BIOLOGY

the dynamic science

Russell, Wolfe, Hertz, Starr & McMillan

Not United States

Contents

1 Introduction to Biological Concepts and Research 1

- 1.1 What Is Life? Characteristics of Living Systems 2
- 1.2 Biological Evolution 7
- 1.3 Biodiversity 9
- 1.4 Biological Research 13

Figure 1.14 Experimental Research
Hypothetical Experiment Illustrating the Use of Control
Treatment and Replicates 15

Figure 1.15 Observational Research
A Field Study Using a Null Hypothesis 17

UNIT ONE MOLECULES AND CELLS 21

2 Life, Chemistry, and Water 21

- 2.1 The Organization of Matter: Elements and Atoms 22
- 2.2 Atomic Structure 23
- 2.3 Chemical Bonds 28
- 2.4 Hydrogen Bonds and the Properties of Water 32
- Water Ionization and Acids, Bases, and Buffers 36
 FOCUS ON RESEARCH
 Basic Research: Using Radioisotopes to Trace Reactions and Save Lives 26

3 Biological Molecules: The Carbon Compounds of Life 41

- 3.1 Carbon Bonding 42
- 3.2 Functional Groups in Biological Molecules 43
- 3.3 Carbohydrates 45
- 3.4 Lipids 50
- 3.5 Proteins 55
- 3.6 Nucleotides and Nucleic Acids 64

FOCUS ON RESEARCH

Applied Research: Fats, Cholesterol, and Coronary Artery Disease 52

INSIGHTS FROM THE MOLECULAR REVOLUTION

Getting Good Vibrations from Proteins 61

4 Energy, Enzymes, and Biological Reactions 71

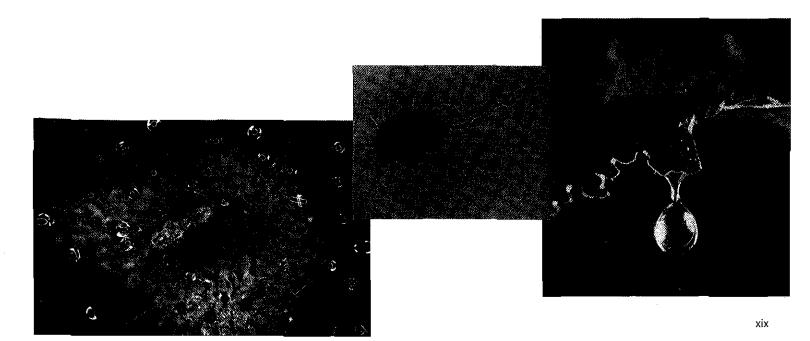
- 4.1 Energy, Life, and the Laws of Thermodynamics 72
- **4.2** How Living Organisms Couple Reactions to Make Synthesis Spontaneous **75**
- 4.3 Thermodynamics and Reversible Reactions 77
- 4.45 Role of Enzymes in Biological Reactions 78
- **4.5** Conditions and Factors That Affect Enzyme Activity **82**
- 4.6 RNA-Based Biological Catalysts: Ribozymes 86

FOCUS ON RESEARCH

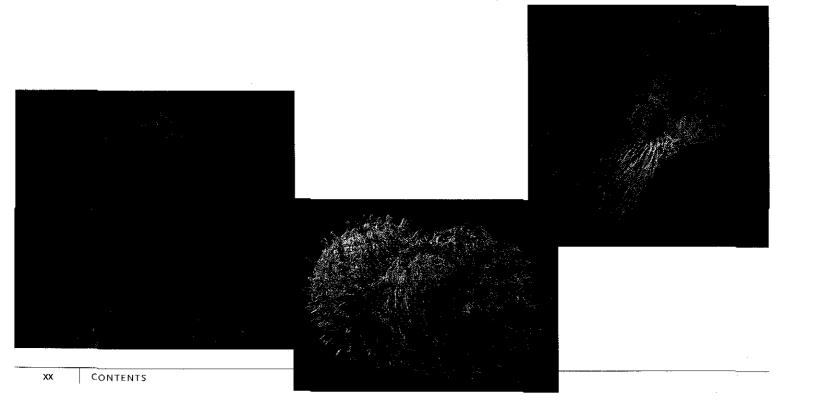
Basic Research: Testing the Transition State 81

Insights from the Molecular Revolution

Ribozymes Take the First Step in Protein Synthesis



5	The Cell: An Overview 91	7	Cell Communication 139	
5.1	Basic Features of Cell Structure and Function 92	7.1	Cell Communication: An Overview 140	
5.2 5.3	Prokaryotic Cells 96 Eukaryotic Cells 97	7.2	Characteristics of Cell Communication Systems with Surface Receptors 143	
5.4 5.5	Specialized Structures of Plant Cells 110		Surface Receptors with Built-In Protein Kinase Activity: Receptor Tyrosine Kinases 145	
	Figure 5.4 Research Method Light and Electron Microscopy 94 INSIGHTS FROM THE MOLECULAR REVOLUTION An Old Kingdom in a New Domain 98	7.4 7.5	G-Protein—Coupled Receptors 146 Pathways Triggered by Internal Receptors: Steroid Hormone Receptors 151	
		7.6	Integration of Cell Communication Pathways 152	
			INSIGHTS FROM THE MOLECULAR REVOLUTION Surviving Something Bad by Taking a Risk 147	
6	Membranes and Transport 119		FOCUS ON RESEARCH	
6.1	Membrane Structure 120		Basic Research: Detecting Calcium Release in Cells 150	
6.2	Functions of Membranes in Transport: Passive Transport 124	8	Harvesting Chemical Energy: Cellular	
6.3	Passive Water Transport and Osmosis 128	0	Respiration 157	
6.4	Active Transport 131	8.1	Overview of Cellular Energy Metabolism 158	
6.5	Exocytosis and Endocytosis 132	8.2	Glycolysis 162	
	Focus on Research Basic Research: Keeping Membranes Fluid at Cold Temperatures 123 Figure 6.6 Experimental Research The Frye-Edidin Experiment Demonstrating That the Phospholipid Bilayer Is Fluid 124	8.3	Pyruvate Oxidation and the Citric Acid Cycle 165	
		8.4	The Electron Transfer System and Oxidative Phosphorylation 168	
		8.5	Fermentation 172	
	Figure 6.7 Research Method Freeze Fracture 125		Figure 8.5 Research Method Cell Fractionation 161	
	Insights from the Molecular Revolution Tracking Gating Movements in a Channel Protein 128		INSIGHTS FROM THE MOLECULAR REVOLUTION Keeping the Potatoes Hot 173	



