

# *brief contents*

## *part one*

### **Evolution of Animal Life**

- 1 Life: General Considerations, Basic Molecules, and Origins, 2**
- 2 The Cell as the Unit of Life, 23**
- 3 Genetic Basis of Evolution, 56**
- 4 Evolution of Animal Diversity, 83**
- 5 Ecology and Distribution of Animals, 112**

## *part two*

### **Animal Form and Function**

- 6 Animal Architecture: Body Organization, Support, and Movement, 138**
- 7 Homeostasis: Osmotic Regulation, Excretion, and Temperature Regulation, 166**
- 8 Internal Fluids and Respiration 187**
- 9 Immunity 210**
- 10 Digestion and Nutrition, 222**
- 11 Nervous Coordination: Nervous System and Sense Organs, 240**
- 12 Chemical Coordination: Endocrine System, 266**
- 13 Animal Behavior, 290**
- 14 Reproduction and Development, 308**

## *part three*

### **The Invertebrate Animals**

- 15 Classification and Phylogeny of Animals, 342**

- 16 The Animal-like Protista, 361**
- 17 Sponges: Phylum Porifera 381**
- 18 Radiate Animals: Cnidarians and Ctenophores, 392**
- 19 Acoelomate Animals: Flatworms, Ribbon Worms, and Jaw Worms, 416**
- 20 Pseudocoelomate Animals, 433**
- 21 Molluscs, 448**
- 22 Segmented Worms: The Annelids, 474**
- 23 Arthropods, 490**
- 24 Lesser Protostomes and Lophophorates, 531**
- 25 Echinoderms, Hemichordates, and Chaetognaths, 542**
- General References to Part III, 562**

## *part four*

### **The Vertebrate Animals**

- 26 Vertebrate Beginnings: The Chordates, 563**
- 27 Fishes, 582**
- 28 The Early Tetrapods and Modern Amphibians, 606**
- 29 Reptiles, 621**
- 30 Birds, 640**
- 31 Mammals, 666**

- Appendix: Basic Structure of Matter, 691**
- Glossary, 699**
- Credits, 733**
- Index, 739**

# contents

*preface, xix*

## *part one* Evolution of Animal Life, 1

### *chapter one*

#### **Life: General Considerations, Basic Molecules, and Origins, 2**

- Principles of Science, 3
  - Nature of Science, 3
  - Scientific Method, 3
  - Physiological and Evolutionary Sciences, 4
- What is Life?, 5
- Chemistry of Life, 6
  - Organic Molecules, 7
- Origin of Life, 11
  - Historical Perspective, 12
  - Modern Experimentation, 13
  - Formation of Polymers, 15
- Origin of Living Systems, 16
  - Origin of Metabolism, 16
  - Appearance of Photosynthesis and Oxidative Metabolism, 17
- Precambrian Life, 17
  - Prokaryotes and the Age of Cyanobacteria, 18
  - Appearance of the Eukaryotes, 19
- Summary*, 20
- Review Questions*, 21
- Selected References*, 22

### *chapter two*

#### **The Cell as the Unit of Life, 23**

- How Cells Are Studied, 24
- Organization of Cells, 26
  - Prokaryotic and Eukaryotic Cells, 26
  - Components of Eukaryotic Cells and Their Functions, 27
  - Surfaces of Cells and Their Specializations, 30
  - Membrane Function, 31
- Cell Division, 35
  - Structure of Chromosomes, 35
  - Stages in Mitosis, 36
  - Cytokinesis: Cytoplasmic Division, 37
  - Cell Cycle, 37
  - Flux of Cells, 38

- Cellular Metabolism, 39
  - Energy and Life, 39
  - Role of Enzymes, 40
  - Cellular Energy Transfer, 42
  - Cellular Respiration, 43
  - Metabolism of Lipids, 50
  - Metabolism of Proteins, 51
  - Management of Metabolism, 52

