

CONTENTS

PART ONE EVOLUTION OF ANIMAL LIFE

1 FITNESS OF THE ENVIRONMENT, 2

- Conditions for life on earth, 3
- Analysis of the environment, 4
- Ecosystems, 7
 - Solar radiation and photosynthesis, 8
 - Production and the food chain, 8
 - Ecologic pyramids, 10
 - Nutrient cycles, 11
- Communities, 15
 - Ecologic dominance, 15
 - Ecologic niche concept, 16
- Populations, 16
 - Natural balance within populations, 16
 - How population growth is curbed, 19

2 ORIGIN OF LIFE, 22

- Historical perspective, 23
 - Renewal of inquiry: Haldane-Oparin hypothesis, 25
- Primitive earth, 25
 - Formation of the solar system, 25
 - Origin of the earth's atmosphere, 25
- Basic molecules of life, 27
 - Amino acids and proteins, 27
 - Nucleic acids, 28
 - Protein synthesis, 32
 - Regulation of gene function, 33
- Chemical evolution, 36
 - Sources of energy, 36
 - Prebiotic synthesis of small organic molecules, 37
 - Formation of polymers, 38

- Origin of living systems, 40
- Origin of metabolism, 41
- Appearance of photosynthesis and oxidative metabolism, 41
- Precambrian life, 42
- Prokaryotes and the age of blue-green algae, 42
- Appearance of the eukaryotes, 42

3 THE CELL AS THE UNIT OF LIFE, 44

- Cell concept, 45
- How cells are studied, 45
- Organization of the cell, 46
- Prokaryotic and eukaryotic cells, 47
- Components of the eukaryotic cell and their function, 48
- Surfaces of cells and their specializations, 52
- Cell division (mitosis), 53
- Structure of chromosomes, 53
- Stages in cell division, 55
- Cell cycle, 56
- Membrane structure and function, 56
- Present concept of membrane structure, 57
- Membrane permeability, 57

4 GENETIC BASIS OF EVOLUTION, 62

- Mendel and the laws of inheritance, 63
- Mendel's investigations, 63
- Monohybrid cross, 63
- Dihybrid and trihybrid crosses, 66
- Laws of probability, 67
- Multiple alleles, 68
- Gene interaction, 68
- Penetrance and expressivity, 70
- Lethal genes, 71
- Chromosomal theory of inheritance, 71
- Meiosis: maturation division of germ cells, 71
- Sex determination, 73
- Sex-linked inheritance, 74
- Autosomal linkage and crossing-over, 76
- Sources of phenotypic variation, 78
- Mutation, 79

5 EVOLUTION OF ANIMAL DIVERSITY, 82

- Development of the idea of organic evolution, 83
- Darwin's great voyage of discovery, 84
- Evidences for evolution, 90
- Reconstructing the past, 90
- Natural system of classification, 94
- Comparative anatomy: homologous resemblances, 95
- Comparative embryology, 95
- Comparative biochemistry, 96
- Natural selection, 96
- Darwin's theory of natural selection, 96
- Appraisal of Darwin's theory, 97
- Genetic variation within species, 98
- Evolution of new species, 102
- Species concept, 102
- Speciation, 102

6 EVOLUTION OF BEHAVIOR, 108

- Ethology and the study of instinct, 109
- Stereotyped behavior, 109
- Instinct and learning, 112
- Social behavior, 117
- Advantages of sociality, 117
- Aggression and dominance, 118
- Territoriality, 121
- Communication, 123

PART TWO ANIMAL FORM AND FUNCTION

7 SUPPORT, PROTECTION, AND MOVEMENT, 128

- Integument among various groups of animals, 129
- Invertebrate integument, 129
- Vertebrate integument, 129
- Skeletal systems, 131
- Exoskeleton and endoskeleton, 131
- Cartilage, 132
- Bone, 132
- Plan of the vertebrate skeleton, 133
- Animal movement, 136
- Ameboid movement, 136
- Ciliary movement, 137
- Muscular movement, 137

8 INTERNAL FLUIDS: Circulation and respiration, 144

- Internal fluid environment, 145
- Composition of the body fluids, 145
- Circulation, 151
- Plan of the circulatory system, 151
- Respiration, 157
- Problems of aquatic and aerial breathing, 157
- Respiration in man, 160

9 INTERNAL FLUIDS: Excretion and homeostasis, 166

- Water and osmotic regulation, 167
- How aquatic animals meet problems of salt and water balance, 167
- How terrestrial animals maintain salt and water balance, 170
- Invertebrate excretory structures, 171
- Vertebrate kidney, 174
- Vertebrate kidney function, 175

10 NUTRITION AND CELLULAR METABOLISM, 182

- Feeding mechanisms, 183
- Digestion, 187
- Intracellular versus extracellular digestion, 187

Vertebrate digestion, 188
Nutritional requirements, 194
Central role of enzymes in the living process, 196
Cellular metabolism, 198