9 Photosynthesis 177

- 9.1 Photosynthesis: An Overview 178
- 9.2 The Light-Dependent Reactions of Photosynthesis 180
- 9.3 The Light-Independent Reactions of Photosynthesis 189
- 9.4 Photorespiration and the C₄ Cycle 194

Figure 9.12 Experimental Research
Demonstration That an H⁺ Gradient Drives ATP Synthesis in
Chloroplasts 189

FOCUS ON RESEARCH

Basic Research: Two-Dimensional Paper Chromatography and the Calvin Cycle 190

Insights from the Molecular Revolution Small but Pushy 193

10 Cell Division and Mitosis 201

- 10.1 The Cycle of Cell Growth and Division: An Overview 202
- 10.2 The Mitotic Cell Cycle 203
- 10.3 Formation and Action of the Mitotic Spindle 209
- 10.4 Cell Cycle Regulation 212
- 10.5 Cell Division in Prokaryotes 216

Figure 10.7 Research Method
Preparing a Human Karyotype 207

FOCUS ON RESEARCH

Basic Research: Growing Cell Clones in Culture 209

Figure 10.14 Experimental Research
How Do Chromosomes Move during Anaphase of
Mitosis? 212

FOCUS ON RESEARCH

Model Research Organisms: The Yeast Saccharomyces

INSIGHTS FROM THE MOLECULAR REVOLUTION
Herpesviruses and Uncontrolled Cell Division 215

UNIT TWO GENETICS 221

11 Meiosis: The Cellular Basis of Sexual Reproduction 221

- 11.1 The Mechanisms of Meiosis 222
- 11.2 Mechanisms That Generate Genetic Variability 227
- **11.3** The Time and Place of Meiosis in Organismal Life Cycles **230**

INSIGHTS FROM THE MOLECULAR REVOLUTION
Fertile Fields in the Human Y Chromosome 226

12 Mendel, Genes, and Inheritance 235

- **12.1** The Beginnings of Genetics: Mendel's Garden Peas **236**
- 12.2 Later Modifications and Additions to Mendel's Hypotheses 245

INSIGHTS FROM THE MOLECULAR REVOLUTION
Why Mendel's Dwarf Pea Plants Were So Short 245

13 Genes, Chromosomes, and Human Genetics 255

- 13.1 Genetic Linkage and Recombination 256
- 13.2 Sex-Linked Genes 261
- 13.3 Chromosomal Alterations That Affect Inheritance 266
- 13.4 Human Genetics and Genetic Counseling 269
- 13.5 Nontraditional Patterns of Inheritance 272

 Figure 13.2 Experimental Research

 Evidence for Gene Linkage 257



FOCUS ON RESEARCH

Model Research Organisms: The Marvelous Fruit Fly, Drosophila melanogaster 258

Figure 13.8 Experimental Research Evidence for Sex-Linked Genes 263

INSIGHTS FROM THE MOLECULAR REVOLUTION
Achondroplastic Dwarfing by a Single Amino Acid
Change 271

14 DNA Structure, Replication, and Organization 277

- 14.1 Establishing DNA as the Hereditary Molecule 278
- 14.2 DNA Structure 281
- 14.3 DNA Replication 284
- 14.4 Mechanisms That Correct Replication Errors 292
- 14.5 DNA Organization in Eukaryotes and Prokaryotes 295

Figure 14.2 Experimental Research

Griffith's Experiment with Infective and Noninfective Strains of Streptococcus pneumoniae 279

Figure 14.3 Experimental Research

The Hershey and Chase Experiment Demonstrating That DNA Is the Hereditary Molecule 280

Figure 14.9 Experimental Research

The Meselson and Stahl Experiment Demonstrating the Semiconservative Model to Be Correct 286

INSIGHTS FROM THE MOLECULAR REVOLUTION

A Fragile Connection between DNA Replication and Mental Retardation 294

15 From DNA to Protein 301

- **15.1** The Connection between DNA, RNA, and Protein **302**
- 15.2 Transcription: DNA-Directed RNA Synthesis 307
- 15.3 Production of mRNAs in Eukaryotes 309
- **15.4** Translation: mRNA-Directed Polypeptide Synthesis **313**

Figure 15.2 Experimental Research
Relationship between Genes and Enzymes 304

INSIGHTS FROM THE MOLECULAR REVOLUTION

Measuring Ribosomes with a Molecular Ruler 320

16 Control of Gene Expression 329

- 16.1 Regulation of Gene Expression in Prokaryotes 330
- 16.2 Regulation of Transcription in Eukaryotes 335
- **16.3** Posttranscriptional, Translational, and Posttranslational Regulation **342**
- 16.4 The Loss of Regulatory Controls in Cancer 345