*Summary*, 52

*Review Questions*, 54

*Selected References*, 55

### *chapter three*

#### **Genetic Basis of Evolution, 56**

- Mendel's Investigations, 57
- Chromosomal Basis of Inheritance, 57
  - Meiosis: Maturation Division of Gametes, 58
  - Sex Determination, 59
- Mendelian Laws of Genetics, 61
  - Mendel's First Law, 61
  - Mendel's Second Law, 63
  - Multiple Alleles, 65
  - Sex-Linked Inheritance, 66
  - Autosomal Linkage and Crossing Over, 66
  - Chromosomal Aberrations, 68
- Gene Theory, 69
  - Gene Concept, 69
- Storage and Transfer of Genetic Information, 70
  - Nucleic Acids: Molecular Basis of Inheritance, 70
  - Transcription and the Role of Messenger RNA, 72
  - Translation: Final Stage in Information Transfer, 75
  - Regulation of Gene Function, 75
  - Genetic Engineering, 77
- Sources of Phenotypic Variation, 78
  - Gene Mutations, 79
- Molecular Genetics of Cancer, 79
  - Oncogenes and Tumor Suppressor Genes, 79
- Summary*, 80
- Review Questions*, 81
- Selected References*, 82

*chapter four***Evolution of Animal Diversity, 83**

- History of Evolutionary Theory, 84
  - Pre-Darwinian Evolutionary Ideas, 84
  - Darwin's Great Voyage of Discovery, 85
- Darwin's Theory of Evolution, 88
- Evidence for Darwin's Five Theories of Evolution, 91
  - Perpetual Change, 91
  - Common Descent, 94
  - Multiplication of Species, 98
  - Gradualism, 100
  - Natural Selection, 102
- Revisions of Darwinian Evolutionary Theory, 103
  - Neo-Darwinism, 103
  - Emergence of Modern Darwinism: The Synthetic Theory, 103
- Microevolution: Genetic Variation and Change within Species, 104
  - Genetic Equilibrium, 105
  - Processes of Evolution: How Genetic Equilibrium Is Upset, 106
- Macroevolution: Major Evolutionary Events, 107
  - Speciation and Extinction through Geological Time, 108
  - Mass Extinctions, 108
- Summary, 109
- Review Questions, 110
- Selected References, 111

*chapter five***Ecology and Distribution of Animals, 112**

- The Hierarchy of Ecology, 113
  - Environment and the Niche, 113
  - Populations, 114
  - Community Ecology, 118
  - Ecosystems, 123
- Distribution of Life on Earth, 127
  - The Biosphere and Its Subdivisions, 127
  - Terrestrial Environments: Biomes, 128
  - Aquatic Environments, 132
- Summary, 133
- Review Questions, 134
- Selected References, 135

*part two* **Animal Form and Function, 137***chapter six***Animal Architecture: Body Organization, Support and Movement, 138**

- The Hierarchical Organization of Animal Complexity, 140
  - Complexity and Body Size, 140
- Extracellular Components of the Metazoan Body, 140
- Types of Tissues, 141
  - Epithelial Tissue, 142
  - Connective Tissue, 142
  - Muscular Tissue, 144
  - Nervous Tissue, 145
- Integument Among Various Groups of Animals, 145
  - Invertebrate Integument, 147
  - Vertebrate Integument, 149
- Skeletal Systems, 150
  - Hydrostatic Skeletons, 150
  - Rigid Skeletons, 150
  - Plan of the Vertebrate Skeleton, 153
  - Effect of Body Size on Bone Stress, 155
- Animal Movement, 156
  - Ameboid Movement, 156
  - Ciliary and Flagellar Movement, 156
  - Muscular Movement, 157
  - Muscle Performance, 163

- Summary, 164
- Review Questions, 164
- Selected References, 165

*chapter seven***Homeostasis: Osmotic Regulation, Excretion, and Temperature Regulation, 166**

