expansants a

Preface xvii



PART ONE

SCIENCE, THE CELL, AND MOLECULAR BIOLOGY 1

chapter one

ZOOLOGY: ITS PLACE IN SCIENCE 3

Outline 3
Concepts 3

Would You Like to Know 3

A One-World View 4 Genetic Unity 4

The Fundamental Unit of Life 5

Evolutionary Oneness and the Diversity of Life 5

Animals and Their Environment 8

What Is Zoology? 11

The Classification of Animals 11

The Scientific Method 11

Summary 14

Selected Key Terms 14

Critical Thinking Questions 14

chapter two

THE CHEMICAL BASIS OF ANIMAL LIFE 15

Outline 15

Concepts 15

Would You Like to Know 15

Atoms and Elements: Building Blocks of All Matter 16

Structure of Atoms 16 Energy-Level Shells 17

Compounds and Molecules: Aggregates of Atoms 18

Covalent Bonds: Sharing Electron Pairs 18

Hydrogen Bonds 19

Ionic Bonds: Opposites Attract 19

Acids, Bases, and Buffers 20

pH: Measuring Acidity and Alkalinity 20

pH: Control with Buffers 20

The Molecules of Animals 21

Carbohydrates: Stored Energy and Structural Support 22

Lipids: Energy, Interfaces, and Signals 23

Proteins: The Basis of Life's Diversity 25

Nucleotides and Nucleic Acids: Information Storage,

Chemical Messengers, and Energy Transfer 26

Summary 28

Selected Key Terms 28

Critical Thinking Questions 28

chapter three

CELLS, TISSUES, ORGANS, AND ORGAN SYSTEMS OF ANIMALS 29

Outline 29

Concepts 29

Would You Like to Know 29

What Are Cells? 30

Why Are Most Cells Small? 32

Cell Membranes 33

Structure of Cell Membranes 33

Functions of Cell Membranes 36

Movement Across Membranes 36

Simple Diffusion 36

Facilitated Diffusion 36

Osmosis 37

Filtration 40

Active Transport 40

Endocytosis 40

Exocytosis 42

Cytoplasm, Organelles, and Cellular Components 42

Cytoplasm 42

Ribosomes: Protein Workbenches 42

Endoplasmic Reticulum: Production and Transport 42

Golgi Apparatus: Packaging, Sorting, and Export 44

Lysosomes: Digestion and Degradation 44

Mitochondria: Power Generators 45

Cytoskeleton: Microtubules, Intermediate Filaments, and

Microfilaments 45

Cilia and Flagella: Movement 46

Centrioles: Specialized Microtubules 46 Cytoplasmic Inclusions: Storage 47 The Nucleus: Information Center 47

Nuclear Envelope: Gateway to the Nucleus 47 Chromosomes: Genetic Containers 47 Nucleolus: Preassembly Point for Ribosomes 47

Tissues 48

Epithelial Tissue: Many Forms and Functions 48 Connective Tissue: Connection and Support 48 Muscle Tissue: Movement 48

Nervous Tissue: Communication 48

Organs 52
Organ Systems 52
Summary 53
Selected Key Terms 53
Critical Thinking Questions 53

chapter four

ENERGY AND ENZYMES: LIFE'S DRIVING AND CONTROLLING FORCES 55

Outline 55 Concepts 55 Would You Like to Know 55 What Is Energy? 56 The Laws of Energy Transformations 56 Activation Energy 56 Enzymes: Biological Catalysts 58 Enzyme Structure 59 Enzyme Function 59 Factors Affecting Enzyme Activity 60 Cofactors and Coenzymes 60 ATP: The Cell's Energy Currency 61 How Cells Trap Energy: An Overview 62 Summary 64 Selected Key Terms 64 Critical Thinking Questions 64

chapter five

HOW ANIMALS HARVEST ENERGY STORED IN NUTRIENTS 65

Outline 65
Concepts 65
Would You Like to Know 65
Glycolysis: The First Phase of Nutrient Metabolism 66
Evolutionary Perspective on Glycolysis 66
Fermentation: "Life Without Oxygen" 68
Aerobic Respiration: The Major Source of ATP 68
The Energy Score for Aerobic Respiration: A Balance
Sheet 70