 INSIGHTS FROM THE MOLECULAR REVOLUTION

 A Viral Tax on Transcriptional Regulation 346

17 Bacterial and Viral Genetics 351

- **17.1** Gene Transfer and Genetic Recombination in Bacteria **353**
- 17.2 Viruses and Viral Recombination 360
- 17.3 Transposable Elements 362

FOCUS ON RESEARCH

Model Research Organisms: Escherichia coli 352

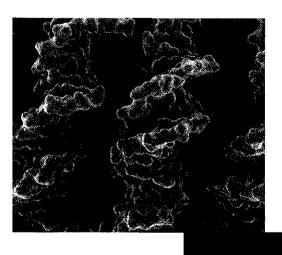


Figure 17.1 Experimental Research Genetic Recombination in Bacteria

Figure 17.5 Research Method Replica Plating 359

INSIGHTS FROM THE MOLECULAR REVOLUTION Genes That Jump a Mite Too Far 366

DNA Technologies and Genomics 371 18

DNA Cloning 372 18.1

Applications of DNA Technologies 379 18.2

18.3 Genome Analysis 390

Figure 18.4 Research Method Cloning a Gene of Interest in a Plasmid Cloning Vector

Figure 18.5 Research Method DNA Hybridization to Identify a DNA Sequence of Interest 377

Figure 18.6 Research Method The Polymerase Chain Reaction (PCR) 378

Figure 18.7 Research Method Separation of DNA Fragments by Agarose Gel Electrophoresis 380

Figure 18.9 Research Method Southern Blot Analysis 382

Figure 18.11 Research Method Introduction of Genes into Mouse Embryos Using Embryonic Germ-Line Cells 385

Figure 18.15 Research Method Using the Ti Plasmid of Rhizobium radiobacter to Produce Transgenic Plants 389

Insights from the Molecular Revolution Engineering Rice for Blight Resistance 391

Figure 18.18 Research Method Dideoxy (Sanger) Method for Sequencing DNA 392

Figure 18.19 Research Method Whole-Genome Shotgun Sequencing

Figure 18.20 Research Method

DNA Microarray Analysis of Gene Expression Levels 396

UNIT THREE EVOLUTIONARY BIOLOGY

19 Development of Evolutionary Thought 401

19.1 Recognition of Evolutionary Change 402

19.2 Darwin's Journeys 405

19.3 Evolutionary Biology since Darwin 411

FOCUS ON RESEARCH

Basic Research: Charles Darwin's Life as a Scientist 408

INSIGHTS FROM THE MOLECULAR REVOLUTION Artificial Selection in the Test Tube 409

Figure 19.11 Experimental Research How Exposure to Insecticide Fosters the Evolution of Insecticide Resistance 412

Figure 19.14 Observational Research How Differences in Amino Acid Sequences among Species Reflect Their Evolutionary Relationships 415

20 Microevolution: Genetic Changes within Populations 419

20.1 Variation in Natural Populations 420

20.2 Population Genetics 423

20.3 The Agents of Microevolution 425

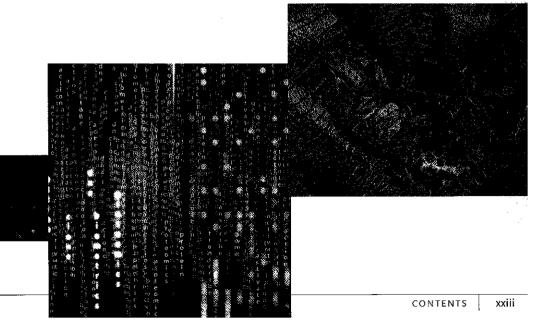
Maintaining Genetic and Phenotypic Variation 435

20.5 Adaptation and Evolutionary Constraints 437

Figure 20.6 Experimental Research Using Artificial Selection to Demonstrate That Activity Level in Mice Has a Genetic Basis 423

FOCUS ON RESEARCH

Basic Research: Using the Hardy-Weinberg Principle 426



Insights from the Molecular Revolution

Genetic Variation Preserved in Humpback Whales 429

Figure 20.10 Observational Research

Evidence for Stabilizing Selection in Humans 431

Figure 20.11 Observational Research

How Opposing Forces of Directional Selection Produce Stabilizing Selection 432

Figure 20.13 Experimental Research

Sexual Selection in Action 434

Figure 20.15 Observational Research

Habitat Variation in Color and Striping Patterns of European Garden Snails 437

Figure 20.16 Experimental Research

Demonstration of Frequency-Dependent Selection 438

27 Speciation 443

- 21.1 What Is a Species? 444
- 21.2 Maintaining Reproductive Isolation 447
- 21.3 The Geography of Speciation 449
- 21.4 Genetic Mechanisms of Speciation 454

FOCUS ON RESEARCH

Basic Research: Speciation in Hawaiian Fruit Flies 452

Figure 21.13 Observational Research

Evidence for Reproductive Isolation in Bent Grass 454

INSIGHTS FROM THE MOLECULAR REVOLUTION

Monkey-Flower Speciation 455

Figure 21.19 Observational Research

Chromosomal Similarities and Differences among the Great Apes 458

22 Paleobiology and Macroevolution 463

- 22.1 The Fossil Record 464
- **22.2** Earth History, Biogeography, and Convergent Evolution **469**
- 22.3 Interpreting Evolutionary Lineages 473
- 22.4 Macroevolutionary Trends in Morphology 477
- 22.5 Macroevolutionary Trends in Biodiversity 480
- 22.6 Evolutionary Developmental Biology 483