- Water and Osmotic Regulation, 167
  - How Marine Invertebrates Meet Problems of Salt and Water Balance, 167
  - Invasion of Fresh Water, 168
  - Return of Fishes to the Sea, 168
  - How Terrestrial Animals Maintain Salt and Water Balance, 170
- Invertebrate Excretory Structures, 171
  - Contractile Vacuole, 171
  - Nephridium, 171
  - Arthropod Kidneys, 172
- Vertebrate Kidney, 173
  - Ancestry and Embryology, 173
  - Vertebrate Kidney Function, 173
  - Glomerular Filtration, 175
  - Tubular Reabsorption, 176
  - Tubular Secretion, 177
  - Water Excretion, 177

- Temperature Regulation, 179
  - Ectothermy and Endothermy, 180
  - How Ectotherms Achieve Temperature Independence, 180
  - Temperature Regulation in Endotherms, 181
  - Adaptive Hypothermia in Birds and Mammals, 183
- Summary*, 185
- Review Questions*, 185
- Selected References*, 186

## *chapter eight*

### **Internal Fluids and Respiration, 187**

- Internal Fluid Environment, 188
  - Composition of the Body Fluids, 188
  - Composition of Blood, 188
  - Hemostasis: Prevention of Blood Loss, 190
- Circulation, 191
  - Open and Closed Circulations, 192
  - Plan of the Vertebrate Circulatory Systems, 193
  - Mammalian Heart, 194
  - Arteries, 195
  - Capillaries, 197
  - Veins, 198
  - Lymphatic System, 198
- Respiration, 199
  - Problems of Aquatic and Aerial Breathing, 199
  - Respiratory Organs, 200
  - Structure and Function of the Mammalian Respiratory System, 202
- Summary*, 207
- Review Questions*, 208
- Selected References*, 209

## *chapter nine*

### **Immunity, 210**

- Innate Defense Mechanisms, 211
  - Phagocytosis, 211
  - Immunity in Invertebrates, 212
  - Innate Immunity in Vertebrates, 212
- Acquired Immune Response in Vertebrates, 213
  - Basis of Self and Nonself Recognition, 213
  - T-Cell Receptors, 215
  - Cells of the Immune Response, 215
  - Cytokines, 215
  - Generation of a Humoral Response, 216
  - The Cell-Mediated Response, 218
  - Acquired Immune Deficiency Syndrome (AIDS), 218
  - Inflammation, 218
- Blood Group Antigens, 219
  - ABO Blood Types, 219
  - Rh Factor, 219
- Summary*, 220
- Review Questions*, 220
- Selected References*, 221

## *chapter ten*

### **Digestion and Nutrition, 222**

- Feeding Mechanisms, 223
  - Feeding on Particulate Matter, 223
  - Feeding on Food Masses, 225
  - Feeding on Fluids, 226
- Digestion, 226
  - Action of Digestive Enzymes, 227
  - Motility in the Alimentary Canal, 228
- Organization and Regional Function of the Alimentary Canal, 228
  - Receiving Region, 228
  - Conduction and Storage Region, 229
  - Region of Grinding and Early Digestion, 229
  - Region of Terminal Digestion and Absorption: The Intestine, 231
  - Region of Water Absorption and Concentration of Solids, 234
- Regulation of Food Intake, 234
- Nutritional Requirements, 235
- Summary*, 238
- Review Questions*, 238
- Selected References*, 239

## *chapter eleven*

### **Nervous Coordination: Nervous System and Sense Organs, 240**

- The Neuron: Functional Unit of the Nervous System, 241
  - Nature of the Nerve Impulse, 242
- Synapses: Junction Points between Nerves, 244
- Evolution of the Nervous System, 244
  - Invertebrates: Development of Centralized Nervous Systems, 244
  - Vertebrates: Fruition of Encephalization, 246
- Sense Organs, 253
  - Classification of Receptors, 253
  - Chemoreception, 253
  - Mechanoreception, 254
  - Photoreception: Vision, 260
- Summary*, 263
- Review Questions*, 264
- Selected References*, 265