Metabolism of Fats and Proteins: Alternative Food
Molecules 72
Control of Metabolism 73
The Metabolic Pool 74
Summary 75
Selected Key Terms 75
Critical Thinking Questions 75
Suggested Readings 75



THE CONTINUITY OF ANIMAL LIFE 79

chapter six

CELL DIVISION 81

Outline 81 Concepts 81 Would You Like to Know 81 Mitosis, Cytokinesis, and the Cell Cycle: An Overview 82 Interphase: Replicating the Hereditary Material 82 Phases of Mitosis 84 Prophase: Formation of the Mitotic Apparatus 84 Metaphase: Alignment of Chromosomes 86 Anaphase: Movement of the Daughter Chromosomes 86 Telophase: Reformation of Nuclei 86 Cytokinesis: Partitioning the Cytoplasm 86 Control of the Cell Cycle 86 Meiosis: The Basis of Sexual Reproduction 88 The First Meiotic Division: Prophase I to Telophase I 88 The Second Meiotic Division: Prophase II to Telophase II 91 Gamete Formation 91

Gamete Formation 91
Spermatogenesis 91
Oogenesis 91
Summary 93
Selected Key Terms 93
Critical Thinking Questions 93

chapter seven

INHERITANCE PATTERNS 95

Outline 95 Concepts 95 Would You Like to Know 95 The Birth of Modern Genetics 96 Mendelian Inheritance Patterns 96 Segregation 97 Independent Assortment 99
Testing Phenotypes 99
Other Inheritance Patterns 99
Multiple Alleles 101
Incomplete Dominance and Codominance 102
Quantitative Traits: Polygenes 102
Environmental Effects and Gene Expression 103
Summary 104
Selected Key Terms 104
Critical Thinking Questions 104

chapter eight

Outline 105

CHROMOSOMES AND GENE LINKAGE 105

Concepts 105 Would You Like to Know 105 Eukaryotic Chromosomes 106 Organization of DNA and Protein 106 Sex Chromosomes and Autosomes 106 Number of Chromosomes 108 Linkage Relationships 108 Autosomal Linkage 109 Sex Linkage 109 Sex-Influenced Traits 111 Changes in Chromosome Number and Structure 112 Detecting Number and Structure Changes 112 Variation in Number 112 Variation in Structure 115 Summary 116 Selected Key Terms 116 Critical Thinking Questions 116

chapter nine

Molecular Genetics: Ultimate Cellular Control 117

Outline 117
Concepts 117
Would You Like to Know 117
DNA: The Genetic Material 118
The Double Helix Model 118
DNA Replication in Eukaryotes 119
Genes in Action 120
Three Major Kinds of RNA 121
The Genetic Code 121
Transcription 121
Translation 122
Posttranslational Modifications 123
Control of Gene Expression in Eukaryotes 125
Mutations 125
Kinds of Point Mutations 125

Causes of Mutations 126
Applications of Genetic Technologies 126
Recombinant DNA 126
Gene Insertion 127
Summary 131
Selected Key Terms 131
Critical Thinking Questions 131

chapter ten

DESCRIPTIVE EMBRYOLOGY 133

Outline 133 Concepts 133 Would You Like to Know 133 Fertilization 134 Egg Activation 135 Metabolic and Nuclear Events 136 Cleavage and Egg Types 137 Quantity and Distribution of Yolk 137 Cleavage Patterns 137 The Primary Germ Layers and Their Derivatives 137 Echinoderm Embryology 138 Vertebrate Embryology 140 The Chordate Body Plan 140 Amphibian Embryology 140 Development in Terrestrial Environments 143 Avian Embryology 143 The Fate of Mesoderm 146 Summary 146 Selected Key Terms 147 Critical Thinking Questions 147 Suggested Readings 147



PART THREE

EVOLUTION 151

chapter eleven

EVOLUTION: A HISTORICAL PERSPECTIVE 153

Outline 153
Concepts 153
Would You Like to Know 153
Pre-Darwinian Theories of Change 154
Lamarck: An Early Proponent of Evolution 154
Darwin's Early Years and His Journey 154
Voyage of the HMS Beagle 156
Early Development of Darwin's Ideas of Evolution 156

