sexual Response 1067

### Fertilization and Early Development 1068

### **Focus On:** Novel Origins 1069

#### The Birth Process 1070

#### Birth Control Methods 1071

Most hormone contraceptives prevent ovulation 1073

Intrauterine devices are widely used 1073

Other common contraceptive methods include the diaphragm and condom 1074

Emergency contraception is available 1074

Sterilization renders an individual incapable of producing offspring 1074

Abortions can be spontaneous or induced 1075

#### Sexually Transmitted Diseases 1075

## 50 ANIMAL DEVELOPMENT 1080

### Development of Form 1081

#### Fertilization 1081

The first step in fertilization involves contact and recognition 1081

Sperm entry is regulated 1082

Fertilization activates the egg 1083

Sperm and egg pronuclei fuse, restoring the diploid state 1083

#### Cleavage 1083

The pattern of cleavage is affected by yolk 1083

Cleavage may distribute developmental determinants 1085

Cleavage provides building blocks for development 1086

#### Gastrulation 1087

The amount of yolk affects the pattern of gastrulation 1087

#### Organogenesis 1089

#### Extraembryonic Membranes 1091

#### Human Development 1091

The placenta is an organ of exchange 1092

Organ development begins during the first trimester 1094

Development continues during the second and third trimesters 1094

More than one mechanism can lead to a multiple birth 1095

Environmental factors affect the embryo 1095

The neonate must adapt to its new environment 1095

Aging is not a uniform process 1097

Homeostatic response to stress decreases during aging 1097

## 51 ANIMAL BEHAVIOR 1101

### Behavior and Adaptation 1102

#### Interaction of Genes and Environment 1102

Behavior depends on physiological readiness 1103

Many behavior patterns depend on motor programs 1104

#### Learning from Experience 1104

An animal habituates to irrelevant stimuli 1105

Imprinting occurs during an early critical period 1105

In classical conditioning, a reflex becomes associated with a new stimulus 1106

In operant conditioning, spontaneous behavior is reinforced 1106

Animal cognition is controversial 1107

Play may be practice behavior 1108

#### Biological Rhythms and Migration 1108

Biological rhythms affect behavior 1108

Migration involves interactions among biological rhythms, physiology, and environment 1109

#### Foraging Behavior 1110

#### Communication and Living in Groups 1111

Communication is necessary for social behavior 1111

Animals benefit from social organization 1113

Many animals defend a territory 1114

#### Sexual Selection 1115

Animals of the same sex compete for mates 1115

Animals choose quality mates 1115

Sexual selection favors polygynous mating systems 1116

Some animals care for their young 1117



**Helping Behavior 1118**

Altruistic behavior can be explained by inclusive fitness 1118  
Helping behavior may have alternative explanations 1120  
Some animals help nonrelatives 1120

**Highly Organized Societies 1121**

Social insects form elaborate societies 1121  
Vertebrate societies tend to be relatively flexible 1122  
Sociobiology explains human social behavior in terms of adaptation 1123

Natural selection shapes the body forms and behaviors of both predator and prey 1153

**Focus On: Batesian Butterflies Disproved 1155**

Symbiosis involves a close association between species 1156  
Keystone species and dominant species affect the character of a community 1157

**Community Biodiversity 1158**

Ecologists seek to explain why some communities have more species than others 1158  
Species richness may promote community stability 1161

**Community Development 1161**

Disturbance influences succession and species richness 1162  
Ecologists continue to study community structure 1163

**Part 8 THE INTERACTIONS OF LIFE: ECOLOGY 1126**

**52 INTRODUCTION TO ECOLOGY: POPULATION ECOLOGY 1126**

**Features of Populations 1127**  
Density and dispersion are important features of populations 1127  
**Changes in Population Size 1129**  
Dispersal affects the growth rate in some populations 1129  
Each population has a characteristic intrinsic rate of increase 1129  
No population can increase exponentially indefinitely 1130  
**Factors Influencing Population Size 1131**  
Density-dependent factors regulate population size 1131  
Density-independent factors are generally abiotic 1133  
**Life History Traits 1134**  
Life tables and survivorship curves indicate mortality and survival 1136  
**Metapopulations 1137**  
**Human Populations 1139**  
Not all countries have the same growth rate 1140  
The age structure of a country helps predict future population growth 1141  
Environmental degradation is related to population growth and resource consumption 1142