## *chapter twelve*

### **Chemical Coordination: Endocrine System, 266**

- Mechanism of Hormone Action, 267
  - Membrane-Bound Receptors and the Second Messenger Concept, 267
  - Nuclear Receptors, 268
- How Secretion Rates of Hormones are Controlled, 268
- Invertebrate Hormones, 269
- Vertebrate Endocrine Glands and Hormones, 270

- Hormones of the Pituitary Gland, Hypothalamus, and Pineal Gland, 270
- Nonendocrine Hormones, 275
- Hormones of Metabolism, 276
- Hormones of Digestion, 282
- Hormones of Vertebrate Reproduction, 282
  - Hormonal Control of the Timing of Reproductive Cycles, 282
  - The Gonadal Steroid and Their Control, 283
  - The Menstrual Cycle, 284
  - Hormones of Human Pregnancy and Birth, 285
- Summary, 287
- Review Questions, 288
- Selected References, 289

## *chapter thirteen*

### **Animal Behavior, 290**

- The Science of Animal Behavior 291
- Describing Behavior: Principles of Classical Ethology, 292
- Control of Behavior, 293
  - The Genetics of Behavior, 294
  - Learning and the Diversity of Behavior, 295
- Social Behavior, 297
  - Advantages of Sociality, 297
  - Aggression and Dominance, 299
  - Territoriality, 301
- Animal Communication, 302
  - Chemical Sex Attraction in Moths, 302
  - Language of the Bees, 303
  - Communication by Displays, 303
  - Communication between Humans and Other Animals, 304
- Summary, 306
- Review Questions, 306
- Selected References, 307

## *chapter fourteen*

### **Reproduction and Development, 308**

- Nature of the Reproductive Process, 309
  - Asexual Reproduction: Reproduction without Gametes, 310
  - Sexual Reproduction: Reproduction with Gametes, 310
  - What Good Is Sex? 313
- Formation of Reproductive Cells, 313
  - Gametogenesis, 314
- Plan of Reproductive Systems, 314
  - Invertebrate Reproductive Systems, 315
  - Vertebrate Reproductive Systems, 316
- The Developmental Process, 318
  - Fertilization, 319
  - Cleavage and Early Development, 320
  - Blastula Formation, 323
  - Gastrulation and the Formation of Germ Layers, 324
- Development of Systems and Organs, 326
  - Derivatives of Ectoderm: Nervous System and Nerve Growth, 326
  - Derivatives of Endoderm: Digestive Tube and Survival of Gill Arches, 328
  - Derivatives of Mesoderm: Support, Movement, and Beating Heart, 328
- Mechanisms of Development, 329
  - Nuclear Equivalence, 329
  - Cytoplasmic Localization: Significance of the Cortex, 329
  - Nuclear Transplantation Experiments, 330
  - Embryonic Induction, 330
  - Gene Expression during Development, 331
- Strategies for Protection of the Developing Embryo, 333
- Vertebrate Development, 333
  - The Common Vertebrate Heritage, 333
  - Amniotes and the Amniotic Egg, 334
  - The Mammalian Placenta and Early Mammalian Development, 335
- Summary, 337
- Review Questions, 338
- Selected References, 339

## *part three* The Invertebrate Animals, 341

## *chapter fifteen*

### **Classification and Phylogeny of Animals, 342**

- Linnaeus and the Development of Classification, 343
- Taxonomic Characters and Phylogenetic Reconstruction, 344
  - Using Character Variation to Reconstruct Phylogeny, 345
  - Sources of Phylogenetic Information, 346
- Theories of Taxonomy, 346
  - Traditional Evolutionary Taxonomy, 346
  - Phylogenetic Systematics/Cladistics, 348

- Current State of Animal Taxonomy, 349
- Species, 350
  - Criteria for Recognition of Species, 350
  - Concepts of Species, 350
- Major Divisions of Life, 351
- Major Subdivisions of the Animal Kingdom, 352
- Body Plans of Animals, 353
  - Symmetry of Animals, 353
  - Body Cavities, 354
  - Metamerism (Segmentation), 358
  - Cephalization, 358
- Summary, 359
- Review Questions, 359
- Selected References, 360