Geology 157
Fossil Evidence 157
Galápagos Islands 157
The Theory of Evolution by Natural Selection 158
Natural Selection 159
Alfred Russel Wallace 160
Evolutionary Thought after Darwin 161
Biogeography 161
Summary 163
Selected Key Terms 163
Critical Thinking Questions 163

chapter twelve

Outline 165

EVOLUTION AND GENE FREQUENCIES 165

Concepts 165
Would You Like to Know 165
The Modern Synthesis: A Closer Look 166
Must Evolution Happen? 166
The Hardy-Weinberg Theorem 166
Evolutionary Mechanisms 167

Population Size, Genetic Drift, and Neutral Selection 168

Gene Flow 170 Mutation 170

Natural Selection Reexamined 170

Balanced Polymorphism and Heterozygote Superiority 172

Species and Speciation 172 Allopatric Speciation 173 Parapatric Speciation 174

Sympatric Speciation 174

Rates of Evolution 174

Molecular Evolution 175 Gene Duplication 176

Mosaic Evolution 176

Summary 176

Selected Key Terms 177

Critical Thinking Questions 177

Suggested Readings 177



PART FOUR

BEHAVIOR AND ECOLOGY 179

chapter thirteen

ANIMAL BEHAVIOR 181

Outline 181 Concepts 181 Would You Like to Know 181 Four Approaches to Animal Behavior 182 Proximate and Ultimate Causes 182 Anthropomorphism 182 Development of Behavior 182 Maturation 182 Instinct/Learning Interactions 182 Imprinting 183 Learning 184 Habituation 184 Classical Conditioning 184 Instrumental Conditioning 184 Latent Learning 185 Insight Learning 185 Control of Behavior 186 Nervous System 186 Endocrine System 187 Communication 187 Visual Communication 187 Acoustic Communication 188 Tactile Communication 188 Chemical Communication 188 Behavioral Ecology 189 Habitat Selection 189 Foraging Behavior 189 Social Behavior 190 Living in Groups 190 Agonistic Behavior, Territories, and Dominance Hierarchies 190 Altruism 191 Summary 192 Selected Key Terms 192

chapter fourteen

Herbivory 199

ECOLOGY 1: INDIVIDUALS AND POPULATIONS 193

Critical Thinking Questions 192

Outline 193
Concepts 193
Would You Like to Know 193
Animals and Their Abiotic Environment 194
Energy 194
Temperature 195
Moisture 196
Light 196
Geology and Soils 196
Populations 197
Population Growth 197
Population Regulation 198
Interspecific Interactions 199

Predation 199
Interspecific Competition 200
Coevolution 200
Symbiosis 202
Other Interspecific Adaptations 203
Summary 205
Selected Key Terms 205
Critical Thinking Questions 205

chapter fifteen

ECOLOGY II: COMMUNITIES AND ECOSYSTEMS 207

Outline 207 Concepts 207 Would You Like to Know 207 Community Structure and Diversity 208 The Ecological Niche 208 Community Stability 208 Ecosystems 209 Trophic Structure 209 Cycling 214 Ecosystems of the Earth 217 Terrestrial Ecosystems 217 Aquatic Ecosystems 220 Ecological Problems 223 Human Population Growth 223 Pollution 224 Resource Depletion and Biodiversity 224 Summary 225 Selected Key Terms 225 Critical Thinking Questions 225 Suggested Readings 226



ANIMALLIKE PROTISTS AND ANIMALIA 227

chapter sixteen

Animal Classification, Phylogeny, and Organization 229

Outline 229 Concepts 229 Would You Like to Know 229 Classification of Organisms 230
A Taxonomic Hierarchy 230
Nomenclature 231
Kingdoms of Life 231
Animal Systematics 231
Molecular Approaches to Animal Systematics 235
Evolutionary Relationships and Tree Diagrams 236
Patterns of Organization 236
Symmetry 237
Other Patterns of Organization 238
Summary 24.1
Selected Key Terms 241
Critical Thinking Questions 241

