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Our Learning Technology Representatives can help. 2 Geteilte Kopien anzeigen 168 Share the publication to a stackLike to get better recommendationsThe publisher does not have the license to enable download PDF 2016 - Mc Graw Hill - ISBN-10: 1259544877 - Biology Laboratory Manual (11 edition) By Darrell S Vodopich, Randy Moore # 8551 2016 | 608 pages | PDF | 168 MB The Biology Laboratory Manual (11 edition) By Darrell S Vodopich, Randy Moore # 8551 2016 | 608 pages | PDF | 168 MB The Biology Laboratory Manual (11 edition) By Darrell S Vodopich, Randy Moore # 8551 2016 | 608 pages | PDF | 168 MB The Biology Laboratory Manual (11 edition) By Darrell S Vodopich, Randy Moore # 8551 2016 | 608 pages | PDF | 168 MB The Biology Laboratory Manual (11 edition) By Darrell S Vodopich, Randy Moore # 8551 2016 | 608 pages | PDF | 168 MB The Biology Laboratory Manual (11 edition) By Darrell S Vodopich, Randy Moore # 8551 2016 | 608 pages | PDF | 168 MB The Biology Laboratory Manual (11 edition) By Darrell S Vodopich, Randy Moore # 8551 2016 | 608 pages | PDF | 168 MB The Biology Laboratory Manual (11 edition) By Darrell S Vodopich, Randy Moore # 8551 2016 | 608 pages | PDF | 608 page course with a broad survey of basic laboratory techniques. The experiments and procedures are simple, safe, easy to perform, and especially appropriate for large classes. Few experiments that help students learn about life. Procedures within each exercise are numerous and discrete so that an exercise can be tailored to the needs of the students, the style of the instructor, and the facilities available. 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Biology Laboratory Manual Twelfth Edition Darrell S. Vodopich Baylor University of Minnesota BIOLOGY LABORATORY MANUAL, TWELFTH EDITION Published by McGraw-Hill Education, 2 Penn Plaza, New York, NY 10121. Copyright © 2020 by McGraw-Hill Education. All rights reserved. Printed in the United States of America. Previous editions © 2017, 2014, and 2011. No part of this publication may be reproduced or distributed in any form or by any means, or stored in a database or retrieval system, without the prior written consent of McGraw-Hill Education, including, but not limited to, in any network or other electronic storage or transmission, or broadcast for distance learning. Some ancillaries, including electronic and print components, may not be available to customers outside the United States. This book is printed on acid-free paper. 1 2 3 4 5 6 7 8 9 LMN 21 20 19 ISBN 978-1-260-20072-0 (bound edition) ISBN 978-1-260-20072-8 (bound edition) ISBN 978-1-260-20072-8 (bound edition) ISBN 978-1-260-20072-0 (bound edition) ISBN 978-1-260-20072-0 (bound edition) ISBN 978-1-260-20072-8 (bound edition) ISBN 978-1-260-20072-0 (bound edition) ISBN 978 (loose-leaf edition) MHID 1-260-41330-6 (loose-leaf edition) Portfolio Manager: Andrew Urban Product Developer: Donna Nemmers Marketing Manager: Kelly Brown Content Project Managers: Jessica Portz & Sandra Schnee Buyer: Laura Fuller Design: David W. Hash Content Licensing Specialist: Lorraine Buczek Cover Image: ©Darrell S. Vodopich Compositor: MPS Limited All credits appearing on page are considered to be an extension of the copyright page. Some of the laboratory experiments included in this text may be hazardous if materials are handled improperly or if procedures are conducted incorrectly. Safety precautions are necessary when you are working with chemicals, glass test tubes, hot water baths, sharp instruments, and the like, or for any procedures that generally require caution. Your school may have set regulations regarding safety procedures that your instructor for help.
The Internet addresses listed in the text were accurate at the time of publication. The inclusion of a website does not indicate an endorsement by the authors or McGraw-Hill Education does not guarantee the accuracy of the information presented at these sites. mheducation.com/highered Contents Preface v Teaching and Learning Tools viii Welcome to the Biology Laboratory ix Exercise 1 Scientific Method: The Process of Science 1 Exercise 2 Exercise 16 Molecular Biology: DNA Isolation and Genetic Transformation 171 Exercise 17 Genetics: The Principles of Mendel 179 Exercise 18 Measurements in Biology: The Metric System and Data Analysis 11 Evolution: Natural Selection and Morphological Change in Green Algae 195 Exercise 3 Exercise 3 Exercise 4 The Cell: Structure and Function 33 Human Evolution: Skull Examination 207 Exercise 20 Ecology: Diversity and Interaction in Plant Communities 217 Exercise 5 Exercise 6 Exercise 6 Exercise 22 Solutions, Acids, and Bases: The pH Scale 49 Biologically Important Molecules: Carbohydrates, Proteins, Lipids, and Nucleic Acids 57 Exercise 7 Separating Organic Compounds: Column Chromatography, and Gel Electrophoresis 71 Exercise 8 Spectrophotometry: Identifying Solutes and Determining Their Concentration 81 Exercise 9 Diffusion and Osmosis: Passive Movement of Molecules in Biological Systems 93 Exercise 10 Cellular Membranes: Effects of Physical and Chemical Stress 105 Exercise 12 Respiration: Aerobic Oxidation of Organic Molecules 125 Exercise 13 Photosynthesis: Pigment Separation, Starch Production, and CO2 Uptake 137 Exercise 24 Survey of Prokaryotes: Domains Archaea and Bacteria 253 Exercise 25 Survey of Protists: The Algae 269 Exercise 26 Survey of Protists: Protozoa and Slime Molds 283 Exercise 27 Survey of the Kingdom Fungi: Molds, Sac Fungi, Mushrooms, and Lichens 293 Exercise 28 Survey of the Plant Kingdom: Liverworts, Mosses, and Hornworts of Phyla Hepaticophyta, and Anthocerophyta 307 Exercise 29 Survey of the Plant Kingdom: Seedless Vascular Plants of Phyla Pterophyta and Lycophyta, 317 Exercise 30 Mitosis: Replication of Eukaryotic Cells 149 Survey of the Plant Kingdom: Gymnosperms of Phyla Cycadophyta, Coniferophyta, and Gnetophyta, 329 Exercise 31 Meiosis: Reduction Division and Gametogenesis 159 TOC-1 Survey of the Plant Kingdom: Angiosperms 339 iii Exercise 32 Exercise 33 Exercise 34 Exercise 34 Exercise 34 Exercise 35 Exercise 35 Exercise 36 Exercise 36 Exercise 37 Bioassay: Measuring Physiologically Active Substances 389 Survey of the Animal Kingdom: Phyla Porifera and Cnidaria 395 Exercise 37 Human Biology: Breathing 505 Human Biology: Circulation and Blood Pressure 515 Human Biology: Sensory Perception 529 Vertebrate Anatomy: External Features and Skeletal System of the Rat 539 Survey of the Animal Kingdom: Phyla Platyhelminthes and Nematoda 411 Exercise 48 Exercise 38 Exercise 39 Exercise 39 Exercise 49 Exercise 40 Survey of the Animal Kingdom: Phyla Echinodermata and Chordata 453 Exercise 41 Vertebrate Anatomy: Muscles and Internal Organs of the Rat 547 Vertebrate Anatomy: Urogenital and Circulatory Systems of the Rat 557 Embryology: Comparative Morphologies and Strategies of Development 569 Exercise 51 Animal Behavior: Taxis, Kinesis, and Agonistic Behavior 579 Vertebrate Animal Tissues: Epithelial, Connective, Muscular, and Nervous Tissues 473 Appendix I Exercise 42 Appendix II Human Biology: The Human Skeletal System 489 iv Dissection of a Fetal Pig 585 Conversion of Metric Units to English Units 592 TOC-2 Preface Contents W e have designed this laboratory manual for an introductory biology course with a broad survey of basic laboratory techniques. The experiments and procedures are simple, safe, easy to perform, and especially appropriate for large classes. Few experiments that help students learn about life. Procedures within each exercise are numerous and discrete so that an exercise can be tailored to the needs of the students, the style of the instructor, and the facilities available. TO THE STUDENT We hope this manual is an interesting guide to many areas of biology. As you read about these areas, you'll probably spend equal amounts of time observing and experimenting. Don't hesitate to go beyond the observations that we've outlined—your future success as a scientist and an informed citizen depends on your ability to seek and notice things that others may overlook. Now is the time to develop this ability with a mixture of hard work and relaxed observation. Have fun, and learning will come easily. Also, remember that this manual is designed with your instructors in mind as well. Go to them often with questions—their experience is a valuable tool that you should use as you work. TO THE INSTRUCTOR This manual's straightforward approach emphasizes experiments and activities that optimize students' investment of time and your investment of supplies, equipment, and preparation. Simple, safe, and straightforward experiments are most effective if you interpret the work in depth. Most experiments can be done easily by a student in 2 to 3 hours. Terminology, structures, photographs, and concepts are limited to those that the student can readily observe and understand In each exercise we have included a few activities requiring a greater investment of effort if resources are available, but omitting them will not detract from the objectives. This manual functions best with an instructor's guidance and is not an autotutorial system. We've tried to guide students from observations to conclusions, to help students make their own discoveries, and to make the transition from observation to understanding biological principles. But P-1 discussions and interactions between student and instructor are major components of a successful laboratory experience. Be sure to examine the "Questions for Further Study and Inquiry" in each exercise. We hope they will help you expand students' perceptions that each exercise has broad application to their world. DIGITAL INTEGRATION As educators, we recognize that today's students are digital learners. Virtually every exercise of this manual is accompanied by tailor-made digital resources, including assignable questions and a variety of high-definition videos, PowerPoint images, and other resources that demonstrate basic techniques, emphasize biological principles, test for understanding, and engage students as they learn biology in the laboratory. Digital resources are available to instructors at connect .mheducation.com. Instructors will want to assign these resources to help students know what they'll be doing, what principles they'll be investigating, and what concepts they'll need to understand before coming to lab. WHAT'S NEW IN THIS EDITION Throughout the manual, we have expanded and improved several of the most popular and effective features of previous editions, including • Learning Objectives have been updated to provide an overview of what students will do and learn in the exercise. • Procedures and Doing Biology Yourself require students to do biology as they apply skills they've learned to develop and study hypotheses about biology. • Questions throughout each exercise encourage students to pause and think about their data and what they've learned in lab. • Questions for Further Study and Inquiry at the end of each exercise help students apply what they've learned to broader topics and issues in biology. • Writing to Learn Biology encourages students to develop their ideas about what they learned in lab. v • Caution and Safety First icons make students aware of safety issues associated with the procedures they'll use in lab. • Exercise 13—Figure 13.2 caption is expanded • Boxed readings titled Inquiry-Based Learning encourage students to apply what they've learned to independently answer questions about intriguing biological topics. • Exercise 15—Labels for figure 15.2 have been added for paternal versus maternal chromosomes; description of the structure of replicated versus nonreplicated chromosomes has been clarified; figure 15.6 is new; figure 15.7 is revised to clarify the state and number of chromosomes in first polar bodies, and corpus albicans has been labeled and added as a defined term in the text • Updated health-related exercises help students better understand topics such as blood pressure, atherosclerosis, and their risk of cardiovascular disease. • Several illustrations have been replaced with photographs to provide more realistic images to support the Exercise content. write their answers. • An assignable, updated library of videos and Connect questions. Instructors may assign these videos before class time to help ensure that students arrive prepared for lab. Exercise-Specific Changes • Exercise 1—Additional explanation provided for both mean and standard deviation • Exercise 2—Mass, volume, and median are further defined; new illustration in figure 2.3 on measuring the volume of liquid; figure 2.4b has explanatory labels added • Exercise 3—Additional questions have been added to Procedure 3.6 Using a dissecting microscope of the volume of liquid; figure 2.4b has explanatory labels added • Exercise 3—Additional questions have been added to Procedure 3.6 Using a dissecting microscope of the volume of liquid; figure 2.4b has explanatory labels added • Exercise 3—Additional questions have been added to Procedure 3.6 Using a dissecting microscope of the volume of liquid; figure 2.4b has explanatory labels added • Exercise 3—Additional questions have been added to Procedure 3.6 Using a dissecting microscope of the volume of the volume of liquid; figure 2.4b has explanatory labels added • Exercise 3—Additional questions have been added to Procedure 3.6 Using a dissecting microscope of the volume o Exercise 4—Several illustrations have better labels; a new photo is supplied for figure 4.6a Elodea cells; figure 4.13 has been redrawn to more directly correlate to the associated photo; a new photo has been added to
figure 6.2 to explain Benedict's test • Exercise 7—Clarifying edits made to introductory material • Exercise 9—Explanations of hypotonic, hypertonic, and isotonic are expanded • Exercise 10—Steps of Procedures 10.1 and 10.2 are clarified; a new question on experimental design has been added to Questions for Further Study and Inquiry vi • Exercise 14—Explanation of the structure of chromatids is expanded • Exercise 16—Global prevalence of genetically transformed crops has been updated to 2017 statistics • Exercise 17—Figure 17.4 has a panel of 3 new photos on sickle cell anemia; figure 17.6 contains improved photos of hairlines • Exercise 18—Definition of evolution is revised to be more concise; questions about Hardy-Weinberg genetics are expanded for clarity; a new question about the effect of natural selection on sickle cell anemia has been revised to better illustrate lineages of human evolution; the term "diastema" has been added and defined; figure 19.4 is relabeled for clarity • Exercise 20—Procedure 20.4 is expanded to help students design and implement experimental controls. • Exercise 22—Formula for population values and growth rates • Exercise 23—Question 1 is revised to emphasize hypothesis testing; table 23.3 is reorganized to accept handwritten student data • Exercise 24—Organization of domains and kingdoms is updated to current taxonomy; table 24.1, prokaryotic versus eukaryotic characteristics, is modified for precision; figure 24.2, structure of a bacterial cell, is revised and contains a new photo; explanation of binary fission is expanded to include protein FtsZ and its role in cell separation • Exercise 25—Explanations of Archaeplastida and the term "protist" are clarify sexual versus asexual reproductive paths; figure 25.8 contains a new photo of Volvox colonies P-2 • Exercise 26—Photomicrograph and illustration of African sleeping sickness blood cells are revised to clarify their relationship • Exercise 27—Explanations of fungal sporangiophores and sporangia are expanded; figure 27.13 is modified to better show the diagnostic reproductive structure, ascus; Questions for Further Study and Inquiry has a new question to explain the benefit of fungi to other organisms • Exercise 31-A learning objective is added on understanding flower structure and function; the explanation of sporogenesis is expanded; a Question for Further Study and Inquiry has been added to help students understand flower parts • Exercise 32—A new question is added to Questions for Further Study and Inquiry on common leaf morphologies • Exercise 35—The definition of bioassay is revised • Exercise 36—Introductions to terms animals, multicellular, and primitive have been clarified; description of intracellular versus extracellular digestion in poriferans has been clarified • Exercise 37—Taxonomic hierarchy of the classes and subphyla of flatworms is updated; taxonomy of tapeworms is updated; taxonomy of major arthropod classes has been updated and reorganized to include Chelicerata, Crustacea, Myriapoda, and Hexapoda; table 39.3 has been relabeled to reflect updated arthropod taxonomy of pre-vertebrate groups has been updated; class Actinopterygidii has replaced Osteichthyes; figure 40.21 of amphibian transitional stages is revised • Exercise 41—Figure 41.2 has revised labeling; figure 41.3 is relabeled to distinguish flat cuboidal and columnar cells; figure 41.7 has been replaced to better show stratified squamous epithelium; types of connective tissue have been separated into connective tissue proper and special connective tissue • Exercise 42—Descriptions of the appendicular skeleton and the axial skeleton and the axial skeleton are added; the number of skull, spine, and rib cage bones has been updated to P-3 conventional values; figure 42.2 is new; Figure 42.4 has been replaced with improved images of normal and osteoporotic bone; revisions to Questions for Further Study and Inquiry • Exercise 43—A new learning objective is added to distinguish between isotonic and isometric contractions; explanations of muscle tone, and muscle tension are expanded; figure 43.2 is relabeled to clearly distinguish between flexion and extension; Procedure 43.1 concerning flexion and extension of the forearm has been modified for clarity • Exercise 44—Descriptions of negative pressure and its role in breathing are expanded and clarified; Procedures to distinguish the role of intercostal muscles and breathing are expanded and clarified; Procedures to distinguish the role of intercostal muscles and breathing are expanded and clarified; Procedures to distinguish the role of intercostal muscles and breathing are expanded and clarified; Procedures to distinguish the role of intercostal muscles and breathing are expanded and clarified; Procedures to distinguish the role of intercostal muscles and breathing are expanded and clarified; Procedures to distinguish the role of intercostal muscles and breathing are expanded and clarified; Procedures to distinguish the role of intercostal muscles and breathing are expanded and clarified; Procedures to distinguish the role of intercostal muscles and breathing are expanded and clarified; Procedures to distinguish the role of intercostal muscles and breathing are expanded and clarified; Procedures to distinguish the role of intercostal muscles and breathing are expanded and clarified; Procedures to distinguish the role of intercostal muscles and breathing are expanded and clarified; Procedures to distinguish the role of intercostal muscles and breathing are expanded and clarified; Procedures to distinguish the role of intercostal muscles are expanded. values for tidal, expiratory, inspiratory, and residual volumes have been provided; directions for measuring breathing rate in Procedure 46.1 has been modified to illustrate fovea centralis; Procedure 46.3 has been modified to accommodate lab partners • Exercise 47—A new Question 2 has been added; Question 3 has been expanded to provide more examples and practice with terms such as cranial, caudal, lateral, distal, etc.; directions for the skinning and abdominal incision during rat dissection are expanded • Exercise 48—Descriptions of the thyroid gland and diaphragm are expanded. are expanded • Exercise 49—Figure 49.4 has been revised and enlarged to better show the structure and cross section of a kidney • Exercise 51—Directions are enhanced for Procedure 51.1 to examine kinesis in pill bugs; directions are enhanced for Procedure 51.2 to study agonistic behavior in fighting fish, to encourage better creativity by the students in experimental design; a new question has been updated to include upcoming changes to how a basic unit of the metric system is defined vii Teaching Contents and Learning Tools McGraw-Hill Connect Biology McGraw-Hill Connect Biology provides online presentation, assignment, and assessment solutions. It connects your students with the tools and resources they'll need to succeed at connect.mheducation.com. With Connect Biology, you can deliver assignment, and assessment solutions. It connects your students with the tools and resources they'll need to succeed at connect.mheducation.com. With Connect Biology, you can deliver assignment, and activities is presented and aligned with this lab manual's learning outcomes. Pre-lab worksheets and Investigation worksheets are also included within Connect. As an instructor, you can edit existing questions. Track students' performance—by question, by assignment, or in relation to the class overall—with detailed grade reports. Integrate grade reports easily with Learning Management Systems (LMS), such as Blackboard—and much more. McGraw-Hill Create by searching through thousands of leading McGraw-Hill textbooks. Arrange your book to fit your teaching style. Create even allows you to personalize your book's appearance by selecting the cover and adding your name, school, and course information. Order a Create book and you'll receive a complimentary print review copy in 3-5 business days or a complimentary electronic review copy in 3-5 business. Create empowers you to teach your students your way. Laboratory Resource Guide The Laboratory Resource Guide is essential for instructors and laboratory Resource stab. With McGraw-Hill Create, you can easily rearrange exercises, combine material from other content you have written, such as your course viii T-1 Contents to the Biology Laboratory! Although reading your textbook and attending lectures are important ways of learning about biology, nothing can replace the importance of the laboratory. In lab you'll get hands-on experience with what you've heard and read about biology— for example, you'll observe organisms, do experiments, test ideas, collect data, and make conclusions about what you've learned. You'll do biology. You'll enjoy the exercises in this manual—they're interesting and informative and can be completed within the time limits of your laboratory period. We've provided questions to test your understanding of what you've posed. To make these exercises most useful and enjoyable, follow these guidelines noted in the next sections. THE IMPORTANCE OF COMING TO CLASS Biology labs are designed to help you experience biology firsthand. To do well in your biology course, you'll need to attend class attendance as it relates to making a good grade in your biology course, examine figure 1, which is a graph showing how grades in an introductory biology 100 A B 80 C D Grade (%) 60 40 F 20 0 0 20 40 60 80 100 Attendance (% of classes attended) Figure 1 Relationship of students' grades in an introductory biology course to their rates of class attendance. W-1 ix course correlate to their rates of class attendance. Data are from a general University of Minnesota. On page xii, write an analysis of the data shown in figure 1. What do these data mean? BEFORE COMING TO LAB Watch the lab you will be completing. These videos will help you know more about what you will be
doing, what principles you will be investigating, and what concepts you need to understand before coming to lab. Read the exercise before coming to lab. Read the exercise before coming to lab. Read the exercise before coming to lab. have questions about these safety issues, contact your lab instructor before starting the lab work. Notify your instructor if you are pregnant, are colorblind, are taking immunosuppressive drugs, have allergies, or have any other conditions that may require precautionary measures. Also, before coming to lab, cover any cuts or scrapes with a sterile, waterproof bandage. 4. Discuss your observations, results, and conclusions with your instructor. 6. If you have questions, ask your instructor. SAFETY IN THE LABORATORY Laboratory accidents can affect individuals, classes, or the entire campus. To avoid such accidents, the exercises in this manual were designed with safety as a top priority. You'll be warned about any potentially hazardous situations or chemicals with this image; When you see this image, pay special attention to the instructions The laboratory safety rules listed in table 1 will help make lab a safe place for everyone to learn biology. Remember, it is much easier to prevent an accident than to deal with its consequences. Read the laboratory safety rules listed in table 1. If you do not understand them, or if you have questions, ask your instructor for an explanation. Then complete table 1 and sign the statement at the bottom of page xii. BEFORE YOU LEAVE LAB Put away all equipment and glassware, and wipe clean your work area. WHEN IN LAB AFTER EACH LABORATORY 1. Know what you are going to do. Read and understand the lab before coming to lab. 2. Don't start the exercise until you've discussed the exercise with your laboratory instructor. She or he will give you specific instructions about the lab and tell you how the exercise may have been modified. 3. Work carefully and thoughtfully, and stay focused as you work. You'll be able to finish each exercise may have been modified. what you did. What questions did you gather? What data did you gather? What conclusions did you make? Also note any questions by using your textbook or visiting the library. If you can't answer these questions, discuss them with your instructor. Welcome to the biology laboratory! x W-2 Table 1 Laborator Safety Rules Rule Why is this rule important? What could happen if this rule is not followed? Behave responsibly. No horseplay or fooling around while in lab. Do not put anything in lab into your mouth. Avoid touching your face, chewing on pens, and other similar behaviors while in lab. Always wear shoes in lab. Unless you are told otherwise by your instructor, assume that all chemicals and solutions in lab are poisonous, and act accordingly. Never pipette by mouth. Always use a mechanical pipetting device (e.g., a suction bulb) to pipette solutions. Clean up all spills immediately, and report all spills to your instructor. Wear safety goggles when working with chemicals from an unlabeled container, and do not return excess chemicals back to their container. Report all spills to your instructor immediately. Unless your instructor, If you have long hair, tie it back. Don't wear dangling jewelry. If you are using open flames, roll up loose sleeves. Wear contact lenses at your own risk; contacts hold substances against the eye and make it difficult to wash your eyes thoroughly. Treat living organisms with care and respect. Your instructor will tell you the locations of lab safety equipment, including fire extinguishers, fire blanket, eyewash stations, and emergency showers. Familiarize yourself with the location of this equipment. If anything is splashed into your eyes, wash your eyes, wash your eyes thoroughly and immediately. Tell your lab instructor of any glassware, do not pick up the pieces of broken glass with your hands. Instead, use a broom and dustpan to gather the broken glass. Ask your instructor how to dispose of the glass. Unless told by your instructor to do otherwise, work only during regular, assigned hours when the instructor is present. Do not conduct any unauthorized experiments; for example, do not mix any chemicals without your instructor's approval. Do not leave any experiments unattended unless you are authorized by your instructor to do so. If you leave your work area, slide your chair under the lab table. Keep walkways and desktops clean and uncluttered as possible. Don't touch or put anything on the surface of hotplates unless told to do so. Many types of hotplates have no visible sign that they are hot. Assume they are hot. Assume they are hot and solutions away from equipment and electrical outlets Report malfunctioning equipment to your instructor. Leave equipment in the same place and condition that you found it. If you have any questions about or problems with equipment, contact your instructor. Know what to do and whom to contact if there is an emergency. Know the fastest way to get out of the lab. Immediately report all injuries—no matter how minor—to your instructor. Seek medical attention immediately if needed. If any injury appears to be life-threatening, call 911 immediately. At the end of each lab, clean your work area, wash your hands thoroughly with soap, slide your chair under the lab table, and return all equipment and supplies to their original locations. Do not remove any chemicals or equipment from the lab. W-3 xi Name Lab Section Your lab instructor may require that you submit this page at the end of today's lab. 1. In the space below, write an analysis of the data shown in figure 1. After completing table 1, read and sign this statement: 2. I have read and I understand and agree to abide by the laboratory safety rules described in this exercise and discussed by my instructor. I know the locations of the safety equipment and materials. If I violate any of the laboratory safety rules, my instructor will lower my grade and/or remove me from the lab. Date xii W-4 E XER CISE 1 Scientific Method The Process of Science Learning Objectives By the end of this exercise you should be able to: 1. Define science and understand the logic and sequence of the scientific method. 2. Develop productive observations, questions, and hypotheses about the natural world. 3. Calculate the range, mean, and standard deviation for a set of replicate measurements. 4. Design and conduct a controlled experiment to test a null hypothesis. 5. Understand the difference between a hypothesis and a . Please visit connect.mheducation.com to review online resources tailored to this lab. T he word science brings to mind different things to different students. To some students, science is a textbook. To others, it's a microscope, a dissected frog, or a course that you take. In fact, science is none of those things. Some definitions are more useful than others, but for biological research a good definition of science is the orderly process of posing and answering questions. This definition emphasizes that science is a process rather than a book, course, or list of facts. Science is not a "thing." It's a way of thinking about and doing things—a way of learning and knowing about the natural world (fig. 1.1). Our definition also emphasizes that people do science by asking questions and then doing experiments to answer those questions. Questions and curiosity are part of human nature, and science is a human activity. Like any human task, it takes practice to do science effectively. Finally, our definition emphasizes that science is a tool for learning about the natural world. It is ineffective for moral choices, ethical dilemmas, and untestable ideas. For example, the scientific method cannot tell us if pollution is good or bad. It can tell us the environmental consequences of pollution, but whether these consequences are "good" or "bad" is a judgment that we make based on our values or goals, not on science. Although this is an important limitation of the most powerful ways of understanding our world. Question 1 What practices besides science are used among world cultures to learn about the natural world? ©nandyphotos/Getty Images Figure 1.1 Science is a process of learning about the natural world. Doing experiments that involve gathering repeated and unbiased measurements (data) is at the heart of testing hypotheses and answering questions. 1-1 The questioning and testing inherent in science systematically sift through natural variation to find underlying patterns. The natural world includes much variation, and learning biology would be relatively easy if simple observations accurately revealed patterns. The natural world. But they usually don't—nature is too complicated to rely solely on simple observation. We can certainly learn much about Scientific Method environment just by looking around us, but casual observations are often biased and misleading because nature varies from time to time and from organism. Biologists need a structured and repeatable process for testing their ideas about the variation in nature. Science is that process. Question 2 What factors might be responsible for variation in measurements of traits such as the heights of 10-year-old pine trees or the kidney filtration rates of 10 replicate lab-mice? The process of science deals with variation primarily through an organized steps, sometimes called method, vary from situation to situation, they are remarkably effective for research and problem solving. The typical steps in the process of science are: •• Make insightful observations •• Pose and clarify testable questions •• Refine hypotheses and retest •• Answer the guestions and make conclusions DEVELOPMENT OF OBSERVATIONS. AND HYPOTHESES Make Insightful observations: Observations: Observations: Observations: Observations: Observations and make conclusions and make than there used to be. Observation 2: The density of elk in Yellowstone National Park has declined during the
consecutive dry years since the reintroduction of them may be true, but the second one is much more insightful because it provides a context to the observation that the elk population is declining. It also suggests a relevant factor—that is, the reintroduction of the wolf population and the variation in the local environment. 2 EXERCISE 1 Procedure 1.1 Make insightful observations 1. Consider the following two observations. Observations is more useful for further investigation? Why? SAFETY FIRST Before coming to lab, you were asked to read this exercise so you would know what to do and be aware of safety issues. Briefly list the safety issues associated with today's procedures. If you have questions about these issues, contact your laboratory assistant before starting work. Record the more insightful of the two observations on Worksheet 1 on page 9.2. Consider this observation: Pillbugs (sometimes called roly-poly bugs) often find food and shelter where fungi are decomposing leaf litter (fig. 1.2). For this example we are interested in whether pillbugs often hide under things. Propose a more productive observation. Observation 2: Record Observation 2 on Worksheet 2 on page 10. You may revise this later. Pose and Clarify Testable Questions rather than abstract hypotheses or numbers. But phrasing a good question takes practice and experience, and the first questions that capture our attention are usually general. For example, "Which nutrients can yeast most readily metabolize?" is a general question that expands the observation posed in procedure 1.1. This question is broadly applicable and is the type of questions are important, but their generality often makes them somewhat vague. The best questions for the process of science are specific enough to answer clearly. Therefore, scientists usually refine and subdivide broad questions into more specific enough to answer clearly. yeast?" Enter this as Specific Question 1 in Worksheet 1. 1-2 Specific Question 1 © BiologyImaging.com Figure 1.2 Pillbugs are excellent experimental organisms to test hypotheses about microenvironments, such as those under logs and within leaf litter. Pillbugs are readily available and easily cultured in the lab (10×). A further clarification might be "Does yeast absorb and metabolize carbohydrates better than it absorbs and metabolizes proteins?" This is a good, specific question because it clearly refers to organisms, processes, and variables that are likely involved. It also suggests a path for investigation—that is, it suggests a path for investigation because it clearly refers to organisms, processes, and variables that are likely involved. It also Consider the questions "What color is your roommate's car?" and "How many legs do cats have?" To answer these questions, would you use the scientific method, or would you use the scientific method, or would you use the scientific method, or would you rely on observation? Why? Procedure 1.2 Posing and refining questions 1. Examine the following two questions. Question 1: Do songbird populations respond to the weather? Question 2: Do songbirds sing more often in warm weather than in cold weather? Which of those question, and record it in Worksheet 2. General Question: What influences the distribution of pillbugs? Propose a specific question that refers to the food of pillbugs as a variable, and record it here and in Worksheet 2. Know that you may revise this later. 1-3 Propose a more specific question here and in Worksheet 2. Know that you may revise this later. Specific Question 2 Formulate Hypotheses Well-organized experiments to answer questions be restated as testable hypothesis is a statement that clearly states the relationship between biological variables. A good hypothesis is a statement that clearly states the relationship between biological variables how the variables will be compared. A hypothesis is a statement rather than a question, and an analysis of your experimental data will ultimately determine whether you accept or reject your hypothesis. Remember that even though a hypothesis can be falsified, it can never be proved true. Accepting or rejecting a hypothesis, with no middle ground, may seen like a rather coarse way to deal with questions about subtle and varying natural processes. But using controlled experimental data that lead to reject a hypothesis is effective. The heart of science is gathering and analyzing experimental data that lead to reject a hypothesis is effective. you are going to do science as you investigate yeast nutrition and then experiment with food choice by pillbugs. As yeast ferments its food, CO2 is produced as a by-product. Therefore, we can measure the growth of yeast might be: H0: CO2 production by yeast fed sugar is not significantly different from the CO2 produces more CO2 when fed protein. A related alternative hypothesis can be similarly stated: Ha: Yeast produces more CO2 when fed sugar than when fed protein. Figure 1.3 These tubes of yeast are fermenting nutrients provided in solution. The CO2 produced by the yeast accumulates at the top of the test tubes and indicates that yeast's rate of metabolism. From left to right, the tubes include a control with no added nutrients, a tube with low nutrients, and a tube with high nutrients. © BiologyImaging.com Scientific Method 3 The first hypothesis (H0) is a null hypothesis because it states that there is no difference This is the most common way to state a clear and testable hypotheses.) Researchers usually find it more useful to associate statistical probabilities with null hypotheses rather than with alternative hypotheses. Enter the null hypothesis into Worksheet 1. A well-written null hypothesis is useful because it is testable. In our experiment, the null hypothesis (1) specifies yeast as the organism, population, or group that we want to learn about; (2) identifies CO2 production as the variable being measured; and (3) leads directly to an experiment to evaluate variables and compare means of replicated measurements. Procedure 1.3 Formulating hypotheses 1. Examine the following two hypotheses: Hypothesis 2: The number of bird songs heard per hour at significantly different from the number heard per hour at some when the weather is warm. temperatures below 80°F (27°C). Which of these hypothesis? Why? 2. Examine the following hypothesis? Why? 2. Examine the following hypothesis. Be sure that it is a null hypothesis? Why? 2. Examine the following hypothesis? Why? 3. Examine the following hypothesis? Why? 4. Example the following hypothesis? Why? 5. Example t is testable, and that it includes the parameter you will control in an experiment. Hypothesis 2 (H0): Enter your null hypothesis in Worksheet 2. EXPERIMENTATION AND DATA ANALYSIS: YEAST NUTRITION Gather Experimental Data To test our hypothesis about yeast growth, we must design a controlled and repeatable experiment. The experiment suggested by our specific question and hypothesis involves offering sugar such as glucose to one population of yeast, 4 EXERCISE 1 offering protein to another population of yeast, and then measuring their respective growth rates. Fortunately, yeast grows readily in test tubes. As yeast grows in a closed, anaerobic container, it produces CO2 in proportion to how readily it uses the available food. CO2 production is easily measured by determining the volume of CO2 that accumulates at the top of an inverted test tube (fig. 1.3). Experiments provide data that determine if a hypothesis should be accepted or rejected. A well-designed experiment links a biological response to different levels of the variable being investigated. In this case, the biological response is CO2 production, which indicates growth. The levels of the variable are sugar and protein. These levels are called treatments, and in our experiment they include glucose, protein, and a control. For this experiment the treatment (i.e., independent) variable being tested is the type of food molecule (i.e., protein, sugar), and the response (i.e., dependent) variable is the CO2 production that indicates yeast growth. An experiment that compensates for natural variable, and (3) include controls. Replications are repeated measures of each treatment under the same conditions. Replications effectively deal with naturally occurring variation. Usually the more replicate test tubes of yeast, each being treated the same. Good design tests only one treatment variable at a time. verify that the biological response we measure is a function of the variable being investigated and nothing else. Controls are standards for comparison. They are replicates with all of the conditions of an experimental treatment except the treatment variable. For example, if the treatment is glucose dissolved in water, then a control has only water (i.e. it lacks only glucose, the treatment variable). This verifies that the response is to glucose and not to the solvent. Controls validate that our results are due only to the treatment variable. Procedure 1.4 An experiment to determine the effects of food type on yeast growth 1. Label 12 test tubes as C1-C4, G1-G4, and P1-P4. See Worksheet 1. 2. To test tubes C1-C4 add 5 mL of water. These are control replicates of the glucose treatment. 5. Swirl the suspension of yeast until the yeast is distributed uniformly in the liquid Then completely fill the remaining volume in each tube with the yeast suspension that is provided. 6. For each tube, slide an inverted, flat-bottomed test tube down over the yeast-filled 1-4 Height of CO2 Bubble (mm) tube firmly against the inside bottom of the cover tube and invert the assembly. Your instructor will demonstrate how to slip this slightly larger empty tube over the top of each yeast tube and invert the assembly. If done properly, no bubble of air will be trapped at the top of the tubes in a rack and incubate them at 50°C. 8. Measure the height (mm) of the bubble of accumulated CO2 after 10, 20, 40, and 60
minutes. Record your results in Worksheet 1 and graph them here: 10 20 40 60 Time (min) 9. When you are finished, clean your work area and dispose of the contents of each tube as instructed by your lab instructor. Test Your Predictions by Analyzing the Experimental Data Analysis begins with summarizing the raw data for biological responses to each treatment. The first calculation is the mean (x-), which is the average of a set of numbers (e.g., measurements) for replicates of each treatment and the control. That is, the mean is a single number that represents the central tendency of the response variable. Later the mean of each treatment will be compared to determine if the treatments have different effects. The second step in data analysis is to calculate variation within each set of replicates. A wide range indicates much variation in the data. The standard deviation (SD), another informative measure of variation, summarizes variation just as the range does, but the standard deviation is less affected by extreme values. Refer to the box "Variation in Replicate Measures" to learn how to calculate the standard deviation. Ouestion 4 Even the seemingly simple guestion "How tall are mature males of the human species?" can be difficult to answer. How would you best express the answer? 1-5 Procedure 1.5 Quantify and summarize the data 1. Examine your raw data in Worksheet 1. 2. Calculate the means for the four replicates, sum the four values and divide by four. Record the mean for the control replicates in Worksheet 1 3. The CO2 production for each glucose and protein replicate must be adjusted with the control mean. This ensures that the final data reflect the effects of only the treatment variable and not the solvent. Subtract the control mean from the CO2 production of each glucose replicate and each protein replicate, and record the results in Worksheet 1. 4. Record in Worksheet 1 the range of adjusted CO2 production for the four adjusted protein treatment replicates. Record the mean in Worksheet 1. 6. Calculate the mean CO2 production for the four adjusted protein treatment replicates. Record the mean in Worksheet 1. 7. Refer to "Variation in Replicate Measures," and calculate the standard deviation for the four adjusted protein treatment values. Record the two standard deviations in Worksheet 1. Test the Hypotheses Our hypotheses Out hypothe mean CO2 production by yeast fed glucose to the mean is higher than the other is not an adequate test because natural variation will always make the two means at least slightly different, even if the two treatments have the same effect on yeast growth. Therefore, the means and the variation about the means must be compared to determine if the means are not just different. To be significantly different. To be significantly different. To be significantly different but significantly different. significant, then the null hypothesis is accepted. Testing for significant differences is usually done with statistical methods. Statistical methods. Statistical methods calculate the probability that the means are significant differences is usually done with statistical methods. between the means of our two treatments. We will declare that two means are significantly different if the means plus or minus 1/2 of the standard deviation occurs in all processes of biology. This variation will inevitably produce different results in replicated treatments. One of the most useful measures of variation of values about the mean, square each deviations. For example, data for CO2 production by yeast in four replicate test tubes might be 22, 19, 18, and 21 mm. The mean is 20 mm. CO2 Production (mm) Mean Deviation 2 - = the sample mean x xi = measurement of an individual sample N The summation sign (Σ) means to add up all the squared i=1 deviations from the first one (i = 1) to the last one (i = N). The sum of squared deviations (10) divided by the number of samples minus one (4 - 1 = 3) produces a value of 10/3 = 3.3 mm2 (the units are millimeters squared). This is the variance, 1.8 cm, equals the standard deviation $22\ 02\ 4\ 19\ 20\ -1\ 1\ 18\ 20\ -2\ 4\ SD = \sqrt{3.3} = 1.8\ 21\ 20\ 1\ 1$ The standard deviation is often reported with the mean in statements such as, "The mean CO2 production was 20 ± 1.8 mm." The standard deviation is zero, all of the numbers in the set are the same. A larger standard deviation implies that individual numbers are farther from the mean. Sum of squared deviations = 10 The summary equation for the sum of squared deviations is Sum of squared deviations is Sum of squared deviations = $N \Sigma$ (x i=1 i - 2 - x) where N = total number of samples For example, consider these two means and their standard deviations = $N \Sigma$ (x i=1 i - 2 - x) where N = total number of samples For example, consider these two means and their standard deviations = $N \Sigma$ (x i=1 i - 2 - x) where N = total number of samples For example, consider these two means and their standard deviations = $N \Sigma$ (x i=1 i - 2 - x) where N = total number of samples For example, consider these two means and their standard deviations = $N \Sigma$ (x i=1 i - 2 - x) where N = total number of samples For example, consider these two means and their standard deviations = $N \Sigma$ (x i=1 i - 2 - x) where N = total number of samples For example, consider these two means and their standard deviations = $N \Sigma$ (x i=1 i - 2 - x) where N = total number of samples For example, consider these two means and their standard deviations = $N \Sigma$ (x i=1 i - 2 - x) where N = total number of samples For example, consider these two means and their standard deviations = $N \Sigma$ (x i=1 i - 2 - x) where N = total number of samples For example, consider these two means and their standard deviations = $N \Sigma$ (x i=1 i - 2 - x) where N = total number of samples For example, consider these two means and their standard deviations = $N \Sigma$ (x i=1 i - 2 - x) where N = total number of samples For example, consider these two means and their standard deviations = $N \Sigma$ (x i=1 i - 2 - x) where N = total number of samples For example, consider these two means and their standard deviations = $N \Sigma$ (x i=1 i - 2 - x) where N = N \Sigma (x i=1 i - 2 - x) where N = N \Sigma (x i=1 i - 2 - x) where N = N \Sigma (x i=1 i - 2 - x) where N = N \Sigma (x i=1 i - 2 - x) where N = N \Sigma (x i=1 i - 2 - x) where N = N \Sigma (x i=1 i - 2 - x) where N = N \Sigma (x i=1 i - 2 - x) where N = N \Sigma (x i=1 i - 2 - x) where N = N \Sigma (x i=1 i - 2 -Meana + $(\frac{1}{2})$ SD = 12.5 Meanb = 20 SD = 10 Meanb - $(\frac{1}{2})$ SD = 25 Are Meana and Meanb significantly different according to our test for significant according to according to according to our test for sign logic to translate these results into the answers of our specific and general questions. If your specific questions were well stated, then answering the mesults of your experiment and hypotheses 1. Consider your null hypothesis and the data presented in Worksheet 1. 2. Calculate the glucose mean - $(\frac{1}{2})$ SD and the glucose mean + $(\frac{1}{2})$ SD. Record them in Worksheet 1. 4. Do the half standard deviations surrounding the means of the two treatments overlap? Record your answer in Worksheet 1. 5. Are the means for the two treatments significantly different? Record your answer in Worksheet 1. 6. Is your null hypothesis testing presented in Worksheet 1. 6. Is your answer in yeast absorb and metabolize carbohydrates better than it absorbs and metabolizes proteins?" Enter your answer in Worksheet 1. 3. Does your experiment adequately answer this question? Why or why not? 4. Specific Question 1 was "What classes of biological molecules are most readily absorbed and metabolized by yeast?" Enter your best response in Worksheet 1. 1-6 5. Does your experiment adequately answer Specific Question 1? Why or why not? 6. The General Question was "Which nutrients can yeast most readily metabolize?" After testing the hypotheses, are you now prepared to answer this general question? Why or why not? EXPERIMENTATION AND DATA ANALYSIS: FOOD PREFERENCE BY PILLBUGS In the previous procedures you developed and recorded observations, questions, and hypotheses concerning food preference by pillbugs. Pillbugs may be attracted to dead leaves as food, or they may be attracted to fungi growing on leaves. Use the following procedures as a guide to the science of experiment to test your hypothesis in Worksheet 2. Procedure 1.8 Design an experiment to test food preference by pillbugs. To do this, specify: Experimental setup Treatment 1 to be tested Control treatment 2 to be tested Control treatment variable Number of replicates Means to be compared 2. Conduct your experiment and record the data in Worksheet 2. 3. Analyze your data. Record the control means and adjusted treatment-means in Worksheet 2. 1-7 4. Calculate the range and standard deviation for your treatments, and record them in Worksheet 2. 5. Test your hypothesis. Determine if the null hypothesis should be accepted or rejected. Record the results in Worksheet 2. 6. Answer the Specific Question 2, Specific Question 1, and General Question 1, and General Question 2. Specific Question 2, Specific questions: food preference by pillbugs 1. Examine the results of your hypothesis testing presented in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. 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adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately answer to Specific Question 2 in Worksheet 2. Does your experiment adequately advestion 2 in Worksheet 2. Does your experiment adequately advestion 2 in Worksheet 2 in Wor answer this question? Why or why not? 4. After testing the hypotheses, are you now prepared to answer your General Question 5 What are some examples of biological theories? Scientific Theories Throughout this course you will make many predictions and observations about biology. When you account for a group of these observations with a generalized explanation, you have proposed a scientific theory. In science, as opposed to common usage, a theory is a well-substantiated explanation of some aspect of the natural world that usually incorporates many confirmed observational and experimental facts. A scientific theory makes predictions consistent with what we see. It is not a guess; on the contrary, a scientific theory is widely accepted within the scientific theory is widely accepted within the scientific theory of a scientific theory is widely accepted within the scientific theory INOUIRY-BASED LEARNING How do changes in temperature affect the production of CO2 is affected by different nutrients (i.e., sugar, protein). Here you'll investigate another variable: temperature? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 1 from your instructor. b. Discuss with your group well-defined questions relevant to the preceding observation and question. Choose and record your group's best question for investigation. c. Translate your question into a testable hypothesis. Ask your instructor to review your proposed investigation. e. Conduct your procedures, record your data, answer your question, and make relevant comments. f. Discuss with your instructor any revisions to your questions, hypothesis, or procedures. Repeat your work as needed. Questions for Further Study and Inquiry 1. Newspaper articles often refer to a discovery as "scientific" or claim that something has been proved "scientifically." What is meant by a discovery as "scientific" or claim that something has been proved "scientific" or claim that something h this description? 2. Experimental results in science are usually reviewed by other scientists before they are published. Why is this done? 3. Have all of our discoveries and understandings about the natural world been the result of applying the scientific method? How so? 4. Suppose that you hear that two means are significantly different. What does this mean? 5. Can means be different but not significantly different? Explain your answer. 6. How can science be used to address "big" issues such as climate change? 7. Some people dismiss evolution by natural selection as being "only a theory." Biologists often respond that yes, evolution is a scientific theory. What does this mean? 8. A hallmark of a scientific theory is that it is falsifiable. What does this mean, and why is it important? 8 EXERCISE 1 1-8 Worksheet 1 The Process of Science: Nutrient Use by Yeast OBSERVATION QUESTIONS General Question 1: Specific Question 2: HYPOTHESIS H0: EXPERIMENTAL DATA: Nutrient Use by Yeast Treatments Minus Control x-Treatments Control Glucose Protein Glucose CO2 Protein CO2 CO2 CO2 CO2 CO2 CO2 Production Productin Production Production Productin range = - Protein SD = Glucose SD = TEST HYPOTHESIS - Glucose x- - $(\frac{1}{2})$ SD = Protein x- - $(\frac{1}{2})$ SD = Protein x- + $(\frac{1}{2})$ SD = Do the half standard deviations surrounding the means of the two treatments overlap? Yes Are the means for the two treatments overlap? Yes Are the means for the two treatments significantly different? Yes Is the null hypothesis accepted? No No or rejected? ANSWER QUESTIONS Answer to Specific Question 1 Answer to Specific Question 1: Specific Question 2: Specific Question 1: Specific Question 1: Specific Question 1: Specific Question 1: Specific Question 2: Specific Question EXPERIMENTAL DATA: Food Preference by Pillbugs Treatment 1 Replicate Treatment 1 x- = Treat range = Treatment 2 SD = Treatment 1 x - $(\frac{1}{2})$ SD = Treatment 1 x - $(\frac{1}{2})$ SD = Treatment 1 x - $(\frac{1}{2})$ SD = Treatment 2 x - $(\frac{1}{2})$ SD = Trea Adjusted for the Control -x No No or rejected? ANSWER QUESTIONS Answer to Specific Question 1 Answer to Specific Question 1 Answer to Specific Question 2 Answer to Specific Question 1 Answer to Specific Question 2 Answer to Specific Question 3 Answer to Specific Question 2 Answer to Specific Question 2 Answer to Specific Question 3 Answer to Specific Question 3 Answer to Specific Question 4 An the difference between accuracy and precision in measurements. 2. Identify the metric units used to measure length, volume, mass, and temperature in metric units. 4. Convert one metric units. 4. Convert one metric units used to measure length, volume, mass, and temperature in metric units. the use of simple statistical calculations such as mean, median, range, and standard deviation. 7. Analyze sample data using statistical tools. Please visit connect.mheducation.com to review online resources tailored to this lab. E very day we're bombarded with numbers and measurements. They come at us from all directions, including while we're at the supermarket, gas station, golf course, and pharmacy, as well as while we're in our classrooms and kitchens. Virtually every package that we touch is described by a measurement. Scientists use a standard method to collect data as well as use mathematics to analyze measurements. We must measure things before we can objectively describe what we are observing, before we can experiment with biological processes, and before we can predict how organisms respond, adjust to, and modify their world. Once we have made our measurements, we can analyze our data and look for variation and the sources of that variation. Then we can infer the causes and effects of the biological processes that interest us. ACCURACY AND PRECISION To help you check your answers, consider an analogy involving shooting arrows at a bull's-eve target (fig. 2.1). In this analogy, each arrow (represented by a dot on the target) would represent a measurement. Accuracy would be the High accuracy, low precision, low accuracy (b) High accuracy, high precision Low precision, low accuracy Scientists strive to make accurate, precise measurements. The accuracy of a group of measurements refers to how closely the measurements agree with each other That is, precision is the degree to which the measurements produce the same results, regardless of their accurate but not precise? Explain. (c) b. Can measurements be accurate and precise? Explain. 2-1 (d) Figure 2.1 Precision and accuracy. Measurements can be (a) accurate but not accurate, (c) neither precise nor accurate, or (d) both precise and accurate, or (d) both precise and accurate, or (d) both precise and accurate of the cluster of arrows, arrows closest to the bullseye would be most accurate. Precision would be the size of the cluster of arrows, arrows closest to the cluster of the cluster of the cluster of arrows. regardless of how close they are to the center of the target. THE METRIC SYSTEM Scientists throughout the world use the metric system to make measurements. The metric system to make measurements in the United States use the antiquated English system of pounds, inches, feet, and so on. Check with your instructor about bringing to class common grocery store items on display. The most modern form of the metric system is called the International System of Units (abbreviated SI). Metric measurement is used worldwide in science to improve communication in the scientific community. Scientists make all of their measurements in the metric system; they do not routinely convert from one system to another. When scientists have mixed metric units with English units, the results have often been confusing, and have sometimes been disastrous. For example, in 1999, the \$125-million Mars Climate Orbiter was approaching Mars to study the planet's climate. Lockheed Martin Astronautics, which built the spacecraft, gave NASA critical flight information in English units, but software aboard the orbiter expected the data in metric Hints for Using the Metric System 1. Use decimals, not fractions

(e.g., 2.5 m, not 21/2 m). 2. Express measurements in units requiring only a few decimal places. For example, 0.3 m is more easily manipulated and understood than 300000000 nm. 3. When measured in cubic meters to mass measured in grams: 1 mL = 1 cm3 = 1 g. 4. The metric symbols (e.g., 1 g, not 1 g.). Use a period after metric symbols (e.g., 1 g, not 1 g.). Use a period after metric symbols (e.g., 9.2 m, not 9 m 200 mm). units. As a result, the orbiter was sent into, rather than safely above, the Mars atmosphere, where it disintegrated. The following conversions will help give you a sense of how some common English units are related to their metric equivalents: 1 inch = 2.5 centimeters 1 foot = 30 centimeters 1 foot liter 1 gallon = 3.8 liters 1 cup = 0.24 liter To learn more about these conversions, see Appendix II. This exercise will introduce you to making metric measurements, not reading background information. Therefore, before lab, read this exercise carefully to familiarize yourself with the basic unit of the metric system. Metric units commonly used in biology include: meter (m)—the basic unit of temperature Unlike the English system with which you are already familiar, the metric system is based on units of ten. This simplifies conversions from one metric unit to another (e.g., from kilometers). This base-ten system, in which 10 cents equal a dime, 10 dimes equal a dollar, and so forth. Units of 10 in the metric system are indicated by Latin and Greek prefixes placed before the base units: Prefix (Latin) Division of Metric Unit deci (d) 0.1 10-1 centi (c) 0.01 10-2 milli (m) 0.000000001 10-12 6. Metric symbols are always singular (e.g., 10 km, not 10 kms). Prefix (Greek) 7. Except for degrees Celsius, always leave a space between a number and a metric symbol (e.g., 20 mm, not 20mm; 10°C, not 10° C). deka (da) 10 101 hecto (h) 100 102 kilo (k) 1000 103 mega (M) 10000000 109 8. Use a zero before a decimal point when the number is less than one (e.g., 0.42 m, not .42 m). 12 EXERCISE 2 Multiple of Metric Unit 2–2 Thus, multiply by Make metric measurements of 0.01 to convert centimeters to meters 0.001 to convert millimeters 0.001 to convert millimeters to meters 0.001 to convert millimeters to meters 0.001 to convert millimeters 0.001 to conv conversion equations, the units being converted from (in this case, centimeters) cancel out, leaving you with the desired units, the number associated with the new units will increase, and vice versa. For example, 620 meters = 0.620 kilometer = 620,000 millimeters = 62,000 centimeters. Question 2 Make the following metric conversions: 1 meters = 92.4 millimeters = meters = 3.1 kilograms = grams = 281 millimeters = meters = 3.1 kilograms = grams = 3.1 kilograms = gram area Most biologists measure lengths with metric rulers or metersticks. 1. Examine intervals marked on the metric rulers and metersticks of this page (Area = Length × Width) Your height Thickness of this manual Height of a 200-mL beaker Height of ceiling Height of your chair Length of your cell phone Question 3 What are some potential sources of error in your measurements? Length and Area The meter (m) is the basic unit of length. 1 m = 100 cm = 1000 mm = 0.001 km = 1 × 10 $km = 1000 m = 103 m 1 cm = 0.01 m = 100 mm^2$ (i.e., 10 mm × 10 mm = 100 mm^2) - 3 To help you appreciate the magnitudes of these units, here are the lengths and areas of some familiar objects: Length Housefly Diameter of baseball Soda can Toyota Camry Mt. Everest 2-3 Volume is the space occupied by an object. Units of volume are cubed (i.e., three-dimensional) units of length. The liter (L) is the basic unit of volume. $1 L = 0.1 \text{ m} \times 0.1 \text{ m} \times$ can One breath of air 0.5 cm 1.9 cm 7.4 cm 12.2 cm 4.7 m 8848 m Area Credit card Total skin area of adult human male Ping-pong table Surface area of human lungs Football field (goal line) Central Park (New York City) Volume 46 cm 2 1.8 m 2 4.18 m 2 80 m 2 3.4 km 2 60 m L 355 m L 500 cm 3 Scientists often measure volumes with pipets and graduated cylinders. Pipets are used to measure small volumes, typically 25 mL or less. Liquid is drawn into a pipet using a bulb or pipet by mouth. Graduated cylinders are used to measure larger volumes. To appreciate how to make a measurement accurately, pour 40-50 mL of water into a 100-mL graduated cylinder, and observe the interface between the water and air. This interface, called the meniscus, is curved because of surface tension and the adhesion of water to the sides of the cylinder. When measuring the liquid in a cylinder, always position your eyes level with the meniscus, is curved because of surface tension and the adhesion of water to the sides of the cylinder. and read the volume at the lowest level (fig. 2.3). Procedure 2.2 Make metric measurements of volume 1. Biologists often use graduated cylinders available in the lab to make the following measurements. Determine what measurements the markings on the graduated cylinder represent. Be sure to include units for each measurement. 2. Measure the volume (in L) needed to fill a cup (provided in the lab). 3. Measure the volume of a solid object by water displacement @BiologyImaging.com Figure 2.2 A pipet is used to extract and dispense volumes of liquid. A suction device (shown in green on the left) draws fluid into a pipet, and graduated markings on the pipet allow precise measurement of a fluid's volume. Never use your mouth to suck fluid into a pipet, and graduated cylinder, always position your eye at the bottom of the meniscus. The correct volume is 20 mL. 14 EXERCISE 2 1. Obtain a 100-mL graduated cylinder, a thumb-sized rock, and a glass marble. 2. Fill the graduated cylinder with 70 mL of water. 3. Gently submerge the rock in the graduated cylinder with 70 mL of water. 3. Gently submerge the rock in the graduated cylinder with 70 mL of water. 3. Gently submerge the rock in the graduated cylinder. meniscus of the fluid and record its volume. 5. Calculate and record the volume of the rock by subtracting the original volume (70 mL) from the new volume of the marble. Marble volume Biologists use pipets to measure and transfer small volumes of liquid from one container to another. The following procedure will help you appreciate the usefulness of pipets. Procedure 2.4 Learn to use a pipet 1. Add approximately 100 mL of water to a 100-mL beaker. 3. Fill the pipet to the zero mark. 4. To read the liquid level correctly, your eve must be directly in line with the bottom of the meniscus. 5. Release the liquid into another container. 2-4 a c d Calibration (tare) Button Power Switch © BiologyImaging.com b Figure 2.4 Biologists use balances to measure mass. (A) The parts of a triple-beam balance include the (a) zeroadjustment knob, (b) measuring pan, (c) movable masses on horizontal beams, and (d) balance marks. (B) A top-loading balance has a measuring pan, a power switch, and a zero calibration ("tare") button. Question 4 What volume of liquid did you measure? marked with graduations: the closest beam has 0.1-g graduations, the middle beam has 100-g graduations, and the farthest beam has 10-g graduations. Procedure 2.5 Make metric measurements of mass Mass The kilogram is the only of water at 4°C. Similarly, 1 kg = 1000 g = 103 g 1 mg = 0.001 g = 10-3 g Note that the kilogram is the only base-unit of SI that includes a prefix ("kilo," symbol "k") as part of its name (see Appendix II). Here are the approximate masses of some familiar objects: Housefly Hummingbird Ping-pong ball Quarter 12 mg 1.6 g 2.45 g 6.25 g 9V battery 40 g Human heart 300 g Basketball 0.62 kg Biologists usually measure mass with a top-loading balance or a triple-beam balances (fig. 2.4). Locate the triplebeam balances or top-loading electronic balances in the lab. Triple-beam balances get their names from their three beams of the balance is 1 Remember that mass is not necessarily synonymous with weight. Mass measures an object's potential to interact with gravity, whereas weight is the force exerted by gravity on an object. Thus, a weightless object in outer space has the same mass as it has on earth. 2-5 1. Before making any measurements, clean the weight by gravity on an object. should line up to indicate zero grams; if they do not, turn the adjustment knob until they do. Measure the mass of an object is the sum of the weights on the three beams. 2. If you're using an electronic balance, turn on the balance and let it warm up for 5 minutes. Wait until the display to 0.0 g, if the display to 0.0 g, press the "tare" button to reset the display to 0.0 g. If you are weighing an object such as a coin or pencil, place the object on the measuring pan. After the display to 0.0 g, if the display to 0.0 g. mass. 3. If you are weighing a liquid, powder, or similar specimen, place the liquid) or a piece of weighing
paper (on which you will place the liquid) or a piece of weighing paper (or the display to 0.0 g. Place the liquid) or a piece of weighing paper (or the balance's measuring pan. After the display to 0.1 g. Place the liquid) or a piece of weighing paper (or the balance's measuring pan. After the display has stabilized, press the "tare" button to reset the display to 0.0 g. Place the liquid in the beaker (or the balance's measuring pan. After the display has stabilized, press the "tare" button to reset the display has stabilized, press the "tare" button to reset the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measuring pan. After the display has stabilized by the balance's measurements at the balance's measurements at the balance's measurements at the balance's m powder on the weighing paper). After the display has stabilized, read and record the mass. Measurements in Biology 15 4. Measure the masses of the following items. Be sure to include units for each measurements in Biology 15 4. Measure the masses of the following items. Density is mass per unit volume. Use data that you've gathered to determine the density of water at room temperature. Density of water = (mass/volume) = b. What is the density of the wooden pencil? Does it float? Why? Temperature is the measure of the kinetic energy of molecules—that is, the amount of heat in a system. Biologists measure temperature with a thermometer calibrated in degrees Celsius (°C). The Celsius scale is based on water freezing at $0^{\circ}C$ and boiling at $100^{\circ}C$. You can interconvert °C and degrees Fahrenheit (°F) by using the formula $5(^{\circ}F) = 9(^{\circ}C) + 160$. Here are some typical temperatures: $-20^{\circ}C - 18^{\circ}C \ 0^{\circ}C \ 4^{\circ}C \ 22^{\circ}C \ 30.6^{\circ}C \ 37^{\circ}C \ 40^{\circ}C \ 50^{\circ}C \ 71^{\circ}C \ 75^{\circ}C$ 100°C 260°C temperature in a freezer mixture of ice and salt water freezes temperature in a refrigerator room temperature butter melts human body temperature a hot summer day hottest day on record in Phoenix, AZ flash pasteurization of milk hot coffee water boils broiler temperature 2.6 Make metric measurements c. What is the density of the rock? Does it sink? Why? of temperature 1. Obtain a thermometer in the lab. Handle the thermometer with care. If it breaks, notify your instructor immediately. Significant Figures Let's suppose that you're measuring the length – as 8 cm? 8.33 cm? 8.3333 cm? 8.33333 cm? 8.3333 To answer this question, you need to know something about significant figures are the number of figures are the number is in doubt. For example, if the ruler you're using is calibrated only in centimeters and you find that the object you're measuring is between 8 and 9 cm long (fig. 2.5), then you should estimate your measurement only to a tenth of a centimeter. That is, a measurement of 8.3 cm is acceptable, but 8.33 is not because it implies a precision that did not exist in the equipment you used to make the measurement. If, however, your ruler was calibrated in millimeters, then 8.33 cm would be acceptable. Remember this: When recording measurements, include all of the digits you are sure of plus an estimate to the nearest onetenth of the next smaller digit. Here are some other guidelines for using the correct number of significant figures in your measurements; When adding or subtracting measurements, the answer should have no more precision than the measurement having the least number of significant figures. For example, 16 EXERCISE 2 suppose the air temperature in an incubator drops from 8.663°C. If the second temperature reading had been 8.200°C, then the correct answer would have been 0.463°C. When converting measurements from one set of units to another, do not introduce precision that is not present in the first number. For example, 8.3 cm = 83 mm, not 83.0 mm. When manipulating two measurements simultaneously, the precision of the final measurements simultaneously, the precision of the first number. calculation for the mass of 17.2 mL of water is 17.2 mL × 0.997821 g mL-1 = 17.2 g, not 17.162521 g. 6789 cm Figure 2.5 How long is this bone? 8 cm? 8.33 cm? 2-6 Rounding Numbers Do not change the value of the last significant digit if that digit is followed by a number that is less than 5. For example, if two significant figures are required, 6.449 rounds to 6.4, 66.449 rounds to 66, 66.641 rounds to 66, 66.641 rounds to 66, 66.641 rounds to 66, encircleant figures: Five significant figures: 49.515 Four significant figures: 49.515 Four significant figures: 49.5149 rounds to 67, and 6.591 rounds to 66, 66.641 r Statisticians disagree on what to do when the number following the last significant figure is exactly 5, as in 89.5 (and, in this case, the precision is limited to two significant figures). Some round the measurement to the higher number, while others claim that doing so introduces bias into the data. You can decide which approach to take, but be 2. Determine the range of the temperatures that can be measured with your thermometer by examining the scale imprinted along the barrel of the thermometer. 3. Measure the following temperatures: Room temperatures: Room temperatures offer a way to organize, summarize, and describe data—the data are usually samples of information from a much larger population. Consequently, the use of statistics enables us to make decisions even though we have incomplete data about a population. Although this may seem unscientific, we do it all the time; for example, we diagnose diseases with a drop of blood. Decisions are based on statistics when it is impossible or unrealistic to analyze an entire population. Let's say that you want to know the mass of a typical apple in your orchard. To obtain this information, you could analyze one apple, but how would you know that you'd picked a "typical" sample? After all, the batch from which you chose the apple may contain many others, each a little different. You'd get a better estimate of "typical" if you increased your sample size to a few hundred apples, or even to 10,000. Or, better yet, to 1,000,000. The only way to be certain of your conclusions would be to accurately measure all the apples in your orchard. This 2-7 is impossible, so you must be working with a representative sample. A statistical analysis of those sample apples reduces the sample values to a few characteristic measurements (e.g., mean mass). As you increase the size of the sample, these characteristic measurements provide an ever-improving estimation of what is "typical." There are a variety of software programs that perform statistical analyses of data; all you have to do is enter your data into a spreadsheet, select the data that you want to analyze, and perform the analysis. Although these software packages save time and can increase accuracy, you still need to understand a few of the basic variables that you'll use to understand your numerical data. We'll start with the mean and median: The mean is the arithmetic average of a group of measurements. Chance errors in measurements tend to cancel themselves when means are calculated for relatively large samples; a value that is too high because of random error is often balanced by a value that is too low for the same reason. The median is, after arranging the measurements from the same reason. The median is, after arranging the measurements from the same reason. even number of measurements, the median is the mean of the two middle values. The median is less sensitive to extreme values than is the mean. To appreciate this, consider a sample consisting of 14 leaves having the following lengths (all in mm): 80 69 62 74 69 51 45 40 9 64 65 64 61 67 The mean length is 58.6 mm. However, none of the leaves are that length, and most of the leaves are longer than 60 mm. In biology, the mean is 5, but the mean is 5, but the mean is 5, but the mean is 6 1 3 5 7 9 - the median is 5, but the mean is 6 1 3 5 7 9 - the median is 5, but the mean is 6 1 3 5 7 9 - the median is 5, but the mean is 10 Question 6 a. Does the mean always describe the "typical" measurement? Why or why not? b. What information about a sample does a mean not provide? Determine the median by arranging the measurements in Biology 17 The median is between the seventh and eighth measurements: 64 mm. In this sample, the mean differs from the median. Question 7 a. What is responsible for this difference between the mean and median? b. How would the median change if the 9-mm-long leaf was not in the sample? b. Could two samples have the same range but different means? Explain. The standard deviation indicates how measurements vary about the mean. The standard deviation is easy to calculate. Begin by calculating the mean, measuring the deviations. For example, consider a group of shrimp
that are 22, 19, 18, and 21 cm long. The mean length of these shrimp is 20 cm. c. How would the mean change if the 9-mm-long leaf was not in the sample? Sample 1: 25 35 32 28 Sample 1: 25 35 32 28 Sample 2: 15 75 10 20 What is the mean for Sample 2: 15 75 10 20 What is the mean for Sample 1: 25 35 32 28 Sample 2: 15 75 10 20 What is the mean for Sample 2: 15 75 10 20 What is the a biological structure or phenomenon. In these instances, a mean may be the only descriptor of the sample. However, if your class combines its data so that you understand the variation within your sample. Variability As you can see, the samples in Question 7d are different, but their means are the same. Thus, the mean does not reveal all there is to know about these samples. To understand how these samples are different, you need other statistics: the range and standard deviation. The range is the difference between the extreme measurements (i.e., smallest and largest) of the sample. In Sample 1, the range is 35 - 25 = 10; in Sample 2 the range is 75 - 10 = 65. The range provides a sense of the variation of the sample, but the range can be artificially inflated by one or two extreme values. Notice the extreme values in the sample of leaf measurements previously discussed. Moreover, ranges do not tell us anything about the measurements between the extremes. Question 8 a. Could two samples have the same mean but different ranges? Explain. 18 EXERCISE 2 Mean Deviations = 10 The summary equation for the sum of squared deviations is: Sum of squared deviations = $N \Sigma$ (x i=1 i x)2 where N = total number of samples x = the sample mean xi = measurement of an individual sample N This formula is simple. The summation sign (Σ) means to add i=1 up all the squared deviations from the first one (i = 1) to the last one (i = produces a value of $10/3 = 3.3 \text{ cm}^2$ (note that the units are centimeters squared). This is the variance = sum of squared deviation (SD): SD = $\sqrt{3.3} = 1.8 \text{ The standard deviation}$ is usually reported with the mean in statements such as, "The mean length of the shrimp was 20 ± 1.8 cm." The standard deviation helps us understand the spread or variation of a sample. For many distributions of measurements, whereas the mean ± 2 SD includes 68% of the 2-8 measurements, whereas the mean ± 2 SD includes 6 tape measure to measure your height in centimeters. Record your height here: cm 2. Record your height and gender (male or female) on the board in the lab. 3. After all of your classmates Male classmates Mal Female classmates Male classmates Female classmates Female classmates Female classmates Female classmates Female classmates and eviation All classmates Female classmates and eviation All classmates and eviation and eviation All classmates and eviation All classmates and eviation All classmates and eviation All classmates and eviation an example (e.g., new cars) and determine its average price (e.g., determine the average price of a new car). Question 9 a. What does your calculation tell you? b. What are the limitations of your sample? Your instructor may ask you to do other statistical tests, such as Student's t, chi-square, and analysis of variance (ANOVA). The type of test you'll do will depend on the amount and type of data you analyze, as well as the hypotheses you are trying to test. INQUIRY-BASED LEARNING How much do the areas and shapes of leaves vary? Observation: Leaves, which are the primary photosynthetic organ of most plants, are adapted for absorbing light. This involves exposing large surface areas to the environment. Question: How do the surface area and shape of leaves vary on different parts of plants? a. Establish a working lab group well-defined questions relevant to the preceding observation and question. If leaves are not available from outdoor plants (e.g., during winter), use the plants provided by your instructor that were grown 2-9 indoors. Choose and record your group's best question into a testable hypothesis and record it. d. Outline on Worksheet 2 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your proposed investigation. e. Conduct your procedures, record your data, answer your questions, hypothesis, or procedures. Repeat your work as needed. Measurements in Biology 19 Questions for Further Study and Inquiry 1. What are the advantages and disadvantages of using the metric system of measurements? 2. Why is it important for all scientists to use a standard system of measurements? 3. Do you lose or gain information when you use statistics to reduce a population to a few characteristic numbers? Explain your answer. 4. Suppose that you made repeated measurements of your height. If you used good technique, would you expect the range to be large or small? Explain your answer. 5. Suppose that a biologist states that the average height of undergraduate students at your university is 205 cm plus or minus a standard deviation of 17 cm. What does this mean? 6. What does a small standard deviation signify? What does a large standard deviation signify? 7. Is it possible to make a perfectly precise measurements? 20 EXERCISE 2 2-10 E XER CISE 3 The Microscope Basic Skills of Light Microscopy Learning Objectives By the end of this exercise you should be able to: 1. Identify and explain the functions of the primary parts of a compound microscope and dissecting microscope an determine the magnification and size of the field of view, and determine the depth of field. Please visit connect.mheducation.com to review online resources tailored to this lab. M any organisms and biological structures are too small to be seen with the unaided eye (fig. 3.1). Biologists often use a light microscope to observe such specimens. A light microscope is a coordinated system of lenses arranged to produce an enlarged, focusable image of a specimen. A light microscope magnifies a specimen, meaning that it increases its apparent size. Magnification with a light microscope is usually accompanied by improved resolution, which is the ability to distinguish two points as separate points. Thus, the better the resolution, the sharper or crisper the image appears. The resolving power of the unaided eye is approximately 0.1 mm (1 in = 25.4 mm), meaning that our eyes can distinguish two points that are 0.1 mm apart. A light microscope, used properly, can improve resolution as much as 1000-fold (i.e., to 0.1
µm). The ability to discern contrast, which is the difference between the lightest and darkest parts of an image. Therefore, many specimens examined with a rificial dyes that increase contrast and make the specimen more visible. The invention of the light microscope was profoundly important to biology used to formulate the cell theory and study biological structure at the cellular level. Light microscopy has revealed a vast new world to the human eye and mind (fig. 3.2). Today, the light microscopy has revealed a vast new world to the human eye and mind (fig. 3.2). microscope shown in figure 3.3. A light microscope has two, sometimes three, systems: an illuminating system, and possibly a viewing and recording system, which concentrates light on the specimen, usually consists of a light source, condenser lens, and iris diaphragm. The light source is a lightbulb located Caring for Your Microscope are powerful tools for understanding biology. However, they're also expensive and fragile and require special care. When you use your microscope are powerful tools for understanding biology. under the base and the other around the microscope's arm (fig. 3.3). •• Always begin by cleaning the ocular and objective lenses with lens paper. •• Always start your examinations with the low-power objective lenses with lens paper. objective lens contacts the slide, stop and restart your examination with the low-power objective lens. •• After shifting to the high-power objective lens. •• When you've completed your work with the microscope, clean the lenses with lens paper, wrap the electrical cord securely around the microscope's arm, and return your microscope to its storage area. The Microscope 21 20 mm 2 mm 0.2 mm 0.2 mm 20 mm 0.2 mm (µm), of a mitochondrion is 2 µm, of a ribosome is 20 nanometers (nm), of a protein molecule is 2 nm, and of an atom is 0.2 nm. at the base of the microscope. The light source illuminates the specimen by passing light through a thin, almost transparent part of the specimen. from the light source onto the specimen. Just below the condenser iris diaphragm, a knurled ring or lever that can be opened and closed to regulate the amount of light reaching the specimen. When the condenser iris diaphragm is open, the image will be dim. Imaging System The imaging system improves resolution and magnifies the image. It consists of the objective and ocular (eyepiece) lenses and a body tube. The objective is a series of several lenses that magnify the image, improve resolution, and correct aberrations in 22 EXERCISE 3 the image. The most common configuration for student microscopes includes four objectives: low magnification (4×), medium magnification (4×), and oil immersion (10×). Using the oil immersion (10×), high magnification (4×), medium immersion objective during this exercise. The magnifying power of each objective is etched on the side of the lens (e.g., 4×). The ocular microscopes, and those with two are binocular microscopes with one ocular are monocular microscopes, and those with two are binocular microscopes. Oculars usually magnify the image 10 times. The body tube is a metal casing through which light passes to the oculars. In microscopes with bent bodytubes and inclined oculars, the body tube contains mirrors and a prism that redirect light to the oculars. The stage secures the glass slide on which the specimen is mounted. 3-2 © Heritage Image Partnership Ltd/Alamy Stock Photo Figure 3.2 "Egad, I thought it was tea, but I see I've been drinking a blooming micro-zoo!" says this horrified, proper 19th-century London woman when she used a microscope to examine her tea. People were shocked to learn that there is an active, living world too small for us to see. Oculars Body tube Arm Nosepiece Objectives Slide holder to adjust position Stage Stage clip Condenser Condenser iris diaphragm Coarse focus adjustment Condenser adjustment Fine focus adjustment Light source Base © BiologyImaging.com Figure 3.3 Major parts of a compound light microscope 23 A Summary of How to Use a Compound Light Microscope 23 A Summary of How to Use a Compound Light Microscope 23 A Summary of How to Use a Compound light microscope 23 A Summary of How to Use a Compound Light Microscope 23 A Summary of How to Use 24 A Summary of How power objective into place. Center the specimen below the objective. 3. Look through the oculars while using the coarse adjustment to focus on the specimen. 5. If you "lose" your specimen when you switch from low power to high power, retrace the previous steps, paying special attention to placing the specimen in the center of the field of view. Viewing and Recording System The viewing and recording system. recording system usually consists of a camera or video screen. Most student microscopes has not increased significantly during the last century, the construction and design of light microscopes have improved the resolution of newer models. For example, built-in light sources have replaced adjustable mirrors in the illuminating system, and lenses are made of better glass than they were in the past. Your lab instructor will review with the parts of a microscope, you're now ready for some hands-on experience with the instrument. The videos at the website associated with this manual (connect.mheducation.com) will be especially useful for helping you understand how to properly use your microscope. Procedure 3.1 Use a compound microscope 1. Remove the microscope from its cabinet and carry it upright with one hand grasping the arm and your other hand supporting the microscope below its base. Place your microscope; they can scratch the lenses. Clean the lenses only with lens paper. 2. Plug in the microscope and turn on the light source. 3. If it isn't already in position, rotate the nosepiece until the lowest-power (4×) objective is often called the "scanning objective" because it enables users to scan large areas of a specimen.) You'll feel the objective click into place when it is positioned properly Always begin examining slides with the lowest-power objective. 4. Locate the coarse adjustment knob moves either the nosepiece (with its objectives) or the stage to focus the lenses on the specimen. Only a partial turn of the coarse adjustment knob moves the stage or nosepiece a relatively large distance. The coarse adjustment should only be used when you're viewing a specimen with the 4× or 10× objective lens. 5. If your microscope is binocular, keep both eyes open when using the microscope. After a little practice you will ignore the image received by the eye not looking through the ocular. 6. Focus a specimen by using the following steps: a. Place a microscope slide of newsprint of the letter e on the horizontal stage so that the e is directly below the lowest-power objective lens and is right side up. It should be centered over the hole in the stage. b. Rotate the coarse adjustment knob to move the objective within 1 cm of the stage (1 cm = 0.4 in). c. Look through the oculars with both eyes open. d. Rotate the coarse adjustment knob (i.e., raising the objective lens or lowering the stage) until the e comes into focus. If you don't see an image, the e is probably off center. Be sure that the e is directly below the objective lens and that you can see a spot of light surrounding the e. e. Focus up and down to achieve the crispest image. f. Adjust the condenser iris diaphragm so that the brightness of the transmitted light provides the best view. g. Observe the letter, then rotate the nosepiece to align the 10× objective to finish your observation. Do not use the oil immersion objective. 3-4 Question 1 a. As you view the letter e, how is it oriented? Upside down or right side up? b. How does the image move when the slide is moved to the right or left? Toward you or away from you? c. What happens to the brightness of the view when you go from 4× to 10×? notice that the image remains near focus and that the field-of-view has gotten smaller. Most light microscopes are parfocal, meaning that the image will remain centered in the field of view after the 40× objective lens is moved into place. 40× objective lens is in place. 5. You may need to readjust the iris diaphragm because the high-magnification objective allows less light to pass through to the ocular. 6. To fine-focus the image, locate the fine adjustment knob on the side of the microscope.
Turning this knob changes the specimen-to-objective distance slightly and therefore makes it easy to fine-focus the image. Use only the fine adjustment when using the 40× (or higher) objective. Magnification 1. Estimate the magnification 1. Estimate the magnification of the e by looking at the magnification (4×), and then at the e without using the microscope. 2. Examine each objective and record the magnifications of the objective following this formula: MagTot = MagObj × MagOcu where Question 2 a. How many times is the image of the e magnified when viewed through the high-power objective? b. If you didn't already know what you were looking at, could you determine at this magnification of the objective lens MagObj = magnification of the objective? b. If you're viewing the specimen with a 4× objective lens and a 10× ocular, the total magnification of the image is 4 × 10 = 40×. That is, the specimen appears 40 times larger than it is. 4. Slowly rotate the high-power (i.e., 40×) objective does not touch the slide! If the objective does not touch the slide! If the objective does not rotate into place without touching the slide, do not force it; ask your lab instructor to help you. After the 40× objective is in place, you should Determine the Size of the Field of View is the area that you can use it to estimate the size of an object you are examining The field of view can be measured with ruled micrometers (fig. 3.5). An ocular micrometer is a small glass disk with thin lines numbered and etched in a row. It was put into an ocular on your microscope so that the lines superimpose on the image and Table 3.1 Total Magnifications and Areas of Field of View (FOV) for Three Objectives Objective Power 3-5 Objective Magnification × Ocular Magnification = 4× × = 10× × = 40× × = Total Magnification FOV Diameter (mm) FOV Area (mm2) Measurement (mm) for 1 Ocular Space The Microscope 25 allow you to measure the specimen. Before you can use the micrometer you must determine for each magnification the apparent distance between the lines on the ocular micrometer. This means that you must calibrate the ocular micrometer by comparing its lines to those lines etched at known intervals. Procedure 3.3 Use a stage micrometer to calibrate the ocular micrometer, and determine the size of the field of view © BiologyImaging.com Figure 3.4 The circular, illuminated field of view of a compound light microscope. Shown here is the letter e from newsprint that is magnified 40 times (i.e., 40×). 1. Rotate the ocular until the lines of the ocular micrometer parallel those of the stage micrometer (fig. 3.5). 2. Align lines at the left edges (0 lines) of the two micrometers by moving the stage micrometer (fig. 3.5). 3. Count how many spaces on the ocular micrometer View of stage micrometer View of stag both micrometers aligned at their 0 lines © BiologyImaging.com Figure 3.5 Stage and ocular micrometers. Micrometers are used to calibrate microscopes and measure the size of specimens. 26 EXERCISE 3 3-6 The smallest space on a stage micrometer = 0.01 mm, so y ocular spaces (mm) = x stage spaces × 0.01 1 ocular space (mm) = (x/y) × 0.02 micrometers are used to calibrate microscopes and measure the size of specimens. 26 EXERCISE 3 3-6 The smallest space on a stage micrometer = 0.01 mm, so y ocular spaces (mm) = x stage spaces × 0.01 1 ocular space (mm) = (x/y) × 0.02 micrometers are used to calibrate microscopes and measure the size of specimens. 26 EXERCISE 3 3-6 The smallest space on a stage micrometer = 0.01 mm, so y ocular spaces (mm) = (x/y) × 0.02 micrometers are used to calibrate microscopes and measure the size of specimens. 26 EXERCISE 3 3-6 The smallest space on a stage micrometers are used to calibrate microscopes and measure the size of specimens. 26 EXERCISE 3 3-6 The smallest space on a stage micrometers are used to calibrate microscopes and measure the size of specimens. 26 EXERCISE 3 3-6 The smallest space on a stage micrometers are used to calibrate microscopes and measure the size of specimens. 26 EXERCISE 3 3-6 The smallest space on a stage micrometers are used to calibrate microscopes and measure the size of specimens. 26 EXERCISE 3 3-6 The smallest space on a stage micrometers are used to calibrate microscopes and measure the size of specimens. 26 EXERCISE 3 3-6 The smallest space on a stage micrometers are used to calibrate microscopes and measure the size of specimens. 26 EXERCISE 3 3-6 The smallest space on a stage micrometers are used to calibrate microscopes and measure the size of specimens. 26 EXERCISE 3 3-6 The smallest space on a stage micrometers are used to calibrate microscopes and measure the size of specimens. 26 EXERCISE 3 3-6 The smallest space on a stage micrometers are used to calibrate microscopes are used to calibrate microscopes are used to calibrate microscopes are used 4. Calculate the distance in millimeters between lines of the ocular micrometer. For example, if the length of 10 spaces on the ocular spaces $(mm) = 7 \text{ stage spaces} \times 0.01 \text{ mm} 1 \text{ ocular space} (mm) = (7 \times 0.01 \text{ mm})/10 1 \text{ ocular space} (mm) = 0.007 \text{ mm}$ 1 ocular space = 7 µm Therefore, if a specimen spans eight spaces on your ocular micrometer with that objective in place, that specimen is 56 µm long. 5. Calibrate the ocular micrometer for each objective lens in table 3.1 the diameter of the field of view (FOV) for each objective. Also record for each objective lens in table 3.1 the measurement (mm) for 1 ocular space. You can use this information in future labs as you measure the sizes of organisms and their parts. 6. Calculate the radius, which is half the diameter. 7. Use this information to determine the area of the circular field of view with the following formula: Area of circle = $\pi \times \text{radius}$ ($\pi = 3.14$) 8. Record your calculated FOV areas in table 3.1. Alternate Procedure 3.3 Use a transparent ruler to determine the stage and under the stage clips of your microscope. If your microscope has a mechanical stage, ask your instructor how to place the ruler to avoid damage. Carefully rotate the nosepiece to the objective of lowest magnification. 3. Slowly focus with the coarse adjustment, and then with the fine adjustment, and then with the fine adjustment, and then with the coarse adjustment, and then with the fine adjustment, and then with the fine adjustment, and then with the fine adjustment, and then with the coarse adjustment, and then with the fine adjustment, and then with the fine adjustment, and then with the fine adjustment, and then with the coarse adjustment, and then with the fine ad interval. 5. Record in table 3.1 the diameter of this lowmagnification field of view. Also calculate the radius, which is half the diameters of the field of view at medium and high magnifications because the markings are too far apart. Therefore, these diameters must be calculated using the following formula: FOVlow × Maglow = FOVhigh × Maghigh where FOVlow = d iameter of the field of view of the high-power objective Maghigh where FOVlow = d iameter of the field of view of the high-power objective Maghigh = m agnification of the high-power objective For example, if 3.0 mm is the diameter of the field of view for a 4× low-power objective? 3.0 mm × 4 = FOVhigh × 40 0.30 mm = FOVhigh 7. Calculate and record in table 3.1 the diameters of the field of view for the 10× and 40× magnifications. 8. Calculate and record in table 3.1 the circular area of the field of view for the three magnifications by using the following formula. Area of circle = π × radius2 (π = 3.14) Question 3 a. Which provides the largest field of view, the 10× or 40× objective? b. How much more area can you see with the 40× objective than with the 40× objective? objective? c. Why is it more difficult to locate an object starting with the high-power objective? d. Which objective? d. Whic same on all slides. 3. Re-examine the threads using the high-power objective lens. Plane 1. 1. Question 4 a. Are all three colored threads in focus at the same time using the high-power objective? 3. Specimen on slide (a) Microscope image at different levels of focus c. Which objective, high or low power, provides the greatest depth of field? Preparing a Wet Mount of a Biological Specimen Procedure 3.5 Prepare a wet mount of a biological specimen can help you to understand its three-dimensional structure. (b) A thin depth of field is apparent in this 100× image of cells is within the thin depth of field and is clearly focused. Determine the Depth of field is the thickness of the object in sharp focus (fig. 3.6). Depth of field varies with different objectives and magnifications. Procedure 3.4 Determine the depth of the field of view 1. Place a drop of water containing algal cells from a culture labeled "Algae" on a clean microscope slide. 2. Place the edge of a clean coverslip at an edge of the drop at a 45° angle; then slowly lower the coverslip onto the drop so that no air bubbles are trapped (fig. 3.7). (Your instructor will demonstrate this technique.) The coverslip holds the specimen in place and prevents the lens of an objective from contacting the water and the specimen with various intensities of illumination. To do this, rotate the 4× objective into place and adjust the condenser iris diaphragm to produce the least four different levels of illumination. The fourth level should have the diaphragm to produce the least illumination. Repeat step 3 for the 10× and 40× objectives. Question 5 a. Is the image always best with the highest illumination? 1. Using the low-power objective, examine a prepared slide of three colored threads mounted on top of each other. 28 EXERCISE 3 3-8 Add a drop of algal culture to a clean microscope slide. Add a clean coverslip © BiologyImaging.com (b) Gently lower the coverslip into Figure 3.7 (a) Preparing a wet mount of a biological specimen. place with a dissecting needle. (b) A wet mount of pond
water will often include the common cyano- bacterium Oscillatoria (200×). See also figures 3.6 and 25.1–25.4. Observe with low-power objective lens. following field of view what you see. Use your calculations for the head of view to estimate the length of the shrimp. (a) b. Is the same level of illumination for the best clarity and contrast? Approximate length of the shrimp: 5. Examine your preparation of algae, and sketch in the following field of view the organisms that you see. Don't mistake air bubbles for organisms! Air bubbles appear as uniformly round structures with dark, thick borders. Question 6 a. Why is it important to put a coverslip? b. Approximately how long and wide is a brine shrimp? Practice 6. Prepare a wet mount of some newly hatched brine shrimp (Artemia, which are popularly referred to as "sea monkeys") and their eggs. Sketch in the 3-9 For practice using your microscope, prepare some wet mounts of pond water or a hay infusion to view the diversity of protozoa and algae (fig. 3.8). If the protozoa are moving too fast for you to examine carefully, add a drop of methylcellulose (often sold commercially as Proto-Slo) to your sample. (The The Microscope 29 and magnification than a compound microscope. Most dissecting microscope 29 and magnification than a compound microscope 0. I. Walker/Science Source Figure 3.8 The diversity of organisms in pond water (200×). methylcellulose will slow the movement of the protozoa.) Also examine these slides in more detail in the coming weeks, so don't worry about their contents. Rather, use this exercise to familiarize yourself with the microscope Also prepare wet mounts of the cultures available in the lab and sketch the organisms that you see. When you've finished, turn off the light source, cover your microscope, and store the microscope offers some advantages over a compound microscope. Although a compound microscope can produce high magnifications and excellent resolution, it has a small working distance, which is the distance between the objective lens and specimen. Therefore, it is difficult to manipulate a specimen while observing it with a compound microscope. microscope are limited to those thin enough for light to pass through them. In contrast, a dissecting microscope is used to view objects that are opaque or too large to see with a compound microscope. A dissecting microscope is used to view objects that are opaque or too large to see with a compound microscope. (compared to a centimeter or less for a compound microscope), making it possible to dissect and manipulate most specimens. Also, most specimens for dissection are too thick to observe with transmitted light from a light source below the specimens; the image you see is formed from reflected light. Dissecting microscopes are always binocular (fig. 3.9). Each ocular views the specimen at different angles through one or more objective lenses. This arrangement provides a three-dimensional image with a large depth of field. This is in contrast to the image in a compound microscope, which is basically two-dimensional However, the advantages of a stereoscopic microscope are often offset by lower resolution 30 EXERCISE 3 1. Carry the dissecting microscope's arm with one hand and placing your other hand under the microscope's base. 2. Use figure 3.9 to familiarize yourself with the parts of your microscope. 3. Use your dissecting microscope to examine the organisms available in the lab. Sketch some of these organisms. 4. Use a ruler to measure the diameter of the field of view when you use the lowest magnification of your dissecting microscope? What about when you use the highest magnification? b. Place a microscope slide of the letter e on the stage. As you view the letter e, how is it oriented? c. How does the image through a dissecting microscope move when the specimen is moved to the right or left? Toward you or away from you? d. How does the direction of illumination differ in dissecting as opposed to compound microscope? A COMPARISON OF COMPOUND AND DISSECTING MICROSCOPES Complete table 3.2 comparing magnification, resolution, size of the field of view and depth of field of a dissecting microscope. Use the terms high, low, or same to describe your comparisons. Question 8 What other differences are there between compound and dissecting microscopes? 3-10 Ocular lenses Arm Stage Base ©science photo/Shutterstock Transmitted light source Figure 3.9 Major parts of a dissecting (stereoscopic) microscope Characteristic Dissecting Microscope Compound Microscope Characteristic Dissecting (stereoscopic) microscope Characteristic Dissecting (stereoscope Characteristic What are the shapes, surface areas, and volumes of red blood cells? Observation: Red blood cells, which are the most common type of blood cells, are filled with hemoglobin, which gives them their characteristic color. Question: What are the shapes, surface areas, and volumes of red blood cells? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 3 from your instructor. b. Discuss with your group's best question for investigation. 3-11 c. Translate your question into a testable hypothesis and record it. d. Outline on Worksheet 3 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your questions, and make relevant comments. f. Discuss with your instructor any revisions to your questions, hypothesis, or procedures. Repeat your work as needed. The Microscope 31 Questions for Further Study and Inquiry 1. What are the advantages of knowing the diameter of the field important in studying biological structures? How can it affect your ability to find and examine a specimens? 4. What is the importance of adjusting the light intensity when viewing specimens with a compound microscope? 5. What is the function of each of the following parts of a compound and dissecting microscope? 5. Stage Coarse adjustment Fine adjustment 6. Examine the micrograph of the letter e shown in figure 3.4. This letter is magnified 40×. What is the actual height of the letter? WRITING TO LEARN BIOLOGY The smallest structures of cells are best seen with a transmission electron microscope. What are some examples of cellular structures that were discovered with a transmission electron microscope? Refer to your textbook or other book and describe how an electron microscope can resolve such small structures. Write a short essay about the advantages and limitations of a transmission electron microscope. 32 EXERCISE 3 3-12 E XER CISE 4 The Cell Structure and Function Learning Objectives By the end of this exercise you should be able to: 1. Understand the differences between prokaryotes and eukaryotes and identity structures characteristic of each. 2. Prepare a wet mount to view cells with a compound microscope. 3. Explain the function of organelles within eukaryotic cells visible with a light microscope. 4. Examine a cell's structure and determine whether it is from a plant or animal. 5. Observe representatives of the protists, a large group of eukaryotic organisms that are heterotrophic. Please visit connect.mheducation.com to review online resources tailored to this lab. C ells are the basic unit of living organisms because they perform all of the processes we collectively call "life." All organisms are made of cells. Although most individual cells are visible only with the aid of a microscope, some may be a meter long (e.g., the yolk of an ostrich egg). Despite these differences, all cells are designed similarly and share fundamental features. Cytology is the study of cellular structure and function. The major tools of cytologists are light microscopy, electron microscopy, and cell know the cell works. In today's lab you will study some of the features and variations among living cells. Prior to this exercise, review in your textbook the general features of cellular structure and function. Ribosomes Nucleoid region Flagellum Pili Cell wall Plasma membrane Cytoplasm © Science Photo Library—Steve Gschmeissner/Brand X Pictures/Getty Images Figure 4.1 The structure of a bacterial cell. Bacterial cell. Bacterial ack a nuclear membrane. All prokaryotic (bacterial) cells have a nucleoid region, ribosomes, plasma membrane, cytoplasm, and cell wall, but not all have flagella (1500×). Many bacterial cells are surrounded by a gelatinous capsule and have pili as well as flagella (1500×). Many bacterial cells are surrounded by a gelatinous capsule and have pili as well as flagella (1500×). contain a membrane-bound nucleus or any other membrane-bound organelles. Organelles are organized structures of macromolecules having specialized functions and are suspended in the cytoplasm. The cytoplasm of prokaryotes is enclosed in a plasma membrane (cellular membrane) and is surrounded by a supporting cell wall covered by a gelatinous capsule. Flagella and hairlike outgrowths called pili are common in prokaryotes; flagella are used for movement, and pili are used to attach some types of bacteria to surfaces or to exchange genetic material with other bacteria. (concentrations of DNA). Prokaryotes do not reproduce sexually, but they have mechanisms for genetic recombination (see Exercise 16). Cyanobacteria, formerly called blue-green algae. They contain chlorophyll a and accessory pigments for photosynthesis, but these pigments are not contained in membrane-bound chloroplasts. Instead, the pigments are held in photosynthetic membranes called thylakoids (fig. 4.2). Cyanobacteria are often surrounded by a mucilaginous sheath. Their ability to photosynthesize made them the primary contributors to the early oxygenation of the ancient earth's atmosphere. SAFETY FIRST Before coming to lab, you were asked to read this exercise so you would know what to do and be aware of safety issues. In the space below, briefly list the safety issues, contact your laboratory assistant before starting work. Cheek scraping is a potential biohazard.