## *chapter sixteen*

### **The Animal-like Protista, 361**

- Form and Function, 363
  - Locomotor Organelles, 363
  - Nutrition and Digestion, 365
  - Excretion and Osmoregulation, 366
  - Reproduction, 367
  - Life Cycles, 368
- Phylum Sarcomastigophora, 369
  - Subphylum Mastigophora, 369
  - Subphylum Sarcodina, 371
- Phylum Apicomplexa, 373
  - Class Sporozoea, 373
- Phylum Ciliophora, 375
  - Reproduction and Life Cycles, 376
- Phylogeny and Adaptive Radiation, 376
  - Phylogeny, 376
  - Adaptive Radiation, 377
- Summary*, 379
- Review Questions*, 379
- Selected References*, 380

## *chapter seventeen*

### **Sponges: Phylum Porifera, 381**

- Ecological Relationships, 382
- Form and Function, 382
  - Types of Canal Systems, 383
  - Types of Cells, 384
  - Types of Skeletons, 385
  - Sponge Physiology, 386
  - Reproduction and Development, 387
- Brief Survey of Sponges, 387
  - Class Calcarea (Calcispongiae), 387
  - Class Hexactinellida (Hyalospongiae), 388
  - Class Demospongiae, 388
  - Class Sclerospongiae, 388
- Phylogeny and Adaptive Radiation, 389
  - Phylogeny, 389
  - Adaptive Radiation, 389
- Summary*, 390
- Review Questions*, 390
- Selected References*, 391

## *chapter eighteen*

### **Radiate Animals: Cnidarians and Ctenophores, 392**

- Phylum Cnidaria, 393
  - Ecological Relationships, 394
  - Form and Function, 394
    - Class Hydrozoa, 399
    - Class Scyphozoa, 402
    - Class Cubozoa, 404
    - Class Anthozoa, 404
- Phylum Ctenophora, 411

- Form and Function, 411
- Phylogeny and Adaptive Radiation, 412
  - Phylogeny, 412
  - Adaptive Radiation, 413
- Summary*, 414
- Review Questions*, 414
- Selected References*, 415

## *chapter nineteen*

### **Acoelomate Animals: Flatworms, Ribbon Worms, and Jaw Worms, 416**

- Phylum Platyhelminthes, 417
  - Ecological Relationships, 417
  - Form and Function, 418
    - Class Turbellaria, 420
    - Class Trematoda, 421
    - Class Monogenea, 423
    - Class Cestoda, 424
- Phylum Nemertea (Rhynchocoela), 427
  - Form and Function, 428
- Phylum Gnathostomulida, 429
  - Phylogeny and Adaptive Radiation, 429
    - Phylogeny, 429
    - Adaptive Radiation, 430
- Summary*, 431
- Review Questions*, 431
- Selected References*, 432

## *chapter twenty*

### **Pseudocoelomate Animals, 433**

- Phylum Rotifera, 434
- Phylum Gastrotricha, 435
- Phylum Kinorhyncha, 436
- Phylum Loricifera, 436
- Phylum Priapulida, 436
- Phylum Nematoda: Roundworms, 437
  - Form and Function, 437
    - Some Nematode Parasites, 438
- Phylum Nematomorpha, 442
- Phylum Acanthocephala, 442
- Phylum Entoprocta, 444
- Phylogeny and Adaptive Radiation, 446
  - Phylogeny, 446
  - Adaptive Radiation, 446
- Summary*, 446
- Review Questions*, 447
- Selected References*, 447

## *chapter twenty-one*

### **Molluscs, 448**

- Ecological Relationships, 449
- Economic Importance, 449
- Form and Function, 451
  - Internal Structure and Function, 452

- Classes Caudofoveata and Solenogastres, 453
- Class Monoplacophora, 453
- Class Polyplacophora: Chitons, 453
- Class Scaphopoda, 454
- Class Gastropoda, 454
  - Form and Function, 455
  - Major Groups of Gastropods, 458
- Class Bivalvia (Pelecypoda), 459
  - Form and Function, 460
- Class Cephalopoda, 464
  - Form and Function, 465
- Phylogeny and Adaptive Radiation, 469
- Summary, 472
- Review Questions, 473
- Selected References, 473