**53 COMMUNITY ECOLOGY 1146**

**Community Structure and Functioning 1147**  
Community interactions are often complex and not readily apparent 1147  
The niche is a species' ecological role in the community 1148  
Competition is intraspecific or interspecific 1149

**54 ECOSYSTEMS AND THE BIOSPHERE 1166**

**Energy Flow through Ecosystems 1167**  
Ecological pyramids illustrate how ecosystems work 1168  
Ecosystems vary in productivity 1169  
Food chains and poisons in the environment 1171  
**Cycles of Matter in Ecosystems 1172**  
Carbon dioxide is the pivotal molecule in the carbon cycle 1173  
Bacteria are essential to the nitrogen cycle 1174  
The phosphorus cycle lacks a gaseous component 1176  
Water moves among the ocean, land, and atmosphere in the hydrologic cycle 1177  
**Ecosystem Regulation from the Bottom Up and the Top Down 1178**  
**Abiotic Factors in Ecosystems 1179**  
The sun warms Earth 1179

**Focus On: Life without the Sun 1180**

The atmosphere contains several gases essential to organisms 1180  
The global ocean covers most of Earth's surface 1182  
Climate profoundly affects organisms 1183  
Fires are a common disturbance in some ecosystems 1184  
**Studying Ecosystem Processes 1185**

**55 ECOLOGY AND THE GEOGRAPHY OF LIFE 1189**

**Biomes 1190**  
Tundra is the cold, boggy plains of the far north 1190  
Boreal forest is the evergreen forest of the north 1191  
Temperate rain forest has cool weather, dense fog, and high precipitation 1192  
Temperate deciduous forest has a canopy of broad-leaf trees 1194

Temperate grasslands occur in areas of moderate precipitation 1194

**Focus On:** The Distribution of Vegetation on Mountains 1195

Chaparral is a thicket of evergreen shrubs and small trees 1196

Deserts are arid ecosystems 1196

Savanna is a tropical grassland with scattered trees 1197

There are two basic types of tropical forests 1198

### **Aquatic Ecosystems 1199**

Freshwater ecosystems are closely linked to land and marine ecosystems 1200

Estuaries occur where fresh water and salt water meet 1203

Marine ecosystems dominate Earth's surface 1204

**Ecotones 1207**

### **Biogeography 1208**

Land areas are divided into six biogeographic realms 1208

## **56 GLOBAL ENVIRONMENTAL ISSUES 1212**

### **The Biodiversity Crisis 1213**

Endangered species have certain characteristics in common 1214

**Focus On:** Declining Amphibian Populations 1215

Human activities contribute to declining biological diversity 1215

### **Conservation Biology 1219**

In situ conservation is the best way to preserve biological diversity 1219

Landscape ecology considers ecosystem types on a regional scale 1220

Restoring damaged or destroyed habitats is the goal of restoration ecology 1221

Ex situ conservation attempts to save species on the brink of extinction 1221

The Endangered Species Act provides some legal protection for species and habitats 1222

International agreements provide some protection of species and habitats 1223

### **Deforestation 1224**

Why are tropical rain forests disappearing? 1224

Why are boreal forests disappearing? 1225

### **Global Warming 1226**

Greenhouse gases cause global warming 1226

What are the probable effects of global warming? 1227

### **Declining Stratospheric Ozone 1229**

Certain chemicals destroy stratospheric ozone 1229

Ozone depletion harms organisms 1230

International cooperation is helping repair the ozone layer 1230

### **Connections among Environmental Problems 1231**

Appendix A Periodic Table of the Elements A-1

Appendix B Classification of Organisms A-2

Appendix C Understanding Biological Terms A-6

Appendix D Abbreviations A-9

Appendix E Answers to Test Your Understanding Questions A-11

Glossary G-1

Index I-1