Check with your instructor before you use this technique. Procedure 4.1 Examine a prepared slide of Oscillatoria, a filament of cells, and one of Gloeocapsa, a loosely arranged colony (fig 4.3). Review Exercise 3 and the associated videos for the proper way to use the microscope. 2. Focus with the low-power objective. 3. Rotate the high-power objective into place to see filaments and masses of cells. Filaments of cells. Filaments of cells (a) © BiologyImaging.com Mucilagenous sheath Vegetative cells Photosynthetic membranes © Dr. Euichi (Luigi) Hirose, Dept. Chem. Biol. & Marine Science, University Ryukyus, Okinawa, Japan Figure 4.2 Electron micrograph of a photosynthetic bacterial cell, Prochloron showing extensively folded photosynthetic membranes. Vesicles, fibrils, and DNA are in the central region of the cell; The DNA is not membrane-bound (5200×). 34 EXERCISE 4 (b) © BiologyImaging.com Figure 4.3 Common cyanobacteria. (a) Oscillatoria (100×). (b) Gloeocapsa (400×). 4-2 4. Prepare a wet mount of Oscillatoria and one of Gloeocapsa. Review procedure 3.5 in Exercise 3 for preparing a wet mount. 5. Observe the cellular structures and draw the cellular shapes and relative sizes of Oscillatoria 3. Focus with the low-power objective. 4. Rotate the high-power objective (40×) into place to see masses of rod-shaped cells. 5. Observe the simple, external structure of the bacteria and draw their cellular shapes in the following space: Gloeocapsa Question 1 a. Where are the pigments located in these cyanobacteria? Question 2 How does the size of Lactobacillus compare with that of Oscillatoria and Gloeocapsa? b. Are nuclei visible in cyanobacterial cells? EUKARYOTIC CELLS c. Which of these two genera has the most prominent mucilaginous sheath? d. How many cells are held within one sheath of Gloeocapsa? Bacteria Most bacteria. The bacterial cells composing most of the yogurt are Lactobacillus, a bacterium adapted to live on milk sugar (lactose). Lactobacillus has been used in many parts of the world by peoples deficient in lactase, an enzyme that breaks down lactose. Many Middle Eastern and African cultures use the more digestible yogurt in their diets instead of milk. Procedure 4.2 Examine bacteria 1. Place a tiny dab of yogurt on a microscope slide. 2. Mix this small amount of yogurt in their diets instead of milk. Procedure 4.2 Examine bacteria 1. Place a tiny dab of yogurt on a microscope slide. 2. Mix this small amount of yogurt in their diets instead of milk. structurally more complex than prokaryotic cells. Although some features of prokaryotic cells are in eukaryotic cells (e.g., ribosomes, cell membrane), eukaryotic cells (and other organelles (figs. 4.4, 4.5). Nuclei contain genetic material of a cell and control metabolism. Cytoplasm forms the matrix of the cell and is contained by the plasma membrane. Within the cytoplasts are elliptical green organelles in plant cells. Chloroplasts are elliptical green organelles. photosynthetic pigment capable of capturing light energy. Mitochondria are organelles found in plant and animal cells. These organelles are where aerobic respiration occurs. When viewed with a conventional light microscope, mitochondria are small, dark, and often difficult to see. All of the material and organelles contained by the plasma membrane are collectively called the protoplast. PLANT CELLS Procedure 4.3 Examine living Elodea cells and chloroplasts 1. Remove a voung leaf from the tip of a sprig of Elodea. Elodea is a common pond-weed used frequently in studies of photosynthesis. cellular structure, and cytoplastic streaming, 2. Place this leaf, with the top surface facing up, in a drop of water on a microscope slide. The cells on the The Cell 35 Table 4.1 Some of the Major Differences between Prokaryotic Cells and between Plant Exterior Structures Cell wall Present (protein-polysaccharide) Absent Present (cellulose) Cell membrane Present Present Present Present Microtubules Absent Present Absent Present Absent Present Absent Present Nucleus Absent Present Present Microtubules Absent Present Microtubules Absent Present Presen Absent Present Chloroplasts Absent Absent Absent or small Usually a large single vacuole Interior Structures Other Organelles upper surface are larger and more easily examined. Add a coverslip, but do not let the leaf dry. Add another drop of water if necessary. 3. Examine the leaf with your microscope. Review Exercise 3 and the associated videos. First use low, then high, magnification to bring the upper layer of cells into focus (fig. 4.6). Each of the small, regularly shaped units you see are cells surrounded by cell walls made primarily of cellulose (fig. 4.6). 4.7). Cellulose is a complex carbohydrate made of glucose molecules attached end-to-end. The plasma membrane lies just inside the cell wall? d. Examine various layers of cells by focusing up and down through the layers. About how many cells thick is the leaf that you are observing? c. What are the functions of the cell wall? d. Use an ocular micrometer or refer to the dimensions of the field of view calculated in Exercise 3 to measure the dimensions? Ouestion 3 a. What three-dimensional shape are Elodea cells? 4. Chloroplasts appear as moderately sized green spheres within the cells (figs. 4.6, 4.8). Locate and 36 EXERCISE 4 4-4 Centrosome: Site where microtubules grow and centrioles are found. Nuclear pore: Passageway for molecules into and out of the nucleus. Nuclear envelope: Double membrane that encloses the nucleus. Nuclear envelope: Double membrane that encloses the nucleus. Rough ER: Site of protein sorting and secretion. Smooth ER: Site of detoxification and lipid synthesis. Chromatin: A complex of protein and DNA. Ribosome: Site of cell signaling. Mitochondrion: Site of ATP synthesis. Cytoskeleton: Protein filaments that provide shape and aid in movement. Lysosome: Site where macromolecules are broken down. Golgi apparatus: Site of modification, sorting, and secretion of lipids and proteins. Cytosol: Site of many metabolic pathways. Figure 4.4 Structure of animal cells. Cells are surrounded by a bilayered plasma membrane containing phospholipids and proteins. The nucleus houses chromosomal DNA and is surrounded by a bilayered plasma membrane containing phospholipids and proteins. Rough ER has many ribosomes, and smooth ER has fewer ribosomes. Mitochrondria are sites of oxidative respiration and ATP synthesis. Microvilli are cytoplasmic projections that increase the surface area of some specialized animal cells. Golgi complexes are flat sacs and vesicles that collect and package substances made in the cell. Ribosomes are aggregations of rRNA and proteins that make protein. Lysosomes contain enzymes important in recycling cellular debris. sketch cells having many chloroplasts; estimate the number of chloroplasts; estimate the number of chloroplasts; estimate the number of chloroplasts? What is their function? 4-5 b. Where are the chloroplasts located within a cell. They may be pushed against the margins of the cell by the large central vacuole containing mostly water and bounded by a vacuolar membrane. The vacuole occupies about 90% of the volume of a mature cell. Its many functions include storage of organic and inorganic molecules, ions, water, enzymes, and waste products. 6. Search for a nucleus; it may or may not be readily visible. Nuclei usually are appressed to the cell wall as a faint gray sphere the size of a chloroplast or larger. The Cell 37 Nuclear envelope: Double membrane that encloses the nucleus. Nucleus: Area where most of the genetic material is organized and expressed. Central vacuole: Site that provides storage; regulation of cell volume. Nuclear pore: Passageway for molecules into and out of the nucleus. Ribosome: Site of polypeptide synthesis. Smooth ER: Site of detoxification and lipid synthesis. Nucleolus: Site of ribosome subunit assembly. Cytosol: Site of many metabolic pathways. Rough ER: Site of protein and DNA. Plasma membrane: Membrane that controls movement of substances into and out of the cell; site of cell signaling. Mitochondrion: Site of many metabolic pathways. of ATP synthesis. Cell wall: Structure that provides cell support. Chloroplast: Site of photosynthesis. Cytoskeleton: Protein filaments that provide and other harmful molecules are broken down. Figure 4.5 Structure of plant cells. Most mature plant cells contain large central vacuoles, which occupy most of the volume of the cell. Cytoplasm contains the cell's organelles. Staining the cells with a drop of iodine may enhance the nucleus. If your preparation is particularly good, a nucleolus may be visible as a dense spot in the nucleus. 7. Search for some cells that may appear pink due to watersoluble pigments called anthocyanins. These pigments give many flowers and fruits their bright reddish color. 8. Warm the slide with intense light for about 10 min and search for movement of the chloroplasts. You may need to search many cells or make a new preparation. This movement is called cytoplasmic streaming, or cyclosis. Chloroplasts are not motile; instead, they are being moved by the activity of the cells with those shown in figure 4.6. 38 EXERCISE 4 10. When you are finished examining Elodea, dispose of the Elodea as specified by your instructor. Question 5 a. Can you see nuclei? 4-6 Figure 4.6 (a) Elodea cells containing abundant chloroplasts (150×). (b) The cellular Free hydroxyl (OH-) groups of the glucose molecules form hydrogen bonds between adjacent cellulose is indigestible and its energy is unavailable. Cellulose passes through the human digestive tract as bulk fiber. 4-7 The Cell 39 Question 6 a. Are all cellular components moving in the same direction and rate during cytoplasmic streaming? Plant Cell Walls Thylakoid disk Granum Cell walls include an outer primary cell wall deposited during growth of the cell and a middle lamella, the substance holding walls of two adjacent cells is connected by
cytoplasmic strands called plasmodesmata that penetrate the cell walls (fig. 4.9). Stroma Thylakoid membrane Procedure 4.4 Examine cell walls and plasmodesmata Granum Stroma 1.5 m ©Dr. Jeremy Burgess/Science Source Figure 4.8 Chloroplast structure. The inner membrane of a chloroplast structure. The inner membrane of a chloroplast structure form stacks of closed vesicles called thylakoids. in columns called grana. d. What is the approximate size of a nucleus? e. Why is the granular-appearing cytoplasm more apparent at the sides of a cell rather than in the middle? 40 EXERCISE 4 1. Prepare a wet mount of Elodea and examine the cell walls. Always begin your examination at the lowest magnification and cautiously move to higher magnifications. The middle lamella may be visible as a faint line between cells. 2. Obtain a prepared slide of tissue showing plasmodesmata. This tissue may be persimmon (Diospyros) endosperm, which has highly thickened primary walls. Sketch what you see. 3. Locate the middle lamella as a faint line between cell walls. 4. Locate the plasmodesmata, appearing as darkened lines perpendicular to the middle lamella and connecting the protoplasts of adjacent cells (fig. 4.9). Question 7 a. What are the functions of plasmodesmata? b. Why do you suspect that there are so many plasmodesmata connecting the cells in this fruit? 4-8 Procedure 4.5 Examine stained onion cells Cell wall

Plasmodesmata © Biophoto Associates/Science Source Figure 4.9 This electron micrograph of the thickened primary cell walls of persimmon endosperm shows plasmodesmata connecting adjacent cells (130,000×). Onion Cells Staining often reveals the structure of cells and cell organelles more clearly. A specimen is stained by adding a dye that preferentially colors some parts of the specimen but not others. Neutral red is a common stain that accumulates in the cell, leaving the cell walls clear. Nuclei appear as dense bodies in the translucent cytoplasm of the cell, leaving the cell walls clear. of the inner epidermis formed at the break point (fig. 4.10), as demonstrated by your lab instructor. 3. Place this epidermal tissue in a drop of water on a microscope slide, add a coverslip, and examine the tissue. This preparation should be one cell thick. small drop of 0.1% neutral red at the edge of the coverslip. Draw the neutral red across the specimen by wicking. To wick the solution, hold the edge of the coverslip and it will withdraw some fluid. This will cause the neutral red to flow over the onion and will not disturb the tissue under the coverslip. 5. Stain the tissue for 5-10 min. 6. Carefully focus to distinguish the vacuole surrounded by the stained cytoplasm. 7. Search for the nucleus may appear circular in the central part of the cell. In other cells it may appear flattened. Question 8 How do you explain the differences in the apparent shapes and positions of the nuclei in different cells? 8. Repeat steps 1-7 and stain a new preparation of onion cells. Figure 4.10 Preparing a wet mount of an onion cells. Figure 4.10 Preparing a wet mount of an onion cells. Nuclear pores Nuclear pore Outer membrane Nuclear envelope, enclosing a fluid-filled interior containing the DNA. In the cross section, the individual nuclear pores extend through the two membrane layers of the nuclear envelope; the material within the pore is protein, which controls access through the pore (1765×). Question 9 a. What cellular structures of onion are more easily seen in stained as compared to unstained preparations? Mitochondria b. Which of the available stains enhanced your observations the most? Procedure 4.6 Examine mitochondria c. Do onion cells have chloroplasts? Explain. d. Use an ocular micrometer or the dimensions of the field of view (FOV) calculated in Exercise 3 to measure the dimensions of an onion epidermal cell. Are these cells larger or smaller than the Elodea cells you examined in procedure 4.3? Mitochondria are surrounded by two membranes (fig 4.12). The inner membrane folds inward to form cristae, which hold respiratory enzymes and other large respiratory molecules in place. Some DNA also occurs in mitochondria. Chloroplasts also are double-membraned and contain DNA. in onion cells 1. On a clean glass slide mix two or three drops of the stain Janus Green B with one drop of 7% sucrose. 2. Prepare a thin piece of onion epidermis (as instructed in procedure 4.5) and mount it in the staining solution. The preparation should be one cell thick. For mitochondria to stain well, the onion cells must be healthy and metabolically active. Add a coverslip. 3. Search the periphery of cells to locate stained mitochondria. about 1 µm in diameter. The color will fade in 5-10 min, so examine your sample quickly and make a new preparation if needed. 4. Label the following structures in the micrograph of the mitochondrion in fig. 4.12: inner membrane, outer membrane sugars and starch, is made and stored. You have already examined chloroplasts, a type of plastid in which photosynthesis occurs. Other plastids that store starch and therefore will stain darkly with iodine. Question 10 a. Are any cellular structures other than amyloplasts stained intensely by iodine? Procedure 4.7 Examine amyloplasts 1. Use a razor blade to make a thin section of a potato tuber. Make the section in a drop of water on a microscope slide and add a coverslip. Add another drop of water to the edge if needed. 3. Locate the small, clam-shaped amyloplasts within the cells. High magnification may reveal the eccentric lines distinguishing layers of deposited starch on the grains. 4. Stain the section by adding a drop of iodine to the edge of the coverslip. Iodine is a stain specific for starch (see Exercise 6, "Biologically Important Molecules"). If necessary, pull the stain under the coverslip by touching a paper towel to the water at the opposite edge of the coverslip. b. What can you conclude about the location of starch in storage cells of potatoes? d. Why are potatoes? share many similarities, and also have several differences (see table 4.1). Human Epithelial Cells Intermembrane space Inner membrane of your mouth. They are flat cells with a readily visible nucleus. Procedure 4.8 Examine human epithelial cells ©CNRI/Science Photo Library/Getty Images Figure 4.12 Mitochondria evolved from bacteria that long ago took up residence within the ancestors of present-day eukaryotes (80,000×). 4-11 1. Check with your instructor about proper technique and disposal of materials for this procedure. Your instructor may substitute examination of a prepared slide for preparation of a wet mount. 2. Gently scrape the inside of your cheek with the broad end of a clean toothpick. 3. Stir the scrapings into a drop of water on a microscope slide, add a coverslip, and examine with your compound microscope. Dispose of used toothpicks in a container designated by your instructor. 4. Stain the cells by placing a small drop of methylene blue at one edge of the coverslip and drawing it under the coverslip and drawing it under the coverslip. The Cell 43 5. Prepare another slide and stain the cells with Janus Green B. Observe the mitochondria. 6. Use an ocular micrometer or the dimensions of the FOV calculated in Exercise 3 to measure the dimensions of a human epithelial cell. 7. After viewing the preparation, put the slides and coverslips in a container of 10% bleach. Question 11 a. What structures visible in the unstained preparation? e. Why do Elodea and onion cells have more consistent shapes than human epithelial cells? PROTISTS Amoeba, Paramecium, and Spirogyra are members of a large group of eukaryotic organisms called protists. You will learn more about protists in Exercises 25 and 26. In today's exercise, you'll examine Amoeba, Paramecium, and Spirogyra. Amoeba be used to b onion epidermal cells (procedure 4.6)? Explain. c. What similarities and differences are there between plant and animal cells? d. How do the size and shape of a human epithelial cell differ from those of the Elodea and onion cells that you examined earlier? Amoeba is an irregularly shaped, heterotrophic protist with many internal organelles (fig. 4.13). Amoeba move via amoeboid movement. Amoeboid movement occurs by means of pseudopodia, which are temporary protrusions of the cell. Pseudopodia also surround food particles and expels water and waste products. Procedure 4.9 Examine Amoeba 1. Use an eyedropper to obtain a few drops from the bottom of an Amoeba culture. Examining the culture with a dissecting microscope to locate a living Amoeba. Your instructor may allow you to view the Amoeba without using a coverslip, but view them only on 4× or 10× magnification. Pseudopodia Contractile vacuoles (a) (b) ©micro_photo/iStockphoto/Getty Images Figure 4.13 Amoeba. (a) Diagram of Amoeba (160×). 44 EXERCISE 4 4-12 4 Decrease the light intensity and observe a demonstration of Amoeba for a few minutes. 5. Locate the structures shown in figure 4.13. 6. Examine a prepared slide of stained Amoeba; then observe a demonstration of Amoeba in the following space. Question 12 a. List the organelles found in plant cells, in Amoeba, and common to both. Paramecium Like Amoeba, Paramecium is also a single-celled, heterotrophic organism (fig. 4.14). Procedure 4.10 Examine Paramecium 1. Place a small ring of methylcellulose ring. 3. Use a toothpick to mix the methylcellulose with the drop of water from the culture of Paramecium. 4. Add a coverslip and examine Paramecium are cilia, which are short hairlike structures used for locomotion. 5. Examine a prepared slide of stained Paramecium. 6. In the following space, sketch a Paramecium. b. Does Amoeba have a cell wall? How can you tell? c. How do the appearances of Amoeba differ in live cells and preserved cells? Question 13 a. How does movement of Paramecium compare to that of Amoeba? Anterior contractile vacuole Micronucleus Food vacuole Gullet Macronucleus Pellicle Cilia Posterior contractile vacuole (a) Cytoproct (b) ©micro photo/Getty Images Figure 4.14 Paramecium. (a) Diagram of Paramecium. (b) Light micrograph of a living Paramecium? ((a)) c. What structures in Amoeba and Paramecium (150×). (b) Light micrograph of a living Paramecium? ((a)) c. What structures in Amoeba and Paramecium? also occur in plant cells? What structures in Amoeba and Paramecium do not occur in plant cells? Spirogyra (fig. 4.15) is a filamentous, autotrophic green alga that is named for the spiral arrangement of its chloroplasts. Examine Spirogyra 1. Place a drop from a culture containing Spirogyra on a microscope slide. 2. Add a coverslip and examine Spirogyra. (a) Diagram of a Spirogyra cell (250×). (b) Light micrograph of a living Spirogyra. Note the spiral-shaped chloroplast for which the alga is named (200×). c. Do the cells have a cell wall? If so, how can you tell? d. What organelles visible in Amoeba and Paramecium? Question 14 a. Filaments of some algal species have the ends of each cell linked to one other cell. In contrast, the cells of other species sometimes give rise to two cells and form forked or branched filaments. Is Spirogyra branched or unbranched? b. In what shapes are the cells? 46 EXERCISE 4 Procedure 4.12 You will be given a slide of an unknown organism. Use what you've learned in today's lab to identify the cells as prokaryotic, identify the cells as plant, animal, or protist. Complete
table 4.2 before leaving the lab. If instructed to do so, turn in table 4.2 before leaving the lab. 4-14 Table 4.2 Using Distinguishing Features to Identify an Unknown Organism is a: (Circle One) Prokaryote Eukaryote If the specimen is a eukaryote, it is a(n): (Circle One) Plant Animal Protist INQUIRY-BASED LEARNING How do single-celled organisms respond to environmental stimuli? Observation: Single-celled organisms respond to environmental stimuli? celled protists affected by temperature? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 4 from your instructor. b. Discuss with your group well-defined question. 4-15 c. Translate your question into a testable hypothesis and record it. d. Outline on Worksheet 4 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your guestion, and make relevant comments. f. Discuss with your instructor any revisions to your questions, hypothesis, or procedures. Repeat your work as needed. The Cell 47 Questions for Further Study and Inquiry 1. What is a cell? 2. Describe the structures do plant and animal cells have in common? 4. Would you expect a cell of a multicellular organism to be more complex than the cell of a unicellular organism? Less complex? Why? 5. What is the purpose of using a biological stain when microscopically examining cellular components? 6. How are they all classified as protists? DOING BIOLOGY YOURSELF Determine the total surface areas and volumes of the chloroplasts in a typical Elodea cell. Assume that each chloroplast is a sphere = (3) μm diameter. (The surface areas and volumes? Would it being a sphere = (3) μm diameter. advantageous for a cell to be filled with chloroplasts? Why or why not? 48 EXERCISE 4 WRITING TO LEARN BIOLOGY What criteria might you use to distinguish colonial organisms, such as many cyanobacteria, from truly multicellular organisms? 4-16 E XER CISE 5 Solutions, Acids, and Bases The pH Scale Learning Objectives By the end of this exercise you should be able to: 1. Apply the concepts of mole and molarity to prepare solutions. 2. Measure the pH of a liquid. 4. Measure the ability of commercial antacids to buffer the pH of a liquid. 4. Measure the ability of commercial antacids to buffer the pH of a liquid. 4. Measure the ability of commercial antacids to buffer the pH of a liquid. 4. Measure the ability of commercial antacids to buffer the pH of a liquid. hemicals in living systems are in solution. Biologists experiment with solutions because dissolved in a solvent. For example, salt water is a solute(s) dissolved in a solvent. For example, salt water is a solute(s) dissolved in water (i.e., the solvent). The concentration of a solute(s) dissolved in water (i.e., the solvent). is often expressed as a percentage of the total solution (e.g., weight/volume or grams solute/100 mL solution). For example, a 3% (weight/volume of 1 L (or 3 g of sucrose in water for a total solution). For example, a 3% (weight/volume) solution of sucrose in water for a total solution of sucrose in water for a total solution). would you dissolve in water for a total volume of 500 mL to make a 5% (weight/volume) solution? b. How many grams of calcium chloride would you add to water for a total volume of 100 mL to make a 5% (weight/volume) solution? c. How many grams of calcium chloride would you add to water for a total volume of 100 mL to make a 5% (weight/volume) solution? (weight/volume) solution? 5-1 Molarity is the most common measure of concentration. To understand how to prepare a molar solution you must first understand what is meant by a mole of a chemical. A mole is a standard measure of the amount of a chemical of NaCl and one mole of sucrose contain the same number of molecular weight. The weight of 1 mole of a chemical's molecular weight in grams. For example, the molecular weight of water (H2O) is 18 grams. (2H = 2 × 1 = 2; O = 16; 16 + 2 = 18). A mole of water weights of its component elements. To further understand why biologists usually prepare solutions in molar concentrations rather than as percentages you must remember that chemicals react on a molecule by molecule basis—that is, the number of molecules is more critical than the weight. It follows that expressing a solution is a 1-molar (1 M) solution. For example, a liter of solution containing 58.5 g of NaCl is a 1 M solution of NaCl (fig. 5.2). Use this formula to answer Questions 2 and 3 before coming to lab: Molarity (M) = moles of solute liters of solution containing 58.5 g of NaCl (fig. 5.2). Use this formula to answer Questions 2 and 3 before coming to lab: Molarity (M) = moles of solution containing 58.5 g of NaCl (fig. 5.2). Use this formula to answer Questions 2 and 3 before coming to lab: Molarity (M) = moles of solution containing 58.5 g of NaCl (fig. 5.2). Use this formula to answer Questions 2 and 3 before coming to lab: Molarity (M) = moles of solution containing 58.5 g of NaCl (fig. 5.2). Use this formula to answer Questions 2 and 3 before coming to lab: Molarity (M) = moles of solution containing 58.5 g of NaCl (fig. 5.2). Use this formula to answer Questions 2 and 3 before coming to lab: Molarity (M) = moles of solution containing 58.5 g of NaCl (fig. 5.2). Use this formula to answer Questions 2 and 3 before coming to lab: Molarity (M) = moles of solution containing 58.5 g of NaCl (fig. 5.2). Use this formula to answer Questions 2 and 3 before coming to lab: Molarity (M) = moles of solution containing 58.5 g of NaCl (fig. 5.2). Use this formula to answer Questions 2 and 3 before coming to lab: Molarity (M) = moles of solution containing 58.5 g of NaCl (fig. 5.2). Use this formula to answer Questions 2 and 3 before coming to lab: Molarity (M) = moles of solution containing 58.5 g of NaCl (fig. 5.2). Use this formula to answer Questions 2 and 3 before coming to lab: Molarity (M) = moles of solution containing 58.5 g of NaCl (fig. 5.2). Use this formula to answer Questions 2 and 3 before coming to lab: Molarity (M) = moles of solution containing 58.5 g of NaCl (fig. 5.2). Use this formula to answer Question containing to lab: Molarity (M) = moles of solution containing to lab. Molarity (M) = moles of solution containing to lab. Molarity (M) = moles of solution containing to lab. Molarity (M) = moles of solution containing to la = 2(1.0) + 16 = 18 g mole-1 VIIIA IA 2 1 1 Hydrogen H IIA Lithium Beryllium 6.941 11 9.0122 12 1.0079 3 2 3 4 Li VA 4 7 Nitrogen N Be Sodium Magnesium 22.989 19 24.305 20 Na Potassium K 39.098 b. How many grams of NaCl (molecular weight = 58.5 g mole-1) would you dissolve in water to make a 50 mM NaCl solution with 500 mL final volume? VIA 8 Oxygen O VIIA 9 Fluorine F 14.0067 15.9994 18.9984 15 16 17 Mg IIIB Calcium Scandium 40.08 44.956 21 Ca Sc Phosphorus P Sulfur S 30.9738 32.064 33 34 Arsenic Selenium 74.992 78.96 As Se Chlorine Cl 35.453 35 Bromine Br 79.904 g Helium He 4.0026 10 Neon Ne 20.179 18 c. How many grams of sucrose (molecular weight = 342 g mole-1) would you dissolve in water to make a 0.22 M sucrose solution with 1 L final volume? g Argon Ar 39.948 36 Krypton Kr 83.80 d. How many grams of sucrose (molecular weight = 342 g mole-1) would you dissolve in water to make a 0.22 mM sucrose solution with 1 L final volume? g Argon Ar 39.948 36 Krypton Kr 83.80 d. How many grams of sucrose (molecular weight = 342 g mole-1) would you dissolve in water to make a 0.22 mM sucrose solution with 1 L final volume? g e. How many grams of calcium chloride (CaCl2; molecular weight = 111 g mole-1) would you dissolve in water to make a 0.111 M CaCl2 solution with 1 L final volume? NaCl molecular weights of elements are listed in the periodic table. Shown here are the portions of the periodic table that would be used to calculate the molecular weights of water (H2O) and table salt (sodium chloride, NaCl). Note that g mole-1 = grams per mole. Question 2 a. How many grams of NaCl (molecular weight = 58.5 g mole-1) would you dissolve in water to make a 0.5 M NaCl solution with 500 mL final volume? g f. How many grams of calcium chloride (CaCl2; molecular weight = 111 g mole-1) would you dissolve in water to make a 0.2 M CaCl2 solution with 200 mL final volume? g g + Add water to total 1 L 1 S8 g KMnO4 Add water to total 1 L 1 S8 g KMnO4 Add water to total 1 L 1 S8 g KMnO4 Add water to total 1 L 1 S8 g KMnO4 Add water to total 1 L 1 S8 g KMnO4 Add water to total 1 L 1 S8 g KMnO4 Add water to total 1 L 1 S8 g KMnO4 Add water to total 1 L 1 M NaCl 58.5 g NaCl ~750 mL water Total volume? ~750 mL water Total volume = 1.0 L + 1 M sucrose Add water to total 1 L 342 g sucrose (C12H22O11) ~750 mL water Total volume = 1.0 L Figure 5.2 Preparing 1.0 M solutions of sodium chloride (NaCl; molecular weight = 58.5 g mole-1), potassium permanganate (KMnO4; molecular weight = 158 g mole-1), and sucrose (C12H22O11) ~750 mL water Total volume = 1.0 L Figure 5.2 Preparing 1.0 M solutions of sodium chloride (NaCl; molecular weight = 58.5 g mole-1), potassium permanganate (KMnO4; molecular weight = 158 g mole-1), and sucrose (C12H22O11) ~750 mL water Total volume = 1.0 L Figure 5.2 Preparing 1.0 M solutions of sodium chloride (NaCl; molecular weight = 58.5 g mole-1), potassium permanganate (KMnO4; molecular weight = 158 g mole-1), and sucrose (C12H22O11) ~750 mL water Total volume = 1.0 L Figure 5.2 Preparing 1.0 M solutions of sodium chloride (NaCl; molecular weight = 58.5 g mole-1), and sucrose (C12H22O11) ~750 mL water Total volume = 1.0 L Figure 5.2 Preparing 1.0 M solutions of sodium chloride (NaCl; molecular weight = 58.5 g mole-1), and sucrose (C12H22O11) ~750 mL water Total volume = 1.0 L Figure 5.2 Preparing 1.0 M solutions of sodium chloride (NaCl; molecular weight = 58.5 g mole-1), and sucrose (C12H22O11) ~750 mL water Total volume = 1.0 L Figure 5.2 Preparing 1.0 M solutions of sodium chloride (NaCl; molecular weight = 58.5 g mole-1), and sucrose (C12H22O11) ~750 mL water Total volume = 1.0 L
Figure 5.2 Preparing 1.0 M solutions of sodium chloride (NaCl; molecular weight = 58.5 g mole-1), and sucrose (C12H22O11) ~750 mL water Total volume = 1.0 L Figure 5.2 Preparing 1.0 M solutions of sodium chloride (NaCl; molecular weight = 58.5 g mole-1), and sucrose (C12H22O11) ~750 mL water Total volume = 1.0 L Figure 5.2 Preparing 1.0 M solutions of sodium chloride (NaCl; molecular weight = 58.5 g mole-1), and sucrose (NaCl; molecular weight = 58.5 g mole-1), and sucrose (NaCl; molecular weight = 58.5 g mole-1), and sucrose (NaCl; molecular weight = 58.5 g mole-1), and sucrose (NaCl; molecular weight = 58.5 g molecular weight = 342 g mole-1). Each of these solutions contains the same number of units of solutes (i.e., 6.02 × 1023 molecules). 50 EXERCISE 5 5-2 h. To prepare the 5% calcium chloride solution called for in Question 1a, how many moles of sugar did you add? What was the molarity of that solution? i. To prepare the 5% calcium chloride solution called for in Question 1b, how many moles of calcium chloride did you add? What was the molarity of that solution? The initial volume (Vi) was 25 mL = 10.7 mL to get our answer: 35.7 mL - 25 mL = 10.7 mL to get our answer: 35.7 mL - 25 mL = 10.7 mL to get our answer: 35.7 mL - 25 mL = 10.7 mL to get our answer: 35.7 mL - 25 mL = 10.7 mL to get our answer: 35.7 mL - 25 mL = 10.7 mL to get our answer: 35.7 mL - 25 mL = 10.7 mL to get our answer: 35.7 mL - 25 mL = 10.7 mL to get our answer: 35.7 mL - 25 mL = 10.7 mL to get our answer: 35.7 mL to get our answer: 35. concentrated (18 M) sulfuric acid (H2SO4) are required to prepare 750 mL of 3 M sulfuric acid? b. How would you prepare 100 mL of 0.4 M MgSO4 from a stock solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution of 2 M MgSO4? j. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose solution would contain 1 mole of sucrose? c. How many milliliters of a 2 M sucrose s a final solution of 0.25 M HCl? Dilutions To save time and space, biologists often prepare commonly used solutions in concentrated forms called dilution. Dilution involves spreading a given amount of solute throughout a larger solution. The number of moles of solute doesn't change when a solution is diluted but the volume (Vi) and initial molarity (Mi) must equal the product of the final volume (Vf) and final molarity (Mf): where Vi Mi = Vf Mf Vi = initial volume (Vi) and initial molarity (Mi) must equal the product of the final volume (Vi) and initial molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must equal the product of the final volume (Vi) and final molarity (Mi) must Mi = initial molarity Vf = final wolume Mf = final molarity Let's now use this simple equation to solve a dilution problem. Suppose we want to know how much water to add to 25 mL of a 0.50 M KOH solution to produce a solution having a KOH concentration of 0.35 M. In this case, Mi = 0.5 M Vi = 25 mL Mf = 0.35 M Vf = ? We can now solve the problem: 5-3 Vi Mi = Vf Mf (25 mL)(0.5 M) = (Vf)(0.35 M) V = 35.7 mL f ACIDS AND BASES One of the most important applications of molarity involves the standard by which all other solution. Pure water is the standard by which all other solutions are compared because pure water is an ionically neutral solution. This neutrality is not due to the absence of ions, but rather to the equal concentrations of positive and negative ions. When the oxygen of water pulls hard enough on an electron from one of its hydrogens, two ions form: H_{-7} M enough on an electron from one of its hydrogens, two ions form: H_{-7} M enough of water pulls hard enough on an electron from one of its hydrogens, two ions form: H_{-7} M enough of water pulls hard enough of wa The solution is neutral because the concentration of H+ and OH- is also 10-7 M. The sum of H+ and OH- is also 10-7 M. The sum of H+ in a solution. Bases are molecules that release hydrogen ions (H+) when dissolved in water. Acids are molecules that release the concentration of H+ in a solution. Bases are molecules that release hydrogen ions (H+) when dissolved in water. Acids are molecules that release hydrogen ions (H+) when dissolved in water. H+ in a solution. When the concentration of H+ increases the concentration of H+; therefore, HCl is an acid. In contrast, sodium hydroxide (NaOH) is a base because it ionizes and increases the concentration of OH-, thereby lowering the relative proportion of H+. Thus, if enough acid Solutions, Acids, and Bases 51 is added to water to raise the H+ concentration would decrease to 10-8 M. By general agreement, the scale we use to measure acidity is the pH scale (pH stands for the potential of hydrogen ions). The pH is the negative logarithm of the concentration of H+; that is, Question 4 a. Vinegar has a pH of 3, and household ammonia has a pH of 11. Is the concentration of H+ goes down. (The brackets indicate concentration of H+; that is, Question 4 a. Vinegar or ammonia? pH = -log [H+] As pH goes up, the concentration of H+; that is, Question 4 a. Vinegar or ammonia? pH = -log [H+] As pH goes up, the concentration of H+ goes down. (The brackets indicate concentration of H+; that is, Question 4 a. Vinegar or ammonia? pH = -log [H+] As pH goes up, the concentration of H+ goes down. 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Vinegar or ammonia? pH = -log [H+] As pH goes up, the concentration of H+ goes down. (The brackets indicate concentration of H+; that is, Question 4 a. Vinegar or ammonia? pH = -log [H+] As pH goes up, the concentration of H+ goes down. (The brackets indicate concentration of H+ goes down.) (The brackets indicate concentration of H+ goes down.) (The brackets indicate concentration of H+ goes down.) (The brackets indicate concentratin of H+ goes down.) (The brackets indicate concentration of (-log 10~); most acidic) to 14 (-log 10-14; most basic). On this scale, pure water has a pH of 7 (-log 10-7); pH values less than 7 are acidic, whereas those above 7 are basic (fig. 5.3). Figure 5.3 shows the pHs of some common (and a few not-so-common) substances. The
pH scale is a logarithmic scale; each unit represents a change of tenfold. Thus a lime with a pH of 2 is ten times more acidic than an apple with a pH of 3 and 100 times more acidic than a tomato having a pH of 4. Each decrease in acidity. Each increase of 1.0 pH unit represents a tenfold decrease in acidity. Each decrease of 1.0 pH unit represents a tenfold decrease in acidity. convenient way of measuring the pH of a solution is with pH paper. pH paper is treated with a chemical indicator that changes colors depending on the concentration of H+ in H+ Ion Concen 9 9 10-10 10 Baking soda, phosphate detergents Great Salt Lake 10-11 11 Household ammonia 10-12 12 Hair remover Household bleach 10-13 13 10-14 14 Hydrochloric acid Stomach acid Lemon juice Vinegar, cola, beer Oranges Tomatoes Black coffee Normal rainwater Urine, root beer Saliva Pure water, tears Blood Seawater, egg white Oven cleaner Sodium hydroxide Figure 5.3 The pH scale. The pH scale is logarithmic: A pH change of 1 means a tenfold change in the concentration of hydrogen ions. Thus, lemon juice is logarithmic: A pH change of 1 means a tenfold change in the concentration of hydrogen ions. 100 times more acidic than tomato juice, and seawater is 10 times more basic than pure water, which has pH of 7. 52 EXERCISE 5 5-4 Procedure 5.1 Indicator pH paper is embedded with chemicals that change color according to the pH of a solution. According to the color chart provided on the container of pH paper, the lemon juice sampled with the paper strip on the left has a pH of 2. The pH test strip on the right indicates that it has contacted (fig. 5.4). The color chart on the container of pH paper relates the color of the pH of the solution that it has contacted (fig. 5.4). Here are some examples of pH indicators: Indicator Range Color Change Methyl violet Bromophenol blue Methyl red Litmus Bromcresol purple Phenol red to blue-violet yellow to blue red to blue yellow to red yellow to blue-violet yellow to blue red to blue yellow to red yellow to red yellow to red yellow to blue yellow to blue yellow to red yellow to red yellow to red yellow to blue yellow to blue yellow to blue yellow to red yellow to blue yellow to blue yellow to blue yellow to red yellow to red yellow to blue yellow to blue yellow to blue yellow to blue yellow to red yellow to red yellow to blue yellow to red yellow to red yellow to blue blue colorless to red SAFETY FIRST Before coming to lab you were asked to read this exercise so you would know what to do and be aware of safety issues. In the space below, briefly list the safety issues associated with today's procedures. If you have questions about these issues, contact your laboratory assistant before starting work. Use pH papers to measure the pH of the following liquids. Be as accurate as possible and use a fresh piece of pH paper or pH dipstick for each test. Vinegar Skim milk Apple juice Grapefruit juice Buttermilk Black coffee Sprite Household bleach Mixture of Sprite and baking soda 10 mM hydrochloric acid 0.01 mM hydrochloric acid 0.01 mM hydrochloric acid Distilled water Tap water Dissolved aspirin Soap solution Shampoo Mouthwash Deodorant Check vour measurements of the hydrochloric acid solutions by comparing them with calculations using the following formula. For example, pH = -log[H+] 10 mM HCl = 10-2 M HCl pH = -log[10-2] pH = 2 Ouestion 5 Are vour measured pH to the calculated pH values? What are possible sources of error? Buffers Handle all of the solutions carefully. Although some are harmless (e.g., water, milk), others are caustic and can stain clothes and burn your skin. 5–5 In most organisms, the pH is kept relatively constant by buffers, which are mixtures of a weak base that can combine with a strong acid or base to limit changes in pH. That is, buffered solution produces a small amount of acid to an unbuffered solution produces a small amount of acid to an unbuffered solution produces a small amount of acid to an unbuffered solution produces a small amount of acid to a buffered solution produces a small amount of acid to buffered solution produces a small amount of a changes the pH drastically. Most biological fluids Solutions, Acids, and Bases 53 pH 6. Repeat steps 4 and 5 for each of the remaining tubes. Record your results in table 5.1. 9 8 7 6 5 4 3 2 1 0 Buffering range 0 1x 2x 3x 4x Amount of base added Question 6 a. Compare the initial pH and the pH after adding acid to each sample. Which is the most effective buffer? Which is least effective? 5x Figure 5.5 Buffers minimize changes in pH. Adding a base to a solution will raise the pH (neutralize some of the pH scale, called the "buffering"). Thus, as more and more base is added, the pH continues to rise. However, a buffer makes the curve rise or fall very slowly over a portion of the pH scale, called the "buffering". range" of that buffer. b. What accounts for the different buffers, the most importance of what you observed? (e.g., milk, blood) contains buffers, the most importance of what you observed? (e.g., milk, blood) contains buffers, the most importance of what you observed? (e.g., milk, blood) contains buffers, the most importance of what you observed? (e.g., milk, blood) contains buffers, the most importance of what you observed? (e.g., milk, blood) contains buffers, the most importance of what you observed? (e.g., milk, blood) contains buffers, the most importance of what you observed? 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Cover the tube with Parafilm and swirl the tube gently to mix the contents. 5. Measure the pH of the acidified solution and record it in table 5.1. Procedure 5.3 Test the effectiveness of commercial antacids and other products Commercial antacids such as Alka-Seltzer, Rolaids, and Tums claim to "neutralize stomach acid" by absorbing excess H+ (produced as hydrochloric acid by the stomach; fig 5.6). To test the abilities of these products to absorb acids, do the following: 1. Use a mortar and pestle to pulverize the amount of antacid that is listed as one dose Dissolve the crushed antacid in 100 mL of distilled water. Some of the products may require extensive stirring to get most or all of the antacid solution into a test tube. Add 4 drops of the indicator bromcresol purple to the tube. Cover the tube with Parafilm and invert the tube to mix the contents. 3. Add 0.1 M hydrochloric acid (HCl) dropwise to the tube; mix after each
drop. Continue this process until the solutions Procedure 5.2 Solution Initial pH pH after Adding Acid Procedure 5.3 Solution Water Alka-Seltzer 0.1 M NaCl Rolaids Skim milk Tums Drops of Acid 0.1 M phosphate buffer 54 EXERCISE 5 5-6 © BiologyImaging.com Figure 5.7 Several over-the-counter products claim to reduce 4. Record in table 5.1 the number of drops of acid needed to generate the change of Acid 0.1 M phosphate buffer 54 EXERCISE 5 5-6 © BiologyImaging.com Figure 5.7 Several over-the-counter products claim to reduce 4. Record in table 5.1 the number of drops of acid needed to generate the change of color. This number of drops is an index to the amount of acid (H+) that the solution neutralizes before the pH drops below the yellow endpoint of bromcresol purple (pH 5.2). Many people also use products such as Zantac, Pepcid AC Complete, Maalox, and Zantac 75 to soothe upset stomachs (fig. 5.7). Examineet stomachs (fig. 5.7). these products in lab, noting their claims and active ingredients. Based on your observations, write a hypothesis predicting each product's ability to absorb acid. prevent acid indigestion, upset stomach, and related problems. How do the product's ability to absorb acid. acid? heartburn and acid indigestion. How do the product's ability to absorb acid. List your results here. b. What is the effect of dose (for example, the size of tablets or the amount of antacid per tablet) on your results and conclusions? Question 8 a. How accurate were your hypotheses? c. Examine the packages of the products you tested. What are the active ingredients of each product? What does this tell you about how these products work? 5-7 b. How does each product? What does this tell you about how these products work? 5-7 b. How does each product? What does this tell you about how these products work? 5-7 b. How does each product? What does this tell you about how these products work? 5-7 b. How does each product? Phillips' Milk of Magnesia is a milky-white liquid that is a popular over-the-counter laxative and antacid. Phillips' Milk of Magnesia at neutralizing acid? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 5 from your instructor. b. Discuss with your group well-defined questions relevant to the preceding observation and question. c. Translate your question for investigation. c. Translate your group's best question for investigation. c. Translate your group well-defined questions relevant to the preceding observation and question. your instructor to review your proposed investigation. e. Conduct your procedures, record your data, answer your question, hypothesis, or procedures. Repeat your work as needed. Questions for Further Study and Inquiry 1. What do buffers do and why are they important in biological systems? 2. Our stomachs secrete hydrochloric acid. Knowing the function of antacids, what do you think causes most "upset stomachs"? 3. The soft drink Mr. Pibb contains (among other things) 39 g of sucrose in 355 mL of solution. What is the molarity of this sucrose solution? What is the percentage (weight/volume) of sucrose in the solution? 4. Our stomachs secrete hydrochloric acid. What functions does this hydrochloric acid serve? 5. Suppose that the concentration of H+ in Solution #1 is 10,000 times greater than in Solution #2. What can you conclude about the difference in pH of these two solutions? 6. What is the active ingredient in Phillips' Milk of Magnesia? How is this different from that of products such as Tums? 56 EXERCISE 5 5-8 Biologically Important Molecules E XER CISE Carbohydrates, Proteins, Lipids, and Nucleic Acids 6 Learning Objectives By the end of this exercise you should be able to: 1. Perform qualitative tests to detect the presence of biologically important carbohydrates proteins, lipids, and nucleic acids. 2. Explain the importance of a positive and a negative control in biochemical tests. 3. Use biochemical tests to identify an unknown compounds in living organisms are carbohydrates, proteins, lipids, or nucleic acids. Each of these macromolecules is made of smaller subunits. These subunits are bonded covalently (fig. 6.1). Similarly, breaking the bond between the subunits are bonded covalently (fig. 6.1). and releases energy. This energy-releasing process is called hydrolysis. The subunits of macromolecules are held together by covalent bonds and relatively little oxygen, while proteins (made of fatty acids) have amino groups (-NH2) and carboxyl (-COOH) groups. These characteristic subunits and groups impart different chemical properties to macromolecules-for example, monosaccharides such as glucose are polar and insoluble in water. H2O HO H HO H (b) Hydrolysis Making and breaking macromolecules. (a) Dehydration synthesis. Many biological macromolecules are polymers formed by linking subunits together. The covalent bond between the subunits is formed by dehydration synthesis, an energy requiring process that creates a water molecule for every bond formed. (b) Hydrolysis. Breaking the bond between subunits requires the returning of a water molecule with a subsequent release of energy, a process called hydrolysis. 6-1 CONTROLLED EXPERIMENTS TO IDENTIFY ORGANIC COMPOUNDS Scientists have devised several biochemical tests to identify the major types of organic compounds in living organisms. Each of these tests involves two or more treatments: (1) an unknown solution to be identified and (2) controls to provide standards for comparison. As its name implies, an unknown solution may or may not contrait, controls are known solutions. We use controls to validate that our procedure is detecting what we expect it to detect and nothing more. During the experimental procedure is detecting; it reacts positively and demonstrates the test's ability to detect what you expect. For example, if you are testing for protein in unknown to control does not contain the variable for which you are searching. It contains only the solvent (often distilled water with no solute) and does not react in the tests. This means that the tests will show whether a particular substance is present in a sample but will not indicate how much of the substance is present. Biologically Important Molecules 57 Polysaccharides are polymers of monosaccharides are polymers of subunits of mono- or disaccharides. These subunits can be combined by dehydration synthesis (see fig. 6.4) to form polysaccharides. (b) Benedict's test is a test for reducing sugars produce a greenish color, high levels produce a greenish color, high levels produce a red color. very high high ©Dave Moyer Benedict's test for sugar (b) CARBOHYDRATES or simple sugars (fig. 6.2a). Paired monosaccharides form disaccharides forms a polysaccharide sugar) is a disaccharide of glucose linked to fructose. Similarly, linking three or more monosaccharides forms a polysaccharide sugar) is a disaccharide of glucose linked to fructose. Benedict's Test for Reducing Sugars Carbohydrates are molecules made of C, H, and O in a ratio of 1:2:1 (e.g., the chemical formula for glucose is C6H12O6). Carbohydrates are molecules made of M OH H OH H O H H Monosaccharides CH2OH CH2OH O HO HO OH Glucose CH2OH O O H HO OH Glucose CH2OH O OH CH2OH O O OH OH OH CH2OH O O OH OH OH CH2OH O O OH CH2OH O O to link monosaccharides (such as glucose and fructose) into disaccharides. The disaccharides shown here are maltose (malt sugar) and sucrose (table sugar). Question 1 Examine figure 6.2a. Which groups of a glucose molecule are involved in forming a polysaccharide? carbohydrates, as well as other macromolecules, involves the removal of a water molecule (dehydration). Figure 6.4 depicts how dehydration synthesis is used to make maltose and fructose are reducing sugars, meaning that they possess free aldehyde (-CHO) or ketone (-C=O) groups that reduce weak oxidizing agents such as the copper in Benedict's reagent contains cupric (Cu2+) ions to cuprous (Cu+) oxide at basic (high) pH. Cuprous oxide is green to reddish orange (fig. 6.2b). Oxidized Benedict's reagent (Cu+) + Reducing sugars, and reddish orange) A green solution indicates a small amount of reducing
sugars, and reddish orange indicates an abundance of 6-3 reducing sugars. Nonreducing sugars such as sucrose produce no change in color (i.e., the solution remains blue). SAFETY FIRST Before coming to lab, you were asked to read this exercise so you would know what to do and be aware of safety issues. In the space below, briefly list the safety issues associated with today's procedures. If you have questions about these issues, contact your laboratory assistant before starting work. Procedure 6.1 Perform the Benedict's test for reducing sugars 1. Obtain seven test tubes and number them 1-7. 2. Add to each tube the materials. If so, include for a solution of these materials are listed in table 6.1). Your instructor may ask you to test some additional materials. If so, include for a solution of these materials are listed in table 6.1). additional numbered test tubes. Add 3 mL of Benedict's solution to each tube. Swirl the contents of each tube. 3. Place all of the tubes in a gently boiling water-bath for 3 min and observe color changes during this time. 4. After 3 min, use a test-tube holder to remove the tubes from the water-bath. After giving the tubes ample time to cool to room temperature, record the color of their contents in table 6.1. 5. When you are finished, dispose of the contents of each tube as instructed by your instructor. Biologically Important Molecules 59 Table 6.1 Solution 1 10 drops potato juice 3 mL 2 10 drops onion juice 3 mL 3 10 drops sucrose solution 3 mL 4 10 drops starch solution 3 mL 5 10 drops reducing-sugar solution 3 mL 6 10 drops reducing-sugar solution 3 mL 6 10 drops starch solutio sucrose or glucose? How do you know? Benedict's Color Reaction Iodine Color Reaction Procedure 6.2 Perform the iodine test for starch 1. Obtain seven test tubes and number them 1-7. 2. Add to each tube the materials. If so, include additional numbered test tubes. 3. Add three to six drops of iodine to each tube. 4. Record the color of the tubes' contents in table 6.1. Question 3 a. Which of the solutions is a positive control? C. Which colors more intensely, onion juice? Why? d What does this tell you about how sugars are stored in onions and potatoes? c. In what parts of a plant is the most starch typically stored? Iodine Test for Starch Starch starch is a coiled polymer of glucose; iodine interacts with these coiled molecules and becomes bluish black. Iodine does not react with carbohydrates that are not coiled and remains yellowish-brown color (i.e., no color change) is a negative test for starch. Glycogen, a common polysaccharide in animals, has a slightly different structure than does starch and produces only an intermediate color reaction. 60 EXERCISE 6 d. What are the functions of carbohydrates in living organisms? PROTEINS Proteins are remarkably versatile structural molecules found in all life forms (fig. 6.5). Proteins are made of amino acids (fig. 6.6) each of which has an amino group (-NH2), a 6-4 ©STEVE GSCHMEISSNER/Science Photo Library/Getty Images (a) Fibrin Thise/Getty Images (b) Collagen ©vonviper/Getty Images (c) Keratin ©Craig Veltri/iStockphoto/Getty Images (b) Collagen ©vonviper/Getty Images (c) Keratin ©Craig Veltri/iStockphoto/Getty Images (c) Keratin ©Craig Veltri electron micrograph shows a red blood cell caught in threads of fibrin (800×). Fibrin is important in the formation of blood clots. (b) Collagen. (c) Keratin. This type of protein makes up bird feathers, such as this peacock feather. (d) Spider silk. The web spun by this agile spider is made of protein. (e) Keratin. Hair is also made of protein. H H2N C CH3 H O H2N C OH O C C CH CH3 OH CH3 H H2N Valine OH CH3 Leucine carboxyl (acid) group of one amino acid and the carboxyl group of an adjacent amino acid and is identified by a Biuret test. Specifically, peptide bonds (C—N bonds) in proteins complex with Cu2+ in Biuret reagent and produce a 6-5 C CH2 CH3 Alanine O C Figure 6.6 Structures of three amino acids common in proteins. Each amino acid has one carbon bonded to both an amine group (-NH2) and a carboxyl group (-COOH). The side chains that make each amino acid unique are shown in red. color; therefore, individual amino acids do not react positively. Long-chain polypeptides (proteins) have many peptide bonds and produce a positive reaction. Biuret reagent is a 1% solution of CuSO4 (copper sulfate). A violet color is a positive test for the presence of protein; the intensity of color relates to the number of peptide bonds that react. Biologically Important Molecules 61 Table 6.2 Solutions and Color Reactions for the Biuret 52 mL Polypeptide chain b. Which contains more protein (C—N bonds), egg albumen or honey? How can you tell? Figure 6.7 A peptide bond joins two amino acids to form polypeptides, or proteins. The formation of a peptide bond (i.e., between the carbon of one amino acid's carboxyl group and the nitrogen of another amino acid's amino group) liberates a water molecule. The R in these amino acids represents a variable side chain that characterizes each type of amino acid shown. Procedure 6.3 Perform the Biuret test for c. Do free amino acids have peptide bonds? d. What are the functions of proteins in living organisms? protein 1. Obtain five test tubes and number them 1–5. Your instructor may ask you to test some additional materials. If so, include additional materials listed in table 6.2. 3. Add 2 mL of 2.5% sodium hydroxide (NaOH) to each tube. Do not spill the NaOH--it is extremely caustic. Rinse your skin if it comes in contact with NaOH. 62 EXERCISE 6 LIPIDS Lipids include a variety of molecules that dissolve in nonpolar solvents such as ether, acetone, methanol, or ethanol, but not as well in polar solvents such as ether. Palmitic acid H H Stearic acid Oleic acid H C H H C H H Figure 6.8 Triglycerides, which are also called triacylglycerides, consist of glycerol, with the removal of a water molecule. (b) Triacylglycerides are fats whose fatty acids vary in length and vary in the presence and location of carbon-carbon double bonds. Question 6 Examine figure 6.8. What are the reactive groups of the fatty acids? Handle acetone carefully; it is toxic. Procedure 6.4 Solubility of lipids in polar and nonpolar solvents 1. O tube, add 5 mL of acetone. 2. Add a few drops of vegetable oil to each tube. 6-7 Question 7 What do you conclude about the solubility of lipids in p olar solvents such as acetone? Procedure 6.5 Perform the Sudan IV test for lipids 1. Obtain five test tubes and number them 1-5. Your instructor may ask you to test some additional materials. If so, include additional numbered test tubes. 2. Add the materials listed in table 6.3. 3. Add five drops of Sudan IV to each of the remaining tubes. Mix the contents of each tube. Record the color of the tubes' contents in table 6.3. Biologically Important Molecules 63 Table 6.3 Solutions and Color Reactions for the Sudan IV Test for Lipids Tube Solution 1 1 mL salad oil + Sudan IV 5 1 mL known lipid solution + Sudan IV 5 1 mL known lipid solution of Reaction 6 7 Question 8 a. Is salad oil + Sudan IV 5 1 mL known lipid solution of the dye with respect to the separated water and oil? e. Lipids supply more than twice as many calories per gram as do carbohydrates. Based on your results, which contains more calories, oil or honey? Grease-Spot Test for Lipids A simpler test for Lipids A simp indicates a positive test for lipid? d. Does honey contain much lipid? Procedure 6.6 Perform the grease-spot test for lipids 1. Obtain a piece of brown wrapping paper or brown paper bag from your lab instructor. 2. Use an eyedropper to add a drop of salad oil near a corner of the piece of paper. 3. Add a drop of water near the opposite corner of the paper. 4. Let the fluids evaporate. 5. Look at the paper as you hold it up to a light. 6. Test other food products and solutions available in the lab in a similar way and record your results in table 6.4. Tabl 8 Table 6.5 Solutions and Color Reactions for Dische Diphenylamine Test for DNA solution 2 1 mL DNA solution 4 2 mL distilled water 3 2 mL RNA solution 4 2 mL distilled water 3 2 Place the tubes in a gently boiling water-bath to speed the reaction. 5. After 10 min, transfer the tubes to an ice bath. Gently mix and observe the color of their contents as the tubes 1 and 2? Why? NUCLEIC ACIDS DNA and RNA are nucleic acids made of nucleotide subunits (fig. 6.9). DNA can be identified chemically with the Dische diphenylamine test. Acidic conditions convert deoxyribose to a molecule that binds with diphenylamine test for DNA 1. Obtain four test tubes and number them 1-4. Your instructor may ask you to test some additional materials. If so, include additional materials. If so, include additional
materials listed in table 6.5. 3. Add 2 mL of the Dische diphenylamine reagent to each tube and mix thoroughly. b. Do DNA and RNA react alike? Why or why not? c. What are the functions of nucleic acids in living organisms? Handle the Dische diphenylamine reagent carefully; it is toxic. Wash your hands after the procedure. 6-9 Biologically Important Molecules 65 Purines Pyrimidines NH 2 O C O C N CH HN C C C N HN C N HN C C C N HN C C C N HN C N HN C C C N HN C N HN C C C N HN HN C N HN C N HN C N N CH H 2N N H H Uracil (in RNA) Adenine N H Guanine Nitrogenous base Phosphate Pentose sugar 5 O -O P O- (a) OH H 0 CH 2 O 4 H H 3 OH H 1 H 2 OH Ribose (in RNA) Figure 6.9 The structure of DNA and RNA. (a) Each nucleotide consists of three smaller building blocks: a nitrogenous base, a pentose sugar, and a phosphate group. (b) Nucleotides are bonded to each other by covalent bonds between the phosphate of one nucleotide. (c) DNA is usually a double strand held together by hydrogen bonds between the phosphate of one nucleotide. double strand is twisted into a double helix. 66 EXERCISE 6 6-10 Phosphate Base Sugar T A G T C T A T A T A G A G C C A (b) C G T (c) Figure 6.9 continued 6-11 Biologically Important Molecules 67 INQUIRY-BASED LEARNING I Identify unknowns Each of the previously described tests is relatively specific; that is, iodine produces a bluish-black color with starch but not with other carbohydrates, protein, lipid, or nucleic acids. This specificity can be used to identify the contents of an unknown solution. a. Obtain 10 clean test tubes. c. Number five tubes for the sample as S1-S5. Number the other five tubes as controls C1-C5. d. Place 2 mL of your unknown solution into each of tubes S1-S5. e. Place 2 mL of distilled water into each of tubes S1-S5. e. Place 2 mL of distilled water into each of tubes S1-S5. in table 6.6. Show table 6.6 and the following report (page 69) to your instructor before you leave the lab. INQUIRY-BASED LEARNING II Do plants store most of their food in roots or in leaves? Observation: Starch is the major storing starch. Iodine reacts with starch to produce a dark blue-black color. Question: What are the relative amounts of starch stored in leaves versus roots of a flowering plant? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 6 from your instructor. b. Discuss with your group well-defined questions relevant to the preceding observation and question. Choose and record your group's best question for investigation. 68 EXERCISE 6 c. Translate your question into a testable hypothesis. Ask your instructor to review your proposed investigation. e. Conduct your procedures, record your data, answer your question, and make relevant comments. f. Discuss with your instructor any revisions to your questions, hypothesis, or procedures. Repeat your work as needed. 6-12 Name Lab Section Unknown No. Table 6.6 Chemical Testing to Identify an Unknown Biochemical Test Color Sample Unknown Result Control (+/-) Benedict's test (reducing sugars) Iodine (starch) Biuret test (DNA) Sudan IV (lipid) Report: Identity of Unknown Indicate which of the following are in your unknown: Reducing sugars) Iodine (starch) Biuret test (DNA) Sudan IV (lipid) Report: Identity of Unknown Indicate which of the following are in your unknown: Reducing sugars) Iodine (starch) Biuret test (DNA) Sudan IV (lipid) Report: Identity of Unknown Indicate which of the following are in your unknown: Reducing sugars) Iodine (starch) Biuret test (DNA) Sudan IV (lipid) Report: Identity of Unknown Indicate which of the following are in your unknown: Reducing sugars) Iodine (starch) Biuret test (DNA) Sudan IV (lipid) Report: Identity of Unknown Indicate which of the following are in your unknown: Reducing sugars) Iodine (starch) Biuret test (DNA) Sudan IV (lipid) Report: Identity of Unknown Indicate which of the following are in your unknown: Reducing sugars) Iodine (starch) Biuret test (DNA) Sudan IV (lipid) Report: Identity of Unknown: Reducing sugars) Iodine (starch) Biuret test (DNA) Sudan IV (lipid) Report: Identity of Unknown: Reducing sugars) Iodine (starch) Biuret test (DNA) Sudan IV (lipid) Report: Identity of Unknown: Reducing sugars) Iodine (starch) Biuret test (DNA) Sudan IV (lipid) Report: Identity of Unknown: Reducing sugars) Iodine (starch) Biuret test (DNA) Sudan IV (lipid) Report: Identity of Unknown: Reducing sugars) Iodine (starch) Biuret test (DNA) Sudan IV (lipid) Report: Identity of Unknown: Reducing sugars) Iodine (starch) Biuret test (DNA) Sudan IV (lipid) Report: Identity of Unknown: Reducing sugars) Iodine (starch) Biuret test (DNA) Sudan IV (lipid) Report: Identity of Unknown: Reducing sugars) Iodine (starch) Biuret test (DNA) Sudan Important Molecules 69 Questions for Further Study and Inquiry 1. What is the importance of a positive control? What is the importance of a negative control? What is the importance of a negative control? What is the importance of a negative control? In today's lab? 3. Why did you include controls in all of your tests? 4. Are controls always necessary? Why or why not? 5. What is a phospholipid? What functions do phospholipids have in cells? 6. What does a "dehydration synthesis" do? 7. Food labels list the amounts of (and calories from) carbohydrates, fats, and proteins, but not nucleic acids. Why not? DOING BIOLOGY YOURSELF Design a procedure to indicate the amount of starch present in various plant tissue samples. How would you weigh your samples? How would you treat your samples? How would you quantify the iodine test? 70 EXERCISE 6 WRITING TO LEARN BIOLOGY What are the limitations of these common techniques in detecting the presence of a class of macromolecules? Do biologists who study plant cells commonly use the iodine test for starch? Why or why not? 6-14 Separating Organic Compounds E XER CISE Column Chromatography, and Gel Electrophoresis 7 Learning Objectives By the end of this exercise you should be able to: 1. Explain how column chromatography, and gel electrophoresis are used to separate compounds from mixtures. 2. Use column chromatography, paper chromatography, and gel electrophoresis to separate organic compounds from mixtures. Please visit connect.mheducation.com to review online resources tailored to this lab. C ells are a mixture of the types of organic compounds that you studied in Exercise 6 ("Biologically Important Molecules"), including carbohydrates, proteins, lipids, and nucleic acids. Biologists characterize and study these compounds, such as amino acids and nucleotides, from mixtures. Biologists often use chromatography to separate mixtures. In this procedure, the mixture is dissolved in a fluid that moves through a matrix made of materials such as beads, paper, or a gel. During the process, the different parts of the mixture move at different speeds, causing them to separate compounds from mixtures. The procedures are simple and model how these techniques are used by biologists in their research. COLUMN CHROMATOGRAPHY Column chromatography often separates molecules according to their size and shape. The procedure is simple and involves placing a sample onto a matrix that is a column of beads having tiny pores. Molecules can move through the column of beads in two ways: a fast route between the beads or a slower route through the column quickly, whereas smaller molecules is analogous to going through or walking around a maze: It takes more time to walk through a maze than to walk around it. The apparatus used for column, a matrix, and a buffer. 7-1 •• The chromatography column is a tube having a frit and a spout at its bottom. The frit is a membrane or porous disk that supports and keeps the matrix in the column but allows water and solutes to pass. •• The matrix is the material in the column that fractionates, or separates, the chemicals mixed in the sample. The matrix is the material in the column that fractionates of beads having the matrix is the material in the column that fractionates. fractionation range, which is the range of molecular weights are measured in units called daltons; 1 dalton ≈ 1 g mole-1. Different kinds of matrices have different fractionation ranges. In today's exercise you'll use a matrix having a fractionation range of 1000 to 5000 daltons. As they move through the matrix, small molecules spend much time in the maze of channels and pores in the matrix. Large molecules do not. •• The buffer is a solution with a known pH that resists changes in pH if other chemicals are added. The pH of a buffer is a solution with a known pH that resists changes in pH if other chemicals are added. because the shapes of molecules such as proteins often vary according to their pH. The buffer carries the sample through the matrix, which separate compounds having the same molecular weight but different shapes. Compact, spherical molecules penetrate the pores and channels of the matrix more readily than do rod-shaped molecules. Thus, spherical molecules move through a column more slowly than do rod-shaped molecules. Porous beads Organic molecules move through a column more slowly than do rod-shaped molecules. fastest and therefore appear in the earlier fractions. 1 2 3 4 5 6 Figure 7.1 Separation of organic molecules are slowed down as they pass through the pores of the beads. Medium-sized molecules will pass through the column, the smaller molecules are slowed down as they pass through the pores of the beads. largest molecules will quickly flow around all the beads. The exiting fluid is collected in fractions. The first fractions collected will containing the sample mixture of chemicals moves through the column and is collected will contain the beats. Biologists then assay the content of the tubes to determine which tubes contain the compounds in which they are interested. SAFETY FIRST Before coming to lab, you were asked to read this exercise so you would know what to do and be aware of safety issues. In the space
below, briefly list the safety issues associated with today's procedures. If you have questions about these issues, contact your laboratory assistant before starting work. Question 1 In today's exercise you will isolate colored compounds from mixtures. However, it is important to note that most biological 72 EXERCISE 7 samples are colorless. How would you determine the contents of the test tubes if all of the samples were transparent? Procedure 7.1 Separate compounds by column chromatography 1. Label nine microtubes 1-9. 2. Obtain an apparatus for column chromatography and carefully remove all of the buffer from above the beads with a transfer pipet. Do not remove any of the matrix. 3. Obtain a sample to be separated. The sample is a mixture of Orange G (molecular weight = 452 g mole-1) and a rodlike polymer of glucose stained blue and having a molecular weight of about 2,000,000 g mole-1. 7-2 Question 2 a. Was the color separate the compounds? Why or why not? b. Suppose your sample had consisted of a mixture of compounds having molecular weights of 50,000, 100,000, and 1,000,000 g mole-1. What type of results would you predict? Explain your answer. PAPER CHROMATOGRAPHY ©EDVOTEK, Inc. Figure 7.2 Apparatus for column chromatography. A fraction is being collected, drop by drop, in the beaker. Smaller fractions would be collected in test tubes. 4. Use a transfer pipet to slowly load 0.2 mL of the sample down the inside walls of the column. 5. Place a beaker under the sample down the inside walls of the beads. Close the valve after the sample to enter the beads. Close the valve after the sample to enter the beads. is exposed to air). 7. Use a transfer pipet to slowly cover the beads with buffer until the reservoir is almost full. 8. Hold microtube 1 under the column and open the valve until you have collected about 1.0 mL of liquid. 9. Repeat step 8 for tubes 2-9. The sample will separate in the column. 10. Identify the tubes containing (1) the most orange dye and (2) the most blue dye that eluted from the column. 11. Refill the reservoir with buffer and cover the reservoir with Parafilm. 7-3 Biologists often analyze the amino acid content of samples to determine protein sequences and enzyme structures. phases of paper chromatography. The stationary phase is the paper fibers, and the mobile phase is an organic solvent that moves along the paper. Separation by paper. The edge of the paper is then placed in a solvent. As the solvent moves up the paper, any sample molecules that are soluble in the solvent. However, some molecules move faster than others based on their attraction to the stationary phase. These competing factors are different for different molecules move faster than others based on their attraction to the stationary phase. moves at a different speed and occurs at a different position on the finished chromatogram. Amino acids in solution have no color but react readily with a ninhydrin solution and heated to detect the amino acids. The distance of these spots from the origin is measured and used to quantify the movement of a sample. The resulting Rf value (retardation factor) characterizes a known molecule in a known solvent under known solvent front Procedure 7.2 Separate amino acids and identify unknowns by paper chromatography 1. Obtain a piece of chromatography paper 15 cm square. Avoid touching the paper with your fingers. Use gloves, tissue, or some other means to handle the paper because oils from your skin will alter the migration of the molecules on the paper. Amino Acid Unknowns Tick Mark Number Amino Acid or Sample Rf Identity of Unknown 1 2 3 4 5 2. Lay the paper on a clean paper towel. Then use a pencil to draw a light line 2 cm from the bottom edge of the paper. 3. Draw five tick marks at 2.5 cm intervals from the left end of the line. Lightly label the marks 1-5 below the line. 4. Locate the five solutions available for the chromatography procedure. Three of the solution is a plant extract or another unknown. 5. Use a wooden or glass applicator stick to "spot" one of the solutions on mark #1. To do this, dip the stick in the solution and touch it to the paper to apply a small drop (2-3 mm in diameter). Let the spot dry; then make three to five more applications on the same spot. Dry between each applications. 7. Staple or paper clip the edges of the paper to form a cylinder with the spots on the outside and at the bottom. 8. Obtain a guart jar containing the chromatography solvent. The solvent should be 1 cm or less deep. The solvent must be below the pencil line and marks. Close the lid to seal the jar out of direct light and heat. Allow the solvent to move up the paper for 2 hours (h) but not all the way to the top. 11. Open the jar and remove the chromatogram. Unclip and flatten the paper. Dry it with a fan or hair dryer. Work under a fume hood if possible to avoid breathing the solvent vapors. 74 EXERCISE 7 12. Spray the chromatogram with ninhydrin. Carefully dry the chromatogram with warm air. 13. Circle with a pencil each of the spots. Measure the distance each of the spots. Measure the distance each of the spots. Measure the distance each of the spots. Record the results in table 7.1. GEL ELECTROPHORESIS Gel electrophoresis separates molecules according to their charged, and size (fig. 7.4). Buffered samples (mixtures of organic chemicals) are loaded into a Jello-like gel, after which an electrical current is placed across the gel. This current moves the charged molecules toward either the cathode or anode of the electrophoresis apparatus. The speed, direction, and distance that each molecule moves are related to its charge, shape, and size. The apparatus for gel electrophoresis is shown in figure 7.5 and consists of an electrophoresis is shown in figure 7.5 and consists of an electrophoresis chamber, gel, buffer, samples, and a power supply. derivative of agar) in hot buffer. When the solution cools, it solidifies into a gel having many pores that function as a molecular sieve. The buffer conducts electricity and helps control the pH. The pH affects the stability and charge of the samples. •• The samples are mixtures of chemicals loaded into wells in the gel. These samples move in the gel during electrophoresis. Samples are often mixed with he buffer. Jar with he buffer. Jar with he buffer so that they will not mix with the buffer. Jar with he buffer so that they will not mix with the buffer. Jar with he buffer so that they will not mix with the buffer so that they will not mix with the buffer. Jar with he buffer so that they will not mix with the buffer so that they will not mix with the buffer. Jar with he buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer. Jar with he buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer. Jar with he buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer. Jar with he buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so that they will not mix with the buffer so they will not mix with the buffer on the chromatogram indicate the positions of multiple samples applied to the chromatogram. The samples will move up the chromatogram along with the solvent. •• The power supply provides a direct current across the gel. Charged molecules move through the gel toward the positive electrode (anode), whereas positively charged molecules move through the gel toward the negative electrode (cathode). The greater the voltage, the faster the molecules move more easily through the pores than do larger molecules. Consequently, small, compact (e.g., spherical) molecules move faster than do large, rodlike molecules having the greatest charge move fastest and, therefore, the farthest. Procedure 7.3 Separate organic molecules by gel electrophoresis 1. Obtain an electrophoresis chamber. Cover the ends of the bed as shown in figure 7.6 and demonstrated by your instructor. 2. Place a six-tooth comb in or near the middle set of notches of the gel-cast bed. There should be a small space between the bottom of the teeth and the bed. Fragments of organic molecules are loaded into wells of a gel Large fragments (-) Small fragments Gel (+) Electric current turned on Fragments, and other organic compounds by causing them to move through an electrically charged gel. Because DNA molecules are negatively charged, the electrical field will push the molecules toward the positive electrode. The fragments also move according to their size and shape, and some fragments can be stained and visualized easily. In the example shown here, the DNA fragments were separated by size. 7-5

Separating Organic Compounds 75 Reaction Reaction Reaction 1 2 3 Power source Figure 7.5 Apparatus for gel electrophoresis. The power supply produces an electrical gradient between the + and - poles and across the gel. Mixture of DNA fragments of different sizes in solution placed at the top of "lanes" in the gel Lane - Cathode Gel + Anode Buffer ©EDVOTEK, Inc. Figure 7.6 Cover the ends of the removable gel bed with rubber end-caps or tape. 3. Mix a 0.8% (weight by volume) mixture of agarose powder in a sufficient volume of buffer to fill the gel chamber. Heat the mixture until the agarose dissolves. 4. When the hot agarose solution has cooled to 50°C, pour the agarose solution into the gel-cast bed (fig. 7.7). 5. After the gel has solidified, gently remove the comb by pulling it straight up (fig. 7.8). Use of a plastic spatula may help prevent tearing the gel. Use the sketch in figure 7.9 to label the wells formed in the gel by the comb. 6. Submerge the gel under the buffer in the electrophoresis chamber. 7. You will study six samples: Sample 1: Bromophenol blue (molecular weight = 670 g mole-1) 76 EXERCISE 7 © EDVOTEK, Inc. Figure 7.7 Place comb near the center set of notches of the gel solidifies, gently remove the rubber end-caps (or tape) and pull the combs straight up from the gel. 7-6 (-) 1 2 3 4 5 6 © EDVOTEK, Inc. Figure 7.10 Submerge the gel in the buffer-filled electrophoresis chamber and load the samples into the wells formed in the gel by the comb as viewed from above. 14. Sample 2: Methylene blue (molecular weight = 320 g mole-1) Sample 3: Orange G (molecular weight = 452 g mole-1) Sample 4: Xylene cyanol (molecular weight = 555 g mole-1) Samples 5 and 6: Unknowns Use a micropipettor, your instructor will demonstrate its use. If you use a simple pipet and bulb, gently squeeze the pipet bulb to draw Sample 1 into the pipet. Be sure that the sample is in the lower part of the pipet. If the sample is near the pipet's opening. 9. Place the pipet tip into the electrophoresis buffer so it is barely inside sample well. I (fig. 7.10). Do not touch the bottom of the sample well. Stop squeezing the pipet when the well is full. Do not 7-7 15. 16. release the pressure on the bulb. Remove the pipet from the well. Thoroughly rinse the pipet with distilled water. Load the remaining five samples into the gel by repeating steps 6-10 (fig. 7.10). Load Sample 2 into the second well, Sample 3 into the third well, etc. Carefully snap on the cover of the electrophoresis chamber (fig. 7.11). The red plug in the cover should be placed on the terminal indicated by the red dot. The black dot. Insert the plug of the power supply. Insert the plug of the power supply. Insert the plug of the red wire into the black dot. voltage at 90 V. You'll soon see bubbles forming on the electrodes. Examine the gel every 10 min. After 30 min, turn off the power and disconnect the leads from the cover from the cover, connect the power source, and runnel disconnect the leads from the cover from the power source. the electrophoresis. Separating Organic Compounds 77 Question 3 a. Bromophenol blue, Orange G, and xylene cyanol each has a negative charge at neutral pH. How does this information relate to your results? c. What compounds do you suspect are in Samples 5 and 6? Explain your answer. INTERPRETING A DNA-SEQUENCING GEL b. Did Orange G, bromophenol blue, and xylene cyanol move the same distance in the gel? Why or why not? Examine figure 7.12, which includes a photograph of a gel used to determine the order, or sequence, of nucleotides in a strand of DNA. To prepare the sample for A T G C Single-stranded DNA fragment to be sequenced 5' A T G C T A T G C T A T G C T A T G C T A T G C T A T G C T A T G C T A T GC T fragments Smaller fragments (e) Courtesv George Kantor Figure 7.12 Determining the sequence of nucleotides in DNA. (a) Treating DNA with sodium hydroxide (NaOH) denatures double-stranded DNA into single-stranded DNA. (b) The enzyme DNA polymerase is added to each tube along with a specific nucleotide-terminator. As polymerase replicates the DNA, the terminator are incorporated and will terminator are incorporated and will terminator ddATP (dideoxy adenosine triphosphate) will terminate a growing strand because it lacks a 3' hydroxyl group and therefore cannot bond with the next deoxynucleotide. (c) Each tube will contain a sample of all possible replicated fragment lengths corresponding to the positions of that specific nucleotide. The sequences in red are the complement strands. (d) During electrophoresis, the fragments migrate at different rates according to their length. (e) The lanes of the resulting gel are labeled according to their base: A, adenine; T, thymine; G, guanine; and C, cytosine. This technique is usually referred to as "Sanger" sequencing in honor of Fred Sanger, a Nobel laureate who, in 1977, first sequenced a piece of DNA. 78 EXERCISE 7 7-8 electrophoresis, samples of the DNA being investigated were put into each of four tubes and induced to replicate. Also, into the first tube, an adenine-terminator was being constructed, the terminators were occasionally incorporated wherever an adenine nucleotide was used. This random incorporation resulted in all possible lengths of DNA pieces that had an adenine on the end. The same process was conducted in the gel. Electrophoresis separated the replicated pieces of DNA by size. Staining the gel revealed which lengths of the complementary DNA were terminated by which nucleotide-terminators. Examine figure 7.12d. The gel consists of four "lanes," labeled A, T, G, and C, indicating either adenine-, thymine-, guanine-, or cytosine-terminated pieces of DNA. By "reading" down the gel, you can determine the sequence of nucleotides in the DNA. For example, the uppermost band of the gel is in the T (thymine) lane. Therefore, the first base of the piece of DNA is thymine. Similarly, the next bands are in the A, C, G, and A lanes. Thus, the first five bases of the complementary strand DNA are T-A-C-G-A. List the next seven nucleotides of the DNA as indicated by the gel. Also list the sequence of the first 12 nucleotides in the original DNA being investigated. Question 4 a. How did the sequence of nucleotides revealed on the gel differ from the sequence of the original strand of DNA? b. Assume that the gel shown in Figure 7.12d is from blood collected at a murder scene. This blood does not match that of the victim. You have collected DNA from five people suspected of murder. Gels comparable to the one shown in Figure 7.12d read as follows for each of the suspects: Suspect #4: T-A-C-G INQUIRY-BASED LEARNING I Is there always room for improvement in laboratory techniques? Carefully planned and refined procedures are critical for laboratory techniques such as paper chromatography. The sensitivity of these techniques are critical for laboratory techniques are critical for l measurements, and temperatures. In procedure 7.2 you were given a rather standardized protocol, but it can always be improved for specific experimental procedure to better resolve two amino acids having approximately the same Rf values? What parameter(s) of the experimental design might be tweaked to increase the technique's resolving power? We suggest that you begin your investigation in the following way: a. List the parameters involved. b. Choose one or two parameters that you can test for their impact on the chromatography results. Why did you choose these? c. Choose two amino acids for experimentation. Why did you conclude? 7-9 Separating Organic Compounds 79 INQUIRY-BASED LEARNING II What's the best column length for effective column chromatography? Observation: Column chromatography is a common means of separating molecules according to their size and shape. The movement of molecules through a column's length. Question: How does the length of a column affect the separation of molecules via column chromatography? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 7 from your instructor. b. Discuss with your group
well-defined question. c. Translate your question into a testable hypothesis and record it. d. Outline on Worksheet 7 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your procedures, record your data, answer your questions, hypothesis, or procedures. Repeat your work as needed. Questions for Further Study and Inquiry 1. How are column chromatography, paper chromatography, paper chromatography, and gel electrophoresis vary if the voltage was increased? If the agarose was made more dense? Or if the migration was allowed to run twice as long? 3. How could knowing the nucleotide base sequence of a piece of DNA be important to someone studying a hereditary disease? 6. How could knowing the nucleotide base sequence of a piece of DNA be important for someone wanting to improve the yield of a crop such as corn? WRITING TO LEARN BIOLOGY Which of the methods discussed in this exercise would best quantify the relative amounts of the molecules being separated? Why? 80 EXERCISE 7 7-10 E XER CISE Spectrophotometry 8 Identifying Solutes and Determining Their Concentration Learning Objectives By the end of this exercise you should be able to: 1. Operate a spectrophotometer. 2. Describe the parts of a spectrophotometer and the function of each. 3. Construct absorption spectra for cobalt chloride and chlorophyll. 4. Construct and use a standard curve to determine the unknown concentration of a dissolved chemical. Please visit connect.mheducation.com to review online resources tailored to this lab. A bsorption and reflect different wavelengths of light; therefore they have different colors. When you recognize things with color, you are observing that they absorb, transmit, and reflect different wavelengths to your eyes and absorbs the other wavelengths of light. For example, a red object reflects red wavelengths to your eyes and absorb the other wavelengths. Light includes the visible wavelengths of the electromagnetic spectrum and is only a small part of the total spectrum. The entire electromagnetic spectrum includes radiation with wavelengths from less than 1 to more than 1 million nanometers. Visible light represents wavelengths between 380 and 700 nm (fig. 8.1). In this exercise you will work within the visible portion of the electromagnetic spectrum. Question 1 a. Chlorophyll reflects and transmits green light (540-560 nm) and absorbs other wavelengths. What biologically important molecules other than chlorophyll absorb and reflect certain colors? Increasing wavelength 10 nm 1000 nm 0.01 cm 1 cm X rays UV light Infrared 1m 100 m Radio waves Visible light 400 nm 430 nm 500 nm 560 nm 600 nm 650 nm 740 nm Figure 8.1 The electromagnetic spectrum. Light is a form of electromagnetic energy and is conveniently thought of as a wave. The shorter the energy. Visible light, which represents a small part of the electromagnetic spectrum, can be separated by a prism. The wavelengths of visible light range between 380 and 700 nanometers (nm). (UV stands for ultraviolet light.) Also see figure 8.5. 8-1 Spectrophotometry 81 b. Is the absorbance of light critical to these molecules' functions or just a consequence of their molecular structure? for assays ranging from blood chemistry to pollutants in lake water. Spectrophotometry is based on the principle that every different atom, molecule, or chemical bond absorbs a different pattern of light. For example, the nitrogenous base cytosine absorbs a different pattern of light than does adenine, uracil, or any other molecule with a different structure. As part of this pattern, some wavelengths are absorbed and some are not absorbed. Conversely, a unique pattern of light is reflected as well as absorbed by each chemical. Each chemical has a unique pattern of "fingerprint" of various wavelengths that it absorbs and/or reflects. In this exercise you will (a) determine the unique pattern of absorption for two common molecules and then (b) use spectrophotometer measures the amount of light absorbed and transmitted by a dissolved chemical. For solutions we usually refer to the nonabsorbed light as transmitted light rather than reflected light. By measuring the pattern of absorbance or transmittance we can identify a chemical and its concentration. A spectrophotometer separates white light into a spectrum of colors (wavelengths). It then directs a specific wavelengths). It then directs a specific wavelength of light at a tube containing a solution that we are trying to measure. The light either is absorbed by the dissolved substance or is transmitted through the solution and exits the sample tube. The spectrophotometer also calculates the amount of light absorbed—the more solute, the higher the absorbance. The basic parts of a spectrophotometer are shown in figure 8.2. The light, a combination of all visible wavelengths. A mixture of all colors of light is white. Spectrophotometery may involve wavelengths outside the visible range, such as ultraviolet and infrared, but the spectrophotometer must have special light sources to produce these wavelengths. In this exercise you will work only with visible light. The filter is adjusted to select the wavelengths. In this exercise you will work only with visible light sources to produce these wavelengths. colors and focuses the desired wavelength (color) on the sample. Or the filter may be a series of colored glass plates that absorb all but the selected wavelength focused on the sample. The sample is a solution contained in a clear test tube or cuvette made of glass or quartz. Digital meter Wavelength selector Wavelength coarse filter Zero control © BiologyImaging.com Figure 8.2 A spectrophotometer and its parts. 82 EXERCISE 8 8-2 wavelength determined by the filter passes into the sample, where it may be completely or partially absorbed or transmitted. The amount of light absorbed depends on the amount and type of chemicals in the solution and the dimensions of the tube. A blank is a test tube or cuvette containing only the solvent used to dissolve the chemical you are analyzing. A blank is distilled water Any light transmitted through the sample on the opposite side and is focused on a photo detector that converts light energy into electricity produced by the photodetector is proportional to the amount of transmitted light: The more light that is transmitted through the sample, the more electricity produced. The meter on the front of the spectrophotometer measures the electrical current produced by the photodetector and displays the results on a scale of absorbance or transmittance values. If a chemical is in solution, we usually refer to its transmittance values. scale on the spectrophotometer indicates that you can measure either absorbance or transmittance is the amount of radiation. Absorbance is the amount of radiation passing through the sample. In mathematical terms, transmittance is the intensity of light exiting the sample divided by the amount entering the sample. Transmittance is usually expressed as a percentage: Percentage Transmittance = (It /Io) × 100 where It = transmittance is the logarithm of the reciprocal of transmittance and is expressed as a ratio with no units. Absorbance can be calculated with the Beer-Lambert Law: Absorbance = log10 (Io /It) Absorbance is not a percentage and is not simply the opposite (reciprocal) of transmittance. Instead, it is a logarithmic function and has no units. This calculation makes absorbance values directly proportional to the concentration of the substance in solution. Thus, a twofold increase in absorbance indicates a twofold increase in concentration. This convenient and direct relationship between concentration and absorbance helps scientists measure an unknown concentrations of dissolved chemicals, two procedures must be done-determine a chemical's absorption spectrum and build a standard curve. As you proceed with this exercise, be sure that you understand the differences between these procedures. ABSORPTION SPECTRUM OF COBALT CHLORIDE Your first task is to learn to operate a spectrophotometer while deriving the absorbed by CoCl2 is its "fingerprint" because it is unique to that chemical. This fingerprint is the absorp tion spectrum of the chemical and is represented as a graph relating absorbance to wavelength (fig. 8.3). Your instructor may choose to use red dye to simulate CoCl2. SAFETY FIRST Before coming to lab, you were asked to read this exercise so you would know what to do and be aware of safety issues. In the space below, briefly list the safety issues associated with today's procedures. If you have questions about these issues, contact your laboratory assistant before starting work. Procedure 8.1 Determine the absorption spectrum of CoCl2 1. When you get to the lab, turn on the spectropho tometer at your work-station. Let it warm up for 10-15 min before you begin work. 2. Check with your instructor or manufacturer's directions for any special instructions for any special instructions for any special instructor or manufacturer's directions for any special instructions for mg/mL) listed in table 8.1. Only tubes 0 and 6 are needed to determine the absorption spectrum. You will use the others later in the lab period. 4. After you have prepared the dilutions, clean the outside of all the tubes with a cloth or paper towel. 5. Verify that the solutions in each of your tubes are free of particles (dust, chalk, etc.) that might scatter the light from the spectrophotometer and produce false absorbance values. If necessary, centrifuge the tubes at 2000 rpm for 5-10 min. Question 2 Why is it important to clean the sample tubes? 6. Cap the tubes and label the caps 0-6. If you label the tubes and label the caps 0-6. If you label the tubes at 2000 rpm for 5-10 min. Question 2 Why is it important to clean the sample tubes? is in the spectrophotometer. 8-3 Spectrophotometery 83 Absorption spectrum of cobalt chloride Absorbance 2 1 0 350 420 460 530
490 570 610 660 Wavelength (nm) Figure 8.3 Absorption spectrum of cobalt chloride (CoCl2). Table 8.1 Volumes of Cobalt Chloride Stock Solution (100 mg/mL) and Water Used to Prepare Seven Known Dilutions Tube Number Concentration of CoCl2 (mg/mL) 0 0 CoCl2 Stock (mL) 0 Distilled H2O (mL) 10.0 1 1 0.1 9.9 2 10 1.0 9.0 3 20 2.0 8.0 4 30 3.0 7.0 5 40 4.0 6.0 6 50 5.0 5.0 7. Place the blank (tube 0) in the sample holder of the spectrophotometer. 8. Adjust the filter to the lowest wavelength (350 nm) and read the absorbance value indicated on the meter. The distilled water blank has no color and should not absorbance is not zero, use the zero adjust knob to calibrate the meter to zero on the absorbance is not zero, use the zero adjust knob to calibrate the meter to zero adjust knob to calibrate the meter to zero adjust knob to calibrate the meter to zero. cobalt chloride. 11. After the meter has stabilized (5-10 sec) read the absorbance value and record the wavelength and absorbance for CoCl2 (50 mg/mL) Wavelength Absorbance Wavelength 350 nm 420 nm 570 nm 460 nm 610 nm 490 nm 660 nm Absorbance Table 8.3 Absorbance Values for Six Solutions of Known Concentration (Standards) of CoCl2 at the Peak Absorbance Wavelength = 1 10 20 30 40 50 13. Put the blank back into the spectrophotometer and readjust for zero absorbance Wavelength. The spectrophotometer should be recalibrated with the blank often, especially when you change the wavelength. 14. Insert tube 6 and measure its absorbance at the new wavelength. Record the absorbance of the contents of tube 6. The absorbance values in table 8.2 represent the absorption spectrum for CoCl2 and are expressed best with a graph. Plot on figure 8.3 the Absorbance versus Wavelength is the peak absorbance of CoCl2? b. Why is it important to recalibrate with your blank sample often? c. Would you expect a curve of the same shape for another molecule such as chlorophyll? Why or why not? THE STANDARD CURVE A graph showing a chemical's concentration versus its absorbance of a wavelength of light is called a standard curve, and the relationship is a straight line. In this exercise you will construct a standard curve and then use it to determine some unknown concentrations of Solutions of CoCl2 prepared by your instructor. Use the six dilutions are standard s because their concentrations are known, and they are used to determine the concentration of an unknown solution. The absorbance of each standard is measured at the peak wavelength of the absorption spectrum for CoCl2. Procedure 8.2 Construct a standard curve for cobalt chloride 1. Refer to your data in table 8.2. Determine the wavelength of peak absorbance of each standard curve for cobalt chloride 1. Refer to your data in table 8.2. Determine the wavelength of peak absorbance for CoCl2 and set the filter of your spectrophotometer to this wavelength. Insert the solvent blank (tube 0) and adjust the spectrophotometer for zero absorbance. 8-5 Spectrophotometry 85 Table 8.4 Measurements of Absorbance Concentration (mg/mL) Unknown Unknown Unknown 3. Replace the blank with tube 1 (1 mg CoCl2/mL), measure its absorbance, and then record the absorbance value in table 8.3. 4. Repeat steps 2–3 for the other five tubes (standards). Be sure and check the zero-absorbance calibration (mg/mL) on the horizontal axis and Absorbance on the vertical axis on the graph paper at the end of this exercise. 6. Because the relationship between concentrations of a straight line that lies as close as possible to each data point. Do not merely connect the dots. Extremely high concentrations of a solute can produce a nonlinear segment of the standard curve. However, the concentrations used in this lab exercise are not high enough to produce such "saturation" effects. 7. If a computer and software are available, calculate and plot the line of best fit. Question 4 Do the plotted data points of your standard curve lie on a straight line? 2. Use the blank tube (tube 0) to zero the spectrophotometer at the wavelength of peak absorbance for CoCl2. 3. Measure the absorbance of the unknown solution and record this value in table 8.4. 4. Find this absorbance of the unknown solution and record the unknown standard curve (see the example in fig. 8.4). 5. Draw a line from the intersection straight down until it intersects the horizontal axis. This point on the unknown solution. 6. Record the concentration of the unknown solutions, determine their absorbance and concentration, and record the values in table 8.4. Ask your instructor to check your results. ABSORPTION SPECTRUM OF CHLOROPHYLL To give you more experience with absorption spectra, your instructor has prepared a plant extract containing chlorophyll, a photosynthetic pigment (fig. 8.5). The extract was made by grinding leaves in acetone. Acetone is flammable. Keep all solvents away from hotplates and flames at all times. Using the Standard Curve, measuring the unknown concentration of a Solution is easy. Your instructor has prepared a series of numbered tubes solvent used for the blank. 2. Using procedure 8.3 for determining an absorption spectrum, measure the absorbance of chlorophyll for at least eight wavelengths available on your results (in fig. 8.6) as you did for the absorption spectrum of CoCl2. 8-6 Absorbance @ peak wavelength of absorbance value of unknown solution 1 Concentration of the concentration of an unknown solution of CoCl2. Chlorophyll a Chlorophyll b on the x-axis at the wavelengths shown Relative absorption of light β-carotene 350 400 450 500 Violet Blue Green 550 600 650 Yellow Red 700 750 Wavelengths of sunlight absorbed by the two common forms of photosynthetic pigment, chlorophylls a and b, and by the carotenoids. Chlorophylls absorb predominantly violet-blue and reflect green light in two narrow bands of the spectrum; this is why chlorophyll appears green. Carotenoids absorb mostly blue and green light in the middle of the spectrum; this is why carotenoids absorb mostly blue and reflect green light in the middle of the spectrum and reflect green. Question 5 a. What is the proper blank for determining the absorption of chlorophyll in a plant extract? b. Which wavelengths are least absorbed by chlorophyll? 8-7 Spectrophotometry 87 Table 8.5 Absorbance Values for a Plant Extract Containing Chlorophyll? 8-7 Spectrophotometry 87 Table 8.5 Absorbance Values for a Plant Extract? nm 660 nm Absorbance Absorption spectrum of chlorophyll Absorbance 2 1 0 350 420 460 490 530 570 610 660 Wavelength (nm) Figure 8.6 Absorption spectrum of chlorophyll? 88 EXERCISE 8 8-8 INQUIRY-BASED LEARNING Biological samples are not always pure. How do contaminants impact spectrophotometry? Observation: Spectrophotometry uses the differential absorp tion of light to identify and measure the concentrations of various molecules. The molecules of interest are not the only molecules that absorb light; contaminants do also and, therefore, affect measurements. Question: How does a contaminant such as salt affect the absorption of light by a spectrophotometric sample? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 8 from your instructor. b. Discuss with your group well-defined questions relevant to the preceding observation and question. Choose and record your group is best question for investigation. c. Translate your question into a testable hypothesis and record it. d. Outline on Worksheet 8 your experimental design and supplies needed to test your procedures, record your data, answer your question, and make relevant comments. f. Discuss with your instructor any revisions to your questions, hypothesis, or procedures. Repeat your work as needed. Questions for Further Study and Inquiry 1. What is the difference between an absorption spectrum and a standard curve? 2. Can spectrophotometry be used to determine the concentration of "colorless" solutes such as salt or sugar? Explain your answer. 3. Why is it important to use standards or to develop a standard curve in spectrophotometry? 4. Why do leaves of plants appear green? Would plants grow well in greenish-yellow light? Explain your answer. 5. How might the basic techniques that you leaves of plants appear green? Would plants grow well in greenish-yellow light? collected during the summer and red leaves collected in autumn? Explain your answer. 8-9 Spectrophotometry 91 92 EXERCISE 8 8-12 E XER CISE 8 8-10 8-11 Spectrophotometry 91 92 EXERCISE 8 8-10 8-11 Spectrophotometry 91 92 8-11 Spectrophotometry 91 92 8-11 Spectrophotometry 91 92 8-11 Spectrophotometry 91 8-11 Spe the end of this exercise you should be able to: 1. Understand Brownian movement and its relationship to molecular movement. 2. Explain the factors controlling a substance's direction and rate of diffusion. 3. Determine the direction and rate of understand Brownian movement. cells surrounded by hypotonic, hypertonic, and isotonic environments. 5. Describe how hypotonic, and isotonic solutions affect the volume and integrity of blood cells and plant cells. Please visit connect.mheducation.com to review online resources tailored to this lab. A ll molecules display random thermal motion, or kinetic energy; this is why a dissolved molecule tends to move around in a solution. This random movement is constant, but the net movement of molecules is homogenous throughout the solution. For example, when a dye dissolves in a container of water, the dye disperses. The rate of dispersal depends on the temperature and concentration of the dye into a glass of water (fig 9.1). SAFETY FIRST Before coming to lab, you were asked to read this exercise so you would know what to do and be aware of safety issues. In the space below, briefly list the safety issues associated with today's procedures. If you have questions about these issues, contact your laboratory assistant before starting work. BROWNIAN MOVEMENT Heat causes random motion of molecules that passively moves molecules in biological systems.