## *chapter twenty-two*

### **Segmented Worms: The Annelids, 474**

- Ecological Relationships, 475
- Economic Importance, 475
- Body Plan, 476
- Class Polychaeta, 477
- Class Oligochaeta, 480
  - Earthworms, 480
  - Form and Function, 481
  - Freshwater Oligochaetes, 484
- Class Hirudinea, 485
  - Form and Function, 485
- Phylogeny and Adaptive Radiation, 486
  - Phylogeny, 486
  - Adaptive Radiation, 488
- Summary, 488
- Review Questions, 489
- Selected References, 489

## *chapter twenty-three*

### **Arthropods, 490**

- Ecological Relationships, 491
- Why Have Arthropods Achieved Such Great Diversity and Abundance?, 491
- Subphylum Trilobita, 492
- Subphylum Chelicerata, 493
  - Class Merostomata, 493
  - Class Pycongonida: Sea Spiders, 493
  - Class Arachnida, 493
- Subphylum Crustacea, 498
  - Form and Function, 499
  - Class Branchiopoda, 504
  - Class Maxillopoda, 504
  - Class Malacostraca, 505
- Subphylum Uniramia, 508

- Class Chilopoda: Centipedes, 508
- Class Diplopoda: Millipedes, 508
- Class Insecta: Insects, 508
- Phylogeny and Adaptive Radiation, 526
  - Phylogeny, 526
  - Adaptive Radiation, 526
- Summary, 528
- Review Questions, 529
- Selected References, 530

## *chapter twenty-four*

### **Lesser Protostomes and Lophophorates, 531**

- The Lesser Protostomes, 532
  - Phylum Sipuncula, 532
  - Phylum Echiura, 532
  - Phylum Pogonophora, 533
  - Phylum Pentastomida, 533
  - Phylum Onychophora, 534
  - Phylum Tardigrada, 535
- The Lophophorates, 535
  - Phylum Phoronida, 536
  - Phylum Ectoprocta, 536
  - Phylum Brachiopoda, 538
  - Phylogeny, 539
- Summary, 540
- Review Questions, 541
- Selected References, 541

## *chapter twenty-five*

### **Echinoderms, Hemichordates, and Chaetognaths 542**

- Phylum Echinodermata, 543
  - Ecological Relationships, 543
  - Class Asterozoa: Sea Stars, 543
  - Class Ophiurozoa: Brittle Stars, 549
  - Class Echinozoa: Sea Urchins, Sand Dollars, and Heart Urchins, 550
  - Class Holothurozoa: Sea Cucumbers, 551
  - Class Crinozoa: Sea Lilies and Feather Stars, 553
  - Class Concentricyclozoa: Sea Daisies, 554
  - Phylogeny and Adaptive Radiation, 554
- Phylum Hemichordata: Acorn Worms, 557
  - Class Enteropneusta, 557
  - Class Pterobranchia, 558
  - Phylogeny, 558
- Phylum Chaetognatha: Arrowworms, 560
- Summary, 560
- Review Questions, 561
- Selected References, 561

## *part four* The Vertebrate Animals, 563

### *chapter twenty-six*

#### **Vertebrate Beginnings: The Chordates, 564**

- Traditional and Cladistic Classification of the Chordates, 565
- Four Chordate Hallmarks, 566
  - Notochord, 569
  - Dorsal, Tubular Nerve Cord, 569
  - Pharyngeal Pouches and Gill Slits, 569
  - Postanal Tail, 570
- Ancestry and Evolution of the Chordates, 570
- Subphylum Urochordata (Tunicata), 570
- Subphylum Cephalochordata, 571
- Subphylum Vertebrata, 573
  - Adaptations That Have Guided Vertebrate Evolution, 573
  - The Search for the Vertebrate Ancestral Stock, 575
  - The Earliest Vertebrates: Jawless Ostracoderms, 576
  - Early Jawed Vertebrates, 577
  - Evolution of Modern Fishes and Tetrapods, 578
- Summary*, 580
- Review Questions*, 580
- Selected References*, 581