11 NERVOUS COORDINATION: Nervous system and sense organs, 208

Nervous systems of invertebrates, 209
Nervous systems of vertebrates, 209
Neurons: functional units of the nervous system, 210
Synapses: junction points between nerves, 213
Components of the reflex arc, 214
Organization of the vertebrate nervous system, 215
Central nervous system, 215
Peripheral nervous system, 220
Sense organs, 222
Classification of receptors, 223

12 CHEMICAL COORDINATION: Endocrine system, 232

Mechanisms of hormone action, 234
Invertebrate hormones, 235
Vertebrate endocrine glands and hormones, 237
Hormones of the pituitary gland and hypothalamus, 239
Hormones of metabolism, 243
Hormones of digestion, 249

13 REPRODUCTION AND DEVELOPMENT, 250

Nature of the reproductive process, 251
Asexual reproduction, 251
Sexual reproduction, 254
Plan of reproductive systems, 254
Human reproductive system, 255
Origin of reproductive cells, 256
Meiosis: germ cell division, 256
Developmental process, 258
Oocyte maturation, 258
Fertilization and activation, 258
Cleavage and early development, 260
Gastrulation, 261
Differentiation, 262
Extraembryonic membranes of the amniotes, 265
Human development, 266
Early development of human embryo, 267
Placenta, 267
Pregnancy and birth, 269
Control of development, 270

PART THREE THE INVERTEBRATE ANIMALS

14 CLASSIFICATION AND PHYLOGENY OF ANIMALS, 276

Animal classification, 277
Linnaeus and the development of classification, 277

Species, 278
Basis for formation of taxa, 279
Animal phylogeny, 279
Kingdoms of life, 280
Divisions of the animal kingdom, 281

15 PROTOZOANS AND SPONGES, 286

Protozoans—phylum Protozoa, 287
Evolution and adaptive radiation, 287
Ecologic relationships, 288
Characteristics, 288
Classification, 288
Form and function, 289
Flagellates—superclass Mastigophora, 297
Amoeboid protozoans—superclass Sarcodina, 297
Sporozoans—class Sporozoa, 299
Ciliates—subphylum Ciliophora, 299
Review of contributions of the protozoans, 303
Sponges—phylum Porifera, 303
Evolution of sponges, 304
Ecologic relationships, 304
Characteristics, 305
Classification, 305
Form and function, 306
Class Calcarea (Calcispongiae), 309
Class Hexactinellida (Hyalospongiae), 309
Class Demospongiae, 310
Review of contributions of the sponges, 310

16 RADIATE ANIMALS, 312

Advancements of the radiate phyla, 313
Evolution of the radiate phyla, 313
Phylum Cnidaria (Coelenterata), 314
Ecologic relationships, 315
Polymorphism in cnidarians, 315
Characteristics, 316
Classification, 316
Form and function, 316
Class Hydrozoa, 320
Class Scyphozoa, 327
Class Anthozoa, 327
Phylum Ctenophora, 331
Characteristics, 332
Classification, 332
Form and function, 332
Review of contributions of the radiate phyla, 334

17 ACOELOMATE ANIMALS—FLATWORMS AND RIBBON WORMS, 336

Evolution and adaptive radiation, 337
Phylum Platyhelminthes, 337
Characteristics, 338
Classification, 338
Class Turbellaria, 338
Class Trematoda—flukes, 342
Class Cestoda—tapeworms, 344

- Phylum Nemertina (Rhynchocoela)—ribbon worms, 348
- Phylum Gnathostomulida, 350
- Review of contributions of the acoelomates, 350

18 PSEUDOCOELOMATE ANIMALS, 352

- Phylum Rotifera, 353
- Phylum Gastrotricha, 354
- Phylum Kinorhyncha, 354
- Phylum Nematoda—roundworms, 355
- Phylum Nematomorpha, 358
- Phylum Acanthocephala—spiny-headed worms, 359
- Phylum Entoprocta, 360

19 MOLLUSCS, 364

- Phylum Mollusca, 365
 - Ecologic relationships, 365
 - Evolution of molluscs, 365
 - Significance of the coelom, 367
 - Characteristics, 367
 - Classification, 368
 - Molluscan body plan, 368
- Segmented molluscs—class Monoplacophora, 370
- Chitons—class Polyplacophora (Amphineura), 370
- Class Aplacophora, 371
- Tusk shells—class Scaphopoda, 371
- Snails and their relatives—class Gastropoda, 371
- Bivalved molluscs—class Pelecypoda, 377
- Squids and octopuses—class Cephalopoda, 380
- Review of contributions of the molluscs, 384

20 SEGMENTED WORMS, 386

- Phylum Annelida, 387
 - Ecologic relationships, 387
 - Evolution of annelids, 387
 - Characteristics, 388
 - Classification of annelids, 388
 - General form and function, 388
- Polychaetes, 390
 - Form and function, 392
- Oligochaetes, 395
 - Earthworms, 395
 - Freshwater oligochaetes, 399
- Leeches—Hirudinea, 399
- Review of contributions of the annelids, 401

21 ARTHROPODS, 402

- Phylum Arthropoda, 403
 - Evolution of arthropods, 404
 - Why have arthropods been so successful? 404
 - Characteristics, 405
 - Classification, 405
- Trilobites, 406
- Chelicerate arthropods, 406
 - Class Merostomata, 407
 - Class Arachnida, 407