Figure 22.4 Research Method Radiometric Dating 468

FOCUS ON RESEARCH

Basic Research: The Great American Interchange 472

Figure 22.12 Observational Research

Evidence Supporting the Punctuated Equilibrium Hypothesis 476

Figure 22.13 Observational Research

Evidence Supporting the Gradualist Hypothesis 478

Figure 22.16 Observational Research

Paedomorphosis in Delphinium Flowers 481

INSIGHTS FROM THE MOLECULAR REVOLUTION

Fancy Footwork from Fins to Fingers 486

23 Systematic Biology: Phylogeny and Classification 491

- 23.1 Systematic Biology: An Overview 492
- 23.2 The Linnaean System of Taxonomy 493
- 3.3 Organismal Traits as Systematic Characters 494
- 23.4 Evaluating Systematic Characters 495





- 23.5 Phylogenetic Inference and Classification 497
- 23.6 Molecular Phylogenetics 501

Figure 23.9 Research Method

Constructing a Cladegram 500

INSIGHTS FROM THE MOLECULAR REVOLUTION Whales with Cow Cousins? 502

Figure 23.10 Observational Research
Using Amino Acid Sequences to Construct
a Phylogenetic Tree 504

Figure 23.11 Research Method Aligning DNA Sequences 505

UNIT FOUR BIODIVERSITY 511

- 24 The Origin of Life 511
- 24.1 The Formation of Molecules Necessary for Life 512
- 24.2 The Origin of Cells 515
- 24.3 The Origins of Eukaryotic Cells 519

 INSIGHTS FROM THE MOLECULAR REVOLUTION
 Replicating the RNA World 518
- 25 Prokaryotes and Viruses 525
- 25.1 Prokaryotic Structure and Function 526
- 25.2 The Domain Bacteria 534
- 25.3 The Domain Archaea 537
- 25.4 Viruses, Viroids, and Prions 540

INSIGHTS FROM THE MOLECULAR REVOLUTION
Extreme but Still in Between 539

- 26 Protists 549
- 26.1 What Is a Protist? 550
- 26.2 The Protist Groups 553

FOCUS ON RESEARCH

Applied Research: Malaria and the *Plasmodium*Life Cycle 559

INSIGHTS FROM THE MOLECULAR REVOLUTION
Getting the Slime Mold Act Together 566

- 27 Plants 575
- 27.1 The Transition to Life on Land 576
- 27.2 Bryophytes: Nonvascular Land Plants 581
- 27.3 Seedless Vascular Plants 585
- 27.4 Gymnosperms: The First Seed Plants 590
- 27.5 Angiosperms: Flowering Plants 595

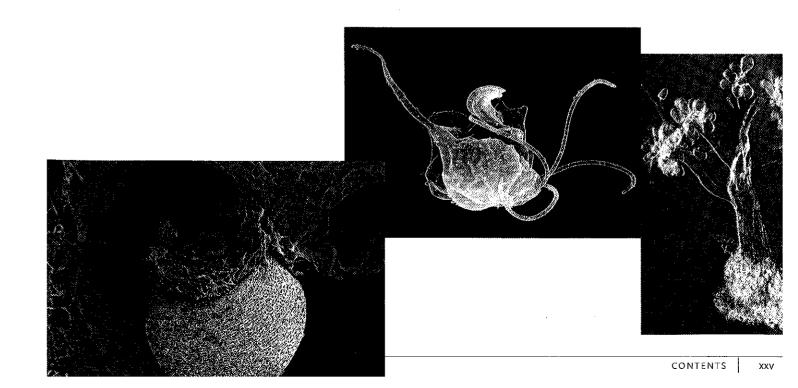
INSIGHTS FROM THE MOLECULAR REVOLUTION
The Powerful Genetic Toolkit for Studying
Plant Evolution 597

- 28 Fungi 605
- 28.1 General Characteristics of Fungi 606
- 28.2 Major Groups of Fungi 610
- 28.3 Fungal Associations 620

Insights from the Molecular Revolution
There Was Probably a Fungus among Us 611

FOCUS ON RESEARCH

Applied Research: Lichens as Monitors of Air Pollution's Biological Damage 621



29	Animal Phylogeny,	Acoelomates,
	and Protostomes	627

- 29.1 What Is an Animal? 628
- 29.2 Key Innovations in Animal Evolution 629
- **29.3** An Overview of Animal Phylogeny and Classification **633**
- 29.4 Animals without Tissues: Parazoa 635
- 29.5 Eumetazoans with Radial Symmetry 636
- 29.6 Lophotrochozoan Protostomes 641
- 29.7 Ecdysozoan Protostomes 653

FOCUS ON RESEARCH

Applied Research: A Rogue's Gallery of Parasitic Worms 644

FOCUS ON RESEARCH

Model Research Organisms: Caenorhabditis elegans 654

Insights from the Molecular Revolution

Unscrambling the Arthropods 656

30 Deuterostomes: Vertebrates and Their Closest Relatives 667

- 30.1 Invertebrate Deuterostomes 668
- 30.2 Overview of the Phylum Chordata 671
- 30.3 The Origin and Diversification of Vertebrates 674
- **30.4** Agriathans: Hagfishes and Lampreys, Conodonts and Ostracoderms **677**
- 30.5 lawed Fishes 678
- 30.6 Early Tetrapods and Modern Amphibians 683

- **30.7** The Origin and Mesozoic Radiations of Amniotes **686**
- 30.8 Testudines: Turtles 688
- **30.9** Living Nonfeathered Diapsids: Sphenodontids, Squamates, and Crocodilians **689**
- 30.10 Aves: Birds 692
- 30.11 Mammalia: Monotremes, Marsupials, and Placentals 695
- 30.12 Nonhuman Primates 697
- 30.13 The Evolution of Humans 702