chapter seventeen

ANIMALLIKE PROTISTS: THE PROTOZOA 243

Outline 243 Concepts 243 Would You Like to Know 243 Evolutionary Perspective 243 Life within a Single Plasma Membrane 245 Maintaining Homeostasis 245 Reproduction 245 Symbiotic Life-Styles 246 Protozoan Taxonomy 247 Phylum Sarcomastigophora 247 Subphylum Mastigophora 247 Class Phytomastigophorea 248 Class Zoomastigophorea 249 Subphylum Sarcodina 251 Class Lobosea 251 Foraminiferans, Heliozoans, and Radiolarians 252 Phylum Labyrinthomorpha 253 Phylum Apicomplexa 253 Class Sporozoea 253 Phylum Microspora 255 Phylum Acetospora 255 Phylum Myxozoa 255 Phylum Ciliophora 256 Cilia and Other Pellicular Structures 256 Nutrition 256 Genetic Control and Reproduction 257 Symbiotic Ciliates 258 Further Phylogenetic Considerations 258 Summary 260 Selected Key Terms 260 Critical Thinking Questions 260

chapter eighteen

MULTICELLULAR AND TISSUE LEVELS OF ORGANIZATION 261

Outline 261 Concepts 261

Would You Like to Know 261

Evolutionary Perspective 262

Origins of Multicellularity 262

Animal Origins 262

Phylum Porifera 264

Cell Types, Body Wall, and Skeletons 265

Water Currents and Body Forms 267

Maintenance Functions 267

Reproduction 268

Phylum Cnidaria (Coelenterata) 270

The Body Wall and Nematocysts 270

Alternation of Generations 271

Maintenance Functions 271

Reproduction 273

Class Hydrozoa 273

Class Scyphozoa 275

Class Cubozoa 276

Class Anthozoa 276

Phylum Ctenophora 280

Further Phylogenetic Considerations 282

Summary 283

Selected Key Terms 283

Critical Thinking Questions 283

endpaper one

Some Lesser Known Invertebrates: Mesozoa and Placozoa 285

chapter nineteen

THE TRIPLOBLASTIC, ACOELOMATE BODY PLAN 287

Outline 287

Concepts 287

Would You Like to Know 287

Evolutionary Perspective 288

Phylum Platyhelminthes 289

Class Turbellaria: The Free-Living Flatworms 289

Class Monogenea 293

Class Trematoda 293

Class Cestoidea: The Tapeworms 298

Phylum Nemertea 300

Further Phylogenetic Considerations 301

Summary 302

Selected Key Terms 302 Critical Thinking Questions 302

chapter twenty

THE PSEUDOCOELOMATE BODY PLAN: ASCHELMINTHS 303

Outline 303

Concepts 303

Would You Like to Know 303

Evolutionary Perspective 304

General Characteristics 305

Phylum Gastrotricha 306

Phylum Rotifera 306

External Features 307

Feeding and the Digestive System 308

Other Organ Systems 308

Reproduction and Development 308

Phylum Kinorhyncha 308

Phylum Nematoda 310

External Features 310

Internal Features 311

Feeding and the Digestive System 311

Other Organ Systems 312

Reproduction and Development 312

Some Important Nematode Parasites of Humans 313

Phylum Nematomorpha 315

Phylum Acanthocephala 316

Phylum Loricifera 317

Phylum Priapulida 318

Phylum Entoprocta 318

Further Phylogenetic Considerations 319

Summary 319

Selected Key Terms 320

Critical Thinking Questions 320

chapter twenty-one

MOLLUSCAN SUCCESS 321

Outline 321

Concepts 321

Would You Like to Know 321

Evolutionary Perspective 322

Relationships to Other Animals 322

Origin of the Coelom 323

Molluscan Characteristics 323

Class Gastropoda 326

Torsion 326

Shell Coiling 327

Locomotion 328

Feeding and Digestion 328

Other Maintenance Functions 328 Reproduction and Development 329

Class Bivalvia 329

Shell and Associated Structures 329

Gas Exchange, Filter Feeding, and Digestion 330

Other Maintenance Functions 331

Reproduction and Development 331

Bivalve Diversity 332

Class Cephalopoda 334

Shell 334

Locomotion 335

Feeding and Digestion 335

Other Maintenance Functions 335