Although we cannot directly see molecules move, we can see small particles move, we can see small particles move, we can see small particles move after they collide with moving molecules. with a microscope. The dead pollen grains were moving. They were being jostled by collisions from water molecules, Brownian movement is visible using your microscope's high magnification. Carmine red dye mixed with soap is a good suspension of small particles. The red dye particles are small enough to vibrate when water molecules bump into them. 9-1 ©McGraw-Hill Education/Charles D. Winters, photogrpaher Figure 9.1 Beakers of water before and after diffusion of a dye. Random movements of water and dye molecules drive diffusion, eventually resulting in a uniform distribution of the dye. Diffusion and Osmosis 93 Procedure 9.1 Observe Brownian movement 1. Place a small drop of a carmine red suspension on a microscope slide and cover the drop with a coverslip. 2. Focus first at low magnification; then rotate to higher power (40×). Be careful not to get dye on the objective lens. 3. Fine focus the image. At first the field of view will appear uniformly reddish gray. But with sharp focus, you will see thousands of small particles vibrating rapidly. 4. Check with your instructor to determine if your microscope has oil immersion magnification and if you need this to easily view the particles. If needed, follow his or her instructors for using this objective. 5. Leave the microscope light on. Observe any changes in motion caused by increased heat. Question 1 a. Briefly describe your observation of the moving pigment particles. b. Does the movement of particles change visibly with heat? If so, how? DIFFUSION In biological systems, substances often move through solutions and across membranes in a predictable direction. This passive, directional movement of molecules is diffusion (fig. 9.2). The direction of diffusion depends on the concentration, heat, and pressure to an area of low concentration, heat, and pressure. The rate of diffusion is determined by the steepness of the gradient and other characteristics of the specific molecule in question, such as its size, polarity, or solubility. Temperature, pressure, and concentration is usually the best predictor of a substance's direction of diffusion. But remember that temperature and pressure gradients may also affect diffusion. Diffusion and Molecular weight = 929 g mole-1), or methylene blue (molecular weight = 374 g mole-1). Question 2 Which would diffuse faster: a substance having a low molecules (solvent) dye mol results Figure 9.2 Process of diffusion. Diffusion is spontaneous, and no chemical energy is required to bring it about. (a) When a dye crystal is placed in water, and there is a net movement of water molecules from a higher to a lower concentration. (c) Eventually the water and dye molecules stop moving when diffusion as affected by b. Do molecules stop moving when diffusion as affected by b. Do molecules are equally distributed throughout the container. 94 EXERCISE 9 9-2 Procedure 9.2 halos of color. These halos indicate that the chemicals have diffused away from the two original spots and moved through the agar. 2. Measure the halos. DIFFUSION AND DIFFERENTIALLY PERMEABLE MEMBRANES molecular weight Question 3 a Considering the different molecular weights of potassium permanganate, malachite green, and methylene blue, which should have the larger halo after the same amount of time? Why? Large organic molecule Membranes surround cells and organelles and organe cellular membrane does not isolate a cell. Instead, it allows a cell to selectively communicate with its environment. Membranes are "alive" in the sense that they respond to their environment and allow some molecules to pass while retarding others. Thus, membranes are selective and differentially permeable (fig. 9.3). This selective permeability results from the basic structure of membranes. They have a two-layered core of nonpolar lipid molecules not readily soluble in lipids. You will learn more about membrane structure in Exercise 10. Membrane permeability to a solute depends on the solute's size, charge (ions), polarity, and lipid solubility. Polar molecules have positively charged areas and negatively charged areas. Nonpolar molecules have no local areas of charge. Small, uncharged, nonpolar, lipid-soluble membrane (see fig. 10.4). Differentially permeable membrane (see fig. 10.4). movements of some molecules but not others. Arrows indicate the movement of small molecules, such as water, from an area of high concentration. The large molecules pass through the membrane more easily than do large molecules. We can demonstrate membrane selection for molecular size by using a bag made from dialysis tubing to model a differentially permeable membrane. Dialysis is the separation of dissolved substances by means of their unequal diffusion through a differentially permeable membrane. differentially permeable membranes because they have small molecules such as glucose. However, remember that living cell membranes also discriminate among molecules such as glucose. However, remember that living cell membranes also discriminate among molecules such as glucose. is only a physical model of a cell, and its selectivity is based only on molecular size. Examine some dialysis tubing. Although the dried material looks like a narrow sheet of cellophane, it is a flattened, open-ended tube. In procedure 9.3 you will use two indicators: phenol phthalein and iodine. Phenolphthalein is a pH indicator that turns red in basic solutions (see Exercise 5). Iodine is a starch indicator that changes from yellow to dark blue in the presence of starch (see Exercise 6). Procedure 9.3 Observe diffusion across a differentially permeable membrane 1. Obtain four pieces of starch (see Exercise 6). of each bag by folding over 1-2 cm of the end. Then accordion-fold this end and tie it tightly with monofilament line or string (fig. 9.4). The ends of the tube must be sealed tightly to prevent leaks. Obtain a soaked dialysis tube Fold one end; tie securely 3. Roll the untied end of each tube between your thumb and finger to open it and form a bag. 4. Use either a graduated cylinder or pipet to fill one tube with 10 mL of starch suspension. Seal the open end of the bag by folding the end and tying it securely. 5. Fill the other bag with 10 mL of starch suspension. Seal the open end of the bag by folding the end and tying it securely. 5. Fill the other bag with 10 mL of starch suspension. tap water. 7. Fill a beaker with 200 mL of tap water and add 10 drops of 1 M sodium hydroxide (NaOH). Submerge the dialysis bag containing phenolphthalein in the beaker. Do not spill the NaOH. It is extremely caustic. If it spills on your skin, wash it off immediately and clean tabletops thoroughly. 8. Fill a beaker with 200 mL of tap water and add 20-40 drops of iodine. Submerge the dialysis bag containing starch in the beaker. 9. Observe color changes in the two bags' contents and the surrounding solutions. 10. In this experiment some of the solutes can move through the membrane, but the movement of water is not of interest in this experiment. 11. Record in figure 9.5 the color inside and outside the bags. Label the contents inside and outside the bags. Add appropriate containing appropriate solution Figure 9.4 Preparation of dialysis tubing as a model of a cell surrounded by a differentially permeable membrane. 96 EXERCISE 9 9-4 (a) (b) Figure 9.5 (a) Movements and reaction of sodium hydroxide and phenolphthalein through a differentially permeable membrane. (b) Movements and reaction of sodium hydroxide and phenolphthalein through a differentially permeable membrane. Question 4 a. Describe color changes in the two bags and their surrounding solutions. b. For which molecules and ions (phenolphthalein, iodine, starch, Na+, OH-) does your experiment give evidence for passage through the membrane from those that do not pass through the membrane? OSMOSIS AND THE RATE OF DIFFUSION ALONG A CONCENTRATION GRADIENT The speed at which a substance diffuses from one areas to another depends primarily on the concentration gradient between those areas. For example, if concentrations of a diffusing substance at the two areas differ greatly, then diffusion is rapid. Conversely, when the concentration of a substance. Osmosis is diffusion rate is zero and there is no net movement of the substance. Osmosis follows the same laws as diffusion but always refers to water, the principal solvent in cells. A solution is a homogenous, liquid mixture of two or more 9-5 kinds of molecules. A solvent is a fluid that dissolves substances, and a solute is a substance dissolved in a solution. We can simulate osmosis by using dialysis bags to model cells under different conditions and then measuring the direction and rate of osmosis. Each of the four dialysis bags to model cells under different conditions and then measuring the direction and rate of osmosis. bags in the following experiment is a model of a cell. Bag A simulates a cell containing a solute concentration that is hypotonic to the solution surrounding the bag is hypertonic to the concentration of solutions. Bag B represents a cell whose solute concentration of the surrounding solution; this cell (bag B) is isotonic to its environment. Isotonic refers to two solutions that have equal concentrations of solutes. The solutions in bags C and D are both hypertonic to the solutions than their surrounding the cells—that is, the cells (bags C and D) contain higher solute (sugar) does not pass through the membrane -only the water does. NOTE Start this experiment at the beginning of the lab period so that you'll have enough time to see results. Procedure 9.4 Observe osmosis across a concentration gradient 1. Obtain eight pieces of string and tying it tightly. Diffusion and Osmosis 97 10% sucrose Bag B 10 mL 1% sucrose Bag B 10 mL 1% sucrose Bag C 10 mL
1% sucrose Bag C 10 mL 1% sucrose Bag B 10 mL 1% sucrose Bag C 10 mL 1% sucrose Bag B 10 the contents shown in figure 9.6. To label each bag, insert a small piece of paper with the appropriate letter (A, B, C, or D written on it in pencil). 4. For each bag, loosely fold the open end and press on the sides to push the fluid up slightly and remove most of the air bubbles. Tie the folded ends securely, rinse the bags, and check for leaks. 5. Gently blot excess water from the outside of the bags and weigh each bag to the nearest 0.1 g. 6. Record these initial weights in table 9.1 in the first column. 7. Place bags B, C, and D in three individual beakers or one large bowl filled with 1% sucrose (fig. 9.6). Record the time. 8. Place bags B, C, and D in three individual beakers or one large bowl filled with 1% sucrose (fig. 9.6). Record the time. 8. Place bags B, C, and D in three individual beakers or one large bowl filled with 1% sucrose (fig. 9.6). Record the time. 8. Place bags B, C, and D in three individual beakers or one large bowl filled with 1% sucrose (fig. 9.6). Record the time. 8. Place bags B, C, and D in three individual beakers or one large bowl filled with 1% sucrose (fig. 9.6). Record the time. 8. Place bags B, C, and D in three individual beakers or one large bowl filled with 1% sucrose (fig. 9.6). Record the time. 8. Place bags B, C, and D in three individual beakers or one large bowl filled with 1% sucrose (fig. 9.6). Record the time. 8. Place bags B, C, and D in three individual beakers or one large bowl filled with 1% sucrose (fig. 9.6). Record the time. 8. Place bags B, C, and D in three individual beakers or one large bowl filled with 1% sucrose (fig. 9.6). Record the time. 8. Place bags B, C, and D in three individual beakers or one large bowl filled with 1% sucrose (fig. 9.6). Record the time (fig. 9.6 sucrose. Record the time. 9. Remove the bags from the beakers at 15-min intervals for the next hour (or at intervals, use your instructor), gently blot them dry, and weigh them to the nearest 0.1 g. Handle the bags delicately to avoid leaks, and quickly return the bags to their respective containers. 10. During the 15-min intervals, use your knowledge of osmosis to make hypotheses about the direction of water flow in each system (i.e., into or out of bag), and the extent of water flow in each system (i.e., in which system (i.e., into or out of bag), and the extent of water flow in each system (i.e., into or out of bag). 11. For each 15-min interval record the total weight of each bag and its contents in table 9.1. Then calculate and record in table 9.1 the change in weight since the previous weighing. Procedure 9.5 Graph osmosis 1. Use the graph paper at the end of this exercise to construct a graph with Total Weight is the dependent variable. The dependent variable is always graphed on the vertical axis. Time is the variable that you established and actively controlled and, therefore, is the independent variable. The independent variable is always graphed on the horizontal axis. Table 9.1 Changes in Weight 30 Min Total Weight Change in Weight 45 Min Total Weight 60 Min Total Weight 60 Min Total Weight Bag A Bag B Bag C Bag D *Each change in weight, Time), a label showing measurement units (e.g., g and min), and values along each axis (e.g., 0, 15, 30, 45, 60). Include these in your graph. 3. Plot the data for all four bags as four separate curves on the same graph. Question 5 a. Did water move across the membrane in all bags containing solutions of sugar? b. In which bags did osmosis occur? WATER POTENTIAL Plants must balance the uptake and loss of water as it moves from one part of a plant to another and in and out of cells by osmosis. However, the concentration gradient of water as it moves from one part of a plant to another and in and out of cells by osmosis. pressure influenced by cell walls and evaporation is also important. Plant physiologists refer to the combined effects of these factors as water potential; water flows from an area of low potential. Similarly, high solutes and low pressure decrease water potential. In simple terms, water flows through a plant from higher water potentials of roots toward lower water potentials of roots toward lower water potentials in leaves are created by their loss of water to the atmosphere (see Exercise 33). In the following procedure you will measure the concentration of solutes in potato cells and relate this concentration to water potential. Procedure 9.6 Determine the concentration gradient for water must be presented the steepest concentration gradient relative to its surrounding environment? d. The steepest gradient should result in the highest rate of diffusion. Examine the data in table 9.1 for Change in Weight during the 15- and 30-min intervals. Did the greatest changes in weight occur in cells with the steepest concentration gradients? Why or why not? Question 6 a. Refer to your graph. How does the slope of a segment of a curve relate to the rate of diffusion? b. What influence on diffusion (i.e., temperature, pressure, concentration) causes the curves for bags C and D eventually to become horizontal (i.e., have a slope = 0)? 9-7 1. Locate the five beakers prepared by your instructor with five concentrations of salt (NaCl) solution. 2. The cylinders of potato that you see in the solutions were all originally the same size (i.e., the same length or weight). Check the beaker labels to determine which measure of size (length or weight) you will be using as your data. 3. Record the initial values in table 9.2. 4. Carefully remove three of the potato cylinders from each solution and measure their size. 5. Record your data in table 9.2. 6. Calculate the mean change in size and record the data in table 9.2. 7. Your instructor may ask you to graph your data (see Question 7 f). Follow his or her instructions. Question 7 a. Which solution(s) contained a higher concentration of solutes and therefore a lower water potential than in the potato cells? Explain your answer. Diffusion and Osmosis 99 Table 9.2 Change in Length of Potato Cylinders Surrounded by Different Salt Concentration of Salt Solution (%) Initial Size of Cylinders or Grams) Changes in Size of Three Sample Cylinders 0 0.9 5 10 15 c. Which salt solution best approximated the water potential in the potato cells? How do you know this? d. For a growing potato plant, what would you predict as the water potential of the potato relative to the leaves? e. What might be some sources of error in this experiment? Mean Change in Size f. How could a graph of your data help you estimate the solute concentration of potato cells? HEMOLYSIS OF BLOOD CELLS Living red blood cells (erythrocytes) are good models for studying osmosis and diffusion in hypotonic, hypertonic, and isotonic solutions. Osmosis occurs when living cells are placed in a hypotonic or hypertonic environment and water diffuses into or out of the cell (fig. 9.7). For example, in the previous experiment, water moved into cells toward the low concentration of a cell by the influx of water. However, osmosis into animal cells increases the hydrostatic (i.e., water) pressure and may burst the cell to burst) is called lysis. Such destruction of a red blood cell is toward the low concentration of a red blood cell is the cell to burst the cells because they lack cell walls. called hemoly sis. If water flows out of a cell into a hypertonic solution, the cell will shrivel and become crenate. Red blood cell Hypotonic solution is hypotonic with respect to the cell, water will move into the cells and the cells will lyse; when it is hypertonic, water will move out of the cells and the cells will shrink (i.e., become crenate). 100 EXERCISE 9 9-8 Table 9.3 Hemolysis of Red Blood Cells Exposed to Three Solutions with Different Solute Concentrations Tube Contents 1 5 mL 10% NaCl 2 5 mL 0.9% NaCl 3 5 mL distilled water Procedure 9.7 Observe hemolysis 1. Obtain and label three test tubes and fill them with the solutions listed in table 9.3. 2. Add four drops of fresh sheep's blood to each tube. Readable Print (yes/no) Cell Condition (crenate/normal/lysed) 7. Record in table 9.3. the cell's condition as crenate, normal, or lysed. Question 8 a. Through which test tubes could you read the printed page? Why? Wash your hands thoroughly after working with blood products. Always handle sheep blood with caution and avoid skin contact. b. Which concentration in a red blood cell? How do you know? PLASMOLYSIS OF PLANT CELLS Figure 9.8 Experimental setup for determining hemolysis. Hypotonic solutions will hemolyze cells. 3. Cover each tube in front of a printed page and determine if you can read the print through the solution (fig. 9.8). Record your results in table 9.3. 5. Obtain a microscope, slide, and coverslip. 6. Use an eyedropper or pipet to obtain one drop from each tube. Make a wet mount and examine the blood cells. Use low magnification first and then higher magnific surrounding the cell (fig. 9.9). During plasmolysis the cellular membrane pulls away from the cells. 2. Add two or three drops of 30% NaCl to one edge of the coverslip. 3. Wick this salt solution under the relevant of a thin layer of onion epidermis or Elodea leaf. Examine the cells. 2. Add two or three drops of 30% NaCl to one edge of the coverslip. 3. Wick this salt solution under the relevant of a thin layer of onion epidermis or Elodea leaf. piece of absorbent paper towel to the fluid at the opposite edge of the coverslip. 4. Examine the cells. The cytoplasm is no longer pressed against the cell wall. This shrinkage is plasmolysis. Diffusion and Osmosis 101 H2O Cell wall Cytoplasm Kytoplasm Vacuole Hypotonic solution Isotonic solution Hypertonic solution causing coversing by fouching plasmolysis Figure 9.9 Osmosis of water into and out of plant cells. In most plant cells, the large central vacuole contains a high concentration of solutes (i.e., the environment surrounding the cells, the
large central vacuole contains a high concentration of solutes (i.e., the environment surrounding the cells, the large central vacuole contains a high concentration of solutes (i.e., the environment surrounding the cells, the large central vacuole contains a high concentration of solutes (i.e., the environment surrounding the cells, the large central vacuole contains a high concentration of solutes (i.e., the environment surrounding the cells, the large central vacuole contains a high concentration of solutes (i.e., the environment surrounding the cells, the large central vacuole contains a high concentration of solutes (i.e., the environment surrounding the cells, the large central vacuole contains a high concentration of solutes (i.e., the environment surrounding the cells, the large central vacuole contains a high concentration of solutes (i.e., the environment surrounding the cells, the large central vacuole contains a high concentration of solutes (i.e., the environment surrounding the cells, the large central vacuole contains a high concentration of solutes (i.e., the environment surrounding the cells, the large central vacuole contains a high concentration of solutes (i.e., the environment surrounding the cells, the environment surrounding the cells, the environment surrounding the cells (i.e., the environment surrounding the cells, the environment surrounding the cells, the environment surrounding the cells (i.e., the environment surrounding the cells, the environment surrounding the cells, the environment surrounding the cells (i.e., the environment surrounding the cells, the environment surrounding the cell immersed in a high-solute (hypertonic) solution, water will leave the cell, causing the cytoplasm to shrink and pull away from the cell wall. Question? To observe the effects of cellular plasmolysis on a larger scale, compare petioles of celery that have been immersed overnight in distilled water or in a salt solution. Question 10 What causes crispness (i.e., firmness, crunchiness) in celery? b. What can you conclude about the permeability of the cell membrane surrounding the vacuole) to water? (a) © M. I. Walker/Science Source (b) ©Ed Reschke/Getty Images Figure 9.10 (a) Turgid Elodea cells (100×). (b) Plasmolyzed Elodea cells (200×) showing the effects of exposure to a hypertonic solution. 102 EXERCISE 9 9-10 INQUIRY-BASED LEARNING How concentrated are the solutes of plant cells? Observation: Water moves into and out of cells along a concentration gradient. The more solutes present in cells, the greater the tendency for water to move into the cells. Question: What is the approximate concentration of solutes in a piece of apple? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 9 from your instructor. b. Discuss with your group well-defined questions relevant to the preceding observation and question. Choose and record your group's best question for investigation. c. Translate your question into a testable hypothesis. Ask your instructor to review your proposed investigation. e. Conduct your procedures, record your data, answer your question, and make relevant comments. f. Discuss with your instructor any revisions to your questions, hypothesis, or procedures. Repeat your work as needed. Questions for Further Study and Inquiry 1. Why must particles be extremely small to demonstrate Brownian movement? 2. What is the difference between molecular motion and diffusion? 3. If you immerse your hand in distilled water for 15 min, will your cells lyse? Why or why not? 4. Your data for diffusion of water across a differentially permeable membrane in response to a sucrose gradient could be graphed with Change in Weight on the vertical axis rather than Total Weight. How would you interpret the slope of the curves produced when you do this? 5. How do cells such as algae and protists avoid lysis in fresh water? WRITING TO LEARN BIOLOGY 9-11 Where in an animal might pressure affect diffusion of a substance? Diffusion and Osmosis 103 104 EXERCISE 9 9-12 E XER CISE 10 Cellular Membranes Effects of Physical and Chemical Stress Learning Objectives By the end of this exercise you should be able to: 1. Relate membrane structure to its function. 2. Describe the aspects of membrane structure most vulnerable to physical and chemical stress. 3. Predict the effect of common organic solvents and extreme temperatures on membrane integrity. 4. Relate the results of experiments with beet membranes to the general structure and function of membranes. Please visit connect.mheducation.com to review online resources tailored to this lab. M embranes separate and organize the myriad of reactions within cells and allow communication with the surrounding environment. Although they are only a few molecules thick (6-10 nm), membranes (1) retard diffusion of selected molecules; (2) house receptor molecules; (3) provide sites for active and passive transport of selected molecules; (3) providing surfaces to accommodate chemical reactions; and (5) help maintain the integrity of cells. As with all biological entities, the structure of a membrane reflects its function. Membranes consist of a phospholipid bilayer; attached to or embedded within this bilayer are thousands of proteins with a variety of functions. A phospholipid bilayer; attached to or embedded within this bilayer are thousands of proteins with a variety of functions. Phospholipids have an unevenly distributed charge; that is, they have charged (polar) and uncharged (nonpolar) areas. In phospholipids, the phospholipids, the phospholipids, the phospholipids, the phospholipids, the phospholipids, the phospholipids are nonpolar and hydropholic ("water-fearing"). Such molecules with two different affinities are amphipathic, and amphipathic phospholipids have a natural tendency to self-assemble into a double-layered sheet (fig. 10.2). In this double layer, the hydrophilic phosphate groups line both surfaces. This elegant assembly is stable, is self-repairing, and resists penetration by most hydrophilic molecules. Membranes also include proteins dispersed throughout the fluid bilayer of lipids (fig. 10.3). These proteins are not fixed in position; they move about freely and may be densely packed in some membranes and to lipids. Nonpolar tail (hydrophobic) CH2 H2C CH2 H2C CH2 H2C CH2 H2C CH2 H3C Chemical structure of a phospholipid. The structure of a phospholipid is glycerol, a three-carbon alcohol. Glycerol is bonded to two fatty acids, both hydrophobic, and to one phospholipid is glycerol, a three-carbon alcohol. acids and by the side chains attached to the phosphate. The polar head may include glycerol, sugars, and nitrogen-containing groups as shown here. Cellular Membranes 105 up or expel molecules that otherwise could not penetrate the membrane. In doing so, these proteins function as pores, permitting and often facilitating the passage of specific ions and polar molecules. In addition to forming pores and sites for active transport, membrane-bound proteins also function as enzymes and receptors that detect signals from the environment or from other cells. The physical and chemical integrity of a membrane is crucial for the proper functioning of the cell or organelle that it surrounds. As a stable sheet of interlocking molecules, the membrane functions as a barrier to simple diffusion. In general, the permeability of a membrane (ions), polarity, and lipid solubility. Small, uncharged, nonpolar, lipid-soluble molecules pass most easily through the lipid core of a membrane (fig. 10.4). Polar heads Schematic drawing of a phospholipids in a biological membranes? Nonpolar tails Polar heads Figure 10.2 Arrangement of phospholipids in a biological membrane, such as the plasma membrane that encloses cells. The hydrophilic regions of the phospholipid face the watery environments on either side of the membrane, while the hydrophobic regions associate with each other in the interior of the membranes promote the movement of ions out of or into cells? identify particular types of cells. These elaborate molecular elements form the fluid mosaic model of membrane structure. Membrane structure. Membrane structure are selectively take Extracellular environment Carbohydrate Phospholipid bilayer Clycolipid Integral membrane protein Glycoprotein Extracellular boundary HO Cytosolic boundary Peripheral membrane proteins Cytosol Cholesterol (found only in animal cells) Polar Nonpolar Polar Figure 10.3 Fluid-mosaic model of membrane structure. The basic framework of a plasma membrane is a phospholipid bilaver. Proteins may span the membrane and may be bound on the surface to other proteins or lipids. Proteins and lipids, which have covalently bound carbohydrates, are called glycoproteins and glycolipids, respectively. 106 EXERCISE 10 10-2 Artificial bilayer Gases High permeability Moderate permeability Key low permeability Very low permeability CO2 N2 O2 Ethanol Very small, uncharged molecules Water H2O Urea H2NCONH2 Polar Sugars organic molecules Ions Na+, K+, Mg2+, Ca2+, Cl- Charged polar molecules and macromolecules Amino acids ATP Proteins Polysaccharides Nucleic acids (DNA and RNA) Figure 10.4 Relative permeability of an artificial phospholipid bilayer to a variety of solutes. Solutes that easily penetrate the membrane are shown with a straight arrow that passes through the bilayer. The dotted line indicates that the membrane has moderate permeability to those solutes. For the remaining solutes shown at the bottom, the membrane is relatively impermeable. c. Could a cell survive without an intact cell membrane? Explain. BEET CELLS AS AN EXPERIMENTAL SYSTEM Beet tissue will be your model to investigate membrane integrity. Roots of beet (Beta vulgaris) contain large amounts of a reddish pigment called the tonoplast. The entire cell (including the vacuole, tonoplast, and cytoplasm) is surrounded by a cell membranes and cell wall. 10-3 In two procedures you will subject beet
cells to a range of temperatures and determine which treatments stress and damage the membranes. betacvanin will leak through the tonoplast and plasma membrane. This leakage from the stressed beet will color the surrounding water red. Thus, you can measure membrane damage by measuring the intensity of color resulting from a treatment. SAFETY FIRST Before coming to lab you were asked to read this exercise so you would know what to do, and be aware of safety issues. In the space below, briefly list the safety issues associated with today's procedures. If you have questions about these issues, contact your laboratory assistant before starting work. THE EFFECT OF TEMPERATURE STRESS ON MEMBRANES Membranes are sensitive to extreme temperatures. collisions that degrade a membrane as a physical barrier to diffusion. Conversely, freezing temperatures cause water to crystallize as ice and expand because of hydrogen bond alignment. This expansion and formation of ice often rupture membranes. Procedure 10.1 Observe the effect of temperature stress on cellular membranes 1. Examine the treatments listed in table 10.1. Hypothesize which treatments will cause the most and least damage. 2. Record your rankings alongside the tube numbers in the column marked Tube Number. 3. Cut six uniform cylinders must be the same size. 4. Place these cylinders of beet tissue in a beaker and rinse them with tap water for 2 min to wash betacyanin from the injured cells on the surface. Be sure that all of the cylinders are washed in the same way. Discard the colored rinse-water. 5. Gently place one of the six beet sections into each of six dry test tubes. Do not crush, stab, or otherwise damage the cylinders when moving them to the test tubes. 6. Label the tubes 1-6 and write the temperature treatment on each tube as listed in table 10.1. Cellular Membranes 107 Table 10.1. The Color Intensity (0-10) Tube Number Treatment (°C) 1 70 2 55 3 40 4 20 5 5 6 -5 Working Group 7. FOR COLD TREATMENTS: a. Place tube 5 in a refrigerator (5°C) and tube 6 in a freezer (-5°C). If a refrigerator and freezer (-5°C). If a refrigerator and freezer (-5°C) and tube 6 in a freezer (-5°C) and tube 6 in a freezer (-5°C). If a refrigerator (5°C) and tube 6 in a freezer (-5°C). with hot treatments (step 8). However, watch your time and return to steps 6c and 6d after 30 min. c. After tubes 5 and 6.8. FOR HOT TREATMENTS: a. Take the beet section out of tube 1 and immerse it in a beaker of hot water at 70°C for 1 min. If a 70°C water-bath is not available, hot tap water should be adequate, but carefully adjust the temperature to 70°C. Handle the beet gently with forceps, and don't squeeze it tightly because you may rupture the beet's cells. b. After 1 min at 70°C, return the beet to tube 1 and add 10.0 mL of distilled water at room temperature. c. If a 55°C. Then immerse the beet from tube 2 for 1 min. Return the beet to tube 2 and add 10.0 mL of distilled water at room temperature. d. If a 40°C water-bath is not available, cool the beaker of hot water to 40°C. Then immerse the beet from tube 3 for 1 min. Return the beet from tube 3 for 1 min. Return the beet from tube 3 for 1 min. Return the beet from tube 3 and add 10.0 mL of distilled water at room temperature. e. If a 20°C water-bath is not available, cool the beaker of hot water to 20°C. Then immerse the beet from tube 4 for 1 min. Return the beet to tube 4 and add 10.0 mL of distilled water at room temperature for 20 min. Then remove and discard the beets and measure the extent of membrane injury according to the amount of betacyanin that diffused into the water. 9. FOR ALL SIX TEMPERATURE TREATMENTS: Quantify the relative color of each solution between 0 (colorless) and 10 (darkest red). If color standards are available in the lab, use them to determine relative values for the colors of your samples. Record the results for your work group in table 10.1. You may be asked to provide your results to the instructor to calculate the class averages. Use the graph paper at the end of this exercise to graph provided by your instructor. Your instructor may also ask you to quantify your results further using a spectrophotometer. If so, see Exercise 8 for instructions for using a spectrophotometer, Read the absorbance of the solutions at 460 nm and record your results in table 10.1. Then graph Temperature versus Absorbance for the class averages. Question 2 a, Which temperature damaged membranes the most? Which the least? How do you know? b. In general, which is more damaging to membranes, extreme heat or extreme cold? Why? 10-4 Table 10.2 The Color Intensity (0-10) Tube Number Treatment 1 1% acetone 2 25% acetone 3 50% acetone 4 1% methanol 5 25% methanol 6 50% methanol 6 50% methanol 7 Isotonic saline c. If the results of this experiment are easily observed with the unaided eye, why use a spectrophotometer? d. The beets were subjected to cold temperatures longer than to hot temperatures to make sure that the beet sections were thoroughly treated. Why does the freezing treatment require more time? e. How accurate were your hypothesized rankings for the temperature treatments? THE EFFECT OF ORGANIC SOLVENT STRESS ON MEMBRANES Organic solvents, such as acetone and methanol, dissolve lipids. If the lipids in membranes dissolve when exposed to acetone and/or methanol, then the colored cell contents of beets will leak out of the damaged cells and color the surrounding solution. Organic solvents are flammable. Extinguish all open flames and heating elements before doing the following procedure. Do not pour organic solvents down the drain. Class Average Absorbance (460 nm) Working Group Class Average Question 3 Which of the organic liquids (acetone or methanol) do you predict will damage membranes 1. Examine the treatments listed in table 10.2. Hypothesize which treatments will cause the most and least damage. 2. Note your rankings alongside the tube numbers in the column marked Tube Number. 3. Cut seven uniform cylinders of beet tissue in a beaker and

rinse them with tap water for 2 min to wash betacyanin from the injured cells on the seven beet sections into each of seven dry test tubes. Do not crush, stab, or otherwise damage the cylinders when moving them to the test tubes. 6. Labe the tubes 1-7 and write the organic-solvent treatment on each tube as listed in table 10.2. 7. Add 10.0 mL of the appropriate solvent (see table 10.2) to each of the seven tubes. 8. Keep all beets at room temperature for 20 min and shake them occasionally. Then remove and discard the beet sections and measure the extent of membrane Cellular 109 damage according to the amount of betacyanin that diffused into the water. 9. Quantify the relative color of each solution between 0 (colorless) and 10 (darkest red). If color standards are available in the lab, use them to determine relative values for the colors of your samples. Record the results for your work group in table 10.2. You may be asked to provide your results to the instructor to calculate the class averages. c. In which solvent are lipids most soluble? d. The concentration of both solvents cause the most damage? Be sure to dispose of the organic solvents as directed by your instructor. Graph Concentration of Organic Solvent versus Relative Color for the class averages according to a dem onstration graph provided by your instructor. Your instructor may also ask you to further quantify your results using a spectrophotometer. If so, see Exercise 8 for instructions for using a spectrophotometer. Read the absorbance of the solutions at 460 nm and record your results and the class average results in table 10.2. Then graph Concentration of Organic Solvent versus Absorbance for the class averages. Question 4 a. Based on your results, are lipids soluble in both acetone and methanol? b. Based on your results, which damages membranes more: 50% methanol or 25% acetone? e. What other solvents might be interesting to test in this experiment? f. What was the purpose of tube 7? g. How accurate were your hypothesized rankings for the treatments involving organic solvents? INQUIRY-BASED LEARNING How sensitive are cellular membranes are the interface between cells and their environment. The integrity of cellular membranes, which is critical for the proper functioning of the membranes and cells, is affected by environmental stimuli. Question: How do solvents or temperature affect membrane permeability? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 10 from your instructor. b. Discuss with your group well-defined questions relevant to the preceding observation and question. 110 EXERCISE 10 c. Translate your question into a testable hypothesis and record it. d. Outline on Worksheet 10 your experimental design and supplies needed too. test your hypothesis. Ask your instructor to review your procedures, record your data, answer your questions, hypothesis, or procedures. Repeat your work as needed. 10-6 Questions for Further Study and Inquiry 1. Are your conclusions about membrane structure and stress valid only for beet cells? Why or why not? 2. What characteristics of beets make them useful as experimental models for studying cellular membranes? 3. Explain why phospholipids have a natural tendency to self-assemble into a bilayer. Why is this biologically important? 4. Freezing temperatures are often used to preserve food. Considering the results of this experiment, which qualities of food are preserved and which are not? 5. Movement of water through a membrane? 6. What suggestions would you make to improve the 10-8 E XER CISE 11 Enzymes Factors Affecting the Rate of Activity Learning Objectives By the end of this exercise you should be able to: 1. Describe the relationship between structure and function of enzymes. 2. Relate structure and function to active sites, modes of inhibition, and optimal conditions for enzymatic activity. 3. Hypothesize and test how inhibitors and changes in temperature and pH affect enzymatic reaction rates. 4. Describe how some enzymatic reaction rates can be measured by color changes and gas liberation as products are formed. Please visit connect.mheducation.com to review online resources tailored to this lab. F ortunately, not all chemical reactions within our cells occur spontaneously. If they did, our metabolism would be chaotic. Instead, most reactions to biologically useful rates. Specifically, enzymes are biocatalysts, meaning that they accelerate metabolic reactions to biologically useful rates. reaction to occur (fig. 11.1). Enzymes bind to reacting molecules called the substrate to form an enzyme-substrate complex. This complex stresses or distorts chemical bonds and forms a transition state in which the substrate becomes more Energy supplied Uncatalyzed Activation energy without enzyme. Reactant Energy released Reactant Product (a) Product (b) Figure 11.1 Activation energy and catalysis. (a) Exergonic reactions (those that release energy) do not necessarily proceed rapidly because energy must be supplied to destabilize existing chemical bonds. This extra energy is the activation energy for the reaction. (b) Catalysts such as fits the shape of its substrate. (b) When the substrate is called energy of activation and is lowered by the enzyme. The site of attachment and the surrounding parts of the enzyme that stress the substrate's bonds constitute the enzyme is released in its original condition. The enzyme is released in its original condition. The enzyme save reusable. Enzymes are proteins made of long chains of amino acids that form complex shapes. Although cells contain many enzymes, each enzyme has a precise structure and function, and catalyzes a specific reaction. This specificity results from an enzyme's unique structure and shape. The complex shape of the active site on the enzyme has a precise structure and structure and shape. change in an enzyme may denature or destroy its effectiveness by altering the active site and slowing the reaction. A denatured enzyme is often permanently ineffective. Denatured enzyme is often permanently ineffective. enzymatic reaction depends on conditions in the immediate environment. These conditions affect the shape of the enzyme and modify the active site and precise fit of an enzyme functions best represents that enzyme's optimal conditions. The optimal conditions for the enzymes of an organism are usually adaptive for the environment of the organism. Other factors such as the amount of substrate or concentration of enzyme also affect the reactions 3. The binding of the substrate and enzyme places stress on the glucose-fructose bond, and the bond breaks. 1. The substrate, sucrose, consists of glucose and fructose bonded together. 2. The substrate binds to the active site of the enzyme, forming an enzyme- substrate complex. Bond H2O Glucose Fructose 4. Products are released, and the enzyme is free to bind other substrates. Active site Enzyme Sucrase Figure 11.3 The catalytic cycle of an enzyme. Enzyme sucrase splits the disaccharide sucrose (steps 1, 2, 3, and 4) into its two parts, the monosaccharides glucose and fructose. After the enzyme releases the glucose and fructose, it can bind another molecule of sucrose and begin the catalytic cycle again. 114 EXERCISE 11 11-2 Rate of Reaction (°C) 80 SAFETY FIRST Before coming to lab, you were asked to read this exercise so you would know what to do and be aware of safety issues. In the space below, briefly list the safety issues associated with today's procedures. If you have questions about these issues, contact your laboratory assistant before starting work. Rate of Reaction (a) Optimum pH for pepsin Optimum pH for trypsin Procedure 11.1 Determine the effect of temperature on catechol oxidase activity 1 2 3 4 5 6 pH of Reaction 7 8 9 (b) Figure 11.4 Enzymes are sensitive to their environment. The activity of an enzyme is influenced by both (a) temperature and (b) pH. Most enzymes are sensitive to their environment. work best at temperatures about 40°C and within a pH range of 6 to 8. As you can see, however, pepsin works best at a much lower pH than does trypsin. (fig. 11.4). You will also investigate how inhibitors affect enzymatic activity. TEMPERATURE AFFECTS THE ACTIVITY OF ENZYMES Heat increases the rate of most chemical reactions. During enzymatic reactions, faster molecular motion caused by heat increases the probability that enzyme molecules. The rate of chemical reactions have an optimal range of temperatures. Temperatures above or below this range decrease the reaction rate. Extreme temperatures often denature enzymes. The effects of temperatures above or below this range decrease the reaction rate. Extreme temperatures often denature enzyme that converts catechol oxidase, a plant enzyme that converts catechol and catechol oxidase. which react to form a brownish product, benzoquinone prevents decay in damaged cells. Your source of catechol oxidase will be potato extract. catechol oxidase Catechol oxidase will test. 2. Prepare water-baths at 40°C and 80°C. Locate a refrigerator or ice bath at or below 4°C. Place a test-tube rack in each bath and in the refrigerator. 3. Obtain seven test tubes and number them at the top 1–7. 4. Obtain a tube of potato extract to the tubes as listed in table 11.1. Shake or swirl to resuspend the potato extract. 6. Place the tubes in the appropriate bath or refrigerator. Allow each tube to stand undisturbed for 5 min at its respective temperature. Put tubes 1–4 in a test-tube rack at room temperature (approximately 22°C). 7. Add 1% catechol solution to tubes 2 and 4–7 as listed in table 11.1. For each tube immediately record in table 11.2 any color changes for 0 min. Record qualitative color changes in the seven tubes over the next 20 min. Always return the tubes to their original temperature locations (e.g., refrigerator, water-bath). 9. If your instructor asks you to further quantify your data, then measure the absorbance of the solution in each tube using a spectrophotometer set to 470 nm with tube 3 as a blank. Refer to Exercise 8 and the videos tailored to that exercise for instructions on how to use the spectrophotometer. 10. Clean your work area and materials. Catechol must be disposed into waste containers, not down the sink drain. Question 1 a. Do your data support or refute your hypotheses? Catechol is toxic. Wash well with soap and water after skin contact. 11-3 Enzymes 115 Table 11.1 Experimental Conditions to Test the Effect of Temperature on Catechol Oxidase Activity Potato Extract (catechol Oualitative Color Change Results Ouantitative Absorbance Results Tube 0 min 5 min 10 min 15 min 20 min 1 0 0 0 0 0 0 0 2 3 4 5 6 7 b. Write a hypothesis for the effect of temperature on catechol oxidase activity. c. What were the enzyme, substrate, and product of the enzymatic reaction? e. Explain the results observed for tubes 1-3. What was the purpose of these tubes? f. Use your results for tubes 4-7 to construct a line graph will include four curves. d. Why was each tube left undisturbed for 5 min in step 6 of procedure 11.1? 116 EXERCISE 11 11-4 g. Use your results to argue for or against the statement, "Catechol oxidase functions equally and efficiently at various temperatures be tested to more accurately determine the range of activity? i. At which temperature was catechol oxidase activity greatest? Should more temperatures be tested to determine its optimum? j. At what temperature was catechol oxidase denaturing an enzyme? l. If an enzyme has a single optimal temperature, then an organism might have difficulty dealing with an environment with wide temperature variation. What adaptive advantage is there in having repetitive enzyme to catalyze the same reaction) that we know many organisms have? peroxide can be effective antibiotics Hydrogen peroxide is a naturally produced toxin in cells and is degraded by the enzyme in your digestive tract) function best at pH as low as 1.6 (fig. 11.4b). The effects of pH can be investigated with catalase, an enzyme in plants and animals that speeds the breakdown of hydrogen peroxide, toxic to cells. It may surprise you that cells can produce a toxin naturally. Could that ability be useful to cells? Occasionally we take advantage of hydrogen peroxide as a powerful oxidizer that denatures macromolecules and kills "germs" (fig. 11.5). Hydrogen peroxide as a powerful oxidizer that denatures macromolecules and kills "germs" (fig. 11.5). pH on catalase activity pH AFFECTS THE ACTIVITY OF ENZYMES Enzymatic activity is sensitive to pH. Acidic and basic solutions are rich in H+ and OH- ions (see Exercise 5), respectively, and they readily react with the charged side groups of the enzyme molecules. As the pH is lowered, side groups gain H+ ions; as the pH is raised, side groups lose H+ ions. In this way, solutions having an extreme pH can change an enzyme's shape enough to alter its active site. Extreme pH can denature and state the null hypothesis that your experiments will test. Review Exercise 1 for the meaning and significance of a null hypothesis. 2. Prepare catalase solution. a. Use a mortar and pestle to macerate a marble-size portion of fresh, raw ground meat in 10 mL of distilled water. b. Filter the solution through cheesecloth into a test tube and add an equal volume of distilled water. 3. Obtain 10 test tubes and number them at the top 1-10. Enzymes 117 Table 11.3 Experimental Conditions to Test the Effect of pH on Catalase Solution 1 5 mL 1 mL, pH 7 2 4 mL 1 mL, pH 7 3 2 mL 1 mL, pH 7 4 1 mL 5 1 mL 1 mL, pH 5 3 mL 1 water Glass tubing Collected gas HCl is a strong caustic acid, and NaOH is a strong caustic base. Follow your instructor's directions for handling, dispensing, and disposing of these chemicals. Rinse immediately with water if you spill any acid or base on your skin. Add distilled water and hydrogen peroxide to each tube as listed in table 11.3. If you are measuring by drops, then 1 mL equals about 20 medium-sized drops. Wait 2 min before proceeding to step 6. 6. Add 1 mL of HCl to tubes 8 and 10. Verify that the pH is approximately 3 or lower. 7. Add 1 mL of HCl to tubes 4 and 9. Verify that the pH is approximately 3 or lower. 7. Add 1 mL of HCl to tubes 4 and 9. Verify that the pH is approximately 3 or lower. 7. Add 1 mL of HCl to tubes 8 and 10. Verify that the pH is approximately 3 or lower. 7. Add 1 mL of HCl to tubes 8 and 10. Verify that the pH is approximately 1 or higher. 8. Add 1 mL of HCl to tubes 8 and 10. Verify that the pH is approximately 1 or higher. 8. Add 1 mL of HCl to tubes 4 and 9. Verify that the pH is approximately 1 or higher. 8. Add 1 mL of HCl to tubes 4 and 9. Verify that the pH is approximately 1 or higher. 8. Add 1 mL of HCl to tubes 4 and 9. Verify that the pH is approximately 1 or higher. 8. Add 1 mL of HCl to tubes 4 and 9. Verify that the pH is approximately 1 or higher. 8. Add 1 mL of HCl to tubes 4 and 9. Verify that the pH is approximately 1 or higher. 8. Add 1 mL of HCl to tubes 4 and 9. Verify that the pH is approximately 1 or higher. 8. Add 1 mL of HCl to tubes 4 and 9. Verify that the pH is approximately 1 or higher. 8. Add 1 mL of HCl to tubes 4 and 9. Verify that the pH is approximately 1 or higher. 8. Add 1 mL of HCl to tubes 4 and 9. Verify that the pH is approximately 1 or higher. 8. Add 1 mL of HCl to tubes 4 and 9. Verify that the pH is approximately 1 or higher. 8. Add 1 mL of HCl to tubes 4 and 9. Verify that the pH is approximately 1 or higher. 8. Add 1 mL of HCl to tubes 4 and 9. Verify that the pH is approximately 1 or higher. 8. Add 1 mL of HCl to tubes 4 and 9. Verify that the pH is approximately 1 or higher. 8. Add 1 mL of HCl to tubes 4 and 9. Verify that the pH is approximately 1 or higher. 8. Add 1 mL of HCl to tubes 4 and 9. Verify that the pH is approximately 1 or higher. 8. Add 1 mL of HCl to tubes 4 and 9. Verify that the pH is approximately 1 or higher. 8. Add 1 mL of HCl to tubes 4 and 9. Verify Your instructor may ask you to verify that the buffers produce the indicated pH. If so, use pH paper to measure the values for each solution and record them in table 11.3. After adding catalase, swirl the solution gently and immediately record in table 11.4 qualitative changes in the bubbling intensity of oxygen production on a scale of 0 (no bubbling) to 5 (vigorous bubbling). 1 2. If your instructor asks you to more rigorously quantify your results, then immediately after adding the catalase place a stopper with tubing over each tube to collect and measure the volume of gases produced in a Rubber tubing 5. 118 EXERCISE 11 Water level Test tube containing the enzymatic reaction Figure 11.6 A method to capture oxygen released by catalase activity. water-filled graduated cylinder inverted in a beaker of water (fig. 11.6). Be sure that the graduated cylinder does not pinch off the rubber tubing. Also be sure the cylinder is vertical when you measure volume. Record these results in table 11.4. 13. Repeat step 11 for each remaining solution. 1 4. After you have gathered your data for all 10 tubes, record in table 11.4. your explanation for the results of the catalase activity in each of the tubes. 1 5. Clean your work area and materials. Follow your instructor's directions concerning the disposal of waste solutions containing HCl and NaOH. 11-6 Table 11.4 Production of Oxygen by Catalase Activity. Qualitative Data Are Observations of Intensity of Oxygen Produced. Oxygen Production Tube Qualitative (mL O2) Explanation 1 2 3 4 5 6 7 8 9 10 Question 2 a. Do your data support or refute your hypothesis? f. Over what pH range was catalase active? b. What were the enzyme, substrate, and product of the enzyme, substrate, and product of the enzyme to refute your hypothesis? f. Over what pH range was catalase active? b. What were the enzyme, substrate, and product of the enzyme to refute your hypothesis? f. Over what pH range was catalase active? b. What were the enzyme, substrate, and product of the enzyme to refute your hypothesis? f. Over what pH range was catalase active? b. What were the enzyme, substrate, and product of the enzyme to refute your hypothesis? f. Over what pH range was catalase active? b. What were the enzyme, substrate, and product of the enzyme to refute your hypothesis? f. Over what pH range was catalase active? b. What were the enzyme, substrate, and product of the enzyme to refute your hypothesis? f. Over what pH range was catalase active? b. What were the enzyme, substrate, and product of the enzyme to refute your hypothesis? f. Over what pH range was catalase active? b. What were the enzyme, substrate, and product of the enzyme to refute your hypothesis? f. Over what pH range was catalase active? b. What were the enzyme, substrate, and product of the enzyme to refute your hypothesis? f. Over what pH range was catalase active? b. What were the enzyme to refute your hypothesis? f. Over what pH range was catalase active? b. What were the enzyme to refute your hypothesis? f. Over what pH range was catalase active? b. What were the enzyme to refute your hypothesis? f. Over what pH range was catalase active? b. What were the enzyme to refute your hypothesis? f. Over what pH range was catalase active? b. What were the enzyme to refute your hypothesis? f. Over what pH range was catalase active? b. What were the enzyme to refute your hypothesis? f. Over what pH range was catalase active? b. What were the enzyme to refute your hypothesis? f. Over what pH range was catalase active? b. What were the enzyme to refute your hypothesis? f 2-9 for all tubes before adding the catalase in step 11? h. At which of the tested pH values did catalase react most rapidly? Should more values be tested to accurately determine its optimum? d. What was the purpose of tubes 1, 2, 3, 9, and 10? i. After experimenting with the effects of pH on enzymes, would you suspect that human blood has a constant pH? Why? What would be the adaptive advantage of this? e. Use your data for tubes 4-8 to construct a line graph of Enzyme S Peroxidase is an enzyme in plants (such as turnips) and some bacteria that converts toxic hydrogen peroxide to H2O and O2 in a reaction similar to that of catalase. Peroxidase is a large protein with a reactive inhibitors are molecules structurally similar to the substrate and therefore competitive for positions at the active sites of enzymes. This ties up the enzyme and makes it unable to bind with the substrate. For example, hydroxylamine (HONH2) is structurally similar to hydrogen peroxide for the active sites of enzyme and makes it unable to bind with the substrate. on peroxidase molecules and reduces the frequency of hydrogen peroxidase molecules. However, a high enough concentration of enzyme with a constant concentration of enzyme capture liberated bubbles of oxygen and measure their total volume. But in the following procedure you will measure oxygen by combining it with a dye that turns from colorless to brown as it is oxidized. Guaiacol is a convenient dye that turns from colorless to brown as it is oxidized by oxygen. amount of oxygen formed by the reaction. You can measure the color change qualitatively with a spectrophotometer measuring the solution's absorbance of 470 nm light. Review Exercise 8 and the associated video for instructions on using a spectrophotometer. O2 + guaiacol (colorless) oxidized guaiacol (brown) 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. Procedure and state the null hypothesis that your experiments will test. Prepare turnip extract. a. Thoroughly blend 6 g of the inner portion of a peeled turnip in a blender with 200 mL of cold water. b. Filter the turnip slurry through cheesecloth into a test tube and determine its absorbance in a spectrophotometer. Refer to Exercise 8 for instructions on spectrophotometery. The absorbance for the turnip slurry through cheesecloth into a test tube and determine its absorbance in a spectrophotometer. Refer to Exercise 8 for instructions on spectrophotometery. The absorbance for the turnip slurry through cheesecloth into a test tube and determine its absorbance in a spectrophotometer. should be between 0.1 and 0.2 at 470 nm to give a reasonable concentration of enzyme. d. Dilute or concentrate the suspension as necessary. Your instructor may provide directions for standardizing this enzyme solution more precisely. Obtain nine test tubes and number them at the top 1-9. Add distilled water to each tube as listed in table 11.5. To tube 1, add 0.1 mL (2 drops) of guaiacol as listed in table 11.5 and swirl the contents. Immediately determine the absorbance every 30 sec for 5 min and record the value each time. To tube 2, add 0.2 mL (4 drops) of hydrogen peroxide as listed in table 11.5. Swirl the contents. Repeat step 6 quickly. To tube 3, add 0.1 mL (2 drops) of guaiacol and 0.2 mL of hydrogen peroxide as listed in table 11.5. Swirl the contents. Repeat step 6 quickly. To tube 4, add 0.1 mL (2 drops) of guaiacol and 1.0 mL of turnip extract as listed in table 11.5. Swirl the contents. Repeat step 6 quickly. Complete all of the measurements for steps 5-9 before proceeding to step 11. For tube 5, add 0.1 mL (2 drops) of guaiacol and 0.2 mL (4 drops) of furnip extract and swirl the contents. Repeat step 6 quickly. For tube 6, add 1.0 mL of turnip extract and 0.5 mL (10 drops) of hydroxylamine and swirl the contents. Repeat step 6 quickly. For tube 7, add 1.5 mL of turnip extract and 0.5 mL (10 drops) of hydroxylamine and swirl the contents. Repeat step 6 quickly. For tube 9, add 3.0 mL of turnip extract and 0.5 mL (10 drops) of hydroxylamine and swirl the contents. Repeat step 6 guickly. Clean your work area and materials. Ouestion 3 a. Do your data support or refute your hypothesis? b. What were the enzyme, substrate, and product of this enzymatic reaction? 11-8 Table 11.5 Experimental Conditions to Test the Inhibition of Hydroxylamine on Peroxidase Activity Hydrogen Peroxida (3%) Tube Distilled Water Guaiacol (25 mM) Turnip Extract Hydroxylamine (10%) 1 5.9 mL 0.1 mL 0.2 mL 1.0 mL 0.2 mL 0.1 mL 0.2 mL 9 2.2 mL 0.1 mL 0.2 mL 3.0 mL 0.5 mL 0.2 mL 1.0 mL Table 11.6 Absorbance at 470 nm of Peroxide/Peroxidase Solutions Tube 0.0 min 1.5 min 2.0 min 3.5 min 4.0 min 1.5 min 3.0 min 1.2 min 3.5 min 4.0 min 4.5 min 5.0 min 1 2 3 4 5 6 7 8 9 c. Explain the results you observed for tubes 1, 2, 3, and 4. What was the purpose of these tubes? d. Use your data for tubes 5-9 to construct a line graph of Enzyme Activity (Absorbance) versus Time. There will be five curves on the graph. You will not graph the values for tubes 1-4. e. In which tubes was peroxidase still active after 5 min? 11-9 f. How does hydroxylamine affect peroxidase activity? presence of the inhibitor by increasing enzyme concentration? Why or why not? h. Inhibitors are common in biological systems. Why might some organisms release enzyme inhibitors into their surrounding environment? Enzymes 121 INQUIRY-BASED LEARNING What factors speed up or slow down enzymatic activity? Observation: Numerous factors affect enzyme reaction rates. Some products inhibit activity, whereas others can stimulate activity. You learned in an earlier lab that pH affects enzymatic activity? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 11 from your instructor. b. Discuss with your group well-defined questions relevant to the preceding observation and question. c. Translate your question into a testable hypothesis and record it. d. Outline on Worksheet 11 your experimental design and Inquiry 1. More substrate increases the probability that an enzyme will contact the substrate and should increase the enzymatic reaction rate. How do you explain the increase in time to complete hydrolysis when more substrate was present? 2. What term describes a change in an enzyme's structure that renders the proteinaceous enzyme nonfunctional? What factors in addition to temperature influence a protein's structure? 3. What happens when an enzyme is denatured? 4. Can a denatured? 4. Can a denatured? 7. Commercial meat tenderizers contain papain (extracted from pineapple), both of which are enzymes Because these enzymes "tenderize" meat, what group of organic compounds that you studied in Exercise 6 do you suspect that these enzymes are proteins, and therefore are structurally linked to DNA sequences. How could natural selection alter the metabolism of an organism? EXERCISE 11 11-10 DOING BIOLOGY YOURSELF Review the structure of starch by amylase. 11-11 WRITING TO LEARN BIOLOGY Propose a mechanism involving enzyme production by which a 123 124 EXERCISE 11 11-12 E XER CISE Respiration Aerobic Oxidation of Organic Molecules 12 Learning Objectives By the end of this exercise you should be able to: 1. Measure carbon dioxide production during anaerobic respiration. 2. Understand the pitors, intermediate compounds, and cofactors in anaerobic respiration. 3. Determine oxygen consumption during aerobic respiration. 4. Use a pH-indicator to measure the relative production of carbon dioxide by plants and animals. 5. Use a respirometer to determine the metabolic rate of an animal. 6. Demonstrate practical applications of anaerobic respiration, such as making wine and kimchee. Please visit connect.mheducation.com to review online resources tailored to this lab. All living organisms respire, meaning that they have metabolic pathways that release energy from organic (rarely inorganic) molecules and capture it in ATP. Some need oxygen to do it, some don't, but they all respire because all organisms need usable chemical energy to fuel their life processes. Respiration is the chemistry that provides that energy. Usually, organic carbon molecules are the energy source, and CO2 and H2O are released as waste. Humans release the waste as they exhale. Respiring yeasts don't exhale, but they can "pump up rising bread by liberating CO2 as the yeasts break down sugar during respiration (fig. 12.1). Cellular respiration involves oxidation of organic molecules and a concomitant release of energy for cellular metabolism. Organisms use the energy stored in ATP to do work such as transport materials, synthesize new compounds, reproduce, contract muscles, and remove wastes. Photosynthesis, the topic of Exercise 13, uses light energy to split H2O and harvest high-energy electrons. These energetic electrons (and accompanying H+) are passed to CO2, thereby reducing CO2 to energy-storing sugars. Respiration removes electrons from (i.e., oxidizes) glucose, captures some of the energy in ATP, and ultimately passes the electrons to oxygen to form H2O. In most cells, respiration begins with the oxidation of glucose to pyruvate via a set of chemical reactions called glycolysis (fig. 12.2a). During glycolysis, some of the energy released from each glucose molecule is stored in ATP. Glycolysis occurs with or without oxygen. If oxygen is present, most organisms continue respiration by oxidizing 12-1
Bread dough rises because respiring yeasts break down sugars to obtain their energy for growth and liberate CO2, thereby forming small bubbles that cause the dough to rise. The lower loaf has been rising 4 hours longer than the upper loaf. pyruvate to CO2 via chemical reactions of the Krebs cycle. Organisms that use oxygen for respiration 125 Outer mitochondrial membrane Glycolysis Glucose Intermembrane space ATP NADH Glucose Pyruvate Pyruvate Pyruvate Animals, some microbes ATP NAD+ FAD O2 H2O - Electron e Transport Chain ATP NADH Inner mitochondrial membrane NAD+ CO2 Chemiosmosis ATP Synthase H+ Lactate (a) Ethanol (b) Figure 12.2 (a) An overview of aerobic respiration. Glycolysis occurs in the cytoplasm, and the Krebs cycle and electron transport chain occur in mitochondria. (b) During anaerobic fermentation, pyruvate directly, as in muscle cells, the product is lactate. In organisms that first remove carbon dioxide, as in yeast cells, the product is ethanol. As aerobes oxidize the acetyl group from the pyruvate in the Krebs cycle, they store energy in electron carriers such as NAD+ (nicotinamide adenine dinucleotide). Specifically, aerobes store e nergy by reducing (adding highenergy electrons to) NAD+ and FAD+. These compounds later transfer their highenergy electron transport chain. The electron transport chain generates proton gradients from energy stored in reduced NAD and related compounds that lead to formation of approximately 18-times more ATP than that formed in glycolysis. Oxygen, the final electron transport chain, is reduced to form H2O (fig. 12.2a). Without oxygen to accept electron transport chain, is reduced to form H2O (fig. 12.2a). Equation for Aerobic Respiration C6H12O6 + 6 O2 - 6 CO2 + 6 H2O + ATP + Heat Glucose Oxygen and exhale CO2? Other organisms called anaerobes live without oxygen and may even be killed by oxygen in the atmosphere. Some of these anaerobes are primitive bacteria that gather their energy with a pathway of anaerobic respiration that uses inorganic compounds as the electron acceptor instead of oxygen. Other anaerobes use glycolysis, but the pyruvate from glycolysis is reduced via anaerobic fermentation to either CO2 and ethanol (in plants and some microbes such as yeast) or lactic acid (in other microbes and oxygen-stressed muscles of animals; fig. 12.2b). We can summarize anaerobic fermentation in figure 12.2b in the following equations: 12-2 Anaerobic Fermentation in Plants and Some Microbes C6H12O6 - 2 C2H5OH + 2 CO2 + ATP + Heat Glucose Ethanol Carbon Dioxide Anaerobic Fermentation in Animals and Some Microbes C6H12O6 - 2 CH3CHOHCOOH + ATP + Heat Glucose Lactic Acid Notice from these equations that plants (as well as prokaryotes and other eukaryotes such as yeasts) can temporarily conduct anaerobic fermentation that reduces pyruvate from glycolysis to ethanol and carbon dioxide. This occurs, for example, in roots that penetrate anaerobic soils and sediments. Anaerobic fermentation does not involve or benefit from the additional ATP produced by the citric acid cycle or electron transport chain. Thus, the ability of an organism to live in the absence of oxygen comes at a price: Anaerobic fermentation produces 18-fold less ATP per glucose molecule than does aerobic respiration. Let's begin with a type of anaerobic fermentation with which you are already familiar: alcoholic fermentation by yeast. SAFETY FIRST Before coming to lab, you were asked to read this exercise so you would know what to do and be aware of safety issues. In the space below, briefly list the safety issues associated with today's procedures. If you have questions about these issues, contact your laboratory assistant before starting work. Magnesium sulfate (MgSO4)—provides Mg2+, a cofactor that activates some enzymes of glycolysis Sodium fluoride (NaF)—an inhibitor of some enzymes of glycolysis Glucose—a common organic molecule used as an energy source for respiration Procedure 12.1 Measure CO2 production during anaerobic fermentation 1. Label seven test-tubes and add the solutions listed in table 12.1. 2. Completely fill the remaining volume in tubes 1-6 with the yeast suspension that is provided. Fill the remaining volume in tube 7 completely fill the remaining volume in tubes 1-6 with the yeast suspension that is provided. 1.3). Hold the yeast-filled tube firmly against the inside bottom of the cover tube and invert the assembly. Your instructor will demonstrate how to slide this slightly larger empty tube over the top of each yeast tube and invert the assembly. If done properly, air will not be trapped at the top of the tube of yeast after inversion. 4. Incubate the tubes at 37°C for 40 min. While you are waiting, write your predictions for each tube: Tube Predicted Results and Brief Explanation 1. 2. 3. 4. 5. PRODUCTION OF CO2 DURING ANAEROBIC FERMENTATION Yeast are fungi used in baking and producing alcoholic beverages. They can respire in the absence of O2 and can oxidize glucose to ethanol and CO2. To demonstrate CO2 production during anaerobic fermentation), follow procedure 12.1. In this procedure you will observe the effects of these compounds on respiration: Pyruvate is reduced to ethanol or lactic acid during anaerobic fermentation 12-3 6. 7. 5. After 40 min, measure the height (in millimeters) of the bubble of accumulated CO2. Record your results in table 12.1. 6. The effects of pyruvate, MgSO4, NaF, and glucose on CO2 production are best determined by comparing each tube to the control rather than by ranking all of Respiration 127 the treatment tubes. For each variable in table 12.2, record the number of the tube containing the compound being tested and the number of the tube serving as the control for that compound. d. Why did tube 6 produce CO2 even though an inhibitor of glycolysis was present? Question 3 a. What was the purpose of tube 7? e. Compare tubes 4 and 5. How was CO2 production affected by the 10-fold increase in the amount of NaF? For example, was it also changed 10-fold? b. How was the effect of concentration of inhibitor tested in this experiment? Why? f. Did magnesium (a cofactor that activates many enzymes) promote respiration? If not, what are some possible reasons? c. Which compounds listed in step 6 are intermediates in the respiratory pathway? g. Smell the containing the most CO2. What compound do you smell? Table 12.1 Experimental Treatments and CO2 Production during Anaerobic Fermentation Tube 3M Na Pyruvate (Activator) 0.1 M MgSO4 (Activator) 0.1 M Water Fill With 1 - - - 7.5 mL Yeast suspension 2 - - 2.5 mL 5.0 mL - 2.5 mL -Effects of Four Chemical Variables on CO2 Production during Anaerobic Fermentation Variable Tube # with Variable Tube # Control Effect of Variable on Respiration Rate Mechanism for the Effect Yeast Glucose NaF Na Pyruvate MgSO4 128 EXERCISE 12 12-4 Clamp Rubber tubing KOH pellets Graduated pipet Cotton Germinating peas Figure 12.3 Test tube containing germinating peas, cotton, and KOH pellets. h. What is the economic importance of fermentation by yeast? i. What gas is responsible for the holes in baked bread? Room-temperature water-bath Figure 12.4 Test tube with stopper having capillary tubes attached. The tube will be covered in foil. If time and facilities are available, repeat procedure 12.1 and incubate the tubes at 4°C (refrigerator), 20°C (incubator). Use your data to explain the effect of temperature on fermentation by yeast. OXYGEN CONSUMPTION DURING AEROBIC RESPIRATION Aerobic respiration uses oxygen as the terminal electron acceptor in the electron transport chain. Because this oxygen is reduced to water, you can measure aerobic respiration by measuring the consumption of oxygen. During respiration in the introduction of this exercise. In the following experiment, KOH is used to absorb the CO2. Therefore, the net change in gas volume is a measure of oxygen consumption. Procedure 12.2 Determine oxygen consumption during peas and another half-full with heat-killed peas. The germinating peas have been soaked in water in the dark for three to four days. 12-5 2. Cover the contents of each tube with a loose-fitting plug of cotton. 3. Cover the cotton with approximately 1 cm of loosely packed pellets of potassium hydroxide (KOH) is a strong, caustic base. Handle it carefully. If you get any KOH on your skin, rinse immediately with water. 4. Place a stopped as topped containing a capillary tube or graduated pipet with an attached outlet tube into both tubes containing peas (fig. 12.4). The capillary tube or graduated pipet should be oriented horizontally. 5. Cover the tube with foil to prevent light and photosynthesis. 6. Vertically clamp the tubes to a ring stand so that the bottom of each tube is submerged in a room-temperature water-bath. The water-bath will minimize temperature fluctuations in the tube. 7. Use a Pasteur pipet to inject enough dye into each capillary tube or graduated pipet should be oriented horizontally. Respiration 129 Table 12.3 Oxygen Consumption by Seeds at Three Temperatures mL O2 Consumed 10 min Treatment 0 min Room temperature 0 Ice bath 0 Warm water-bath 0 Alive Heat-Killed 8. After waiting 1 min for equilibration, attach a pinch clamp to the outlet tube and mark the position of the dye with a wax pencil. Write your predicted results and a brief explanation here: 20 min Alive Heat-Killed Question 4 a. What was the purpose of adding heat-killed peas to a tube? Alive Heat-Killed PRODUCTION OF CO2 DURING AEROBIC RESPIRATION CO2 produced during cellular respiration can combine with water to form carbonic acid: CO2 Carbon dioxide 9. Use a wax pencil to mark the position of the dye every 10 min for the next 30 min. 10. After each time interval, measure the distance the dye to the end of the capillary tube by tilting the capillary tube incubated in an ice bath and warm (35°C) water bath. You can save time by running all of these treatments simultaneously. Record your results in table 12.3. 30 min + H2O \leftrightarrow Water H2CO3 Carbonic acid In this procedure (fig. 12.5), you will use phenolphthalein to detect changes in pH resulting from the production of CO2 (and, therefore, carbonic acid) during cellular respiration. Phenolphthalein is red in basic solutions and colorless in acidic solutions. Thus, you can monitor cellular respiration by measuring acid production as change in pH > 7 are basic (see Exercise 5). In procedure 12.3, you will notic solutions having a pH > 7 are basic (see Exercise 5). directly measure the volume of CO2 produced by the CO2, and thereby calculate a relative measure of respiration. Question 5 The organisms you will study include an animal (snail) and a plant (Elodea). Which do you think will respire more? Write your hypothesis here: b. In which direction did the dye move? Why? c. What does this experiment tell you about the influence of temperature on oxygen consumption? 130 EXERCISE 12 Procedure 12.3 Measure relative CO2 production by aerobic organisms Experimental Setup 1. Obtain 225 mL of culture solution provided by your instructor. This solution has been dechlorinated and adjusted to be slightly acidic. 2. Place 75 mL of this solution in each organisms listed in table 12.4 from your instructor and determine the volume of each organism by following steps 4-6. Your instructor may substitute a small fish for the snail. Note that the control beaker contains no living organisms. Determine Volume by Water Displacement (a) pH indicator pH indicator pH indicator 4. Place exactly 25 mL of water in a 50-mL graduated cylinder. 5. Place the organism in the cylinder and note the increase in volume above the original 25 mL. This increase equals the volume of the organism. 6. Record the volumes in table 12.4. Gently place similar masses of each plant or animal in the appropriate beaker. Incubate Experimental Treatments (b) NaOH NaOH 7. Cover each beaker with a plastic film or petri dish top and set them aside on your lab bench. Place the beaker containing the Elodea in the dark by covering it with a coffee can or aluminum foil. 8. Allow the organisms to respire for 15 min. 9. Gently remove the organisms from the beakers and return them to their original culture bowls. NaOH Titrate to Gather Your Raw Data pH ≥ 7 (c) Control (d) Snail treatment Elodea treatment Figure 12.5 The procedure to determine the relative respiration rates of a plant and animal. (a) During respiration, organisms release CO2, which combines with water to form carbonic acid (H2CO3). (b) The acidic solutions remain colorless after addition of phenolphthalein, a pH indicator. (c) Titration of the control with NaOH (a base) will make the solution basic and pink when the pH reaches the end-point of phenolphthalein. (d) The treatment solutions are then titrated to the pink end-point indicates the relative amounts of dissolved CO2 produced during respiration. 10. Add four drops of phenolphthalein to the contents of each beaker. The solutions should remain clear because the solutions are acidic. 11. Obtain a burette or dropper bottle to dispense NaOH (2.5 mM). Add NaOH drop by drop to the contents of the end-point of phenolphthalein. The end-point is when you first notice that the solution is pink. 12. Repeat step 11 for beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until the solution is the same shade of pink as the control beaker 1; be sure to add NaOH only until Production during Respiration (Organisms) Total Volume of Organisms (mL) Milliliters of NaOH to Reach End-Point (mL NaOH) Relative Respiration Rate per Milliliter of Organisms (mL NaOH) Relative Respiration 131 Calculate Your Results 14. For beaker 1, determine the relative respiration rate for organisms by subtracting the milliliters NaOH added to beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 2. 16. For beakers 1 and 2, determine the respiration rate per milliliters NaOH added to the control beaker from the milliliters NaOH added to beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Repeat step 14 for beaker 1. Record this value in table 12.4. 15. Record this value in table 12 relative respiration rate for organisms by the volume of the organism(s). Record these values in table 12.4. Question 6 a. In this exercise you measured the relative respiration rates of an animal and a plant. Why should you be cautious about having no algae in the control beaker? DEMONSTRATION: DETERMINING THE METABOLIC RATE OF A MOUSE The rate of O2 uptake during cellular respiration indicates the metabolic rate of an organism. In procedure 12.4 you will measure O2 uptake by measuring changes in air pressure as O2 is removed from the air by a respiring mouse. Changes in air pressure can be attributed primarily to O2 consumption (rather than CO2 production or exhalation of water vapor) only if exhaled CO2 and H2O are removed from the air. This is accomplished by adding ascarite (which adsorbs H2O) to the experimental setup (fig. 12.6). Use procedure 12.4 to estimate the metabolic rate of a mouse b. Before you gathered your raw data, you formulated a hypothesis? Why? c. What is your major conclusion from the results of this procedure? d. What features of the biology of the organisms that you used most likely contributed to the observed differences in respiration rate? e. Do you feel justified in drawing conclusions from your work about all plants and animals? Or only about snails and Elodea? Why? f. How would you expand this experiment to further test your conclusions about other plants and other animals? G. What other plants and other animals? I how would you expand this experiment to further test your conclusions about other plants and experiment? Why did you expand this experiment to further test your conclusions about other plants and experiment? Why did you expand this experiment to further test your conclusions about other plants and experiment? choose these organisms? 132 EXERCISE 12 1. Weigh a mouse to the nearest 0.1 g. Record this weight in table 12.5 and place the mouse in the jar of a respirometer (fig. 12.6). Use a fan to circulate air in the jar and allow the mouse in the jar of a respirometer (a respirometer) are spirometer (a respirometer). with a lid. Then close the air escape line with a clamp and record the position of the dye solution in the right column of the curved capillary tube. This tube is called a manometer. 4. Inject 10 mL of air into the respirometer. 4. Inject 10 mL of air into the respirometer. air into the respirometer, record the position of the dye level in the respire. The air pressure in the respirometer should decrease as O2 is consumed, and the dye level to return to its original position. This is the time for the mouse to consume 10 mL of O2. Record this time as "A" in the Calculations section of table 12.5. 7. Gently return the mouse per day by using the following formula: Liters of O2 consumed per day = 1440 minutes to consume 1 liter of O2 Record this as "B" in the Calculations section of table 12.5. 9. Calculate and record in table 12.5. the mouse's metabolic rate in kcal/day, assuming that 4.8 kcal of energy are used for each liter of O2 consumed. Record this as "C" in the Calculations section of table 12.5. 12-8 Air escape Syringe Introduction of dye 3-way valve Manometer Respirometer chamber CO2 and H2O absorbants Figure 12.6 Respiration of dye solution: Position of dye solution after injection of 10 mL of air: Minutes for dye level to return to initial position: (minutes per 10 mL oxygen): min Calculations A Minutes to consume 1 liter of O2 = (minutes per 10 mL oxygen) \times 100 = B Liters of O2 consumed per day = B \times 4.8 kcal per liter O2 = D Predicted metabolic rate = 70 \times (weight of mouse)3/4 = 10. Calculate and record the predicted metabolic rate obtained from the following general equation for metabolic rate of small mammals: min liters per day kcal p table 12.5. 11. Compare your experimental value with the predicted value for metabolic rate. 12-9 Respiration? Observations: Respiration, like all biochemical processes, responds to environmental stimuli (e.g., temperature, salinity, acidity, light). However, some organisms tolerate a wider range of conditions than others. Question: How is the rate of cellular respiration affected by environmental stimuli? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 12 from your instructor. b. The preceding question will give you a general direction for your work, but you'll need to refine it before proceeding. Discuss with your group well-defined questions relevant to the preceding observation and question. c. Translate your question into a testable hypothesis and record it. d. Review procedures 12.1 and 12.3, which use yeast, snails, and Elodea as model organisms to investigate respiration. Outline on Worksheet 12 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your procedures, record your data, answer your question, and make relevant comments. f. Discuss with your instructor any revisions to your questions, hypothesis, or procedures. Repeat your work as needed. b. What could cause any differences in these values? c. Determine the metabolic rates compare with that of a mouse? Yeast and juice APPLICATIONS OF ANAEROBIC RESPIRATION Making Wine In this exercise, you've seen how easy it is to demonstrate alcoholic fermentation by yeast. Many biologists as well as nonbiologists use this reaction to make their own wine. If you're game for an introduction to home wine-making, try the following procedure 12.5 Making wine 1. Thoroughly clean and sterilize all glassware. 2. Combine a cake of yeast with either bottled grape juice or cranberry juice. Mix the yeast and juice in a ratio of approximately 5 liters of juice to 1 gram of yeast. 3. Add approximately 650 mL of the juice-yeast mix to each of four 1-liter Erlenmeyer flasks (or use 1 to 2-liter recycled plastic pop bottles). 4. Dissolve the following amounts of sucrose in each flask: Flask 1: 75 g Flask 3: 300 g Flask 2: 150 g Flask 4: no sucrose 134 EXERCISE 12 Water Figure 12.7. 6. Be sure to keep the procedure anaerobic by keeping the end of the exit tube under water in the adjacent flasks. This will prevent contamination by airborne bacteria and yeast. 7. Incubate the flasks at temperatures between 15°C and 22°C. Although fermentation will continue for a month or so, most fermentation will continue for a month or so, most fermentation will continue for a month or so a piece of tubing to siphon off the wine solution without disturbing the sediment in the bottom of the flasks. You may then want to filter the solution to remove any remaining yeast cells from the wine. 9. Taste your wine. If your wine has been contaminated by bacteria that produce acetic acid, vinegar may have been formed, so take your first sip cautiously. 12-10 Question 8 a. What differences are there in wines produced with different amounts of sugar? Cut below the shoulder b. What would happen if oxygen were present (i.e., if conditions were not anaerobic)? If you have time, test your hypothesis. 1. How would you modify the experimental setup to introduce oxygen? Petri plate 2. What results would you predict? (a) (b) 3. Based on your results, was your hypothesis accurate? Explain. If you're interested in the finer points of wine making, visit your local bookstore or library. There may also be a local society of amateur wine-makers in your area who will be glad to give you some pointers on creating "a simply delightful bouquet." Kimchee Name Petri plate Date pH Date Making Kimchee Pickling is an ancient way of preserving food. Pickling involves the anaerobic fermentation of sugars to lactic acid; this acid lowers the pH of the medium, thereby creating an environment in which other food-spoiling organisms cannot grow. Common foods preserved with pickling include sauerkraut, yogurt, and dill pickles. The ancient Chinese cabbage product kimchee, still a major part of the Korean diet, is also made with pickling. Here's how to make kimchee from being watery. 2. Making kimchee 1. Coarsely shred a head of cabbage. Place it in a mixing bowl with salt and allow it to wilt. This will draw some of the liquid out and prevent the finished kimchee from being watery. 2. Cut a 2-liter bottle just below the shoulder, as shown in figure 12.8a. 3. Add alternating layers of cabbage, garlic, pepper, and a sprinkling of salt in the bottle is full. If you're using chilies or pepper, and a sprinkling of salt in the bottle is full. If you're using chilies or pepper, and a sprinkling of salt in the bottle is full. If you're using chilies or pepper, and a sprinkling of salt in the bottle is full. If you're using chilies or pepper, and a sprinkling of salt in the bottle is full. If you're using chilies or pepper, and a sprinkling of salt in the bottle is full. the text for the recipe and procedure. 4. Place the petri plate lid, rim side up, atop the ingredients. Press down (fig. 12.8b). Within a few minutes, the salt will draw liquid from the cabbage; that liquid will begin to accumulate in the bottle. 5. For the next hour or so, continue to press the cabbage. You should then be able to fit the bottle top inside the bottle bottom, forming a sliding seal (fig. 12.8c). When you press with the sliding seal, cabbage juice will rise above the petri plate and air will bubble out around the edge of the plate. 6. The cabbage will pack half to two-thirds of the bottle's volume (fig. 12.8d). Every day, press on the sliding seal to keep the cabbage covered by a layer of juice. Respiration 135 Question 9 What happens when you press on the cabbage? How do you explain this? 7. Use pH-indicator paper to measure and record the pH of the juice each day (see Exercise 5). 8. After 4 to 7 days (depending on the temperature), the pH will have dropped from about 6.5 to about 3.5. Enjoy your kimchee! Questions for Further Study and Inquiry 1. What is the difference between respiration occur simultaneously with photosynthesis in plants? How could you determine the relative rates of each? 3. What role does cellular respiration play in the metabolism of an organism? 4. What modifications of cellular respiration might you expect to find in dormant seeds? 5. In procedure 12.3, why did you subtract the control value from the titrant in beaker 2? 6. Why is the volume of CO2 production rate? Doing Biology Yourself Repeat the procedure to measure relative CO2 production by aerobic organisms and include in your design an animal such as a fish. Would you expect greater CO2 production from a fish or a snail? Why? 136 EXERCISE 12 Doing Biology Yourself Repeat procedure 12.1 to measure CO2 production in yeast and include in your design and include the tubes at 4°C (incubator), and/or 50°C (incubator). How a fish or a snail? Why? 136 EXERCISE 12 Doing Biology Yourself Repeat procedure 12.1 to measure CO2 production from a fish or a snail? Why? 136 EXERCISE 12 Doing Biology Yourself Repeat procedure 12.1 to measure CO2 production from a fish or a snail? does temperature affect the rate of fermentation by yeast? 12-12 E XER CISE Photosynthesis Pigment Separation, Starch Production, and CO2 Uptake 13 Learning Objectives By the end of this exercise you should be able to: 1. Relate each part of the summary equation for photosynthesis to the synthesis of sugar. 2. Describe the differences between the light-dependent and light-independent reactions involved in photosynthesis. 3. Separate the photosynthetic pigments using paper chromatography and calculate their Rf numbers. 4. Use a spectroscope to describe the absorption of visible light by chlorophyll. 5. Describe fluorescence. 6. Describe the process of electron transport in chloroplasts and its role in photosynthesis. 7. Describe the change of pH that occurs as plants take up CO2 from their environment during photosynthesis relative to the amount of light they receive and the distribution of starch in leaves resulting from photosynthesis. resources tailored to this lab. P hotosynthesis is the most important series of chemical reactions that occurs on earth (fig. 13.1). Indeed, virtually all life depends on photosynthesis is a complex chemical process that converts radiant energy (light) to chemical energy (sugar). The following equation summarizes photosynthesis: light 6 CO2 + 12 H2O C6H12O6 + 6 H2O + 6 O2 chlorophyll Carbon Water Sugar Water Oxygen of carbon dioxide and water to sugar, water, and oxygen. Oxygen is released to the environment, and sugar is used to fuel growth or is stored as starch, a polysaccharide. Although water is present on both sides of the summary equation, these are not the same water molecules. The "product" water molecules (i.e., those on the right side of the equation) are assembled from hydrogen and oxygen released during the photochemical (i.e., light-independent) reactions." The biochemical 13-1 © BiologyImaging.com Figure 13.1 The energy that drives photosynthesis comes from the sun. Less than 1% of all the energy that reactions are often referred to as the "dark reactions" or the Calvin cycle, in honor of Melvin Calvin, the botanist who described the reactions. Photosynthesis 137 CO 2 CO 2 Biochemical reactions (Calvin cycle) ATP Light NADPH Photochemical reactions Thylakoid membranes Stroma NADP ADP Pi Sugar Chloroplasts and consists of photochemical (the light-dependent "light reactions") and biochemical (the light reactions") and b The photochemical (i.e., light) reactions convert light-energy to chemical energy captured in ATP and NADPH. The biochemical reactions occur on thylakoid membranes, whereas the biochemical reactions occur in the stroma. Chloroplasts perform the chemical reactions linking the inorganic world (CO2) to the organic stroma. Slower, but still instantaneous) extremely fast Light-dependent Splits water to Converts (fixes) release oxygen, carbon dioxide to electrons, and protons sugar In today's exercise, you'll investigate some of the major aspects of photosynthesis, beginning with the isolation and identification of photosynthetic pigments. Before you begin studying photosynthesis, we should remind you that all organisms (including plants) carry out respiration in one form or another, but chlorophyll- containing organisms can also photosynthesize. PAPER CHROMATOGRAPHY OF PHOTOSYNTHETIC PIGMENTS Light must be absorbed before its energy can be used. A substance that absorbs light is a pigment. The primary photosynthetic pigments that absorb light for photosynthetic pigments such as carotenoids and xanthophylls also absorb light and transfer energy to chlorophyll a. Paper chromatography is a technique for separating dissolved compounds such as chlorophyll, carotene, 138 EXERCISE 13 and xanthophyll. When a solution of these pigments is applied to strips of paper, the pigments adsorb onto the fibers of the paper. When the tip of the paper is immersed in a solvent, the solvent is absorbed and moves up through the paper. As the solvent moves through the spot of applied pigments, the pigments dissolve in the moving solvent. However, the pigments do not always keep up with the moving solvent, whereas others move more slowly. This differential movement of pigments results from each pigment's solubility and characteristic tendency to stick (i.e., be adsorbed) to the cellulose fibers of the paper. A pigment's molecular size, polarity, and solubility determine the strength of this tendency; pigments adsorbed weakly move fastest. Thus, each pigment has a characteristic rate of movement, and the pigments can be separated from each other. In procedure 13.1, four bands of color will appear on the strip—a yellow-band of carotenes, a blue-green band of chlorophyll b. The relationship of the distance moved by a pigment to the distance moved by the solvent front is specific for a given set of conditions. We call this relationship the Rf number and define it as follows: Rf = Distance moved by pigment origin to solvent front Paper chromatography can be used to identify each pigment origin to solvent front Paper chromatography can be used to identify each pigment origin to solvent front Paper chromatography can be used to identify each pigment origin to solvent front Paper chromatography can be used to identify each pigment origin to solvent front Paper chromatography can be used to identify each pigment origin to solvent front Paper chromatography can be used to identify each pigment origin to solvent front Paper chromatography can be used to identify each pigment origin to solvent front Paper chromatography can be used to identify each pigment origin to solvent front Paper chromatography can be used to identify each pigment origin to solvent front Paper chromatography can be used to identify each pigment origin to solvent front Paper chromatography can be used to identify each pigment origin to solvent front Paper chromatography can be used to identify each pigment origin to solvent front Paper chromatography can be used to identify each pigment origin to solvent front Paper chromatography can be used to identify each pigment origin to solvent front Paper chromatography can be used to identify each pigment origin to solvent front asked to read this exercise so you would know what to do and be aware of safety issues. In the space below, briefly list the safety issues, contact your laboratory assistant before starting work. Procedure 13.1 Separate plant pigments by paper chromatography 1. Observe the contents of the container labeled "Plant Extract." You'll use paper chromatography to separate its pigments. Extinguish all hotplates and flames at all times. Question 1 What color is the plant extract, and why is it this color? 2. Obtain a strip of chromatography paper from your lab instructor. Handle the paper by its edges so that oil on your fingers does not contaminate the paper. 3. Use a Pasteur pipet or a fine-tipped brush to apply a stripe of plant extract approximately 2 cm from the tip of the paper (fig. 13.3). Blow the stripe dry and repeat this application at least 15 times. For this separation to work well, you must start with an extremely concentrated application of extract on the paper. 4. An alternate procedure is to place a fresh leaf directly on the leaf to crush the cells and form a stripe of pigment. 5. Place the chromatography strip in a test tube containing 2 mL of chromatography solvent (9 parts petroleum ether : 1 part acetone). Position the strip of paper with a pin inserted in the strip of paper with a pin inserted in the strip of paper with a pin inserted in the solvent. You can do this by hooking the strip of paper with a pin inserted in the tube's stopper (fig. 13.4). 6. Place the tube in a test-tube rack and watch as the solvent moves up the paper. Keep the tubes capped and undisturbed during solvent movement. 7. Remove the chromatography strip when the solvent front is within 1 cm of the strip aside to dry. Observe the bands of color, then draw your results on figure 13.5. Use your textbook or other materials in lab to identify the different bands of pigments according to their position and color. For example, xanthophylls appear yellow. 8. Use a ruler to measure the distance from the pigment; record your data in table 13.1. Chromatography strip Pigment extract Chromatography solvent Figure 13.3 Application of pigment extract to a chromatography strip. 13-3 Figure 13.4 Chromatography solvent front d. If yellow xanthophylls were present in the extract, why did the extract appear green? e. Is it possible to have an Rf number greater than 1? Why or why not? Pigment origin Figure 13.5 Completed chromatogram. On the chromatogram. On the right of the arrows, write the name of the pigment. A spectroscope is an instrument that separates white light into its component colors. These colors range from red to violet and appear as a spectrum when separated (fig. 13.6). Observe this spectrum by looking through the spectroscope provided in the lab. Now insert a chlorophyll sample between the light and spectroscope, and observe the resulting spectrum. Light not visible through the extract has been absorbed. Table 13.1 Rf Numbers for Four Plant Pigments Pigment Rf Carotene Xanthophyll Chlorophyll a Question 2 a. What does a small Rf number tell you about the characteristics of the moving molecules? b. Which are more soluble in the chromatography solvent, xanthophylls or chlorophyll a? How do you conclude this? Relative absorption (percent) Chlorophyll a Chlorophyll b 80 Chlorophyll b 80 Chlorophyll b 80 Chlorophyll a Chlorophyll b 80 Chl wavelengths of sunlight absorbed by the two common forms of photosynthetic pigment, chlorophylls a and b, and by the carotenoids. Chlorophylls absorb predominantly violetblue and reflect orange and yellow light. 140 EXERCISE 13 13-4 Question 3 What colors are diminished or absent? Based on this observation, complete the following absorption spectrum for chlorophyll. For each color, estimate the relative absorbance of that colors by placing an X above the color name at the appropriate position along the y-axis. Connect the X's for all colors to complete the absorption spectrum. High The absorbed light "excites" the chlorophyll by boosting electrons to a higher-energy orbital. During photosynthesis, the energy of these excited electrons from chlorophyll's central magnesium atom is passed efficiently to another pigment molecule and photosynthesis proceeds. However, to easily observe these energized electrons, we can disrupt the photosynthetic system by blending the cells during the preparation of the plant extract. The chlorophyll electrons in the extract are still energized if you shine light on them, but they are left with nowhere to go. They quickly release their energy by falling back to their original orbitals rather than continuing photosynthesis. As they fall back, they emit a photon of red light energy is fluorescence. The wavelength of reemitted light is determined by the structure of the molecule reemitting the light. Procedure 13.2 front of a bright light. View the extract from the side. (If a UV light is available, you can use the thin-layer chromatography strip from procedure 13.1 to observe fluorescence.) Question 5 What color of light would be least effective for plant photosynthesis? Why? ELECTRON TRANSPORT IN CHLOROPLASTS b. If available, use an extract from red or orange peppers to plot an absorption spectrum for carotenoids? What is the significance of this? The photochemical reactions of photosynthesis transfer electrons among various compounds within chloroplasts (fig. 13.7). In 1937, Robin Hill demonstrated that isolated FLUORESCENCE Light produces reactions only if it is absorbed by a molecule. When sunlight strikes a plant, the chlorophyll absorbs some of the light. The green light is reflected and is responsible for the plant's green color. 13-5

