

Contents

Preface 3

1 Scientific Investigation 29

Laboratory Objectives 29

Introduction 29

Exercise 1.1 Questions and Hypotheses 30

Exercise 1.2 Designing Experiments to Test Hypotheses 32

Exercise 1.3 Designing an Experiment 38

Exercise 1.4 Presenting and Analyzing Results 42

Exercise 1.5 Interpreting and Communicating Results 48

Reviewing Your Knowledge 49

Applying Your Knowledge 52

Student Media: BioFlix, Activities, Investigations, Videos,
and Data Tables 56

References 56

Websites 57

2 Microscopes and Cells 61

Laboratory Objectives 61

Introduction 61

Exercise 2.1 The Compound Light Microscope 62

Exercise 2.2 Basic Microscope Techniques 65

Exercise 2.3 The Stereoscopic Microscope 69

Exercise 2.4 The Transmission Electron Microscope 72

Exercise 2.5 The Organization of Cells 74

Reviewing Your Knowledge 81

Applying Your Knowledge 82

Investigative Extensions 83

Student Media: BioFlix, Activities, Investigations, and Videos 84

References 84

Websites 84

3 Diffusion and Osmosis 87

Laboratory Objectives 87

Introduction 87

Exercise 3.1 Diffusion of Molecules 89

Exercise 3.2 Osmotic Activity in Cells 93

Exercise 3.3 Investigating Osmolarity of Plant Cells 99

Reviewing Your Knowledge 108

Applying Your Knowledge 109

Investigative Extensions 110

Student Media: BioFlix, Activities, Investigations, Videos,
and Data Tables 110

References 111

Websites 111

4 Enzymes 115

Laboratory Objectives 115

Introduction 115

Exercise 4.1 Experimental Method and the Action of Catechol Oxidase 116

Exercise 4.2 Inhibiting the Action of Catechol Oxidase 119

Exercise 4.3 Influence of Concentration, pH, and Temperature
on the Activity of Amylase 122

Reviewing Your Knowledge 133

Applying Your Knowledge 133

Investigative Extensions 135

Student Media: BioFlix, Activities, Investigations, Videos,
and Data Tables 136

References 137

Websites 137

5 Cellular Respiration and Fermentation 141

Laboratory Objectives 141

Introduction 141

Exercise 5.1 Alcoholic Fermentation 144

Exercise 5.2 Cellular Respiration 151

Exercise 5.3 Designing and Performing Your Open-Inquiry Investigation 158

Reviewing Your Knowledge 160

Applying Your Knowledge 161

Student Media: BioFlix, Activities, Investigations, Videos,
and Data Tables 162

References 162

Websites 162

6 Photosynthesis 165

Laboratory Objectives 165

Introduction 165

Exercise 6.1 The Wavelengths of Light for Photosynthesis 166

Exercise 6.2 Pigments in Photosynthesis 169

Exercise 6.3 Separation and Identification of Plant Pigments by Paper
Chromatography 172

Exercise 6.4 Determining the Absorption Spectrum for Leaf Pigments 175

Reviewing Your Knowledge 180

Applying Your Knowledge 180

Investigative Extensions 182

Student Media: BioFlix, Activities, Investigations, Videos,
and Data Tables 182

References 182

Websites 182

7 Mitosis and Meiosis 185

Laboratory Objectives 185

Introduction 185

Exercise 7.1 Modeling the Cell Cycle and Mitosis in an Animal Cell 186

Exercise 7.2 Observing Mitosis and Cytokinesis in Plant Cells 191

- Exercise 7.3 Observing Chromosomes, Mitosis, and Cytokinesis in Animal Cells 194
- Exercise 7.4 Modeling Meiosis 197
- Exercise 7.5 Meiosis in *Sordaria fimicola*: A Study of Crossing Over 203