FOCUS ON RESEARCH

Model Research Organisms: *Anolis* Lizards of the Caribbean **691**

INSIGHTS FROM THE MOLECULAR REVOLUTION

The Guinea Pig Is Not a Rat 698

Unit Five Plant Structure and Function 711

31 The Plant Body 711

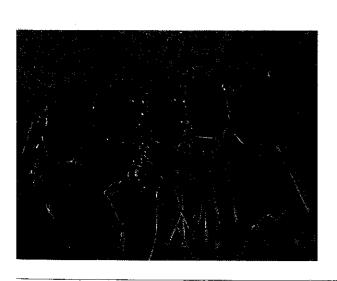
- 31.1 Plant Structure and Growth: An Overview 712
- 31.2 The Three Plant Tissue Systems 715
- 31.3 Primary Shoot Systems 721
- 31.4 Root Systems 727
- 31.5 Secondary Growth 730

INSIGHTS FROM THE MOLECULAR REVOLUTION

Shaping up Flower Color 720

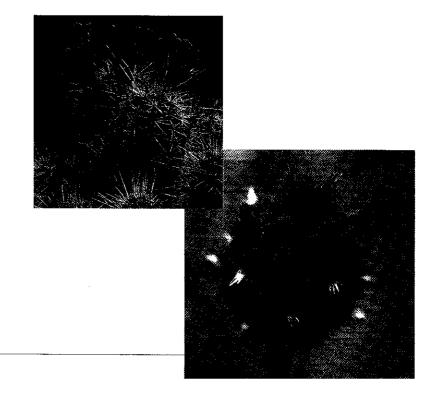
FOCUS ON RESEARCH

Basic Research: Homeobox Genes: How the Meristem
Gives Its Marching Orders 724



CONTENTS

XXV



32	Trans	port in	Plants	737
----	-------	---------	---------------	-----

- **32.1** Principles of Water and Solute Movement in Plants **738**
- 32.2 Transport in Roots 742
- 32.3 Transport of Water and Minerals in the Xylem 745
- 32.4 Transport of Organic Substances in the Phloem 750

Insights from the Molecular Revolution

A Plant Water Channel Gives Oocytes a Drink 742

Figure 32.14 Experimental Research
Translocation Pressure 751

33 Plant Nutrition 757

- 33.1 Plant Nutritional Requirements 758
- 33,2 Soil 762
- 33.3 Obtaining and Absorbing Nutrients 765

Figure 33.2 Research Method Hydroponic Culture 759

FOCUS ON RESEARCH

Applied Research: Plants Poised for Environmental Cleanup **766**

INSIGHTS FROM THE MOLECULAR REVOLUTION
Getting to the Roots of Plant Nutrition 767

34 Reproduction and Development in Flowering Plants 775

- 34.1 Overview of Flowering Plant Reproduction 776
- 34.2 The Formation of Flowers and Gametes 778
- 34.3 Pollination, Fertilization, and Germination 781

34.4 Asexual Reproduction of Flowering Plants 787

34.5 Early Development of Plant Form and Function 789

Figure 34.15 Research Method Plant Cell Culture 790

FOCUS ON RESEARCH

Model Research Organisms: Arabidopsis thaliana 791

INSIGHTS FROM THE MOLECULAR REVOLUTION

Trichomes: Window on Development

in a Single Plant Cell 793

Figure 34.21 Experimental Research

Probing the Roles of Floral Organ Identity Genes 796

35 Control of Plant Growth and Development 801

- 35.1 Plant Hormones 802
- 35.2 Plant Chemical Defenses 812
- 35.3 Plant Responses to the Environment: Movements 817
- **35.4** Plant Responses to the Environment: Biological Clocks **821**
- 35.5 Signal Responses at the Cellular Level 826

Figure 35.2 Experimental Research

The Darwins' Experiments on Phototropism 804

Figure 35.5 Experimental Research

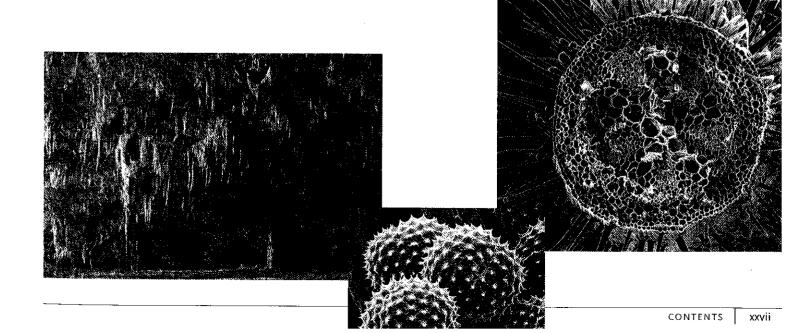
Evidence for the Polar Transport of Auxin in Plant Tissues 806

Insights from the Molecular Revolution

Stressing Out in Plants and People 813

FOCUS ON RESEARCH

Research Methods: Using DNA Microarray Analysis to Track Down "Florigen" 825



UNIT SIX ANIMAL STRUCTURE AND FUNCTION 831

36 Introduction to Animal Organization and Physiology 831

- 36.1 Organization of the Animal Body 832
- 36.2 Animal Tissues 833
- 36.3 Coordination of Tissues in Organs and Organ Systems 840
- 36.4 Homeostasis 841
 INSIGHTS FROM THE MOLECULAR REVOLUTION
 Cultured Stem Cells 835

37 Information Flow and the Neuron 847

- 37.1 Neurons and Their Organizationin Nervous Systems 848
- 37.2 Signal Conduction by Neurons 851
- 37.3 Conduction across Chemical Synapses 858
- 37.4 Integration of Incoming Signals by Neurons 862
 Figure 37.7 Research Method
 Measuring Membrane Potential 852
 INSIGHTS FROM THE MOLECULAR REVOLUTION
 Dissecting Neurotransmitter Receptor Functions 860
- 38 Nervous Systems 867
- 38.1 Invertebrate and Vertebrate Nervous Systems Compared 868
- 38.2 The Peripheral Nervous System 871