© BiologyImaging.com Figure 13.7 These photosynthetic cells of a moss are packed with bright-green chloroplasts (1000×). Photosynthesis 141 chloroplasts could transfer electron transport does not require CO2-fixation to occur. That is, electron transfer and CO2-fixation involve separate sets of reactions. You can detect electron transfer using a dye called 2,6-dichlorophenol-indolephenol (DCPIP). In its oxidized state, DCPIP is blue. After accepting electrons, DCPIP becomes reduced and colorless. DCPIP can accept electron transfer using a dye called 2,6-dichlorophenol-indolephenol (DCPIP). photosynthesis. The rate of DCPIP decoloration depends on its concentration and the rate of electron flow. By measuring decoloration of DCPIP we can indirectly measure the rate of some reactions of photosynthesis. Because the rate of some reactions of photosynthesis. The phosphate buffer used in this experiment maintains a constant pH of the incubation mixture. b. What happens when you illuminate the tube containing herbicide? c. Based on this result, what do you think is the mode of action of these herbicide? C. Based on this result, what do you think is the mode of action of these herbicide? transport in Phenol red (phenol-sulforphthalein) is a pH-indicator that turns yellow in an acidic solution (pH < 7) and becomes red in a neutral to basic solution (pH > 7). (For more about pH and pH indicators, see Exercise 5.) In this experiment you will use the pH-indicator phenol red to detect the uptake of CO2 by a photosynthesizing aquatic plant Elodea (see fig. 4.6). Recall that plants use CO2 during the light- independent reactions of photosynthesis. To detect CO2 uptake you will put a plant into an environment that you have made slightly acidic with your breath. Carbon dioxide in your breath will dissolve in water to form carbonic acid, which lowers the pH of the solution: chloroplasts 1. Prepare test tubes according to table 13.2. Metabolically active chloroplasts will be provided by your instructor. 2. Mix the contents of each tube well and place it with the other three tubes. Do not position tubes behind each other. Keep all tubes directly in the path of the light. 3. Observe the contents of the tubes intermittently; describe the changes in color that you see. 4. If you have time, prepare a replicate of tube 2 in which water is replaced by 1 mL of 0.1 mM simizane or monuron, both herbicides. Handle all herbicides and pesticides carefully. Question 6 a. What was the purpose the changes in color that you see. 4. If you have time, prepare a replicate of tube 2 in which water is replaced by 1 mL of 0.1 mM simizane or monuron, both herbicides. of each of the tubes used in this experiment? Which tubes were controls? - + Water (H2O) + + Carbon dioxide (CO2) Carbonic acid (H2CO3) + Bicarbonate Hydrogen + ion ion - + (HCO3) (H) As the plant fixes CO2 the pH rises. When the pH rises above 7, the solution turns red. Table 13.2 Solutions for Comparison of Photosynthetic Reaction Rates Tube Chloroplasts 0.1 M PO4 Buffer (pH 6.5) H2O 1 0.5 mL 3 mL 0.5 mL 1 mL 3 0 3 mL 1.0 mL 1 mL 4 0.5 mL 3 mL 0.5 mL 1 mL 4 0.5 mL 3 mL 0.5 mL 1 mL 4 0.5 mL 3 mL 0.5 mL 1 mL 4 0.5 mL 3 mL 0.5 mL 3 mL 0.5 mL 1 mL 4 0.5 mL 3 mL 0.5 mL 1 mL 4 0.5 mL 3 mL 0.5 mL 1 mL 4 0.5 mL 3 mL 0.5 mL 3 mL 0.5 mL 3 mL 0.5 mL 1 mL 4 0.5 mL 3 mL 0.5 mL 1 mL 4 0.5 mL 3 mL 0.5 mL 1 mL 4 0.5 mL 3 mL 0.5 mL 1 mL 4 0.5 mL 3 mL 0.5 mL 1 mL 4 0.5 mL 3 mL 0.5 mL 1 mL 4 0.5 mL 3 mL 0.5 mL 1 mL 4 0.5 mL 3 mL 0.5 mL 3 mL 0.5 mL 1 mL 4 0.5 mL 3 mL 0.5 mL 1 mL 4 0.5 mL 3 mL 0.5 mL 1 mL 4 0.5 mL 3 mL 0.5 mL 1 mL 4 0.5 mL 4 0.5 mL 4 0.5 mL 4 mL 4 provided by your laboratory instructor (fig. 13.8). (Your instructor may have prepared this solution with carbonated water, which is acidic because it has been enriched with CO2. If this procedure.) 2. Use a straw to gently blow your breath into the phenol red solution. Because excess carbonic acid will lengthen this experiment, stop blowing in the tubes. Pour off excess solution above the Elodea. 4. Cover the tops of the tubes with plastic film or foil to prevent gases from the atmosphere from diffusing into the tubes. Then place both tubes approximately 0.5 m in front of a 100-watt bulb for 30-60 min. What do you think will happen? Write your prediction and a brief explanation here: 5. Observe the tubes about every 10 min. Fill two tubes half full with a dilute solution of pheno. red. Use a straw to gently blow into each tube until the solution turns yellow. Add Elodea, cover with foil or plastic film, and place in front of a light. Question 7 a. What is the reason for the color change? Figure 13.8 Preparation of treatment and control test tubes to determine how photosynthesis affects the pH of a solution. c. Did the solution in the control tube change color? Why or why not? d. Considering the summary equation for photosynthesis 143 a chloroplast (fig. 13.9; also see fig. 4.8). Thylakoids are stacked to form columns called grana, held in place by lamellae. A semiliquid stroma bathes the interior of the chloroplast and contains the enzymes that catalyze the lightindependent reactions of photosynthesis. To produce this starch, photosynthesis are often stored as starch. source. In the absence of light, sugars and starch are not produced. Photosynthesis also requires chlorophyll to capture light energy. In the following procedures you will detect the presence of starch by staining it with a solution of iodine and observe the requirement of light and chlorophyll for photosynthesis. USE OF LIGHT AND CHLOROPHYLL TO PRODUCE STARCH DURING PHOTOSYNTHESIS The light-dependent reactions of photosynthetic membranes. In photosynthesis occur on photosynthetic membranes are called thylakoids and are located within a special organelle called Cuticle Epidermis Mesophyll Vascular bundle Stoma Vacuole Cell wall Inner membrane 0.5 µm Courtesy Dr. Kenneth Miller, Brown University Chloroplast. Thylakoid Membrane 1.5 µm Courtesy Dr. Kenneth Miller, Brown University Chloroplast. Chloroplasts are bounded by a double membrane and contain photosynthetic membranes called thylakoids. Stacked one on top of the entire chloroplast is bathed by a semiliquid called the stroma. The openings that enable CO2 to enter the leaf are stomata (singular, stoma). 144 EXERCISE 13 13-8 Procedure 13.5 Stain starch with iodine 1. Place separate drops of water, glucose, and starch solutions on a glass slide. 2. Add a drop of iodine to each and describe your results. 2. Repeat the bleaching and staining steps described in procedure 13.6. 3. Describe and explain any color change in the leaf. 4. Record in figure 13.10b the color of the leaves after each successive treatment. Procedure 13.6 Observe starch production Question 9 Does a leaf produce starch if it has been deprived of light? during photosynthesis 1. Remove a leaf from a Geranium plant that has been illuminated for several hours. 2. After immersing the leaf in boiling water for 1 min, bleach the pigments from the leaf by boiling the leaf in methanol for 3-5 min. This part of the procedure (i.e., the boiling methanol) must be done in a fume hood. Boiling the leaf will remove pigments so that you can see the color changes of the iodine starch test. Exercise extreme caution when you heat methanol. 3. Place the leaf in a petri dish containing a small amount of water and then add five to eight drops of iodine. 4. Observe any color change in the leaf? How can you tell? Procedure 13.8 Observe the requirement of chlorophyll for photosynthesis 1. Obtain leaves of a variegated Coleus plant (fig. 13.11a) and a purple-leafed Coleus plant (fig. 13.11b). Make sketches of their original pigmentation patterns in figure 13.10c, d. Indicate which areas are green, red, green/red, and white. 2. Extract the pigments such as the red cyanins, and boiling the leaf in alcohol will remove chlorophyll. These pigments must be removed for you to see the color changes of the iodine starch test. 3. Record in figure 13.10c, d the color of the leaves after each successive treatment. Question 10 a. How does the pattern of starch storage relate to the distribution of chlorophyll? b. Would you expect leaves to be the primary organ for starch storage in plants? Why or why not? b. Photosynthesis requires chlorophyll (green), but some of the Coleus leaves that you tested were purple. How do you explain your results? Procedure 13.7 Observe the requirement of light for photosynthesis 1. Obtain a Geranium leaf that has been half or completely covered with metal foil or thick paper for three or four days. 13-9 Photosynthesis 145 (a) Fresh Geranium leaf kept in light Then boiled in water Then boiled in methanol Then stained with iodine Variegated Coleus leaf kept in light Then boiled in water Then boiled in methanol Then stained with iodine (b) (c) (d) Figure 13.10 The requirement of light and chlorophyll and the production of starch during photosynthesis. Within each diagram, record the color of the leaf following the treatments to indicate (a) the production of starch, (b) the need for chlorophyll for photosynthesis. Record your results from the appropriate procedure by writing the resulting color of each treated leaf directly onto the outline of the leaf. 146 EXERCISE 13 13-10 © BiologyImaging.com (a) (b) Figure 13.11 Coleus plants. (a) Leaves of this purple, and pink areas resulting from combinations of chlorophylls and anthocyanin (red) pigments. (b) Leaves of this purple Coleus have the same pigment combination throughout the leaf. INQUIRY-BASED LEARNING Does a plant's respiration produce as much carbon dioxide as photosynthesis captures? Observations: Recall from Exercise 12 that aerobic cellular respiration releases CO2, which can combine with water to form carbonic acid and lower the pH (see procedure 12.3). Elodea growing in light respires and photosynthesizes. Elodea's relative uptake and production of CO2. Question: What is the relative uptake versus production of CO2
during photosynthesis and respiration? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 13 from your instructor. b. Discuss with your group a well-defined question relevant to the preceding observation and question. Record it on Worksheet 13. DOING BIOLOGY YOURSELF Recall that respiration produces CO2, which combines with water to form carbonic acid that lowers the pH of a surrounding solution. Design an experiment to measure the relative dynamics (mass balance) of photosynthesis versus respiration for Elodea. 13-11 c. Translate your question into a testable hypothesis and record it. d. Review procedure 12.3 that provides a method to quantify CO2 production. Outline on Worksheet 13 your experimental design and supplies needed to test your question. and make relevant comments. f. Discuss with your instructor any revisions to your questions, hypothesis, or procedures. Repeat your work as needed. WRITING TO LEARN BIOLOGY Use a reference to determine the relative pene tration of different wavelengths of light through water. submerged plants. Photosynthesis 147 Questions for Further Study and Inquiry 1. Why does chlorophyll appear green? 2. Is starch produced when a leaf is kept in the dark? Why or why not? 3. What causes leaves to turn from green to yellow and red in autumn? 4. Of what value to animals is starch? 5. What is the significance of electron transport in the photochemical (i.e., light-dependent) reactions of photosynthesis? 6. Design an experiment to determine if plants respire. Be sure to explain how you would include in the experimental design. 148 EXERCISE 13 13-12 E XER CISE 14 Mitosis Replication of Eukaryotic Cells Learning Objectives By the end of this exercise you should be able to: 1. Describe events associated with the cell cycle. 2. Describe events associated with mitosis. 3. Distinguish the stages of mitotic cells. 4. Stain and examine chromosomes in mitotic cells. 5. Estimate the duration of various stages of mitosis from experimental observations. Please visit connect.mheducation.com to review online resources tailored to this lab. C ells grow, have specialized functions, and usually replicate during their life. Although cell enlargement is part of organismal growth, cell replication allows each cell to grow without becoming too large. All of these activities are part of a repeating set of events called the cell cycle. A major feature of the cell cycle is cellular replication, and a major feature of the cell cycle is cellular replication, and a major feature of the cell cycle is cellular replication. replicated by enzymes and then separated into two identical sets—each set is then surrounded by a nuclear membrane. Each of the genetic information for the organism. Prokaryotic cells lack nuclei and do not undergo mitosis. Instead, they replicate their chromosome and then divide in half during a process called binary fission (described in Exercise 24). Mitosis is usually associated with cytokinesis, the division of the cell and cytokinesis, the division of the cells are multinucleate. Mitosis and cytokinesis are important because they provide a mechanism for orderly growth of living organisms. Question 1 Consider the surface-to-volume ratios of large versus small cells. Is it adaptive for cells of a growing organism to remain small? Explain your answer. THE CELL CYCLE This exercise emphasizes events associated with mitosis, but mitosis is only part of the cell cycle (fig. 14.1). The remainder of the cycle is called interphase and is subdivided further into cytokinesis (C), gap 1 (G1), synthesis (S), and gap 2 (G2) phases. M Metaphase Prophase Telophase C G2 G1 S G2 M C S Interphase Mitosis Cytokinesis G1 Figure 14.1 The cell cycle is depicted as a circle. The first gap phase, G1, involves growth and preparation for DNA synthesis. During the S phase, a copy of the genome is synthesized. The second gap phase, G2, prepares the cell into two cells with identical genomes. 14-1 Mitosis 149 Sister chromatid Centromere region of chromosome Kinetochore microtubules Metaphase chromosome, kinetochore microtubules are anchored to proteins at the centromere. (b) This electron micrograph shows how human chromosomes appear during the early stages of nuclear division. Each strand of DNA has already been replicated and condensed to form discrete sister chromatids identical to each other and held together by a centromere. The cell cycle begins with the formation of a new cell and ends with replication of that cell. The G1 phase of the cell cycle begins with the formation of a new cell and ends with replication of that cell. the majority of cellular activity for the functions of the cell occurs. Many cell-specific proteins and other molecules are produced for the metabolism of the cell during G1. During the S phase, the DNA composing the chromosomes (a) Interphase is duplicated. At the end of the S phase each chromosome consists of an identical pair of chromosomal DNA strands, called sister chromatids, attached at a centromere (fig. 14.2). During the G2 phase, molecules and structures necessary for mitosis are synthesized. Mitosis (M phase) usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually lasts for less than 10% of the time of the cell cycle, which usually Spindle pole Two centrosomes, each with centriole pairs 1 Chromosomes have already replicated during interphase. Mitotic spindle starts to form. Nuclear membrane begins to dissociate into vesicles. 3 Nuclear membrane has completely dissociated into vesicles and the spindle is fully formed. Sister chromatids attach to spindle via kinetochore microtubules. Figure 14.3 Interphase and the stages of mitosis in an animal cell. The cleavage furrow signifying cytokinesis may first appear during tissues may spend more than 10% of their time in mitosis, whereas static cells such as bone cells or neurons may rarely enter M phase. Cytokinesis may begin during mitosis but is highly variable in length and timing. Tissues such as striated muscle fibers, and some algal filaments, may undergo mitosis without cytokinesis and produce multinucleate cells. Question 2 a. Mitosis and cytokinesis are often referred to collectively as "cellular division." Why are they more accurately called cellular replication? b. Does the cell cycle have a beginning and an end? Explain. (d) Metaphase STAGES AND EVENTS OF MITOSIS Mitosis (1) separates the genetic material duplicated during interphase into two identical sets of chromosomes and (2) reconstitutes a nucleus to house each set. As a result, mitosis produces two identical nuclei from one. In animals, mitosis occurs in body (i.e., non-sex) cells. Mitosis is traditionally divided into five stages: prophase, prometaphase, and telophase, and telophase (fig. 14.3). The actual events of mitosis are not discrete but occur in a continuous sequence; separation of mitosis into five stages is merely convenient for our discussion and organization. During these stages, important cellular structures are synthesized and perform the mechanics of mitosis (fig. 14.3). For example, in animal cells, two microtubuleorganizing centers called centrosomes contain cylinders of microtubules called centrioles, which replicate at the onset of mitrosis. The pairs of centrioles move apart and form an axis of proteinaceous microtubules called the mitotic spindle (or spindle apparatus) extending between them (fig. 14.6). Kinetochore microtubules (fig. 14.2) attach to each chromosome's kinetochore, which is a complex of proteins that binds to the centroubules brace the poles of the cell, the centroubules brace the poles of the cell apparatus. centrioles against the cell membrane. This arrangement of microtubules (e) Anaphase plate cleavage furrow Polar microtubules (f) Telophase and cytokinesis Individual chromosomes Metaphase plate. 14–3 5 Sister chromatids separate and individual chromosomes move toward poles as kinetochore microtubules shorten. Polar microtubules lengthen and push poles apart. 6 Chromosomes decondense and nuclear membranes re-form. Cleavage furrow separates the 2 cells. Mitosis 151 Cancer—A Corrupt Cell Cycle Cancer is unrestrained cell proliferation caused by damage to genes that regulate the cell
division cycle. Cancer produces a cluster of cells called a tumor that constantly expands. Tumors from cells in connective tissue, bone, or muscle are known as sarcomas, while those from epithelial tissue, such as skin, are called carcinomas (fig.14.4). In the United States, the four deadliest human cancers (about 55% of all cancer deaths) are lung cancer, breast cancer, and leukemia/lymphomas. Recent work has identified one of the culprits in cancer. Officially dubbed p53, this gene plays a key role in the G1 checkpoint of cell division (fig. 14.5). The gene's product— the p53 protein—monitors the integrity of DNA, checking that it is undamaged. If the p53 protein detects damaged DNA, it halts cell division and stimulates enzymes to repair the damage. After repair, p53 allows cell division to continue. If the DNA damage is irreparable, then the p53 directs the cells and is therefore a tumor-suppressor gene. Researchers have found that p53 is absent or damaged in the majority of cancerous cells they have examined. It is precisely because p53 is nonfunctional that cancer cells are able to repeatedly undergo cell division without being halted at the G1 phase of the cell cycle. Abnormal p53 Figure 14.4 Portrait of a cancer. This carcinoma is developing from epithelial cells that line the interior of a human lung. As the mass of cells grows, it invades the surrounding tissues, eventually penetrating lymphatic and blood vessels, both of which are plentiful in the lung. These vessels carry metastatic cancer cells throughout the body, where they lodge and grow, forming new masses of cancerous tissue. p53 allows cells with repaired DNA to divide. p53 protein DNA repair enzyme 1. DNA damage is caused by heat, radiation, or chemicals. 2. Cell division stops, and p53 triggers the destruction of cells damaged beyond repair. Cancer cell 2. The p53 protein fails to stop cell division and repair DNA. Cell divides without repair to damaged DNA. 3. Damaged cells continue to divide. If other damage accumulates, the cell can turn cancerous. Figure 14.5 Cell division, cancer, and p53 protein fails to stop cell division or repair DNA. As damaged cells proliferate, cancer develops. 152 EXERCISE 14 14-4 Pole Centrosome with centriole pair Astral microtubules Sister chromatids Kinetochore Polar microtubules Sister chromatids Kinetochore Polar microtubules Sister chromatids Kinetochore microtubules Figure 14.6 of microtubules. The astral microtubules are attached to the kinetochores of sister chromatids. radiating from a centriole is called an aster with astral microtubules. Plant cells lack centrioles and asters, but spindle fibers still form between opposite poles of the cell. Interestingly, animal cells deprived of centrioles will still form a spindle apparatus and are moved and separate to opposite poles. The distribution of chromosomes will also occur if the cell is haploid (i.e., has a single set of chromosomes). The vegetative cells of many organisms such as fungi are haploid (have a double set of chromosomes). However, the steps of mitosis are the same as for diploid cells. SAFETY FIRST Before coming to lab, you were asked to read this exercise so you would know what to do and be aware of safety issues. In the space below, briefly list the safety issues associated with today's procedures. If you have questions about these issues, contact your lab meeting, review in your textbook the events associated with each stage of mitosis in addition to the preparatory stage, interphase. List these events in table 14.1. Some events and structures occur only in plant cells and some occur only in plant cells. Mark these events in your list with an asterisk. This list can serve as an excellent study guide, so be as complete as possible. One event for each stage is provided in figure 14.3. Table 14.1 Events of Mitosis and Interphase Interphase Although interphase is not part of nuclear replication, understanding its events is essential to understanding its events is essential to understanding its events is essential to understanding mitosis. Prophase Prometaphase Metaphase Anaphase Telophase Interphase is not part of nuclear replication, understanding its events is essential to understanding mitosis. during metaphase? b. How many does it have after mitosis is complete? 9. Move the chromosome models appropriately to depict telophase. 11. Draw the results of cytokinesis and the re-formation of nuclear membranes. 12. Chromosomal events occur as a continuous process of movements rather than in distinct steps. Therefore, repeat steps 4-11 as a continuous process and ask your instructor to verify your simulation. MITOSIS IN ANIMAL CELLS Understanding mitosis. You can simulate these movements of chromosomes is crucial to understanding mitosis. popsicle sticks. This is a simple procedure but a valuable one. It will be especially helpful when you are comparing the events of mitosis to the events of mitosis to the centromere. A replicated chromosome (fig. 14.2a) has two strands of DNA strands of DNA strands of DNA strands attached to the centromere. but it is still considered one chromosome. When the strands (chromatids) separate during anaphase, the replicated chromosome becomes two chromosome becomes two chromosome becomes two chromosomes. Procedure 14.2 Simulate chromosome becomes two chromosome becomes two chromosomes. differences in chromosomes represented by various colors, lengths, or shapes of materials. Also identify materials representing the boundaries of the mitotic cell. 4. Assemble the chromosomes needed to represent nuclear material in a cell of a diploid organism with a total of six chromosomes in the cell. 5. Arrange the chromosomes are usually not condensed, as the chromosomes are usually not condensed, as the chromosomes are usually not condensed. (During G1 the chromosomes are usually not condensed, as the chromosomes after completing interphase S. Use additional "nuclear material" if needed. 7. Move the chromosome models appropriately to depict metaphase. 154 EXERCISE 14 The most distinctive features of cellular replication in animal cells are the formation of asters with centrioles at their center and early developmental stages undergo rapid cell divisions (as do all embryonic cells). A blastula is an early embryonic stage of a vertebrate and consists of a sphere of 25-100 cells with a high frequency of different mitotic stages. Exercise 50 (Embryology) details the formation of a blastula during embryonic cells). and describe mitosis in animal cells 1. Obtain a prepared slide of a cross section through the blastula of a whitefish. 2. Examine the cells contain condensed and stained chromosomes. Cleavage furrow @MedicalRF.com/Alamy Stock Photo Figure 14.7 Cytokinesis in an animal cell. Cytokinesis, the physical division of the cell's cytoplasm, usually occurs after nuclear replication is complete. A cleavage furrow is forming around this dividing sea urchin egg. 14-6 Chromosomes Spindle fibers ©Ed Reschke (a) Prophase (b) Prometaphase / Metaphase ©Ed Reschke (a) Prophase (b) Prometaphase (b) Prometaphase (c) Anaphase ©Ed Reschke (c) Prometaphase (c) Anaphase (c Reschke (d) Telophase Figure 14.8 Stages of mitosis in cells of a whitefish embryonic blastula (400×). Prometaphase and metaphase may not always be distinguishable by light microscopy. 3. Refer to figure 14.3 for a summary of the stages of mitosis. Identify examples of each stage on your prepared slide (fig. 14.8). Verify these stages with your lab partner or teaching assistant. 4. Also identify cells that you believe are between stages. 5. Examine the whitefish cells for signs of cytokinesis. 6. Prepared cross-sections of cells show only two dimensional process. In the following space, draw two cells in metaphase: one in which the cross section is parallel to the axis of the spindle apparatus and one in which the cross section is perpendicular to the spindle apparatus. Question 4 a. Why would we choose an embryonic mass of cells for procedure 14.3 in which to study the stages of mitosis? 14-7 b. Which stage of mitosis? 14-7 b. model to study cellular replication in plants is the root tips of plants contain meristems, which are localized areas of rapid cell division due to active growth at the root tips. In plant cells, cytokinesis includes formation of a partition called a cell plate perpendicular to the axis of the spindle apparatus. The cell plate forms in the middle of the cell and grows out to the periphery. It will separate the two new cells. Interestingly, the formation of the spindle apparatus and other microtubule systems in plant and fungal cells have no centrosomes, as in animal cells. But plant and fungal cells have no centrosomes, as in animal cells. centrioles remain somewhat of a mystery. Mitosis 155 (a) Prophase © BiologyImaging.com (b) Prometaphase © BiologyImaging.com (c) Anaphase © Bi diagram mitosis in plant cells 1. Examine a prepared slide of a longitudinal section through an onion root tip. 2. Search for examples of all stages of mitosis (fig. 14.9). Notice that most cells are in some part of interphase. 3. Search for signs of cell plate formation. Prophase 4. In figure 14.10, diagram a plant cell with a diploid number of three pairs of chromosomes in each of the stages of mitosis. Diploid refers to a nucleus with two of each type of chromosome. Be sure to label the cell wall and cell plate. 5. Prepared cross sections of cells show only two dimensions, but mitosis is a three-dimensional process. In the following space draw two cells in metaphase: one in which the plane of section is parallel to the axis of the Prometaphase / Metaphase Figure 14.10 Diagram the stages Anaphase 156 EXERCISE 14 Telophase of mitosis in a plant cell with six chromosomes. The outlines represent the cell walls of each of four cells. 14-8 INQUIRY-BASED LEARNING How much time elapses during the various stages of mitosis? Observations: The cell cycle of actively dividing cells
of root tips of Allium is approximately 24 h long. The phases of mitosis take? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 14 from your instructor. b. Discuss with your group a well-defined question relevant to the preceding observation and question. Record it on Worksheet 14. c. Translate your question into a testable hypothesis and record it. Stage of Mitosis Predicted Duration (hours) Number of Cells in Each Stage Interphase Prophase Prometaphase/ Metaphase/ Totals spindle apparatus and one in which the cross section is perpendicular to the spindle apparatus. Question 5 a. What region of a root has the most mitotic activity? b. How does cytokinesis differ in plant versus animal cells? 14-9 d. Each prepared slide of a root tip of Allium reveals a snapshot in time of all stages of Anaphase mitosis. e. The relative abundance of cells in a phase of mitosis is directly proportional to the length of time for that phase. f. Outline on Worksheet 14 your experimental design and supplies needed to test your hypothesis. The table below offers insight to a reasonable design. Ask your instructor to review your proposed investigation. g. Conduct your procedures, record your data, answer your question, and make relevant comments. h. Discuss with your instructor any revisions to your questions, hypothesis, or procedures. Repeat your work as needed. Total Number of Cells in Each Stage Class Total Number of Cells in Each Stage Clas inadequate for cytokinesis in plant cells? d. What is a cell plate, and in what stage of mitosis does it form? e. Locate a plant cell in late telophase. What is the volume of the two new cells relative to a mature cell? Mitosis 157 PREPARING AND STAINING CHROMOSOMES Your instructor has prepared some living onion root tips for you to process further and use to observe the stages of mitosis. Procedure 14.5 Stain chromosomes 1. Obtain an onion root tip and place it is a colorless liquid that becomes bright red after reaction. Keep the vial in the dark and at room temperature until the root tip becomes purple. Your instructor may have already stained some root tips for you. 2. Place the root tip in a drop of 45% acetic acid is corrosive. Do not spill it. 3. Crush the root tip with a blunt probe and cover the tissue with a coverslip. 4. Smash the tissue by pressing on the coverslip with the eraser of your pencil. Your instructor will demonstrate this procedure. 5. Scan your preparation at low magnification to locate stained chromosomes. Then switch to high magnification to locate stained chromosomes. edge of the coverslip to avoid desiccation. 7. Locate as many stages of mitosis as you can. Be sure to look at preparations done by other students. Questions for Further Study and Inquiry 1. Interphase has sometimes been called a "resting stage." Why is this inaccurate? 2. Most general functions of a cell occur during G1 of interphase. What events that occur during other phases of the cell cycle might inhibit general metabolism? 3. Read in your textbook about prokaryotic cellular replication; list the fundamental cellular/structural differences? 4. Some specialized cells such as neurons and red blood cells lose their ability to replicate when they mature. Which phase of the cell cycle do you suspect is terminal for these cells? Why? 5. Find a concise definition of "cancer." How might methods to treat cancer relate to what you learned in this lab exercise? WRITING TO LEARN BIOLOGY Refer to your textbook to review the properties of a chemical called colchicine. Describe how colchicine affects dividing cells. What is the mechanism of this effect? How might colchicine be used as a tool in scientific research or medicine? 158 EXERCISE 14 WRITING TO LEARN BIOLOGY Write a summary of the mechanism and consequences of using the drug Vincristine that blocks mitotic spindle formation by cancer (and other) cells. Reference the scientific literature. 14-10 E XER CISE 15 Meiosis Reduction Division and Gametogenesis Learning Objectives By the end of this exercise you should be able to: 1. Describe the events of meiosis. 2. Compare and contrast meiosis and mitosis. 3. List the most significant events of meiosis. 4. Explain the relevance of meiosis to sexual reproduction and evolutionary change. 5. Explain the relationship of meiosis and gametogenesis. 6. Describe the events of spermatogenesis. 8. Describe the events of spermatogen the significance of sex, and meiosis in particular, is the recombination of a parent's genes are combined with another occur in pairs; that is, the nuclei are diploid (2n). The two chromosomes of a pair are called homologous chromosomes, and each homologues may carry different alleles at homologous loci. A nucleus, such as that in a gamete, with only one chromosome of each homologous pair is haploid (n). Meiosis produces haploid daughter nuclei and is sometimes called "reduction division." Reducing the number of chromosomes in the nucleus during sexual reproduction and restore the original diploid number of chromosomes to the new individual (fig. 15.1). 15-1 Haploid egg (n) Haploid sperm (n) Fertilization (2n) Maternal homologue Diploid zygote Figure 15.1 In animals, meiosis produces eggs and sperm, both of which are haploid (n). Fusion of an egg and sperm during fertilization produces a zygote, which diploid (2n). Question 1 a. Why would shuffling genetic material to produce new combinations of characteristics be advantageous to a species? Meiosis 159 Homologous chromosomes Kinetochore Replication Cohesin proteins Centromere Kinetochores Paternal Maternal Sister chromatids Figure 15.2 The difference between homologous chromosome and sister chromatids. Homologous chromosome are the maternal and paternal copies of the same chromosome held together at their centromeres by cohesin proteins after DNA replication. The kinetochore is composed of proteins found at the centromere that attach to microtubules during mitosis, is preceded by the replication of each chromosome to form two sister chromatids attached at a centromere (fig. 15.2). However, two events that do not occur in mitosis include final reduction of the chromosome number by half and production of new genetic combinations. Meiosis reduces the chromosome number during two rounds of chromosome separation called meiosis. This allocates half the original number of chromosomes (one of each original pair) to each daughter cell. That is, the nuclei are haploid. To produce new genetic combinations, each chromosome (composed of two sister chromatids) initially pairs along its length with its homologue to form a bivalent (fig. 15.3). This pairing of homologous chromatids) initially pairs along its length with its homologue to form a bivalent (fig. 15.3). Chiasma Bivalent Synaptonemal complex forming 1 Homologous chromosomes condense. 2 Synapsis begins. 3 Bivalents form. 4 Crossing-over occurs. 5 The chiasma becomes visible as chromosome arms separate during late prophase. Figure 15.3 Formation of a bivalent separate during late prophase. chromosomes pair with each other to form a bivalent, usually with a synaptonemal complex between them. Crossing-over then occurs between homologous chromatids within the bivalent. During this process, homologues exchange segments of chromosomes. 160 EXERCISE 15 15-2 homologous segments of genetic material called alleles. Alleles are alternate states of a gene, such as a Type A allele, or Type O allele, or Type O allele, or Type O allele, which together determine a person's blood type. This exchange of genetic material among chromatids is called crossing-over there is no gain or loss of g enetic material. But afterward, each chromatid of the chromosomes contains different segments (alleles) that it exchanged with other chromatids. The temporary points of attachment of two chromatids at a point of genetic exchange are called chiasmata (fig. 15.3). Compare the outline in table 15.1 with your outline in table 14.1 on mitosis. Question 2 a. Synapsis occurs after chromosomal DNA has replicated. How many chromatids are involved in crossingover of a homologous pair of chromosomes, and one had alleles for green eyes and brown hair where the other had alleles for green eyes and brown hair where the other had alleles for green eyes and brown hair where the other had alleles for green eyes and brown hair where the other had alleles for green eyes and brown hair where the other had alleles for green eyes and brown hair where the other had alleles for green eyes and brown hair where the other had alleles for green eyes and brown hair where the other had alleles for green eyes and brown hair where the other had alleles for green eyes and brown hair where the other had alleles for green eyes blonde hair. How many different combinations of these alleles would be possible? STAGES AND EVENTS OF MEIOSIS Although meiosis is a continuous process, we can study it more easily by dividing it into stages just as we did for mitosis. Meiosis and mitosis are similar, and their corresponding stages of prophase, prometaphase, metaphase, metaphase, metaphase, metaphase, metaphase, metaphase, metaphase, metaphase anaphase, and telophase have much in common. However, meiosis I and meiosis I. Homologous chromosomes are separated at the end of meiosis I, and chromatids composing each chromosome are separated during meiosis II. Each reduction involves the events of prophase, prometaphase, and telophase, and telophase (fig. 15.4). Before your lab meeting, review in your textbook the events associated with each stage of meiosis, including the preparatory stage, interphase. List these events in table 15.1. This list can serve as an excellent study guide, so be as complete as possible. Ask your instructor to check for errors. One or two events for each stage are provided in figure 15.4. Premeiotic Interphase, including replication of the chromosomes. Each chromosome is replicated. 15–3 Question 3 a. If a nucleus has eight
chromosomes when it begins meiosis, how many chromosomes does it have after telophase I? Telophase I? Telophase I? Telophase II? c. What are some minor? Understanding meiosis. You can simulate these movements of chromosomes is crucial to understanding the movements of chromosomes models made of pipe. cleaners or popsicle sticks. This simple but valuable exercise is especially instructive if you compare your simulation of meiosis 1. Examine the materials for chromosome models provided by your instructor. 2. Identify the differences in chromosomes represented by various colors, lengths, or shapes of the materials to represent the boundaries of the meiotic cell. 4. Assemble the chromosomes needed to represent the nuclear material in a cell of a diploid organism with a total of six chromosomes to depict the position and status of chromosomes during interphase G1. (During G1 the chromosomes are usually not condensec as the chromosome models imply; nevertheless, the models are an adequate representation.) 6. Depict the chromosomes after completing interphase I Bivalent Spindle forming Centrosome 2 Homologous chromosomes synapse to form bivalents, and crossing-over occurs. Chromosomes condense and the nuclear membrane begins to fragments of nuclear membrane Bivalents secome attached to kinetochore microtubules. 3 Bivalents align along the metaphase plate. Meiosis II (f) Prophase II 6 Sister chromatids condense and the spindle starts to form. Nuclear membrane begins to fragment. (g) Prometaphase II 7 (h) Metaphase II 7 (h) Met 7. Depict the chromosomes during prophase I, and telophase I, and telophase I, and telophase I, and telophase I. 8. The interval between meiosis I and meiosis anaphase II, and telophase II. 10. Draw the results of cytokinesis and the re-formation of nuclear membranes. 162 EXERCISE 15 11. Chromosomal events are a continuous process and ask your instructor to verify your simulation. GAMETOGENESIS Meiosis occurs in all sexually reproducing eukaryotes and produces haploid nuclei. However, organisms vary in the timing and structures associated with producing functional gametes. Gametes are reproductive cells with haploid nuclei resulting 15-4 (d) Anaphase I (e) Telophase I and cytokinesis Cleavage furrow 4 Homologous chromosomes separate and move toward opposite poles. (i) Anaphase II Nuclear membranes re-form and the chromosomes decondense. The 2 cells are separated by a cleavage furrow. 5 (j) Telophase II and cytokinesis Four haploid cells 9 Sister chromatids separate and individual chromosomes move toward poles as kinetochore microtubules shorten. Polar microtubules lengthen and push poles apart. from meiosis, and the formation of gametogenesis. Meiosis is the primary element of gametogenesis in animals, but after meiosis the cells must mature and usually change their morphology before becoming a functional gameto. In this exercise, you will examine mammalian gametogenesis. Gametogenesis includes spermatogenesis, the formation of sperm cells, and oogenesis, the formation of egg cells (fig. 15.5). Mammalian Spermatogenesis occurs in male testes made of tightly coiled tubes called seminiferous tubules (fig. 15.6). Examine a 15-5 10 Chromosomes decondense and nuclear membranes re-form. Cleavage furrow separates the 2 cells into 4 cells. prepared slide of a cross-section through the seminiferous tubules of a monkey, rat, or grasshopper. Packed against the inner walls of the tubules are diploid cells called spermatogonia. These cells constantly replicate mitotically during the life of males. They are assisted by nongerminal cells called sertoli cells. Some of the daughter cells from spermatogonia mitosis move inward toward the lumen of the tubule and begin meiosis. These cells are called primary spermatocytes, each with a haploid set of replicated chromosomes. Review figure 15.2 to see the structural difference between a replicated chromosome and an unreplicated chromosome. Meiosis 163 Table 15.1 Events of Meiosis Prophase I Prometaphase/Metaphase II Anaphase II Telophase II Human Sperm Cells by the Numbers •• Healthy males produce 100-200 million sperm cells per day. •• There are an estimated 250 million sperm cells per ejaculation. •• There are 200-300 million sperm cells for every one egg. Meiosis II separates the chromatids of each replicated chromatids of each replicated chromatids. spermatogenesis in figure 15.5. Then examine some prepared slides of sperm cells from vertebrates such as guinea pig, rat, and human. Question 4 a. During gametogenesis a sperm cell undergoes considerable structural change. What are the basics of sperm structure and how do these features relate to function? 164 EXERCISE 15 •• There are about 20 million sperm/mL of semen. •• About 20% of all sperm are deformed. •• Sperm can live inside a female reproductive system for up to 6 or 7 days. •• Conception can occur several days after sexual intercourse. b. What is the adaptive advantage of producing sperm in a system of tubes rather than in solid tissue? c. What is each strand of a double-stranded chromosome called? 15-6 Oogonium (2n) DNA replication Primary spermatocyte (2n) Meiosis I Secondary spe Spermatogenesis (males) Mature ovum (n) Degenerates (b) Oogenesis (females) Figure 15.5 Gametogenesis in (a) males and (b) females. Both male and female germ cells are diploid (2n) Nucleus of Sertoli cell Primary spermatocyte (2n) Tubule lumen Secondary spermatocyte (n) Spermatid (n) Mature sperm (n) Vas deferences Coiled seminiferous tubules of the testis, germinal cells called spermatogonia progress through spermatocyte and spermatid stages to develop into sperm. Each mature sperm has a long tail coupled to a head, which contains a haploid nucleus. 15-7 Meiosis 165 Mammalian Oogenesis occurs in ovaries of females (fig. 15.7). Cells of the ovary, as spermatocytes are produced by the testes. During early fetal development, oogonia (germinal cells) are produced in the ovaries. These oogonia replicate mitotically to produce as many as two million primary oocytes that she will ever have (i.e., oogonia produce no more primary oocytes). At birth the primary oocytes in a female have begun meiosis I but are arrested in prophase I. They are surrounded by supportive follicular cells, and together they are called follicles. At puberty, circulating hormones stimulate growth of one or two of these dormant follicles (and their primary oocytes) each month. The oocyte enlarges and the number of follicular cells increases. Just before ovulation (release of the oocyte completes meiosis I, which produces a secondary oocyte (fig. 15.8). Each secondary oocyte contains a haploid set of double stranded chromosomes (two chromatids), but cytoplasmic cleavage is unequal. The secondary oocyte retains most of the cytoplasm and the first polar body usually disintegrates. Examine a prepared slide of a mammalian ovary cross-section. In the following space, sketch a Graafian follicle and two or three less mature stages. Fetal development Fertilization and meiosis II Germinal cell (diploid) Fallopian tube Arrest at prophase I Primary oocyte (diploid) Ruptured follicle (secondary oocyte (diploid) Ruptured follicle (secondary oocyte) MEIOSIS II Corpus albicans Primary follicle (secondary oocyte) MEIOSIS II Corpus albi Secondary oocyte (haploid) MEIOSIS II Fertilization Cleavage Second polar bodies Ovum (haploid) Figure 15.7 Oogenesis. A primary oocyte is diploid (2n). After its first meiotic division, one product is eliminated as a polar body. The other product, the second meiotic division of the second meiotic division of the second meiotic division of the second meiotic division. division, and a second polar body and a haploid (n) ovum nucleus with a haploid (n) sperm nucleus with a haploid (n) sperm nucleus produces a diploid (n) sperm nucleus produces a diploid (2n) zygote that subsequently forms an embryo. 166 EXERCISE 15 15-8 b. Are polar body and a haploid ovum are produces a diploid (2n) zygote that subsequently forms an embryo. ovulation the remaining follicle cells form the corpus luteum on the surface of the ovary. The corpus luteum produces hormones that prepare the uterus for the potential arrival of a fertilized egg. The corpus luteum declines after 8-9 days and becomes a white body of connective tissue called the corpus luteum declines after 8-9 days and becomes a white body of connective tissue called the corpus luteum declines after 8-9 days and becomes a white body of connective tissue called the corpus luteum declines after 8-9 days and becomes a white body of connective tissue called the corpus luteum declines after 8-9 days and becomes a white body of connective tissue called the corpus luteum declines after 8-9 days and becomes a white body of connective tissue called the corpus luteum declines after 8-9 days and becomes a white body of connective tissue called the corpus luteum declines after 8-9 days and becomes a white body of connective tissue called the corpus luteum declines after 8-9 days and becomes a white body of connective tissue called the corpus luteum declines after 8-9 days and becomes a white body of connective tissue called the corpus luteum declines after 8-9 days and becomes a white body of connective tissue called the corpus luteum declines after 8-9 days and becomes a white body of connective tissue called the corpus luteum declines after 8-9 days and becomes a white body of connective tissue called the corpus luteum declines after 8-9 days and becomes a white body of connective tissue called the corpus luteum declines after 8-9 days and becomes a white body of connective tissue called the corpus luteum declines after 8-9 days and becomes a white body of connective tissue called the corpus luteum declines after 8-9 days and becomes a white body of connective tissue called the corpus luteum declines after 8-9 days and becomes a white body of connective tissue called the corpus luteum declines after 8-9 days and becomes
a white body of connective tissue called the corpus luteum declines after 8-9 days a Figure 15.8 A mature secondary oocyte in an ovarian follicle of a cat (400×). This secondary oocyte awaits ovulation. Question 5 How would retaining extra cytoplasm enhance survival of a developing oocyte? Meiosis II proceeds but is not completed until after a sperm cell penetrates the egg. Completion of meiosis II produces another polar body and a haploid egg cell ready for fertilization (fusion of nuclei). Review these basic stages of oogenesis in figure 15.5. Then examine a cross-section of a cat ovary. Question 6 a. What are the relative sizes of oocytes in a dormant follicle, a growing follicle, and a Graafian follicle? 15-9 The formation of gametes in plants is somewhat different because their sexual life cycle includes an alternation of generations between haploid forms. However, meiosis is still the critical process by which plants, meiosis occurs in the anther, the spores resulting from meiosis produce a stage of the life cycle (pollen) that will eventually produce female gametes. In the ovary, the spores resulting from meiosis produce a stage of the life cycle (ovule) that will eventually produce female gametes. In this procedure, you will observe prepared slides showing stages of the beginning, middle, and end of meiosis I and II in a representative plant. Procedure 15.2 Diagram and observe stages of meiosis 1. In figure 15.9, diagram a plant cell with three pairs of chromosomes in each of the stages of meiosis. Be sure to label the cell wall and cell plate. 2. Examine the following prepared slides of stages of meiosis in a Lilium anther (see figs. 31.10, 31.11). a. Lilium anther—part prophase I b. Lilium anther—part prophase I c. Lilium anther—first meiotic division d. Lilium anther—first meio ovary—"mother cell," prophase I b. Lilium ovary—binucleate stage, end of meiosis I c. Lilium ovary—four nucleate stage, end of meiosis I Meiosis 167 Interphase I Prophase I Pro and meiosis are both forms of cellular replication, but they play different roles in the life cycle of animals and plants. Mitosis may occur in either haploid or diploid cells and is necessary for cell production and growth. Meiosis 168 EXERCISE 15 Metaphase II Telophase II (label cell plates) o ccurs in diploid cells. Its role is to produce cells with a reduced number of chromosomes and shuffle the genetic material so an organism can reproduce sexually. To compare mitosis, review table 15.2 and complete the column with the contrasting features of meiosis. 15–10 INQUIRY-BASED LEARNING How much does the anatomy of sperm cells vary among the animal species that you examined? Observation: The morphology of sperm cells directly relates to their function. Sperm of vertebrates such as guinea pigs, rats, and humans vary in size and shape. Question: How does sperm cell morphology vary among species of vertebrates? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 15 from your instructor, b. Discuss with your group the measurements and observations you might make to reveal variation in sperm morphology. Pose a well-defined guestion. Record it on Worksheet 15, c. Translate your guestion into a testable hypothesis and record it. d. Outline on Worksheet 15 the procedures and supplies needed to test your hypothesis. Ask your instructor to review your proposed investigation. e. Conduct your procedures, record your data, answer your questions, hypothesis, or procedures. Repeat your work as needed. Table 15.2 A Comparison of the Major Features of Mitosis Meiosis Meiosis Meiosis Purpose of process Number of cells groduced Number of nuclear divisions Haploidy or diploidy of resulting cells Genetically identical cells (yes or no) Occurrence of crossing-over (yes or no) 15-11 Meiosis 169 Questions for Further Study and Inquiry 1. How would you diagram the chromosomal arrangement for transitional stages such as late prophase/early metaphase I? Or late anaphase/early metaphase I? Or late anaphase/early telophase I? 2. Would evolution occur without the events of meiosis and other vertebrates that are associated with continuous production of egg cells? 4. Which process is most accurately referred to as nuclear division: meiosis or mitosis? 5. What special event does interkinesis lack compared to premeiotic interphase? 6. How are mammalian sperm cells produced and incubated at a lower temperature? 7. How old is an ovulated oocyte of a 35-year-old woman? What consequences does this have? WRITING TO LEARN BIOLOGY Wouldn't it be easier for a cell simply to divide the chromosomes once rather than duplicating them and then dividing them twice during meiosis? Why do you suppose this isn't done? 170 EXERCISE 15 15-12 E XER CISE Molecular Biology and Biotechnology DNA Isolation and Genetic Transformation 16 Learning Objectives By the end of this exercise you should be able to: 1. Isolate DNA from a bacterium. 2. Understand how temperature and pH affect DNA. 3. Insert a gene for resistance to ampicillin into a bacterium. Please visit connect.mheducation.com to review online resources tailored to this lab. B iotechnology is the manipulation of organisms to do practical things and to products. Bio technology has been around for centuries: Humans have selectively bred livestock for meat products, controlled pollination to produce more food, and used bacteria and fungi to make wine and cheese. But recent progress in molecular biology has revolutionized biotechnology, and its products include vaccines, detergents, drugs, biodegradable plastics, alcoholic beverages, industrial chemicals (e.g., ethanol, acetone), antibiotics, hybrid crops, livestock food, cooking oils, improved textiles and fabrics, lower-cholesterol meats and eggs, and many common foods (e.g., corn, watermelon, chicken, cheese) and beverages (e.g., milk, beer, wine). The revolution stems from new molecular techniques that have made genetic engineering possible. Genetic engineering is the direct manipulation of genes for practical purposes (fig. 16.1). Genetic engineers can inter vene directly in the genetic fate of organisms. We can isolate genes, move them from one organism to the next, and even move genes from one species to the next. The most common goals of this engineering are to harvest the valuable proteins made by engineered genes and to benefit from the new char acteristics the genes. provide to the target organisms, including humans. Indeed, the impact on society of the current revolution in genetic engineering may soon surpass that of such historical changes as the industrial revolution of the past two centuries. Genetic engineering got its start in 1973 when Stan Cohen and Herb Boyer transplanted a gene for antibiotic resistance from a frog into a bacterium, and thus "engi neered" an antibiotic-resistant organism. In 1980, molecular biologists successfully inserted a human gene for interferon, an antibiotic-resistant organism. In 1980, molecular biologists successfully inserted a human gene for interferon and thus "engi neered" and thus the "transformed" bacterium. When the "transformed" bacterium reproduced, it generated billions of progeny, each a miniature drug factory. As a result of this engineering, 16-1 © MyLoupe/Getty Images Figure 16.1 The United States is the world's top per-capita consumer of genetically engineered to corn was used to grow genetically engineered corn; by 2017, this percentage had increased to more than 15 billion bushels per acre in 1996 to more than 170 bushels per acre in 2017. The more than 15 billion bushels per acre in 2017. The more than 15 billion bushels of corn harvested in 2017 were eaten and used to make ethanol, beverages, dyes, adhesives, tires, drugs, and countless other products. biologists could cheaply harvest a drug that was previously expensive and generally unavailable. Genetic engineering has since been applied to medicine (gene therapy, drug production) and the production of new foods and environmentally Molecular Biology and Biotechnology 171 benign pesticides. Today, millions of diabetics worldwide use synthetic humaninsulin to regulate their blood-sugar levels. Insulin is made by genetically engineered bacteria and yeast. At the heart of genetic engineering is the science of molecules critical to life). Molecular biologists recently have concentrated their efforts on manipulating "information molecules" such as DNA and proteins because all outward characteristics of organisms have their basis in proteins from genes made of DNA. In addition to providing techniques for genetic engineering, molecular biology has also impacted fields such as forensics (e.g., linking suspects to crimes, settling paternity disputes), hiring practices (pinpointing employees at high risk for cancer). and agriculture (e.g., in 2017, more than 18 million farmers in 27 countries planted biotech crops on more than 440 million acres of farmland). In the United States, genetically modified crops constituted more than 90% of the nation's sugar beets, feed corn, cotton, and soybeans in 2017. To introduce yourself to the core information of molecular biology, you should review DNA structure in your textbook and in Exercise 6, "Biologically Important Molecules." In this exercise you'll learn two techniques used routinely by molecular biologists: (1) isolation of DNA and (2) genetic transformation. ISOLATION OF DNA is a routine and important procedure for molecular biologists. Once isolated, the DNA and the sequence of its subunits can be determined, manipulated, or altered. Bacteria each contains only about 10-14 g of DNA, which accounts for approximately 5% of the organism's dry weight. However, molecules of this DNA can be very long; for example, the DNA in an E. coli, if strung out, would be approximately 1 mm long. (By analogy, if the bacterium were the size of a grapefruit, then its DNA would be more than 80 km long.) The ability to pack this much DNA is a
rather stiff molecule (fig. 16.2). When DNA or other large molecules are isolated from cells, the surrounding solution becomes viscous (i.e., thick, syrupy, and resistant to flow). This is because DNA mole cules are long and tend to stick to each other due to cohesion among molecules and hydrogen bonding (recall that hydro gen bonding those between correspond ing nitrogenous bases of DNA. Molecular collisions produced by high heat can tear molecular structure will isolate DNA from Halobacterium salinarum, a halophilic ("salt-loving") bacterium that grows only in salty environments (4-5 M NaCl). It's espe cially easy to isolate DNA from this organism because its cell walls disintegrate when placed in low-salt environments (0-2 M NaCl). 172 EXERCISE 16 © Don W. Fawcett/Science Source Figure 16.2 A human chromosome contains an enormous amount of DNA (35,000×). The dark element at the bottom of the photograph is part of the protein matrix of a single chromosome. All of the surrounding material is the DNA of the chromosome. SAFETY FIRST Before coming to lab, you were asked to read this exercise so you would know what to do and be aware of safety issues. In the space below, briefly list the safety issues associated with today's procedures. If you have questions about these issues, contact your laboratory assistant before starting work. Procedure 16.1 Isolate DNA from Halobacterium salinarum. Obtain one of these cultures from your instructor. 2. Use a flexible plastic ruler to scrape the bacterial growth from the surface of the agar and collect it in a test tube. 3. Add 1 mL of distilled water to the tube. One milliliter equals about 20 drops. 4. Place a small piece of plastic film over the tube and hold it securely in place with your thumb. Invert the tube and hold it securely in place with your thumb. will become viscous. 5. Use an eyedropper to slowly and gently pour 1 mL of ice-cold 95% ethanol down the side of the tube. Do not shake or disturb the tube. Do not shake or disturb the tube. Do not shake or disturb the tube. rod as it is twirled. Question 1 What is the texture of the DNA you've isolated? The DNA that you've isolated is not pure; rather, it is con taminated with small amounts of protein and RNA. ISOLATE DNA FROM YOUR CELLS If time permits, your instructor may also ask you to extract DNA from your cheek cells. These procedures will work best if you have not eaten or chewed gum lately. Examine the cells from which you will extract your DNA. 1. Place a drop of methylene blue on a clean microscope slide. Be careful; methylene blue will stain your skin and clothes. 2. Gently scrape the inside of a toothpick. Swirl this end of the toothpick in the drop of methylene blue. Then throw the toothpick away. 3. Place a coverslip on the drop of methylene blue and examine the slide with your light microscope. At low power, cells with a higher-power objective. These are the cells from which you will extract your DNA. Extracting your DNA You'll extract your DNA by (1) collecting your cells, (2) releasing the DNA by using detergent to lyse the cell and nuclear membranes of your cells, and (3) precipitating your cells, and (3) precipitating your check cells by vigorously swirling the sports drink or salt solution in your mouth for 1 min. While swirling will dis lodge cells, which will be the source of your DNA. The longer and more vigorously you swirl the solution in your mouth, rub your mouth, rub your mouth are easily loosened, and this swirling will dis lodge cells, which will be the solution in your mouth are easily loosened. the more cells and DNA you will collect. 16-3 (This solution will also contain bacteria from your mouth, from which you will also isolate the DNA.) 3. Spit the sports-drink solution from the cup into a test tube containing 5 mL of a 25% solution of dishwashing detergent. The detergent will break the lipid-based cell and nuclear membranes, thereby releasing the cells' DNA into solution. (This is why we use detergents to remove fats—that is, lipids—from dirty dishes.) 5. Add a pinch of meat tenderizer to the test tube. Each of our cells contains enough DNA that, if stretched end-to-end, would span 2-3 m. To fit this much DNA into a tiny cell, the DNA is wrapped tightly around proteins. Meat tenderizer is a protease, which is an enzyme that digests protein and, in doing so, releases DNA from the tube 4-5 times. Do not vigorously shake or tilt the tube; doing so will shear the DNA into smaller pieces that will be hard to see later. If caps or corks are not avail able, you can also cover the end of the test tube with your gloved thumb or a piece of Parafilm. 7. Let the tube stand for 1 min. 8. After uncapping the tube, gently tilt the tube to a 45° angle and use a pipette to gently add 10 mL of ice-cold ethanol down the side of the tube. (The colder the alcohol, the more DNA will precipitate.) Alcohol is less dense than the detergent solution, so the alcohol will form a layer atop the detergent. 9. Let the tube stand for 10 min. Do not shake, tip, mix, or agitate the tube. Watch what happens at the interface between the alcohol and detergent. 10. Use a glass rod to slowly move some of the alcohol into the detergent. When you do this, your DNA— which is insoluble in alcohol-will precipitate as white, cottony strands at the alcohol-detergent inter face. The lipids and proteins will remain dissolved. Bubbles displaced from the sports drink may get trapped in the DNA and make it easier to see. 11. Spool your DNA on the glass rod by slowly twirling the rod in one direction. The Influence of Heat and pH on DNA in a test tube following steps 1-5 in procedure 16.1 for isolating DNA. 2. Place the tube into a boiling water-bath for 10 min. 3. Place the tube in an ice bath. Molecular Biology and Biotechnology 173 b. What do you think is the mechanism for this pH-induced change in viscosity? 4. Insert and twirl a glass rod in the tube. 5. Compare the viscosity of the heat-treated DNA with untreated DNA. Question 2 a. What effect does heat have on the viscosity of DNA? GENETIC TRANSFORMATION Much of biotechnology is based on genetic transformation, summarized in figure 16.3, requires three conditions: (1) a host into which DNA can be inserted, (2) a means of carrying the DNA into the host, and (3) a method for selecting and isolating the successfully transformed organisms in the successfully transformed organisms. b. What do you think is the mechanism for this change in viscosity? The Host: Escherichia coli The host organisms. b. What do you think is the mechanism for this change in viscosity? the world. E. coli has the following properties that make it ide ally suited for transformation: Procedure 16.3 Test the influence of pH on DNA 1. Precipitate DNA in a test tube following steps 1-5 in procedure 16.1 for isolating DNA. 2. Add 2 mL of 1.0 N NaOH to the tube. less than 0.2% of that of the human genome. NaOH is caustic. Don't spill it on yourself or your clothes. •• E. coli grows rapidly. Transformations in bacteria are rare and occur in only about 0.1% of cells. Therefore, transfor mations are observed most easily in large, rapidly grow ing populations. E. coli is ideal for transformation studies because, in ideal conditions, it divides every 20 min. As a result, in 10 h a bacterium can produce a billion progeny (30 generations) in only 1 mL of nutrient broth. 3. Insert and twirl a glass rod in the tube. 4. Compare the viscosity of the alkali-treated DNA with untreated DNA and with heat-treated DNA. Question 3 a. What effect does alkaline pH have on the

viscosity of DNA? DNA plasmids with genetic code for resistance to ampicillin Only a small percentage of bacterial cells in a culture can be transformed. Also, small lengths. However, competence of the bacteria (i.e., the chances for successful transformation) increases during the early and middle stages of its growth. Site of plasmid uptake mRNA synthesis of mRNA from Translation of mRNA plasmid DNA into proteins Proteins added to cell with plasmid DNA. In this example, the DNA plasmid contains the genetic code for resistance to the antibiotic ampicillin. After uptake of the plasmid, the code is transcribed to messenger RNA, which is translated during protein synthesis. Addition of these proteins to the cell wall will retard attack by ampicillin. 174 EXERCISE 16 16-4 Preincubation to Increase Competency © Professor Stanley N. Cohen/Science Source Figure 16.4 A famous plasmid. The circular molecule in this electron micrograph (70,000×) was the first plasmid used successfully to clone a vertebrate gene, pSC101. Its name refers to it being the 101st plasmid isolated by Stanley Cohen. Competence also increases when cells suspended in a cold solution of CaCl2 are heat-shocked. Yield is usually about 106 transformants per milligram of DNA available for insertion. A Vector to Move DNA into the Host A biological vector is a DNA molecule that carries DNA made of 1000 to 200,000 base-pairs (fig. 16.4). Plasmids exist separately from the bac terial chromosome and they must contain a gene that confers some selective advantage (e.g., resistance to an antibiotic) to remain in the host. We don't completely understand how plas mids enter host cells, but they seem to enter consistently. Selecting Transformed Organisms You'll insert into E. coli a plasmid (pAMP) containing a gene for resistance to ampicillin, and antibiotic lethal to many bacteria (fig. 16.5). (Refer to Exercise 24 for information on bacterial cell wall structure and how ampicillin by spreading the transformed organisms onto nutrient medium containing ampicillin. Organisms that grow on this medium have been transformed. Because E. coli grows so fast, you can check for transformed organisms only 12-24 h after completing the experiment. Procedure 16.5 before beginning. Wash your hands. Your instructor will demonstrate and discuss sterile technique, which will eliminate contamination of your cultures by other organisms (e.g., bacteria, fungi). Use sterile technique when doing this procedure. 2. Fill a 250-mL beaker with about 50 mL of ethanol and place a glass-rod bacterial spreader in the ethanol to soak. 16-5 3. Obtain a test tube with 1 mL of sterile, yellow nutrient broth and a tube with 1 mL of clear, colorless 50 mM CaCl2. Label these tubes NB and CaCl2, respectively. 4. Fill a 250-mL beaker half full with crushed ice. Place the min the beaker of ice. 6. Obtain a packaged, sterile, plastic pipet, and locate the graduation indicating a volume of 0.25 mL. 7. Open the packaged pipet to add 0.25 mL of a sterile, ice-cold solution of 50 mM CaCl2 to each of the two transformation tubes. Use sterile technique. This is shown in step 1 of figure 16.5. 8. Several days ago your lab instructor streaked starter plates of nutrient agar with E. coli. Scrape a colony of E. coli (3-mm diameter) from one of these plates with a sterile, plastic inoculating loop. The bacteria are growing as a thin film on the surface of the agar; when you scrape a colony off the surface, be sure not to take up any of the agar. Use sterile technique. This is shown in step 2 of figure 16.5. 9. Place the loopful of bacteria into the transformation tube labeled (-)P. Rinse the bacteria from the loop by gently twirling the loop by gently twirling the loop by gently twirling the loop handle between your fingers. 10. To mix the bacteria into the transformation tube labeled (-)P. Rinse the bacteria from the loop by gently twirling the loop by gently tw in the bottom of the tube and gently use a rubber bulb to suck the fluid in and out of the tip three or four times. Be sure the tip is empty before withdrawing the pipet. 11. For tube (+)P, repeat steps 8-10. Use a fresh loop and pipet to inoculate and mix the bacteria. Try to get the same amount of bacteria into each tube. Replace the two tubes in the ice bath and chill the tubes for at least 5 min. Incubation 12. Use a sterile loop to obtain one loopful (10 µL) of an ice-cold solution of DNA plasmids from the loop. These plasmids from the loop. These plasmids from the loop to resistance to ampicillin. Do not add plasmids to tube (-)P. This is shown in step 3 of figure 16.5. 13. Place both tubes in ice for 15 min. 14. While the tubes are cooling, obtain two agar plates labeled (+)AM, meaning nutrient agar with ampicillin. Label one of each pair of plates as (-)P and the other two plates as (+)P. Molecular Biology and Biotechnology 175 Step 1 Add 0.25 mL of cold transformation tubes +P -P Step 2 -P Inoculate appropriately labeled plates Add E. coli E. coli starter plates +P -P Step 3 Plasmid for resistance to ampicillin Step 6 Add plasmid to + only +P -P Figure 16.5 Summary of the procedure to transform bacteria by exposing E. coli to a plasmid. Step 4 Add nutrient broth NB + P - P Nutrient broth (NB) Heat Shock the transformation tubes (-)P and (+)P by placing them in a 42°C water-bath for 2 min. Shake the tubes while they are in the water-bath. Heat shock increases the uptake of the plasmid by the bacterial cells. 176 EXERCISE 16 Spread inoculum and incubate stacked, labeled plates 16. Chill the tubes in ice for 5 min. 17. Remove the tubes from the ice bath; place them in a test-tube rack or empty beaker. Recovery and Plating the Samples 18. Using a sterile pipet, add 0.25 mL nutrient broth to each tube and tap gently to mix the contents This is shown in step 4 of figure 16.5. 19. Using sterile technique and a sterile pipet, transfer 0.10 mL of the (-)P cell suspension onto the plate labeled (+)AM/(-)P. Close the plates. This is shown in step 5 of figure 16.5. 20. Using another sterile pipet, transfer 0.10 mL of the (+)P cell suspension onto the middle of the plate labeled (+)AM/(+)P. Transfer another 0.10 mL onto the plate labeled (-)AM/(+)P. Close the plate labeled (-)AM/(+)P. Transfer another 0.10 mL onto the plate labeled (-)AM/(+)P. spreader cool. Before spreading the bacteria in the first of your four plates, further cool the spreader to the edge of the plate and gently drag it back and forth three times. Rotate the plate 90° and repeat. This is shown in step 6 of figure 16.5. Remember to steril ize the bacteria spreader between each plate. Repeat this procedure to spread the bacterial growth after 24 h. Draw the appearance and coverage of bacterial colonies and explain possible reasons for no growth: (-)AM/(+)P (-)AM/(-)P Reason for no growth: Reason for no Incubate the plates upside down at 37°C. 23. Place all the tubes, loops, and other such materials, in a central location for disposal. Wipe your work area with a weak bleach solution and wash your reasoning for each prediction in the provided space. (-)AM/(+)P (-)AM/(-)P Explain your prediction: (+)AM/(-)P (+)AM/(-)P Question 4 a. Which treatment produced transformed bacteria? b. How many prediction: Molecular Biology and Biotechnology 177 INQUIRY-BASED LEARNING How narrow is the range of antibiotic resistance for transformed bacteria? Observation: In this lab you inserted a plasmid into the bac terium Escherichia coli. That plasmid conferred resistance to the antibiotic resistance for transformed bacteria that are resistant to ampi cillin also resistant to other antibiotics? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 16 from your instructor. b. Discuss with your group well-defined questions relevant to the preceding observation and question. C. Translate your question into a testable hypothesis and record it. d. Outline on Worksheet 16 your experimental design and supplies needed to test your proposed investigation. e. Conduct your procedures, record your data, answer your question, and make relevant comments. f. Discuss with your instructor any revisions to your questions, hypothesis, or procedures. Repeat your work as needed. Questions for Further Study and Inquiry 1. Consider the ubiquitous occurrence of bacteria in nature, along with the constant fragmentation and release of DNA as cells decompose. How frequently do genetic transformations occur in nature? Explain your answer. 2. How could genetic transformations improve our quality of life? 3. Why is molecular biology often referred to as genetic engineering or biotechnology? 4. How could the uptake of plasmids in natural systems be important? 5. The development of antibiotic resistance is a major threat to our health. Why? How extensive isstance is a major threat to our health. this problem? 6. In 1997, only 10% of the U.S. cotton crop was genetically engineered, but that percentage had increased to more than 90% in 2018. Similarly, only 17% of the U.S. cotton crop was genetically engineered in 1997, but the percentage exceeded 85% in 2018. Why are genetically engineered crops becoming so popular in the United States? 7. As of 2016, only two genetically modified crops—including a type of corn engineered to fight off pests such as the European Union. What concerns have limited the impact of genetically modified crops in European Corn borer—were approved for cultivation in the European Union. What concerns have limited the impact of genetically modified crops in European Corn borer—were approved for cultivation in the European Corn borer—were approved for cultivation in the European Union. What concerns have limited the impact of genetically modified crops in European Corn borer—were approved for cultivation in the European Union. DOING BIOLOGY YOURSELF Design and conduct an experiment to test the effects of acid pH on the integrity of isolated DNA. How do the results compare to the effects of basic
solutions on DNA? 178 EXERCISE 16 WRITING TO LEARN BIOLOGY Many people resist the use of genetic engineering to alter organisms. What are their arguments? Do you agree? 16-8 E XER CISE 17 Genetics The Principles of Mendel Learning Objectives By the end of this exercise you should be able to: 1. Describe possible genotypes for some of your personal traits inherited as dominance, and lethal inheritance. 2. Describe possible genotypes for some of your personal traits inherited as dominance, and lethal inheritance. importance of Mendel's Law of Segregation and Law of Independent Assortment. 4. Distinguish between an organism's phenotype and genotype. Please visit connect.mheducation.com to review online resources tailored to this lab. P ublished papers are the primary means of communicating scientific discoveries. One of the most famous of these papers, titled "Experiments in Plant Hybridization," was written in 1866 by Gregor Mendel, an Austrian monk (fig. 17.1). Although Mendel's paper later became the basis for genetics and inheritance, it went largely unnoticed until it was rediscovered independently by several European scientists in 1900. The experiments and conclusions in Mendel's paper now form the foundation of Mendelian genetics, the topic of today's exercise. Mendel's greatest contribution was to replace the blending theory of inheritance, which stated that all traits @McGraw-Hill Education/Steven P. Lynch, photographer Figure 17.1 Gregor Mendel (1822-1884) grew and tended pea plants (Pisum sativum) like these for his experiments. For each experiment, he observed and counted as many offspring as possible. Pea plants are easy to grow and have many distinct traits; this made it easy for Mendel to analyze many crosses involving lots of offspring. In one set of crosses, he observed and counted as total of 7324 peas! 17-1 blend with each other, with the particulate theory. Mendel's particulate theory states that (1) inherited characters are determined by particular factors (now called genes), (2) these factors occur in pairs (i.e., genes occur on maternal and paternal homologous pair is contained in a particular gamete. Recall from Exercise 15 (Meiosis) that each gamete has an equal chance of possessing either member of a pair of homologous chromosomes. This part of the particulate theory is collectively known as Mendel's First Law, or the Law of Segregation. Mendel's Second Law, or the Law of Independent Assortment, states that genes on nonhomologous or different chromosomes will be distributed randomly into gametes (figs. 17.2, 17.3). Mendel's laws describe the inheritance of traits and their inheritance. Remember, however, that not all traits are inherited according to Mendel's laws. For example, several diseases that affect eyes and muscles are inherited from DNA in mitochondria (i.e., not the nucleus). Your textbook discusses this and other types of non-Mendelian inheritance. Before you start this exercise, briefly review in your textbook discusses that affect eyes and terms pertinent to today's exercise. A gene is a unit of heredity on a chromosome. A gene has alternate states called alleles, contributed to an organism by its parents. Alleles for a particular gene occur in pairs. Alleles for a particular gene occur in pairs. Alleles that mask expression of other alleles but are themselves expression is masked by dominant alleles are recessive and designated by a lowercase letter (for example, p). The genotype of an organism includes all the alleles present in Genetics 179 Paternal gamete Homologous pairs Diploid offspring Potential gametes Figure 17.2 Independent assortment increases genetic variability. Independent assortment contributes new gene combinations to the next generation because the orientation of chromosomes, eight different gametes can result, each with different gametes can result, each with different gametes can result, each with different gametes can result. generation are all Pp heterozygotes (white flowers); Pp heterozygotes (also purple flowers); and pp homozygotes (white flowers); Pp heterozygotes (also purple flowers); and pp homozygotes (also purple flowers); and pp homozygotes (also purple flowers); Pp heterozygotes (also purple flowers); and pp homozygotes (also purple of genotypes is 1:2:1 (1PP:2Pp:1pp). 180 EXERCISE 17 Purple heterozygote Pp p P Pp pp p F2 generation 3 Purple:1 White (1PP:2Pp:1pp) 17-2 (a) ©Andrew Syred/Science Source (b) ©Eye of Science/Science Source (c) ©Eye of Science/ Individuals homozygous for the sickle cell allele have many red blood cells with irregular and sickle shapes (7400×). the cell, whether they are dominant to white flowers (p), a plant with purple flowers can have a genotype PP or Pp. A plant with white flowers can only have a genotype pp (fig. 17.3). When the paired alleles are identical (PP or pp), the genotype is homozygous. With this minimal review, you're prepared to apply this information to solve some genetics problems. SIMPLE DOMINANCE Assume that purple flowers are dominant to white flowers. If a homozygous purple-flowered plant is crossed (mated) with a homozygous white-flowered plant, what will be the phenotype (physical appearance) and genotype of the offspring? Parents: PP (homozygous dominant = purple flowers) × pp (homozygous recessive = white flowers) Gametes: P from the purple-flowered parent p from the white-flowered parent Offspring: genotype = Pp phenotype = purple flowers This first generation of offspring can produce two possible gametes, P and p. Mendel noted that the gametes from each of the parents combine with each other randomly. Thus, you can simulate the random mating of gametes from the F1 generation by flipping two coins simultaneously. Assume that heads designates the white-flower allele (P) and tails designates the white-flower allele (P). Flipping one coin will determine the type of gamete from one parent and flipping the other will determine the gamete from the other parent. To demonstrate this technique, flip two coins simultaneously 64 times and record the occurrence of each of the three possible combinations in table 17.1. 17-3 Table 17.1. Results of Coin-Flipping Experiment Simulating Random Mating of Heterozygous (Pp) Individuals Response Number Heads-heads = PP = purple flowers Heads-tails = Pp = purple flowers Tails-tails = pp = white flowers Question 1 What is the ratio of purple-flowered (PP or Pp) to whiteflowered (PP or Pp) to white p) Offspring genotypes: PP Pp pP pp Offspring phenotypes: 3 purple 1 white Thus, the theoretical genotypic ratio is 3 purple : 1 white. Question 2 a. How do these ratios compare with your data derived from coin flipping? Genetics 181 b. Would you have expected a closer similarity if you had flipped the coins 64,000 times instead of 64 times? Why or why not? Height of Plants Number of tall pla list the safety issues associated with today's procedures. If you have questions about these issues, contact your laboratory assistant before starting work. Procedure 17.1 Determine genotypic ratios for albinism Albinos are homozygous recessive for the pair of alleles that produce pigments of skin, hair, and eyes. Suppose a woman having normal colored skin and an albino mother marries an albino man. Record the genotypic and phenotypic ratios of their children. Probable genotypes of parents × 3. The preceding crosses involved only one trait and thus are termed monohybrid crosses. Let's now examine a cross involving two traits; that is, a dihybrid cross. Your instructor will review with you the basis for working genetics problems involving dihybrid crosses. In corn, red (R) seed color is dominant to white (r) seed color, and smoothness (S) is dominant to white (r) seed color, and smoothness (S) is dominant to white (r) seed color. F1 generation? b. Will all F1 offspring have the same phenotype? Genotype of children Procedure 17.2 Determine color and height ratios for corn plants An ear of corn provides a large family of siblings in which we can study how traits are passed from one generation to the next. The color of grains (karyopses) and the height of Zea mays (corn) plants are often determined by a single gene. 1. Examine (a) the ears of corn having red and yellow grains, and (b) the tray of tall and dwarf plants on demonstration. 2. Record your observations here and determine the probable genotypes of the parents: Color of Corn Grains Number of red grains Question 4 a. What are the predicted phenotypes for the F2 (i.e., second) generation that is produced by the cross RrSs × RrSs? b. In what ratio will they occur? 4. To test your prediction in Question 4, count the number of kernels are the F1 generation produced by the cross RrSs. Red, smooth Number of white grains Red, wrinkled Ratio of red : white grains White smooth Probable genotypes of parents 182 EXERCISE 17 × White, wrinkled 17-4 Question 5 a. How do your data compare with those that you predicted? b. What are the genotypes of the F2 generation that is produced by the cross RrSs × RrSs? b. Based on this ratio, what might you expect were the genotypes of the parents? Question 8 Why is it impossible to cross a green and an albino plant? OTHER SOURCES OF GENETIC DIVERSITY c. In what ratio will they occur? Genetic diversity can also result from multiple alleles, gene interactions (epistasis), continuous variation, pleiotropy, environmental effects, linkage, and sex linkage. topics, be sure to review them in your textbook. BLOOD TYPE INCOMPLETE DOMINANCE Some traits such as flower color are controlled by incomplete dominance. In this type of inheritance, the heterozygous genotype results in an intermediate characteristic. For example, if a plant with red flowers (RR) is crossed with a plant having white flowers (rr), all of the offspring in the first filial (F1) generation will have pink flowers (Rr). Parents: Gametes: Offspring: RR (red) × rr (white) R×r Rr (pink) Question 6 What are the expected ratios of red, pink, and
white flowers in a cross involving two pink-flowered parents? LETHAL INHERITANCE Lethal inheritance involves inheriting a gene that kills the offspring. Observe the tray of green and albino seedlings of corn. (Your instructor may substitute tobacco seedlings.) The albino plants cannot photosynthesize and therefore die as soon as their food reserves are exhausted. Question 7 a. What is the ratio of green to albino seedlings? Blood type of humans provides an excellent example of codominance, another type of Mendelian inheritance. In codominance, both alleles contribute to the phenotype of a heterozygote. For example, all individuals have one of four blood types: A, B, AB, and O (fig. 17.5). These blood groups are determined by the p resence of compounds called antigens on the surfaces of their red blood cells. If antigen A or B is present, no antibodies against this antigen are produced. Thus, if a person has antibodies (proteins) that agglutinate type B blood cells. Similarly, a person having antigen-B on his or her blood cells has type B blood and has antibodies that agglutinate type A blood cells. If a person has antigen-B on his or her blood cells, then the person has type AB blood and lacks A and B antibodies. If a person has not antigens (table 17.2). This system is rather unusua in that individuals have antibodies against the blood antigens that they do not possess. Blood typing is often important for establishing the possible identity of an individual in forensic work and paternity suits. For example, assume that a woman with type O blood. Could the suspected father with type AB blood be the child's father? The answer is no because the cross would have the following results: Parents: ii (type AB) Gametes: i and i, IA and IB Offspring: IAi or IBi Half of the offspring from the mother and the suspected father would have type A blood (genotype = IAi), and the other half would have type B blood (genotype = IBi). 17-5 Genetics 183 Possible alleles from female IA or IAIA IB or i IAIB Blood types and agglutination IAi Recipient (serum type) A B AB O or IB IAIB IBIB IBi Blood donor (blood cell type) Possible alleles from male IA or i Blood types IAi A IBi AB ii B A B AB O O ©Ed Reschke/Getty Images (a) (b) + = Agglutination - = No reaction (c) Figure 17.5 ABO blood groups. (a) Multiple alleles control the ABO blood groups. (a) Multiple alleles control the ABO blood groups. (b) and type O (ii four different blood type phenotypes: type A (either IBIB homozygotes), type B (either IBIB homozygotes), type B (either IBIB homozygotes), type A (either IBIB homozygotes), type A (either IBIB homozygotes), type B (either IBIB homozygotes), type homozygotes). (b) The blood agglutination reaction. Agglutination occurs when blood cells stick and clump together. (c) Agglutination will occur when donor blood cells are incompatible with this mother. ABO blood typing can be used to eliminate a person as a potential parent but not to prove paternity. To appreciate this, suppose there is a mix-up of children in the maternity ward of a hospital after the genotypes of the children in the maternity ward of a hospital after the genotypes. The following unidentified children in the maternity ward of a hospital after the genotypes of the children in the maternity. (genotype IAIA or IAi) against B antigens, and people with type B blood produce antibodies against A antigens. If someone having type B blood from someone having type B blood received blood, the recipient's antibodies would react with and agglutinate the red blood cells received from the donor (fig. 17.5b). As a result, the recipient would die. Question 10 a. Can a person with type O blood safely donate blood to a person having type A blood? Why or why not? Child 2: type B (genotype IAIB) Child 4: type O (genotype ii) Question 9 Which child or children could belong to a couple having AB and O blood types? b. Which blood type would be a universal ype would be a universal recipient? Blood typing is also important for determining the safety of blood transfusions. Your body automatically Types Blood Type Antigen on Red Blood Cell Antibody in Plasma Genotype % of U.S. Population A A anti-B I I or I i 42 B B anti-A I I or I i 10 AB A and B none IAIB O O (none) anti-A in a none IAIB O O (none) anti-B ii 184 EXERCISE 17 A A B B A B 4 44 17-6 Procedure 17.3 Determine blood type for ABO b. What is the blood type of your sample? system 1. You will be provided with various samples of synthetic blood. This material simulates the blood type characteristics of human blood, and it is safe. Also obtain two bottles of antisera. 2. Obtain a clean slide and label the ends A and B. Near one end of the slide place a drop of antiserum B (containing antibodies against antigen-B). 3. Place drops of blood near (but not touching) the two drops of antiserum B. Use a different toothpick to mix each antiserum. 5. Dispose of all used materials properly. 6. Observe any agglutination of blood cells in either of the two antisera. Agglutination indicates the presence of the respective antigens. Question 11 a. What antigens are present on the artificial red blood cells that you tested? Rh Incompatibility You've probably heard of the incompatibility (agglutination) problems that Rh-negative women may have with their Rhpositive trait is inherited from the child's father). This problem usually occurs with the second and subsequent children because women with the Rh blood system must be sensitized to the antigen before antibody production begins. This sensitization usually occurs during birth of the first child. If you are a woman having Rh-negative blood, you should be concerned but not alarmed. Rh incompatibility is handled routinely by injections of anti-Rh antibodies. These antibodies destroy Rh-positive red cells and thus eliminate the Rh-associated risk of subsequent childbirth. 17-7 You are probably familiar with another characteristic of blood called Rh factor. Although more than two alleles determine Rh, we'll use "positive" and "negative" for simplicity and convenience. Procedure 17.4 Determine Rh 1. Place a drop of anti-Rh serum on a clean slide. 2. Using the procedure just described, mix a drop of blood from the synthetic blood sample will agglutinate within a few minutes if it is Rh-positive. The absence of agglutination indicates the blood is Rh-negative. 5. Dispose of all materials properly. OTHER HUMAN TRAITS The following traits are determined by a single gene. List your genotype for each trait in table 17.3 and, if possible, list your genotype could be GG or Gg, in which case you should enter G in table 17.3. If you have the dominant trait and one of your parents shows the recessive trait, you must be heterozygous (Gg) for that trait. Give your results to your instructor so that she or he can provide you with the phenotypic results for your class. Widow's peak—The W allele for widow's peak (i.e., a pointed hairline) is dominant to the w allele for a straight hairline (fig. 17.6). Bent little finger—Lay your hands flat on the table and relax them. If the last joint of your little finger bends toward the fourth finger, you have the dominant allele B (fig. 17.7). Albinism—The A allele is dominant and leads to production of melanin, a pigment. Individuals with an aa genotype lack pigment in their skin, hair, and iris. Pigmented iris, and your eyes are the color of the back layer of the iris). The P allele produces pigment in the front layer of the iris (green, hazel, brown, or black), which masks the blue or gray color of the back layer of the iris. Genetics 185 Table 17.3 Phenotypes and Genotype* Dominant Recessive Widow's peak Bent little finger Albinism Pigmented iris Attached earlobes Hitchhiker's thumb Interlacing fingers PTC tasting Middigital hair Dimpled chin Six fingers *Homozygous dominant, heterozygous, or homozygous recessive ©Dzmitry Kliapitski/123RF Bent little finger Figure 17.7 Bent little finger Figure 17.7 Bent little finger Straight little finger S straight hairline (bottom). Free earlobes—If part of your earlobe is unattached (i.e., free) below where it attaches to your head, you have the dominant E allele for a free earlobe (fig. 17.8). Hitchhiker's thumb—Bend your thumb backward as far as possible. If you can bend the last joint of the thumb back at an angle of 60° or more, you are showing the recessive allele h (fig. 17.9). 186 EXERCISE 17 © Geoff du Feu/Alamy (a) (b) Stock Photo © Voronin76/Shutterstock Figure 17.8 (a) Free earlobe. (b) Attached earlobe. 17-8 do not have this disease. The treatment for galactose-free diet. Phenylketonuria (PKU), an inability to metabolize the amino acid phenylalanine. Approximately 100 cases occur per million births. The treatment for PKU is a phenylalanine-free diet. If untreated, this disease produces mental impairment. This disease is inherited as a recessive trait; people who are heterozygous or homozygous dominant do not have this disease. ©Fotomaton/Alamy stock Photo Figure 17.9 Hitchhiker's thumb. Interlacing fingers—Casually fold your hands together so that your fingers is dominant over the c allele for crossing your right thumb over your left. PTC tasting—Obtain a piece of paper impregnated with phenylthiocarbamide (PTC). Taste the paper by chewing on it for a few seconds. If you detect a bitter taste, you have the dominant allele T. Middigital hair. If hair is present on the middigit of any finger, you have the dominant allele. Dimpled chin. A dimpled chin is caused by a dominant allele M. People who have a dimpled chin are either homozygous dominant (MM) or heterozygous dominant (MM) or heterozygous dominant (SS) or heterozygous (Ss). People who have only five fingers are homozygous recessive (ss) for this trait. Several diseases are inherited as single-gene traits. These diseases include Cystic fibrosis, a disease characterized by chronic bronchial obstruction and growth reduction. This disease is inherited as a recessive trait;
people who are heterozygous or homozygous dominant do not have this disease. Medications can help manage the symptoms of cystic fibrosis, but there is no cure. Galactosemia is inherited as an autosomal recessive trait. Approximately five cases occur per million births. Prenatal diagnosis can be performed on cells obtained through amniocentesis or chorionic villi sampling. Galactosemia is inherited as a recessive trait; people who are heterozygous or homozygous or homozygous dominant 17-9 Juvenile retinoblastoma, a cancer of the retina. The allele is located on chromosome 13. This disease is inherited as a recessive trait; people who are heterozygous or homozygous dominant do not have this disease. Huntington's disease, a mental disorder involving uncontrollable, involuntary muscle movements. The disease occurs relatively late in life, so many affected individuals bear children before they realize that they are carriers. Approximately 100 cases occur per million births. Unlike most other genetic diseases, Huntington's disease is inherited as a dominant trait; people who are homozygous recessive (hh) do not have the disease. Medications can help manage the symptoms of Huntington's disease, but treatment cannot prevent the behavioral, mental, and physical decline associated with the condition. Question 12 What conclusion about your genotype is evident if one of your siblings, but neither parent, shows the recessive trait? All of the traits listed above are produced by alleles on autosomes, which are chromosomes that are not sex chromosomes. As a result, these traits are not linked to gender and occur in equal frequencies in males and females. This is why autosomal traits such as galactosemia, Tay Sachs, and Huntington's disease are equally frequent in males and females. Several other traits, however, are produced by alleles on sex chromosomes, and are referred to as sex-linked traits. SEX-LINKED INHERITANCE Humans have two kinds of sex chromosomes: X and Y. Sexlinked traits are produced by alleles on these chromosomes (i.e., they are XX), and males have two X chromosomes (i.e., they are XX), and males have one X and one Y chromosomes (i.e., they are XX). chromosome, both can have X-linked traits. If the X chromosome in a male carries the recessive allele, that allele is expressed because there is no chance for the allele to be masked by its counterpart on another Genetics 187 The Human X-Chromosome Gene Map Inheritance patterns among affected and unaffected individuals have revealed 59 the cause there is no chance for the allele is expressed because the common diseases specific to segments of the X chromosome is shown here; a more detailed map would require a much larger figure. The black bands represent staining patterns that are specific to alleles involved in the indicated disease. The constriction represents the position of the centromere. The X chromosome sequence has 1098 gene loci, many of which may have mutant alleles that produce diseases. Ichthyosis, X-linked Placental steroid sulfatase deficiency Kallmann syndrome Chondrodysplasia punctata, X-linked Placental steroid sulfatase deficiency Kallmann syndrome Chondrodysplasia punctata, X-linked Placental steroid sulfatase deficiency Kallmann syndrome Chondrodysplasia punctata, X-linked Placental steroid sulfatase deficiency Kallmann syndrome Chondrodysplasia punctata, X-linked Placental steroid sulfatase deficiency Kallmann syndrome Chondrodysplasia punctata, X-linked Placental steroid sulfatase deficiency Kallmann syndrome Chondrodysplasia punctata, X-linked Placental steroid sulfatase deficiency Kallmann syndrome Chondrodysplasia punctata, X-linked Placental steroid sulfatase deficiency Kallmann syndrome Chondrodysplasia punctata, X-linked Placental steroid sulfatase deficiency Kallmann syndrome Chondrodysplasia punctata, X-linked Placental steroid sulfatase deficiency Kallmann syndrome Chondrodysplasia punctata, X-linked Placental steroid sulfatase deficiency Kallmann syndrome Chondrodysplasia punctata, X-linked Placental steroid sulfatase deficiency Kallmann syndrome Chondrodysplasia punctata, X-linked Placental steroid sulfatase deficiency Kallmann syndrome Chondrodysplasia punctata, X-linked Placental steroid sulfatase deficiency Kallmann syndrome Chondrodysplasia punctata, X-linked Placental steroid sulfatase deficiency Kallmann syndrome Chondrodysplasia punctata, X-linked Placental steroid sulfatase deficiency Kallmann syndrome Chondrodysplasia punctata, X-linked Placental steroid sulfatase deficiency Kallmann syndrome Chondrodysplasia punctata, X-linked Placental steroid sulfatase deficiency Kallmann syndrome S Ocular albinism Retinoschisis Duchenne muscular dystrophy Becker muscular dystrophy Adrenal hypoplasia Glycerol kinase deficiency Norrie disease Retinitis pigmentosa-2 Incontinentia pigmentosa-3 Ornithine transcarbamylase deficiency Norrie disease Retinitis insensitivity Charcot-Marie-Tooth neuropathy Choroideremia Cleft palate, X-linked Spastic paraplegia, X-linked, uncomplicated Deafness with stapes fixation Sideroblastic anemia Aarskog-Scott syndrome PGK deficiency hemolytic anemia PRPS-related gout Anhidrotic ectodermal dysplasia Lowe syndrome Agammaglobulinemia Kennedy disease Lesch-Nyhan syndrome HPRT-related gout Pelizaeus-Merzbacher disease Alport syndrome Fabry disease Hunter syndrome Hemophilia B Hemophil Adrenoleukodystrophy Adrenomyeloneuropathy Emery-Dreifuss muscular dystrophy Diabetes insipidus, renal Myotubular myopathy, X-linked Immunodeficiency, X-linked Imm bands represent alleles involved in the listed diseases. X chromosome.1 For example, consider a cross between a male who is not colorblind (i.e., XAX) and a female who is not colorblind but is a carrier of the recessive allele (i.e., XAX) and a female who is not colorblind. If a male has an X-linked recessive disorder (XaY) and his female partner does not carry the allele (XAXA), all of their girls will be carriers of the allele, and none of their boys will inherit the disorder. 1 Xa Y XA XAXa XAY Question 13 a. Suppose that Donna is colorblind, but Darrell is not. If Donna and Darrell have a family, what percentage of their boys will be colorblind? The X chromosome carries more than 1000 alleles, but the much smaller Y chromosome carries fewer than 30 alleles are missing the result is low sperm count and infertility (almost one-third of infertile couples in the United States are infertile because of Y-linked alleles). Only one gene on the Y chromosome (the SRY gene) produces male anatomical traits. 188 EXERCISE 17 17-10 Table 17.4 Some Dominant and Recessive Traits in Humans Recessive Traits Phenotypes Dominant Traits Phenotypes Albinism Lack of melanin pigmentation Middigital hair Presence of hair on middle segment of fingers Red-green color blindness Inability to distinguish red or green wavelengths of light Huntington's disease Degeneration of nervous system, starting in middle age Cystic fibrosis Abnormal gland secretion, leading to liver degeneration and lung failure Phenylthiocarbamide (PTC) sensitivity Ability to taste PTC as bitter Duchenne muscular dystrophy Wasting away of muscles during childhood Camptodactyly Inability to straighten the little finger Hemophilia Inability of blood to cloud properly; some clots form, but the process is delayed Hypercholesterolemia (the most common human Mendelian disorder) Elevated levels of blood cells to curve and stick together Polydactyly Extra fingers and toes b. What percentage of their girls will be colorblind? Biologists use the following symbols in pedigrees: Male ANALYZING PEDIGREES Many human traits display both dominant and recessive inheritance, geneticists study crosses that have been performed already—in other words, family histories. This involves a pedigree, which is a consistent graphical presented in this lab, you can trace a trait in a pedigree (i.e., family tree) to determine if it is inheritance of cystic fibrosis 1. Among Caucasians, about 1 of every 2500 newborn infants is born with cystic fibrosis. In these individuals, a defective membrane protein results in the respiratory system. People having cystic fibrosis often have recurrent and serious infections, and most die in their 20s or 30s. 2. Use the following pedigree to determine whether the allele for cystic fibrosis is inherited as a dominant or recessive allele. b. What is the inheritance pattern for the cystic fibrosis allele? What is your reasoning for this conclusion? 2. Use the following pedigree to determine whether the allele for phenylketonuria is inherited as a dominant or recessive allele. b. Can you determine the genotypes of any