Reviewing Your Knowledge 207

Applying Your Knowledge 209

Investigative Extensions 210

Student Media: BioFlix, Activities, Investigations, and Videos 212

References 212

Websites 213

8 Mendelian Genetics I: Fast Plants 217

Laboratory Objectives 217

Introduction 217

- Exercise 8.1 Inheritance of Anthocyanin Gene 225
- Exercise 8.2 Inheritance of Plant Color: Green, Yellow-Green, and Purple (Anthocyanin Present) 229
- Exercise 8.3 Inheritance of Variegated and Nonvariegated Leaf Color 234

Reviewing Your Knowledge 238

Applying Your Knowledge 239

Investigative Extensions 240

Student Media: BioFlix, Activities, Investigations, Videos, and Data Tables 242

References 242

Websites 242

9 Mendelian Genetics II: *Drosophila* 245

Laboratory Objectives 245

Introduction 245

- Exercise 9.1 Establishing the Enzyme Reaction Controls 246
- Exercise 9.2 Determining the Pattern of Inheritance of the Aldox Gene 251
- Exercise 9.3 Determining Parental Genotypes Using Evidence from Progeny 255
- Exercise 9.4 Mapping Genes 258

Reviewing Your Knowledge	263
Applying Your Knowledge	263
Investigative Extensions	264
Student Media: BioFlix, Activities, Investigations, Videos, and Data Tables	265
References	265
Websites	265

10 Molecular Biology 271

Laboratory Objectives	271
Introduction	271
Exercise 10.1 Mapping DNA Using Restriction Enzymes and Electrophoresis	274
Exercise 10.2 Practice Problem for Mapping DNA	288
Reviewing Your Knowledge	292
Applying Your Knowledge	294
Investigative Extensions	295
Student Media: BioFlix, Activities, Investigations, and Videos	295
References	295
Websites	296

11 Population Genetics: The Hardy-Weinberg Principle 299

Laboratory Objectives	299
Introduction	299
Exercise 11.1 Testing Hardy-Weinberg Equilibrium Using a Bead Model	303
Exercise 11.2 Simulation of Evolutionary Change Using the Bead Model	306
Exercise 11.3 Open-Inquiry Computer Simulation of Evolution	321
Reviewing Your Knowledge	322
Applying Your Knowledge	323
Investigative Extensions	325
Student Media: BioFlix, Activities, Investigations, Videos, and Data Tables	325
References	326
Websites	326

12 Bacteriology 329

Laboratory Objectives 329

Introduction 329

Exercise 12.1 Investigating Characteristics of Bacteria 331

Exercise 12.2 Ecological Succession of Bacteria in Milk 339

Exercise 12.3 Bacteria in the Environment 342

Exercise 12.4 Controlling the Growth of Bacteria 349

Reviewing Your Knowledge 354

Applying Your Knowledge 355

Investigative Extensions 356

Student Media: BioFlix, Activities, Investigations, and Videos 358

References 358

Websites 358

13 Protists 363

Laboratory Objectives 363

Introduction 363

Exercise 13.1 Supergroup Excavata 366

Exercise 13.2 Supergroup "SAR" 368

Exercise 13.3 Supergroup Unikonta 377

Exercise 13.4 Supergroup Archaeplastida 381

Exercise 13.5 Designing and Performing an Open-Inquiry Investigation 387

Reviewing Your Knowledge 390

Applying Your Knowledge 392

Student Media: BioFlix, Activities, Investigations, and Videos 393

References 393

Websites 393

14 Plant Diversity I: Bryophytes (Nonvascular Plants) and Seedless Vascular Plants 397

Laboratory Objectives 397

Introduction 397

Exercise 14.1 Bryophytes (Nonvascular Plants) 401

Exercise 14.2 Seedless Vascular Plants 407

Reviewing Your Knowledge	417
Applying Your Knowledge	418
Investigative Extensions	421
Student Media: BioFlix, Activities, Investigations, and Videos	421
References	421
Websites	422