Reproduction and Development 336

Class Polyplacophora 336

Class Scaphopoda 337

Class Monoplacophora 337

Class Caudofoveata 338

Class Aplacophora 338

Further Phylogenetic Considerations 338

Summary 340

Selected Key Terms 340

Critical Thinking Questions 340

chapter twenty-two

Annelida: The Metameric Body Form 341

Outline 341

Concepts 341

Would You Like to Know 341

Evolutionary Perspective 342

Relationships to Other Animals 342

Metamerism and Tagmatization 342

Class Polychaeta 345

External Structure and Locomotion 345

Feeding and the Digestive System 345

Gas Exchange and Circulation 346

Nervous and Sensory Functions 347

Excretion 348

Regeneration, Reproduction, and Development 349

Class Oligochaeta 350

External Structure and Locomotion 350

Feeding and the Digestive System 351

Gas Exchange and Circulation 352

Nervous and Sensory Functions 352

Excretion 352

Reproduction and Development 352

Class Hirudinea 353

External Structure and Locomotion 353

Feeding and the Digestive System 353

Gas Exchange and Circulation 355

Nervous and Sensory Functions 355

Excretion 355

Reproduction and Development 355

Further Phylogenetic Considerations 355

Summary 357

Selected Key Terms 357

Critical Thinking Questions 357

endpaper two

Some Lesser Known Invertebrates: Possible Annelid Relatives 359

chapter twenty-three

THE ARTHROPODS: BLUEPRINT FOR SUCCESS 361

Outline 361

Concepts 361

Would You Like to Know 361

Evolutionary Perspective 362

Classification and Relationships to Other Animals 362

Metamerism and Tagmatization 362

The Exoskeleton 363

Metamorphosis 365

Subphylum Trilobitomorpha 365

Subphylum Chelicerata 366

Class Merostomata 366

Class Arachnida 367

Class Pycnogonida 372

Subphylum Crustacea 373

Class Malacostraca 373

Class Branchiopoda 377

Class Copepoda 378

Class Cirripedia 378

Further Phylogenetic Considerations 379

Summary 380

Selected Key Terms 380

Critical Thinking Questions 380

chapter twenty-four

THE HEXAPODS AND MYRIAPODS: TERRESTRIAL TRIUMPHS 381

Outline 381

Concepts 381

Would You Like to Know 381

Evolutionary Perspective 382

Class Diplopoda 383

Class Chilopoda 383

Classes Pauropoda and Symphyla 385

Class Hexapoda 386

External Structure and Locomotion 386 Nutrition and the Digestive System 387

Gas Exchange 387

Circulation and Temperature Regulation 388

Nervous and Sensory Functions 389

Excretion 390

Chemical Regulation 390

Reproduction and Development 392

Insect Behavior 393

Insects and Humans 394

Further Phylogenetic Considerations 395

Summary 397

Selected Key Terms 398

Critical Thinking Questions 398

endpaper three

Some Lesser Known Invertebrates: Possible Arthropod Relatives 399

chapter twenty-five

THE ECHINODERMS 401

Outline 401

Concepts 401

Would You Like to Know 401

Evolutionary Perspective 402

Relationships to Other Animals 402

Echinoderm Characteristics 402

Class Asteroidea 404

Maintenance Functions 405

Regeneration, Reproduction, and Development 406

Class Ophiuroidea 407

Maintenance Functions 407

Regeneration, Reproduction, and Development 408

Class Echinoidea 409

Maintenance Functions 410

Reproduction and Development 410

Class Holothuroidea 410

Maintenance Functions 411

Reproduction and Development 411

Class Crinoidea 411

Maintenance Functions 412

Reproduction and Development 412

Class Concentricycloidea 413

Further Phylogenetic Considerations 413

Summary 414

Selected Key Terms 414

Critical Thinking Questions 414

endpaper four

Some Lesser Known Invertebrates: The Lophophorates 415