individuals in the pedigree? If so, which ones? Explain your reasoning. Procedure 17.6 Analyze a pedigree of inheritance of Huntington's disease 1. Huntington's disease is a severe disorder of the nervous system that usually causes death. 2. Use the following pedigree to determine whether the allele for Huntington's disease is inherited as a dominant or recessive allele? What is your reasoning for this conclusion? b. Can you determine the genotypes of any individuals in the pedigree? If so, which ones? Explain your reasoning. c. Examine figure 17.11. Shana's mother has Huntington's disease, and Shana has a 50-50 chance of developing Huntington's disease. Explain the genetic basis for Shana's chances of inheritance of developing Huntington's disease. phenylketonuria 1. Phenylketonuria, or PKU, results from an inability to metabolize the amino acid phenylalanine. If untreated, PKU leads to mental retardation. 190 EXERCISE 17 Question 17 a. What is the inheritance pattern for the phenylketonuria allele? What is your reasoning for this conclusion? b. Can you determine the genotypes of any individuals in the pedigree? If so, which ones? Explain your reasoning. TRANSPOSONS For many decades, geneticists thought that genes do not move in cells. However, in 1947 Barbara McClintock proposed that genes could move within and between chromosomes. McClintock based her conclusion on a series of experiments involving genetic crosses in corn. Specifically, McClintock showed that there is a fragment of DNA that can move to and be inserted at the locus for the production of pigment, the resulting kernel is yellow or white. However, subsequent removal of the DNA fragment results in the cell resuming production of the purple pigment; therefore, the resulting kernel is purple. Thus, Indian corn often has kernels with varying pigmentation, depending on when the DNA fragment was inserted or removed. This colorful pigmentation, depending on when the DNA fragment was inserted or removed. the production of other pigments in corn kernels. The translocation to and from the locus for production of these pigments several 17-12 Figure 17.11 Huntington's Disease Society of America times during kernel development produces the red-orange swirls characteristic of many kernels. that McClintock studied are now called transposons. Transposons are a useful tool for genetic engineering because they provide a way of inserting foreign DNA into a host cell's chromosome. For her work, McClintock received a Nobel Prize in 1983; she was the first American woman to win an unshared Nobel Prize. inherited as a dominant trait. What is the genetic basis for Shana's statement that she has a 50-50 chance of getting Huntington's disease? 2. Look for examples of kernels. Procedure 17.8 Observe corn kernels with (a) purple or white spots, (b) red-orange swirls, and (c) other unusual color patterns. Sketch the pigmentation patterns in 2-3 kernels. Procedure 17.8 to understand the effects of transposons 1. Work in a group of two to four people. Obtain an ear of Indian corn for your group. 17-13 3. Use the information presented in this exercise and in your textbook to determine how transposons could produce such unusual patterns of pigmentation. Genetics 191 INQUIRY-BASED LEARNING Are homozygous recessive traits rare among humans? Observation: In humans, traits such as widow's peak, attached earlobes, and a dimpled chin among your recessive traits such as widow's peak, attached earlobes, and a dimpled chin among your classmates? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 17 from your instructor. b. Discuss with your group well-defined questions relevant to the preceding observation and question. c. Translate your group well-defined questions relevant to the preceding observation and questions relevant to the preceding observation and question. d. Outline on Worksheet 17 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your procedures, record your data, answer your question, and make relevant comments. f. Discuss with your instructor any revisions to your questions, hypothesis, or procedures. Repeat your work as needed. Testing for Understanding: Solving Genetics Problems 1. When reclusive billionaire Howard Hughes died in 1976, a variety of people claimed that they were his children. Hughes died in 1976, a variety of people claimed that they were his children. man's mother had type A blood. If you were the judge in the case, what would you rule? Explain your answer. 2. Suppose that flowers are dominant to white flowers. If a homozygous recessive individual is crossed with a homozygous dominant individual, what is the probability of obtaining a purple-flowered offspring? a. 100% b. 75% c. 50% d. 25% e. 0% 3. Bob is heterozygous for phenylketonuria, and Loretta is homozygous recessive for phenylketonuria? a. 100% b. 75% c. 50% d. 25% e. 0% 3. Bob is heterozygous for the allele that causes Huntington's disease, (2) Susan is homozygous recessive for the allele that causes Huntington's disease? a. 100% b. 75% c. 50% d. 25% e. 0% 5. In question 4, what is the probability that their first daughter will get Huntington's disease? a. 100% b. 75% c. 50% d. 25% e. 0% 5. In question 4, what is the probability that their first daughter will get Huntington's disease? disease? a. 100% b. 75% c. 50% d. 25% e. 0% 6. Suppose that someone having type A blood has a child with someone having type A blood? a. 100% b. 75% c. 50% d. 25% e. 0% 7. Suppose that you cross a red-flowered carnation. All of the offspring have pink flowers. What can you conclude? 192 EXERCISE 17 a. Flower color is inherited by incomplete dominance, and the red-flowered carnation is heterozygous for flower color. c. Flower color is inherited by simple dominance. d. Half of the offspring are heterozygous and half are homozygous for flower color. e. None of the above statements are true. 8. Suppose that a trait is inherited by simple dominance. If two heterozygous recessive offspring? a. 100% b. 75% c. 50% d. 25% e. 0% 9. Tay-Sachs disease is characterized by the inability to produce an enzyme needed to metabolize lipids in brain cells. If this enzyme is not present, lipids accumulate in the brain and gradually destroy its ability to function (homozygous recessive children usually die by the age of four or five). Suppose that you are a carrier for TaySachs disease and that your partner is not. What is the probability that you and your partner will have a child with Tay-Sachs disease? a. 100% b. 75% c. 50% d. 25% e. 0% 10. A normally pigmented man marries a normally pig- mented woman. Their second child is an albino. a. What is the genotype of the man? b. What is the genotype of the woman? c. What is the genotype of the albino child? d. What is the probability that their next child will be an albino? 11. Darrell and Matilda each has type O blood. If they start a family, the probability that they will have a child having type A blood is . a. 100% b. 75% c. 50% d. 25% e. 0% 17-14 12. Is it possible for someone having type B blood and someone having type A blood to have a child having type O blood? Explain your answer. 13. Wanda, who has type O blood, gives birth to a baby having type O blood. a. Could Randy be the father? b. Can this information alone prove that Randy is the father? Explain your answer. 14. Suppose that two c. What is the genotype of their second child? people having free earlobes start a family. Their first child has free earlobes and their second has attached earlobes. a. What are the genotypes of the parents? b. What is the genotype of their first child? 15. Suppose that a trait is inherited by simple dominance. If two heterozygotes are mated, what is the probability of having an offspring that has the same phenotype as the parents? a. 100% b. 75% c. 50% d. 25% e. 0% 16. Suppose that Donna is a carrier for hemophilia and that Darrell does not have hemophilia. If Donna and Darrell have a family, what percentage of their girls will have hemophilia? What percentage of their boys will have hemophilia? 17. Darrell has type B blood. To people having what blood types can he safely donate blood? 18. Albinism, which is inherited as an autosomal recessive allele, is a genetic condition characterized by the absence of the pigment melanin in skin, hair, and eyes. The lack of melanin results from being homozygous recessive (aa). Approximately one in 17,000 people worldwide is an albino. The ability to taste the chemical phenylthiocarbamide (PTC) is also inherited as an autosomal recessive allele; not being able to taste PTC results from being homozygous recessive (pp). pigmented man who cannot taste PTC, and Randy's father is an albino who can taste PTC. A. If Randy and Matilda have a family, what are the possible genotypes of their children? 17-15 b. What percentage of their children will be albino? c What percentage of their children will be able to taste PTC? 19. In certain species of flies, eye color is controlled by simple dominance by a single pair of alleles. A red-eyed fly was crossed with a white-eyed fly, both of whose parents had white eyes. All of their offspring (both female and male) had red eyes. a. Which is dominant, the allele for red eyes or the allele for white eyes? b. What is the genotype of the white-eyed parents? c. If the white-eyed parent was mated with one of the red-eyed offspring, what phenotypic ratio would you expect regarding eye color? 20. In cattle, hair color is controlled by incomplete dominance. Red results from homozygous dominant alleles (RR), roan from heterozygous alleles (Rr), and white from homozygous recessive alleles (rr). What are the predicted phenotypes and their frequencies of the following cases of disputed paternity, identify the probable father: Blood type Blood type Blood type Blood type of mother of child of father #2 B O A AB B AB A B 22. A man with type B blood starts a family
with a woman having type A blood. What is the probability that the couple's first child will be a boy having type O blood? 23. Suppose that a woman having normal vision normal vision have a son who is colorblind. What is the probability that their second child will be a colorblind girl? 24. Albinism results from an autosomal recessive gene. Two parents with normal pigmentation have an albino child. a. What is the probability that their next child will be an albino? b. What is the probability that their second child will be a colorblind girl? 24. Albinism results from an autosomal recessive gene. next two children will both be albino? Genetics 193 Answers to Genetics Problems 1. The man could not be Hughes' son. Hughes had type AB blood. Regardless of the blood type of the mother, a child of Hughes could not have type O blood 2. a 3. c 4. c 5. c 6. c 7. a 8. d 9. e 10a. Aa 10b. Aa 10c. aa 10d. 25% 11. e 12. Yes, but only if the person having type B blood has a BO genotype, and if the person having type A blood has an AO genotype. 13b. No, information about blood type cannot prove that anyone is the parent of a child; it can only eliminate people who are not parents of the child. 14a. Ee 14b. EE or Ee 14c. ee 15. b 16. None of their girls will have hemophilia, and 50% of their boys will have hemophilia. 17. B and AB 18a. AApp, Aapp probable father is father #1 (type A blood). 22. 0% 23. 0% 24a. 25% 24b. 6.25% Questions for Further Study and Inquiry 1. What determines how often a phenotype occurs in a population? 2. Are dominant characteristics always more frequent in a population? 2. Are dominant characteristics? Why or why not? 3. Is it possible to determine the genotype of an individual having a dominant phenotype? How? 4. Why is hybrid seed so expensive to produce? 5. What blood types are not expected for children to have if their parents have AB blood? O blood? WRITING TO LEARN BIOLOGY Organisms heterozygous for a recessive trait are often called carriers of that trait. What does this mean? 194 EXERCISE 17 17-16 E XER CISE Evolution Natural Selection and Morphological Change in Green Algae 18 Learning Objectives By the end of this exercise you should be able to: 1. Give a working definition of evolution, fitness, selection pressure, and natural selection. 2. Determine the genotypic and phenotypic frequency of a population while properly using the terms allele, dominant, recessive, homozygous, and heterozygous. 3. Explain the Hardy-Weinberg Principle and use it to demonstrate negative selection pressures on a population. 4. Describe the significance of the Volvocine line, particularly in the areas of cellular specialization and colonial complexity. Please visit connect.mheducation.com to review online resources tailored to this lab. E volution is the change in heritable characteristics of a populations. The existence of genetic change in heritable characteristics of a population. The theory of evolution is the change in heritable characteristics of a population over successive generations. The theory of evolution is the change in heritable characteristics of a population over successive generations. that many mechanisms can change the genetic makeup of populations, but the relative importance of each mechanism remains to be fully described. Events such as mutations (changes in the genetic massage of a cell, fig. 18.1) and catastrophes (e.g., meteor showers, ice ages) can produce genetic change. However, Charles Darwin (fig. 18.2) formulated a theory that explains a major force behind genetic change that produces adaptation: natural selection. Darwin postulated that organisms that survive and reproduce successfully have genetic traits enhance an organism stat survive and reproduce successfully have genetic traits enhance and reproduce successfully have genetic trait individuals, and therefore contribute more genes to the next generation. Darwin noticed that fit individuals (that is, ones that reproduce the most) produce the most) produce the most generation. Darwin noticed that fit individuals are transmitted to the next generation more often, then more of these traits will be found in the next generations, the frequency of these traits will increase in the population, and the nature of the section and proposed it as a major force that guides genetic change while producing adaptations and forming new species. Review in your textbook the theories of evolution and the mechanism of natural s election. 18-1 ©Otero/gtphoto Figure 18.1 Mutations produce new alleles and new genetic combinations. This child has a streak of white hair, caused by a somatic mutation in a single cell during embryonic development. This cell continued to divide to produce a streak of white hair. Showing the effects of natural selection in living populations with nonliving, colored beads representing organisms and their gametes. With this artificial population Evolution 195 In this exercise you will simulate evolutionary changes in allelic and genotypic frequencies in an artificial population. The trait you will simulate evolutionary changes in allelic for white fur (b). An individual is represented by two gametes (beads). Individuals with genotypes BB and Bb have black fur, and those with bb have white fur. Procedure 18.2 Darwin greets his "monkey ancestor." In his time, Darwin was often portrayed unsympathetically, as in this drawing from an 1874 publication. you can quickly follow genetic change over many generations. Before you begin work, review the previous exercise on genetics, especially the terms gene, allele, dominant alleles, recessive alleles, homozygous, and heterozygous. You will begin your experiments using a "stock population" of organisms consisting of a container of beads. Each bead represents an allele it is carrying. Individual organisms from this population are diploid (having two sets of chromosomes) and therefore are represented by two beads. UNDERSTANDING ALLELIC AND GENOTYPIC FREQUENCIES Frequency is the proportion of individuals in a certain category relative to the total number of individuals considered. The frequency of an allele or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the total alleles or genotype is expressed as a decimal proportion of the frequency of Bb is 0.25. If 3/4 of all alleles in a population are B, then the frequency of B is 0.75. 1. Obtain a "stock population" of organisms consisting of a container marked "Parental Population." 3. From the stock population, select 25 homozygous dominant individuals (BB) and place them in the container marked "Parental Population." Each individual is represented by two colored beads. 4. From the stock population, select 50 heterozygous individual is represented by a colored beads. 5. From the stock population, select 25 homozygous recessive individuals (bb) and place them in the container marked "Parental Population." Each individual is represented by two white beads. 6. Calculate the total number of alleles in your newly established parental population." frequencies for your parental population. 7. Complete table 18.1 with the number and frequency of each of the two alleles are present for this particular trait? b. How many alleles are present for this particular trait? Frequency Alleles BB B bb bb 196 EXERCISE 18 Frequency 0.25 18-2 c. What color fur do Bb individuals have? •• Choice of mates is random. •• Mutation does not occur. •• Individuals have? •• Choice of mates is random. enables us to calculate and predict allelic and genotypic frequencies. We can compare these predictions with actual changes that we observe in natural populations and learn about factors that influence gene frequencies. Deviations of observed frequencies from frequencies from frequencies are compare these predictions with actual changes that we observe in natural populations are compare these predictions with actual changes that we observe in natural populations are compare these predictions with actual changes that we observe in natural populations are compare these predictions with actual changes that we observe in natural populations are compare these predictions with actual changes that we observe in natural populations are compare the second s model
includes two simple equations first described for stable populations by Godfrey Hardy and Wilhelm Weinberg. Hardy-Weinberg equations (1) predict allelic and genotypic frequencies from natural populations. For example, if we know the frequency of B or BB, we can calculate the frequency of b, Bb, and bb. Then we can compare these frequencies with those of a natural population that we might be studying. If our observed data vary from our predictions, we can study the reasons for this genetic change. This comparison is important because biological characteristics of natural populations rarely correspond exactly to theoretical calculations. Furthermore, deviations are important because they often reveal unknown factors influencing the population being studied. According to the Hardy-Weinberg Principle, the frequency of the dominant allele of a pair is represented by the letter p, and that of the recessive allele by the letter q. Also, the genotypic frequencies of BB (homozygous dominant), Bb (heterozygous), and bb (homozygous recessive) are represented by p2, 2 pq, and q2, respectively. Examine the frequencies in table 18.1 and verify the Hardy-Weinberg equations: p = frequency of dominant allele q = frequency of recessive allele p+q=1p2 + 2 pg + g2 = 1 The Hardy-Weinberg Principle and its equations predict that frequencies of alleles and genotypes will remain constant from generation to generation in stable populations. Therefore, these equations can be used to predict genetic frequencies through time. However, the Hardy-Weinberg prediction assumes that •• There is no selection pressure. Question 2 a. Because all of the conditions listed above never occur simultaneously in nature, Hardy-Weinberg equilibrium never occurs in real populations. If the frequency of a recessive allele is 0.3, what is the frequency of the dominant allele? c. If the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous dominant genotype is 0.49, what is the frequency of the homozygous domi what is the frequency of the homozygous recessive genotype? e. Which Hardy-Weinberg equation relates the frequencies of the alleles at a particular gene locus? f. Which Hardy-Weinberg equation relates the frequencies of the phenotypes for a gene? •• The population is large enough to overcome random events. 18-3 Evolution 197 B b BB bb 25 (a) Genotypes 50 25 Parental population ??? Next generation (d) Retrieve 75-100 offspring Genotype Number BB Bb bb 25 (a) Genotypes 50 25 Parental population?? Frequency B b (e) Record the genotype of each selected individual. Figure 18.3 Verification of the Hardy-Weinberg Principle are at the end of this exercise. To verify the predictions of the Hardy-Weinberg Principle are at the end of this exercise. use the following procedure to produce a generation of offspring from the parental population you created in the previous procedure 18.2 Verify the Hardy-Weinberg Principle 1. Examine figure 18.3 for an overview of the steps of this procedure. 2. Establish the parental population (fig. 18.3a, 18.3b). 3. Simulate the random mating of individuals by mixing the population (fig. 18.3c). 4. Reach into the parental container (without looking) and randomly select two gametes. Determine their genotype (fig. 18.3d). This pair of gametes with colored or white alleles represents an individual offspring. 5. Record the occurrence of the genotype in figure 18.3e as a mark under the heading "Number" or temporarily on a second sheet of paper and return the beads to the container. 6. Repeat steps 4 and 5 (100 times) to simulate the production of 100 offspring. 7. Calculate the frequency of each genotype and allele, and record the frequencies write (in parentheses) the original frequency of that specific genotype or allele from table 18.1. 198 EXERCISE 18 b. If the frequencies were different, then one of the assumptions of the Hardy-Weinberg Principle was probably violated. Which one? EFFECT OF A SELECTION PRESSURE Selection is the differential reproduction of phenotypes (and their associated genotypes) are passed to the next generation more often than others. In positive selection, genotypes representing adaptive traits in an environment increase in frequency because their bearers are more likely to survive and reproduce. In negative selection, genotypes representing nonadaptive traits in an environment decrease in frequency because their bearers are less likely to survive and reproduce. 18-4 characteristic. For example, mice with white fur may be easy prev for a fox if they live on a black lava field. This dark environment is a negative selection pressure against white fur. If survival and reproduction of mice with white fur were eliminated (i.e., if there is 100% negative selection), would the frequency of white mice in the population decrease with subsequent generations? To test this, use the following procedure to randomly mate members of the original parental population to produce 100 offspring (fig. 18.5). Procedure 18.3 Simulate the production of an offspring from this population by randomly withdrawing two gametes to represent an individual offspring is BB or Bb, place it in a container for the accumulation of the "Next Generation." Record the occurrence of this genotype on a separate sheet of paper. 4. If the offspring is bb, place this individual in a container for those that "Cannot Reproduce." Individuals in this container should not be used to produce subsequent generations. Record the occurrence of this generation, © BiologyImaging.com Figure 18.4 Reproduction. These birds hatching from eggs may or may not survive to reproduce. On average, birds with characteristics best adapted to their environment will survive and reproduce more than those with less adaptive characteristics. As a result, the frequencies of adaptive traits (and their alleles) in the population will increase from generation. This change in frequencies of adaptive characteristics. pressures are factors such as temperature and predation that affect organisms and result in selective reproduction of phenotypes. Some pressures may elicit 100% negative selection against a characteristic and eliminate any successful reproduction of individuals having that Homozygous recessive Heterozygous Homozygous dominant Parental population First generation Figure 18.5 Demonstrating the effect of 100% Cannot reproduce Second generations. In this example, selection is against the homozygous recessive genotype. Random mating within the parental population is simulated by mixing the gametes (beads), and the parental population is sampled by removing two alleles (i.e., one individual) and placing them in the next generation. Homozygous recessive individuals are removed (selected against) from the population. The production of each generation depletes the beads in the previous generation in this simulation. Evolution 199 Table 18.2 Genotypic Frequencies for 100% Negative Selection Generation must equal 1.0. 6. Calculate the frequencies of each of the three genotypes recorded on the separate sheet and record these frequencies for the first generation in table 18.2. Individuals in the next generation will serve as the parental population for each subsequent generation. 7. Repeat steps 2-5 to produce a second, third, fourth, and fifth generation. After the production of

each generation, record your results in table 18.2. 8. Graph your data from table 18.2. using the graph paper at the end of this exercise. Generation is the independent variable on the x-axis and Genotype is the dependent variable on the y-axis. Graph three curves, one for each genotype. Because some members (i.e., the bb individuals that you removed) of each generation cannot reproduce, the number of offspring from each successive generations? Explain your answer b. Was the decrease of white individuals from the first to second generation? From the second to the third generation? From the third generation? Why or why not? c. How many generation? From the second to the third generation? From the third generation? Why or why not? c. How many generation the second to the third generation? From the third generation? Why or why not? c. How many generation? From the third generation? Why or why not? c. How many reproduction by the affected individuals. Instead, their reproductive capacity is reduced by a small proportion. To show this, use procedure 18.4 Simulate 20% negative selection pressure 1. Establish the same parental population that you used to test the Hardy-Weinberg prediction. 2. Simulate the production of an offspring from this population by randomly withdrawing two gametes to represent an individual offspring. 3. If the offspring is BB or Bb, place it in a container for production of the "Next Generation." Record the occurrence of this genotype on a separate sheet of paper. 4. If the offspring is BB or Bb, place it in a container for production of the "Next Generation." Record the occurrence of this genotype on a separate sheet of paper. 4. If the offspring is BB or Bb, place it in a container for production of the "Next Generation." Record the occurrence of this genotype on a separate sheet of paper. 4. If the offspring is BB or Bb, place it in a container for production of the "Next Generation." Record the occurrence of this genotype on a separate sheet of paper. bb, place every fifth individual (20%) in a separate container for those that "Cannot Repro duce." Individuals in this container for production of the "Next Generation." Record the occurrence of this genotype on a sheet of paper. 5. Repeat steps 2-4 until the parental population is depleted, thus completing the first generation. 6. Calculate the frequencies of each of the three genotypes recorded on the separate sheet and record these frequencies of each of the three genotypes recorded on the separate sheet and record these frequencies of each of the three genotypes recorded on the separate sheet and record these frequencies of each of the first generation. "Next Generation" will serve as the parental population for each subsequent generation. After the production of each generation, record your results in table 18.3 using the graph paper at the end of this exercise. Generation is the independent variable on the yaxis. Graph three curves, one for each generation of your 200 EXERCISE 18 18-6 Table 18.3 Genotypic Frequencies for 20% Negative Selection Generation Generation of your 200 EXERCISE 18 18-6 Table 18.3 Genotypic Frequencies for 20% Negative Selection Generation of your 200 EXERCISE 18 18-6 Table 18.3 Genotypic Frequencies for 20% Negative Selection Generation Generation of your 200 EXERCISE 18 18-6 Table 18.3 Genotypic Frequencies for 20% Negative Selection Generation G The total of frequencies for each generation must equal 1.0. population will decrease. However, the frequency of each generations would be necessary to eliminate the allele for white fur? Question 5 a. Did the frequency of white individuals decrease with successive generations? AN EXAMPLE OF EVOLUTION: THE VOLVOCINE LINE b. Consult your graphs and compare the rate of selection for procedures 18.3 and 18.4. Was the rate of decrease for 20% negative selection similar to the rate of selection? If not, how did the rate of decrease for 20% negative selection similar to the rate of selection similar to the rate of decrease for 20% negative selection? lab, but we can examine modern species to learn about changes that likely occurred over evolutionary time. Researchers might ask which characteristics are conserved throughout an evolutionary time. Researchers might ask which characteristics are conserved throughout an evolutionary time. of modern species that reflects an easily recognized sequence of changes INQUIRY-BASED LEARNING Heterozygotes can "hide" traits. How effective is selection against heterozygotes? Observations: Natural selection by a particular phenotype) against a homozygous genotype can reduce allelic frequencies in only a few generations. The results of selection against heterozygous individuals over many generations. The results of selection against heterozygous individuals over many generations affect allelic frequencies in only a few generations. Based Learning Worksheet 18 from your instructor. b. Discuss with your group a well-defined question relevant to the preceding observation and question. Record it. d. Review procedures 18.3 and 18.4. Outline on Worksheet 18 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your proposed investigation. e. Conduct your procedures, record your data, answer your questions, hypothesis, or procedures. Repeat your work as needed. Evolution common ancestors evolved. In this example, the changes were in colony complexity. Studies of morphology and molecular genetics indicate that an ancient species similar to today's flagellated Chlamydomonas (fig. 18.6) was probably the original and most ancient species similar to today's flagellated Chlamydomonas (fig. 18.6) was probably the original and most ancient species similar to today's flagellated Chlamydomonas (fig. 18.6) was probably the original and most ancient species similar to today's flagellated Chlamydomonas (fig. 18.6) was probably the original and most ancient species similar to today's flagellated Chlamydomonas (fig. 18.6) was probably the original and most ancient species similar to today's flagellated Chlamydomonas (fig. 18.6) was probably the original and most ancient species similar to today's flagellated Chlamydomonas (fig. 18.6) was probably the original and most ancient species similar to today's flagellated Chlamydomonas (fig. 18.6) was probably the original and most ancient species similar to today's flagellated Chlamydomonas (fig. 18.6) was probably the original and most ancient species similar to today's flagellated Chlamydomonas (fig. 18.6) was probably the original and most ancient species similar to today's flagellated Chlamydomonas (fig. 18.6) was probably the original and most ancient species similar to today's flagellated Chlamydomonas (fig. 18.6) was probably the original and most ancient species similar to today's flagellated Chlamydomonas (fig. 18.6) was probably the original and most ancient species similar to today's flagellated Chlamydomonas (fig. 18.6) was probably the original and most ancient species similar to today's flagellated Chlamydomonas (fig. 18.6) was probably the original and most ancient species similar to today's flagellated Chlamydomonas (fig. 18.6) was probably the original and most ancient species similar to today's flagellated Chlamydomonas (fig. 18.6) was probably the original and most ancient species similar to today's flagellated Chlamydomonas (fig. ancestor of unicellular Chlamydomonas evolved a novel colonial morphology that was successful and gave rise to today's Pandorina (fig. 18.9) and then Eudorina (fig. 18.10). That colonial ancestor later gave rise to today's Pandorina (fig. 18.11), the most complex alga of the Volvocine line. These five genera are modern representatives of a lineage of species that evolved along a path of colonial green alga composed of 16 cells (400×). ©Aaron J. Bell/Science Source Figure 18.6 Chlamydomonas, a unicellular green alga (1700×). Chlamydomonas has two flagella. Gonium algal cells (890×). Pandorina Eudorina Volvox Time Chlamydomonas © Michael Abbey/Science Source Figure 18.9 Pandorina, a colony of 16 or 32 flagellated green Colony complexity Figure 18.7 A cladogram representing the simplified phylogeny (family tree) of the Volvocine line. Proposed common ancestors are represented by the branching points called nodes. 202 EXERCISE 18 Courtesy EPA Figure 18.10 Eudorina, a colony of 32 flagellated green algal cells (420×). 18-8 a ball. After attaining its maximum size, each cell of the colony divides to form a new colony. The parent matrix then breaks open like Pandora's box (hence the name Pandorina) and releases the newly formed colonies. Pandorina is isogamous. Question 7 What is the significance of a specialization at one end of the colony? ©McGraw-Hill Education/Stephen Durr, photographer Figure 18.11 Volvox, a common green alga (200×). Colonies of Volvox often consist of hundreds of cells Daughter colonies are visible within the larger parent colony. Procedure 18.5 Examine members of the Volvocine line of algae 1. Follow steps 2-6 to sequentially examine each of the organisms with your microscope. When preparing each of the colonial specimens, try both a standard microscope slide and a deep-well or depression slide. Determine which works best for colonies of cells. 2. Chlamydomonas is among the most primitive and widespread of the green algae. It is a unicellular biflagellate alga (fig. 18.6). All species of the Volvocine line consist of cells are in different configurations. 3. Gonium is the simplest colonial member of the Volvocine line (fig. 18.8). A Gonium colony consists of 4, 8, 16, or 32 Chlamydomonas-like cells held together in the shape of a disk by a gelatinous matrix. Each cell in the Gonium is isogamous. 5. Eudorina is a spherical colony composed of 32, 64, or 128 cells (fig. 18.10). Cells in a colony of Eudorina differ in size; smaller cells are located at the anterior part of the colony. The anterior surface is
determined by the direction of movement. Question 8 What is the significance of these structural and functional specializations of Eudorina? 6. Volvox is the largest and most spectacular organism of the Volvocine line. Volvox is a spherical colony made of thousands of vegetative cells and a few reproductive cells (fig. 18.11). Flagella spin the colony on its axis. In some species of Volvox and Gonium, cytoplasmic strands form a conspicuous network among the cells. Question 9 a. Does the Volvox colony spin clockwise? Question 6 Why do colonies of Gonium consist of only 4, 8, 16, or 32 cells? Why are there no 23-cell colonies? b. What is the significance of the cytoplasmic network in Volvox? 4. Pandorina moves. Flagella on Pandorina move the ellipsoidal alga through the water like 18-9 To organize your information and observations complete table 18.4. Evolution 203 Table 18.4. Evolutionary Specialization of Members of the Volvocine Line Characteristic Chlamydomonas Gonium Pandorina Eudorina Volvox Number of cells Reproductive specialization (isogamy versus oogamy) Testing for Understanding: Solving Hardy-Weinberg Problems 1. Galactosemia is inherited as a homozygous recessive trait (i.e., gg). You have sampled a population in which 36% of people have galactosemia. a. What is the frequency of the G allele? c. What is the frequency of the G and Gg genotypes? 2. Suppose that in wasps, brown wings are dominant to white wings, and 40% of all wasps is heterozygous? b. What percentage of the wasps is heterozygous? 10 females) are on a cruise, and your ship sinks near a deserted island. You and all of your friends make it to shore and start a new population isolated from the recessive allele (i.e., are heterozygous) for phenylketonuria. If the frequency of this allele does not change as the population on your island increases, what will be the incidence of phenylketonuria on your island? 4. Albinos produce very little of the pigment melanin in their skin and hair. Albinism is inherited as a homozygous recessive trait. In North America, about 1 in 20,000 people is an albino. a. What is the frequency of the dominant allele for albinism? b. What is the frequency of albinos? c. What is the frequency of heterozygous recessive for the sickle-cell trait have some sickling of their blood cells, but these cells trait have normal blood cells, but these cells trait have normal blood cells, but these cells trait have normal blood cells. are easily infected with malarial parasites. As a result, many of these individuals are killed by sickle-cell anemia. People who are homozygous recessive for the sickle-cell trait resist infections by malarial parasites, but their sickle-cell trait resist infections by malarial parasites. they homozygous dominant or homozygous recessive—are less likely to survive than are heterozygous individuals. Suppose that 9% of a population will be heterozygous recessive and the recessive allele in a population that produces twice as many homozygous recessive individuals as heterozygotes? Answers to Hardy-Weinberg Problems 1a. 60% 1b. 40% 1c. GG = 16%; Gg = 48% 2a. 47% 204 EXERCISE 18 2b. 14% 3. 0.25% 4a. 99.3% 4b. 0.005% 4c. 1.4% 5. 42% 6. q = 0.8 18-10 Questions for Further Study and Inquiry 1. How would selection against heterozygous individuals over many generations affect the frequencies of p and q? Could you test this experimentally? How? 2. How are genetic characteristics associated with nonreproductive activities such as feeding affected by natural selection? 3. Although Charles Darwin wasn't the first person to suggest that populations, is natural selection, which produces adaptations, is natural selection. What is natural selection? 4. Does evolutionary change always leads to greater complexity? Why or why not? 5. Is natural selection the only means of evolution? Explain. 6. Is natural selection the only means of evolution to understanding disease is widespread and productive. What is the benefit of applying Darwinian principles to medical practice? 9. How could natural selection affect the frequency of sickle cell anemia (Fig. 17.4)? 18-11 Evolution 205 DOING BIOLOGY YOURSELF Design an experiment to determine the phylogenetic relationships among members of the Volvocine line of algae. What information about their DNA sequences would be useful? WRITING TO LEARN BIOLOGY Summarize the most recent books and publications that review the benefits of applying Darwinian principles to medical practice. fertilization must be random. Is that true for most wildflower populations? What characteristics of these plants influence pollination Learning Objectives By the end of this exercise you should be able to: 1. Describe the parts of a modern human skull. 2. Distinguish between skulls of males and females. 3. Distinguish between skulls of apes and modern humans. Please visit connect.mheducation.com to review online resources tailored to this lab. T hroughout time, no issue has interested humans more than learning about our origins. Where did we come from? What did our ancestors look like? Where did they live? Today, we are beginning to understand those questions, thanks to evidence provided by biologists and anthropologists. Nevertheless, the topic remains controversial and often elicits strong responses from people. In this exercise, you will examine some of the information underlying recent ideas about human evolution by examining the skulls of human and humanlike organisms. Specifically, you will examine skulls of Gorilla gorilla, the modern gorilla. Gorillas and humans share a common ancestor. Australopithecus (fig. 19.1), a relatively small, humanlike organism that had small, pointed canine teeth and an elongated face and was adapted for bipedalism and an upright stance. The most famous australopithecine is "Lucy," discovered in 1974 in Ethiopia. Australopithecus, the best known of the early humanlike organisms, lived 3.5-2.5 million years ago. Homo erectus, a human ancestor characterized by an upright posture, a sloping forehead, a large brow ridge, a thick skull, and a larger braincase (900 cm3) than earlier humanlike organisms. H. erectus lived 1,800,000-27,000 years ago. Homo sapiens, or modern humans, are characterized by a vertical forehead, small brow ridge, thin skulls, and a larger braincase (1400 cm3) than earlier humanlike organisms. H. sapiens appeared 200,000 years ago. These species represent well-documented stages in the lineage of modern humans. As you examine these skulls, think 19-1 ©DEA/G CIGOLINI/AGE Fotostock Figure 19.1 Australopithecus africanus was the first australopithecus africanus african making new discoveries of early human fossils and that the specimens you will analyze represent a small subset of these species (fig.19.2). THE MODERN HUMAN SKULL The human skull (fig. 19.3), including the lower jaw, consists of 22 bones, 8 of which are paired. All of the bones fit together at joints called sutures, which appear as wavy lines. Projections and raised lines are sites of muscle attachment. Human Evolution 207 Time 5.0 Millions of years ago (mya) 3.0 2.0 4.0 1.0 0 Denisovan H. heidelbergensis Paranthropus robustus Australopithecus afarensis ("Lucy") Ardipithecine ancestor (bipedalism) Bipedalism Slender body H. ergaster A. africanus A. garhi H. neanderthalensis Stocky body Homo habilis Homo sapiens H. erectus Large brains, stone tools Figure 19.2 A possible scenario for human evolution. In this human family tree, several species lived contemporaneously with one another, but only one lineage gave rise to modern humans (Homo sapiens). Dotted lines indicate controversial time lines and branching patterns. 0 inches 7 0 inches 7 Male Skull Feature Female Skull Large Marked Retreating Developed Rounded Square Nearly a right angle Large Present A. Braincase Smaller than male B. Muscle lines Slight C. Forehead Bulging D. Brow ridges Absent E. Upper rim of eye socket Sharp F. Chin Rounded G. Angle of jaw Angle more obtuse (over 120°) H. Mastoid process Small I. External occipital protuberance Absent Figure 19.3 A comparison of male and females share many features, they usually can be distinguished. However, such a diagnosis—even when done by experts is only about 90% reliable (80% if the lower jaw is missing). Procedure 19.1 Examine skulls of modern humans 1. Examine the skulls of modern humans 1. Examine skulls of modern humans 1. Examine the skulls of modern humans 1. Examine the skulls of modern humans 1. Examine the skulls of modern humans 1. Examine skulls o beside each feature in the table correspond to those shown in the diagrams. Question 1 a. How do skulls of females differ from those of males? b. What is the biological significance of the skull through which the spinal cord passes The position of the foramen magnum reflects the posture of the body (and, indirectly, the pattern of movement) of hominoids. Humans stand erect and walk with the head directly over the vertical spinal column. Conversely, the knuckle-walking apes hold their heads forward, with the foramen magnum toward the rear. Thus, the foramen magnum is located in a more rear position in apes than in humans. Teeth and Jaws Adult apes and humans have the same number and types of teeth: 4 canines, 8 premolars, 12 molars, and 8 incisors. Identify these teeth on the skulls and diagrams. In apes the canine teeth are longer and more pointed than others. Notice that nonhuman primates have large lower canines (fig. 19.4). Therefore, the upper jaw must have a diastema (space) on each side to receive those canine swhen the jaw is closed. The canine teeth seldom project above the others. In humans, the four front teeth (incisors) are smaller, more vertical, and flatter than in apes. In nonhuman primates, the canine diastema is the gap in the teeth corresponding to the canines of the opposite jaw. Question 2 a. Between which teeth does the gap occur? Why are these gaps essential in nonhuman primates? b. Why are they usually absent
in humans? Use figure 19.4 and the specimens in the lab to study the following features of ape and human skulls. Face Prognathism is the extent to which the face and jaws protrude forward when viewed from the side. Their larger teeth and jaws cause apes to exhibit more prognathism than do humans. Braincase The brow ridge in apes is prominent. In humans, the brow ridge of modern humans is largely internalized because our frontal bone has expanded outward to a more vertical angle. The sagittal crest is a sociated with having a small braincase and powerful jaws. In apes, the sagittal crest is an attachment site for the large temporalis muscle used for chewing. 19-3 Humans have an outward projection on the lower part of their jaw. In humans, teeth are arranged in a relatively continuous curve from the third molar around to the other third molar. The arrangement of teeth in apes is straighter, with a slight curve in front. This is primarily because of the larger size of the incisors and canines. To summarize the differences between skulls of fossil primates Use the information and diagrams in figures 19.5–19.8 to learn about skulls of humans and ancient primates. At first glance, full skeletons of humans and modern apes look quite similar. But closer examination reveals distinctive differences and adaptations, many of which are related to bipedalism, jaw shape, and brain size. Human Evolution 209 Gorilla J J 0 inches 5 Underside of skull Side view Figure 4.1 Structure 4.1 Structur 19.4 Comparison of skull features of modern Homo sapiens, gorilla, and Australopithecus skull and jaws: A. Incisors B. Canines C. Premolars D. Molars E. Zygomatic arch F. Foramen magnum G. Vertical ramus for muscle attachment J. Sagittal crest for muscle attachment 19-4 Table 19.1 Prominent Features of Skulls of Apes and Humans Feature Apes Humans Sagittal crest Brow ridge Foramen magnum Prognathism Canines Canine diastema Incisors Chin Arrangement of teeth Procedure 19.4 Compare human and chimpanzee skeletal adaptations for standing 1. Compare the skeletons illustrated in figure 19.9. 2. For each of the following skeletal features, record the difference between human and chimpanzee anatomy. Then speculate on the adaptive significance of those features of Chimpanzees and/or food habits. Summarize your work by completing table 19.2. Table 19.2. Table 19.2. Humans Feature Chimpanzee Human Tooth number and size Spine shape Braincase size Insertion point of head on the spinal column Thumb and big toe size and angle Arm length of the femur 19-5 Human Evolution 211 Paranthropus boisei © Dinoton/Shutterstock © The Natural History Museum/Alamy Stock Photo Figure 19.5 Views of the skull and teeth of Paranthropus boisei. Age: 1.8 million years. This skull includes massive molar teeth (similar in size to those of gorillas) and is nearly complete except for the lower jaw. It is commonly known as "Zinj," an abbreviation of the original genus name Zinjanthropus. Zinj and the remains of many smaller hominins (humanlike organisms) were discovered in the Olduvai Gorge in Tanzania by Mary and Louis Leakey in 1959. 212 EXERCISE 19 19-6 © Puwadol Jaturawutthichai/Shutterstock Figure 19.6 Views of the skull and teeth of Homo erectus. Age: Less than 1 million years. This diagram shows a reconstruction that includes parts of skulls discovered in 1937 and 1939 in Java (Sangiran). The skull of Homo erectus differs from modern human skulls in that it is low vaulted and has a relatively small volume; H. erectus skulls have volumes of 900-1100 cm3, whereas skulls of modern humans have volumes of approximately 1400 cm3. Skulls of H. erectus also have small mastoid processes behind the ear openings, large jaws, small chins, and large molar teeth. 19–7 Human Evolution 213 Homo sapiens. Also known as Neanderthal Man, this type jaws, small chins, and large molar teeth. was recovered in 1932 from Mugharet-es-Skhull, Wadi el-Mughara, Israel. The skull is nearly complete. Homo sapiens (modern) Figure 19.8 Skull of modern Homo sapiens. Age: About 10,000 years. This skull is from one of at least 50 skeletons recovered at Oued Agrious, Algeria, during the late 1920s. 214 EXERCISE 19 19–8 Human spine exits from the skull's center; ape spine exits from rear of skull. Human spine is S-shaped; ape pelvis is longer and more narrow. Human femurs angle inward to the knees; ape femurs angle out a bit. Human knee can support more weight than ape knee. Human foot has an arch; ape foot has no arch. (a) (b) Figure 19.9 Adaptations for standing. (a) Human skeleton compared to (b) chimpanzee skeleton. INQUIRY-BASED LEARNING Humans don't stand still. Along what paths did our common ancestors migrate during our evolution? Observations: Some of the oldest fossils of our human ancestors have been found in Africa. Current theories of human evolution involve the migration of ancestral primates and early hominins from Africa to Europe and back to Africa. Question: What migration by ancestral primates and early hominins away from and back to Africa. c. Record your findings on Worksheet 19. d. Discuss your findings with your instructor and with other students. a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 19 from your instructor. 19–9 Human Evolution 215 Questions for Further Study and Inquiry 1. What could changes in our ancestors' teeth tell us about the evolutionary history of humans? 2. Is the skull shown in figure 19.7 that of a man or a woman? Explain your answer. 3. Neanderthalensis). However, some anthropologists consider modern humans and Neanderthalensis). that they should be the same species? Why or why not? What species-related criteria are you using as a basis for your claim? What does this judgment imply about the ability of these two groups of people to interbreed when they lived together in Europe 34,000 years ago? WRITING TO LEARN BIOLOGY Describe what other evidence you would use to study the evolution of humans. Where would you get that evidence? 216 EXERCISE 19 WRITING TO LEARN BIOLOGY Read an article on a more recent fossil is similar to and different from the species they measured in this lab. Describe distinctive features of the skeleton and describe what it in Plant Communities 20 Learning Objectives By the end of this exercise you should be able to: 1. Observe the physical factors, plant dominance, and interactions among organisms in a terrestrial community and characterize Quantify the distribution and abundance of plants in a community, 3. Detect the experimental effects of competition and allelopathy among plants. 4. Explain four different plant species in a plant community, using transect data. Please visit connect.mheducation.com to review online resources of different plant species in a plant community, using transect data. tailored to this lab. E cological communities are extraordinarily complex. The assemblage of plants that you observe at any time results from interactions among plants and animals. All of these interactions are driven by a flow of energy captured by green plants and passed to herbivores (plant eaters), predators, and decomposers. It is beyond the scope of this exercise to explain all of the processes occurring in a plant communities. SAFETY FIRST Before coming to lab, you were asked to read this exercise so you would know what to do and be aware of safety issues. In the space below, briefly list the safety issues associated with today's procedures. If you have questions about these issues, contact your laboratory assistant before starting work. QUALITATIVE COMMUNITY ASSESSMENT Procedure 20.1 Observe and assess the ecological characteristics of a terrestrial community 1. Locate and visit a terrestrial community designated by your instructor. 2. Characterize the community according to the criteria and questions, discuss your observations with your instructor and other groups. Be prepared to use your observations as a basis for describing your assessment of energy flow through the community, diversity of the community, and interactions among organisms. Physical Factors Observations 1. What levels of light intensity occur throughout the community? 2. Does the community include shade-tolerant as well as shade-intolerant plants? 20-1 Ecology 217 3. How does light differ among different vertical levels of vegetation? Why could this be important? 4. What is the temperature 2 m above ground? 5. What is the temperature 2 m above ground? 5. What is the temperature 3. What is the temperature 2 m above ground? 5. What is the temperature 3. Wh a layer of leaf litter on the ground? 10. Is the community generally a moist, moderate, or dry environment? Interpretations 1. How might be cooler than others? Interpretations 1. How might be cooler than others? What parts of the community might be cooler than others? Why is this important? 4. Why would ground slope be important? 5. Based on your observations of slope and soil type, would you expect the soil to retain moisture? 6. How long has this community? 218 EXERCISE 20 20-2 Plant Dominance Observations 1. Which plant species and soil type, would you expect the soil to retain moisture? 6. How long has this community? are most abundant in numbers? 2. Which plant species are most abundant in biomass? 3. What general categories of plant types (shrubs, trees, etc.) are apparent? 4. What is the vertical distribution of vegetation? Interpretations 1. Would you describe this community as diverse? Why or why not? 2. What comparison community in your local area would you consider to be more diverse? Less diverse? Less diverse? Less diverse? A What observations led you to your conclusion for the previous question? 4. What specific factors? Geology? Interactions among Organisms Observations 1. What evidence do you see of resident vertebrates? 2. What evidence do you see of plant-plant interactions? 5. What evidence do you see of plant-animal interactions? 4. What evidence do you see of plant-plant
interactions? 5. What evidence do you see of plant-animal interactions? 5. What evidence do you see of plant-plant interactions? 5. What evidence do you see available resources? Interpretations 1. If you don't see any vertebrates, does that mean they are not around? Explain your answer. 2. Reexamine the observations are apparent in the community? 4. What types of mutually beneficial interactions are apparent in the communities, and distributions of organisms in terrestrial plant communities. One widely used technique is to count organisms within randomly distributed quadrats (sometimes called plots) of uniform size. Other techniques involve measuring distances between plants or the distance from randomly chosen points to nearest plants. In the line-intercept method, a transect, or line, is established and laid out within the community. Organisms that touch this line are counted and measured. Calculations based on these measurements of quadrats and transects reveal the relative abundances, frequencies, and distributions of the plant species that compose the community. 220 EXERCISE 20 Procedure 20.2 Assessing a community with the line-intercept method 1. With the help of your instructor, locate a suitable field site with a plant community to be examined. 2. Obtain a measuring tape 10-13 m long, a meterstick, and a notepad. If a measuring tape is unavailable, use a measuring tape is unavailable, use a measuring tape 10-13 m long, a meterstick and a notepad. If a measuring tape is unavailable, use a measuring tape is unavailable, use a measured piece of string or rope. 3. Assess the general layout of the community to be sampled. With the aid of your instructor, decide on a reasonable set of criteria to govern the placement of a transect for each group of students. 20-4 Table 20.1 Summary of Raw Data for Species i Occurring along a Transect Intervals in Which Species i Occurring along a Total length of transect intercepted = Question 1 What concepts or ideas should govern the placement of your transect to obtain a representative sample of the community? Are there any "wrong" places to put a transect? Why or why not? 4. You and your lab partners will work on a single transect. Stretch the measuring tape on the ground to establish a transect. 5. Divide the transect into 1- or 5-m intervals. Each intervals. Each intervals. Each intervepts. For plants that touch, overlie, or underlie the transect begin counting plants that touch, overlie, or underlie the transect begin counting plants that touch. overhang the line, record the length of the imaginary vertical plane of the line that the plant would intercept. Record these raw data for each interval in your field notepad. Also record any uncovered (bare) lengths within the transects. 7. When all plants from all intervals have been recorded, summarize your data in table 20.1. 20-5 8. Sum the values in each of the three data columns of table 20.1 to calculate F, N, and C. Record the calculations at the bottom of each column. 9. Use the data in table 20.1 to calculate the following four parameters for each species within the community. Record your results in table 20.1 to calculate F, N, and C. Record the calculate the following four parameters for each species within the community. Importance value of species i = Relative frequency + Relative density + Relative coverage Question 2 What is the meaning of an importance value? Why would we calculate this in addition to density, coverage, and f requency? Ecology 221 Table 20.2 Relative Values of Each Species in a Selected Community Using Parameters of the Line-Intercept the second Method Species Relative Frequency Relative Density Relative Coverage Importance Value PLANT INTERACTIONS Competition is usually negative (disadvantageous) for both competitors. The intensity of competition for a resource such as light, food, water, space, and nutrients depends on the amount of resource, the number of individuals competition. Procedure 20.3 Examine competition by sunflower seedlings 1. Obtain five pots containing enough potting soil to plant at least 20% more seeds so you can later reduce the number of seedlings to the numbers previously listed. Label each pot with the number of seeds, the date, and your name. 3. Water each pot growth area so that each pot has the same environmental conditions of light, temperature, and so on. After the seedlings are established, remove excess seedlings so the treatments will have the correct number of seedlings listed in step 2. 5. Examine the pots at regular intervals as directed by your instructor. Record measurements of the parameters called for in table 20.3. Your instructor may ask you to plot your results. 222 EXERCISE 20 © Design Pics/PunchStock Figure 20.1 Competition in a forest. Each plant in this forest competes with all the individuals around it for light, soil nutrients, and moisture. Question 3 a. Was competition on Sunflower Seedling the competitors might you have measured? e. In what environments would you expect that competition among sunflowers would be most intense? d. Did competition among sunflowers would be most
intense? d. Did competition among sunflowers would be most intense? d. Did competition among sunflowers would be most intense? d. Did competition among sunflowers would be most intense? d. Did competition among sunflowers would be most intense? d. Did competition among sunflowers would be most intense? d. Did competition among sunflowers would be most intense? d. Did competition among sunflowers would be most intense? d. Did competition among sunflowers would be most intense? d. Did competition among sunflowers would be most intense? d. Did competition among sunflowers would be most intense? d. Did competition 223 g. Would plants and animals compete for the same resources? What might be some differences? Allelopathy is a form of competition involving the inhibition of a plant's germination or growth by exposure to compounds produced by another plant. These compounds may be airborne or leach from various plant parts. Rainfall, runoff, and diffusion typically distribute inhibitory compounds in the immediate area surrounding the producing allelopathic compounds? b. What are the possible disadvantages of producing allelopathic compounds? b. What are the possible disadvantages of producing allelopathic compounds? Procedure 20.4 Demonstrate allelopathy 1. Determine from your instructor the overall experimental design for the class—how many plants your group will test and how many replicates you will set up for each plant. 2. Obtain tissue (stems and leaves) from the variety of plants provided by your instructor. Some of these plants are suspected to produce allelopathic compounds. 3. For each plant. 2. Obtain tissue (stems and leaves) from the variety of plants provided by your instructor. water in a blender and homogenize. Let the slurry soak for 5-10 min to leach chemicals from the disrupted tissue. 4. Filter or strain the slurry to remove large particulates. Drain the slurry to remove large particulates. Drain the slurry to remove large particulates. being tested in that dish. 7. Saturate the filter paper with a measured amount (5-8 mL) of the extract. 8. Repeat steps 3-7 for each replicate and each plant being tested. 9. Obtain seeds of radish, lettuce, or oat. Distribute 50 seeds uniformly on the filter paper in each dish. 10. Your instructor may enhance the experimental design by asking you to set up replicate dishes for each extract and to test the effects on different kinds of seeds. Follow the directions given by your instructor. 11. You may also be asked to design and implement an experimental control of a water-only treatment that is blended and then filtered. greenhouse. After 24 and 48 h, count the number of seeds that have germinated and calculate the percent germinated. 13. After 72 h (or the length of time specified by your instructor) measure the length of the radicle and make relevant observations for as many days as specified by your instructor. 14. Record your results in table 20.4. Question 5 a. Did your observations reveal any differences in allelopathy? © Arto Hakola/Shutterstock Figure 20.2 Allelopathic inhibition of nearby plant competitors for nutrients and water often results in barren areas surrounding the established plant producing the inhibitors. 224 EXERCISE 20 20-8 Table 20.4 Effects of Allelopathy on Germinated Total No. of Seeds Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Radicle Observations Rep 1 Rep 2 Rep 3 Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Radicle Observations Rep 1 Rep 2 Rep 3 Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Radicle Observations Rep 1 Rep 2 Rep 3 Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Radicle Observations Rep 1 Rep 2 Rep 3 Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Radicle Observations Rep 1 Rep 2 Rep 3 Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Radicle Observations Rep 1 Rep 2 Rep 3 Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Radicle Observations Rep 1 Rep 2 Rep 3 Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Radicle Observations Rep 1 Rep 2 Rep 3 Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Radicle Observations Rep 1 Rep 2 Rep 3 Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Radicle Observations Rep 1 Rep 2 Rep 3 Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Radicle Observations Rep 1 Rep 2 Rep 3 Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Radicle Observations Rep 1 Rep 2 Rep 3 Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Radicle Observations Rep 1 Rep 2 Rep 3 Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Radicle Observations Rep 1 Rep 2 Rep 3 Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Radicle Observations Rep 1 Rep 3 Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Radicle Observations Rep 1 Rep 3 Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Radicle Observations Rep 1 Rep 3 Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Radicle Observations Rep 3 Plant Extract Seed Species Time % Germinated Total No. of Seeds Length of Ra leaves, roots, and stems all produce allelopathic compounds? Observation: Many plants produce chemicals are adaptive because they reduce competition. Question: Do all organs (e.g., roots, stems, leaves) of allelopathic plants produce the same amounts of allelopathic chemicals? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 20 from your instructor. b. Discuss with your group's best question. 20-9 c. Translate your question into a testable hypothesis and record it. d. Outline on Worksheet 20 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your proposed investigation. e. Conduct your procedures, record your data, answer your question, and make relevant comments. f. Discuss with your instructor any revisions to your questions, hypothesis, or procedures. Repeat your work as needed. Ecology 225 Questions for Further Study and Inquiry 1. Diverse plant communities have many species representing a variety of plant types such as grasses, shrubs, succulents, hardwood trees, vines, and ferns. What factors increase a community's diversity? Age of the second trees, softwood trees, soft the community? Energy input? Moisture? Nutrients? Disturbance? Human activity? How do they do so? 2. What characteristics of a community make it more resilient than other communities to a particular disturbance? Describe both the type of disturbance? Disturbance? Describe both the type of disturbance? In the type of disturbance? Describe both the type of disturbance? been disturbed for a few years? 4. How does competition influence natural selection? Is the presence of competitors a selective force? 226 EXERCISE 20 20-10 E XER CISE Community succession occurs. 3. Describe how succession occurs. 3. Describe how succession 21 Learning Objectives By the end of this exercise you should be able to: 1. Define community succession 22. Describe how succession occurs. 3. Describe how succession occurs. 3 how the environment and resources influence succession. Please visit connect.mheducation.com to review online resources tailored to this lab. A s time passes, most environments are inhabited by a succession of different communities. Succession of different communities. that live and interact in the same area at the same time. The growth of the bacterial community in a carton of milk produces a succession of changes in milk that, in turn, create conditions for other organisms to grow. This phenomenon—that is, the changes in milk that, in turn, create conditions for other organisms to grow. succession, each community of o rganisms (i.e., each stage in succession) changes the environment. Ironically, during succession a community inhibits its own long-term growth. When this happens, a different community (a new successional stage) takes its place. Thus, communities change over time. Primary succession occurs in areas where there is little or no organic soil and no living organisms have become established. Examples of primary succession occurs when a disturbance restarts succession at a different point than that which occurs with primary succession. Examples of secondary succession include the changes caused to ecosystems by disease, forest fires, weather (e.g., hurricanes, drought), and human activities (e.g., cutting down a forest, plowing a field, mowing a lawn). Secondary succession because organic soil is already present and conditioned for use by plants. As you might guess, community succession occurs at multiple scales and levels, ranging from large-scale ecosystems (e.g., the forests surrounding Mt. St. Helens volcano, or the wildfires of the western states) to local areas affected by timber harvest, and development. 21-1 Virtually succession occurs at multiple scales and levels, ranging from large-scale ecosystems (e.g., the forests surrounding Mt. St. Helens volcano, or the wildfires of the western states) to local areas affected by timber harvest, and development. everyone is familiar with the consequences of community succession in a container of milk. Milk contains carbohydrates (lactose, or milk sugar), protein (casein, or curd), and lipids (butterfat); all of these nutrients can support the growth of a variety of microbes. Pasteurization retards this growth and involves heating milk to about 170°C to kill pathogenic bacteria. Then the milk is rapidly cooled. However, pasteurization does not kill all nonpathogenic bacteria. Although these nonpathogenic bacteria divide slowly when they are refrigerated, they will ultimately "spoil" the milk, even if the milk is
refrigerated. Leaving the milk at room temperature greatly speeds the spoilage. Question 1 What are some examples of community succession occurring on your campus or in nearby areas? In large-scale, so-called old-field succession that occurs in places such as forests and fields, most of the organisms are multicellular, sexually reproducing, relatively long-lived species that colonize the site at various times. During this type of succession the composition of the community changes and is dominated by autotrophs. In contrast, small-scale communities such as carcasses or cartons of milk are dominated by unicellular, asexually reproducing, relatively short-lived individuals largely descended from individuals largely descended from individuals largely descended from individuals largely descended from individuals present at the start. are exceptions to this statement, for they are not present on living individuals.) This type of succession is "degradative" because the availability of energy and nutrients is highest at the early stages and declines over time. Community Succession 227 SUCCESSIONAL CHANGES IN MILK In this exercise, you will study community succession in milk. This process of succession is often more complex than you might suspect. For example, 1. Pseudomonas and Achromobacter (both Gram-negative rods; see fig. 24.3 in Exercise 24) are common bacteria that digest butterfat and give milk a putrid smell. 2. Lactobacillus (a Gram-positive rods; see fig. 24.3 in Exercise 24) are common bacteria that digest butterfat and give milk a putrid smell. 2. Lactobacillus (a Gram-positive rods; see fig. 24.3 in Exercise 24) are common bacteria that digest butterfat and give milk a putrid smell. 2. Lactobacillus (a Gram-positive rods; see fig. 24.3 in Exercise 24) are common bacteria that digest butterfat and give milk a putrid smell. 2. Lactobacillus (a Gram-positive rods; see fig. 24.3 in Exercise 24) are common bacteria that digest butterfat and give milk a putrid smell. survive pasteurization. These bacteria ferment lactose to lactic acid and acetic acid. 3. Acidity sours the milk and converts the casein to curd. 4. Under acidic compounds. 5. Finally, Bacillus (a Grampositive rod) metabolize proteins into ammonia products and raise the milk's pH. The characteristic odor of spoiled milk becomes apparent when this occurs. Succession in milk, under the right conditions and with the proper bacteria, can lead to the formation of cheese. Similarly, bacteria added to milk and the subsequent succession can produce buttermilk, yogurt, and sour cream. However, the most common instance of community succession in milk usually occurs in dairy cases at supermarkets and in our kitchen refrigerators. There, bacteria ferment lactose into acid, thereby spoiling the milk. Procedure 21.1 Compare community succession in different types of milk 1. Work in small groups as instructed by your lab instructor. 2. Each group will be given one of the following sets of samples: Treatment 1: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 3: Whole milk, incubated at 37°C; 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole milk, kept in a refrigerator (4°C); 2, 5, and 8 days old. Treatment 4: Whole mi milk, boiled, then cooled to room temperature (25°C); 2, 5, and 8 days old. Treatment 5: Chocolate milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 7: Buttermilk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 7: Buttermilk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and 8 days old. Treatment 6: Skim milk, kept at room temperature (25°C); 2, 5, and Optional treatment, determined by the instructor. 3. Use pH paper to measure the pH of each sample of each treatment. Record your data in table 21.1. 4. Note each sample's odor, color, and consistency. Pay particular attention to physical changes in the milk's composition and record any odors, particular attention to physical changes in the milk's composition and record any odors, particular attention to physical changes in the milk's composition and record any odors, particular attention to physical changes in the milk's composition and record any odors, particular attention to physical changes in the milk's composition and record any odors, particular attention to physical changes in the milk's composition and record any odors, particular attention to physical changes in the milk's composition and record any odors, particular attention to physical changes in the milk's composition and record any odors, particular attention to physical changes in the milk's composition and record any odors, particular attention to physical changes in the milk's composition and record any odors, particular attention to physical changes in the milk's composition and record any odors, particular attention to physical changes in the milk's composition attentinge flask. 5. Use the Gram stain procedure (see Exercise 24) to identify the shapes, staining properties, and relative amounts of the bacteria in the milk. 6. Record your observations in table 21.1. 7. Plot your pH data for Treatments 1-3 in figure 21.2, and Treatments 1-3. Treatments 1-3 in figure 21.1, Treatments 1-3 in figure 21.1, Treatments 1-3 in figure 21.1, Treatments 1-3. 7.0 6.0 pH pH 7.0 5.0 5.0 4.0 4.0 0 1 2 3 4 5 6 Time (days) 7 8 9 10 Figure 21.1 The effect of boiling and sealing on succession (as measured by changes in pH) in a biological community in whole milk. 228 EXERCISE 21 0 1 2 3 4 5 6 Time (days) 7 8 9 10 Figure 21.2 biological community in whole milk. 21-2 Figure 21.3 Community succession (as measured by changes in pH) in chocolate milk, skim milk, buttermilk, and whole milk. Treatment 1: Whole milk kept at room temperature (25°C) pH Odor Coloriate milk, skim milk, buttermilk, and whole milk. Treatment 1: Whole milk kept at room temperature (25°C) pH Odor Coloriate milk, skim milk, buttermilk, and whole milk kept at room temperature (25°C) pH Odor Coloriate milk, skim milk, buttermilk, and whole milk kept at room temperature (25°C) pH Odor Coloriate milk, skim milk, buttermilk, and whole milk kept at room temperature (25°C) pH Odor Coloriate milk, skim milk, buttermilk, and whole milk kept at room temperature (25°C) pH Odor Coloriate milk, skim milk, buttermilk, and whole milk kept at room temperature (25°C) pH Odor Coloriate milk, skim milk, buttermilk, and whole milk kept at room temperature (25°C) pH Odor Coloriate milk, skim milk, buttermilk, and whole milk kept at room temperature (25°C) pH Odor Coloriate milk, skim milk, buttermilk, and whole milk kept at room temperature (25°C) pH Odor Coloriate
milk, skim milk, buttermilk, and whole milk kept at room temperature (25°C) pH Odor Coloriate milk kept at room temperature (25°C) pH Odor Coloriate milk, skim milk kept at room temperature (25°C) pH Odor Coloriate milk kept at room temperature (25°C) pH Odor Coloriate milk kept at room temperature (25°C) pH Odor Coloriate milk kept at room temperature (25°C) pH Odor Coloriate milk kept at room temperature (25°C) pH Odor Coloriate milk kept at room temperature (25°C) pH Odor Coloriate milk kept at room temperature (25°C) pH Odor Coloriate milk kept at room temperature (25°C) pH Odor Coloriate milk kept at room temperature (25°C) pH Odor Coloriate milk kept at room temperature (25°C) pH Odor Coloriate milk kept at room temperature (25°C) pH Odor Coloriate milk kept at room temperature (25°C) pH Odor Coloriate milk kept at room temperature (25°C) pH Odor Coloriate milk kept at room temperature (25°C) pH Odor Coloriate milk kep Type of Bacteria Present Comments Color Type of Bacteria Present Comments Day 0 Day 2 Day 5 Day 8 Treatment 2: Whole milk kept in a refrigerator (4°C) pH Odor Day 0 Day 2 Day 5 Day 8 21-3 Community Succession 229 Treatment 3: Whole milk kept at 37°C pH Odor Day 0 Day 2 Day 5 Day 8 21-3 Community Succession 229 Treatment 3: Whole milk kept at 37°C pH Odor Day 0 Day 2 Day 5 Day 8 21-3 Community Succession 229 Treatment 3: Whole milk kept at 37°C pH Odor Day 0 Day 2 Day 5 Day 8 21-3 Community Succession 229 Treatment 3: Whole milk kept at 37°C pH Odor Day 0 Day 2 Day 5 Day 8 21-3 Community Succession 229 Treatment 3: Whole milk kept at 37°C pH Odor Day 0 Day 2 Day 5 Day 8 21-3 Community Succession 229 Treatment 3: Whole milk kept at 37°C pH Odor Day 0 Day 2 Day 5 Day 8 21-3 Community Succession 229 Treatment 3: Whole milk kept at 37°C pH Odor Day 0 Day 2 Day 5 Day 8 21-3 Community Succession 229 Treatment 3: Whole milk kept at 37°C pH Odor Day 0 Day 2 Day 5 Day 8 21-3 Community Succession 229 Treatment 3: Whole milk kept at 37°C pH Odor Day 0 Day 2 Day 5 Day 8 21-3 Community Succession 229 Treatment 3: Whole milk kept at 37°C pH Odor Day 0 Day 2 Day 5 Day 8 21-3 Community Succession 229 Treatment 3: Whole milk kept at 37°C pH Odor Day 0 Day 2 Day 5 Day 8 21-3 Community Succession 229 Treatment 3: Whole milk kept at 37°C pH Odor Day 0 Day 2 Day 5 Day 8 21-3 Community Succession 229 Treatment 3: Whole milk kept at 37°C pH Odor Day 0 Day 2 Day 5 Day 8 21-3 Community Succession 229 Treatment 3: Whole milk kept at 37°C pH Odor Day 0 Day 2 Day 5 Day 8 21-3 Community Succession 229 Treatment 3: Whole milk kept at 37°C pH Odor Day 0 Day 2 Day 5 Day 8 21-3 Community Succession 229 Treatment 3: Whole milk kept at 37°C pH Odor Day 0 Day 1 Day Comments Color Type of Bacteria Present Comments Day 0 Day 2 Day 5 Day 8 Treatment 4: Whole milk, boiled, then cooled to room temperature (25°C) pH Odor Day 0 Day 2 Day 5 Day 8 Treatment 5: Chocolate milk kept at room temperature (25°C) pH Odor Day 0 Day 2 Day 5 Day 8 Treatment 5: Chocolate milk kept at room temperature (25°C) pH Odor Day 0 Day 2 Day 5 Day 8 Treatment 5: Chocolate milk kept at room temperature (25°C) pH Odor Day 0 Day 2 Day 5 Day 8 Treatment 5: Chocolate milk kept at room temperature (25°C) pH Odor Day 0 Day 2 Day 5 Day 8 Treatment 5: Chocolate milk kept at room temperature (25°C) pH Odor Day 0 Day 2 Day 5 Day 8 Treatment 5: Chocolate milk kept at room temperature (25°C) pH Odor Day 0 Day 2 Day 5 Day 8 Treatment 5: Chocolate milk kept at room temperature (25°C) pH Odor Day 0 Day 2 Day 5 Day 8 Treatment 5: Chocolate milk kept at room temperature (25°C) pH Odor Day 0 Day 2 Day 5 Day 8 Treatment 5: Chocolate milk kept at room temperature (25°C) pH Odor Day 0 Day 2 Day 5 Day 8 Treatment 5: Chocolate milk kept at room temperature (25°C) pH Odor Day 0 Day 2 Day 5 Day 8 Treatment 5: Chocolate milk kept at room temperature (25°C) pH Odor Day 0 Day 2 Day 5 Day 8 Treatment 5: Chocolate milk kept at room temperature (25°C) pH Odor Day 0 Day 2 Day 5 Day 8 Treatment 5: Chocolate milk kept at room temperature (25°C) pH Odor Day 0 Day 2 Day 5 Day 8 Treatment 5: Chocolate milk kept at room temperature (25°C) pH Odor Day 0 Day 2 Day 5 Day 8 Treatment 5: Chocolate milk kept at room temperature (25°C) pH Odor Day 0 Day 2 Day 5 Day 8 Treatment 5: Chocolate milk kept at room temperature (25°C) pH Odor Day 0 Day 2 Day 5 Day 8 Treatment 5: Chocolate milk kept at room temperature (25°C) pH Odor Day 0 Day 1 Day temperature (25°C) pH Odor Color Type of Bacteria Present Comments Color Type of Bacte Day 0 Day 2 Day 5 Day 5 Day 8 21-5 Community Succession 231 Question 2 Which milk changed the slowest? Why? EXAMINING LARGER ECOSYSTEMS If time permits, your instructor will take you to a disturbed site on campus, an abandoned agricultural field, or a nature preserve. While you are there, examine the site closely. Describe the site in the following space. Question 3 How did the pH of milk change over time in your different samples? Why do you think this happened? Question 5 How did the abundance and type of organisms in the milk change over time? Why is this important? c. How does the area you are examining differ from areas that surround it? What accounts for these differences? Question 6 Acidity sours the milk and converts the casein to curd. How long does it take for this change to occur at room temperature? When the milk is refrigerated? Question 7 Why did you plot the pH data from Treatment 1 on all three of the graphs (figs. 21.1, 21.2, and 21.3)? 232 EXERCISE 21 21-6 INQUIRY-BASED LEARNING Community Succession and the "Spoilage" of Beverages Observation: In this lab you measured how dairy products "spoil" and how the changes associated with spoilage are associated with community succession. Many other kinds of beverages also "spoil." Question: Is the "spoilage" of a beverage or product always associated with similar types of community succession? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 21 from your instructor. b. Discuss with your group well-defined questions relevant to the preceding observation and question. C. Translate your group's best question for investigation. C. Translate your group's best questi e. Conduct your procedures, record your data, answer your questions, hypotheses, or procedures. Repeat your work as needed. Questions for Further Study and Inquiry 1. Question 1 in this exercise asked you to describe local examples of community succession. How are these examples similar to the "milk community" model that you studied in this lab? How are they different? 2. What is biological succession occur? What factors influence the rate of succession? 21-7 Community Succession 233 4. What human activities try to prevent (or slow) biological succession? 5. In this exercise you studied how microbes affect a rather small ecosystems? 234 EXERCISE 21 21-8 E XER CISE 22 Population Growth Limitations of the Environment Learning Objectives By the end of this exercise you should be able to: 1. Described and the environment Learning Objectives By the end of this exercise you should be able to: 1. Described and the environment Learning Objectives By the end of this exercise you should be able to: 1. Described and the environment Learning Objectives By the end of this exercise you should be able to: 1. Described and the environment Learning Objectives By the end of this exercise you should be able to: 1. Described and the environment Learning Objectives By the end of this exercise you should be able to: 1. Described and the environment Learning Objectives By the end of this exercise you should be able to: 1. Described and the environment Learning Objectives By the end of this exercise you should be able to: 1. Described and the environment Learning Objectives By the end of this exercise you should be able to: 1. Described and the environment Learning Objectives By the end of this exercise you should be able to: 1. Described and the environment Learning Objectives By the end of the environment Learning Objectives By the environme how to quantify the growth of populations. 2. Show the effects of resources and environmental conditions on population refers to a group of organisms of the term population refers to a group of organisms of the term population refers to a group of organism of the term population. same species living and reproducing together. Notice that all members of a population are of the same species and live in the same general area. A species is a group of organisms that can reproduce with each other but are reproductively incompatible with other organisms. Typically a species is distributed in multiple populations across its entire range. There may be little or no gene flow between populations. For example, the population of ground squirrels on the South Rim. They are the same species but constitute two populations. In optimal conditions (e.g., plenty of food, water, space, etc.), populations grow in a predictable pattern. Early growth is slow (the so-called lag phase of growth), after which growth is extremely rapid (fig. 22.1). This rapid, logarithmic (i.e., "log") phase of growth represents the organism's biotic potential, which is its maximal reproductive capacity if given unlimited resources. The number of ©blickwinkel/Alamy Stock Photo Number of individuals Carrying capacity One dot = 7500 people Log phase (b) Time (a) 22-1 U.S. Department of Commerce, Economics and Statistics Administration, U.S. Census Bureau Figure 22.1 Populations. (a, left) The theoretical growth of a popula- tion. The dotted line represents the ecosystem's carrying capacity. (b, above) The world's population already exceeds 7.3 billion, and growth continues. Population Growth 235 individuals at a given generation during logarithmic growth can be determined from the following formula: Nt = a2t where Nt = the number of individuals at time t a = the number of individuals present initially t = time, expressed as the number of generations This equation
shows how fast populations can grow. For example, consider Escherichia coli, a common bacterium that can divide by way of binary fission every 20 min in ideal conditions. In only one day (1440 min), these bacteria can go through 72 (1440/20) generations. Therefore, if we start our experiment with one bacterium, and if we assume that no bacteria die, the number of bacteria present after one day would be: = (1 bacteria many bacteria aren't the only organisms having such an incredible biotic potential. For example, •• Each oyster produces about 50 million eggs per year. •• In 6 years a single pair of Atlantic cod and their descendants reproducing without hindrance would completely fill the Atlantic Ocean. •• The 80 offspring produced every 6 months by a pair of cockroaches would produce 130,000 roaches in only 18 months—enough to overrun any apartment (fig. 22.2). NVIRONMENTAL RESISTANCE E AND CARRYING CAPACITY Organisms in the "real world" do not always reproduce at maximum rates, and populations do not grow at ever-increasing rates. Maximum logarithmic growth cannot be sustained © Chip Clark/National Museum of Natural History, Smithsonian Institution Figure 22.2 The consequences of exponential growth. All organisms have the potential to produce populations larger than those that actually occur in nature. The German cockroach (Blatella germanica), a major household pest, produces 80 young every 6 months. If every cockroach that hatched survived for three generations, kitchens might look like this culinary nightmare concocted by the Smithsonian Museum of Natural History. because environmental resistance includes factors such as disease, accumulation of waste products, and lack of food. Ultimately the size and growth of a population are balanced by the environmental resistance prevents a population from continuing to reproduce at its biotic potential. To understand the effects of environmental resistance, complete table 22.1. This table provides actual data for a growing but limited population of E. coli if given unlimited resources and if no bacteria. For comparison, you must calculate the size of a theoretical population of E. these calculations, plot the growth of the theoretical and actual populations on figure 22.3. Table 22.1 Theoretical and Actual 1 0 8 8 2 20 16 15 3 40 32 28 4 60 48 5 80 120 6 100 220 7 120 221 236 EXERCISE 22 22-2 Population size 0 1 Time (hours) Figure 22.3 Theoretical population growth of E. coli. Question 1 a. How did growth of the experiment? At later stages? b. How long did it take the real populations to double during early stages of the experiment? Middle stages? Later stages? c. When was growth of the actual population most rapid? d. At what stage was growth slowest? Why? 2 in this broth, but you can measure the increase in turbidity means more bacteria (living as well as dead). In most natural populations (excluding bacteria), immigration and emigration would also occur, but these factors are ignored for simplicity in the models of population growth that you will examine in this exercise. There's a lag time before the limiting factors are realized. In these cases, the birth rate may not decline immediately as the carrying capacity is reached; this means that the population may overshoot the carrying capacity before settling down to reach the carrying capacity. Your instructor has previously inoculated some test tubes of culture media with E. coli, a common bacterium. At regular time intervals some of the tubes were put into a refrigerator to stop growth. Examine the cultures by using procedure 22.1. Remember that the turbidity is due to living and dead bacteria. SAFETY FIRST Before coming to lab, you were asked to read this exercise so you would know what to do and be aware of safety issues. In the space below, briefly list the safety issues. In the space below, briefly list the safety issues. In the space below, briefly list the safety issues. In the space below, briefly list the safety issues. Measure population growth of bacteria 1. Examine cultures of E. coli grown for 0, 4, 8, 12, 24, and 48 h. The greater the turbidity, the more dense the population of bacteria. 2. Estimate the relative turbidity, the more dense the population of bacteria. turbidity of the solutions according to procedures demonstrated by your instructor. Spectrophotometers may also be used at 600 or 750 nm. Record your results in table 22.2. Procedure 22.2 Measure how resources and environmental conditions affect the size of a population. because of limiting factors such as disease, the presence of predators, competition for resources, and lack of food. This stability occurs when the birth rate equals the death rate and is referred to as the carrying capacity as long as limiting factors are constant. In the laboratory, you can measure the growth of real populations such as bacteria reproduce quickly. As bacteria reproduce in a clear nutrient broth, the broth becomes turbid (cloudy). You can't accurately count individual bacteria 22-3 1. Examine cultures of E. coli that have grown for 10 days in the following environments: Distilled water, pH 7 Nutrient broth, pH 3 Nutrient broth, pH 5 Nutrient broth, pH 5 Nutrient broth, pH 7 Nutrient broth, pH 9 Nutrient broth, pH 11 2. Quantify the relative turbid), 3. Record your results in table 22.3. Population Growth 237 Table 22.2 Growth of Bacteria in a Limited-Nutrient Medium Time (hours) Turbidity Intensity (0-10) Absorbance Value Turbidity Intensity (0-10) Absorbance Value 0 4 8 12 24 48 Table 22.3 Growth of Bacteria in a Limited-Nutrient broth, pH 5 Nutrient broth, pH 7 Nutrient b turbidity of the solutions according to procedures demonstrated by your instructor. If spectrophotometers are available, measure the absorbance of the solution. Record your results in table 22.3. Question 2 a. Compare your data for populations grown in nutrient broth and in distilled water. Does the presence of nutrients ensure rapid growth of bacteria? Why or why not? aquarium. Each week since then, he or she has counted the number of plants in the aquarium. Those data are posted by the aquarium. Those data are posted by the aquarium. Those data are posted by the aquarium. growth of duckweed? b. What role does pH play in the growth of bacterial population? b. What will eventually happen to the size of the population? Why? Procedure 22.3 Measure population? Why? Procedure 22.3 Measure population? Why? Procedure 22.3 Measure population? sexually, but it usually reproduces asexually. 1. During the first week of this term your instructor placed 10 duckweed (Lemna) plants in an illuminated 238 EXERCISE 22 22-4 1990 5300 2000 6200 2010 6900 2018 7500 2030 8500 (projected by the United Nations) 2050 9700 (projected by the United Nating) 2050 9700 (projected by the U Nations) Plot these data in figure 22.5. Use a dashed line (----) to plot the projected estimates of population beyond 2018. Question 4 a. How does the shape of this graph compare with those you made for the bacteria? Courtesy Robert H. Mohlenbrock @ USDA-NRCS PLANTS Database, USDA NRCS, 1995. Northeast Wetland Flora: Field Office Guide to Plant Species. Northeast National Technical Center, Chester, PA (a) Y Number of plants b. What do you conclude from this? X Time (days) (b) Figure 22.4 (a) Duckweed (Lemna) is a small flowering plant that grows in mats on the surface of stagnant ponds. (b) Population growth of duckweed (Lemna). its doubling time. In 1850, the doubling time for our population was 135 years. Today, the doubling time is about 65 years. This means that during the next 65 years. This means that during the next 65 years. (millions) 5 90 1 130 1650 550 1750 720 1800 910 1850 1100 1900 1600 1950 2400 1960 3000 1970 3700 1980 4600 22-5 10,000 Population in millions The population in millions The population of humans is growing fast. Consider these data: 8000 6000 4000 2000 B. C. 6000 B. C. 6000 B. C. 4000 2000 B. C. B. C. Time 0 A. D. 2000 A. D. Figure 22.5 Growth of the human population. Population Growth 239 The human population has increased explosively during the past three centuries (fig. 22.6). Although the birth rate is now at about 19 births per 1000 people, the death rate has fallen to about 9 per 1000 people, the death rate has fallen to about 9 per 1000 people per year. is growing at a rate of about 1.2% per year. Here's what that means: 8 7 6 •• Each hour the world's population grows by 8700. •• Each year there are about 76 million more people on Earth. That annual increase in our population grows by 8700. Finland. •• In the 6 seconds it takes to read this sentence, 14 more people will be added to our population. Each of these people eats food; generates wastes; and, in his or her own way, affects our Earth. •• During the 20th century alone, the population of the world increased from 1.65 billion to 6 billion. •• In 1970, there were roughly half as many people as there are now. Billions of People 5 4 3 Significant advances in public health 2 Industrial Revolution 1 Bubonic plague "Black Death" 4000 B.C. 2000 B.C. 200 like the Black Death of the 1400s, have little lasting impact. Explosive growth began with the Industrial Revolution in the 1700s, which lengthened human lifespans and thereby increased reproductive opportunities. The current population exceeds 7.3 billion, and at the current rate will double in 61 years. b. Can this continue? Why or why not? living. Improving our standard of living will require that we more than double our resources. Question 5 a. What is the importance of population has already reached its carrying capacity? Explain the basis for your answer. b. The doubling time for populations in developed countries far exceeds that of developing countries. What is the significance of this? 240 EXERCISE 22 22-6 INQUIRY-BASED LEARNING How does population are strongly influenced by the environment is always changing. The growth and size of a population growth respond to environment and
size of a population are strongly influenced by the environment. short life cycles and fast growth rates is particularly sensitive to changes in abiotic factors. Question: How does population growth respond to environmental stimuli? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 22 from your instructor. b. Discuss with your group well-defined questions relevant to the preceding observation and question. Choose and record your group's best question for investigation. d. What will happen when the worldwide population exceeds the earth's carrying capacity? c. Translate your question into a testable hypothesis and record it. d. Review procedures 22.1 and 22.3, which use bacteria and duckweed to investigate population growth. Outline on Worksheet 22 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your questions, hypotheses, or procedures. Repeat your work as needed. g. In some countries, the human population has shrunk in recent years. Is this good or bad? Why? e. How has the growth of other populations? h. In mid-2018, the U.S. population was near 340 million people and growing at an annual rate of approximately 0.7% per year. At this growth rate, how many people are added to the population in a year? f. How does the growth of the human population for Further Study and Inquiry 1. How can the growth of a population be slowed by its own numbers? 2. Some people are now realizing the significance of population growth. Although this exercise treated the problems only in biological terms, the reality of population growth is much more complex because it involves many political, social, and economic problems? How do they affect you now? How will they affect you later in life (e.g., when you want to retire)? 3. Should we do anything to slow the "population explosion"? If so, what? If not, why? 4. From a purely ecological standpoint, can the problem of world hunger ever be overcome by improved agriculture alone? What other components must a hunger-control policy include? 5. How are problems such as deforestation, pollution, and world hunger linked with population growth? 6. The late Garrett Hardin (1915-2003), a famous biologist, wrote that "Freedom to breed will bring ruin to us all." Do you agree with him? Explain your answer. DOING BIOLOGY YOURSELF Design a simple spreadsheet to facilitate calcula tion of population size for each generation based on different generation times or different numbers of offspring per individual. 242 EXERCISE 22 WRITING TO LEARN BIOLOGY Charles Darwin's ideas about natural selection as a driving force for evolution were strongly influenced by ideas in an essay entitled "Essay on Population" by Thomas Malthus. Go to the library and read about Malthus's ideas. How did they influence Darwin? How are they relevant to this exercise? 22-8 E XER CISE Pollution 23 The Effects of Chemical, and Acidic Pollution, thermal pollution, thermal pollution, and acid rain affect the growth and reproduction of selected organisms. 2. Determine what factors can lead to excessive growth of algae. Please visit connect.mheducation.com to review online resources tailored to this lab. S eldom a day passes in which we don't hear a pollution-related problems that affect our lives. The effects of pollution can be disastrous, as exemplified by the nuclear leakage from power plants of Fukushima, Japan; oil spills along the coasts of Alaska and Spain; the leakage of 40 tons of toxic gas in 1984 in India (which killed thousands and injured hundreds of thousands and injured hundreds of thousands and injured hundreds of thousands and spain; the leakage from power plants of Fukushima, Japan; oil spills along the coasts of Alaska and Spain; the leakage of 40 tons of toxic gas in 1984 in India (which killed thousands and injured hundreds of thousands and injured hundreds of thousands and injured hundreds of thousands and spain; the leakage from power plants of Fukushima, Japan; oil spills along the coasts pollutant is any physical or chemical agent that decreases the aesthetic value, economic productivity, or health of the biosphere. There are many types of pollutants, including noise, chemicals, radiation, and heat. Whether or not it makes headlines, pollutants, including noise, chemicals, radiation, and heat.