- 38.3 The Central Nervous System (CNS) and Its Functions 872
- 38.4 Memory, Learning, and Consciousness 879

 Figure 38.12 Experimental Research

 Investigating the Functions of the Cerebral Hemispheres 880

 INSIGHTS FROM THE MOLECULAR REVOLUTION

 Knocked-Out Mice with a Bad Memory 881

39 Sensory Systems 885

- 39.1 Overview of Sensory Receptors and Pathways 886
- **39.2** Mechanoreceptors and the Tactile and Spatial Senses 888
- 39.3 Mechanoreceptors and Hearing 891
- 39.4 Photoreceptors and Vision 894
- 39.5 Chemoreceptors 899
- 39.6 Thermoreceptors and Nociceptors 903
- 39.7 Magnetoreceptors and Electroreceptors 904

 INSIGHTS FROM THE MOLECULAR REVOLUTION
 Hot News in Taste Research 904

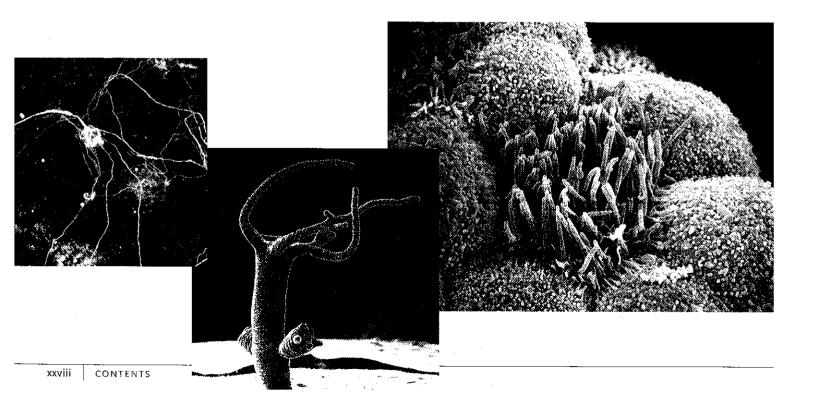
 Figure 39.23 Experimental Research

 Demonstration That Magnetoreceptors Play a Key Role

in Loggerhead Sea Turtle Migration 905

40 The Endocrine System 909

- 40.1 Hormones and Their Secretion 910
- 40.2 Mechanisms of Hormone Action 912
- 40.3 The Hypothalamus and Pituitary 919



- 40.4 Other Major Endocrine Glands of Vertebrates 922
- 40.5 Endocrine Systems in Invertebrates 929

Figure 40.5 Experimental Research

Demonstration That Binding of Epinephrine to β Receptors Triggers a Signal Transduction Pathway within Cells 915

INSIGHTS FROM THE MOLECULAR REVOLUTION

Two Receptors for Estrogens 916

FOCUS ON RESEARCH

Basic Research: Neuroendocrine and Behavioral Effects of Anabolic–Androgenic Steroids in Humans 926

41 Muscles, Bones, and Body Movements 933

- **41.1** Vertebrate Skeletal Muscle: Structure and Function **934**
- 41.2 Skeletal Systems 941
- **41.3** Vertebrate Movement: The Interactions between Muscles and Bones **943**

INSIGHTS FROM THE MOLECULAR REVOLUTION
A Substitute Player That May Be a Big Winner in Muscular Dystrophy 938

42 The Circulatory System 949

- 42.1 Animal Circulatory Systems: An Introduction 950
- 42.2 Blood and Its Components 953
- 42.3 The Heart 956
- 42.4 Blood Vessels of the Circulatory System 961
- 42.5 Maintaining Blood Flow and Pressure 965
- 42.6 The Lymphatic System 967

INSIGHTS FROM THE MOLECULAR REVOLUTION

Identifying the Role of a Hormone Receptor in Blood

Pressure Regulation Using Knockout Mice 966

43 Defenses against Disease 971

- 43.1 Three Lines of Defense against Invasion 972
- 43.2 Nonspecific Defenses: Innate Immunity 973
- 43.3 Specific Defenses: Adaptive Immunity 976
- **43.4** Malfunctions and Failures of the Immune System **989**
- 43.5 Defenses in Other Animals 992

FOCUS ON RESEARCH

Research Organisms: The Mighty Mouse 979

INSIGHTS FROM THE MOLECULAR REVOLUTION

Some Cancer Cells Kill Cytotoxic T Cells to Defeat

the Immune System 987

Figure 43.14 Research Method

Production of Monoclonal Antibodies 988

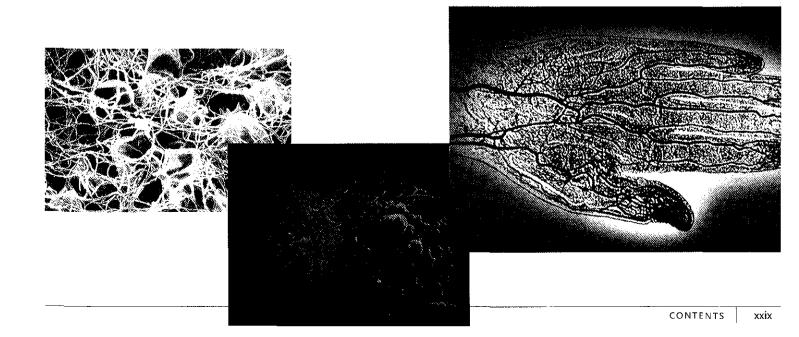
FOCUS ON RESEARCH

Applied Research: HIV and AIDS 990

44 Gas Exchange: The Respiratory System 997

- 44.1 The Function of Gas Exchange 998
- 44.2 Adaptations for Respiration 1001
- 44.3 The Mammalian Respiratory System 1004
- **44.4** Mechanisms of Gas Exchange and Transport **1007**
- **44.5** Respiration at High Altitudes and in Ocean Depths **1010**