chapter twenty-six

HEMICHORDATA AND INVERTEBRATE CHORDATES 419

Outline 419

Concepts 419

Would You Like to Know 419

Evolutionary Perspective 420

Phylogenetic Relationships 420

Phylum Hemichordata 420

Class Enteropneusta 420

Class Pterobranchia 423

Phylum Chordata 423

Subphylum Urochordata 424

Subphylum Cephalochordata 427

Further Phylogenetic Considerations 428

Summary 430

Selected Key Terms 430

Critical Thinking Questions 430

chapter twenty-seven

THE FISHES: VERTEBRATE SUCCESS IN WATER 431

Outline 431

Concepts 431

Would You Like to Know 431

Evolutionary Perspective 432

Phylogenetic Relationships 432

Survey of Fishes 432

Superclass Agnatha 432

Superclass Gnathostomata 436

Evolutionary Pressures 441

Locomotion 442

Nutrition and the Digestive System 442

Circulation and Gas Exchange 442

Nervous and Sensory Functions 445

Excretion and Osmoregulation 447

Reproduction and Development 448

Further Phylogenetic Considerations 449

Summary 449

Selected Key Terms 449

Critical Thinking Questions 450

chapter twenty-eight

Outline 451

AMPHIBIANS: THE FIRST TERRESTRIAL VERTEBRATES 451

Concepts 451 Would You Like to Know 451 **Evolutionary Perspective 452** Phylogenetic Relationships 452 Survey of Amphibians 452 Order Caudata 452 Order Gymnophiona 454 Order Anura 454 **Evolutionary Pressures 456** External Structure and Locomotion 456 Nutrition and the Digestive System 458 Circulation, Gas Exchange, and Temperature Regulation 459 Nervous and Sensory Functions 461 Excretion and Osmoregulation 462 Reproduction, Development, and Metamorphosis 463 Further Phylogenetic Considerations 464

chapter twenty-nine

Selected Key Terms 466

Critical Thinking Questions 466

Summary 466

REPTILES: THE FIRST AMNIOTES 467

Outline 467 Concepts 467 Would You Like to Know 467 Evolutionary Perspective 468 Cladistic Interpretation of the Amniotic Lineage 469 Survey of the Reptiles 469 Order Testudines or Chelonia 470 Order Rhynchocephalia 472 Order Squamata 472 Order Crocodilia 474 **Evolutionary Pressures 474** External Structure and Locomotion 475 Nutrition and the Digestive System 476 Circulation, Gas Exchange, and Temperature Regulation 477 Nervous and Sensory Functions 478 Excretion and Osmoregulation 480 Reproduction and Development 480 Further Phylogenetic Considerations 481 Summary 482 Selected Key Terms 482 Critical Thinking Questions 482

chapter thirty

BIRDS: FEATHERS, FLIGHT, AND ENDOTHERMY 483

Outline 483 Concepts 483 Would You Like to Know 483 Evolutionary Perspective 484 Phylogenetic Relationships 484 Ancient Birds and the Evolution of Flight 484 Diversity of Modern Birds 485 **Evolutionary Pressures** 487 External Structure and Locomotion 487 Nutrition and the Digestive System 491 Circulation, Gas Exchange, and Temperature Regulation 492 Nervous and Sensory Systems 493 Excretion and Osmoregulation 495 Reproduction and Development 495 Migration and Navigation 496 Summary 499 Selected Key Terms 499 Critical Thinking Questions 499

chapter thirty-one

Mammals: Specialized Teeth, Endothermy, Hair, and Viviparity 501

Outline 501 Concepts 501 Would You Like to Know 501 Evolutionary Perspective 502 Diversity of Mammals 503 **Evolutionary Pressures** 503 External Structure and Locomotion 503 Nutrition and the Digestive System 511 Circulation, Gas Exchange, and Temperature Regulation 511 Nervous and Sensory Functions 514 Excretion and Osmoregulation 514 Behavior 515 Reproduction and Development 516 Summary 518 Selected Key Terms 519 Critical Thinking Questions 519 Suggested Readings 519