and behave. Because populations of organisms interact among themselves and with their environment, pollution always affects more than one organism. For example, consider the following food chain: algae \rightarrow zooplankton \rightarrow small fish \rightarrow large fish \rightarrow humans A pollutant that reduces a population at any step of this food chain will affect all other levels of the food chain because all steps of the chain are linked. Thus, water polluted with chemicals, such as herbicides that kill algae, will decrease populations of fish and other organisms that are part of the food chain. In this exercise, you will study several types of pollution. Specifically, you will •• Simulate the effects of acid precipitation by examining seed germination and survival of organisms at acidic pH. 23-1 •• Study chemical pollution by examining how organisms survive at unnaturally high temperatures. •• Examine water polluted with an overabundance of algae. •• Use the Allium Test to assay the effects of a variety of pollutants on plant growth. SIMULATING THE EFFECTS OF ACID RAIN Acid rain is a worldwide problem caused by atmospheric pollution (fig. 23.1a). Compounds such as nitrates and sulfates released into the atmosphere by automobiles and industries combine with water to form nitric acids that are deposited across the pH of the soil, affects the availability of nutrients and metals, and usually diminishes plant growth. The effects of acid rain are often subtle but significant; for example, the cumulative pollution of decades of acid rain can destroy landmarks and reproduction and (2) growth and reproduction of brine shrimp. You will simulate acid rain with dilute solutions of sulfuric acid. Be careful while you handle the cultures and do not get the sulfuric acid solutions on yourself. If you do, wash yourself immediately and thoroughly. Pollution 243 Precipitation pH 5.3 (b) (a) © Marek Mnich/E+/Getty Images Figure 23.1 Acid rain and its effects. (a) The pH of snow and rain throughout the United States. (b) Acid rain often kills trees and damages landmarks such as sculptures and buildings. SAFETY FIRST Before coming to lab, you were asked to read this exercise so you would know what to do and be aware of safety issues. In the space below, briefly list the safety issues associated with today's procedures. If you have questions about these issues, contact your laboratory assistant before starting work. b. How do you think that lowering the pH will affect seed germination? Formulate a hypothesis for how lowering the pH will affect seed germination for each treatment. Record your results in table 23.1. Procedure 23.1 Observe seed germination 1. Examine the set of petri dishes labeled "Acid Rain and Seed Germination." Each of the dishes was inoculated several days ago with 50 seeds of corn (Zea mays). Dish 1 contains seeds germinate in their typical environments), dish 2 contains seeds soaked in a solution having a pH of 4, and dish 3 contains seeds soaked in a solution having a pH of 2. Question 1 a. Examine dish 1 (pH 7). What percentage of the seeds germinated? A germinated seed is one in which the root or shoot has punctured the seed coat. Use the following formula to calculate the percentage germination: % Germination = 3. Do your data in table 23.1 support your hypothesis? Explain. Question 2 a. How did acidity affect seed germination? How accurate were your predictions in Question 1? b. What does this tell you about the effect of acid rain on seed germination? How accurate were your predictions in Ruestion 2. How would the decreased growth of plants in response to acid rain affect animals in the same environment? number of germinated seeds × 100 total number of seeds 244 EXERCISE 23 23-2 Table 23.1 Germination of Seeds in Environments of Different pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Environments of Lifferent pH = 2 Table 23.2 Growth of Brine Shrimp in Different pH Counts of Number of Living Shrimp Treatment 1 2 3 4 5 Total Mean pH = 7 pH = 4 pH = 2 Procedure 23.2 Observe growth of brine shrimp are often used as live food in aquarity and the three cultures labeled "Acid Rain and Brine Shrimp." Several days ago all of the cultures were inoculated with the same number of brine shrimp growing in a solution having a pH of 4, and culture 2 contains shrimp growing in a solution having a pH of 4. 2. Compare these cultures with that in dish 3 at neutral pH (pH = 7). Use your dissecting microscope to count the number of living shrimp in five randomly selected fields of view of each culture. 3. Record your results in table 23.2. Question 3 a. How does acidity affect hatching and growth of brine shrimp in your experiment? What does this tell you about the effect of acid rain on survival of brine shrimp? c. Comment on the validity of extrapolating the results of your experiments with seed germination and brine shrimp? c. Comment on the validity of extrapolating the results of your experiments with seed germination and brine shrimp? ponds undergo a nutrient-enrichment process called eutrophication (fig. 23.2). Some instances of eutrophication occur naturally, whereas others are produced by human activities such as pollution. Most nutrients is exceeded, eutrophication occurs. b. Consider the food chain described in the introduction of this exercise. How would acid rain affect fish and humans in this food chain? © Jerome Wexler/Science Source Figure 23.2 A eutrophic pond. The surface bloom of green algae indicates the abundance of nutrients in the water. 23-3 Pollution 245 Table 23.3 Effects of Nutrient Enrichment on Algal Cultures Culture Observations 1 Eutrophication, anaerobic 3 Control Nitrogen and phosphorous are important nutrients that can limit plant growth. These nutrients are also major sources of anthropogenic eutrophication. These nutrients that can limit plant growth. runoff, excess fertilizer from lawns and gardens, and some detergents. In extreme situations, this excessive input of nutrients can cause rapid growth of algae and aguatic plants, thereby leading to the accelerated filling of lakes and ponds. In this exercise, you will study eutrophication by observing the growth rates of several organisms in both nutrient-enriched and unenriched media. Several days ago algal cultures were started with similar amounts of algae. Culture 1 contains an excess of nitrogen and minimal oxygen to simulate anaerobic conditions that occur naturally when bacterial populations in water increase rapidly in response to added sewage. As the bacteria grow and reproduce, they rapidly deplete the oxygen supply in the water, thus producing anaerobic conditions. Culture 3 is an aerobically grown control containing normal amounts of nitrogen. occurrences of fish-kills in overly eutrophic lakes and ponds to nutrient stimulation of rapid bacterial growth that depletes the dissolved oxygen. Procedure 23.3 Examine the effects of simulated eutrophication 1. Examine the two algal cultures labeled "Control." 2. Make at least three observations of each culture. Record your observations in table 23.3. ©2006 Fred Ward Figure 23.3 Huge amounts of pesticides and herbicides, such as those being applied by this crop duster, are used in agriculturists and other biologists is the development of integrated pest management and systems involving genetically engineered organisms that will avoid the need for such chemical excesses. c. What does this tell you about the influence of excessive amounts of nutrients on algal growth? d. How could you reverse the effects of eutrophication? e. Can eutrophicatio? e. growth? PESTICIDE POLLUTION b. Which has the least? 246 EXERCISE 23 Pesticides are common pollutants, and the increase trop yields (fig. 23.3). These pesticides are often effective, but residues washed from the soil by rain contaminate lakes, ponds, and the underground water supply. These pollutants can harm organisms that drink and live in these waters. 23-4 Table 23.4 Effects of Pesticide culture 1 Pesticide culture 2 Pesticide culture 3 Control culture 4 Table 23.5 Effects of Temperature on Survival of Brine Shrimp Culture 0 Servations Replicate 3 Mean Culture 1 (room temperature) Culture 2 (35°C)
Procedure 23.4 Examine the effect of a pesticide are toxic. 1. Examine the four cultures labeled "Pesticides." Several days ago these cultures were started with the same number of brine shrimp and kept at the same number of brine shripe at the same number of brine is a control that lacks pesticide. 3. Examine three samples from each culture with your dissecting microscope. Record your observations of each culture contains the most living shrimp? b. Which culture contains the most living shrimp? b. Which culture contains the most living shrimp? b. Which culture in table 23.4. Question 5 a. Which culture contains the most living shrimp? b. Which culture contains the most living shrimp? b. Which culture contains the most living shrimp? b. Which culture contains the most living shrimp? aquatic organisms? d. How might this pollution affect terrestrial organisms that depend on the water for drinking water? THERMAL POLLUTION Excessive heat is a common pollutant. Many factories use water from lakes, reservoirs, or rivers to cool heat-generating equipment and release the hot water to reservoirs or ponds, where it raises the water temperature. Thermal pollution: •• Speeds biochemical reactions, thereby altering the growth of organisms and composition of water. •• Decreases the oxygen supply in the water because warm water holds less oxygen than does cool water. Procedure 23.5 Examine the effect of temperature on the survival of brine shrimp 1. Use your dissection microscope to examine the two cultures labeled "Thermal Pollution." Both cultures ago with the same number of brine shrimp 1. Use your dissection microscope to examine the two cultures labeled "Thermal Pollution." Both cultures ago with the same number of brine shrimp 1. Use your dissection microscope to examine the two cultures labeled "Thermal Pollution." Both cultures ago with the same number of brine shrimp 1. Use your dissection microscope to examine the two cultures ago with the same number of brine shrimp 1. Use your dissection microscope to examine the two cultures ago with the same number of brine shrimp 1. Use your dissection microscope to examine the two cultures ago with the same number of brine shrimp 1. Use your dissection microscope to examine the two cultures ago with the same number of brine shrimp 1. Use your dissection microscope to examine the two cultures ago with the same number of brine shrimp 1. Use your dissection microscope to examine the two cultures ago with the same number of brine shrimp 1. Use your dissection microscope to examine the two cultures ago with the same number of brine shrimp 1. Use your dissection microscope to examine the two cultures ago with the same number of brine shrimp 1. Use your dissection microscope to examine the two cultures ago with the same number of brine shrimp 1. Use your dissection microscope to examine the two cultures ago with the same number of brine shrimp 1. Use your dissection microscope to examine the two cultures ago with the same number of brine shrimp 1. Use your dissection microscope to examine the two cultures ago with the same number of brine shrimp 1. Use your dissection microscope to examine the two cultures ago with the same number of brine shrine in oxygen-depleted water. Count the number of living brine shrimp in three fields of view. Record your observations of each culture contains fewer living shrimp? c. What does this tell you about the influence of thermal pollution on growth of aquatic organisms? d. How might thermal pollution of a lake or pond affect nearby terrestrial organisms. Thus, the most informative assay for these pollutants involves measuring growth of living organisms exposed to controlled treatments of suspected pollutants. The Allium Test provides this kind of assay. In the Allium Test, bulbs of the common onion, Allium, are subjected to solutions of water being investigated for pollutant toxicity. Roots develop quickly, and their number and length after 5 days estimate the effect of the potential pollutant on a common aspect of plant growth. Do not open the pesticide cultures or spill the liquids on yourself. Pesticides are toxic. Table 23.6 Growth of Allium Roots Exposed to a Specific Treatment Mean Length of Roots Control Treatment Control Table 23.7 Root Growth of Replicate Allium Bulbs Exposed to a Specific Treatment Solution Treatment: Number of Roots Mean = 248 EXERCISE 23 Control: Length of Roots Mean = Number of Roots Mean = 23-6 Procedure 23.6 Use the Allium Test. Record the solutions in Examine the solutions in Examine the solutions provided by your instructor for your class to assay with the Allium Test. Record the solutions in Examine the solutions in Examine the solutions provided by your instructor for your class to assay with the Allium Test. Record the solutions in Examine the solutions provided by your instructor for your class to assay with the Allium Test. Record the solutions in Examine the solutions provided by your instructor for your class to assay with the Allium Test. Record the solutions in Examine the solutions provided by your instructor for your class to assay with the Allium Test. Record the solutions in Examine the solutions provided by your instructor for your class to assay with the Allium Test. Record the solutions in Examine the solutions provided by your instructor for your class to assay with the Allium Test. Record the solutions in Examine the solutions provided by your instructor for your class to assay with the Allium Test. Record the solutions in Examine the solutions provided by your instructor for your class to assay with the Allium Test. Record the solutions in Examine the solutions provided by your instructor for your class to assay with the Allium Test. table 23.6.2. You may need to work in small groups to assay all of the solutions. Determine which solutions tested by your group. 3 responsibility. Some of the treatments may involve different temperatures and some may involve solutions tested by your group. 3 responsibility. Obtain onion bulbs. You will need 5 to 10 bulbs for each treatment and 5 to 10 bulbs for controls for each treatment. 4. Trim the outer, loose layers of each bulb. Use a razor blade to trim exposed tissue from the root crown. Your instructor will demonstrate how to do this. 5. Obtain a beaker (or test tube) wide enough to support the onion but that will allow the root crown to protrude into the solution. 6. Fill 5 to 10 replicate beakers with the solution being tested. 7. Fill 5 to 10 beakers with the appropriate control solutions. Question 7 What is the appropriate control solution for your treatment? Explain your answer. 8. Put a trimmed onion bulb on your beaker so the root crown is completely submerged (fig. 23.4). 9. Incubate the treatments and controls in the dark at room temperature for 3 to 5 days. Allium Test setup. The number and length of the growing roots estimate the toxicity of the solution being assayed. 10. Check and supplement the solution levels in the beakers periodically if needed. 11. After 4 to 7 days, determine the mean root length and number of roots for each bulb. Record the values from table 23.7. These are the results for the solutions that your group tested. 12. Record your mean values from table 23.7. These are the results for the results for the solutions that your group tested. 12. Record your mean values from table 23.7. These are the results for the results for the solutions that your group tested. 14. Record your mean values from table 23.7. These are the results for the results for the solutions that your group tested. 14. Record your mean values from table 23.7. These are the results for the results for the solutions that your group tested. 15. Record your mean values from table 23.7. These are the results for the results for the solutions that your group tested. 14. Record your mean values from table 23.7. These are the results for the results for the solutions that your group tested. 15. Record your mean values from table 23.7. These are the results for the results for the solutions that your group tested. 15. Record your mean values from table 23.7. These are the results for the results for the solutions that your group tested. 15. Record your mean values from table 23.7. These are the results for the results for the solutions that your group tested. 15. Record your mean values from table 23.7. These are the results for the results for the solutions that your group tested. 15. Record your mean values from table 23.7. These are the results for the results for the solutions that your group tested. 16. Record your mean values from table 23.7. These are the results for the results for the solutions that your group tested. 16. Record your mean values from table 23.7. These are the results for the resoluts for the results for the results for
the results for tested by the other groups. 14. Compare the number and length of roots on treated bulbs with those of controls. Question 8 a. Why did each group need to run controls, rather than one set of controls for everyone? INQUIRY-BASED LEARNING Using the Allium Test to Detect Variation in Water Quality Observations: The presence and concentration of biologically active compounds can be measured directly or by their indirect effect on a quantifiable biological process, such as a bioassay. Root production by Allium is sensitive to a variety of compounds that humans introduce each year into our environment is immense. Question: How does root growth by Allium respond to environmental contaminants? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 23 from your instructor. b. Discuss with your group and instructor. b. Discuss with your group and instructor. a testable hypothesis and record it. d. Review the Allium Test procedure 23.6. Then outline on Worksheet 23 your experimental design and supplies needed to test your hypothesis. You may choose to use a bioassay other than the Allium Test. Ask your instructor to review your procedures, record your data, answer your question, and make relevant comments. f. Discuss with your instructor any revisions to your questions, hypotheses, or procedures. Repeat your work as needed. Pollution – 249 Work in small groups to assess algal pollution in the water samples Filter Filter support Filter base Vacuum attachment Receiving flask Figure 23.5 Diagram of filtration apparatus used to collect organisms from a water sample. b. The Allium Test is a common test in environmental science. What are some disadvantages to this test? c. The Allium Test for thermal pollution may show that higher temperatures accelerate growth. Is this bad? Why or why not? 1. Dip a filter base and funnel (fig. 23.5) into 70% ethanol for 1 min. Shake off the excess alcohol and let the apparatus air dry. 2. Use sterilized forceps to place a filter base. Screw the funnel onto the support (fig. 23.5) so that the filter is held securely in place. 3. Add 200 mL of the water sample to the funnel. If the water sample is heavily polluted, decrease the sample to 100, 50, or 25 mL. 4. Use a hand vacuum pump or water aspirator (fig. 23.6) to evacuate the receiving flask. Algae will be trapped on the filter. 5. Remove and dry the filter in an oven at 45°C for 8 min (or overnight at room temperature). 6. Float the dried filter on approximately 5 mL of immersion oil in a small petri dish. The dry filter will become transparent in the oil. If the filter remains opaque after a few minutes, place the petri dish on a warm surface until the filter remains opaque after a few minutes. place all of these pieces of filter on one clean microscope slide. 9. Use a dissecting microscope to examine the filter. 10. Count the algae in each of 10 randomly selected fields of view and record the number in the following table: No. of Algae in Each Field of View Field 1 2 3 4 5 6 7 8 9 10 Total Number of Algae 11. Use the following formula to calculate the total number of algae on your filter: ALGAL POLLUTION OF WATER SUPPLIES Growing human populations have created great demands on groundwater supplies. To circumvent these demands, many areas have started using surface water usually contains large amounts of algae, surface water needs. Unlike groundwater, which is usually free of algae, surface water usually contains large amounts of algae that produce toxins (Anabaena). and form mats covering a lake or reservoir (Oscillatoria, Spirogyra). 250 EXERCISE 23 Total no. of algae on filter = total n of the 47-mm filter that you used to collect the algae. 23-8 (a) (b) Figure 23.6 Vacuum filtration of samples. Area of field of view = d. In what ways might they harm other organisms? 12. Use the following formula to calculate the number of algae per milliliter of sample: No. of algae mL-1 = No. of algae mL-1 no. of algae on filter volume of sample (mL) = lgal populations exceeding 1000 organisms mL-1 A indicate that the water is over-enriched by sewage or other nutrients. Question 9 a. How many algae per milliliter are in your water sample? b. Is your sample polluted? c. In what ways might these algae benefit other organisms in the water? 23-9 e. Suppose you are responsible for "cleaning up" a lake polluted with algae. What would you do, and why? BIOREMEDIATION Bioremediation is the use of living organisms (usually microbes) to remove pollutants from an environment. For example, bacteria that metabolize hydrocarbons are often used to minimize the impact of oil spills. Similarly, several bacteria have been genetically engineered (Exercise 16) to metabolize ionic mercury and other dangerous chemicals from nuclear waste. Question 10 Bacteria that remove dangerous chemicals have an obvious value for remedying pollution. Are there any drawbacks or limitations of bioremediation? If so, what are they? Pollution 251 Questions for Further Study and Inquiry 1. What causes pollution? 2. Is all pollution? 2. Is all pollution? 3. What are the consequences of using water from ponds and rivers to cool industrial processes? What are the consequences of stopping the thermal pollution (forcing an industry to stop releasing the heated water)? 5. Polluting lakes with laundry water and sewage often produces an algal "bloom." Why don't populations of predators (i.e., zooplankton and fish) increase to offset this bloom and keep the algal population in check? 6. Diseases such as typhoid fever (caused by Salmonella typhosa) and dysentery are often associated with lakes polluted by sewage. Suppose that you live near a large lake in which sewage is dumped and that as a local health official you are in charge of reducing the incidence of typhoid in your area. How would you do this, assuming that you had the complete cooperation of city and other local officials? How would you do this if you couldn't prevent sewage from being dumped in the lake? What would be the consequences of your actions? 7. Define pollution. Can something be a pollutant in some situations but not in others? Explain your answer. 8. Does pollution always result from the demands of expanding populations? Why or why not? DOING BIOLOGY YOURSELF Design your own assay similar in concept to the Allium Test. Use a living plant and test potential pollutants of your choice. 252 EXERCISE 23 WRITING TO LEARN BIOLOGY Rachel Carson devoted much of her life to studying how organisms are affected by pollution. Her masterpiece, Silent Spring, raised public awareness of pollution and made the word ecology a household word. Go to the library and read an article about this remarkable woman. What was her message, and why is it still important? 23-10 E XER CISE Survey of Prokaryotes Domains Archaea and Bacteria 24 Learning Objectives By the end of this exercise you should be able to: 1. Describe distinguishing features of members of kingdoms Archaebacteria and Bacteria. 2. Describe the major differences between bacteria, and cyanobacteria. 3. Identify representative examples of archaebacteria, and cyanobacteria. 4. Perform a Gram stain. Please visit connect.mheducation.com to review online resources tailored to this lab. C ellular organisms have evolved along two lines. Species with cells lacking membrane-bound organelles are prokaryotes (tab. 24.1). Those with membrane-bound organelles are eukaryotes and include plants, animals, fungi, and protists. About 5000 species of prokaryotes have been described, and many more await identification and d escription Prokaryotes were long thought to be a unified group commonly called bacteria. However, genetic analysis as recently as 1996 of the DNA of prokaryotes. This new information has led to recognition of three domains of organisms (fig. 24.1). Domain Archaebacteria, which are all prokaryotes and the most abundant organisms on Earth (fig. 24.2). Domain Eukarya includes kingdom Bacteria, which are all prokaryotes and the most abundant organisms on Earth (fig. 24.2). kingdoms Fungi, Plantae, Animalia, and the polyphyletic (multiple origins) protists (see Exercise 25 for the current status of protistan classification). All of the kingdoms in domain Eukarya are eukaryotes and are d escribed in Exercises 25-31 and 36-40. This classification). accepted, but much phylogenetic information remains to be revealed. Classification is an exciting and ongoing process. KINGDOM ARCHAEBACTERIA Archaebacteria independently. 24-1 Archaebacteria are diverse prokaryotes that share ribosomal RNA sequences as well as several important biochemical characteristics quite distinctive from those of all other types of organisms. Archaebacteria have distinctive from those of all other types of organisms. Today's Archaebacteria are probably survivors of ancient lines that have persisted in habitats similar to those present when bacteria are called extremophiles. Many Archaebacteria can live in an anaerobic atmosphere rich in carbon dioxide and hydrogen as well as the more benign environments typical of bacteria and eukaryotes. See Exercise 16 for a procedure describing Halobacterium salinarum, a common archaebacterium that inhabits salty environments. KINGDOM BACTERIA Bacteria of kingdom Bacteria of kingdom Bacteria of kingdom Bacteria of kingdom Bacteria and eukaryotes. are microscopic (1 µm or less in diameter, figs. 24.2 and 24.3); a single gram of soil may contain over a billion bacteria. Bacteria have cell walls, which give them three characteristic shapes (fig. 24.4). molecules made by other organisms. Survey of Prokaryotes are basically single-celled. Even though some bacteria may adhere together or form filaments, their cytoplasm is not directly interconnected, and their activities are not as integrated and coordinated as cells of multicellular eukaryotic cells are 1-10 micrometers in diameter, while most eukaryotic cells are over 10 times that size. Kingdom Fungi ©BSIP
SA/Alamy Stock Photo Internal Compartmentalization. Unlike eukaryotic cells, bacterial cells contain little internal compartmentalization, no internal membrane systems such as Golgi or ER, and no cell nucleus. Domain Eukaryotic cell Kingdom Animalia Bacterial cell Chromosomes. Prokaryotic cells divide by binary fission. The cells pinch in two. In eukaryotes, microtubules pull chromosomes to opposite poles during the cell division process, called mitosis. Kingdom Plantae Example Bacterial genome Binary fission in bacteria Flagella are simple, composed of a single fiber of protein that spins like a propeller. back and forth, rather than rotating. Metabolic Diversity. Prokaryotes possess many metabolic abilities not found among eukaryotes; some prokaryotes can perform several different kinds of anaerobic and aerobic photos Eukaryotic cell Eukaryotic chromosomes Mitosis in eukaryotes Bacterial cell Simple bacterial flagellum Protists Domain Archaea Kingdom Archaeas; (b) ©Don Farrall/Getty Images; (c) ©Taiga/123RF; (d) ©Ro-ma Stock Photography/Getty Images; (e) ©Science Photography/Getty Images; (b) ©Don Farrall/Getty Images; (c) ©Caiga/123RF; (d) ©Ro-ma Stock Photography/Getty Images; (c) ©Caiga/123RF; (d) ©Ro-ma Stock Photography/Getty Images; (c) ©Science Photography/Getty Images; (c) ©Caiga/123RF; (d) ©Ro-ma Stock Photography/Getty Images; (c) ©Science Photography/Getty Images; (c) ©Caiga/123RF; (d) ©Ro-ma Stock Photography/Getty Images; (c) ©Science Library/Alamy Stock Photo; (f) ©Russell Illig/Getty Images; (g) ©Corbis Super RF/Alamy Stock Photo; (h) ©Flirt/Alamy Stock Photo; (h) ©Gerd Guenther/Science Source; (h) ©Corbis Super RF/Alamy Stock Photo; (h) ©Wolfgang Baumeister/Science Source; (o) ©McGraw-Hill Education/Don Rubbelke, photographer; (p) ©Alfred Pasieka/ Science Source Figure 24.1 The diversity of life. Biologists categorize all liv- ing things into three kingdoms: Plantae Fungi, and Animalia. Heterotrophic bacteria are decomposers such as bacteria release nutrients? © BiologyImaging.com Some prokaryotes, such as Rivularia, can fix nitrogen from the atmosphere. 24-2 Ribosome site of protein synthesis Inclusion body: stored nutrients for later use Mesosome: plasma membrane that folds into the surfaces Conjugation pilus: elongated, hollow appendage used for DNA transfer to other bacterial cells Nucleoid: location of the bacterial chromosome Plasma membrane: sheath around cytoplasm that regulates entrance and exit of molecules Cell wall: if compact, called a slime layer Flagellum: rotating filament present in some bacteria that pushes the cell forward Escherichia coli © Sercomi/Science Source Figure 24.2 The structure of a bacterial cell. ©Dr. Tony Brain and David Parker/ (a) (b) (c) (d) Science Source Photo Library/Science Source Photo L 24.3 Four views of a contaminated pin, which would seem an unlikely site for bacteria to grow. (a) The tip of the pin, magnifications—(b) 35×, (c) 178×, and (d) 4375×—you see rod-shaped bacteria growing there. 24-3 Survey of Prokaryotes 255 ©BSIP SA/Alamy Stock Photo ©BSIP/UIG/Getty Images (a) (b) (c) ©Michael Abbey/Science Source Figure 24.4 The three basic shapes of bacteria: (a) bacillus (Pseudomonas); (b) coccus (Streptococcus); and (c) spirillan, 400×. 1. Attachment of chromosome cell wall plasma membrane cytoplasm 2. The cell is preparing for binary fission by enlarging its cell wall, plasma membrane, and overall volume. 3. DNA replication produces two identical chromosomes. Cell wall and plasma membrane, and overall volume. 3. DNA replication produces two identical chromosomes are pulled apart. Cytoplasm is being distributed evenly. 200 nm © Barry Dowsett & Jeremy Burgess/ Science Photo Library/Corbis 5. New cell wall and plasma membrane divide the daughter cells. Figure 24.5 Binary Fission First, DNA replicates, and as the cell lengthens, the two chromosomes separate, and the cells divide. The two chromosomes separate, and the cells divide. at the site of cell separation. This protein is similar to that forming the mitotic spindle of eukaryotes. 256 EXERCISE 24 24-4 Table 24.2 Important Bacterial Diseases That Affect Humans Disease Pathogen Vector/Reservoir Epidemiology Anthrax Bacillus anthracis Animals, including processed skins Bacterial infection that can be transmitted through contact or ingested. Rare except in sporadic outbreaks. May be fatal. Botulism Clostridium botulinum Improperly prepared food Contracted through ingestion or contact with wound. Produces acute toxic poison; can be fatal. Chlamydia trachomatis Humans, Sexually Transmitted Infection Urogenital infections with possible spread to eyes and respiratory tract. Occurs worldwide; increasingly common over past 30 years. Cholera Human feces, plankton Causes severe diarrhea that can lead to death by dehydration; 50% peak mortality if the disease goes untreated. A major killer in times of crowding and poor sanitation; over 100,000 died in Rwanda in 1994 during a cholera outbreak. Dental caries (tooth decay) Streptococcus Humans A dense collection of this bacteria on the surface of teeth leads to secretion of acids that destroy minerals in tooth enamel—sugar alone will not cause cavities. fatal. Hansen's disease (leprosy) Mycobacterium leprae Humans, feral armadillos Chronic infected tick. Lesion followed by bite of infected tick. Lesion followed by malaise, fever, fatigue, pain, stiff neck, and headache. Peptic ulcers Helicobacter pylori Humans Infects the stomach, where it causes ulcers. About 40% of the world's population harbors H. pylori, he got an ulcer. Plague Yersinia pestis Fleas of wild rodents: rats and squirrels Killed 1/4 of the population of Europe in the 14th century; endemic in wild rodent populations of the lungs, often fatal without treatment Tuberculosis Humans An acute bacterial infection of the lungs, often fatal without treatment Tuberculosis Humans Andre acute bacterial infection of the lungs, often fatal without treatment Tuberculosis Humans Andre acute bacterial infection of the lungs, often fatal without treatment Tuberculosis Humans Andre acute bacterial infection of the lungs, often fatal without treatment Tuberculosis Humans Andre acute bacterial infection of the lungs, often fatal without treatment Tuberculosis Humans Andre acute bacterial infection of the lungs, often fatal without treatment Tuberculosis Humans Andre acute bacterial infection of the lungs, often fatal without treatment Tuberculosis Humans Andre acute bacterial infection of the lungs, often fatal without treatment Tuberculosis Humans Andre acute bacterial infection of the lungs, often fatal without treatment Tuberculosis Humans Andre acute bacterial infection of the lungs, often fatal without treatment Tuberculosis Humans Andre acute bacterial infection of the lungs, often fatal without treatment Tuberculosis Humans Andre acute bacterial infection of the lungs, often fatal without treatment Tuberculosis Humans Andre acute bacterial infection of the lungs, often fatal without treatment Humans Andre acute bacterial infection of the lungs, often fatal without treatment Humans Andre acute bacterial infection of the lungs, often fatal without treatment Humans Andre acute bacterial infection of the lungs, often fatal without treatment Humans Andre acute bacterial infection of the lungs, often fatal without treatment Humans Andre acute bacterial infection of the lungs, often fatal without treatment humans Andre acute bacterial infection of the lungs, often fatal without treatment humans Andre acute bacterial infection of the lungs, often fatal without treatment humans Andre acute bacterial infection of the lungs, often fatal withou lymph, and meninges. Its incidence is on the rise, complicated by the development of new strains of the bacteria that are resistant to antibiotics. Typhus has a peak untreated mortality rate of 70%. b. What term best describes heterotrophic bacteria that feed on living tissue? Bacteria that derive their energy from photosynthesis or the oxidation of inorganic molecules are autotrophic. However, photosynthesis in bacteria that derive their energy from photosynthesis or the oxidation of inorganic molecules are autotrophic. is sometimes produced as a by-product. A laboratory culture of bacteria usually consists of a tube of liquid nutrients (broth) containing growing on 24-5 the surface.1 The jellylike agar is melted, mixed with nutrients, and poured into tubes or plates to solidify. Many species of bacteria can be cultured in nutrient broth or on a layer of nutrient-rich agar. It may surprise you to know that most species of bacteria are not culturable in vitro. We just don't know enough about the nutrient and environmental requirements of these bacteria are not culturable in vitro. replicates and the cell pinches in half without the nuclear and chromosomal events associated with mitosis (see Exercise 14) (fig. 24.5). Some bacterium is transferred to another bacterium and a new set of genes is assembled. 1 Agar is a gelatinous polysaccharide used in culture media for microbiology labs. You'll learn more about agar and the red algae it comes from in Exercise 25. Survey of Prokaryotes 257 Acidic polysaccharides Thick peptidoglycan layer Lipopolysaccharides thick peptidoglycan layer Lipopolysaccharides and the red algae it comes from in Exercise 25. Survey of Prokaryotes 257 Acidic polysaccharides Thick peptidoglycan layer Lipopolysaccharides and the red algae it comes from in Exercise 25. Survey of Prokaryotes 257 Acidic polysaccharides and the red algae it comes from in Exercise 25. Survey of Prokaryotes 257 Acidic polysaccharides and the red algae it comes from in Exercise 25. Survey of Prokaryotes 257 Acidic polysaccharides and the red algae it comes from in Exercise 250. Survey of Prokaryotes 257 Acidic polysaccharides and the red algae it comes from in Exercise 250. Survey of Prokaryotes 257 Acidic polysaccharides and the red algae it comes from in Exercise 250. Survey of
Prokaryotes 257 Acidic polysaccharides and the red algae it comes from in Exercise 250. Survey of Prokaryotes 257 Acidic polysaccharides and the red algae it comes from in Exercise 250. Survey of Prokaryotes 250. Survey of Prokaryotes 250. Survey of Prokaryotes 257 Acidic polysaccharides and the red algae it comes from in Exercise 250. Survey of Prokaryotes 257 Acidic polysaccharides and the red algae it comes from in Exercise 250. Survey of Prokaryotes 257 Acidic polysaccharides and the red algae it comes from in Exercise 250. Survey of Prokaryotes 257 Acidic polysaccharides and the red algae it comes from in Exercise 250. Survey of Prokaryotes 257 Acidic polysaccharides and the red algae it comes from in Exercise 250. Survey of Prokaryotes 257 Acidic polysaccharides and the red algae it comes from in Exercise 257 Acidic polysaccharides and the red algae it comes from in Exercise 257 Acidic polysaccharides and the red algae it comes from in Exercise 257 Acidic polysaccharides and the red algae it comes from in Exercise 257 Acidic polysaccharides and the red alga peptidoglycan cell wall layer, no outer envelope (b) Gram-negative: thinner peptidoglycan cell walls of Gram-positive bacteria. (a) Cell walls of Gram-positive bacteria have a thick peptidoglycan layer. (b) Cell walls of Gram-negative bacteria have an outer envelope of lipopolysaccharides. Gram stains don't stick to this outer envelope. Some bacteria are pathogenic (table 24.2); that is, they cause diseases such as pneumonia and tuberculosis. However, most bacteria are harmless to humans. Indeed, many beneficial bacteria live in and on your body Nevertheless, you should handle all bacterial cultures with care. The preparation of wet mounts of bacterial cultures requires proper use of a transfer loop and sterilizing flame. Your instructor will demonstrate this aseptic technique. aware of safety issues. In the space below, briefly list the safety issues associated with today's procedures. If you have questions about these issues, contact your laboratory assistant before starting work. Procedure 24.1 Culture common bacteria 1. Obtain a sterile cotton swab and a closed petri dish containing sterile nutrient agar. 2. Open these issues, contact your laboratory assistant before starting work. packaged swab and drag the tip over a surface such as your teeth, face, or tabletop. 3. Open the petri dish and drag the exposed swab over the surface of the agar in the manner demonstrated by your instructor. 4. Close the lid and tape it shut. Label the dish with a wax pencil. 5. Turn the dish upside down and place it in the incubator or in a warm area. 258 EXERCISE 24 6. After 24-48 h examine the agar for bacterial growth. Record your observations. Question 2 What are the shape and size of each bacterial colony? Gram Stain One of the most important techniques to classify bacterial is the Gram stain, based on the different structural and chemical compositions of bacterial cell walls (fig. 24.6). Gram staining is important because it often correlates with the sensitivity of a bacteria (e.g., Escherichia coli, Serratia) bacteria have a much thinner cell wall that does not retain the dye. During the Gram stain technique, crystal violet and iodine are applied to stain all of the bacteria purple. Then alcohol is used to remove the stain from the stain. Finally, safranin is used to counterstain the Gram-negative cells with a red color contrasting with purple Gram-positive cells (fig. 24.7). In the following procedure, you will Gram-positive 2. Gram-positive and Gram-positive organisms. 24-6 1. Crystal violet is applied. Gram-negative Both cell walls affix the dye. Gram-positive Crystal violet is applied. Gram-positive and 3. Alcohol wash is applied. 4. Safranin (red dye) is applied. Gram-positive Gram-negative peptidoglycan (PG) layer encasing Gram-positive bacteria traps crystal violet dye, so the bacteria appear purple in a Gram-stained smear (named after Hans Christian Gram, Danish bacteriologist, 1853-1938, who developed the technique). Because Gram-negative bacteria have an outer envelope covering their thin peptidoglycan layer, they do not retain the crystal violet dye. A red counterstain (usually a safranin dye) is applied to emphasize contrast with the purple Gram-positive cells. (b) A micrograph showing the results of a Gram stain with both Gram-negative cells. (b) 10 µm © De Agostini Picture Library/Getty Images Procedure 24.2 Observe stained bacteria with oil immersion magnification 1. Obtain a microscope and a small bottle of immersion oil. Recall from Exercise 3 that the resolving power of a lens depends, among other things, on the amount of light that it gathers. More light improves resolution, and light is scattered when it passes through air. If a drop of immersion oil, a fluid with the same refractive index (ability to bend light) as glass, is placed between the objective lens and the specimen, then the lens can gather more light. 2. Examine the microscope is equipped with an oil-immersion objective. This objective can resolve micrometer-sized particles such as bacteria. 3. Rotate the low-power objective into observation position. 4. Obtain some prepared slides of stained bacteria from your instructor. These may be commercially prepared slides or slides or slides with bacteria that your instructor. These may be commercially prepared slides or slides with bacteria that your microscope. 24-7 5. Place a slide on the stage with the specimen centered over the light path through the hole in the stage. 6. While watching from the side, slowly rotate the low-power objective as close as possible to the slide without the objective touching the slide. Adjust the diaphragm for medium light-intensity. 7. Look through the oculars and slowly adjust the coarse adjustment to increase the working distance. Stop when you see the color of the stained bacteria and are roughly focused on the smear of bacteria. 8. Improve the illumination and sharpen the image as much as possible with the fine-adjustment knob. At this low magnification you will only see small dots, at best. 9. Rotate a higher-power objective into position and refocus. 10. Rotate the nosepiece so that the alignment is halfway between the oil-immersion objective and the next lowest-power objective. There should not be an objective in correct position for observation. This position will allow you to place a drop of oil on the slide. Survey of Prokaryotes 259 11. Put one drop of immersion oil on the coverslip directly over the spot of the light path. Do not touch the dropper to the slide or it will contaminate the oil when the dropper is returned to the bottle. 12. Rotate the oil-immersion lens directly into observation position and directly into the drop of oil. 13. While looking from the side, use the fine-adjustment knob to lower the objective until it gently touches the coverslip. 14. Look through the oculars and slowly rotate the fineadjustment knob to increase the working distance. This rotation should be counterclockwise. Stop when the stained bacterial color appears. Slowly rotate the fineadjustment knob back and forth until the bacteria are in focus. 15. Improve your resolution by adjusting the diaphragm. 16. Examine the sizes, shapes, and stains of the bacteria on the slide. 17. Repeat this entire procedure for each of the slides offered by your instructor. 18. When you finish your work, clean the oil from the slides and objectives with the lens paper provided. Procedure 24.3 Use known bacterial cultures to prepare and observe a Gram stain 1. Obtain a slide, coverslip, transfer loop, alcohol burner, and a culture of living bacteria. 2. Available cultures should include the following bacteria, among others: Bacillus megaterium—a large bacteria. Staphylococcus epidermidis—a coccus found among the normal flora of skin. 3. Apply a loop of bacteria to a drop of water on a slide. If your cultures are in liquid broth, then add one drop of culture medium to your slide. Your instructor will demonstrate how to use sterile technique to open, sample, and close the culture of bacteria. Do not add a coverslip to the slide 4. Heat the slide gently by holding it with a clothespin and passing it over the top of a flame three to four times. Drying time is critical to success. Check with your instructor to avoid heating the slide too little or too much. Be careful not to break the slide. If hot plates are available, hold the slide to the hot surface for 10 sec. This heat will adhere the bacteria to the slide. 260 EXERCISE 24 Be careful not to inhale or spill on your skin crystal violet for 20 sec. 6. Rinse the slide for 2 sec. 8. Rinse the sec with a gentle but steady stream of water from a squirt bottle. 7. Gently drench the bacterial smear with drops of iodine for 1 min. 8. Drop 95% alcohol (decolorizer) on the smear with an eyedropper until no purple shows in the alcohol coming off the slide. Quickly rinse the slide with water to remove the alcohol. 9. Gently drench the bacterial smear with drops of safranin for 20 sec. 10. Gently rinse the slide, or blot gently if necessary. Add a coverslip. 11. Observe the smear with your microscope using low power and/or the oil-immersion. 12. Determine if the bacteria are Gram positive or Gram negative. 13. Repeat the Gram stain procedure using other known bacteria that you obtain from culture tubes. 14. Record your observations in table 24.3. Procedure 24.4 Use a Gram stain to observe living bacteria from your teeth 1. Obtain a slide, coverslip, transfer loop, and alcohol burner. 2. Use the wide end of a toothpick to scrape your teeth near the gum line. 3. Thoroughly mix what's on the tip of the toothpick in a small drop of water on a microscope slide. 4. Allow this bacterial smear to dry. 5. Repeat steps 4–13 of procedure 24.3. Question 3 a. Which type of bacteria is most prevalent in the sample from your teeth? 24–8 Deadly Food! Beware! The bacterium Clostridium botulinum can grow
in food products and produces a toxin called botulinum, the most toxic substance known. Microbiologists estimate that 1 gram of this toxin can kill 14 million adults! The good news is that C. botulinum is extremely tolerant to stress; it can withstand boiling water (100°C) for short periods, but is killed at 120°C in 5 min. This tolerance makes C. botulinum a serious concern when people can vegetables. If home canning is not done properly, this bacterium will grow in the anaerobic conditions of the sealed container and be extremely poisonous. Several adults and infants die every year from botulism in the United States. Tolerance to stress is enhanced in C. botulinum and many other bacteria by the formation of the surrounding cytoplasm. These highly resistant endospores (fig. 24.8) may later germinate and grow after decades or even centuries of inactivity. The endospores of Clostridium botulinum can germinate in poorly prepared canned goods, so never eat food from a swollen (gas-filled) can of food; you risk contracting botulism leading to nerve paralysis, severe vomiting, and death. ©PTP/Phototake Figure 24.8 Endospores. The round orange circle in the upper cell is an endospore forming within a cell of Clostridium botulinum, the bacterium to survive in improperly sterilized canned and bottled foods. Table 24.3 The Relative Size and Shape of Some Common Bacteria Bacterial Species Gram Stain (+/-) Relative Size Shape b. Is Bacillus megaterium Gram positive or Gram negative? How do you know? colony growing on the surface of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics dependence of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics depending on the surface of nutrient agar often has distinctive characteristics dependence of nutrient agar often has distinctive characteristics dependence of nutrient agar often has distinctive characteristics dependence of nutrient agar often has distincteristics dependence of nutrient agar often has distincted has distincted has distincteristics dependence of nutrient common features of bacterial colony morphology. Bacterial Colony Morphology Procedure 24.5 Evaluate the colony morphology A bacterial colony is a visible speck or patch of millions of 4-6 bacterial species provided by your instructor for your evaluation. 24-9 of bacterial species Survey of Prokaryotes 261 Circular Pinpoint Irregular and Spreading Filamentous Convex Umbonate MARGINS ELEVATIONS Figure 24.9 Colony characteristics. Colonies are classified by form, margin, and elevation as well as color and diameter. 2. Familiarize yourself with the colony morphologies shown in figure 24.9. 3. Use a stereomicroscope or hand lens to evaluate a representative colony on each of the plates. Record your observations in table 24.4. 4. When you have completed your analysis, your instructor will provide the species names associated with each of the plates and the accepted colony descriptions for that species. Use this information to evaluate the accuracy of your observations. Table 24.4 An Evaluation of Bacterial Colony Morphology Plate ID Species Colony Diameter (mm) Color Form Elevation Margin A B C D E F 262 EXERCISE 24 24-10 Nitrogen Fixation by Bacteria Certain bacteria and cyanobacteria transform atmospheric nitrogen (N2) into other nitrogen as a component of their nucleic acids, proteins, and amino acids. However, chemical reactions capable of breaking the strong triple bond between atoms of atmospheric nitrogen are limited to certain bacteria and cyanobacteria. This process uses an enzyme called nitrogenase along with ATP, energized electrons, and water to convert N2 to ammonia (NH3). Ammonia can be absorbed by plants and used to make proteins and other macromolecules. Rhizobium is a bacterium that can fix nitrogen and can grow intimately with roots of some plants called legumes (e.g., clover, alfalfa, and soybeans). Such associations between Rhizobium and host roots form nodules on the roots (fig. 24.10). These resident nitrogen fixers provide ammonia to the plant provides sugars and other nutrients to the bacteria. Procedure 24.6 Observe root nodules 1. Observe the root systems on display and note the nodules. 2. Examine a prepared slide of a cross section of a nodule. Question 4 a. Where are the bacteria? Are they between cells or inside cells? b. Why is this relationship between a plant and bacterium called a mutualism? c. How does Rhizobium benefit from this association? d. How does the host plant benefit from the association? Bacterial Sensitivity to Inhibitors such as antibiotics than is growth of other species. For example, an antibiotic may be more effective against Staphylococcus than against Streptococcus. This is important information to a physician who must select one of many available antibiotics to treat a bacterial infection. To determine the most effective against Staphylococcus than against Streptococcus. petri dish of solid medium that has been uniformly inoculated on its entire surface with a known bacterium or an unknown sample from an infected patient. After inoculation, four to eight small paper disks—each soaked in a different antibiotic will produce a visible halo of clear surface around the disks where it inhibited growth of the bacteria (fig. 24.11). If the antibiotic was ineffective, the bacterial agent Zone of inhibition Bacterial growth Disk with ineffective antibacterial agent © McGraw Hill Education/Lisa Burgess, photographer Figure 24.11 A sensitivity plate is used to determine the effective antibiotics, each of which is on the surface of a paper disk. Any disk containing an effective antibiotics, each of which is on the disk You've probably seen television commercials for products such as mouthwash or disinfectant that "kills germs on contact." Many of these products are developed and tested using sensitivity plates. The mouthwash is effective if no bacteria grow around a paper disk soaked in the mouthwash. Procedure 24.7 Examine sensitivity plates 2. Examine each plate, note the bacterial growth strongly, weakly, or not at all. 4. Record the bacterial growth strongly, weakly, or not Inhibition of Four Bacterial Species by Various Growth Inhibitors Antibiotic/Antiseptic Plate 2 Plate 2 Plate 2 Plate 2 Plate 3 Plate 4 24-12 Question 5 Based on their appearance, which drugs or chemicals inhibit the growth of bacteria? Cyanobacteria (Blue-Green Algae) Cyanobacteria are a major group of photosynthetic bacteria that grow in many environments. Most cyanobacteria are free-living, whereas others live symbiotically with plants and other organisms. Cyanobacteria are photosynthetic, and their
pigments include chlorophyll a and the accessory pigments phycocyanin (blue) and the accessory pigments phycocyanin (blue) and phyco cyanobacteria are blue-green in color; other cyanobacteria range in color from brown to olive green. Cyanobacteria reproduce by fission and are often surrounded by a jellylike sheath. Because cyanobacteria reproduce by fission and are often surrounded by a jellylike sheath. tastes, colors, and odors in water. Procedure 24.8 Examine cyanobacteria (a) © Sinclair Stamers/Science source Vegetative cells Heterocysts 1. With your microscope, examine living material and prepared slides of Oscillatoria (fig. 24.12a). Oscillatoria (fig. 24.12a). appear similar? (b) 2. Examine living material and a prepared slide of Anabaena or Nostoc (commonly called witch's butter or starjelly) (fig. 24.12b). Filaments of these cyanobacteria consist of small grapelike colonies. Trichomes of N ostoc consist of small grapelike colonies. Examine a wet mount of living Gloeocapsa, characterized by a thick, gelatinous sheath (fig. 24.12c). 4. Add a drop of dilute India ink to the slide of Gloeocapsa forms clusters of cells and therefore has a colonial body form. Locate one of these colonies. 5. Add a drop of methylene blue to a fresh slide of Gloeocapsa and determine if it enhances your observation more than does India ink. 24-13 © BiologyImaging.com Gelatinous matrix Vegetative cells (c) © Michael Abbey/Science Source Figure 24.12 Cyanobacteria. (a) Oscillatoria (200×); (b) Nostoc (400×); and (c) Gloeocapsa (400×). Survey of Prokaryotes 265 non sheath? 6. Examine some living Merismopedia, which also form colonies. Sketch these cyanobacteria in the following space. b. What do you suppose is the function of the sheath? Question 8 a. How is the shape of Merismopedia different from other cyanobacteria you studied in this exercise? c. Do Juestion / a. Do adiacent cells snare a com clusters of Gloeocapsa represent multicellular organisms? Why or why not? b. How would a colony attain this shape? d. What is the best stain for Gloeocapsa, India ink or methylene blue? INQUIRY-BASED LEARNING Do we reach every microenvironment with our household disinfectants? Observations: Bacteria grow virtually everywhere. Some common household products effectively inhibit bacterial growth on floors and tabletops but may leave behind resistant species. Some microenvironments, however, are not exposed to the selection pressure of disinfectants especially well? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 24 from your instructor. b. Discuss with your group a well-defined question on Worksheet 24. 266 EXERCISE 24 c. Translate your question into a testable hypothesis and record it. d. Review the discussion of sensitivity plates and procedure 24.7. Outline on Worksheet 24 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your proposed investigation. e. Conduct your procedures, record your data, answer your question, and make relevant comments. f. Discuss with your instructor any revisions to your questions, hypotheses, or procedures. Repeat your work as needed. 24-14 Questions for Further Study and Inquiry 1. What is meant by Gram positive? Explain the mechanism of Gram-positive? Explain the mechanism of Gram-positive? Explain the mechanism of Gram-positive? 5. How do antibiotics kill bacteria? Why do they not affect viruses? 6. How could bacteria become resistant to an antibiotic? 24-15 Survey of Prokaryotes 267 7. Antibiotic resistance is promoted by overprescription of antibiotic? 24-15 Survey of Prokaryotes 267 7. Antibiotic resistance is promoted by overprescription of antibiotic? 24-15 Survey of Prokaryotes 267 7. Antibiotic? 24-15 Survey of Prokaryotes 26 two nutrient agar plates. Touch and drag the tip of your finger on the agar surface of one plate. Wash your hand and repeat the procedure on the other plates for 24-48 h. Then compare colony appearances and number. What can you conclude about the presence and diversity of bacteria on your plates? Is the appearance of a colony a good way to distinguish species of bacteria? Why or why not? DOING BIOLOGY YOURSELF Doorknobs, sinks, tables, and so on are often laden with bacteria. WRITING TO LEARN BIOLOGY There is a great diversity of roles in a typical ecosystem, some shared by a variety of organisms. What ecological roles are performed by cyanobacteria? 268 EXERCISE 24 24-16 E XER CISE 25 Survey of Protists The Algae Learning Objectives By the end of this exercise you should be able to: 1. Discuss the distinguishing features of different groups of algae. 2. Appreciate the economic importance of algae. 3. Outline the events of "alternation of generations" in green algae. Please visit connect.mheducation.com to review online resources tailored to this lab. T his exercise begins your study of domain Eukarva. Eukarvotes are organisms composed of cells having membrane-bound nuclei. This domain is commonly divided into three well-defined kingdoms—Fungi, Animalia, Plantae—along with a group of organisms with diverse origins called protists. In a sense, protists live in moist habitats and include simple eukaryotes such as amoebas, as well as multicellular organisms such as the brown alga, kelp. Fungi have cell walls and are heterotrophic. Heterotrophic organisms feed on organic matter produced by other organisms feed on organic matter produced by other organisms. Animals are ingestive-feeding heterotrophs that lack cell walls and can respond rapidly to external stimuli. Animals are multicellular. Plants are multicellular, autotrophic organic substances using external energy, usually sunlight. Protists share two common characteristics: They are most abundant in moist habitats, and most of them are microscopic in size. But diversity of protists is immense (fig. 25.1). Despite shared features, modern phylogenetic analysis of DNA sequences and cellular features, modern phylogenetic analysis of DNA sequences and cellular features reveal that protists are not a well-defined, monophyletic group. Protists probably share common ancestry with fungi, plants, and animals. The diversity of protists clearly makes understanding their phylogeny and taxonomy a challenge. Currently, we classify protists into several eukaryotic supergroups that each displays distinctive features and represents 25-1 a separate evolutionary lineage. Notice that one supergroup, Archaeplastida, includes a lineage giving rise to land plants (table 25.1). Review information in your textbook for a more thorough examination of the phylogenetic relationships among protists. Protists presented in this exercise and funguslike protists (typically autotrophs) and protozoa and funguslike protists (typically autotrophs). heterotrophs). You will study algae in this exercise and protozoa and slime molds in the next exercise. The term algae (Latin for "seaweeds") applies to about 10 groups of protists that are predominantly photosynthetic species. Despite the common feature of photosynthetic species. ancestor. They are polyphyletic (i.e., they have more than one common ancestor), and the details of their phylogenies are still being discovered. INTRODUCTION TO ALGAE One way to determine the importance of something is to remove it and see what happens. If we did that with algae, most people would be shocked by the result. Global oxygen production would immediately decline. A major food source, perhaps the major food source for the world's ecosystems, would be gone. Tens of thousands of irreplaceable algal species would be lost, along with their unique diversity of potentially useful chemicals, many with pharmaceutical value. The absence of algae would lead to rapid extinction of many hundreds of thousands of invertebrate animal species. Ecosystems would collapse. Fortunately we won't lose algae anytime soon; they have thrived for 1.5 billion years. Survey of Protists 269 DOMAIN: Eukarya Protists CHARACTERISTICS Usually a complex single cell; photosynthesize, ingest, or absorb food; haploid life cycle Supergroup Members Distinguishing Features Archaeplastida Green algae, red algae, red algae, charophytes Plastids; unicellular, colonial, and multicellular, colonial, and multicellular Chromalveolata Stramenopiles: brown algae, water molds Alveolates: ciliates, apicomplexans, dinoflagellates Most with plastids; unicellular and multicellular Excavata Euglenoids, kinetoplastids, parabasalids, diplomonads Feeding groove; unique flagella; unicellular Amoebozoa Amoeboids; some with tests; unicellular Amoebozoa, and cellular colonial Assorted fossilized diatoms Alveoli support plasma membrane; unicellular Onychodromus, a giant ciliate ingesting one of its own kind Plasmodium, a single-celled green alga (chlorophyte) Nonionina, a foraminiferan Ceratium, an armored dinoflagellate Bossiella, a coralline red alga Synura, a colony-forming golden brown alga Amoeba proteus, a protozoan (a) ©Eric Graves/Science Source; (b) ©Astrid & Hanns-Frieder Michler/Science Source; (c) ©D.P. Wilson/Science Sou Images; (q) ©McGraw-Hill Education/Stephen Durr, photographer; (h) ©Roland Birke/Getty Images; (i) ©M. I. Walker/Science Source; (j) ©Greg Antipa/Science Source; (k) ©Patrick W. Grace/Science Source; (k) ©Patrick W. Grace/Science Source; (k) ©Patrick W. Grace/Science Source; (k) ©Creg Antipa/Science Source; (k) ©Patrick W. Grace/Science Source; (k) ©Patrick W. Grace/Scien Supergroup Groups Unifying Characteristics EXCAVATA euglenoids flagellates Unicellular flagellates, often with feeding groove; mitochondria highly modified in specialized parasites; secondary plastids having only two envelope membranes CHROMALVEOLATA dinoflagellates ciliates apicomplexans diatoms brown algae, some have secondary plastids derived from green apicomplexans have secondary plastids derived from red or green algae. Strawlike flagellar hairs; fucoxanthin accessory pigment common in autotrophic forms RHIZARIA
radiolarians foraminiferans Thin, cytoplasmic projections; secondary plastids (when present) derived from endosymbiotic green algae. pseudopodia OPISTHOKONTA choanoflagellates Swimming cells possess a single posterior flagellum. Table 25.2 The Common Pigments in Addition to Chlorophyll a, Storage Products, and Cell Wall Green algae Unicellular, filamentous, colonial Chlorophyll a,b Starch Mainly cellulose Brown algae Filamentous, multicellular Chlorophyll a,c, fucoxanthin Laminarin, mannitol, lipids Cellulose, agar, carrageenan Diatoms Unicellular Chlorophyll a,c, fucoxanthin Laminarin, mannitol, lipids Cellulose, agar, carrageenan Diatoms Unicellular Chlorophyll a,c, fucoxanthin Laminarin, mannitol, lipids Cellulose, agar, carrageenan Diatoms Unicellular Chlorophyll a,c, fucoxanthin Laminarin, mannitol, lipids Cellulose, agar, carrageenan Diatoms Unicellular Chlorophyll a,c, fucoxanthin Laminarin, mannitol, lipids Cellulose, agar, carrageenan Diatoms Unicellular Chlorophyll a,c, fucoxanthin Laminarin, mannitol, lipids Cellulose, agar, carrageenan Diatoms Unicellular Chlorophyll a,c, fucoxanthin Laminarin, mannitol, lipids Cellulose, agar, carrageenan Diatoms Unicellular Chlorophyll a,c, fucoxanthin Laminarin, mannitol, lipids Cellulose, agar, carrageenan Diatoms Unicellular Chlorophyll a,c, fucoxanthin Laminarin, mannitol, lipids Cellulose, agar, carrageenan Diatoms Unicellular Chlorophyll a,c, fucoxanthin Laminarin, mannitol, lipids Cellulose, agar, carrageenan Diatoms Unicellular Chlorophyll a,c, fucoxanthin Laminarin, mannitol, lipids Cellulose, agar, carrageenan Diatoms Unicellular Chlorophyll a,c, fucoxanthin Laminarin, mannitol, lipids Cellulose, agar, carrageenan Diatoms Unicellular Chlorophyll a,c, fucoxanthin Laminarin, fucoxanthin Laminarin, fucoxanthin Laminarin, fucoxanthin Laminarin, fucoxanthin Laminarin, fucox Chrysolaminarin, lipids Silica Dinoflagellates Unicellular Chlorophyll a, c Starch, lipids Pectin, cellulose plates Euglenoids Unicellular Starch, lipids Proteinaceous pellicle Algae are photosynthetic, eukaryotic organisms typically lacking multicellular sex organs. The major groups of algae are distinguished in part by their energy storage products, cell walls, and color, resulting from the type and abundance of colored pigments (substances that absorb light) in their plastids (table 25.2). Biologists often group algae by the colors of these pigments—for example, green algae, brown algae, and red algae. Algae are also distinguished by their cellular organization (fig. 25.2). Unicellular algal species occur as single, unattached cells that may or may not be motile. Filamentous algal species occur as chains of cells attached to each other in a nonfilamentous 25-3 manner. For example, a colony may include several to many cells adhering to each other as a sphere, flat sheet, or other three-dimensional shape. Colonies are clonal—that is, their cells are identical. Multicellular organization is not typical of protists but describes algae of more complex design than simple colonies. Multicellular species have cells of different types and functions and show significant interdependence. GREEN ALGAE (SUPERGROUP ARCHAEPLASTIDA) Green algae in fresh water (fig. 25.3). However, a few genera live in salt water. Although Survey of Protists 271 Planktonic protists Attached protists One cell 10 µm (a) Single-celled Chlamydomonas with flagella 32 µm 0.2 mm (b) The colonial genus Pediastrum (c) The filamentous genus Acetabularia (a) ©De Agostini Picture Library/Science Source; (b) ©Roland Birke/Phototake; (c) ©Marek Mis/Science Source; (d) © buccaneer/123RF; (e) © Free styler/Shutterstock Figure 25.2 The diversity of algal body-types reflects their habitats. (a) The single-celled flagellate genus Chlamydomonas occurs in the phytoplankton of lakes. alga afloat in water. (c) The filamentous genus Desmidium occurs as a twisted row of cells. (d) The branched filamentous genus Cladophora that grows attached to nearshore surfaces is large enough to see with the unaided eye. (e) The relatively large seaweed genus Acetabularia lives on rocks and coral rubble in shallow tropical oceans. the common name chlorophyte means "green chlorophyll blants, such as •• Chlorophyll b, which occurs in algae and green plants. Green algae may be ancestral to land plants, such as •• Chlorophyll b, which occurs in land plants and in the green and euglenoid algae •• Starch as the carbohydrate storage material •• Cell walls made of cellulose Let's examine a few representatives of green algae. Unicellular Green Alga: Chlamydomonas is a motile, unicellular alga found in soil, lakes, and ditches (fig. 25.3). It probably has the simplest structure and type of reproduction among green algae. The eggshaped cells of Chlamydomonas contain a large chloroplast and a pyrenoid involved in the production and storage of starch. Procedure 25.1 Observe a drop of water containing living Chlamy domonas and note the movement of the cells. If necessary, review in Exercise 3 the proper use of a compound microscope and the associated videos at the lab manual's website. 2. If the movement is too fast, make a new preparation by placing one or two drops of methylcellulose on a slide and adding a drop of water containing Chlamydomonas. 3. Mix gently and add a coverslip. 272 EXERCISE 25 ©M.I. Walker/Science Source Figure 25.3 Chlamydomonas is a common alga that is rich in chlorophylls a and b. It is a single-celled green alga less than 100 µm long. 4. Note the stigma, which appears as a reddish, lightabsorbing spot at the anterior end of the cell. 5. Examine prepared slides of Chlamydomonas. Question 1 a. Is the movement of Chlamydomonas smooth or does it appear jerky? 25-4 b. Can you see both flagella? (You may need to reduce the light intensity to see flagella.) Sexual reproduction c. How does methylcellulose affect the movement of Chlamydomonas? - Gamete Asexual reproduction + Gamete MITOSIS - Strain Pairing of positive and negative mating strains MITOSIS n + Strain 2n FERTILIZATION d. How does the stigma help Chlamydomonas survive? M EI OS IS Zygospore (diploid) Asexual and Sexual Reproduction in Chlamydomonas usually reproduces asexually via mitosis. Sexual reproduction in Chlamydomonas usually reproduces as a response to unfavorable environmental conditions. For sexual reproduction, vegetative cells of Chlamydomonas undergo mitosis to produce gametes. The gametes fuse to form a diploid zygote, the resting stage of the life cycle. In most species of Chlamydomonas, the gametes of two strains are referred to as + or -. Gametes unite to form a diploid zygote. Syngamy is the pairing and fusion of morphologically similar haploid gametes to form a diploid zygote. Syngamy is similar to fertilization, but fertilization, but fertilization typically refers to fusion of unequal gametes such as egg and sperm cells. The zygote surrounds itself with a resistant surface and is called a zygospore. Under favorable conditions the zygote undergoes meiosis to produce haploid individuals called spores. Spores are reproductive cells capable of developing into an adult without fusing with another cell. Study the life cycle of Chlamydomonas shown in figure 25.4. Figure 25.4. Figure 25.4. Figure 25.4. divide asexually, producing copies of themselves. At times, such haploid cells act as gametes, fusing to produce a zygote. The zygote develops a thick, resistant wall, becoming a zygospore (as shown in the lower right-hand side of the diagram). Meiosis then produces four haploid individuals. Only + and - strains can mate with one another, although both may also divide asexually and reproduce themselves. Question 2 a. Under what environmental conditions would a zygote not undergo meiosis immediately? b. Are spores of Chlamydomonas haploid? c. Which portions of the life cycle of Chlamydomonas haploid? c. Which portions of the life cycle of Chlamydomonas are haploid? C. Which portions of the life cycle of Chlamydomonas are haploid? of Chlamydomonas provided by your instructor next to each other on a microscope slide, being careful not to mix the two drops. Do not add a coverslip. 2. While you observe the drops through low power of the microscope, mix the two drops. Bo not add a coverslip. 3. Switch to high magnification and note the clumping gametes. Try to locate cells that have

paired. 25-5 d. Which are diploid? Survey of Protists 273 Filamentous Green Algae: Spirogyra and Cladophora is also common in streams of cool fresh water and secretes mucilage that makes it feel slippery. Cladophora is also common in streams of cool fresh water and secretes mucilage that makes it feel slippery. and has a much coarser appearance and texture. Spirogyra reproduces sexually by a process called conjugation as well as asexually by fragmentation. During conjugation, filaments of opposite mating types lie side by side and form projections that grow toward each other. conjugation tube (fig. 25.5, also see fig. 4.15). The cellular contents of the (-) strain then migrate through the conjugation tube and fuse with that of the nonmotile (-) strain. The cellular contents of these two strains function as nonflagellated isogametes. The zygote resulting from the fusion of gametes develops a thick, resistant cell wall and is termed a zygospore. The zygospore is released when the filament disintegrates, at which time the zygospore undergoes meiosis to form haploid cells that become new filaments. Cell wall Chloroplast Vacuole Nucleus Zygote Cytoplasm Conjugation tubes (a) Cell anatomy (b) Conjugation 20 µm © M.I. Walker/Science Source Figure 25.5 Spirogyra (watersilk). (a) Spiral, ribbonlike chloroplasts occur in each cell. (b) During conjugation, the cell contents of one filament (+strain) enter the cells of another filament (-strain) through a conjugation tube (200×). Procedure 25.3 Examine Spirogyra and Cladophora 1. Obtain and examine a living culture of Spirogyra. 2. Prepare a wet mount with a small amount of living Spirogyra. Examine it with low and then high magnification. Notice the arrangement of the chloroplasts and whether filaments are branched. 3. Examine a prepared slide of Spirogyra. 4. In the following space, sketch a filament of Spirogyra and note the arrangement of its chloroplasts. © blickwinkel/Alamy Stock Photo Figure 25.6 The green alga Cladophora forms branched filaments consisting of multinucleate cells (100×). 5. Examine a prepared slide of Cladophora. 7. In the following space, draw a few cells of Cladophora showing their general shape and the filament's branching pattern. 274 EXERCISE 25 Question 3 a. Are filaments of Spirogyra branched? 25-6 b. What is the arrangement of chloroplasts of Spirogyra? Gametes form by mitosis and differentiation Spores germinate to form mature thallus c. Can you see any conjugation tubes? If you can't, examine the prepared slides that show these structures. Gametes fuse (Syngamy) Zygote (2n) d. How do you think Spirogyra reproduces asexually? Meiosis and spore formation by sporophyte Question 4 a. How is Cladophora morphologically similar to Spirogyra? How is it different? Zygote germinates to form mature thallus Figure 25.7 Alternation of generations, the haploid (n) gametophytes alternate with diploid (2n) sporophytes. Gametophytes produce haploid gametes that fuse to form a diploid zygote, the first cell of the sporophyte generation. The zygote germinates and undergoes meiosis to form haploid spores, the first cells of the gametophyte generation. The gametophyte generation. The gametophyte generation. The gametophyte generation is to produce gametes, thereby completing the life cycle. Colonial Green Alga: Volvox b. What is the shape of its chloroplasts? Mature Cladophora exists in diploid and haploid forms. The diploid stage of the life cycle produces spores and is called the sporophyte. This phenomenon of alternation of generations is a reproductive c ycle in which the haploid gametophyte produces gametes that fuse to form a zygote that germinates to produce a diploid sporophyte, thus completing the cycle (fig. 25.7). Alternation of generations occurs in many green algae, including Cladophora, and in all land plants. You should become familiar with the concept of alternation of generations because it occurs frequently in the plant kingdom and we will refer to jour textbook or instructor for more information. 25-7 Volvox consists of many Chlamydomonas-like cells bound in a common spherical matrix (fig. 25.8). Each cell in the sphere has two flagella extending outward from the surface of the colony. Synchronized beating of the flagella spins the colony through the water like a globe on its axis. Volvox is one of the most structurally advanced colonial forms of algae, so much so that some biologists consider Volvox to be multicellular. Some of the cells of a Volvox colony are functionally differentiated; a few specialized cells can produce new colonies, and eggs and sperm are formed by different cells in the colony. Volvox reproduces by oogamy. Motile sperm swim to and fuse with the large nonmotile eggs to form a diploid zygote. The zygote enlarges and develops into a thick-walled zygospore released when the parent colony disintegrates. The zygospore then undergoes meiosis to produce haploid cells that subsequently undergo mitosis and become a new colonies that initially are held within the parent colony. Procedure 25.4 Observe Volvox 1. Examine a prepared slide of Volvox. Survey of Protists 275 BROWN ALGAE (SUPERGROUP CHROMALVEOLATA) © Lebendkulturen.de/Shutterstock Figure 25.8 Colonies of Volvox. Many parent colonies contain asexually produced daughter colonies (400×). 2. Obtain a living culture of Volvox. Place a drop of living Volvox on a depression slide. 3. Under low magnification, observe the large, hollow, spherical colonies for a few minutes to appreciate their elegance and beauty. 4. Search for flagella on the surface. 5. Complement your observations of this alga by re-examining prepared slides of Volvox. Question 5 a. What is oogamy? b. What are the tiny spheres inside the larger sphere of Volvox? c. How do you suppose they get out? d. How do you think the number of cells in a young Volvox colony? 276 EXERCISE 25 Brown algae are primarily marine and structurally complex; there are no unicellular or colonial brown algae. Brown algae usually grow in cool water and obtain their name from the presence of a brown pigment called fucoxanthin. Brown algae are similar to those of land plants. Review table 25.2 for the characteristics of brown algae. Among the larger brown algae is Macrocystis, a kelp reaching 100 m in length (fig. 25.9). The flat blades of this kelp float on the surface of the water, while the base is anchored far below the surface. Another ecologically important brown alga is sargasso weed (Sargassum; fig. 25.10), which forms huge floating masses that dominate the vast Sargasso Sea in the Atlantic Ocean northeast of the Caribbean. These is anchored far below the surface of the water, while the base is anchored far below the surface. mats are microhabitats for a variety of highly adapted and cryptically colored animals. Fucus is another common genus of brown algae (fig. 25.11). Fucus (rockweed) typically attaches to rocks in the intertidal zone via a specialized structure called a holdfast. The outer surface of Fucus is covered by a gelatinous sheath. Tips of Fucus branches, called conceptacles, may be swollen and contain reproductive structures called oogonia (female) and antheridia are multicellular sex organs that produce sperm. Most protists do not have multicellular reproductive organs. The life cycle of Fucus is similar to the common life cycle of animals. The mature thallus is diploid, and cells within reproductive structures undergo meiosis to produce gametes, thereby skipping the multicellular haploid stage common to many protists, plants, and fungi. Procedure 25.5 Examine Fucus 1. Refer to figure 25.11 as you examine Fucus in the lab. Use your dissecting microscope to examine a cross section of the flattened, dichotomously branched thallus of Fucus. 2. Notice the presence of swollen areas on the thallus of Fucus. 3. Work in a group to dissect one of these structures. 4. Examine prepared slides of antheridia and oogonia of Fucus. 3. Work in a group to dissect one of these structures. 4. Examine prepared slides of antheridia and oogonia of Fucus. 3. Work in a group to dissect one of these structures. Images © Kingsley Stern Figure 25.9 Brown alga. The giant kelp, Macrocystis pyrifera, grows in relatively shallow water along coasts throughout the world and provides food and shelter for many different kinds of organisms. Mitosis and egg formation (n) Zygote (2n) Gametes fuse (Syngamy) Figure 25.10 Sargassum, a floating brown alga from which the Sargasso Sea got its name. Sargassum also lives in other oceans. Egg Zygote germinates Meiosis Mitosis and sperm formation (n) Immature antheridium Meiosis Immature of Fucus have separate male thalli and female thalli containing conceptacles with only antheridia, and only oogonia, respectively. 25-9 Survey of Protists 277 Question 6 a. How does the structure of Fucus differ from that of the green algae that you examined earlier in this exercise? 2. Observe the products on display and, in the case of foods, read their contents labels. RED ALGAE (SUPERGROUP ARCHAEPLASTIDA) b. Are all portions of the thallus photosynthetic? How can you tell? Red algae obtain their color from the presence of red phycobilins in their color from the presence of red phycobilins in their color from the presence of red phycobilins in their color from the presence of red phycobilins in their color from the presence of red phycobilins in their color from the presence of red phycobilins in their color from the presence of red phycobilins in their color from the presence of red phycobilins in their color from the presence of red phycobilins in their color from the presence of red phycobilins in their color from the presence of red phycobilins in their color from the presence of the phycobilins in the phycobilins Examine Polysiphonia, c. Considering where Fucus lives, what do you think is the function of its gelatinous sheath? d. Are the swollen structures solid masses or are they hollow? Question 7 a. Are the gametes
of Fucus isogamous or oogamous? b. How does the structure of tissue surrounding the reproductive structures compare with that of green algae? Porphyra, and commercial products of red algae 1. Obtain prepared slides of Polysiphonia. This genus is highly and any living cultures that are available in lab. 2. Examine a prepared slide of Polysiphonia. This genus is highly and any living cultures that are available in lab. 2. Examine a prepared slide of Polysiphonia. This genus is highly a soft of the filaments compared with that of filaments compared slides of Polysiphonia. branched and filamentous. As with other red algae, their life cycles can be quite complex. Gametophytes of these organisms are dioecious (i.e., they are either male or female). 4. Examine some prepared slides and living Porphyra if available. Compare the structure of Polysiphonia with that of Porphyra. "Blades" of two layers of cells separated by colloidal material. 5. Study the display of carrageenan, agar, and other products derived from red algae used as a solidifying agent in culture media for microbiology labs (fig. 25.13b). A 1% suspension of hot agar remains liquid until it cools to about body temperature. Economic Importance of Brown Algae In the Orient, some brown algae are used as food. One of these algae is Laminaria, a kelp marketed as "kombu." Brown algae are also important sources of alginic acid, a hydrophilic substance (i.e., it absorbs large quantities of water). Alginic acid is used as an emulsifier (an additive used to stabilize processed food and other products) in dripless paint, ice cream, pudding mixes, and cosmetics. Procedure 25.6 Examine some commercial products of brown algae 1. Taste a small piece of kelp packaged as a food product. How would you describe its taste and texture? 278 EXERCISE 25 ©Dr. D. P. Wilson/Science Source © Premaphotos/Alamy Stock Photo Figure 25.12 Red algae come in many forms and sizes. 25–10 DIATOMS (SUPERGROUP CHROMALVEOLATA) Diatoms are unicellular algae come in many forms and sizes. 25–10 DIATOMS (SUPERGROUP CHROMALVEOLATA) Diatoms are unicellular algae containing chlorophylls a and c and xanthophyll pigments that give them their goldenbrown color. Although diatoms are tiny, their great numbers, rapid rates of reproduction, and photosynthetic capacity make them vitally important as a primary link in the food chain of the oceans. Diatoms have a hard cell wall made of silicon dioxide (glass) (fig. 25.14). These walls are arranged in overlapping halves, much like the halves of a petri dish. The glass walls of diatoms persist long after the remainder of the cell disintegrates (fig. 25.15) and may accumulate in layers of diatomaceous earth several hundred meters deep. This depth indicates how many diatoms (a) (b) ©Dennis Strete Figure 25.13 A red alga and a common extract, agar. (a) Irish moss (Chondrus crispus) is a red alga that is commercially important as a source of carrageenan is used as a stabilizer in paints and cosmetics, as well as in foods such as salad dressings and dairy products. (b) Microbiologists grow a variety of organisms on media solidified with agar (shown here) extracted from seaweeds such as a stabilizer in paints and cosmetics, as well as in foods such as salad dressings and dairy products. shown in figure 27.10 are growing on agar. Agar is also used to make drug capsules, cosmetics, and gelatin desserts. (a) (b) ©Eric Grave/Science Source ©Dr. Norbert Lange/Shutterstock Figure 25.14 Diatoms. (b) Several different kinds of diatoms, including some centric (round) species (600×). 25-11 Survey of Protists 279 d. How would diatomaceous earth compare to sand as a material for swimming pool filters? Which would be better and why? DINOFLAGELLATES (SUPERGROUP CHROMALVEOLATA) © Philippe Crassous/Science Source Figure 25.15 wall (1000×). A diatom showing its ornate, silicon cell Procedure 25.8 Examine prepared slides of Dinoflagellates are all unicellular and characterized by the bizarre appearance of their cellulose plates and by the presence of two flagellate called Ptychodiscus brevis produce a "red tide." Toxin production and oxygen depletion by these blooms of algae can kill massive numbers of fish. Dinoflagellates are important primary producers in oceans (second only to diatoms) and include many autotrophic and heterotrophic. diatoms, living diatoms, and diatomaceous earth 1. Examine a prepared slide of diatoms. Sketch some of the cells here. Some cells are long and thin, whereas others are disklike. 2. Prepare a wet-mount slide from a culture of living diatoms. Compare the shapes of the cells with those on the prepared slide. 3. Mount a small amount of diatomaceous earth in water on a microscope slide. Examine the diatomaceous earth with your microscope. Note the variety of shells, some broken and others intact. A mass of these shells is clean, insoluble, and porous. Procedure 25.9 Examine a prepared slide of Peridinium or Ceratium. Look for longitudinal and transverse flagella and flagellar grooves. 2. Prepare a wet-mount slide from a living culture of dinoflagellates. Dinoflagellates are quite small, so be patient while searching for organisms. Question 9 How do the shapes of dinoflagellates compare with other unicellular algae that you have observed in this exercise? Question 8 a. Can you see any pores in the walls of diatoms? cellulose plate b. Are any of the diatoms moving? flagella 2 µm c. If diatoms lack flagella, how do you explain their motility? Figure 25.16 Dinoflagellate Gonyaulax. Most dinoflagellates have rigid cellulose plates and pair of flagella in perpendicular grooves. 280 EXERCISE 25 25-12 EUGLENOIDS (SUPERGROUP EXCAVATA) Euglenoids include mostly freshwater unicellular forms. Although plastids of euglenoids contain chlorophylls a and b (like the green algae), euglenoids are motile and have two flagella (fig. 25.17). Procedure 25.10 Observe Euglena 1. Observe living and prepared slides of Euglena available in the lab while referring to figure 25.17. 2. You may want to add a drop of methylcellulose in your preparation to slow the Euglena. 3. Note the colored eyespot near the base of the flagella. 4. Observe the movement and changing shapes of the flagella. 4. Observe the movement and changing shapes of the flagella. 4. Observe the movement and changing shapes of the flagella. 4. Observe the movement and changing shapes of the flagella. clear, circular area within the plastid. Euglena is best known for its ability to be autotrophic, heterotrophic, and saprophytic. Its specific mode of nutrition is determined by current environmental conditions. This phenomenon illustrates why it is often impossible to distinguish plant from animal at the cellular level and why classification of protists seems so unwieldy. Our classification schemes for these and other organisms will improve as we learn more about them. Question 10 What is the function of the eyespot of Euglena? (a) 6.5 µm @Andrew Syred/Science Source Stigma Second flagellum Contractile vacuole Reservoir Basal bodies Paramylon granule Mitochondrion Pellicle Nucleus Flagellum Chloroplast (b) Figure 25.17 Euglenoids. (a) Micrograph of individuals of the genus Euglena. Paramylon granules store food reserves. INQUIRY-BASED LEARNING How do algae respond to changing environmental stimuli? Observation: You learned in Exercise 23 how algae are affected by environmental stimulation of the genus Euglena. changes involving nutrients, pollutants, and temperature changes. As a result, algal growth can be used to monitor environmental changes (e.g., eutrophication). Question: How can algae be used to monitor environmental conditions? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 25 from your instructor. b. Discuss with your group well-defined questions relevant to the preceding observation and question. Choose and record your group's best question for investigation. 25-13 c. Translate your hypothesis and record it. d. Outline on Worksheet 25 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your proposed investigation. e. Conduct your procedures, record your data, answer your question, and make relevant comments. f. Discuss with your instructor any revisions to your questions, hypotheses, or procedures. Repeat your work as needed. Survey of Protists 281 Questions for Further Study and Inquiry 1. What are examples of unicellular, filamentous, and colonial green algae? 2. How are green algae different from cyanobacteria? 3. What is meant by "alternation of generations"? 4. What is meant by the term "kelp"? 5. Are the stem, holdfast, and blade of brown algae contain chlorophyll. Why, then, do they appear brown and not green? 7. What are the main differences and similarities among the major groups of algae? How are these groups related to each other evolutionarily? 8. Describe three ways that algae affect your life. 9. Why are green algae considered to be ancestral to plants? DOING BIOLOGY YOURSELF Would you expect environmental conditions to influence syngamy? Design two experiments to investigate the effects of two environmental conditions on the frequency? 282 EXERCISE 25 WRITING TO LEARN BIOLOGY Describe the plant-like character istics of Euglena. Which characteristics conclusively define a plant? Which ones define an animal? 25-14 E XER CISE 26 Survey of Protists Protozoa and Slime Molds Learning Objectives By the end of this exercise you should be able to: 1. Describe the features characterizing protozoa and slime molds. 2. List examples, habitats, reproductive methods, and unique features of the protozoans. 3. Become familiar with representative protozoans and slime molds. Please visit connect.mheducation.com to review online resources tailored to this lab. P rotozoans (proto = first, zoan = animal) are among the most versatile of all eukaryotes on earth. Protozoans (proto = first, zoan = animal) are among the most versatile of all
eukaryotes on earth. Protozoans are eukaryotes with an animal-like, heterotrophic ecology, which means they are active consumers and not photosynthetic. (Remember that heterotrophs get their nutritional energy from organic molecules made by other organisms.) Typically, protozoans have food vacuoles to enclose food particles for digestion, and contractile vacuoles to expel excess water. Their single cells employ a variety of features for motility, and they live everywhere from a drop of pond water to the intestines of termites. Review table 25.1 and the supergroups of protists that include common protozoans. AMOEBAS (SUPERGROUP AMOEBAS (SUPERGROUP AMOEBAS of the intestines) of termites and the supergroups of protists that include common protozoans. terrestrial environments. Their unifying characteristic is the presence of pseudopods, which are movable extensions of cytoplasm used for locomotion and gathering food. Amoebas are likely polyphyletic, lack flagella, and most reproduce asexually. physiology typical of most amoeboid genera (fig. 26.1). Amoeba are phagocytic, meaning they engulf food particles and form a food vacuole for intracellular digestion. A contractile 26-1 vacuole maintains the cell's water balance by accumulating and expelling excess water Other common amoebas include Difflugia, which makes a protective case of sand grains called a test. Test is a general term referring to a secreted or partially secreted covering, much like a shell (fig. 26.2). Examine a prepared slide of Difflugia. 26.1 Observe Amoeba movement and structure 1. Review microscope use and procedures in Exercise 3, as well as the associated videos at the lab manual's website. Use a dissecting microscope (see Exercise 3) to examine a culture of living Amoeba by using an eyedropper to remove a few drops from the bottom of the culture of organisms. 3. Put the drops in a depression slide if one is available or use a standard slide. 4. Cover the preparation with a coverslip and examine it under low power (10×) (see Exercise 3). Soon the Amoeba should move by extending their pseudopods. 5. If nutrient broth is available, add a drop to the preparation and observe the Amoeba's response. 6. Examine a prepared slide of stained Amoeba, and locate the structures shown in figure 26.1. 7. Examine any other live amoebas and prepared slides that are available. Draw the basic structure of these organisms. Survey of Protists 283 Pseudopodia Test (a) ©M I (Spike) Walker/Alamy Stock Photo plasma membrane Figure 26.2 Difflugia oblongata, a common freshwater amoeba with a sand-grain case. The case consists of cemented mineral particles collected by the amoeba (150×). mitochondrion pseudopod (b) d. About how long would it take an Amoeba to move across the field of view on low power? e. Why is a contractile vacuole? Figure 26.1 Amoebas. (a) Light micrograph of Amoebas. (b) Anatomy of Amoeba contractile vacuole? a. Can you detect moving cytoplasm in the extending pseudopods of Amoeba? b. What do you suppose the living Amoeba is moving toward or away from? f. Why would excess water tend to accumulate in Amoeba? FORAMINIFERANS (SUPERGROUP RHIZARIA) These marine organisms are called "shelled amoebas" because they surround themselves with a secreted test and have long, thin, rather stiff pseudopods protruding from their tests (fig. 26.3). The test is made of calcium carbonate and is often used by oil companies to locate oil-bearing strata. 284 EXERCISE 26 26-2 Procedure 26.2 Examine foram tests 1. Obtain a prepared slide of foram tests. 2. Search with low magnification the edges of the cover slips for the foraminiferan tests. They are relatively heavy and shift to the side easily. Question 2 How could fossilized forams in different geological layers of rock or sediment indicate the probability of finding oil? FLAGELLATES (SUPERGROUP EXCAVATA) Flagellates have at least one flagellum and are likely the most primitive protozoans. Flagellates are parasitic as well as free-living heterotrophs. @Alfred Pasieka/Getty Images (a) Trypanosoma Among flagellates are parasitic as well as free-living heterotrophs. Charles Darwin may have died from Chagas' disease, for during his later years he suffered from general fatigue, irregular fever, and heart damage. All of these are symptoms of Chagas' disease transmitted by the bite of an assassin bug, which resembles a common stinkbug. Trypanosomes are common in the tropics and spread by infection from biting insects such as mosquitoes, sand flies, and tsetse flies (fig. 26.4b). (b) 8.3 µm @McGraw-Hill Education/Claude Carre/Science Source Figure 26.3 Examine a prepared slide of Trypanosoma and compare its size to that of Amoeba some representative foraminiferans (40×). (b) Podia, which are thin cytoplasmic projections, extend through pores in the calcareous test of this living foram (40×). 1. Obtain a prepared slide of Trypanosomes (a) 20 µm (b) © Martin Dohrn/Science Photo Library/Getty Images Source: Dr. Myron G. Schultz/Centers for Disease Control Figure 26.4 A parasite and its vector. (a) Trypanosoma among red blood cells. The nuclei (dark-staining bodies), anterior flagella, and undulating, changeable shape of the trypanosomes are visible in this photomicrograph (400×). (b) The tsetse fly, shown here sucking blood from a human arm, can carry and transmit trypanosomes. 26–3 Survey of Protists 285 African Sleeping Sickness Human African trypanosoma are transmitted to humans by the bite of tsetse flies (Glossina spp.; fig. 26.4b), which acquire their infection from humans or other infected animals (World Health Organization Fact Sheet No. 259) The most vulnerable people are in rural populations dependent on agriculture, fishing, animal husbandry, or hunting. Trypanosoma brucei gambiense (T.b.g) accounts for 95% of reported in 2009 dropped below 10,000 for the first time in 50 years. This end of the first time in 50 years.) with 7139 new cases reported. For unknown reasons, many regions of 36 sub-Saharan affected countries have tsetse flies, but no sleeping sickness. A person can be infected for months or even years without developing the major signs and symptoms of the disease, which include fever. Advanced stages disrupt the sleep cycle and disrupt coordination. Figure 26.5 Trypanosoma brucei. (a) Micrograph of Trypanosoma brucei, a causal agent of African sleeping sickness, among red blood cells. (b) This drawing shows the general structure of Trypanosoma brucei. red blood cells Science/Science Source (b) 2. Locate the organisms intermingled with the blood cells (fig. 26.4). The organisms are not inside the blood cells; they are in the surrounding plasma. 3. Try to distinguish the flagellum and undulating membrane of an individual. The undulating membrane is a thin, flat surface that can be undulated (i.e., waved) for locomotion. A rippling wave travels along the membrane and pushes the organism forward. 4. Trypanosomes are quite small. To estimate its size, first note the magnification of the objective you are using. 5. Refer to your notes from Exercise 3 (The Microscope) concerning the diameter of the field of view associated with the current magnification. 6 Estimate the portion of the diameter of the field of view occupied by a Trypanosome. 7. Make a similar estimation. 286 EXERCISE 26 Question 3 a. How large is a trypanosome relative to Amoeba? b. What alga does a trypanosome superficially resemble? CILIATES (SUPERGROUP CHROMALVEOLATA) More than 8000 species of ciliates have been described, all having characteristically large numbers of ciliates have been described, all having characteristically large numbers of ciliates have been described. micronuclei, control cellular function, and they divide when ciliates reproduce asexually by mitosis. 26-4 Paramecium This free-living, freshwater genus is widely studied and easily observed. Paramecium, like most ciliates, undergoes a sexual process called conjugation (fig. 26.7). During conjugation individuals from two different strains align longitudinally and exchange nuclear material (fig. 26.7b). This exchange seems to stimulate metabolism of the individuals and is usually followed by frequent mitosis. Asexual reproduction is more common than conjugation and includes mitosis of the micronucleus and transverse fission (fig. 26.7a) of the individuals and is usually followed by frequent mitosis. macronucleus and cell body. 1. Prepare a wet mount from a culture of living organisms. 2. Add a drop of methylcellulose to your wet mount to slow the Paramecium and make it easier to examine. 3. Describe aspects of their movement in comparison to Amoeba. 4. Identify as many structures as possible in figure 26.6. Procedure 26.4 Examine. conjugating and Question 4 a. Are cilia visible on living or prepared Paramecium? 1. Obtain a prepared slide of conjugating cells. Their nuclei are in close proximity. 3. Notice the plane of division of the transversely dividing cells. b Does Paramecium rotate as it moves? dividing Paramecium. The main features of this Anterior contractile vacuole familiar ciliate include cilia, two nuclei, and numerous specialized organelles. Macronucleus Micronucleus Micronucleus Posterior contractile vacuole familiar ciliate include cilia, two nuclei, and numerous specialized organelles. Reschke/Getty Images Figure 26.7 Reproduction among paramecia. (a) A mature Paramecium divides asexually by transverse fission (100×). (b) During conjugation, individuals exchange genetic material. Conjugation is a sexual process. 26-5 Survey of Protists 287 c. How does movement of Paramecium divides asexually by transverse fission (100×). flagellated alga? Question 5 a. Why is the division of Paramecium cells called "transverse fission? b. Why is transverse fission not a sexual process? ©blickwinkel/Alamy Stock Photo c. What are the advantages and disadvantages of conjugation in Paramecium? Vorticella and Other Ciliates This freshwater ciliate is sessile (i.e., attached to a
substrate) and has two notable features: (1) a contractile stalk that attaches the organism to the substrate and (2) a cell body with a corona of cilia. To feed, Vorticella extends its contractile stalk to push the cell body as far as possible from the substrate and from other individuals. Then it rapidly beats its cilia to capture food particles. This is a type of filter feeding (fig. 26.8). Figure 26.8 Vorticella are heterotrophic, feed largely on bacteria, and have retractable stalks (80×). Question 6 a. What is the probable function of the moving cilia of Vorticella? b. What is the value or function of the stalk of Vorticella? b. What is the probable function of the stalk of Vorticella? b. What is the value or function of the value of Vorticella? b. What is the value or function of the value of Vorticella? b. What is the v microscope to examine a living colony of Vorticella, which often grows on the glass and other hard substrates in stagnant aquaria. 2. Tap the sides of the dish and observe the contraction of each bell-shaped individual. 4. Examine a prepared and stained slide of Vorticella and draw its general shape. APICOMPLEXANS (SUPERGROUP CHROMALVEOLATA) Apicomplexans are typically nonmotile parasites of animals. Frequently, these parasites of animals. Frequently, these parasites or preparec slides of ciliates available in the lab. Draw the general shape of these organisms and describe the movement of living specimens. 288 EXERCISE 26 This pathogen is the best-known apicomplexan and has been the most common killer of humans in history. human to human (fig. 26.9). These malarial parasites infect and rupture red blood cells, causing cycles of fever and chills. Sexual reproductive stages occur in the human host. 26-6 6 5 In mosquitoes, gametocytes produce gametes that fuse to form a diploid zygote. In the gut, zygotes divide by meiosis to produce haploid sporozoites, which move to the salivary glands of the mosquito. Fertilization Zygote (2n) Mitosis Gametocytes (n) Insid e mo Insid squi e hu to Sporozoites (n) in salivary glands man 1 4 Merozoites continue to infect more red blood cells, causing cycles of chills and fever in the infected person. Liver cell Plasmodium sporozoites enter liver cells, where the merozoite stages of Plasmodium form. Merozoites are released from liver cells, enter red blood cells, and reproduce, causing red blood cells to burst. Figure 26.9 Diagram of the life cycle of Plasmodium falciparum, the agent of malaria. This life cycle requires two alternate hosts, humans and Anopheles mosquitoes. Procedure 26.7 Examine a blood smear from a SLIME MOLDS (SUPERGROUP AMOEBOZOA) 1. Obtain a prepared slide with Plasmodium. 2. Locate the infected blood cells. The organisms are inside the infected blood cells, not in the surrounding plasma as are trypanosomes. 3. Locate and compare infected blood cells. The infected blood cells. Slime molds have o ften been classified in kingdom Fungi, but they have amoeboid characteristics such as phagocytic nutrition and unique unicellular forms and assemblages. They also lack the prominent hyphae of fungi. Slime molds as protists. In this exercise, you will examine Physarum as a representative slime mold. Bizarre plasmodial slime molds such as Physarum stream along the damp forest floor in a mass of brightly colored protoplasm called a plasmodium in which individual cells are indistinguishable. Plasmodia are coenocytic (multinucleate) because their nuclei are not separated by cell victim of malaria 4. Review in your textbook the life cycle of Plasmodium (fig. 26.9). 26-7 Survey of Protists 289 c. What is a possible function of cytoplasmic movement in Physarum? Red blood cell (500×). walls, and the entire plasmodium resembles a moving mass of slime. The plasmodium of a slime mold should not be confused with the sporozoan genus with the same name. Often plasmodia occasionally occur on lawns or on mulch beneath shrubs. The moving protoplasm of a plasmodium conspicuously pulsates back and forth as it engulfs and digests bacteria, yeasts, and other organic particles. The Physarum on demonstration is in the vegetative plasmodial stage and feeds on the oatmeal (fig. 26.11). However, if environmental conditions become less than optimal (e.g., if food or moisture decreases), the plasmodium may dry into a hard resistant structure called a sclerotium and remain dormant until conditions improve. Or, if light is available, the diploid plasmodium will move to the illuminated area and coalesce. The condensed structure will grow sporangia, and meiosis will produce spores for dispersal (fig. 26.12). Light is associated with an open environment that allows successful reproductive dispersal; dispersal under or within a tree trunk would be ineffective. Haploid spores produced by meiosis in the sporangia germinate as amoeboid or flagellated organisms. These haploid stages may later fuse as gametes and grow into a new plasmodium. Procedure 26.8 Examine a culture of Physarum 1. Obtain a dissecting microscope and a petri plate containing a culture of Physarum growing on oatmeal flakes. 2. Examine the yellowish trails of the organism beginning to condense into darkly tipped sporangia. Sporangia are easily visible without a microscope. Question 7 a. Is cytoplasmic movement of Physarum apparent? Plasmodium Oat flake © BiologyImaging.com Figure 26.11 Slime mold (Physarum). Slime mold (Physarum). Slime mold share characteristics with fungi but also with amoeboid or flagellated cells. b. Is the movement in a particular direction? 290 EXERCISE 26 26-8 (b) ©DP Wildlife Fungi/Alamy Stock Photo (a) ©Science Photo Library/Alamy Stock Photo (b) ©DP Wildlife Fungi/Alamy Stock Photo (c) ©DP Wildlife Fungi/Ala sensitive to changes in their aquatic world, including changes in the amount and type of nutrients include a variety of organic compounds, including fats, carbohydrates, and proteins. Question: What kinds of nutrients elicit the strongest response from protozoa? mature plasmodium young plasmodium sporangia formation begins young sporangium zygote diploid (2n) SYNGAMY MEIOSIS haploid (n) mature sporangium a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 26 from your instructor. b. Discuss with your group ways to measure protozoan response to introduced solutes Pose a well-defined question relevant to the preceding observation and question. Record your question on Worksheet 26. c. Translate your question into a testable hypothesis and record it. d. Outline on Worksheet 26 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your proposed investigation. e. Conduct your procedures, record your data, answer your question, and make relevant comments. f. Discuss with your instructor any revisions to your questions, hypotheses, or procedures. Repeat your work as needed. Spore food or moisture is scarce, a diploid, mature plasmodium stops moving and forms sporangia. Haploid spores form by meiosis. The spores wait until conditions are favorable to germinate. Spores can give rise to flagellated or amoeboid gametes; the two forms convert from one to the other readily. Fusion of the gametes (syngamy) forms the diploid zygote, which gives rise to flagellated or amoeboid gametes; the two forms convert from one to the other readily. to the mobile, feeding plasmodium by mitosis. flagellated cells 26-9 Survey of Protists 291 Questions for Further Study and Inquiry 1. What requirements might make culturing parasitic zoomastigotes difficult in the lab? 2. Why do some scientists call conjugation "sexual reproduction" and others do not? 3. Is the cell the fundamental unit of life in plasmodial slime molds? Or is the "whole organism," regardless of cellular composition, the fundamental unit? Explain your answer. 4. What functions do cilia, flagella, and pseudopods have in common? 5. What factors may account for the ubiquitous occurrence and great structural diversity of unicellular organisms? 6. In what sense are protists "primitive" and in what sense are they "advanced"? 7. Why are unicellular organisms that reproduce by mitosis considered immortal? 292 EXERCISE 26 26-10 E XER CISE Survey of the Kingdom Fungi Molds, Sac Fungi, Mushrooms, and Lichens 27 Learning Objectives By the end of this exercise you should be able to: 1. Describe the characteristic features of the kingdom Fungi. 2. Discuss variation in structures and sequence of events of sexual and asexual reproduction for the major phyla of the kingdom Fungi. Please visit connect.mheducation.com to review online resources tailored to this lab. F ungi are as cute as a colorful mushroom and as ugly as the fuzzy slime on a spoiled pork chop. We have a colorful mushroom and as ugly