15 Plant Diversity II: Seed Plants 425

Laboratory Objectives	425
Exercise 15.1 Gymnosperms	428
Exercise 15.2 Angiosperms	435
Reviewing Your Knowledge	447
Applying Your Knowledge	448
Investigative Extensions	450
Student Media: BioFlix, Activities, Investigations, and Videos	451
References	451
Websites	451

16 Bioinformatics: Molecular Phylogeny of Plants 455

Laboratory Objectives	455
Introduction	455
Exercise 16.1 Establishing Molecular Phylogenetic Relationships Among Rubisco Large Subunit Genes	458
Exercise 16.2 Analyzing Phylogenetic Trees and Reporting Results	466
Reviewing Your Knowledge	467
Applying Your Knowledge	468
Investigative Extensions	469
Student Media: BioFlix, Activities, Investigations, and Videos	470
References	470
Websites	470

17 The Kingdom Fungi 473

Laboratory Objectives 473

Introduction 473

Exercise 17.1 A Survey of Major Fungal Groups 475

Exercise 17.2 Designing and Performing an Open-Inquiry Investigation 487

Reviewing Your Knowledge 490

Applying Your Knowledge 491

Student Media: BioFlix, Activities, Investigations, and Videos 491

References 491

Websites 492

18 Animal Diversity I: Porifera, Cnidaria, Platyhelminthes, Mollusca, and Annelida 495

Laboratory Objectives 495

Introduction 495

Exercise 18.1 Phylum Porifera—Sponges (*Scypha*) 500

Exercise 18.2 Phylum Cnidaria—Hydras (*Hydra*) 502

Exercise 18.3 Phylum Platyhelminthes—Planarians (*Dugesia*) 505

Exercise 18.4 Phylum Mollusca—Clams 508

Exercise 18.5 Phylum Annelida—Clamworms (*Nereis*) and Earthworms (*Lumbricus terrestris*) 511

Reviewing Your Knowledge 516

Applying Your Knowledge 517

Investigative Extensions 517

Student Media: BioFlix, Activities, Investigations, and Videos 518

References 518

Websites 518

19 Animal Diversity II: Nematoda, Arthropoda, Echinodermata, and Chordata 521

Exercise 19.1 Phylum Nematoda—Roundworms (*Ascaris*) 521

Exercise 19.2 Phylum Arthropoda 525

Exercise 19.3 Phylum Echinodermata—Sea Star 532

Exercise 19.4 Phylum Chordata 535

Reviewing Your Knowledge—Lab Topics 18 and 19 542

Applying Your Knowledge 542

Investigative Extensions 547

Student Media: BioFlix, Activities, Investigations, and Videos 548

References 548

Websites 549

20 Plant Anatomy 555

Laboratory Objectives 555

Introduction 555

Exercise 20.1 Plant Morphology 559

Exercise 20.2 Plant Primary Growth and Development 561

Exercise 20.3 Cell Structure of Primary Tissues 564

Exercise 20.4 Structure of Tissues Produced by Secondary Growth 576

Exercise 20.5 Grocery Store Botany: Modifications of Plant Organs 579

Reviewing Your Knowledge 580

Applying Your Knowledge 582

Investigative Extensions 584

Student Media: BioFlix, Activities, Investigations, and Videos 584

References 584

Websites 585

21 Plant Growth 587

Laboratory Objectives 587

Introduction 587

Exercise 21.1 Factors Influencing Seed Germination 592

Exercise 21.2 Plant Growth Regulators: Auxin 595

Exercise 21.3 Plant Growth Regulators: Gibberellins 599

Exercise 21.4 Designing and Performing an Open-Inquiry Investigation 603

Reviewing Your Knowledge 605

Applying Your Knowledge 605

Student Media: BioFlix, Activities, Investigations, Videos,
and Data Table 607

References 607

Websites 608

22 Vertebrate Anatomy I: The Skin and Digestive System 611

Laboratory Objectives 612

Introduction 612

Exercise 22.1 Histology of the Skin 616

Exercise 22.2 Introduction to the Fetal Pig 619

Exercise 22.3 The Digestive System in the Fetal Pig 623

Reviewing Your Knowledge 630

Applying Your Knowledge 631

Case Study 633

Student Media: BioFlix, Activities, Investigations, and Videos 634

References 635

Websites 635

23 Vertebrate Anatomy II: The Circulatory and Respiratory Systems 637

Laboratory Objectives 637

Introduction 637

Exercise 23.1 Glands and Respiratory Structures of the Neck
and Thoracic Cavity 638