INSIGHTS FROM THE MOLECULAR REVOLUTION Giving Hemoglobin and Myoglobin Air 1010



45 Animal Nutrition 1015

- 45.1 Feeding and Nutrition 1016
- 45.2 Digestive Processes 1018
- 45.3 Digestion in Humans and Other Mammals 1020
- 45.4 Regulation of the Digestive Process 1032
- 45.5 Digestive Specializations in Vertebrates 1033
 INSIGHTS FROM THE MOLECULAR REVOLUTION
 Food for Thought on the Feeding Response 1033

46 Regulating the Internal Environment 1039

- **46.1** Introduction to Osmoregulation and Excretion **1040**
- **46.2** Osmoregulation and Excretion in Invertebrates **1043**
- 46.3 Osmoregulation and Excretion in Mammals 1045
- 46.4 Regulation of Mammalian Kidney Function 1052
- **46.5** Kidney Function in Nonmammalian Vertebrates **1054**
- 46.6 Introduction to Thermoregulation 1056
- 46.7 Ectothermy 1058
- **46.8** Endothermy **1060**

INSIGHTS FROM THE MOLECULAR REVOLUTION
An Ore Spells Relief for Osmotic Stress 1050

47 Animal Reproduction 1069

- **47.1** Animal Reproductive Modes: Asexual and Sexual Reproduction **1070**
- 47.2 Cellular Mechanisms of Sexual Reproduction 1071
- 47.3 Sexual Reproduction in Humans 1078
- **47.4** Methods for Preventing Pregnancy: Contraception **1087**

INSIGHTS FROM THE MOLECULAR REVOLUTION Egging on the Sperm 1085

48 Animal Development 1093

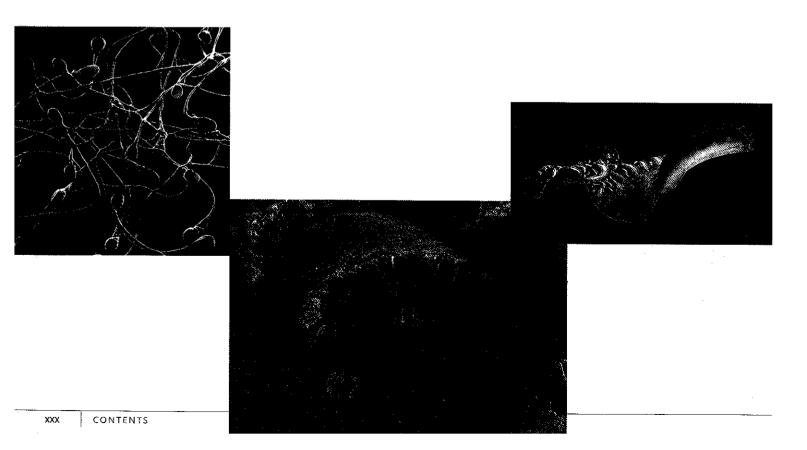
- 48.1 Mechanisms of Embryonic Development 1094
- 48.2 Major Patterns of Cleavage and Gastrulation 1097
- **48.3** From Gastrulation to Adult Body Structures: Organogenesis 1101
- **48.4** Embryonic Development of Humans and Other Mammals **1104**
- **48.5** The Cellular Basis of Development **1109**
- **48.6** The Genetic and Molecular Control of Development **1115**

INSIGHTS FROM THE MOLECULAR REVOLUTION
Turning On Male Development 1111

Figure 48.20 Experimental Research

Demonstrating the Selective Adhesion Properties
of Cells 1113

Figure 48.21 Experimental Research
Spemann and Mangold's Experiment Demonstrating
Induction in Embryos 1114



FOCUS ON RESEARCH

Model Research Organisms: The Zebrafish Makes a Big Splash as the Vertebrate Fruit Fly 1117

UNIT SEVEN ECOLOGY AND BEHAVIOR 1125

49 Population Ecology 7125

- 49.1 The Science of Ecology 1126
- 49.2 Population Characteristics 1127
- 49.3 Demography 1129
- 49.4 The Evolution of Life Histories 1132
- 49.5 Models of Population Growth 1133
- 49.6 Population Regulation 1139
- 49.7 Human Population Growth 1145

Figure 49.3 Research Method Using Mark-Release-Recapture to Estimate Population Size 1128

INSIGHTS FROM THE MOLECULAR REVOLUTION
Tracing Armadillo Paternity and Migration 3130

FOCUS ON RESEARCH

Basic Research: The Evolution of Life History Traits in Guppies 1134

Figure 49.16 Experimental Research
Evaluating Density-Dependent Interactions
between Species 1142

50 Population Interactions and Community Ecology 1151

- 50.1 Population Interactions 1152
- 50.2 The Nature of Ecological Communities 1160
- 50.3 Community Characteristics 1163
- **50.4** Effects of Population Interactions on Community Characteristics **1166**
- **50.5** Effects of Disturbance on Community Characteristics **1167**
- **50.6** Ecological Succession: Responses to Disturbance 1170
- 50.7 Variations in Species Richness among Communities 1174

Figure 50.8 Experimental Research
Gause's Experiments on Interspecific Competition
in Paramecium 1156

Figure 50.12 Experimental Research
Demonstration of Competition between Two Species
of Barnacles 1159

INSIGHTS FROM THE MOLECULAR REVOLUTION
Finding a Molecular Passport to Mutualism 1161