as the fuzzy slime on a spoiled pork chop. slice some species to put on our salads, while others would kill us within minutes of eating them. Some species produce antibiotics vital to medicine, while just as quickly they can attack our crops and our refrigerated foods. They do all this, yet they are among the organisms least understood by introductory biology students. Fungi are basically filamentous strands of cells that secrete enzymes and feed on the organic material may be humus in the soil where mushrooms grow or a stale loaf of bread where mold thrives. It may be the skin between your toes inhabited by athlete's foot fungus or a decaying animal on the forest floor being decomposed by fungi digesting the animal's dead tissue. Fungi not only cause disease; they are also important decomposers that recycle nutrients from dead organisms. The basic structure of a fungus is the hypha (pl., hyphae)—a slender filament of cytoplasm and nuclei enclosed by a cell wall (fig. 27.1). A mass of these hyphae makes up an individual organism and is collectively called a mycelium. A mycelium can permeate soil, water, or living tissue; fungi certainly seem to grow everywhere. In all cases, the hyphae of a fungus secrete enzymes for extracellular digestion of the organic substrate. Then the mycelium and its hyphae absorb the digested nutrients. For this reason, fungi are called absorptive heterotrophs. Heterotrophs. Heterotrophs obtain their energy from organic matter and are called saprophytes. Other fungi feed on living organisms and are parasites. Many of the parasitic fungi have modified 27-1 hyphae of some species of fungi have crosswalls called septa that separate cytoplasm and nuclei into cells. Hyphae of other species have incomplete or no septa (i.e., are aseptate) and therefore are coenocytic (multinucleate). Notably, the cell walls of fungi are usually not cellulose, but instead are made of chitin, the same polysaccharides that comprise the exoskeleton of insects and crustaceans. REPRODUCTION IN KINGDOM FUNGI Reproduction in fungi can be sexual or asexual. Subtle variation in the patterns and morphology of sexual reproduction distinguish one phylum from another. Asexual Reproduced in sporangia, conidiophores, and other related structures. Spores are microscopic and surrounded by a covering well suited for the rigors of distribution into the environment. Pilobolus, an interesting fungus, points its sporangia toward the sun. This orientation of an organism to light is called phototaxis. Pilobolus ejects its entire sporangium as far as two meters to distribute its spore. Budding and fragmentation are two other methods of asexual reproduction. Budding, which is mitosis followed by an uneven distribution of cytoplasm, is common in yeasts. After budding, an outgrowth of the original cell detaches and matures into a new individual. Survey of the Kingdom Fungi 293 Sexual Reproduction Spore Mycelium The sexual life history of fungi includes the familiar events is unique in fungi. Fungi reproduce sexually when hyphae of two genetically different individuals of the same species encounter each other. In many fungal life cycles, haploid cells (n) from two mating strains will fuse their cytoplasms, plasmogamy, and become dikaryotic (n + n) with two nuclei per cell. Later the nuclei will fuse, via a process called karyogamy, to become diploid (2n) zygotes. Karyogamy is equivalent to fertilization. A generalized life cycle of fungi (fig. 27.2) illustrates four important features of fungi: Hypha Haustorium •• Nuclei of a fungal mycelium are haploid during most of the life cycle. Coenocytic hypha •• Gametes are produced by mitosis and differentiation of haploid stage •• Haploid cells produced by meiosis are not gametes; rather, they are spores that grow into a mature haploid organism. Recall that asexual reproduction produces spores by mitosis. In both cases, haploid spores grow into mature mycelia. Hyphae None of these features of the sexual cycle are unique to fungi, but together they describe the typical fungal life cycle. 13.3 µm Mycelium (b) Classification of Fungi (b)(1) © Micro Discovery/Getty Images; (b)(2) © Hecker/Sauer/AGE Fotostock Figure 27.1 Fungal mycelium. (a) Fundamental elements of fungal structure. (b) This mycelium. (a) Fundamental elements of fungal structure. from modifications of hyphae into varied and specialized reproductive structures often unique to a phylum, genus, or species. The four major phyla of fungi are Chytridiomycota, Ascomycota, Ascomycota, Ascomycota, Mitosis Mitosis Mycelium (n) Spores (n) Figure 27.2 Generalized life cycle of a fungus. 294 EXERCISE 27 27-2. Algal cell wall Hyphae Figure 27.3 Chytrids growing on a freshwater alga. The Chytrid 20 µm © Photographs by H. Cantor-Lund reproduced with permission of Freshwater alga. The Chytrid 20 µm © Photographs by H. Cantor-Lund reproduced with permission of Freshwater alga. the fundamental structure of vegetative mycelia and specialized structures associated with sexual and asexual reproduction. The names of phyla of fungi are derived from sexual reproductive structures (table 27.1). However, each phylum has various modifications for both sexual and asexual reproduction. Colorless chytrids produce hyphae that penetrate the cellulose cell walls of the dinoflagellate Ceratium hirundinella, absorbing organic materials from the alga. Chytrids use these materials to productive Feature of Phyla of Fungi Phylum Key Reproductive Feature PHYLUM CHYTRIDIOMYCOTA (CHYTRIDS) Chytridiomycota (chytrids) Motile spores with flagella Molecular genetic evidence indicates that chytrids may be the most ancient fungi. They are typically aquatic saprobes or parasites on plants, and protists (fig. 27.3). Although they have flagella, considered a nonfungal characteristic, they also have absorptive nutrition and chitinous cell walls and share proteins and nucleic acids common to other fungi. Their distinctive reproductive feature is motile spores with flagella. In some areas, infections by chytrids have significantly reduced the population of many amphibians. Zygomycota (zygote fungi) Resistant zygosporangium as sexual stage Ascomycota (sac fungi) Sexual spores borne internally in sacs called asci Basidiomycota (club fungi) Sexual spores borne externally on club-shaped structures called basidia SAFETY FIRST Before coming to lab, you were asked to read this exercise so you would know what to do and be aware of safety issues. In the safety list the safety safety list the safety set of safety list the safety set of safety list the safety set of safety set of safety list the safety set of safety se issues associated with today's procedures. If you have questions about these issues, contact your laboratory assistant before starting work. Procedure 27.1 Examine a representative of phylum Chytridiomycota 1. Obtain a culture of Allomyces or Chytridium, two common genera of chytrids. 2. Prepare a wet mount and use your microscope to examine chytrid morphology. If necessary, review in Exercise 3 the proper use of a compound microscope. 27-3 Survey of the Kingdom Fungi 295 3. Be prepared to compare chytrid morphology with the morphology common to the other major fungal groups. Question 1 a. Are hyphae apparent? b. Are the cells motile? Sporangium Stolon Sporangiophore Rhizoid Figure 27.4 Vegetative and asexual reproductive structures of Rhizopus, a bread mold. PHYLUM ZYGOMYCOTA (BREAD MOLDS) Zygomycetes (750 species), which include common bread molds, derive their name from resting sexual structures called zygosporangia that characterize the group. Most zygomycetes are saprophytic and their vegetative hyphae lack septa (i.e., they are aseptate). Procedure 27.2 Examine common bread mold 1. Obtain from your instructor a petri dish containing a piece of moldy bread moistened and exposed to air for a few days. 2. Note the velvet texture and various colors of the molds. 3. Use a dissecting microscope to examine the mycelia and notice that they grow as a tangled mass of hyphae. formation), as shown in figure 27.4. Sporangiophores are upright hyphal filaments supporting sporangium, haploid n uclei become spores and are separated by cell walls. These spores are released to the environment when the mature sporangium breaks open. Rhizopus appears dark from the thousands of black sporangia of a growing mycelium; hence, a common name of Rhizopus is black bread mold. Because Rhizopus is black bread mold. Because Rhizopus is black bread mold. Rhizopus was introduced, and on the other side a - strain was introduced. These strains grew toward each other and formed reproductive structures called gametangia where they came into contact. Question 2 a. How many species of mold are on the bread? b. Is pigment distributed uniformly in each mycelium? If not, where is the pigment concentrated in each mold? c. What is the adaptive significance of spores forming on ends of upright filaments), and sporangia (sites of asexual haploid spore 296 EXERCISE 27 ©Dr. Jeremy Burgess/SPL/Science Source Figure 27.5 A sporangium of Rhizopus (a) and its life cycle (b). Hyphae grow and feed on the surface of the bread or other material and produce clumps of erect, sporangium-bearing stalks. If both + and - strains are present in a colony, they may grow together, and their nuclei may fuse to form within a thick, dark structure called a zygosporangium. Meiosis occurs in the zygosporangium, and vegetative haploid hyphae grow from the resulting haploid (n) cells. (a) 667 µm ©Carolina Biological Supply Company/Phototake Asexual reproduction Spores Sporangium +Mating strain MEIOSIS + Hypha - n 2n n+n M Y Zygosporangium PLASMOGAMY KA A OG RY Gametangia (b) Sexual Reproduction in Rhizopus 1. Sexual reproduction begins when hyphae of each strain touch each other (fig. 27.6). 4. A typically massive and elaborate zygosporangium differentiates around the zygotes. Except for the zygotes. Except for the zygotes. Except for the
zygotes. gametangia many nuclei differentiate to serve as gametes from each strain. 5. Soon after the zygosporangium forms, the zyg zygosporangium. 6. The hyphae of the germinating cells break out of the zygosporangium, produce a new generation of mycelia. b. Is Rhizopus reproducing sexually as well as asexually in the same petri dish? How can you tell? Procedure 27.3 Examine Rhizopus 1. Obtain a pure culture of Rhizopus from your instructor. This culture is growing in a sealed petri plate containing nutrient-fortified agar. Do not remove the top of the dish because you may contaminate the culture and unnecessarily release spores into the room. 2. Your instructor has prepared a demonstration slide of Rhizopus stained with lactophenol cotton blue for you to examine. Examine this slide and sketch what you see. 3. Your instructor has also prepared some cultures of Rhizopus (or Mucor, or Phycomyces) for observing the structures formed during sexual reproduction. which the different strains have come in contact. 4. Locate gametangia and zygosporangia in the living culture. 5. Examine a prepared slide of Rhizopus with developed zygosporangia (figs. 27.6 and 27.7). Then observe the zygosporangia where the strains have touched. Be careful not to confuse zygosporangia with dark sporangia on top of sporangiophores. PHYLUM ASCOMYCOTA (SAC FUNGI) Phylum Ascomycota (30,000 species) includes yeasts, some molds, morels, and truffles (fig. 27.8). Its name is derived from a microscopic, sac-shaped, sexual reproductive structure called an ascus. Ascomycetes also reproduce asexually by forming spores called conidia. Modified hyphae called hores partition nuclei in longitudinal chains of beadlike conidia (fig. 27.9). Each conidium contains one or more nuclei. Conidia form on the surface of conidiophores (in contrast to spores that form within sporangia in Rhizopus). When mature, conidia are released in large numbers and germinate to produce new organisms. Aspergillus and Penicillium are common examples of fungi that form conidia. A number of fungal species produce only asexual conidia; these fungi have no known sexual phyla. They were traditionally classified as fungi imperfecti or deuteromycota. Question 3 a. In what structure is the dark pigment of Rhizopus concentrated? ©BiologyImaging.com (a) Zygosporangium (b) ©BiologyImaging.com Figure 27.8 Representatives of Ascomycota. All visible struc- ©Richard H. Gross/Biological Photography Figure 27.7 Sexual conjugation in Rhizopus (200×). 298 EXERCISE 27 tures of fleshy fungi, such as the ones shown here, arise from an extensive network of filaments (hyphae) that penetrate and interweave with the substrate on which they grow. (a) Helvella esculenta is a poisonous ascomycete known as "false morel." Many people have died after mistaking this mushroom for an edible species. (b) A cup fungus in the rain forest of the Amazon Basin. 27-6. Agar Penicillium Conidia Conidiophore © BiologyImaging.com Figure 27.9 Thin section through a sporangium of Aspergillis sp. However, most are likely ascomycetes that have lost their ability to sexually reproduce. Many ascomycetes that have lost their ability to sexually reproduce. in caves near Roquefort-sur-Soulzon, France, gives a unique flavor to Roquefort cheese. Aspergillus oryzae is used to brew Japanese saki and to enrich food for livestock. Procedure 27.4 Examine fungi with conidia 1. Obtain a culture plate of living Aspergillus, Penicillium, or Neurospora. Notice the soft texture of the colonies. 2. Use a dissecting microscope to examine the colonies' hyphae and their reproductive conidia. Note the rounded tufts of these reproductive cells. 3. Conidia are quite small. You will examine them more closely in procedure 27.5 Examine Penicillium 1. Examine them more closely in procedure 27.5 examine the colonies' hyphae and their reproductive cells. 27.10). 2. Notice the formation of conidia. Question 4 What is the relative size of Penicillium hyphae compared with Rhizopus hyphae? 27-7 © BiologyImaging.com Figure 27.10 Penicillium, an ascomycete, growing on agar. Yeasts are common unicellular ascomycetes and include about 40 genera. Most of their reproduction is asexual by cell fission or budding (i.e., the formation of a smaller cell from a larger one). Occasionally, two sexually reproducing yeast cells will fuse to form one cell with two nuclei. This cell functions as an ascus in which syngamy is followed to not form conidia. The yeast used to produce wine and beer is usually a strain of Saccharomyces cerevisiae. The yeasts and other fungi growing naturally on grapes used for making wine may impart a unique flavor to a wine more than does the specific variety of grapes. Procedure 27.6 Examine Saccharomyces, a yeast, and Peziza, a cup fungus 1. Obtain and examine a stock culture of Saccharomyces (fig. 27.11). 2. Prepare a wet mount of the yeast from a culture dispensed by your instructor. Only a small amount of yeast is needed to make a good slide. 3. Review the description of sexual reproduction in cup fungi. 4. Examine a prepared slide of a cross section through the ascocarp of Peziza (fig. 27.12). Locate the asci. Question 5 a. Do you see chains of yeast cells produced by budding? Survey of the Kingdom Fungi 299 Daughter cell (bud) Mother cell ©Richard H. GrossSCIMAT/Science Source Figure 27.11 Budding in the yeast Saccharomyces cerevisiae (500×). 2. Where the hyphae touch, large multinucleate swellings appear (antheridia and ascogonia) and eventually fuse. Haploid nuclei of the two strains intermingle in the swelling (ascogonium). 3. A dikaryotic mycelium grows from this swelling. Each dikaryotic hyphae grow and mingle with monokaryotic hyphae from each parent to form a cup-shaped ascocarp. 5. Dikaryotic cells lining the inside of the ascocarp form sac-shaped asci (sing., ascus). 6. The nuclei fuse (karyogamy) in each ascus to form a zygote in each ascus divides meiotically to produce four haploid (n) nuclei. Each of these nuclei then divides mitotically. These meiotic and mitotic divisions produce a column of eight ascospores in each ascus (400×). b. How is the structure of yeast hyphae different from that of molds? 7. After fusion, meiosis produces four haploid ascospores. 8. Subsequent mitosis produces eight ascospores within each mature ascus. 9. The asci on the surface of the ascocarp rupture and release ascospore can product and what is the difference between dikaryotic and diploid cells? Sexual Reproduction in Ascomycota 1. Sexual reproduction begins with contact of monokaryotic hyphae from two mating strains (fig. 27.13). 300 EXERCISE 27 27-8. Figure 27.13 The sexual life cycle of an ascomycete. Representative ascomycetes include (a) morels and (b) cup fungi, both of which undergo (c) a sexual life cycle including formation of characteristic asci. © BiologyImaging.com (b) (a) © Robert Marien/Corbis/Getty Images Conidia Asexual reproduction Ascospore Each haploid nucleus divides once by mitosis Developing mycelium Conidia Ascogonium Antheridium -Mating strain Ascus + Mating strain MITOSIS n 2n n+n PLASMOG AMY SIS Young ascus) Fully developed ascocarp composed of dikaryotic hyphae and sterile hyphae (c) 27-9 Survey of the Kingdom Fungi 301 © BiologyImaging.com (a) © siloto/Shutterstock (b) (c) © BiologyImaging.com Figure 27.14 Representative basidiomycetes. (a) Fly amanita muscaria). Many species of Amanita are poisonous. (b) A common stinkhorn fungus (Phallus impudicus). (c) Earthstar (Geaster). PHYLUM BASIDIOMYCOTA (CLUB FUNGI) Basidiomycetes (25,000 species) are probably the most familiar fungi (fig. 27.14). They include mushrooms, puffballs, shelf fungi, and economically important plant pathogens such as rusts and smuts. Agaricus campestris is a common field mushroom, and its close relative A. bisporus is cultivated for more than 60,000 tons of food per year in the United States. However, just one bite of Amanita phaloides, the "destroying angel" mushroom, may be fatal. Phylum Basidiomycota derives its name from the characteristic sexual reproductive structure, the basidiomycota derives its name from the characteristic sexual reproduction in Basidiomycota derives its name from the characteristic sexual reproductive structure, the basidiomycota derives its name from the characteristic sexual reproduction in Basidiomycota derives its name from the characteristic sexual reproductive structure, the basidiomycota derives its name from the characteristic sexual reproductive structure, the basidiomycota derives its name from the characteristic sexual reproductive structure, the basidiomycota derives its name from the characteristic sexual reproductive structure, the basidiomycota derives its name from the characteristic sexual reproductive structure, the basidiomycota derives its name from the characteristic sexual reproductive structure, the basidiomycota derives its name from the characteristic sexual reproductive structure, the basidiomycota derives its name from the characteristic sexual reproductive structure, the basidiomycota derives its name from the characteristic sexual reproductive structure, the basidiomycota derives its name from the characteristic sexual reproductive structure, the basidiomycota derives its name from the characteristic sexual reproductive structure, the basidiomycota derives its name from the characteristic sexual reproductive structure, the basidiomycota derives its name from the characteristic sexual reproductive structure, the basidiomycota derives its name from the characteristic sexual reproductive structure, the basidiomycota derives its name from the characteristic sexual reproductive structure, the basidiomycota derives its name from the characteristic sexual reproductive structure, the basidiomycota derives its name from the characteristic sexual reproductive sexual reproductive sexual reproductive sexual reproductive sexual re 1. Haploid hyphae from different mating strains permeate the substrate
(fig. 27.15). 2. Septa form between the nucleus in each cell. 3. Cells of the primary mycelia of different mating strains touch, fuse (plasmogamy), and produce a dikaryotic secondary mycelium. 4. The secondary mycelium grows in the substrate as a tight bundle of hyphae of the secondary mycelium eventually coalesce and protrude above the substrate as a tight bundle of hyphae of the secondary mycelium eventually coalesce and protrude above the substrate as a tight bundle of hyphae of the substrate as a tight bundle of hyphae called a basidiocarp (mushroom). 6. The basidiocarp (mushroom). the sites of sexual reproduction, especially meiosis. 302 EXERCISE 27 8. The two nuclei in each basidiospores are released from the basidiospores. 10. The basidiospores are released from the basidiospores are released from the basidiospores are released from the basidiospores. into a new mycelium. Procedure 27.7 Examine some common mushrooms and their relatives 1. Examine a specimen of an earthstar (Geaster). Earthstars are oddly structured basidiomycetes with an array of support structures shaped much like a star (fig. 27.14c). 2. Examine some mushrooms are familiar examples of the aboveground portions of extensive mycelia permeating the soil. Note the mushroom's stalk and umbrellalike cap (also called the pileus). 3. Find the gills on the undersurface of the cap. Gills are lined with microscopic, club-shaped cells called basidia where sexual reproduction occurs. Phylum Basidiomycota is sometimes called the "club fungi" and derives its name from these characteristic basidia. Procedure 27.8 Examine a prepared slide of gills from the cap of Coprinus, a common mushroom (fig. 27.16). 2. Note the dark basidiospores in rows along the surface of the gills. Interestingly, the gills form perpendicular to the ground and allow spores to free-fall and disperse. Research suggests that gravity influences the orientation of gills. 27-10. Figure 27.15 Mushrooms (a) and their life cycle (b). Coalescing mycelia from compatible strains produce dikaryotic cells fuse, undergo meiosis, and produce basidiospores that germinate into new mycelia. The basidium is the site of karyogamy, which is the fusion of nuclei to form a zygote. © BiologyImaging.com (a) Basidiocarp Gills lined with basidia Basidium n+n Secondary mycelium n KARYOGAMY 2n Zygote PLA SM O Y GA M Basidium MEIO -Mating strain SIS +Mating strain Primary mycelium (monokaryotic) Basidiospores Sterigma (b) Question 7 How many spores would you estimate are present on the gills of a single cap of Coprinus? Remember that a prepared slide shows only a cross section. Gills Basidiospores Basidia © Biology Pics/Science Source Figure 27.16 Gills of the mushroom Coprinus, a basidiomycete (400×). 27-11 Survey of the Kingdom Fungi 303 LICHENS Lichens (25,000 species) are common, brightly colored organisms found on most hard substrates from the tropics to the artic. Trees, rocks, and firm soil provide all the support these slow-growing organisms need. A lichen includes an ascomycete (rarely other fungi) living symbiotically with a photosynthetic alga (a protist) or cyanobacterium. Symbiosis means living in a close and sometimes dependent association. About 26 genera of algae occur in different species. Lichens reproduce asexually by releasing fragments of tissue or specialized, stress-resistant packets of fungal and algal cells. Each of the two components (fungus and alga) may reproduce sexually by mechanisms may continue the lichen association. The durable construction of fungi, linked with photosynthetic algae, enables lichens to proliferate in the harshest terrestrial habitats. Lichens have three basic growth forms: crustose, foliose, and fruticose. The thallus of crustose lichens adhere to their substrate, but some of the thallus peels and folds away from the substrate in small sheets. Fruticose lichens are often sites of ascus formation by the sexually reproducing ascomycete symbiont. Lichens are extremely sensitive to air pollution. This is probably because they are adapted to efficiently absorb nutrients and minerals from the air. This makes lichens particularly susceptible to airborne toxins. Procedure 27.9 Examine lichens 1. Examine the dried lichens on display and note the three basic growth forms: crustose, fruticose, and foliose (fig. 27.17). Question 8 a. What are the advantages of having an alga and a fungus in a lichen? What could each organism contribute to the partnership? b. Would you expect lichens to grow best in rural or urban environments? Why? INQUIRY-BASED LEARNING How effective are antimicrobial properties of common fungi? Observation: Many fungi produce antibiotics that hinder or stop the growth of microbes. These antibiotics are adaptive because they reduce competition and protect the fungus from predators. Question: Do common fungi such as bread mold produce antibiotics are adaptive because they reduce competition and protect the fungus from predators. Worksheet 27 from your instructor. b. Discuss with your group well-defined questions relevant to the preceding observation and question. 304 EXERCISE 27 c. Translate your question into a testable hypothesis and record it. d. Outline on Worksheet 27 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your proposed investigation. e. Conduct your guestions, hypotheses, or procedures, record your data, answer your guestions, hypotheses, or procedures. Repeat your work as needed. 27-12. algal cell (a) reproductive unit fungal hyphae fungal hyphae fungal hyphae sac fungi reproductive cups (b) Crustose lichen @BiologyImaging.com (c) Fruticose lichen 27-13 ©BiologyImaging.com Figure 27.17 Lichen morphology. (a) A section of a compact crustose lichen shows the placement of the algal cells and the fungal hyphae, which encircle and penetrate the alga. (b) Thin sheets of crustose lichens are leaflike. Survey of the Kingdom Fungi 305 Questions for Further Study and Inquiry 1. Mushrooms often sprout from soil in rows or circles commonly called "fairy rings." How would you explain the shapes of these formations? 2. What advantages does asexual reproduction? 3. Does dominance of the haploid condition in a fungal life cycle offer an adaptive advantage? Why or why not? 4. Compare and contrast the structure of a fungal mycelium with the structure of a filamentous alga. 5. What is the advantage of maintaining a dikaryotic condition rather than immediate nuclear fusion? 6. In fungi, the only distinction between a spore and a gamete is function. Explain. 7. Describe three ways that fungi affect your life. 8. What are the major differences in the four phyla of fungi? 9. Draw and label a life cycle for one fungal phylum. 10. What products or activities by fungi benefit other organisms? What products or activities of fungi are harmful to other organisms? DOING BIOLOGY YOURSELF Wine-making is a multimillion-dollar industry, but the biology of wine-making is simple. Make your own special brand of wine by following the instructions in Exercise 12. Good luck! 306 EXERCISE 27 WRITING TO LEARN BIOLOGY Compare and contrast the fundamental life cycle of a fungus with that of plants and animals. When does meiosis occur in the sequence of events? Which stages are haploid and which are diploid? 27-14. Survey of the Plant Kingdom Liverworts, Mosses, and Hornworts of Phyla Hepaticophyta, Bryophyta, and Anthocerophyta E XER CISE 28 Learning Objectives By the end of this exercise you should be able to: 1. Describe the distinguishing features of bryophytes. 2. Describe the distinguishing features of bryophytes. 2. Describe the distinguishing features of bryophytes. 2. Describe the life histories and related reproductive structures of bryophytes. 2. Describe the distinguishing features of bryophytes. that allow liverworts, mosses, and hornworts to live on land. 4. Describe the role of bryophytes in the environment. Please visit connect.mheducation.com to review online resources tailored to this lab. P lants evolved from a freshwater green algal species more than 550 million years ago and today comprise a remarkably diverse group of multicellular organisms. With few exceptions, plants are autotrophic, contain chlo rophyll a, and have cell walls containing cellulose. Life cycles of all members of the plant kingdom are varia tions on alternation of generations. Be sure to review in your textbook this generalized life c ycle and be familiar with the major stages presented in f igure 28.1. In this and upcoming exercises, you'll learn how various modifica tions of this generalized life cycle characterize all of the phyla that comprise the plants: Phylum Example Hepaticophyta liverworts Bryophyta mosses Anthocerophyta hornworts Pterophyta ferns Lycophyta club mosses Cycadophyta cycads Ginkgophyta Ginkgo Coniferophyta conifers Gnetophyta gnetophytes Anthophyta flowering plants These groups of plants are distinguished by morphology, life cycle, and the presence or absence of vascular tissues (fig. 28.2). Pay special attention to variations in each of these characteristics as you survey the plant kingdom in upcoming weeks. Bryophytes include liverworts, mosses, and horn worts and are the most primitive group of terrestrial plants. 28-1 Gametophyte (n) MITOSIS Spore n Sperm n n n Egg Spores MEIOSIS n FERTILIZATION 2n 2n Spore mother cell 2n Zygote Spores MEIOSIS n FERTILIZATION 2n 2n Spore mother cell 2n Zygote Spores MEIOSIS n FERTILIZATION 2n 2n Spore mother cell 2n Zygote Spores MEIOSIS n FERTILIZATION 2n 2n Spore mother cell 2n Zygote Spores MEIOSIS n FERTILIZATION 2n 2n Spore mother cell 2n Zygote Spores MEIOSIS n FERTILIZATION 2n 2n Spore mother cell 2n Zygote Spores MEIOSIS n FERTILIZATION 2n 2n Spore mother cell 2n Zygote Spores MEIOSIS n FERTILIZATION 2n 2n Spore mother cell 2n Zygote Spores MEIOSIS n FERTILIZATION 2n 2n Spore mother cell 2n Zygote Spores MEIOSIS n FERTILIZATION 2n 2n Spore mother cell 2n Zygote Spores
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cycle, gametophytes, which are haploid (n), alternate with sporophytes, which are diploid (2n). Antheridia (male) and archegonia (female) are the sex organs produce the first diploid cell of the sporophyte generation, the zygoteential (male) are the sex organs produce the first diploid (2n). Meiosis occurs within sporangia, which are the spore-producing organs of the sporephyte. The resulting spores are haploid and are the first cells of the gametophytes do not gen erally possess specialized vascular tissues, which transport materials between roots and shoots. This lack of developed vascular tissues in bryophytes typically limits their distribution to moist habitats because their rhizoids neither penetrate the soil very far nor absorb many nutrients. Also, the lack Survey of the Plant Kingdom 307 Streptophytes Land plants (kingdom Plantae) (embryophytes) Vascular plants (tracheophytes) Seed plants (spermatophytes) 248 Ordovician Millions of years ago (mya) PALEOZOIC Silurian Angiosperms Flowers, fruits, endosperm in seeds Permian Carboniferous Pteridophytes Seedless vascular plants Lycophytes Mosses Liverworts Complex streptophyte algae MESOZOIC 65 Simple streptophyte algae 0 Chlorophyte green algae CENOZOIC Green algae Kernworts Bryophytes (nonvascular plants) Ovules, pollen, seeds, euphylls, wood 354 417 Lignin in walls of water-conducting cells; cutin common on plant surfaces; dominant sporophyte generation; true roots, stems, leaves 443 490 Cambrian 543 PROTEROZOIC Sporic life cycle, embryo, sporopollenin-walled spores, tissue-producing apical meristem, gametangia, sporangia Plasmodesmata, plant-specific features of cell division, sexual reproduced in plastidsmodesmata, plant-specific features of cell division, sexual reproduced in plastidsmodesmata, plant-specific features of cell division, sexual reproduced in plastidsmodesmata, plant-specific features of cell division, sexual reproduced in plastidsmodesmata, plant-specific features of cell division, sexual reproduced in plastidsmodesmata, plant-specific features of cell division, sexual reproduced in plastidsmodesmata, plant-specific features of cell division, sexual reproduced in plastidsmodesmata, plant-specific features of cell division, sexual reproduced in plastidsmodesmata, plant-specific features of cell division, sexual reproduced in plastidsmodesmata, plant-specific features of cell division, sexual reproduced in plastidsmodesmata, plant-specific features of cell division, sexual reproduced in plastidsmodesmata, plant-specific features of cell division, sexual reproduced in plastidsmodesmata, plant-specific features of cell division, sexual reproduced in plastidsmodesmata, plant-specific features of cell division, sexual reproduced in plastidsmodesmata, plant-specific features of cell division, sexual reproduced in plastidsmodesmata, plant-specific features of cell division, sexual reproduced in plastidsmodesmata, plant-specific features of cell division, sexual reproduced in plastidsmodesmata, plant-specific features of cell division, sexual reproduced in plastidsmodesmata, plant-specific features of cell division, sexual reproduced in plant-specific features of cell division, sexu 2500 Common protist ancestor KEY Critical innovations (a) © Roland Birke/Phototake; (b) © Pavel Skaloud; (c) © Lee W. Wilcox; (d) © Lee W. Wilcox; (e) © Lee ©William Manning/Corbis; (1) ©WILDLIFE GmbH/Alamy Stock Photo Figure 28.2 The evolutionary history of plants. The evolution of plants to successfully invade a variety of terrestrial habitats. Land plants gradually evolved several important adaptations, including protected multicellular embryos that enabled plants to successfully invade a variety of terrestrial habitats. adaptations that enabled them to thrive in terrestrial habitats. Streptophyte algae refers to those algal species with specific features in common with land plants. of vascular tissues, are often absent, bryophytes are relatively small and inconspicuous. Despite their diminutive size, however, bryophytes occur throughout the world in habitats ranging from the tropics to Antarctica. 308 EXERCISE 28 There are approximately 24,000 species of bryo phytes, more than any other group of plants except the flowering plants. Bryophytes fix CO2, degrade rocks to soil, stabilize soil, and reduce erosion. Humans have used bryophytes in a number of ways, including as a fuel, in the production of Scotch whiskey, and as packing materials. In 28-2 many terrestrial ecosystems, bryophytes reduce the leaching of nitrogen and other nutrients from the soil. The plant body of bryophytes is called a thallus (pl., thalli). Liverwort thalli are flattened dorsoventrally (from back and front plane, rather than from side to side plane) and are bilaterally symmetrical (i.e., have two equal halves). For comparison, moss thalli are erect and radially symmetrical (i.e., have two equal halves). alternation of generations that includes both gametophyte and sporophyte (from fertilized egg) (2n) SPOROPHYTE (2n) Meiosis GAMETOPHYTE (n) Fertilization Spores Archegonium containing egg (n) Archegoniophore Female gametophytes (n) (fig. 28.3). Bryophytes have multicellular sex organs that produce swimming, biflagellate sperm. Bryophytes require free water—usually provided as rain or dew—for sexual reproduction because their sperm must swim to eggs. These sperm fertilize eggs produced in archegonium to produce the sporophyte, which remains attached to and nutritionally dependent on the gametophyte. The mature sporophyte produces haploid spores (via meiosis), each of which can develop into a gametophyte. Some bryophytes have a sperm-delivery system that improves their rate of sexual reproduction. For example, fertile moss plants produce scented compounds that attract tiny insects such as mites and springtails; sperm can attach to these insects as the wade through dew on these plants. When the insects are lured to another moss plant by its scent, the insects deliver the hitchhiking sperm and, in the process, increase the rate of fertilization. Before continuing this exercise, review figure 28.1; be sure you understand the ploidy (i.e., haploid versus diploid) of the gametophyte and sporophyte generations of the life cycle. PHYLUM HEPATICOPHYTA: LIVERWORTS Liverworts are the earliest land plants. Although many liv erworts are "leafy," we will restrict our observations to a thallus-type liverwort, Marchantia. The gametophytic thal lus of this liverwort grows as a large, flat, photosynthetic structure on the surface of the ground (fig 28.4). Liverwort Gametophyte Procedure 28.1 Examine the thallus of Marchantia Antheridiophore Gemma 1. Observe some living Marchantia and note the Y-shaped (dichotomous) growth. Rhizoids extend downward from the lower (ventral) surface of the thallus. gametophyte (n) Thallus Figure 28.3 Life cycle of Marchantia, a liverwort. During sexual reproduces antheridia, each of which produces many sperm. After fertilization, the sporophyte develops within the archegonium and produces a capsule with spores. Marchantia reproduces asexually by fragmentation and gemmae. 28-3 Question 1 What are the functions of rhizoids? 2. View the upper (dorsal) surface of the thallus with a dissecting microscope and note the pores in the center of the diamond-shaped areas. Obtain a prepared slide of a thallus of Marchantia and locate a pore in cross sec tion. These pores in the dorsal surface of the Plant Kingdom 309 ©Ed Reschke/Getty Images (a) (b) ©Ed Reschke/Getty Images Figure 28.4 Marchantia. The flat, leafy thallus of this liverwort grows close to the ground. (a) A thallus bearing upright male reproductive structures called archegoniophores (4×). Question 2 What is the function of these pores? 3. Gently return the living materials to their containers. Asexual Reproduction in Liverworts can reproduce asexually via fragmentation. In this process, the older, central portions of the thallus die, leaving the growing tips isolated to form individual plants. Structures called gemmae cups occur on the dorsal (upper) surface of some thalli near the midrib (fig. 28.5). Gemmae cups represent another means of asexual reproduc tion by liverworts. Inside the gemmae cups are lens-shaped outgrowths called gemmae (sing., gemma), which are splashed out of the cup by falling drops of rain. If a gemma lands in an adequate environment, it can produce a new gametophyte plant. Examine a prepared slide of gemmae cups. Also examine available live or preserved material. In the follow ing space, diagram and label what you see, and compare it to figure 28.5. Sexual Reproduction in Liverworts female plants that bear archegonia. Each flask-shaped arche gonium consists of a neck and a venter, which contains the egg (fig. 28.6a). Antheridiophores are specialized stalks on male plants that bear antheridia (fig. 28.4). Sperm form in antheridia (fig. 28.6b). Flagellated sperm are released and washed from the venter. The zygote remains in the venter and grows into a sporophyte plant. Procedure 28.2 Examine archegonia and antheridia of liverworts 1. Examine living or prepared liverworts having mature arche goniophores that bear archegonia. Archegonia at various stages of development are located on the ventral surface. 2. Locate an egg in an archegonia. Archegonia at various stages of development are located on the ventral surface. smaller but greater in number. 3. Examine living or preserved liverworts with mature antheridiophores bearing antheridia. 4. Examine a prepared slide of cross sections of an antheridiophore. Antheridia are located just below the upper surface of the disk in a chamber that leads to the surface of the disk through a pore. Question 3 How do the positions of the archegonium and antheridium relate to their reproductive function? Many species of Marchantia are dioecious, meaning that they have separate male and female plants. Gametes from each plant are produced in specialized stalks on 310
EXERCISE 28 28 4 Gemmae ©M. I. Walker/Science Source (a) © BiologyImaging.com (b) Figure 28.5 (a) Gemmae cups ("splash cups") containing gemmae on the gametophytes, each identical to the parent plant that produced it by mitosis (5×). (b) Longitudinal section of a gemmae cup (10×). Neck Archegonium Venter ©Ed Reschke Egg ©Ed Reschke (a) Antheridia (90×). 5. Return materials and slides to their containers. Liverwort Sporophyte of Marchantia. The nonphotosynthetic sporophyte of liverworts 1. Examine a prepared slide of a sporophyte by a structure called the foot. Spores 28-5 are produced by meiosis in a capsule located on a seta (stalk) that extends downward from the foot (fig. 28.3). 2. Locate elongate cells called elaters among the spores. Elaters help disperse spores by twisting. In humid con ditions the elaters expand, pushing the spores apart and rupturing the spore case to release the spores. 3. Gamete release, fertilization, spore release, and germi nation are most efficient in individually specific envi ronmental conditions. Survey of the Plant Kingdom 311 Question 4 a. What is the function of the foot? Sperm Gametophytes Male Egg b. Are the spores to moisture? Bud Rhizoid MITOSIS Mosses are often more visible than liverworts because of their greater numbers and more widespread distribution and because gametophyte plants of mosses are leafy and usu ally stand upright. Mosses also withstand desiccation better than do liverworts. The moss gametophyte is radially symmetrical and is the most con spicuous phase of the moss on display called Polytrichum (fig. 28.8). The "leafy" green portions of the moss are the gametophytes and are often only one cell thick (except at the midrib). 2. Make a wet mount of a single leaflet and examine it with low magnification. Question 5 a. How many cells thick is the leaflet? S I ON MITOSIS 2n Capsule Mature sporophyte EI O SI RT I AT Zygote n M PHYLUM BRYOPHYTA: MOSSES Female Calyptra Spores FE Z LI Sporangium Parent gametophyte Developing sporophyte in archegonium 2n n Figure 28.7 Moss life cycle. Haploid (n) sperm are released from antheridia on the male gametophytes. The sperm then swim through water to the archegonia and down their necks to fertilize the eggs. The resulting diploid (2n) zygote develops into a diploid sporophyte. The sporophyte grows out of the archegonium and differentiates into a slender seta with a swollen capsule at its apex. The capsule is covered with a cap, or calyptra, formed from the archegonium. The spores germinate, giving rise to gametophytes intially grow along the ground. Ultimately, bud produce leafy gametophytes. c. Are pores visible on the leaf surface? d. How does the symmetry of a moss gametophyte compare with that of a liverworts? In what ways are they different? 312 EXERCISE 28 28-6 Sporangium Operculum Sporophyte (2n) Sporophyte (2n Although moss sporophytes may be green and perform a limited amount of photosynthesis when they are immature, they are soon completely dependent, in a nutritional sense, on the gametophytes have specialized cells that aid in the absorption and retention of water. Mats of moss act, in effect, like sponges. The following procedure demonstrates the water-absorbing potential of mosses. Procedure 28.5 Water absorption by moss 1. Weigh 3 g of Sphagnum, a peat moss, and 3 g of paper towel. 2. Add the moss and towel to separate beakers each con taining 100 mL of water. 3. After several minutes, remove the materials from the beaker. 4. Measure the amount of water left in each beaker by pouring the water into a 100-mL graduated cylinder. Remember that 1 mL of water weighs 1 g. 5. Record your data. c. Why is Sphagnum often used to ship items that must be kept moist? 6. Return all materials to their containers and clean your work area. Asexual Reproduction in Mosses Unlike liverworts, mosses lack structures such as gemmae for asexual reproduction. Mosses reproduce asexually by fragmentation. Sexual Reproductive structures are on separate individuals). Archegonia or antheridia are borne either on tips of the erect gametophyte stalks or as lateral branches on the stalks. The apex of stalks of the female plant (the plant that bears arche gonia) appears as a cluster of leaves, with the archegonia buried inside. Procedure 28.6 Examine archegonia and antheridia of mosses 1. Examine living or preserved mosses having mature archegonia. 28-7 Survey of the Plant Kingdom 313 Sperm Archegonium Neck canal Antheridium Venter Egg Courtesy G.S. Ellmore Figure 28.9 A longitudinal section through the tip of a male gametophyte of a moss (45×). 2. Examine a prepared slide of moss archegonium. When the archegonium matures, cells lining the neck disintegrate and form a canal leading to the egg. Sperm, following a chemical attractant released by the archegonium, swim through this canal to reach the egg. Moss Sporophyte sonsist of capsules located atop stalks, called setae, that extend upward from the moss gametophyte (fig. 28.8a). A sporophyte is attached to the gametophyte by a structure called a foot. Question 9 Is the sporophyte more prominent in mosses or liverworts? Question 7 Where is the egg located in the archegonium? 3. Examine living or preserved mosses having mature antheridia. The male plant (i.e., the plant that bears antheridia) has a platelike structure on the tip with the "leaves" expanding outward to form a rosette. This structure is sometimes called a "moss flower" because of its appearance or a "splash cup" because of its func tion (i.e., the dispersal of sperm by falling raindrops). 4. Examine a prepared slide of moss antheridia, which appear as elongate, saclike structures (fig. 28.10). 5. Locate the outer sterile jacket and the inner mass of cells destined to become sperm. Question 8 Are sperm haploid or diploid? 314 EXERCISE 28 The capsule atop the seta is covered by the hoodlike calyptra, which is the upper portion of archegonium that covers the apex of the capsule are numerous hap loid spores formed by meiosis. Question 10 What is the adaptive significance of the seta of the spore phyte growing well above the mat of the gametophytes? If enough living moss is available in the lab, remove the calyptra from a sporophyte capsule. On the tip of the capsule. On the tip of the lidlike structure. These teeth help control the release of spores from the capsule. In wet weather these teeth bend inward and prevent release of the spores. In dry weather they bend outward, facilitating distribution of spores released. Question 11 a. What process produces spores? b. Is the capsule haploid or diploid? Moss spores germinate and form a photosynthetic protonema, which resembles a branching, filamentous alga. Leafy moss plants arise from "buds" located along the protonema. Question 12 Can you think of any evolutionary implications of the similarity between a moss protonema. ANTHOCEROPHYTA: HORNWORTS The hornworts are the smallest group of bryophytes; there are only about 100 species in six genera. Hornworts have several features that distinguish them from most other bryo phytes. The sporophyte is shaped like a long, tapered horn that protrudes from a flattened thallus. Also, archegonia are not discrete organs. Rather, they are embedded in the thallus and are in contact with surrounding vegetative cells. ©Daniel Vega/Getty Images Figure 28.11 Anthoceros, a hornwort sporophytes of hornwort sporophytes of hornwort sporophytes. The most familiar hornwort is Anthoceros. Locate the gametophyte stending from its lower surface. Spores are produced in the horn of the sporophyte. If prepared slides are available, locate spores in various stages of development within the sporophyte. ORGANIZING WHAT YOU'VE LEARNED Go to page 354, which follows Exercise 31. Complete the portions of the table that refer to the phyla you studied in today's lab. INQUIRY-BASED LEARNING What are the roles of bryophytes in the environment? Observation: Although they are usually overlooked, bryophytes often grow in places that other plants cannot grow and are important parts of many ecosystems. Find a place where bryophytes are growing on campus. Consider what these plants are best suited for the growth of bryophytes? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 28 from your instructor. b. Discuss with your group's best question for investigation. 28–9 c. Translate your question into a testable hypothesis and record it. d. Outline on Worksheet 28 your experimental design and supplies needed to test your hypothesis. Ask your instructor any revisions to your question, and make relevant comments. f. Discuss with your instructor any revisions to your question, and make relevant comments. tions, hypotheses, or procedures. Repeat your work as needed. Survey of the Plant Kingdom 315 Questions for Further Study and Inquiry 1. Compare and contrast the complexity of bryophytes and algae regarding their morphology, habitat, asexual reproduction, and sexual reproduction. 2. What event begins the sporophyte phase of the life cycle? Where does this event occur in liverworts and mosses? 4. What features distinguish a moss from a liverwort? 5. Diagram the life cycle of a liverwort? 5. Dia life cycle of a moss, indicating which stages are sporophytic and which are gametophytic. Also indicate where meiosis and syngamy occur. 7. How did liverworts play in the environment? 9. Is the sporophyte of mosses ever independent of the gametophyte? Explain. 10. Why do you think that bryophytes are sometimes referred to as the amphibians of the plant kingdom? 11. What limits the height of mosses? DOING BIOLOGY YOURSELF Liverworts and mosses from two or three sites. Bring the collection to class and compare yours with those of other students. Use reference books in your lab or library to identify the plants that you've collected. 316 EXERCISE 28 WRITING TO LEARN BIOLOGY Because water is required for the swimming sperm to reach the archegonium, would you say that this
means that bryophytes are not truly land plants? Why or why not? 28-10 Survey of the Plant Kingdom Seedless Vascular Plants of Phyla Pterophyta and Lycophyta E XER CISE 29 Learning Objectives By the end of this exercise you should be able to: 1. Discuss similarities and differences between ferns and other plants you have studied in the lab. 2. Describe the life cycles of ferns and their allies. 3. Describe the distinguishing features of true ferns, club mosses, whisk ferns, and horsetails. 4. Name some roles of ferns and fern allies. Please visit connect.mheducation.com to review online resources tailored to this lab. S eedless vascular plants include two phyla of nonflowering plants include two phyla of nonflow whisk ferns, and horsetails) and phylum Lycophyta (club mosses) (table 29.1). The life cycle of seedless vascular plants includes both gametophyte and sporophyte phases, but in Table 29.1). The life cycle of seedless vascular plants includes both gametophyte and sporophyte phases, but in Table 29.1). homosporous (a few heterosporous) vascular plants. Sperm motile. External water necessary for fertilization. Leaves are megaphylls that uncoil as they mature. Sporophytes and virtually all gametophytes photosynthetic. About 365 genera. 11,000 Horsetails Homosporous vascular plants. ribbed, jointed, either photosynthetic or nonphotosynthetic. Leaves scalelike, in whorls, nonphotosynthetic at maturity. One genus (Equisetum). 15 Whisk ferns Homosporous vascular plants. Sperm motile. External water necessary for fertilization. No differentiation between root and shoot. No leaves; one of the two genera has scalelike enations and the other leaflike appendages. 6 Club mosses Homosporous or heterosporous vascular plants. Sperm motile. External water necessary for fertilization. Leaves are microphylls. About 12-13 genera. 1275 Lycophyta 29-1 Survey of the Plant Kingdom 317 contrast to bryophytes (Exercise 28), in this group the sporophyte is the dominant phase (fig. 29.1). The sporophyte is the conspicuous adult stage in the life cycle of seedless vascular plants. All ferns and fern allies possess sporophylls (mega = large, -phyll = leaf) with several to many veins (aspect of seedless vascular plants. All ferns and fern allies possess sporophylls (mega = large, -phyll = leaf) with several to many veins (aspect of seedless vascular plants. All ferns and fern allies possess sporophylls (mega = large, -phyll = leaf). in the megaphylls of true ferns), or they may be smaller microphylls (micro = small, -phyll = leaf) with one vein (as in whisk ferns, scouring rush, and club mosses). Sporangia occur somewhere on all Antheridium Archegonium Rhizoids Archegonium Egg Sperm Gametophyte (Prothallium) MITOSIS Antheridium Spores FE MEI OSI IL RT TIO IZA S N n Zygote 2n n 2n Underside of leaf frond Mature frond Leaf of young sporophyte Embryo 2n Adult sporophyte The haploid gametophyte (i.e., the prothallium) grows in moist places. Rhizoids are anchoring structures that project from the lower surface of a prothallium. Eggs and sperm develop in archegonia and fertilize the single egg. The zygote -the first cell of the diploid sporophyte g eneration—starts to grow within the archegonium and eventually becomes much larger than the gametophyte. Most ferns have horizontal stems, called rhizomes, that grow below the ground. On the sporophyte g eneration—starts to grow within the archegonium and eventually becomes much larger than the gametophyte. When released, the spores germinate and become new gametophytes called prothallia. 318 EXERCISE 29 29-2 plants. In ferns, the sporangia are on the backs of leaves; this is why the leaves are called sporophylls (fig. 29.2). Like bryophytes, ferns require water for fertilization. b. What are the primary functions (e.g., support, transport, photosynthesis, reproduction) of the major organs shown in fig. 29.1? Ouestion 1 a. Like bryophytes, ferns require water for fertilization. Why? Explain your answer. PHYLUM PTEROPHYTA (FERNS) (a) © BiologyImaging.com True ferns (phylum Pterophyta) inhabit almost all types of environments and possess characteristics of the more advanced staghorn ferns. Tree ferns reach heights of up to 16 m. Along with other plants, these ferns once formed forests that were transformed into coal deposits. Today, humans use ferns as decorations and to grow rice. Review the fern life cycle shown in figure 29.1. Question 2 a. Which parts of the life cycle are haploid? (b) © BiologyImaging.com b. Which are diploid? c. What is the role of the gametophyte in ferns? (c) © BiologyImaging.com Figure 29.2 Fern sporangia. Most ferns, such as the Japanese holly fern (Crytomium falcatum), each sorus is covered by a flap of leaf tissue called an indusium (also see fig. 29.3). (b) Other ferns bear uncovered sori, as shown here in the autumn fern (Dryopteris erythrosora). (c) In still other ferns, as in the maidenhair fern (Adiantum tenerum), sori are enfolded by the edge of the frond itself. 29–3 d. How is this different from that of the gametophyte in bryophytes? Survey of the Plant Kingdom ferns, how does the size of the gametophyte compare with that of the sporophyte? Frond f. How does this compare with bryophytes, and why is this important? Sporangia Indusium © BiologyImaging.com Fern sporophytes grow indefinitely via underground stems called rhizomes (fig. 29.1). Examine the fern rhizomes on display. Also examine the different ferns available in the lab and note the different shapes of the leaflike fronds. Identify the stalk, blade, and pinnae? d. Rhizomes are involved in the asexual reproduction of ferns. How could this happen? Groups of sporangia called sori (singular = sorus) form on the underside of fern fronds (fig. 29.3), a specialized outgrowth of a frond. Meiosis in the sporangium produces haploid spores, the first stage of the gametophyte. Figure 29.3 Fern sorus (20×). In most ferns, sori are on the undersides of leaves. Question 4 Are any spores in the sporangium? Be careful when handling acetone as few drops of acetone as few minutes, adding a needed. 4. Describe what you see. Question 5 a. Did the application of acetone cause the spores of the fern to disperse? b. How is the mechanism for spore the sorus. 320 EXERCISE 29 5. Examine prepared slides of fern sori, referring to figure 29.3. Diagram and label each structure that you see, listing its function. 29-4 Fern Reproduction When conditions are favorable, fern spores germinate and form a threadlike protonema. prothallium ("valentine plant"). Leaf of young sporophyte Question 6 a. Is the prothallium haploid or diploid? Rhizoid b. Is the prothallium sporophyte or gametophyte? archegonia mature at different times. Globe-shaped antheridia form first, followed by archegonia are vase-shaped and are located near the cleft of the heart-shaped prothallium. After producing sperm, antheridia drop off, leaving sperm to swim to the archegonia and antheridia form first, followed by archegonia and antheridia 1 Observe archegonia and antheridia (see fig. 29.1) on prepared slides. 2. Observe archegonia and antheridia on a living prothallium. Root Figure 29.4 Young fern sporophyte break through the soil in a coiled position called a fiddlehead (fig. 29.5). The fiddlehead then unrolls to display the frond, a single leaf. Fiddleheads are considered a culinary delicacy in some parts of the world. Most terrestrial ferns are homosporous; this means that they produce so that develops into a single leaf. and archegonia (see fig. 29.1). Conversely, aquatic ferns such as Question 7 a. What is the adaptive significance of having sperm and egg produced at different times? The zygote develops in the archegonium and is nutritionally dependent on the gametophyte for a short time (fig. 29.4). Soon thereafter, the sporophyte becomes leaflike and crushes the prothallium. 29-5 © BiologyImaging.com Figure 29.5 A fiddlehead of a tropical tree fern. Survey of the Plant Kingdom 321 Salvinia and Azolla are heterosporous, meaning that they produce two types of spores megaspores and microspores. (You will learn more about heterospory in Exercise 30.) A megaspore forms a gametophyte with only archegonia, and a microspore forms a gametophyte with only archegonia. Examined earlier? WHISK FERNS (a) Source: Larry Allain/National Wetlands Research Center USGS (b) © Biology Imaging.com Whisk ferns are close relatives: Psilotum has a widespread distribution, whereas Tmesipteris is restricted to the South Pacific. Psilotum lacks leaves and roots and is homosporous. Procedure 29.3 Examine a prepared slide of a Psilotum plants in the lab. Question 9 a. How would you describe the branching pattern of Psilotum? Figure 29.6 (a) Salvinia and (b) Azolla are ferns that grow in aquatic habitats. b. Are any roots present? c. Are any leaves present? d. Where are the sporangia? e. Where does photosynthesis occur in Psilotum? © William Ormerod/Encyclopedia/Corbis Figure 29.7 Whisk ferns (Psilotum sp.) are so called because their branching pattern gives the impression of a whisk broom. The stems bear lobed sporangia (fig. 29.8). 322 EXERCISE 29 29-6 Question 10 a. Where are the leaves? Spores b. What part of the plant is photosynthetic? Sporangium c. Which part of the life cycle of Equisetum is dominant, the sporophyte or gametophyte? © BiologyImaging.com Figure 29.8 Psilotum sporangium (18×). HORSETAILS Equisetum (also called scouring rush) is the only extant genus of horsetails, another small but distinctive group of ferns (fig. 29.9). Equisetum is an example of a plant whose vegetative structure: Equisetum is distinguished by its jointed and ribbed stem. Examine the living Equisetum plants available in lab. Feel the ribbed stem of an Equisetum plant. Its rough texture results from siliceous deposits in its epidermal cells. During frontier times, Equisetum was used to clean pots and pans, sand wooden floors, and scour plowshares, thus accounting for its common name of "scouring
rush." Strobili of Equisetum occur at the tips of reproductive stems. Within a strobilus, sporangia form atop umbrellalike modified branches called sporangiophores. Elaters in sporangia of Equisetum help disperse spores. Examine prepared slides of Equisetum strobili (fig. 29.10). Diagram, label, and state the function of each major structure composing the strobilus. Question 11 How do elaters aid in the dispersal of spores? PHYLUM LYCOPHYTA CLUB MOSSES © Stuart Wilson/Science Source Figure 29.9 Scouring rush, Equisetum telmateia, of the phylum Pterophyta. This species forms two types of erect stems, a green, photosynthetic type and a brownish type terminating in sporeproducing cones. The spores produced by meiosis in the cones give rise to a single kind of tiny, green, nutritionally independent gametophyte. 29-7 During the Devonian and Carboniferous periods (300-400 million years ago), club mosses, whisk ferns, and scouring rush were among the dominant plants on earth. Indeed, most of our coal deposits consist largely of these plants. are relatively small compared to their giant ancestors. Club mosses (phylum Lycophyta) possess true roots, stems, and leaves. Most asexual reproduction by club mosses occurs via rhizomes. If one is available, locate the rhizome on a Lycopodium, a club moss. Study the aboveground portion of the Lycopodium plant (fig. 29.11). Lycopodium is evergreen, as are some ferns, most gymnosperms, and some angiosperms. Survey of the Plant Kingdom 323 Sporangia at the tips of reproductive stems. (b) Cross-section of a strobilus showing spores within sporangia at the tips of sporangiophores (20×). b. How is a rhizome different from a rhizoid? c. Does the rhizome have leaves? e. What are the shape and size of the leaves? e. What is the significance of the leaves? e. What is the significance of the leaves? e. What is the significance of the leaves? e. What are the shape and size of the leaves? e. What is the significance of the leaves? e. What are the shape and size of the leaves? e. What is the significance of the leaves? e. What is the significance of the leaves? e. What are the shape and size of the leaves? e. What is the significance of the leaves? e. What are the shape and size of the leaves? e. What are the shap of Lycopodium obscurum, a club moss. Question 12 a. How could a rhizome be involved in asexual reproduction? 324 EXERCISE 29 f. Is a midvein visible? g. What does the term "evergreen" mean? 29-8 3. Examine prepared slides of spores of Lycopodium as well as those available on plants growing in the lab. Sketch what you see. Spores Sporangia Question 13 a. How many sporangia occur on each sporophyll? Sporophyll? Sporophyll? Sporophyll? Sporophyll b. Can you see why spores of Lycopodium are sometimes called "vegetable sulfur"? © BiologyImaging.com Figure 29.12 Sporophyll and sporangia of Lycopodium. a club c. Why are the spores a good dry lubricant? moss (15×). h. Is being evergreen a good characteristic for classifying plants? Why or why not? Sporangia of Lycopodium occur on small modified leaves called sporophylls clustered in strobili (cones) that form at the tips of branches. Species with these cones probably shared common ancestry with the familiar cone- bearing gymnosperms such as pine (Pinus) (see Exercise 30). d. Which is the dominant part of branches. the Lycopodium life cycle, the sporophyte or gametophyte? 4. Examine living Selaginella plants (fig. 29.13). Many species of Selaginella produce two types of strobili, Procedure 29.4 Examine strobili on a living Lycopodium plant. Also examine prepared slides of strobili of Lycopodium (fig. 29.12). 2. Diagram, label, and state the function of each major feature of the strobilus. © BiologyImaging.com Figure 29.13 Selaginella, a club moss. 29-9 Survey of the Plant Kingdom 325 typically red and yellow. If strobili are present, examine spores derived from these cones. 5. Examine hydrated and dehydrated resurrection plants (Selaginella lepidophylla). Question 14 a. Are spores of Selaginella similar in size? b. What is this condition called? ©blickwinkel/Alamy Stock Photo Figure 29.14 Quillworts (Isoetes) are so-named because of their c. What is the functional significance of the difference in the appearance of dehydrated and rehydrated and rehydrated Selaginella? d. Can you see why these plants are sometimes referred to as "resurrection plants"? e. How does the formation of strobili in Equisetum compare with that in Lycopodium and Selaginella? narrow, quill-like leaves. Most quillwort, is an aquatic or semi-aquatic lycopod that usually grows in clear ponds and slow-moving streams. At the branching points along the stem of Isoetes, you'll see an unusual runnerlike organ. These proplike axes are called rhizophores and have structural features that are intermediate between stems and roots. Procedure 29.5 Examine Isoetes 1. If available, examine living Isoetes (quillwort) plants (fig. 29.14). 2. Compare and contrast the following features of Isoetes with Lycopodium and Selaginella: • Shape of aerial portion of plant • Shape, size, and arrangement of leaves ORGANIZING WHAT YOU'VE LEARNED Go to page 354, which follows Exercise 31. Complete the portions of the table that refer to the phyla you studied in today's lab. Also, to review the structures and characteristics of seedless vascular plants, complete table 29.2 on the next page. 326 EXERCISE 29 29-10 Table 29.2 Summary of the Structures Common to Seedless Vascular Plants Plant Structure Sporophyte or Gametophyte Function Prothallium Pinna Spore Frond Annulus Sporangium Antheridium Archegonium Microspore Megaspore Microphyll Megaphyll INQUIRY-BASED LEARNING What happens during the "resurrection" of a "resurrection plant"? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 29 from your instructor. b. Discuss with your group's best question. Choose and record your group well-defined question. Choose and record your group well-defined question. and record it. d. Outline on Worksheet 29 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your questions, and make relevant comments. f. Discuss with your instructor any revisions to your questions, hypotheses, or procedures. Repeat your work as needed. Survey of the Plant Kingdom 327 Questions for Further Study and Inquiry 1. How are ferns and fern allies similarities and differences? 2. What structures and features do ferns possess that bryophytes do not that may have contributed to their success in a broader range of environments? 3. What are the advantages of vascular tissues in land plants? 4. What are the distinguishing features of club mosses, whisk ferns, and horsetails? How are these plants different from ferns? WRITING TO LEARN BIOLOGY What problems did plants? adaptations of mosses, liverworts, ferns, and other seedless plants are relevant to the transition? 328 EXERCISE 29 29-12 Survey of the Plant Kingdom Gymnosperms of Phyla Cycadophyta, Coniferophyta, and Gnetophyta E XER CISE 30 Learning Objectives By the end of this exercise you should be able to: 1. Describe the distinguishing features of the gymnosperms. 2. Understand the life cycle of pine, a representative gymnosperm. 3. Understand the function of a cone. 5. Identify the parts and understand the function of a seed. Please visit connect.mheducation.com to review online resources tailored to this lab. G ymnosperms were the first group of plants to (1) protect their developing embryos in nutrient-containing seeds and (2) make the evolutionary transition from swimming sperm to pollen-enclosed sperm. These adaptations helped make the evolutionary transition from swimming sperms produce exposed seeds borne on scalelike structures called cones (strobili). Like ferns, gymnosperms have a well-developed alternation of generations. Unlike most ferns, however, gymnosperms have a well-developed alternation of generations. Unlike most ferns, however, gymnosperms have a well-developed alternation of generations. Kingdom 329 Table 30.1 The Five Phyla of Extant Gymnosperms Approximate Number of Living Species Phylum Examples Key Characteristics Cycadophyta Cycads Heterosporous vascular seed plants. Sperm flagellated and motile but confined within a pollen tube that grows to the egg. Palmlike plants with pinnate leaves. Secondary growth slow compared with that of the conifers. Ten genera. Ginkgophyta Ginkgo Heterosporous vascular seed plants. Sperm flagellated and motile but conducted to the vicinity of the egg by a pollen tube. Deciduous tree with fan-shaped leaves that have evenly forking veins. Seeds resemble a small plum with f leshy, ill-scented outer covering. One species: Ginkgo biloba Coniferophyta Conifers, spruces, firs, yews redwoods, and others) Heterosporous seed plants. Sperm not motile; conducted to egg by a pollen tube. Leaves mostly needlelike or scalelike. Vascular. Trees, shrubs. About 50 genera. 630 Gnetophytas Heterosporous vascula seed plants. Sperm not motile; conducted to egg by a pollen tube. The only gymnosperms with vessels. Trees,
shrubs, vines. Three very diverse genera (Ephedra, Gnetum, Welwitschia). 65 occur in female cones and form female gametophytes. Gametophytes of gymnosperms are microscopic and completely dependent on the large, free-living sporophyte. In gymnosperms, pollen grains are the male gametophyte. Pollination is the transfer of pollen from male cones (where the pollen is carried from male cones by wind. Gymnosperms, pollen is carried from male cones to female cones (where the pollen is carried from male cones to female cones) wind. transfer sperm to egg, and were therefore able to colonize terrestrial habitats. Gymnosperms were the dominant land plants during the Age of Dinosaurs (i.e., during the Mesozoic Era, 225-65 million years ago). Today, we use gymnosperms for products ranging from lumber (e.g., pine, fir, spruce, cedar) to soaps, varnish, nail polish, gum, food, and perfume. Gymnosperms include four phyla: Cycadophyta, Ginkgophyta, Coniferophyta, and Gnetophyta, is discussed only briefly here because the phylum consists of a few rare genera. PHYLUM CYCADOPHYTA The Cycadophyta, is discussed only briefly here because the phylum consists of a new rare genera. PHYLUM CYCADOPHYTA The Cycadophyta, is discussed only briefly here because the phylum consists of a new rare genera. genera and 306 species. Cycads resemble palms because they have unbranched trunks and large, closely packed leaves that are evergreen 330 EXERCISE 30 306 1 and tough (fig. 30.2). Sperm of cycads are flagellated. Examine a branch of a cycad such as Zamia bearing developing seeds. The seeds are flagellated to the e nvironment Question 1 a. Based on your knowledge of reproduction in bryophytes (Exercise 28) and ferns (Exercise 29), is the presence of flagellated sperm a primitive or advanced characteristic in the plant kingdom? Why? PHYLUM GINKGOPHYTA The Ginkgophyta consists of one species, Ginkgo biloba (maidenhair tree), a large dioecious tree that does not bear cones. Ginkgo are hardy plants in urban environments and 30-2 (a) © BiologyImaging.com (b) Figure 30.2 Cycads. (a) A male cycad (Cycas revoluta) with a strobilus. (b) A female cycad with strobili. Zamia sp. is the only genus of cycad native to the United States. The starchy roots and stems (mostly underground) of cycads were used by Native Americans for food. in the wild and would probably be extinct but for its cultivation in ancient Chinese gardens. Question 2 What does dioecious mean? PHYLUM CONIFEROPHYTA ©Lexington Herald-Leader/Getty Images Figure 30.3 Maidenhair tree, Ginkgo biloba, is the only living representative of the phylum Ginkgophyta, a group of plants abundant 200 million years ago. Among living seed plants, only the cycads and fleshy seeds. tolerate insects, fungi, and pollutants. Males are usually planted because femalesative of the phylum Ginkgophyta, a group of plants abundant 200 million years ago. produce fleshy, smelly, and messy fruit that superficially resemble cherries. Leaves of Ginkgo have a unique shape (fig. 30.3). Ginkgo has not been found 30-3 The Coniferophyta are a large group of cone-bearing plants that includes the 5000-year-old bristlecone pines, the earth's oldest living individual organisms. The cones they bear are reproductive structures of the sporophyte generation that consist of several scalelike sporophylls arranged about a central axis (fig. 30.4). Sporophylls, also present in ferns and their allies, are modified leaves specialized for reproduction. Sporophylls bear spores. In conifers, sporophylls of male cones are called microsporophylls (see fig. 30.8). On the surface of each microsporophyll is a layer of cells called a microsporangium that produces spores. Male cones are megasporophylls; each of these "scales" of the female cone bears two spore-producing megasporangia on its upper surface. Microsporangia and megasporangia are patches of Survey of the Plant Kingdom 331 (a) © BiologyImaging.com (b) © BiologyImaging.com Figure 30.4 Pinecones at time of fertilization. cells near the central axis of the sporophylls composing the cones on the respective sporophylls. Male cones are small and similar in all conifers (fig. 30.5). However, female cones are variable; they may be small (1-3 cm in Pinus). In this exercise you'll study pine (Pinus), a representative and widely distributed conifer. Pine has considerable economic value because it is used to produce lumber, wood pulp, pine tar, resin, and turpentine. Other examples of conifers (fig. 30.6). You are already familiar with the sporophyte of pine—it is the tree. Procedure 30.1 Examine pine twigs and leaves 1. Examine pine twigs having leaves (needles) and a terminal bud. Notice that the leaves are borne on short branches only a few millimeters long. The length and number of leaves distinguish many of the species of Pinus. 2. Examine a prepared slide of a cross section of a pine leaf; locate the structures labeled in figure 30.7. Question 3 a. How are needles (i.e., leaves) arranged? © BiologyImaging.com Figure 30.5 Pollen-bearing cones of Pinus. These cones are usually found on the lower branches of Pinus. These cones are usually found on the lower branches of Pinus. These cones are usually found on the lower branches of Pinus. mother cells S Pollen tube Sperm Megaspores Pollen grains Megaspore mother cell n 2n Pollenbearing cone Ovulate (seed-bearing) cone (15 months after pollination) FE RT IL IZ AT IO N Zygote Sporophyte Seedling Pine seed Section of seed (second year), showing embryo embedded in megagametophyte Figure 30.6 Pine life cycle. In seed plants the gametophyte generation is greatly reduced. A germinating pollen grain is the mature microsporangia are borne in pairs on the scales of the delicate pollen-bearing cones. Megagametophytes, in contrast, develop within the ovule. The familiar seed-bearing cones of pines are much heavier than the pollen-bearing cones. Two ovules, and ultimately two seeds, are borne on the upper surface of each scale of a cone. In the spring, when the seed-bearing cones are small and young, their scales are slightly separated. Drops of sticky fluid, to which the airborne pollen grains adhere, form between these scales. Pollination occurs more than a year before the ovule produces a mature female gametophyte. These pollen grains germinate, and slender pollen tubes grow slowly toward the egg and producing a zygote there. The development of the zygote into an embryo occurs within the ovule, which matures into a seed. Seeds mature up to 6 months after fertilization. Eventually, the seed falls from the cone and germinates, the embryo resuming growth and becoming a new pine tree. b. How many leaves are in a bundle? 30-5 c. Pine "needles" are modified leaves. How are pine needles different from the leaves of broad-leaved trees such as maples and oaks? Survey of the Plant Kingdom 333 Cuticle Epidermis Photosynthetic tissue Stoma Resin duct Vascular tissue © BiologyImaging.com Figure 30.7 Cross section of a pine leaf (needle) (40×). d. Why are pines called evergreens? Microsporophyll M Microgametophytes from microspores via meiosis (10×). Tube cell Generative cell Wings g. How do the structural features of pine leaves adapt the tree for life in dry environments? Male cones usually form on the lower branches with staminate (male) and ovulate (female) cones. Examine a prepared slide of a young staminate cone and note the pine pollen in various stages of development. Each scale (microspore mother cells undergo meiosis to produce microspores that develop via mitotic divisions into microspore mother cells (fig. 30.8). Microspore mother cells undergo meiosis to produce microspores that develop via mitotic divisions into microspore mother cells (fig. 30.9). Each pollen grain consists of four nuclei and a pair of bladderlike wings. The gametophytes of gymnosperms are reduced to only a few cells. 334 EXERCISE 30 ©Dr. Keith Wheeler/Science Source Figure 30.9 Pollen grains of Pinus, each with enclosed male gametophyte. Each gametophyte includes a small generative cell and a larger tube cell. When the pollen grain germinates, the pollen tube will emerge between the two bladder-shaped wings (20×). Procedure 30.2 Examinate pinecones and pollen 1. If male cones are available, prepare a wet mount of some pine pollen; notice their characteristic shape. 30-6 2. Remove a scale from a mature staminate cone and tease open the microsporangium. 3. Prepare a wet mount of the microsporangium and its contents, and examine the contents with your microscope. 4. In the space below, draw the shape of a pine pollen grains; sketch the shape of a pine pollen grains; sketch the shape of a pine pollen grain. If male cones the same size? c. What is the probable function of the wings of a pine pollen grain? Each ovuliferous scale of the female cone bears two megaspore mother cell undergoes meiosis to produce a megaspore that develops via mitotic divisions into a megaspore mother cell. immediately surrounding the megagametophyte is the nucellus (nutritive tissue) surrounded by integuments (which will form the seed coat). A megagametophyte and its surrounding tissues constitute and ovules b. Recall that in terms the antheridia and archegonia on a prothallium mature at different times to avoid selffertilization. How might the different locations of male and female cones will develop and enlarge considerably before they are mature. 2. Examine a prepared slide of a young ovulate cone ready for pollination. 3. Examine a prepared slide of an ovulate cone that has been sectioned through an ovule (fig. 30.10). An ovule develops into a seed. 4. Examine a mature ovulate cone and notice its spirally arranged ovuliferous scales. These scales are analogous to microsporophylls of staminate cones. At the base of each scale you'll find two naked seeds. Notice that the seeds are exposed to the environment. Megasporophyll Integument Megasporophyle inside the seed. The nucellus is a nutritive tissue, and integuments
form the seed coat (15×). 30-7 Survey of the Plant Kingdom 335 Question 5 a. On which surface of the scale are the seeds located? b. What is the male gametophyte? b. How large is a staminate cone? compared to a mature ovulate cone? compared to a mature ovulate cone? c. What is the female gametophyte? d. What is an ovule? Pollination and Seed Formation in Pine Pollination is the transfer of pollen to a receptive surface. Pollen grains sift through the ovuliferous scales and stick in a drop of resin at the micropylar end of an ovule. Pollination occurs more than a year before the ovule produces a mature female gametophyte. The pollen grain then germinates and grows a tube into the archegonium, where it releases its two nonmotile sperm nuclei. One of these sperms disintegrates; the other fuses with the egg to form a zygote, while in the ovule, develops into the embryo of a new sporophyte. The ovule is now a seed and consists of an embryo, a seed coat (integuments of the megagametophyte). Seeds mature up to six months after fertilization. e. What is an integument? f. How are other gymnosperms similar to pine? g. How are they different? h. What evolutionary advantages might arise from not needing free water for fertilization? Procedure 30.4 Examine a prepared slide of a pine seed 1. Examine a prepared slide of a pine seed 1. Examine a prepared slide of a pine seed 1. Examine a prepared slide of a pine seed 1. Examine a prepared slide of a pine seed 1. Examine a prepared slide of a pine seed 1. Examine a pine seed 1. E extensions of the seed coat. Seed The evolution of seeds is one of the most significant events in the history of the plant kingdom. Indeed, the evolution of seeds is one of the factors responsible for the dominance of seed plants in today's environment because a seed permits a small but multicellular sporophyte to remain dormant until conditions are favorable for continued growth. While dormant, the young sporophyte is protected by a seed coat and is surrounded by a food supply. Refer to the pine life cycle shown in figure 30.6 to answer Question 6. If plant material and time are available, examine other gymnosperms in the lab. 336 EXERCISE 30 PHYLUM GNETOPHYTA The gnetophytes (71 species in three genera) include some of the most distinctive (if not bizarre) of all seed plants (fig. 30.11). They have many similarities with angiosperms, such as flowerlike compound strobili, vessels in the secondary xylem, loss of archegonia, and double fertilization. The slow-growing Welwitschia plants are extraordinary in appearance and live only in the deserts of southwestern Africa. Most of their moisture is derived from fog that rolls in from the ocean at night. Welwitschia stems are short and broad (1 m). Mature, 100-year-old plants have only two wide, straplike leaves. ORGANIZING WHAT YOU'VE LEARNED Go to page 354, which follows Exercise 31. Complete the portions of the table that refer to the phyla you studied in today's lab. 30-8 (a) © Robert & Linda Mitchell (b) ©LOETSCHER CHLAUS/Alamy Stock Photo Figure 30.11 Gnetophytes. (a) Leaves and immature seeds of (c) © Biology Imaging.com Gnetum, Gnetum grows as a shrub or woody vine in tropical forests. (b) Welwitschia plants in the Namib Desert of southwest Africa. (c) Ephedra, the only living genus of Gnetophyta found in the United States, is a common dietary supplement. INOUIRY-BASED LEARNING How much pollen. In some people this pollen contributes to hay fever and other sinusrelated problems. Question: How much pollen is released by a male pinecone? a. Establish a working lab group well-defined questions relevant to the preceding observation and question. Choose and record your group's best question for investigation. 30-9 c. Translate your guestion into a testable hypothesis and record it. d. Outline on Worksheet 30 your experimental design and supplies needed to test your proposed investigation. e. Conduct your proposed investigation. e. Conduct your guestion, and make relevant comments. f. Discuss with your instructor any revisions to your questions, hypotheses, or procedures. Repeat your work as needed. Survey of the Plant Kingdom 337 Questions for Further Study and Inquiry 1. What is the difference between pollination? 2. What does the term gymnosperm mean? Is this term an appropriate description? Explain your answer. 3. How is alternation of generations different in ferns and pines? 4. How are the environmental agents for uniting sperm and egg different in pines and bryophytes? 5. Compare and contrast alternation of generations in mosses, ferns, and pines? ecological advantages that the production of seeds has over the reproductive process in ferns. 338 EXERCISE 30 30-10 E XER CISE Survey of the Plant Kingdom Angiosperms 31 Learning Objectives By the end of this exercise you should be able to: 1. Relate the life cycle of angiosperms to the other phyla of the plant kingdom. 2. Discuss the events associated with development of microspores, megaspores, gametophytes, ga plants (phylum Anthophyta—also referred to as angiosperms)—are the most abundant, diverse, and widespread of all land plants. They owe their success to several factors, including their structural diversity, efficient vascular systems, and mutualisms with fungi and insects (fig. 31.1). Angiosperms' flowers attract insects and other pollinators, and thereby make repro duction more efficient. Fruits, which contain seeds and nutritive tissue, help disperse angiosperms to new environments. © BiologyImaging.com Figure 31.1 This bee is pollinating a rock rose in central Texas. The evolution of flowers and the success of flowering plants correlate with the development of mutualisms with insects and other pollinators. 31-1 PHYLUM ANTHOPHYTA Angiosperms range in size from 1 mm (Wolffia) to over 100 m tall (Eucalyptus). As in gymnosperms, the sporophyte (embryo sac) are completely dependent on the sporophyte. Angiosperms are important to humans because our world economy is overwhelmingly based on them. We eat and use vegetative structures (roots, stems, leaves) as well as reproductive structures (roots, stems, leaves) of angiosperms. There are more than 250,000 living species of angiosperms. Until the late 1990s, most botanists grouped angiosperms into two groups, depending on the number of cotyledons (seed leaves) in the embryo; species having one cotyledon were called dicots, and those with two cotyledons were called dicots, and those with two cotyledons were called dicots. However, genetic analyses revealed that species traditionally called dicots evolved from more than one common ancestor. As a result, the vast majority of species once classified as dicots are now known as eudicots. (The other former dicots comprise several small lineages that will not be considered in this exercise.) These studies also showed that all monocots remains unchanged (fig. 31.2). The "typical" features of these groups of plantsector; as a result, their classification as monocots remains unchanged (fig. 31.2). are described in table 31.1. Having studied gymnosperms, you probably con cluded that vegetative adaptations of angiosperms and gymnosperms and fruit. Survey of the Plant Kingdom 339 Stamen Anther Filament Petal Carpel Stigma Style Ovary Ovule Sepal Receptacle © BiologyImaging.com Figure 31.2 In monocots such as this lily (Lilium sp.), flower parts usually occur in multiples of three. A lily has six stamens, three petals, and a three-chambered ovary. STRUCTURE AND FUNCTION OF FLOWERS Luckily for florists, angiosperms include a seemingly infinite variety of flowers, ranging from the microscopic flowers of Table 31.1 Characteristics and Examples of the Two Major Classes of Angiosperms Monocots (~70,000 species) 1. One cotyledon per embryo 2. Flower parts in sets of three 3. Parallel venation in leaves 4. Multiple rings of vascular bundles in stem 5. Lack a true vascular cambium (lateral meristem) 6. Fibrous root system 7. Pollen grains have one pore. Examples: Orchids, barley, corn, lily, wheat, daffodils, onion, bamboo, banana Eudicots (~170,000 species) 1. Two cotyledons per embryo 2. Flower parts in sets of four or five 3. Reticulate (i.e., netted) venation in leaves 4. One ring of vascular bundles or cylinder of vascular tissue in stem 5. Have a true vascular cambium (lateral meristem) 6. Tap root system 7. Pollen grains have three pores. Examples: Zucchini, roses, oaks poppy, peas, beans, mint, daisies, tomato 340 EXERCISE 31 all stamens = androecium all carpels = cynoecium all petals = corolla all sepals = calvx Figure 31.3 The parts of a flower. This is a generalized flower with four primary parts: sepals, petals, stamens, and carpels and stamens are the fertile parts of a flower. The roles of carpels and stamens are the fertile parts of a flower. The roles of carpels and stamens are the fertile parts of a flower. today's exercise, we'll consider only the "typical" flower depicted in figure 31.3. Examine the flower stalk. •• Receptacle—the part of the flower stalk that bears the flower stalk that bears the flower; usually not large or noticeable. •• Sepals—the lowermost or outermost whorls of structures, which are usually leaflike and protect the developing flower; the sepals collectively con stitute the calyx. •• Petals—whorls of structures located inside and usually above the sepals; may be large and pig mented (in insect-pollinated flowers) or incon spicuous (in wind-pollinated plants); the petals collectively constitute the corolla. •• Androecium—the male portion of the plant that rises above and inside the petals; consists of stamens, each of which consists of a filament atop which is located an anther; inside the anther; inside the anther; inside the anther; inside the petals; consists of stamens, each of which consists of a filament atop which is located an anther; inside the petals; consists of a filament atop which is located an anther; inside the anther; inside female portion of the plant that rises
above and inside the androecium; con sists of one or more carpels, each made up of an ovary, style, and stigma; the ovary contains female gametophyte; the 31-2 megagametophyte is called the embryo sac and contains female gametophyte; the 31-2 megagametophyte is called the embryo sac and contains female gametophyte; the 31-2 megagametophyte is called the embryo sac and contains female gametophyte; the 31-2 megagametophyte; the 31-2 megagametophyte is called the embryo sac and contains female gametophyte; the 31-2 megagametophyte is called the embryo sac and contains female gametophyte; the 31-2 megagametophyte is called the embryo sac and contains female gametophyte is called the embryo sac and contains female gametophyte; the 31-2 megagametophyte; the 31-2 megagametophyte is called the embryo sac and contains female gametophyte; the 31-2 megagametophyte; the 31-2 megagametophy parts of a flower, and a variety of flower types are dis tinguished by their sepal and petal characteristics. In radially symmetrical flowers such as snapdragons, one or more parts of at least one whorl are different from other parts of the same whorl. These flowers are usually bilaterally symmetrical. Procedure 31.1 Examine flowers and their parts 1. Obtain a flower provided in the laboratory. 2. Remove the parts 1. Obtain a flower provided in the laboratory. and determine their arrangement and point of attachment. Question 1 How would you describe this flower? 8. Examine the other types of flowers available in the lab. Repeat procedure 31.1 to guide your examination. Pre served specimens of Lilium (lily) and Ranunculus (but tercup) may also be provided for you to study and dissect. Alternation of Generations in Flowering Plants The life cycle of flowering plants involves the alternation of a multicellular haploid stage with a multicellular diploid spores by meiosis. Each haploid spore develops into the gametophyte by mitosis and cellular differentiation. In angiosperms the sporophyte is the large, mature organism with flowers that you easily recog nize. The gametophyte within an ovule. Be sure to review your textbook's description of alternation of generations. Production of spores in the sporophyte by meiosis is part of a larger process called sporogenesis. Flowering plants produce two types of spores: microsporogenesis, Production of Pollen, and Microgametogenesis 4. Remove the petals and sepals. 5. Locate and remove a stamen and place it on a slide. Examine the stamen with low magnification. 6. Examine a prepared slide of pollen grains. Use high magnification to locate the generative and tube nucleus is larger and centered. You'll learn more about pollen nuclei later in this exercise. 7. Locate the gynoecium of the flower, and make longitu dinal and transverse sections. The gynoecium consists of one or more fused carpels, each with an interior cavity called a locule containing ovules. Question 2 a. How many carpels (locules) are apparent? b. How many ovules are developing in each locule? 31-3 Many of the terms associated with flowers are similar to those you've learned in earlier exercises, except that with angiosperms is called microsporo genesis. Microsporogenesis is the production of microspores within microspores grow and mature into microspore mother cells (microsporecytes) (fig. 31.5). These microspores grow and mature pollen grain include a tube nucleus (or vegetative nucleus) and a generative nucleus. During pollination, pollen grains are transferred to the stigma, where they germinate and grow a tube through the style to the ovary. The tube nucleus replicates to produce two sperm nuclei. Pollen of some plants cause allergies in many people. However, studies of pollen are important to science beyond the treatment of allergies. For example, geologists examine pollen brought up in sediment cores during oil drilling. Dark brown to black pollen suggest that a well will likely produce natural gas. Orange pollen suggest the less intense heat asso ciated with highquality oil production. In addition, exami nation of fossil pollen tells us about the diversity of ancient flora and climatic change through the ages, and helps us locate ancient seas and their shorelines where pollen is known to accumulate. Survey of the Plant Kingdom 341 Megaspore (n) Pollen Grain Generative cell Polar nuclei Tube nucleus M Egg EI OS IS Ovule Megaspore mother cell (2n) Pollen tube Sperm Pollen (n) Anther Tube nucleus Formation of pollen tube (n) Stigma Germinating pollen grain Anther (2n) Sperm Cotyledons O N Polar nuclei Egg Endosperm MI Seed coat TO SIS Embryo (2n) Endosperm (3n) Zygote DOUBLE FERTILIZATION GE RM IN AT I Seed (2n) Pollen tube Sperm Egg Figure 31.4 Angiosperm life cycle. Eggs form within the embryo sac inside the ovules, which, in turn, are enclosed in the carpels. The pollen grains, meanwhile, form within the sporangia of the anthers and are shed. Fertilization is a double process. A sperm and an

egg fuse to produce a zygote; at the same time, another sperm fuses with the polar nuclei to produce the endosperm. The endosperm is the tissue, unique to angiosperms, that nourishes the embryo and young plant. Procedure 31.2 Examine stages of microsporogenesis and microgametogenesis in dehiscent (split-open) and predehiscent anthers? b. Which stage is the most mature? 342 EXERCISE 31 2. Examine a prepared cross section of a young anther. Note the immature sporangia tissue that will form microsporocytes. 3 Examine a prepared cross section of a lily anther showing microsporocytes in early prophase I (fig. 31.8c). 6. Examine a prepared slide showing mature pollen with two or more nuclei (fig. 31.8d). 7. Examine living or prepared pollen from various plants if available. Note any differences among pollen grains and differences among pollen grains and differences between pollen from various plants if available. Note any differences among pollen grains and differences among pollen grains and differences between pollen from various plants if available. producing) cell (a) Mitosis Microspores (n) Tube nucleus Pollen Grain on Anther (microgametophyte) Microgametophyte) Mic electron micrograph of pollen grains of different species (1200×). Question 4 a. How many pollen grains germinated? Germinating Pollen Grain on Stigma Figure 31.5 Microsporogenesis and microsporogenesis and microsporogenesis and microgametogenesis are shown in figure 31.8. b. Can you see vegetative and generative nuclei in the pollen grains. Open, mature microsporangia Pollen grains @BiologyImaging.com Figure 31.7 Lilium anther (40×). Mature pollen grains are the product of microsporogenesis and microsporagia of flower anthers. A higher-magnification view of developing pollen grains is shown in figure 31.8. 31-5 Survey of the Plant Kingdom 343 ©M. I. Walker/Science Source (a) (b) © Biophoto Associates/Science Source ©Ed Reschke/Getty Images (c) (d) © Noble Proctor/Science Source Figure 31.8 Stages of microsporegenesis and microsporegenesis in Lilium. (a) Cells in early prophase I (350×). (b) Cells in second meiotic division (500×). (c) Tetrads of microspores from meiosis (680×). (d) Mature pollen (230×). For an overview of these stages, see figure 31.5. 344 EXERCISE 31 31-6 In Ovary Megasporogenesis Megasporocytes). These megaspores undergo megagametophytes are called an ovule. Ovules usually have two coverings that is, they develop into megagametophytes. The megagametophytes are called an ovule. called integuments. The entire haploid structure is called the embryo sac and consists of only six to ten nuclei 2 golar nucle Megagametogenesis megasporogenesis and megagametophyte) Figure 31.9 Megasporogenesis and megagametophyte. The embryo sac is the mature megagametophyte. The locations of these processes are shown in figures 31.10 and 31.11. Megasporogenesis, Production of Ovules, and Megagametogenesis Megasporogenesis is the production of megasporogenesis is the production of a Lilium ovary and locate the six megasporocyte will form and develop. The stages for development of a megasporocyte are shown in figures 31.9, 31.10, and 31.11. 2. Examine a prepared slide of a cross section of a Lilium ovary showing a diploid megasporocyte within the spo rangium before meiosis (fig. 31.11a). 3. Examine a prepared slide showing the four-nucleate embryo sac In most angiosperms, three of the four nuclei degenerate and the single remaining nucleus passes through two mitotic divisions before the next stage. Lilium is atypi cal because all four products of meiosis contribute nuclei to the embryo sac, but only one develops into the egg cell. 4. Examine a prepared slide showing the eight-nucleate embryo sac (fig. 31.11c). Because of the large size of the embryo sac, it is seldom possible to observe all eight nuclei in the same section. 5. At the end of the megagametophyte toward the micro pyle (the small opening where the pollen tube enters the ovule), locate the eight nuclei including the egg and two synergid nuclei associated with fertilization Megaspore mother cell (2n) Antipodal cells Integument Haploid megaspores resulting from meiosis (a) (b) Polar nuclei Egg Young megagametophyte Synergids (c) Figure 31.10 Megasporogenesis and megagametophyte Synergids (c) Figure 31.10 megasporocyte in lily ovary. (b) Embryo sac with four nuclei produced by meiosis. (c) Embryo sac (mature megagametophyte) with eight nuclei (only six are visible in this image). For an overview of these stages, see figure 31.9. Synergids Two nuclei of central cell (polar nuclei) Megaspore wall Egg cell Sporangium Ovule Female gametophyte (withir megaspore wall) Integuments Micropyle opening Attachment to ovary Figure 31.12 Mature female gametophyte within an ovule. (figures 31.11c and 31.12). At the opposite end locate three antipodal cells that usually do not participate in reproduction. In the center are two polar nuclei that migrated from each pole of the megagametophyte. POLLINATION AND FERTILIZATION Biologists have long been interested in plant pollination, for obvious economic reasons. Angiosperm reproduction depends on pollination, for obvious economic reasons. Angiosperm reproduction depends on pollination. a megagametophyte (ovule) with an egg, sexual reproduction in angiosperms occurs as follows: 1. Pollination occurs when pollen is transported to the surface of the flower's stigma (fig. 31.13). 2. The pollen grain germinates, and a pollen tube grows through the stigma and style to the surface of the flower's stigma (fig. 31.13). the pollen grain. 346 EXERCISE 31 3. One sperm nucleus fuses with the egg to form the dip loid (2n) zygote, and the other sperm fuses with the two polar nuclei to form a triploid (3n) nucleus. This process is called double fertilization and is character istic of angiosperms. 4. The zygote develops into the embryo. The triple f usion of the sperm nucleus and two polar nuclei forms the trip loid endosperm that provides food for the embryo. 5. The integuments of the ovule form the seed coat, and the fruit develops from the ovary and other parts of the flower. SEED AND EMBRYO DEVELOPMENT A seed is a mature ovule that includes a seed coat, a food supply, and an embryo. Seeds range in size from tiny (e.g., a broomrape seed weighs only a few micrograms) to massive (e.g., an avocado seed can weigh more than 50 g). Embryology and its controlling factors are com plex, but various stages of development are easily observed. The stages of embryology and its controlling factors are com plex, but various stages of development are easily observed. development in the seed of Capsella (a eudicot) are shown in figure 31.14. The development includes the following stages: •• Proembryo stage. During development, the zygote divides to form a mass of cells called the embryo. Ini tially the embryo consists of a basal cell, suspensor, and a two-celled proembryo. The suspensor is the column of cells that pushes the embryo into the endosperm. The endosperm is extensive but is being digested. organization. 31-8 Antipodal cells Pollen grain Stigma Pollen tube Style Endosperm nucleus (3n) Zygote (2n) Pollen tube grows into style 2 One sperm nucleus fuses with egg nucleus to form diploid zygote. The other sperm nucleus fuses with two polar nuclei to form triploid endosperm. Two sperm nuclei travel through pollen tube to ovary. Figure 31.13 Pollen germination and double fertilizes the egg to form a zygote, and the other fertilizes the polar nuclei to yield the endosperm. •• Heart-shaped embryo. The enlarging cotyledons store digested food from the endosperm. Tissue differentia tion begins, and root and shoot meristems soon appear. •• Torpedo stage The cotyledons and root axis soon elongate to produce an elongate torpedo-stage embryo. The mature embryo has large, bent cotyledons on each side of the stem apical meristem. The radicle, later to form the root, is differentiated toward the suspensor. The radicle has a root apical meristem and root cap. The hypocotyl is the region between the apical meristem and the radicle. The endosperm is depleted, and food is stored in the cotyledons. The epicotyl is the region between attachment of the cotyledons and the stem apical meristem; it has not elongated in the mature embryo. Procedure 31.5 Examine development of a Capsella embryo 2. The cross section most likely passes through an entire fruit of Capsella and shows a number of sectioned off-center and the stage may not be obvious. Nevertheless, each slide should include an example of at least one stage 3. Locate as many of the following stages of seed develop ment as possible on your slide: globular, heart, torpedo, and mature embryos. These stages are continuous, so each slide may have multiple stages and intermediates between stages. 4. You may need to examine several slides. Find exam ples of as many stages as you can. 5. Compare your observations with figure 31.14. Question 5 a. Why is the endosperm being digested? b. Is Capsella a monocot or a eudicot? How can you tell? 1. Obtain and examine prepared slides showing the various stages of embryo development. 31-9 Survey of the Plant Kingdom 347 Triploid endosperm mother cell Polar nuclei Cotyledons Root apex Zygote Micropyle Egg Sperm (a) Endosperm Cotyledons Hilum Seed coat Proembryo Fertilization Shoot apex Root apex corn (monocot). (a) The two cotyledons in each seed of garden bean (Phaseolus vulgaris) absorb the endosperm before germination. (b) Corn (Zea mays) has seeds in kernels (grains); the single cotyledon is an endosperm-absorbing structure called a scutellum. Root apex Figure 31.14 Stages of development in a Capsella embryo. This 4. Add a drop of iodine to the cut surface and observe the staining pattern. (Recall from Exercise 6 that iodine stains starch black.) Show this pattern on figure 31.15. 5. Repeat steps 2-4 with soaked peas. SEED STRUCTURE Question 6 How are seeds of peas and beans similar? How are they different? Torpedo stage
Mature embryo Cotyledons development transforms a zygote into a mature embryo. Do not eat any seeds or fruits used in this laboratory. Procedure 31.6 Observe parts of a bean seed 1. Obtain some beans that have been soaked in water for 24 h. 2. Peel off the seed coat and separate the two cotyledons. Between the cotyledons you'll see the young root and shoot. 3. Examine the opened seed and compare its structure with that shown in figure 31.15. Look for these features: • Micropyle—a small opening on the surface of the seed through which the pollen tube grew. • Hilum—an adjacent, elliptical area at which the ovule was attached to the ovary. • Cotyledon—food for the embryo. • Embryo with young root and shoot—develops into the new sporophyte. 348 EXERCISE 31 Procedure 31.7 Examine a corn grain (fig. 31.16). Identify the following features: • Endosperm • Scutellum (cotyledon; this structure helps absorb the endosperm) • Coleoptile (sheath enclosing shoot apical meristem and leaf primordia of grass embryos) • Root • Root cap • Coleorhiza (sheath enclosing embryonic root of grass embryo) • Shoot apical meristem 31-10 Most fruits are either dry wall surrounds the seed until it germinates. The fruit wall is usually tough and hard and is sometimes referred to as stony. The seeds of fleshy fruits remain in the tissue until germination. A typical fruit has an outer wall called a pericarp composed of an exocarp, mesocarp, and placental tissues. The fruit often includes the receptacle of the flower. The structure of a fruit depends on the number of carpels in each flower and whether or not the carpels are fused. Endosperm Coleoptile Scutellum (cotyledon) Shoot apex Procedure 31.8 Observe the diversity of fruits available in the lab. This list is not complete but describes a few common types of fruits 1. Use the following descriptions to study and classify fruits available in the lab. structure of a bean, Coleorhiza sunflower, corn grain, apple, and tomato ©Dr. Keith Wheeler/Science Source Figure 31.16 The structure of a corn grain, longitudinally split a water-soaked corn grain. 3. Add a drop of iodine to the cut surface and observe the staining pattern. Indicate this pattern on figure 31.16. Question 7 a. What does this staining pattern tell you about the content of their food in cotyledons? How can you tell? 1. Examine the pod of a string bean. This single carpel has two seams that car open to release seeds. Remove the seed coat. Split the seed coat. Split the seed coat. Split the seed and locate the embryo. Question 8 a. Does the pod appear to be a single carpel with one cavity containing seeds? b. Is the micropyle near the attachment of the seed to the pod? 2. Crack the outer coat of a sunflower fruit and remove the seed. Locate the embryo and determine whether sunflower is a monocot or eudicot. Question 9 a. Before today would you have referred to the uncracked sunflower achene as a fruit? Why or why not? FRUIT A fruit is a mature, ripened ovary plus any associated tis sues. Therefore, a fruit contains seeds. Are you surprised that tomatoes, beans, and okra are fruit? A mature fruit is often larger than the ovary at the time of pollination and fer tilization, which indicates that a great deal of development occurs while the seeds are maturing. 31-11 b. Is sunflower a monocot or eudicot? Survey of the Plant Kingdom 349 Dichotomous Key to Major Types of Fruit b. Does a corn grain have a cotyledon as well as an endosperm? I. Fleshy fruits A. Simple fruits develop from a single ovary. 1. Flesh mostly of ovary tissue a. Endocarp hard and stony; ovary usually many-seeded (tomato, grape, green pepper): berry 2. Flesh mostly of receptacle tissue (apple pear, quince): pome B. Complex fruits develop from more than one ovary. 4. Examine an apple, which is an example of a pome. Section the apple is derived from tissue other than the ovary. Locate the outer limit of the pericarp and the limit of the endocarp. Question 11 a. How many carpels are fused to form an apple? 1. Fruit from carpels of many flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit from many carpels of many flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit from many carpels of many flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit from many carpels of many flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit from many carpels of many flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit from many carpels of many flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit from many carpels of many flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit from many carpels of many flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit from many carpels of many flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit from many carpels of many flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit from many carpels of many flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit from many carpels of many flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit from many carpels of many flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit from many carpels of many flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit from many flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit from many flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit from many flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit flowers fused together (pineapple, mulberry): aggregate fruit 2. Fruit flowers fused togeth the fleshy pericarp aid in seed dispersal? A. Fruits that split open at maturity (usually more than one seed) 1. Split occurs along two seams in the ovary. Seeds borne on one of the halves of the split ovary (pea and bean pods, peanuts): legume 2. Seeds released through pores or multiple seams (poppies, irises, lilies): capsule B. Fruits that do not split open at maturity (usually one seed) 5. Examine a tomato and section it transversely. Compare its structure with that shown in figure 31.18. The jelly like material is the placenta giving rise to the ovules. Question 12 How many carpels are fused to form a tomato? 1. Pericarp hard and thick, with a cup at its base (acorn, chestnut, hickory): nut 2. Pericarp thin and winged (maple, ash, elm): samara 3. Pericarp thin and not winged (sunflower, buttercup): achene (cereal grains): caryopsis 3. Examine an ear of corn from which the husks have been removed without disturbing the "silk." The strands of silk are styles of the gynoecium. Question 10 a. If a corn grain is actually a fruit, where is the pericarp? Our Uses of Angiosperms We have countless uses for angiosperms, including wood (e.g., oak, maple), food (e.g., wheat, rice, corn, apples, toma toes), textiles (e.g., jute), shade, decorations, insect repel lants, spices, and landscaping. Modern agriculture is based almost entirely on angiosperms. We also used angiosperms as sources of numerous drugs. For example, Taxol (a drug used to treat cancer) and morphine (a painkiller) are derived from flowering plants, as are illicit drugs such as cocaine, opium, and heroin. So, too, is caffeine, a drug ingested by more than 100 million Americans every day. ORGANIZING WHAT YOU'VE LEARNED Go to page 354, which follows this exercise. Complete the portions of the table that refer to the phyla you studied in today's lab. 350 EXERCISE 31 31-12 That Morning Cup of Coffee is a \$60 billion industry. Brazil is the world's leading producer of coffee; it produces 30% of the world's crop. Worldwide, nearly 7 million tons of green coffee beans are produced per year. About 80% of this coffee comes from Coffea arabica, and the remaining 20% from Coffea arabica, and the remaining 20% from the red/purple state arabica. coffee fruits are called "cherries." Except for pea berry coffee, whose fruits each contains one smaller, rounder seed, each coffee fruit contains two seeds which are referred to as "beans" (despite the fact that they are not true beans). In the United States, coffee is the second-most popular drink (water is first). Coffee drinkers drink an average of 3.1 9-ounce cups of coffee per day. Fifty-four percent of Americans at least 18 years old drink coffee every morn ing, and another 30% drink specialty drinks such as lattes and cappuccinos; only about 35% of coffee drinkers like their coffee black. The average coffee-drinker spends \$165 per year on coffee from a coffee house stand in line there about 45 hours per year. O H 3C O N N CH3 H N N CH3 Caffeine © Science Photo Library/Alamy Stock Photo Figure 31.17 Coffee seeds (i.e., "beans") contain caffeine, which, in nature, is a natural pesticide that paralyzes and kills certain insects that attack coffee plants. In humans, caffeine is a stimulant that temporarily wards off drowsiness and restores alertness. INQUIRY-BASED LEARNING Grocery store botany: What plant organs are sold at your local grocery store? Observation: The produce sections of grocery stores and mar kets contain a vast array of plant organs. each having a char acteristic shape, taste, and texture. These plants have been the subject of intensive artificial selection. Question: What plant organ (e.g., modified root, stem, leaf, flower) are you purchasing when you buy items for a salad? Assume that your salad includes beets, radishes, sweet potatoes, celery, carrots, broccoli, asparagus, eggplant, lettuce, and onion. a. Establish a working lab group well-defined questions relevant to the preceding observation and question. Choose and record your group's best question for investigation. 31-13 c.