- Mandibulate arthropods, 414
 - Class Crustacea, 414
 - Myriapods, 424
 - Class Insecta, 425
- Review of contributions of the arthropods, 448

22 LESSER PROTOSTOMES AND LOPHOPHORATES, 450

- Lesser protostomes, 451
 - Phylum Sipunculida, 451
 - Phylum Echiurida, 451
 - Phylum Priapulida, 452
 - Phylum Pentastomida, 452
 - Phylum Tardigrada, 453
 - Phylum Onychophora, 454
- Lophophorates, 454
 - Phylum Phoronida, 455
 - Phylum Ectoprocta, 457
 - Phylum Brachiopoda, 458

23 ECHINODERMS AND LESSER DEUTEROSTOMES, 462

- Deuterostomes, 463
- Echinoderms—phylum Echinodermata, 463
 - Ecology and distribution, 463
 - Characteristics, 463
 - Classification, 464
 - Echinoderm development, 465
 - Sea stars—class Asteroidea, 465
 - Brittle stars and basket stars—class Ophiuroidea, 470
 - Sea urchins and sand dollars—class Echinoidea, 470
 - Sea cucumbers—class Holothuroidea, 472
 - Sea lilies and feather stars—class Crinoidea, 474
 - Echinoderm phylogeny, 475
 - Review of contributions of the echinoderms, 475
- Lesser deuterostomes, 475
 - Arrowworms—phylum Chaetognatha, 475
 - Beardworms—phylum Pogonophora, 476
 - Acorn worms and pterobranchs—phylum Hemichordata, 478

PART FOUR THE VERTEBRATE ANIMALS

24 VERTEBRATE BEGINNINGS: The earliest chordates, 484

- Introduction to the phylum Chordata, 485
 - Characteristics, 486
 - Classification, 487
- Ancestry and evolution, 487
 - Candidates for vertebrate ancestral stock, 489
 - Jawless ostracoderms—earliest vertebrates, 490
 - Early jawed vertebrates, 491
 - Evolution of modern fishes and tetrapods, 492
- Subphylum Urochordata (Tunicata), 493
- Subphylum Cephalochordata, 494

- Subphylum Vertebrata, 494
 Characteristics, 494
 Review of contributions of the chordates, 496
- 25 FISHES, 498**
 Ancestry of major groups of fishes, 499
 Classification of living fishes, 501
 Jawless fishes—superclass Agnatha, 501
 Characteristics of the Agnatha, 501
 Lampreys—class Petromyzontes, 502
 Hagfishes—class Myxini, 504
 Cartilaginous fishes—class Chondrichthyes, 504
 Sharks, skates, and rays—subclass Elasmobranchii, 504
 Chimaeras—subclass Holocephali, 505
 Bony fishes—class Osteichthyes (Teleostomi), 506
 Characteristics, 506
 Classification, 506
 Lobe-finned fishes—subclass Crossopterygii, 507
 Lungfishes—subclass Dipneusti, 507
 Ray-finned fishes—subclass Actinopterygii, 509
 Some structural and functional adaptations of fishes, 510
 Locomotion in water, 510
 Neutral buoyancy and the swim bladder, 511
 Respiration, 513
 Osmotic regulation, 514
 Coloration and concealment, 514
 Migration, 517
- 26 AMPHIBIANS, 520**
 Movement onto land, 521
 Physical contrast between aquatic and land habitats, 521
 Origin and relationships of amphibians, 522
 Earliest amphibians, 522
 Amphibians' contribution to vertebrate evolution, 523
 Characteristics, 524
 Brief classification, 525
 Structure and natural history of amphibian orders, 525
 Caecilians—order Gymnophiona (Apoda), 525
 Salamanders and newts—order Urodela (Caudata), 525
 Frogs and toads—order Salientia (Anura), 527
- 27 REPTILES, 532**
 Origin and adaptive radiation of reptiles, 533
 Characteristics, 535
 Brief classification, 535
 How reptiles show advancements over amphibians, 535
 Structure and natural history of reptilian orders, 537
 Lizards and snakes—order Squamata, 537
 Turtles—order Testudines (Chelonia), 542
 Crocodiles and alligators—order Crocodylia, 543
 The tuatara—order Rhynchocephalia, 544
- 28 BIRDS, 546**
 Origin and relationships, 547
 Characteristics, 550
 Brief classification, 550
 Adaptations of bird structure and function for flight, 551
 Flight, 559
 Migration and navigation, 562
 Bird society, 565
 Bird populations, 566
- 29 MAMMALS, 570**
 Origin and relationships, 571
 Characteristics, 573
 Classification, 573
 Structural and functional adaptations of mammals, 575
 Integument and its derivatives, 575
 Food and feeding, 579
 Body temperature regulation, 582
 Migration, 586
 Hibernation, 586
 Flight and echolocation, 587
 Reproduction, 588
 Territory and home range, 590
 Mammal populations, 591
- GLOSSARY, 594**