Exercise 23.2 The Heart and the Pulmonary Blood Circuit 639

Exercise 23.3 The Heart and the Systemic Circuit in the Thorax 643

Exercise 23.4 The Systemic Circuit in the Abdominal Cavity 645

Exercise 23.5 Blood 650

Exercise 23.6 Fetal Pig Circulation 651

Exercise 23.7 Details of the Respiratory System 653

Reviewing Your Knowledge 655

Applying Your Knowledge 656

Case Studies 658

Student Media: BioFlix, Activities, Investigations, and Videos 658

References 658

Websites 659

24 Vertebrate Anatomy III: The Excretory, Reproductive, and Nervous Systems 661

Laboratory Objectives 661

Introduction 661

Exercise 24.1 The Excretory System 662

Exercise 24.2 The Reproductive System 665

Exercise 24.3 Nervous Tissue, the Reflex Arc, and the Vertebrate Eye 673

Reviewing Your Knowledge 679

Applying Your Knowledge 680

Case Studies 680

Student Media: BioFlix, Activities, Investigations, and Videos 681

References 681

Websites 681

25 Animal Development 683

Laboratory Objectives 683

Introduction 683

Exercise 25.1 Development in Echinoderms: Sea Urchin and Sea Star 688

Exercise 25.2 Development in an Amphibian 695

Exercise 25.3 Development in the Zebrafish 697

Exercise 25.4 Development in a Bird: The Chicken 702

Reviewing Your Knowledge 710

Applying Your Knowledge 711

Investigative Extensions 713

Student Media: BioFlix, Activities, Investigations, and Videos 714

References 714

Websites 715

26 Animal Behavior 717

Laboratory Objectives 717

Introduction 717

Exercise 26.1 Taxis in Brine Shrimp 719

Exercise 26.2 Kinesis in Pill Bugs 722

Exercise 26.3 Agonistic Display in Male Siamese Fighting Fish 725

Exercise 26.4 Reproductive Behavior in Fruit Flies 729

Exercise 26.5 Designing and Performing Your Open-Inquiry Investigation 733

Reviewing Your Knowledge 735

Applying Your Knowledge 735

Student Media: BioFlix, Activities, Investigations, and Videos 737

References 737

Websites 737

27 Ecology I: Terrestrial Ecology 741

Laboratory Objectives 741

Introduction 741

Exercise 27.1 Biotic Components 744

Exercise 27.2 Abiotic Components 757

Exercise 27.3 Data Analysis 761

Reviewing Your Knowledge 770

Applying Your Knowledge 771

Optional Exercise 27.1 773

Student Media: BioFlix, Activities, Investigations, Videos,
and Data Tables 773

References 774

Websites 774

28 Ecology II: Computer Simulations of a Pond Ecosystem 781

Laboratory Objectives 781

Introduction 781

Exercise 28.1 Computer Model of the Pond Ecosystem 783

Exercise 28.2 Investigating the Effects of Disturbance on the Pond Ecosystem 792

Reviewing Your Knowledge 801

Applying Your Knowledge 802

Investigative Extensions 804

Student Media: BioFlix, Activities, Investigations, and Videos 804

References 804

Websites 805

Appendix **A** Scientific Writing and Communication 809

Appendix **B** The Metric System 823

Appendix **C** Instrumentation and Techniques 825

Appendix **D** Chi-Square Test 833

Appendix **E** Terminology and Techniques for Dissection 837