FORM AND FUNCTION: A COMPARATIVE PERSPECTIVE 525

chapter thirty-two

PROTECTION, SUPPORT, AND MOVEMENT 527

Outline 527 Concepts 527

Would You Like to Know 527

Protection: Integumentary Systems 528

The Integumentary System of Invertebrates 528

The Integumentary System of Vertebrates 528

Movement and Support: Skeletal Systems 533

The Skeletal System of Invertebrates 533

The Skeletal System of Vertebrates 535

Movement: Nonmuscular Movement and Muscular Systems 537

Nonmuscular Movement 538

The Muscular System of Invertebrates 539

The Muscular System of Vertebrates 542

Summary 545

Selected Key Terms 546

Critical Thinking Questions 546

chapter thirty-three

COMMUNICATION I: Nerves 547

Outline 547

Concepts 547

Would You Like to Know 547

Neurons: The Basic Units of the Nervous System 548

Neuron Structure: The Key to Function 548

Neuron Communication 549

Resting Membrane Potential 549

Mechanism of Neuron Action: Changing the Resting

Membrane Potential into the Action Potential (Nerve

Impulse) 550

Transmission of the Action Potential between Cells 551

Invertebrate Nervous Systems 552

Vertebrate Nervous Systems 553

The Spinal Cord 555

Spinal Nerves 555

The Brain 555

Cranial Nerves 558
The Autonomic Nervous System 558
Summary 560
Selected Key Terms 560
Critical Thinking Questions 560

chapter thirty-four

COMMUNICATION II: SENSES 561

Outline 561

Concepts 561

Would You Like to Know 561

Sensory Reception 562

Invertebrate Sensory Receptors 562

Baroreceptors 562

Chemoreceptors 563

Georeceptors 563

Hygroreceptors 563

Phonoreceptors 564

Photoreceptors 564

Proprioceptors 566

Tactile Receptors 566

Thermoreceptors 566

Vertebrate Sensory Receptors 567

Lateral-Line System and Electrical Sensing 567

Lateral-Line System and Mechanoreception 568

Hearing and Equilibrium in Air 568

Hearing and Equilibrium in Water 571

Skin Sensors of Damaging Stimuli 572

Skin Sensors of Heat and Cold 572

Chi Canada of Heat and Cold 512

Skin Sensors of Mechanical Stimuli 572

Sonar 572

Smell 572

Taste 574

Vision 574

Summary 576

Selected Key Terms 577

Critical Thinking Questions 577

chapter thirty-five

COMMUNICATION III: THE ENDOCRINE SYSTEM AND CHEMICAL MESSENGERS 579

Outline 579

Concepts 579

Would You Like to Know 579

Chemical Messengers 580

Hormones and Their Feedback Systems 581

Biochemistry of Hormones 581

Feedback Control System of Hormone Secretion 581

Mechanisms of Hormone Control 582 Fixed-Membrane-Receptor Mechanism 582

Mobile-Receptor Mechanism 582

Some Hormones of Invertebrates 583

Porifera 583

Cnidarians 583

Platyhelminthes 583

Nemerteans 583

Nematodes 583

Molluscs 583

Annelids 583

Arthopods 584

Echinoderms 585

An Overview of the Vertebrate Endocrine System 585 Endocrine Systems of Vertebrates Other Than Birds or

Mammals 586

Endocrine Systems of Birds and Mammals 587

Birds 589

Mammals 591

Summary 596

Selected Key Terms 596

Critical Thinking Questions 596

chapter thirty-six

CIRCULATION, IMMUNITY, AND GAS EXCHANGE 597

Outline 597

Concepts 597

Would You Like to Know 597

Internal Transport and Circulatory Systems 598

Transport Systems in Invertebrates 598

Characteristics of Invertebrate Coelomic Fluid.