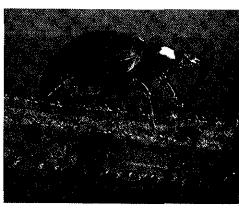
Figure 50.22 Experimental Research
Effect of a Predator on the Species Richness of Its Prey 1168

Figure 50.23 Experimental Research
The Complex Effects of an Herbivorous Snail on Algal
Species Richness 1169

FOCUS ON RESEARCH

Basic Research: Testing the Theory of Island Biogeography 1177





51	Ecosystems	1187
•		

- 51.1 Energy Flow and Ecosystem Energetics 1182
- 51.2 Nutrient Cycling in Ecosystems 1191

51.3 Ecosystem Modeling 1199

Figure 51.6 Observational Research

Energy Flow in the Silver Springs Ecosystem 1187

INSIGHTS FROM THE MOLECULAR REVOLUTION

Fishing Fleets at Loggerheads with Sea Turtles 1190

FOCUS ON RESEARCH

Basic Research: Studies of the Hubbard Brook Watershed 1193

FOCUS ON RESEARCH

Applied Research: Disruption of the Carbon Cycle 1196

52 The Biosphere 1203

- 52.1 Environmental Diversity of the Biosphere 1205
- **52.2** Organismal Responses to Environmental Variation **1209**
- 52.3 Terrestrial Biomes 1211
- 52.4 Freshwater Biomes 1219
- 52.5 Marine Biomes 1221

INSIGHTS FROM THE MOLECULAR REVOLUTION

Fish Antifreeze Proteins 1210

Figure 52.9 Observational Research

How Lizards Compensate for Altitudinal Variations in Environmental Temperature 1211

FOCUS ON RESEARCH

Basic Research: Exploring the Rain Forest Canopy 1214

Figure 52.24 Experimental Research

Artificial Eutrophication of a Lake 1222

53 Biodiversity and Conservation Biology 1229

- 53.1 The Benefits of Biodiversity 1230
- 53.2 The Biodiversity Crisis 1232
- 53.3 Biodiversity Hotspots 1239
- 53.4 Conservation Biology; Principles and Theory 1241
- **53.5** Conservation Biology: Practical Strategies and Economic Tools **1247**

Figure 53.4 Experimental Research

Predation on Songbird Nests in Forests and Forest Fragments 1232

FOCUS ON RESEARCH

Applied Research: Biological Magnification 1236

Insights from the Molecular Revolution

Developing a DNA Barcode System 1242 FOCUS ON RESEARCH

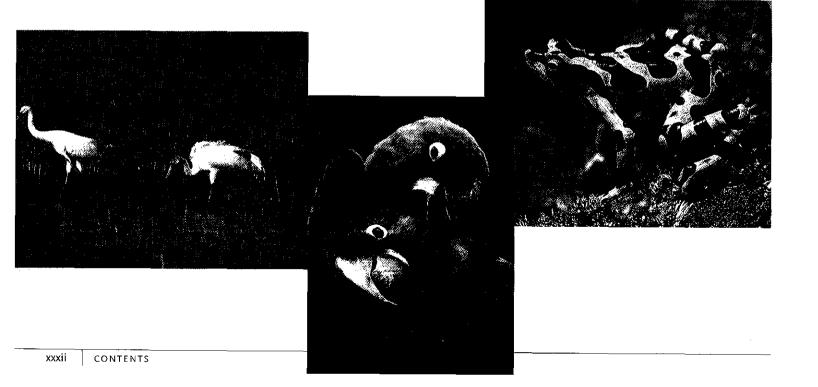
Applied Research: Preserving the Yellow-Bellied Glider 1244

Figure 53.16 Observational Research

Metapopulation Structure of the Bay Checkerspot Butterfly 1245

Figure 53.19 Experimental Research

Effect of Landscape Corridors on Plant Species Richness in Habitat Fragments 1247



54 The Physiology and Genetics of Animal Behavior 1253

54.1 Genetic and Environmental Contributions to Behavior 1254

54.2 Instinctive Behaviors 1255

54.3 Learned Behaviors 1257

54.4 The Neurophysiological Control of Behavior 1259

54.5 Hormones and Behavior 1260

54.6 Nervous System Anatomy and Behavior 1263

Figure 54.2 Experimental Research

The Role of Sign Stimuli in Parent-Offspring Interactions 1256

INSIGHTS FROM THE MOLECULAR REVOLUTION

A Knockout by a Whisker 1258

Figure 54.10 Experimental Research

Effects of the Social Environment on Brain Anatomy and Chemistry 1262

Figure 54.12 Experimental Research

Nervous System Structure and Appropriate

Behavioral Responses 1265

55 The Ecology and Evolution of Animal Behavior 1269

55.1 Migration and Wayfinding 1270

55.2 Habitat Selection and Territoriality 1274

55.3 The Evolution of Communication 1276

55.4 The Evolution of Reproductive Behavior and Mating Systems **1279**

55.5 The Evolution of Social Behavior 1281

55.6 An Evolutionary View of Human Social Behavior **1285**

Figure 55.4 Experimental Research

Using Landmarks to Find the Way Home 1272

Figure 55.5 Experimental Research

Experimental Analysis of the Indigo Bunting's

Star Compass 1273

Figure 55.18 Research Method

Calculating Degrees of Relatedness 1283

INSIGHTS FROM THE MOLECULAR REVOLUTION

Unadorned Truths about Naked Mole-Rat Workers 1286

Figure 55.21 Observational Research

An Evolutionary Analysis of Human Cruelty 1287

Appendix A: Answers A-1

Appendix B: Classification A-34

Appendix C: Annotations to a Journal Article

A-38

Glossary G-1

Credits C-1

Index 1-1