### *chapter twenty-seven*

#### **Fishes, 582**

- Ancestry and Relationships of Major Groups of Fishes, 583
- Superclass Agnatha: Jawless Fishes, 583
  - Hagfishes: Class Myxini, 583
  - Lampreys: Class Cephalaspidomorphi, 587
- Cartilaginous Fishes: Class Chondrichthyes, 587
  - Sharks and Rays: Subclass Elasmobranchii, 588
  - Chimaeras: Subclass Holocephali, 590
- Bony Fishes: Class Osteichthyes, 591
  - Origin, Evolution, and Diversity, 591
  - Ray-Finned Fishes: Subclass Actinopterygii, 591
  - The Fleshy-Finned Fishes: Subclass Sarcopterygii, 593
- Structural and Functional Adaptations of Fishes, 595
  - Locomotion in Water, 595
  - Neutral Buoyancy and the Swim Bladder, 596
  - Respiration, 597
  - Migration, 598
  - Reproduction and Growth, 600
- Summary*, 604
- Review Questions*, 604
- Selected References*, 605

### *chapter twenty-eight*

#### **The Early Tetrapods and Modern Amphibians, 606**

- Movement onto Land, 607

- Early Evolution of Terrestrial Vertebrates, 607
  - Devonian Origin of the Tetrapods, 607
  - Carboniferous Radiation of the Tetrapods, 609
- The Modern Amphibians, 609
  - Caecilians: Order Gymnophiona (Apoda), 611
  - Salamanders: Order Caudata (Urodela), 612
  - Frogs and Toads: Order Anura (Salientia), 615
- Summary*, 619
- Review Questions*, 620
- Selected References*, 620

### *chapter twenty-nine*

#### **Reptiles, 621**

- Origin and Adaptive Radiation of Reptiles, 622
  - Changes in Traditional Classification of Reptiles, 622
- Characteristics of Reptiles That Distinguish Them from Amphibians, 625
- Characteristics and Natural History of Reptilian Orders, 627
  - Anapsid Reptiles: Subclass Anapsida, 627
  - Diapsid Reptiles: Subclass Diapsida, 628
- Summary*, 638
- Review Questions*, 639
- Selected References*, 639

### *chapter thirty*

#### **Birds, 640**

- Origin and Relationships, 641
- Adaptations of Bird Structure and Function for Flight, 645
  - Feathers, 645
  - Skeleton, 646
  - Muscular System, 646
  - Digestive System, 648
  - Circulatory System, 649
  - Respiratory System, 649
  - Excretory System, 649
  - Nervous and Sensory System, 650
- Flight, 652
  - Bird Wing as a Lift Device, 652
  - Basic Forms of Bird Wings, 652
  - Flapping Flight, 653
- Migration and Navigation, 654
  - Migration Routes, 654
  - Stimulus for Migration, 654
  - Direction Finding in Migration, 655
- Social Behavior and Reproduction, 656
  - Reproductive System, 656
  - Mating Systems, 657
  - Nesting and Care of Young, 658
- Bird Populations, 659
- Summary*, 664
- Review Questions*, 664
- Selected References*, 665



## *chapter thirty-one*

---

### **Mammals, 666**

- Origin and Evolution of Mammals, 667
- Structural and Functional Adaptations of Mammals, 671
  - Integument and Its Derivatives, 671
  - Food and Feeding, 674
  - Migration, 676
  - Flight and Echolocation, 677
  - Reproduction, 679

- Mammal Populations, 680
- Human Evolution, 682
- Summary, 688
- Review Questions, 689
- Selected References, 690

- Appendix: Basic Structure of Matter, 691*
- Glossary, 699*
- Credits, 733*
- Index, 739*