Hemolymph, and Blood Cells 598

Transport Systems in Vertebrates 600

Characteristics of Vertebrate Blood and Blood Cells 600

Vertebrate Blood Vessels 603

The Hearts and Circulatory Systems of Bony Fishes,

Amphibians, and Reptiles 603

The Hearts and Circulatory Systems in Birds and

Mammals 603

The Human Heart 604

Blood Pressure 606

The Lymphatic System 606

Immunity 606

Nonspecific Defenses 607

Specific Defenses: The Immune Response 607

Gas Exchange 611

Respiratory Surfaces 611

Invertebrate Respiratory Systems 611

Vertebrate Respiratory Systems 613

Cutaneous Exchange 613

Gills 613

Lungs 614

Lung Ventilation 615

Human Respiratory System 616

Gas Transport 618

Summary 620

Selected Key Terms 620

Critical Thinking Questions 620

chapter thirty-seven

NUTRITION AND DIGESTION 621

Outline 621

Concepts 621

Would You Like to Know 621

Evolution of Nutrition 622

The Metabolic Fates of Nutrients in Heterotrophs 622

Calories and Energy 622

Macronutrients 622

Micronutrients 623

Digestion 624

Animal Strategies for Getting and Using Food 626

Continuous versus Discontinuous Feeders 626

Suspension Feeders 626

Deposit Feeders 626

Herbivory 627

Predation-627

Surface Nutrient Absorption 627

Fluid Feeders 627

Diversity in Digestive Structures: Invertebrates 629

Protozoa 630

Bivalve Molluscs 631

Insects 631

Diversity in Digestive Structures: Vertebrates 632

Tonigues 632

Teeth 632

Salivary Glands 632

Esophagi 632

Stomachs 632

Gizzards 634

Rumens 634

Cecae 636

Livers and Gallbladders 636

Pancreata 636

Intestines 637

The Mammalian Digestive System 637

Gastrointestinal Motility and Its Control 638

Oral Cavity 638

Pharynx and Esophagus 639

Stomach 640

Small Intestine: Main Site of Digestion 640

Large Intestine 643

Role of the Pancreas in Digestion 643

Role of the Liver and Gallbladder in Digestion 643

Summary 645 Selected Key Terms 645 Critical Thinking Questions 645

chapter thirty-eight

TEMPERATURE AND BODY FLUID REGULATION 647

Outline 647 Concepts 647

Would You Like to Know 647

Homeostasis and Temperature Regulation 648
The Impact of Temperature on Animal Life 648

Heat Gains and Losses 648

Some Solutions to Temperature Fluctuations 649

Temperature Regulation in Invertebrates 650

Temperature Regulation in Fishes 651

Temperature Regulation in Amphibians and Reptiles 652

Temperature Regulation in Birds and Mammals 652

Heat Production in Birds and Mammals 653

The Control of Water and Solutes (Osmoregulation and Excretion) 655

Invertebrate Excretory Systems 656

Contractile Vacuoles 656

Protonephridia 656

Metanepridia 656

Antennal (Green) and Maxillary Glands 657

Malpighian Tubules 658

Coxal Glands 658

Vertebrate Excretory Systems 658

How Osmoregulation Is Achieved in Vertebrates 659

Vertebrate Kidney Variations 659

How the Metanephric Kidney Functions 663

Summary 668

Selected Key Terms 668

Critical Thinking Questions 668

chapter thirty-nine

REPRODUCTION AND DEVELOPMENT 669

Outline 669

Concepts 669

Would You Like to Know 669

Asexual Reproduction in Invertebrates 670

Fission 670

Budding 670

Fragmentation 670

Parthenogenesis 670

Advantages and Disadvantages

of Asexual Reproduction 671

Sexual Reproduction in Invertebrates 672

External Fertilization 672

Internal Fertilization 672

Advantages and Disadvantages of Sexual Reproduction 673

Sexual Reproduction in Vertebrates 673

Some Basic Vertebrate Reproductive Strategies 673

Examples of Reproduction among Various Vertebrate

Classes 673

Fishes 674

Amphibians 674

Reptiles 674

Birds 674

Mammals 674

The Human Male Reproductive System 675

Production and Transport of Sperm 675

Hormonal Control of Male Reproductive Function 676

The Human Female Reproductive System 677

Production and Transport of the Egg 678

Hormonal Control of Female Reproductive Function 680

Hormonal Regulation in the Pregnant Female 681

Prenatal Development and Birth 682

Events of Prenatal Development: From Zygote

to Newborn 682

The Placenta: Exchange Site and Hormone Producer 685

Birth: An End and a Beginning 685

Milk Production and Lactation 685

Summary 687

Selected Key Terms 688

Critical Thinking Questions 688

Suggested Readings 688

Glossary 691

Credits 723

Index 729