Translate your question into a testable hypothesis and record it. d. Outline on Worksheet 31 your experimental design and supplies needed to test your proposed investigation. e. Conduct your procedures, record your data, answer your question, and make relevant comments. f. Discuss with your instructor any revisions to your questions, hypotheses, or procedures. Repeat your work as needed. Survey of the Plant Kingdom 351 Petals Style Style Stamen Seed Ovary Receptacle Ovary Receptacle Sepal Strawberry — aggregate fruit Sepal Seed Exocarp Ovule Receptacle Endocarp Ovary Apple — pome fruit Figure 31.18 Diagrams of fruit and their originating flowers. 352 EXERCISE 31 31-14 Questions for Further Study and Inquiry 1. What is meant by "double fertilization"? 2. What features of seeds and fruits have enabled angiosperms to become so widespread? 3. What are the similarities and differences between cones and flowers? 4. What is the difference between a fruit and a vegetable? 5. In what ways does human welfare depend on seed plants? 6. How can you distinguish a monocot from a eudicot? 7. How are insects such as bees important for the reproduction of angiosperms? 8. What advantages do flowers give angiosperms over gymnosperms? 9. Draw three fruits (including one dry fruit) that you observed in lab. Describe a probable method for dispersal of each. 10. What are the major parts (and their functions) of your favorite flower? WRITING TO LEARN BIOLOGY 31-15 What are the functions of a flower? Describe how a flower of your choice is adapted to each function. Survey of the Plant Kingdom 353 Summarizing What You've Learned After each of your studies of plants (Exercises 28-31), complete the relevant parts of this table to help you summarize what you've learned. Exercises 28-31), complete the relevant parts of this table to help you summarize what you've learned. Exercises 28-31), complete the relevant parts of this table to help you summarize what you've learned. Anthocerophyta 29 Pterophyta 29 Lycophyta 30 Coniferophyta 30 Coniferophyta 30 Coniferophyta 30 Gnetophyta 30 Gnetophyta 31-16 E XER CISE Plant Anatomy Vegetative Structure of Vascular Plants 32 Learning Objectives By the end of this exercise you should be able to: 1. Describe the functions of roots, stems, and leaves. 2. Distinguish between primary and secondary growth. 3. Describe the functional significance of the internal and external structure of roots, stems, and leaves. 4. Explain what causes growth rings in wood. Please visit connect.mheducation.com to review online resources tailored to this lab. T he structure of plants varies greatly among species; compare, for example, an oak tree with a cactus. However, these structural differences among roots, stems, and leaves result not from tissues unique to one species or another, but rather from differences arrangements and proportions of the same tissues. These differences among plants represent a variety of adaptations to achieve the universal evolutionary goals of survival and reproduction. This exercise will concentrate on the structure of roots, stems, and leaves of vascular plants. Question 1 a. How do taproot systems and fibrous root systems help plants survive and reproduce? b. Would one type of root system provide more adaptive advantages in a particular environment such as a rain forest? A desert? Explain your answer. ROOTS During seed germination, a radicle or young primary root soon produces numerous secondary roots and forms a root system that absorbs water and minerals, anchors the plant, and stores food. Root systems have different morphologies. For example, a taproot system, the primary and secondary roots are similar in size (e.g., roots of many grasses) (fig. 32.1). Examine the displays of taproot and fibrous root systems available in the lab. Primary growth of roots and all primary tissues is formed by apical meristems. A meristem is a localized area of cellular division. Apical meristems occur at the tips of roots and stems. Primary growth in length) produces herbaceous (nonwoody) tissue Secondary growth refers to growth in girth resulting from nonapical meristems, some of which are discussed later in this exercise. 32-1 The Root Apex Examine the root tips of two-day-old seedlings of radish (Raphanus) and corn (Zea) with your dissecting microscope. Refer to figure 32.2 and identify the root cap, root apical meristem, zone of elongation, and zone of maturation. The cone of loosely arranged cells at the root cap perceives gravity and protects the root grows through the soil (fig. 32.3). The root apical meristem is behind the root cap and produces all of the new cells for primary growth. These cells elongate in the zone of elongation, which is 1-4 mm behind the root tip. This elongation produces primary growth. Plant Anatomy 355 (a) © Maarigard/Getty Images (b) © McGraw-Hill Education/Evelyn Jo Johnson, photographer Figure 32.1 Two common types of root systems of vascular plants. (a) The taproot system nt, thickened taproot, (b) The fibrous root system of a grass consists of many similarly sized roots. Fibrous root systems form extensive networks in the following space, sketch the root tips that you examined. In which area of a root tip are cells largest? In which smallest? b. What is the function of root hairs? Primary Tissues of the Root b. Aside from their size, do all cells in the root tip appear similar? Why is this significant? Re-examine the two-day-old radish seedling with your dissecting microscope. Note the many root hairs? short-lived. Root hairs increase the surface area of the root. Question 3 a. Why do you think root hairs occur only in the zone of elongation? 356 EXERCISE 32 The root apical meristem produces cells that differentiate into primary tissues of the root. The outer layer of cells is the epidermis. Just inside the volume that a some of elongation? s the cortex, whose cells contain numerous amyloplasts, which are starch-containing plastids. The inner layer of the cortex is the endodermis, which regulates water flow to the vascular tissue in the center of the root. Immediately inside the endodermis, which regulates water flow to the vascular tissue in the center of the cortex is the endodermis and produce secondary roots (figs. The inner layer of the contex) which regulates water flow to the vascular tissue in the center of the root. 32.4 and 32.5). Procedure 32.1 Examine primary tissues of a root 1. Examine a prepared slide of a cross section of a buttercup (Ranunculus, a eudicot) root (figs. 32.4 and 32.5). Sketch what you see. Label and state the function of each tissue that is present. (Note: Your instructor may 32-2 Endodermis Root hair Epidermis Ground tissue Vascular tissue Zone of maturation Root apical meristem Zone of elongation Ground meristem Procambium Protoderm Quiescent center Apical meristem Mucilage (c) © BioPhot (d) © BioPhot (d) © BioPhot Figure 32.2 (a) Root tip showing root cap, root apical meristem, zones of structure and function. (b) The root apical meristem is covered by a thimble-shaped root cap that protects the meristem as the root as it grows through the soil (60×). (c) Mucilage produced by the root cap that protects the meristem as the root as it grows through the soil (420×). removed from the rest of the root (6×). 32-3 Plant Anatomy 357 have you examine a slide comparing cross sections of roots and eudicots.) 2. Examine a prepared slide labeled "lateral root origin." Locate the epidermits, cortex, pericycle, and newly formed secondary root. Sketch the lateral root and label its parts. 3. If time permits, also examine a prepared slide of a cross section of a corn (Zea, a monocot) root. Question 4 a. Based on the primary root or on its surface? © BioPhot Figure 32.3 Tips of roots secrete large amounts of mucilage, a lubricant that helps the root force its way through the soil. The mucilage is secreted primarily by the root cap. Movement of the root through soil is also aided by the sloughed cells are visible in the drop of mucilage on the tip of this root. c. How does the structure of a monocot root differ from that of a eudicot? Cortex Epidermis Vascular cylinder (a) © BiologyImaging.com (b) © BiologyImaging.com Figure 32.4 Transverse sections of a root of a buttercup (Ranunculus), a eudicot. (a) Overall view of mature root. The vascular cylinder includes tissues specialized for long-distance transport of water and solutes, whereas the epidermis forms a protective outer layer of the root (16×). (b) Detail of cortex (250×). Each parenchyma cell in the contex contains many amyloplasts, which store starch. 358 EXERCISE 32 32-4 In the center of the buttercup root is the vascular (fluid-conducting) cylinder composed of xylem and phloem (fig. 32.5). Xylem transports water and most organic compounds in the center of the buttercup root is the vascular (fluid-conducting) cylinder composed of xylem and phloem (fig. 32.5). plant, including carbohydrates. Water-conducting cells in the xylem of angiosperms are called tracheids and vessel elements and are dead and hollow at maturity. Tracheids are long, spindle-shaped cells with thin areas called tracheids and vessel elements and are dead and hollow at maturity. are stacks of cylindrical cells with thin or completely open end-walls. Water moves through vessel elements in straight, open tubes are usually stained red in slide preparations of buttercup roots. Conducting cells in phloem are called sieve cells and sieve tube members and are alive at maturity. Phloem cells are small, thin-walled, and arranged in bundles that alternate with the poles of xylem (fig. 32.5). Sieve tube members are usually stained green. Procedure 32.2 Examine carrot root. 2. Stain one slice with iodine (a stain for starch) and examine it with your microscope. 3. Stain the other section of carrot root with phloroglucinol. Phloroglucinol stains lignin, a molecule that strengthens xylary cell walls. Phloroglucinol contains hydrochloric acid.
Do not spill any on yourself or your belongings! Endodermis Pericycle Question 5 a. Where is starch located in a carrot root? Phloem Xylem b. What can you conclude from this observation? © BiologyImaging.com Figure 32.5 A cross section through the center of a root of a buttercup (Ranunculus), a eudicot (125×). The phloem and xylem are vascular tissues of the vascular tissues of the vascular cylinder shown in figure 32.4a. Vessel element (a) (b) Vessel element (c) (d) ©NC Brown Center for Ultrastructure Studies, SUNY College of Environmental Science and Forestry, Syracuse, NY Figure 32.6 Comparison of vessel elements and tracheids. (a) In tracheids, water passes from cell to cell through pores, which may be simple or interrupted by bars. (d) The large openings shown in this scanning electron micrograph of the wood of a red maple (Acer rubrum, a eudicot) are vessel elements (350×). 32-5 Plant Anatomy 359 Older leaf primordium Leaf base (node) Axillary bud © BiologyImaging.com Figure 32.7 Shoot tip of Coleus, a eudicot. The apical meristem is the site of rapid cell division and primary growth. Young leaves are produced at the tip of the shoot. Shoot tips, are not covered by a cap (20×). STEMS Stems are often conspicuous organs whose functions include support and the transport of water and solutes. Some stems (e.g., cacti) also photosynthesize and store food. c. Are all cells in the shoot apex the same size? Why is this significant? The Shoot Apex Examine a prepared slide of a longitudinal section of a shoot tip of Coleus (fig. 32.7). The dome-shaped shoot apical meristem is not covered by a cap as was the root. The shoot apical meristem produces young leaves (leaf primordia) that attach to the stem at a node. An axillary bud between the young leaf and the stem forms a branch or flower. Question 6 a. How does the absence of a cap at a shoot apex differ from the apical meristem of a contract twig (fig. 32.8). A terminal bud containing the apical meristem is at the stem tip and is surrounded by bud scales. Leaf scars from shed leaves occur at regularly spaced nodes along the length of the stem. The portions of stem between the nodes are called internodes. Vascular bundle scars may be visible within the leaf scars. Axillary buds protrude from the stem just distal to each leaf scar. Search for clusters of bud scale scars. The distance between clusters or from a cluster to the terminal bud indicates the length of yearly growth. Primary Tissues of Stems b. How would you explain this difference? An epidermis is coated with a waxy, waterproof substance called cutin. Below the epidermis is the cortex, which stores food. The pith in the center of the stem also stores food (fig. 32.9). In sunflower stems, the cortex just below the epidermis are smaller, rectangular cells with unevenly thickened cell walls. These are collenchyma cells; they support elongating regions of the plant (fig. 32.10). In stems, xylem and phloem are arranged in bundles (fig. 32.10). Procedure 32.3 Examine the primary tissues of stems 1. Examine the primary tissues 1. Examine the primary tissues Bundle scar Axillary bud Node Leaf scar Pith Internode Blade Petiole (a) Terminal bud scale scars (b) Figure 32.8 A woody twig. (a) In summer. (b) The twig in its dormant winter condition. © BiologyImaging.com Figure 32.9 Cross-sectional view of a stem of alfalfa (Medicago sp.), a eudicot (10×). Note the ring of vascular bundles surrounding the scare stem of alfalfa (Medicago sp.), a eudicot (10×). pith. A high-magnification view of a vascular bundle from this stem is shown in figure 32.10. Xylem Phloem Sclerenchyma fibers are much thicker than those of adjacent cells. 32-7 Plant Anatomy 361 2. On the slide you are examining, locate a vascular bundle. Sketch what you see. Ground tissue Epidermis? ©Ed Reschke Figure 32.11 Cross section of a stem of corn (Zea mays), a monocot (5×). Unlike in eudicots such as alfalfa (fig. 32.9), bundles of vascular tissue in monocots occur throughout the ground tissue. The stem is surrounded by an epidermis. Secondary Growth of Stems b. How does the arrangement of xylem and phloem in stems differ from that in roots? Between the xylem and phloem and each vascular bundle in eudicot stems is a meristematic tissue called vascular cambium is a secondary growth (i.e., growth in girth). The vascular cambium is cylindrical and produces secondary growth? The darkly stained, thick-walled cells just outside the phloem in figure 32.10 are sclerenchyma fibers, which function in support. Sclerenchyma fibers, which are flowering plants with two cotyledons (seed leaves; see Exercise 31). Examine a prepared slide of a cross section of a corn stem (fig. 32.11). Corn is a monocot (a flowering plant with only one cotyledon). In the following space, sketch a cross section of a sunflower stem and a corn stem. Note the distribution of the vascular bundles. Question 8 How does the arrangement of vascular bundles differ in stems of monocots as compared to eudicots? 362 EXERCISE 32 Procedure 32.4 Examine secondary growth in woody stems 1. Examine se three stems. The secondary xylem of older stems consists of concentric annual rings made of alternating layers of large and small cells. The following space draw cross sections of 1-, 2-, and 3-year-old stems. 32-8 Cork cells sloughing off Periderm Cortex Primary phloem Secondary phloem Vascular cambium Annual ring of secondary xylem Secondary xylem (30×). The vascular cambium produces secondary xylem (30×). The vascular cambium produces secondary phloem to the outside Note the annual rings in the secondary xylem. A close-up of a growth ring from pine is shown in figure 32.13. Question 10 a. How do you account for this seasonal production of different-sized cells? b. What is the common name for secondary xylem? c. What is the common name for secondary xylem? important function of secondary xylem? 4. Examine a prepared slide of a cross section of secondary xylem of pine (Pinus) (fig. 32.13). In cone-bearing plants such as pine, the conducting cells of xylem are all tracheids. The absence of vessel elements gives wood of these plants a relatively uniform appearance. 5. Now examine a prepared slide of a cross section of secondary xylem of oak (Quercus), a flowering plant (fig. 32.14). Sketch what you see. Plant Anatomy 363 © BiologyImaging.com Figure 32.13 The wood of gymnosperms (such as this pine) consists almost exclusively of tracheids. These water-conducting cells are relatively small and help to support the plant Although water moves slower through tracheids are less likely to be disabled by air bubbles that form in response to freezing and wind-induced bending of branches. The larger cells on the right side of this photo form during the wet days of spring and are called spring wood; the smaller cells at the left form during the drier days of summer and are called summer wood. The change in density between spring and summer wood produces a growth ring, which appears as "grain" in wood (280×). Question 11 a. What are the large cells in oak wood? Figure 32.14 Unlike the xylem of gymnosperms, which contains only tracheids, the xylem of angiosperms also contains vessel elements. These vessel elements are much wider than tracheids and appear in this micrograph as large circles. Vessel elements are an adaptation for increased rates of water flow in angiosperms (see fig. 32.6c) (40×). cork parenchyma to the inside. Cork cells stain red because of the presence of suberin, a water-impermeable lipid. Question 12 Is the amount of cork similar in 1-, 2-, and 3-year-old stems? If not, how does it differ? Why is this important? b. What is their function? c. Which type of wood do you think transports more water per unit area, pine or oak? Why? Bark Bark includes all tissues outside of the vascular cambium, including the secondary phloem (fig. 32.12). When viewed in cross section, secondary phloem consists of pyramidal masses of thick- and thin-walled cells. The thin-walled cells. The thin-walled cells. The thin-walled cells are the conducting cells. The thin-walled cells are the conducting cells. The thin-walled cells are the conducting cells. cambium eventually ruptures the epidermis. The ruptured epidermis is replaced by a tissue called the periderm that, like the epidermis, functions to minimize water loss. Periderm consists of cork cells produced by another secondary meristem called the cork cambium. Locate the cork cambium in cross sections of 1-, 2-, and 3-year-old basswood stems. The cork cambium is a 364 EXERCISE 32 As the stem diameter continues to increase, the original periderm ruptures and new periderm die and form encrusting layers of bark. Gas exchange through structures called lenticels (fig. 32.15). Examine a prepared slide of a lenticel and locate lenticels on a mature woody stem. Question 13 How does a lenticel differ from the remainder of the periderm? LEAVES With few exceptions, most photosynthesis occurs in leaves, although some may occur in green stems. Leaves typically consist of a blade and a petiole. The petiole attaches the leaf blade to the stem. Simple leaves have one blade connected to the petiole, whereas compound leaves have several 32-10 Simple leaf Leaflet Petioles Lenticel in a cross section of part of a young stem of elderberry (Sambucus). Gas exchange across the cork layer of the stem occurs through lenticels (80×). leaflets sharing one petiole (fig. 32.16). Palmate leaflets of a compound leaf arise from your palm. Pinnate leaflets arise from a central area, as your fingers arise from a central area, as your fingers arise from your palm. are also classified according to their venation (i.e., arrangement of veins) (fig. 32.17). Parallel veins extend the entire length of the leaf with little or no crosslinking. Pinnately veined leaves have one major vein (i.e., a midrib) from which other veins branch. Palmately veined leaves have several veins extend the entire length of the leaf with
little or no crosslinking. leaves are continuous with vascular bundles in stems. Examine the leaves on display in the lab and determine their venation. List the names of common leaves on demonstration in each leaf is parallel, pinnate, or palmate. 32-11 Figure 32.16 Simple and compound leaves. The arrangement of leaves on a stem is called phyllotaxis refers to two leaves per node located on opposite sides of the stem. Alternate phyllotaxis refers to one leaf per node, with leaves appearing first on one side of the stem and then on another. Whorled phyllotaxis refers to more than two leaves per node. Examine the plants on display in the lab to determine their phyllotaxis. What Good Is Bark? You've doubtless seen chips of bark used as garden mulch that is spread around plants. Because bark cells (secondary phloem and periderm) were once alive, they contain many nutrients that are released into the soil as the bark decays. However, sawdust is a poor mulch for plants. Tree Girdling You've probably heard of "tree girdling," which is the stripping of a ring of bark from a branch. (In the wild, porcupines also girdle trees.) Girdling removes secondary phloem from the roots to the girdled trees.) Girdling removes secondary phloem from the roots to the girdled trees.) branch to renew growth. Thus, the branch or tree dies the year after it is girdled. Plant Anatomy 365 spongy mesophyll cells with numerous intercellular spaces. Examine and sketch a cross section of a corn leaf. Parallel Palmate Pinnate Question 14 a. What is the function of stomata? Figure 32.17 Palmate, pinnate, and parallel venation of leaves. b. Do epidermal cells of leaves have a cuticle? Why is this important? c. What is the significance of chloroplasts being concentrated near the lower surface of the leaf? Alternate (spiral) Whorled Figure 32.18 Patterns of leaf arrangement (phyllotaxis). e. How is the internal anatomy of a corn leaf different from that of Ligustrum? Internal Anatomy of a leaf of Ligustrum? Internal Anatomy of a leaf of Ligustrum? Internal Anatomy of a corn leaf different from that of Ligustrum? Internal Anatomy of a leaf of Ligustrum? will study stomata again in the next exercise). Just below the upper epidermis are closely packed cells called palisade mesophyll cells; these cells contain about 50 chloroplasts per cell. Below the palisade mesophyll cells; these cells contain about 50 chloroplasts per cell. cells Bundle sheath cell Vascular bundle (vein) Lower epidermis Guard cell Stoma Cuticle Figure 32.19 Ligustrum leaf, cross section. Most photosynthesis occurs in the densely packed palisade mesophyll cells, just beneath the upper epidermis of the leaf. the leaf. Water loss is minimized by the waxy cuticle that covers the leaf. g. Based on the arrangement of vascular tissue, how could you distinguish the upper versus lower surfaces of a leaf? h. If time permits, also examine prepared slides of leaves of corn (Zea mays, a monocot) and pine (Pinus, a gymnosperm). What differences are there in the structures of these leaves? How do these structural differences? INQUIRY-BASED LEARNING How do plants sense and respond to light and gravity? Observation: The ability of plant roots to grow downward and shoots to grow downward is adaptive because it increases the plants' chances of encountering water (by the roots) and light (by the shoot). Question: When the roots of a corn (Zea mays) seedling grow downward, is this a negative response to light or a positive response to light or a positive response to gravity? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 32 from your instructor. b. Discuss with your group well-defined questions relevant to the preceding observation and question. Choose and record your group's best question for investigation. 32-13 c. Translate your question into a testable hypothesis. Ask your instructor to review your proposed investigation. e. Conduct your procedures, record your data, answer your questions, hypotheses, or procedures. Repeat your work as needed. Plant Anatomy 367 Questions for Further Study and Inquiry 1. What is the function of xylem? Phloem? Vascular cambium? Epidermis? 2. What are the functions of stomata and lenticels? In what ways do these structures differ? 3. How is the internal anatomy of a stem different from that of a root? 4. How is primary growth? 5. How is a leaf structurally adapted for its function? 6. Why does a stem typically contain more sclerenchyma and collenchyma than does a leaf? 7. An old friend tells you that 30 years ago she nailed a sign into a tree trunk at a height of 1 meter. She now says the sign is 25 meters up in the tree. Should you believe her? Why or why not? 8. Compare and contrast (a) monocot and dicot stems. 9. What are three examples of plants growing on your campusition of the tree. that have (a) simple leaves and (b) compound leaves? DOING BIOLOGY YOURSELF Choose a couple of defined environments nearby, such as a vacant field or riverside. Survey the variety of leaf morphologies of the dominant plants. What can you conclude about the predominance of monocots versus eudicots in each environment? WRITING TO LEARN BIOLOGY WRITING TO LEARN BIOLOGY 368 EXERCISE 32 Why is leaf abscission especially important for temperate plants? Would you expect to find annual rings in wood of a tropical dicot tree? Why or why not? 32-14 E XER CISE 33 Plant Physiology Transpiration Learning Objectives By the end of this exercise you should be able to: 1 Describe the structure and function of stomata. 2. Describe how environmental conditions such as wind and light influence stomatal opening. 3. Measure the transpiration rate of a plant. Please visit connect.mheducation.com to review online resources tailored to this lab. To survive and reproduce, land plants must cope with many environmental challenges. Among the biggest of these problems are obtaining water and avoiding desiccation (water loss). Solutions to these and other challenges require expenditure of energy and an efficient structure and physiology. Structural and functional solutions, and the study of these and other challenges require expenditure of energy and an efficient structure and physiology. adaptations is among the most interesting aspects of biology (fig. 33.1). In this exercise, you will study the "water physiology" of plants—how plants are adapted to control their water content and evaporative loss. Before starting today's exercise, review in your textbook the structure and function of xylem and stomata, and review how water moves through plants (fig. 33.2). The loss of water from plants is called transpiration occurs through stomata of leaves. However, transpiration in flowers 1. Obtain a small beaker containing a solution of food color from your lab instructor at the beginning of your laboratory period. 2. Working in groups of three or four, cut the stem of a white flower such as periwinkle (Catharanthus) or carnation (Dianthus) so that the cut is about 0.5 cm from the base of the flower. Do not cut all the way through the stem. 3. Remove the remainder of the stem about 2.0 cm below the partial cut. 4. Float the flower in the food color so that the partial cut is submerged. 33-1 © Magda Urbanova/Shutterstock Figure 33.1 The droplets of water at the edges of these leaves of a strawberry plant are formed by guttation. Guttation results from root pressure (i.e., a positive pressure in the xylem) common in small plants growing in moist soil on cool, damp mornings. Although most water movement in plants results from evaporation of water from leaves, guttation may be an important way of moving water in short, herbaceous plants. 5. Set the beaker containing the flower as and examine the flower as and examine the flower and dye in an illuminated area, and examine the flower is the dye located? Plant Physiology 369 Water exits through stomata CO2 and light Photosynthesis produces carbohydrates and water go up and down phloem H2O O2 Stoma H2O O2 CO2 H2O Carbohydrates Water go up and down phloem Carbohydrates and water go up and down phloem H2O O2 Stoma H2O O2 CO2 H2O Carbohydrates water go up and down phloem H2O O2 Stoma H2O O2 CO2 H2O Carbohydrates and water go up and down phloem H2O O2 Stoma H2O O2 CO2 H2O Carbohydrates Water go up and down phloem Carbohydrates Water go up and down phloem H2O O2 Stoma H2O O2 CO2 H2O Carbohydrates Water go up and down phloem H2O O2 Stoma H2O Stoma H2O O2 Stoma H2O O2 Stoma H2O O2 Stoma H2O Stoma H minerals Root hair Xylem Phloem Figure 33.2 Flow of materials in a plant. Water with dissolved minerals enters the plant through the vascular system. Most of this water is eventually lost through the leaves during transpiration. Dissolved minerals are used by plant cells for metabolic reactions Carbohydrates made during photosynthesis move throughout the plant in the phloem. These carbohydrates are either stored or used as an energy source for metabolism and growth. 370 EXERCISE 33 33-2 b. What do you conclude from this observation? PLANT-WATER RELATIONS Leaves of most plants have epidermal pores called stomata (sing., stoma), formed by the separation of a pair of guard cells (fig. 33.3). Together, the guard cells and the pore between them form a stomata surrounded by guard cells. If enough water is available, guard cells absorb water and become turgid. When guard cells are turgid, they expand and bend to form a stomatal pore through which CO2 e nters and water vapor exits a leaf. When water is scarce, guard cells lose their turgidity and shrink. As a result, guard cells touch each other and the stomatal pore closes (fig. 33.4). Thus, the water status of a plant determines whether stomata are open or closed and indirectly determines whether gases move in and out of the leaf. STOMATAL STRUCTURE Guard cells in dicots are bean-shaped and attached to each other at their ends. expand around the middle. Instead, they lengthen and bow apart, thereby opening the
stomatal pore. Use procedure 33.2 to examine living guard cells and how they respond to changing environmental conditions. Procedure 33.2 Stomatal structure ©DR IEREMY BURGESS/SCIENCE PHOTO LIBRARY/ Getty Images Figure 33.3 a tobacco plant. Guard cells change shape and, in doing so, open and close a pore. In dry conditions, stomata close and minimize water loss (100×). Water passes out through the stomata, and carbon dioxide enters by the same portals. The mechanism of stomata close and minimize water loss (100×). watered Kalanchöe or Zebrina plant that has been illuminated for 4-5 hours. Bend the leaf until it snaps; then pull the surface portion of the leaf away from the leaf. 2. Quickly place the piece of epidermis in a few drops of distilled water on a microscope slide (do not let the tissue desiccate) and place a coverslip on the tissue or coverslip on the tissue. Be careful not to trap any air bubbles beneath the tissue desiccate) and place a coverslip on the tissue desiccate (do not let the tissue desiccate) and place a coverslip on the tissue or coverslip on the tissue desiccate) and place a coverslip on the tissue desiccate (do not let the tissue desiccate) and place a coverslip on the tissue desiccate (do not let the tissue desiccate) and place a coverslip on the tissue desiccate (do not let the tissue desiccate) and place a coverslip on the tissue desiccate (do not let the tissue desiccate) and place a coverslip on the tissue desiccate (do not let the tissue desiccate) and place a coverslip on the tissue desiccate (do not let the tissue desiccate) and place a coverslip on the tissue desiccate (do not let the tissue desiccate) and place a coverslip on the tissue desiccate (do not let the tissue desiccate) and place a coverslip on the tissue desiccate (do not let the tissue desiccate) and place a coverslip on the tissue desiccate (do not let the tissue desiccate) and place (do not let t closing of stomata. (a) Two guard cells form each stoma on the surface of a leaf. When H+ ions are pumped from guard cells, K+ and Cl- move into the guard cells and causes water to diffuse into the cells by osmosis. This influx of water causes the cells to swell and bow apart, thereby forming a pore and opening the stoma. Water evaporates through these stomatal pores during transpiration. (b) When the solute pressure is low in the quard cells, water diffuses out, the quard cells, water diffuses out, the quard cells, water diffuses out, the stomatal pore closes. A variety of environmental factors cause stomata to open and close. 33-3 Plant Physiology 371 3. Examine the tissue with your microscope. Diagram the epidermis and its stomata. 4. Make a wet mount of epidermis from both sides of the coverslip by touching the tissue. 6. Wick this solution under the coverslip by touching the tissue. 7. Reexamine the stomata. Sketch what you see. b. Are the densities of stomata similar on the upper and lower surfaces of Kalancho"e and Zebrina? c. The guard cells of Kalancho"e and Zebrina? c. The guard cell epidermal peel of Zea mays (corn), a monocot. Diagram cells of the epidermis of corn. e. Are stomata of the two plants arranged in a pattern, or do they occur randomly? Question 2 a. Approximately how many stomata are in a mm2 of the lower surface area of Kalancho" e and Zebrina? f. How is the structure of individual stomata different in Zea mays than in Kalancho"e and Zebrina? 372 EXERCISE 33 33-4 Question 3 a. Did the NaCl solution cause stomata to close? Why or why not? b. What is the advantages? Procedure 33.3 Stomatal density in other plants Unlike Kalancho"e and Zebrina, not all plants have an epidermis that can be removed easily from their leaves. We can examine the stomata of these plants by creating a mold of the epidermis made with nail polish. Before starting this procedure, examine leaves on the plants available in lab. For each plant, which surface of the leaf—that is, the upper or lower surface—do you think will have the most stomata? Which do you think will have the fewest? Why? Write your hypotheses here: Test your hypotheses by making molds of the surfaces of the leaves, and then calculating the stomatal density of each surfaces of the leaves from a plant available in lab. 2. Paint a coating of clear nail polish onto the upper and lower sides of the leaves. The polish should cover 1-2 cm2. Handle the nail polish carefully; it can be toxic if ingested or inhaled. 4. When the polish. (Do not use opaque tapes such as Scotch matte-finish "Magic" tape; instead, use clear carton-sealing tape.) 5. Lay the leaves flat on the table and use your thumb to gently press the hardened polish is the impression of the leaf surface that you will examine. 7. Tape your mold of the leaf surface to a clean microscope slide (with the sticky side of the tape down). If the mold doesn't come off the leaf cleanly, use forceps to remove the polish. 8. Examine the nail-polish mold with the high-power objective of your light microscope. Search for areas that are clean and intact and in which you can see stomata. Write the name of the plant and the leaf surface (i.e., upper or lower) you are examining on the slide. 9. Count the number of stomata in at least three different fields of view; then convert those numbers into stomata per field of view Density (stomata mm-2) Lower surface Number of stomata per field of view Density (stomata mm-2) Question 4 What is the average density of stomata on the upper versus lower surface of the leaf? Why is this significant? 10. If other plants, formulate hypotheses about the abundance of stomata on the upper and lower surfaces of their leaves. Write your hypotheses here: 3. Wait for the polish to dry completely. This will take 15-20 min. The dried polish is now a mold of the leaf surface. 33-5 Plant Physiology 373 Tray Figure 33.5 Method of cutting submerged stems. Cutting the stem underwater avoids introducing air into the vascular tissue. H2O movement during transpiration Pipet with graduations Figure 33.6 Experimental setup for measuring transpiration. As water is transpiration Condition Transpiration Rate (mL H2O h-1) 11. Test your hypotheses by making molds of the leaves' surfaces and calculating the density of stomata. Record your results here: Control (standard illumination) Darkness or reduced light Light; mild breeze (created by a small fan) Dark; epidermis of the plants you examined? Light; leaves coated with petroleum jelly Light; all leaves removed 374 EXERCISE 33 33-6 TRANSPIRATION Transpiration is the levels of CO2, light, wind, and humidity. Use procedure 33.4 to quantify the effects of light and wind on transpiration. Question 6 State your conclusion about the influence of light, dark, breeze, clogged stomata, and removed leaves on water movement in plants. Light: Procedure 33.4 Quantify transpiration 1. Obtain a sunflower (Helianthus) plant from your lab instructor. If sunflower plants are not available, use the pine branches or other stems available in the lab. 2. Submerge the stem in water and obliquely cut the stem with a sharp scalpel (fig. 33.5). 3. While it is still submerged in water, attach the severed stem to a water-filled tube connected to a 1.0-mL pipet as shown in figure 33.6. Keep the pipet in a horizontal position. Be sure that no air bubbles are in the system and that no water is on the leaves. 4. Place the stem in an illuminated area. Transpiration will move water through the pipet to stabilize. Note the position of the meniscus in the pipet. 6. Allow transpiration to occur for 15 min. 7. Determine and record the volume of water (mL) transpiration in table 33.1 as the control value. 9. Continue to determine the transpiration rate under the conditions in the order listed in table 33.1. 10. If data from other groups are available, determine the mean transpiration rates for each condition and record them next to your group's values. Dark: Breeze: Clogged stomata: Removed leaves: INQUIRY-BASED LEARNING How do transpiration rates vary in different species of plants? Observation: In this lab you measured the rates of transpiration through individual parts of plants. All plants transpire, and their rates of transpiration are influenced by the environments in which they grow. Question: Do transpiration rates vary among different species of plants? a. Establish a working lab group well-defined questions relevant to the preceding observation and question. Choose and record it. d. Outline on Worksheet 33 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your proposed investigation. e. Conduct your procedures, record your data, answer your question, and make relevant comments. f. Discuss with your instructor any revisions for Further Study and Inquiry 1. What structural features of plants minimize water loss? 2. Why was it important in today's exercise to sever the stems while they were submerged in water? 3. What adaptations help plants conserve water? DOING BIOLOGY YOURSELF Assume that a maple tree in your front yard has 100,000 leaves, each having an average area of 35 cm2. If the transpiration rate of each leaf is 0.05 mL H2O h-1 cm-2 leaf area, how many liters of water move through the plant in a day? 376 EXERCISE 33 WRITING TO LEARN BIOLOGY Describe any adaptations that would improve water economy in plants. In which environments might you expect to find the adaptations that would improve water economy in plants. In which environments might you expect to find the adaptations that would improve water economy in plants. Regulators 34 Learning Objectives By the end of this exercise you should be able to: 1. Define the terms phototropism and gravitropism. 2. Describe symptoms of mineral deficiency in plants. 3. Explain how the guality and guantity of light affect seed germination. 4. Explain the modes of action of auxin and gibberellic acid. Please visit connect.mheducation.com to review online resources tailored to this lab. P lants
respond to a variety of environmental stimuli such as light and gravity, and require several nutrients such as calcium and gibberellic acid are examples of growth regulators in plants. In this exercise, you will study a variety of common physiological responses is an adaptation for the survival and reproduction of plants in varied environments. PLANT TROPISMS A tropism is a movement in response to an external stimulus. The directed growth in response to light (fig. 34.1), and gravitropism, which is directed growth in response to light (fig. 34.2). 3. Use a protractor to measure curvature of the seedlings every 30 min for 2 h. 4. Record your results in table 34.1. Question 1 a. In which direction did the seedlings curve? b. Is this curvature positive or negative phototropism? c. What is the adaptive significance of phototropism? c. What is the adaptive significance of phototropism? Phototropism? C. What is the adaptive significance of phototropism? Phototropism? Phototropism? c. What is the adaptive significance of phototropism? C. What is the adaptive significance o (Raphanus) seedlings. These seeds have been grown in diffuse, overhead light. 2. At the beginning of the lab period, place your seedlings approximately 25 cm from a 100-watt light so that light so t of Phototropism Time (h) Mean Curvature (degrees) 0.5 1.0 1.5 2.0 Gravitropism Plants may perceive gravity by the movement of starch-laden amyloplasts within cells (fig. 34.4). Yesterday, your instructor placed Zea mays (corn) seedlings having roots approximately 1 cm long in a glass beaker. Seedlings labeled "H" had their root oriented ©Gaertner/Alamy Stock Photo Figure 34.1 Sunflowers and other plants (e.g. cotton, alfalfa, beans) helps the plants regulate the amount of light that they absorb. Desert plants such as the "compass plant" use phototropism to orient their leaves perpendicular to the sun's rays to maximize the amount of light absorbed for photosynthesis. Gravity (b) 25 µm ©BioPhot Figure 34.3 Perception of gravity in root caps. (a) Cells in ©Martin Shields/Alamy Stock Photo Figure 34.2 Negative gravitropism by a stem. This plant was placed on its side in the dark 24 hours before this picture was taken. The stems have curved away from the pull of gravity. 378 EXERCISE 34 the center of a root cap contain numerous starch-laden amyloplasts located in the bottom of the cells (5×). (b) Amyloplasts has long been thought to be the basis for how roots perceive gravity (upper photo) (see fig. 34.4). To see a higher-magnification view of the root cap, see figures 32.2b and 32.3. 34-2 Table 34.2 Observations of Gravitropism in Roots Treatment or Orientation Direction of Gravitropism in Roots and 32.3. 34-2 Table 34.2 Observations and 34.2 Detipped roots oriented horizontally (H*) (a) © Professor Malcolm B. Wilkins d. Where in roots does the differential growth occur that produces gravitropism? e. Are roots positively or negatively gravitropism? e. Are roots does the differential growth occur that produces gravitropism? e. Are roots does the differential growth occur that produces gravitropism? e. Are roots positively or negatively gravitropism? gravitropism? Downward curvature (a) begins within 30 min and (b) is completed within a few hours. Curvature results from faster elongation of the upper side of the root than of the lower side. horizontally, whereas those labeled "D" had their root pointing down. The terminal 3-4 mm was removed from the roots of seedlings labeled with an asterisk (*), whereas the other seedlings were not cut. Procedure 34.2 Observe root gravitropism 1. Obtain the containers of corn seedlings oriented horizontally and vertically. 2. Examine the experimental setup and the direction of root growth. 3. Record your observations in table 34.2. Question 2 a. Which roots grew down? b. Which one(s) didn't? c. What do you conclude from these observations? 34-3 Procedure 34.3 Examine stem gravitropism 1. Obtain three containers of tomato plants (Lycopersicon) or sunflower (Helianthus) plants. 2. Turn the potted plants horizontally. 3. Measure the distance from the stem tip to the table's surface. Record your measurements in table 34.3. 4. Every 30 min remeasure the distance between the stem tips and table, and record your results. 5. Some of the plants available in the lab were turned horizontally and inverted yesterday; others were left upright. 6. Examine stem curvatures after 24 h and record your observation in table 34.3. 7. Make a simple sketch of the seedling stem curvatures after 24 h. Question 3 a. How are the stems oriented after 24 h? b. What is the adaptive advantage of a gravitropism in Stems Treatment-Time Distance of Stem Tip from Table Surface Biological response: flowering is blocked Horizontal—Time 0 min Destruction Phytochrome Pfr Horizontal—Time 30 min Horizontal—Time 60 min Far-red light (730 nm) Horizontal—Time 90 min Red light (660 nm) Long period of darkness Horizontal—Time 24 hours Observation: Phytochrome Pr Synthesis Precursor Pp SEED GERMINATION Several environmental factors affect seed germination. For example, seeds of many plants germinate only in response to certain types of light. The pigment that absorbs light affecting seed germination (and several other developmental responses) is phytochrome alternates between two forms, depending on the light it has absorbed. Phytochrome alternates between two forms, depending on the light it has absorbed by red light. (730 nm) and/or darkness (fig. 34.5). The activation and deactivation reactions are reversible, and the ultimate physiological effect induced by the phytochrome absorbed last. More than 50 different developmental processes are affected by phytochrome absorbed last.

seeds (Lactuca sativa) are excellent models for examining the effects of light on germination because they are sensitive to light and germinate quickly. The seeds are dormant when they are first shed, and germination because they are sensitive to light absorption by phytochrome usually exists in the red-absorbing form. Activation (absorption of red light) causes increased water absorption by the radicle cells, and the radicle grows and elongates. Germination of Figure 34.4 Observe germination of Figure 34.5 How phytochrome works. Phytochrome works. Phytochrome works. precursor. When exposed to red light, Pr changes to Pfr, which is the active form that elicits a response in plants. Pfr is converted to Pr when exposed to far-red light, and it also converts to Pr or is destroyed in darkness. The destroyed in darkness. Treatment 1: Continuous darkness (wrap the dish in metal foil) Treatment 2: Continuous light for 10 min, then darkness Treatment 4: Far-red light for 10 min, then darkness Treatment 5: Red light for 10 min, far-red light for 10 min, then darkness Treatment 5: Red light for 10 min, then darkness Treatment 4: Far-red light for 10 min, then darkness Treatment 5: Red light for 10 m for 10 min, then darkness 4. During your next laboratory period determine the percentage of germination resulting from each treatment. 5. Record your results in table 34.4. Question 4 What do you conclude about the influence of light on germination of lettuce seeds? lettuce seeds? lettuce seeds? instructor. 2. Working in small groups, place 50 seeds in each of six petri dishes containing water-soaked filter paper. 380 EXERCISE 34 34-4 Table 34.4 Germination of Lettuce Seeds under Six Different Light Treatments Treatment c. How could seed germination of Lettuce Seeds under Six Different Light Treatments Treatment c. How could seed germination be influenced by depth of planting? How might phytochrome be involved in such a response? Percentage Germination 1. Dark 2. Constant room light 3. Red light, then dark 4. Far-red light, then dark 6. Red light, then dark 6. Red light, then dark 7. Red light, then dark 7. Red light, then dark 6. Red light, then dark 7. Red light, then dark 6. Red light, then dark 6. Red light, then dark 7. Red light, then dark 7. Red light, then dark 6. Red light, then dark 7. Red light, then dark 6. Red light, then dark 7. Red lig Many seeds germinate in the dark and push their stems above the soil to receive light. If the seedlings do not receive light, they grow abnormally; the leaves grow longer and the plant is exposed to light. Activation of phytochrome helps promote normal growth. Use procedure 34.6 to observe etiolation. Room light Procedure 34.6 Examine etiolation Dark 1. Obtain two groups of bean (Phaseolus) seedlings. They were planted 10-14 days ago, with one group being grown in the dark and one group in light. 2. Complete the first two lines of table 34.6 with your observations. 3. After completing and recording your observations, reverse the two treatments and examine the plants during your next lab period. 4. Complete the last two lines of table 34.6 with your final observations. Germinating seeds of different plants often respond different plants often respond to the plants during your next lab period. sensitivity with procedure 34.5. Procedure 34.5. Procedure 34.5. Observe germination of onion seeds by placing 25 in each of two petri dishes and label the lids "light" and "dark." Place one petri dish in room light and the other dish in darkness. 3. Examine the seeds during your next lab period and record the percentage germination in table 34.5. Question 5 a. Does light promote or inhibit germination of onion seeds? Question 6 a. How did the seedlings manage to grow at all while in the dark? b. Did etiolation include stem elongation? c. What is the advantage of rapid stem elongation in a seed germinating in the dark? b. Is this response different from that of lettuce? PLANT NUTRITION Growth of green plants requires suitable temperature and adequate amounts of carbon, hydrogen, and 34-5 Plant Physiology 381 Table 34.6 Plant Growth under Different Light Treatments Treatment Leaf Size Stem Diameter Height Color of Shoots Stem Strength Light Table 34.7 Hoagland's Solution, a Common Nutrient Medium for Healthy Plant Grams/Liter G CuSO4 · 5H2O 0.05 H2Mo4 · 4H2O 0.02 Ferric tartrate 0.50 oxygen compose 98% of the fresh weight of plants. The remaining 2% is composed of 13 other elements classified either as macronutrients: •• Macronutrients are nutrients are nutrients. potassium (K), magnesium (Mg), and sulfur (S) are macronutrients. •• Micronutrients are nutrients needed in relatively small amounts (3 cm), wings long, transparent, and with many strong veins; abdomen long and slender..... ..(dragonflies) Odonata Smaller insects, wing venation faint, wings extending posterior to the ...(termites) Isoptera 7. Wings covered with fine, opaque scales; tubular, coiled, sucking mouthparts(butterflies, moths) Lepidoptera Wings thin, transparent, and not covered with scales; mandibles well developed(ants, bees, wasps) Hymenoptera Questions for Further Study and Inquiry 1. Arthropods usually have a distinct head. How would you define a "head"? What are the advantages and disadvantages of having such a body region? 2. Does an insect's exoskeleton limit growth? Why or why not? 3. Diagram the arrangement of muscles necessary to bend a joint with an exoskeleton versus a joint supported by an endoskeleton. 4. Arthropod body segments are sometimes distinct, sometimes indistinct, and sometimes fused as groups to form body regions. Which appear the least segmented? 39-13 Survey of the Animal Kingdom 451 5. What effect would 2.5 million spiders per acre have on the insect community? 6. Do you suspect that each eye of a spider provides the same sensory input to the brain? Why or why not? 7. What activities and body functions of arthropods require the most specialized appendages? 8. Do beetles have wings? If so, where are they? 9. What other group of organisms you have studied thus far has chitin as part of its outer covering? 10. What group of arthropods dominates the sea? 11. Prepare a simple table of all of the taxonomic groups, their common names, their distinguishing characteristics, and all representative genera covered in this exercise. Keep this table with your study notes. 12. Does a crayfish have an open or closed circulatory system? Review detailed references and summarize how the circulatory systems vary among animal phyla. 13. A major feature of annelids and arthropods is segmentation. WRITING TO LEARN BIOLOGY Do you think that arthropods constitute a single phylum, or should they be divided into multiple phyla? Describe what divisions you would make and your reasons for them. 452 EXERCISE 39 39-14 E XER CISE Survey of the Animal Kingdom Phyla Echinoderm and chordate to: 1. List echinoderm and chordate and Chordate 40 Learning Objectives By the end of this exercise you should be able to: 1. List echinoderm and chordate to: 1. List echinoderm and chordate and Chordate 40 Learning Objectives By the end of this exercise you should be able to: 1. List echinoderm and chordate to: 1. List echinoderm and chordate to: 1. List echinoderm and chordate and Chordate 40 Learning Objectives By the end of this exercise you should be able to: 1. List echinoderm and chordate to: 1. List echinod survival. 2. Describe the morphology of organisms of phyla Echinodermata and Chordata. 3. List characteristics that echinoderms and chordates that are unique or advanced compared to more primitive phyla. 5. Describe the water vascular system of echinoderms. 6. Discuss embryological characteristics that distinguish deuterostomes from protostomes. 7. Understand which phyla are protostomes and which phyla are protostomes and which are deuterostomes. 7. Understand which phyla are protostomes and which phyla are protostomes from protostomes. 7. Understand which phyla are protostomes and which phyla are protostomes and which phyla are protostomes from protostomes. 7. Understand which phyla are protostomes from protostomes from protostomes from protostomes and which phyla are protostomes from protostomes. Echinodermata and Chordata—are deuterostomes. Deuterostomes are a major
departure from the phylogenetic line of protostomes such as annelids, mollusks, and arthropods. The fundamental basis for the separation of deuterostomes from protostomes such as annelids, mollusks, and arthropods. blastopore of deuterostomes gives rise to an anus rather than the mouth. The blastopore is the opening to the first cavity formed in a developing embryo and is discussed more in Exercise 50. Examine figure 40.1 carefully. Refer to your textbook for a more detailed comparison of protostomes and deuterostomes. Question 1 Describe three major differences between deuterostome and protostome development. PHYLUM ECHINODERMATA Echinoderms (6000 species) are marine bottom-dwellers and include sea stars, brittle stars, sea urchins, sand dollars, sea cucumbers, and sea lilies (table 40.1, fig. 40.2). These organisms are called echinoderms (echino = spiny, derm = skin) because their internal skeleton of calcareous plates, 40-1 called ossicles, usually has spines protruding through a thin layer of skin. The five classes of echinoderms are radially symmetrical, and their bodies typically consist of a ring of five repetitive parts (i.e., they are pentaradial). In contrast, larvae of echinoderms are bilaterally symmetry is secondarily derived and not directly related to the symmetry of more ancient phyla such as Cnidaria. Echinoderms have a unique water vascular system consisting of a series of coelomic water-filled canals ending in hollow. projections called tube feet. Muscle contractions and hydrostatic pressure in the water vascular system extend and move the tube feet and other parts of the system and thereby move the skin, and spines of class Asteroidea, including the common sea star Asteria, are arranged loosely under the skin, and spines of the system and thereby move the animal (fig. 40.4). Class Asteroidea, including the common sea star Asteria, are arranged loosely under the skin, and spines of the system and thereby move the skin, and spines of the system and thereby move the skin, and spines of the system and thereby move the skin and spines of the system and thereby move the skin and spines of the system and thereby move the skin and spines of the system and thereby move the skin and spines of the system and thereby move the skin and spines of the system and thereby move the skin and spines of the system and thereby move the skin and spines of the system and thereby move the skin and spines of the system and thereby move the skin and spines of the system and thereby move the skin and spines of the system and thereby move the skin and spines of the system and thereby move the skin and spines of the system and thereby move the skin and spines of the system and thereby move the skin and spines of the system and thereby move the skin and spines of the system and thereby move the skin and spines of the system and thereby move the skin and spines of the system and thereby move the skin and spines of the system and thereby move the skin and thereby move the are small and blunt. Arms of sea stars are continuous with the central disk. The mouth is at the central disk. aboral surface is the madreporite, a sieve connecting the water vascular system with the environment. Survey of the Animal Kingdom 453 Deuterostomes top view side view Cleavage is radial and indeterminate. Protostomes Cleavage is radial and indeterminate. to lab, you were asked to read this exercise so you would know what to do and be aware of safety issues. In the space below, briefly list the safety issues associated with today's procedures. If you have questions about these issues, contact your laboratory assistant before starting work. Procedure 40.1 Examine the external anatomy mouth blastopore anus primitive gut anus primitive gut mouth Fate of blastopore blastopore blastopore becomes the anus. Protostomes Deuterostomes Coelom formation Blastopore becomes the anus. Protostomes Deuterostomes Coelom formation Blastopore becomes the anus. and locate the external and internal features shown in figure 40.6. 3. Examine the oral surface of the sea star, and locate the central mouth. Locate the central mouth. Locate the tube feet protruding from the ambulacral grooves. 4. Use a dissecting microscope to examine the spines on the aboral surface of the sea star, and locate the central mouth. consistency. 6. Examine figure 40.4 and trace the path of water from the madreporite to the tube feet. 7. If living sea stars are available, observe their locomotion. mesoderm Question 2 a. How many tube feet would you estimate are on the oral surface of a sea star? gut Coelom forms by a outpocketing of primitive gut. Figure 40.1 Patterns of embryonic development of protostomes. Left: In the embryo of protostomes, cleavage is spiral and determinate—new cells form at an angle to old cells—and each cell has limited potential and cannot develop into a complete embryo. The blastospore is associated with the mouth, and the coelom, if present, develops by a splitting of the mesoderm. Right: In deuterostomes, cleavage is radial and indeterminate—new cells sit on top of old cells—and each one can develop into a complete embryo. The blastopore is associated with the anus, and the coelom, if present, develops by an outpocketing of the primitive gut. Sea stars often prey on oysters and clams by using their arms and tube feet to grip the shell and persistently apply pressure to pry it open. Sea star spines movable? c. What is the consistency of the madreporite? d. How fast does a living sea star move? e. Do tube feet of a living sea star move in unison? 40-2 Table 40.1 Phyla Echinodermata and Chordata Approximate Number of Named Species Phylum Typical examples Key Characteristics Echinodermata (echinodermata and chordata Approximate Number of Named Species Phylum Typical examples Key Characteristics Echinodermata (echinodermata and chordata Approximate Number of Named Species Phylum Typical examples Key Characteristics Echinodermata (echinodermata and chordata Approximate Number of Named Species Phylum Typical examples Key Characteristics Echinodermata (echinodermata and chordata Approximate Number of Named Species Phylum Typical examples Key Characteristics Echinodermata (echinodermata and chordata Approximate Number of Named Species Phylum Typical examples Key Characteristics Echinodermata (echinodermata and chordata Approximate Number of Named Species Phylum Typical examples Key Characteristics Echinodermata (echinodermata (echinodermata (echinodermata and chordata Approximate Number of Named Species Phylum Typical examples Key Characteristics Echinodermata (echinodermata calcium plates; five-part body plan and unique water vascular system with tube feet; able to regenerate lost body parts; marine 6000 Chordates with a notochord; possess a dorsal nerve cord, pharyngeal slits, and a tail at some stage of life; in vertebrates, the notochord is replaced during development by the spinal column; 20,000 species are terrestrial; deuterostomes 42,500 Procedure 40.2 Examine the internal anatomy of a sea star 1. Obtain a preserved sea star 1. Obtain a preserved sea star 2. Examine the internal anatomy of a sea star 1. Obtain a preserved sea star 2. Examine the internal anatomy of a sea star 1. Obtain a preserved sea star 2. Examine the severed end and compare the structures with those shown in figure 40.7. 3. Cut along both sides of the arm up to the central disk. Then cut across the aboral (upper) surface to join the two lateral incisions. 4. Remove one of the digestive glands so you can examine the gonad lying underneath. 6. Cut around the perimeter of the central disk. Then cut from the perimeter up to and around the madreporite. 7. Remove the upper body wall without tearing away the madreporite. 7. Remove the upper body wall. As you lift it, try to see the delicate connection between the anus and the surface of the thick-walled pyloric stomach below. 8. Locate the structures shown in figure 40.8. Question 3 a. How many tube feet would you estimate are in one arm? 40-3 b. What part of their locomotion system? d. Does the stomach wall appear highly folded and extensible? How does that relate to the feeding method of most sea stars? Class Ophiuroidea (Brittle Stars) Examine a preserved brittle star such as Ophioderma. Brittle stars are typically thick and have attached musculature. They may form "shields" on the surface. As the name "brittle" stars implies, their arms detach easily, allowing escape from predators. The ambulacral grooves are closed in brittle stars allow them to crawl rapidly like an octopus rather than creep slowly like sea stars. Brittle stars eat suspended food particles captured with their tube feet and passed to their mouth. Survey of the Animal Kingdom 455 © BiologyImaging.com (a) (b) (c) © BiologyImaging.com (a) (b) (c) © BiologyImaging.com (a) Sea star, Dermasterius imbricata (class Asteroidea), in the Gulf of California. (b) California sea cucumber, Parastichopus californicus (class Holothuroidea), uses its highly branched arms in filter feeding. Although filter feeding. Although filter feeding. (c) Feather star, Florometra serrastissima (class Holothuroidea), uses its highly branched arms in filter feeding. use their arms for locomotion, capturing prey, and scavenging the substrate for food. (d) Brittle star, Ophiothrix (class Ophiuroidea). (e) Sea urchin, class Echinoidea. Urchins, such as this red sea urchin, Strongylocentodus franciscanus, defend themselves with long and sometimes barbed spines, often filled with toxins. 40-4 Question 4 a. Between brittle stars and sea stars, which have the most apparent ossicles? Do they overlap? Mouth Gut b. Are tube feet visible in Ophioderma? Anus © BiologyImaging.com Figure 40.3 The free-swimming larva of the common sea star, Asterias rubens. Such bilaterally symmetrical larvae suggest that the ancestors of the echinoderms may not have been Tube feet are used for locomotion and for gripping and pulling apart prey
such as clams. Spine (a) (b) (c) Figure 40.5 Pedicellaria of Asterias. (a) Forceps-type pedicellaria of Asterias. (b) Spine surrounded by (c) scissors-type pedicellaria of Asterias. Central disk Ambulacral groove Spines Mouth Madreporite Figure 40.6 External features of sea stars. Question 5 How does the position of the mouth and anus of a crinoid relate to a primitive sessile existence? Digestive gland Gonad Radial canal Ampulla Tube foot © BiologyImaging.com Figure 40.7 Cross section of an arm of a sea-star showing internal anatomy (5×). Class Crinoidea (Sea Lilies and Feather Stars) Examine a preserved crinoid. Crinoids are the most ancient echinoderms; only a few genera live today (figs. 40.2c, 40.9). They differ from other living echinoderms; only a few genera live today (figs. 40.2c, 40.9). coarse, jointed appearance. Highly branched and feathery arms surround the mouth and anus. Most ancient crinoids were attached to the substrate by a stalk and appeared to be plants. However, most modern species are not stalked or permanently attached. Crinoids filter feed by capturing food particles on the mucus of their tube feet. 458 EXERCISE 40 Class Echinoidea (Sea Urchins and Sand Dollars) Examine a sand dollar and compare its test of fused ossicles to an urchin's test. Urchins lack distinct arms, and their ossicles are fused into a solid shell called a test (fig. 40.2e). Holes in the test allow long tube feet to protrude. Spines of sea urchins are jointed, movable, and long tube feet control locomotion of urchins. The mouth contains five ossified plates, or teeth, used to scavenge and scrape surfaces of rocks and gather algae for food. This small internal structure of five teeth is called Aristotle's lantern. Question 6 a. Is an urchin's test pentaradially symmetrical? b. Urchins and sand dollars lack arms. How do they move? 40-6 Tube feet Water vascular system Ambulacral ridge Gonad Digestive gland Anus Eyespot Madreporite Gonad Ampulla Stomach Stomach Intestinal cecum Digestive gland (a) (b) © BiologyImaging.com Figure 40.8 Sea star internal anatomy. (a) Schematic with aboral surface removed. (b) Partially dissected sea star. Sea Urchins and RAGs The vertebrate immune system is astoundingly complex, even though fewer than 1% of human genes encode antibodies that recognize invaders. Underlying this versatile immune system is the ability to shuffle and reshuffle DNA fragments that recognize a virtually limitless variety of invading astignes. Surprisingly, scientists have learned much about the vertebrate immune system and its encoding system for antibodies by studying sea urchins. By studying the genome of the purple sea urchin, Strongylocentrotus purpuratus, scientists have revised our understanding of the vertebrate immunologist Jonathan Rast and his colleagues searched the echinoderm's DNA for evidence of genes required for vertebrate-style adaptive immunity, they found genes encoding a pair of enzymes are called RAG proteins, for recombination activating gene. In vertebrates, two RAG proteins (called Rag1 and Rag2) must be present for lymphocytes to mature properly; these two proteins interact to recognize sites where a DNA fragment is to be cut and spliced. The origin of our vertebrate immune system may have begun taking shape in ancestors of our distant deuterostome cousins, the echinoderms! ©gcammino/Getty Images 40-7 Survey of the Animal Kingdom 459 Pinnules Arm Pinnules Crown Arm Calyx Stalk Calyx Cirri Cirri (a) (b) Figure 40.9 Class Crinoidea. (a) A sea lily (Ptilocrinus). (b) A feather star (Neometra). Aboral surface Intestine Figure 40.10 External anatomy of a sea urchin. Spines and tube feet are removed on the right half of the diagram to show the test. Class Holothuroidea (Sea Cucumbers) Examine a sea cucumbers look different from other echinoderms because they have soft bodies with reduced ossicles and few if any spines (figs. 40.2b, 40.11). Radial symmetry is less evident 460 EXERCISE 40 Rectum Anus Figure 40.11 Internal structure of a sea cucumber, Thyone. The mouth leads to a stomach supported by a calcareous ring. The calcareous ring is also the attachment site for longitudinal retractor muscles of the body. Contractions of these muscles pull the tentacles into the anterior end of the body. The stomach leads to a looped intestine. 40-8 Table 40.2 A Comparison of the Major Characteristics of the Classes of Echinoidea Echinoidea Echinoidea Echinoidea Shape of arms Development of the body. Spine structure in sea cucumbers and their body axis is oriented horizontally. This orientation gives sea cucumbers a semblance of cephalization. The tentacles secrete a mucus that captures small floating organisms, which they eat. Interestingly, some sea cucumbers are been cucumbers and their body axis is oriented horizontally. digestive tract, and other organs. This process is called evisceration; because of it, the animal must regenerate the lost parts of the organs. Some gourmets consider sea cucumbers a delicacy. Examine other preserved echinoderms and review in your textbook the major characteristics of each class. Then complete table 40.2. PHYLUM CHORDATA Chordates include 42,500 species of fish, amphibians, reptiles, birds, and mammals. They all are characterized by (1) a dorsal hollow nerve cord; (2) a notochord, a cartilaginous rod that forms on the dorsal side of the gut in the embryo; (3) pharyngeal slits, openings in the throat that filter water that has entered through the mouth, and (4) a postanal tail (fig. 40.12). An internal, bony skeleton is also common and provides sites for muscle attachment for efficient movement. Question 7 a. Are tube feet visible on the sea cucumber? Hollow dorsal functions? What functions are tube feet visible on the sea cucumber? common? Pharyngeal slits Notochord c. Describe the functions of pedicellariae, madreporite, dermal gills, Aristotle's lantern, tube feet, water vascular system. Postanal tail Figure 40.12 The four principal features of the chordates, shown in a generalized embryo. 40-9 Survey of the Animal Kingdom 461 Excurrent siphon Nerve ganglion Incurrent siphon Mouth (incurrent siphon) Atriopore (excurrent siphon) Dorsal nerve cord Pharynx Intestine Genital duct Gill slits Heart (a) © Joao Pedro Silva/Getty Images (b) Notochord Heart (c) Figure 40.13 Tunicates (phylum Chordata, subphylum Urochordata). (a) Living adult. (b) Structure of adult tunicate. (c) Larval structure. Subphylum Urochordata (Tunicates or Sea Squirts) Examine a preserved adult tunicate. Urochordates, sometimes called tunicate, sometimes called tunicates, are sessile or planktonic marine organisms whose larvae possess the general chordate form—that is, they are elongated with a notochord and dorsal nerve cord (fig. 40.13). In contrast to larvae, the structure of an adult is highly modified to include a sievelike basket perforated with pharyngeal gill slits and surrounded by a cellulose sac called a tunic. Water is actively filtered; some tunicates only a few centimeters long can filter 170 liters of water per day. Food collected by mucus on the pharyngeal basket is moved by cilia to the stomach and intestine. The intestine empties into the body cavity near the excurrent siphon. Examine a prepared slide of larval tunicates. A larval tunicate has bilateral symmetry, a dorsal nerve cord, a notochord, and a postanal tail but loses these features when it settles for adult life (fig. 40.13c). (a) © Paulo de Oliveira/Photoshot Images/Newscom Oral hood with tentacles Notochord Dorsal nerve cord Pharynx Muscle blocks Pharyngeal slits Question 8 What other group of organisms has cellulose in its supporting structures? Does this shared feature surprise you? Intestine Anus Postanal tail (b) Figure 40.14 (a) A lancelet, Branchiostoma lanceolatum Subphylum Cephalochordata (Lancelets) Examine either a preserved lancelet or a slide of a whole mount and compare the specimen with that shown in figure 40.14. Also examine a cross section through the pharynx and try to visualize the paths of food and water (fig. 40.15). 462 EXERCISE 40 (phylum Chordata, subphylum Cephalochordata), protruding from shell gravel. The muscle segments are visible; the square, pale yellow objects along the side of the body are gonads, indicating that this is a male lancelet. (b) Internal structure of amphioxus. This bottom-dwelling cephalochordate has the four distinctive features of (fig. 40.16). Three classes of vertebrates discussed here are fishes and four are terrestrial tetrapods. Dorsal fin Muscle Dorsal nerve cord Class Cephalaspidomorphi (Lampreys) Notochord Gill arches Atrium Pharynx Gonad © BiologyImaging.com Figure 40.15 Cross section through the pharynx of a lancelet (20×). Lancelets are small, fishlike, marine chordates that burrow in sand or mud. They are commonly called amphioxus, but the most common genus is Branchiostoma. The dorsal nerve cord and notochord extend the length of the animal. The buccal cavity surrounds the mouth followed by a long pharynx with many gill slits (openings) separated by gill arches of reinforced tissue. As seawater enters the mouth and exits through the slits, it must pass over the surfaces of the arches that form the slits. As this occurs, food particles are caught on the arches and vertebrates have a postanal tail, another diagnostic trait of chordates. After water passes by the gill arches, it moves into a surrounding chamber called an atrium and then leaves the body through the atriopore. Ectoderm Examine a prepared slide of an ammocoete, the larva of a lamprey. Also examine a prepared slide of an ammocoete, the larva of a lamprey. evolution of vertebrates. They lack jaws typical of other vertebrates but have a cartilaginous endoskeleton and a notochord. Seven pharyngeal gill slits are reinforced with cartilage. The mouth is at the center of the round buccal funnel and is armed with horny teeth and a rasping tongue. They attach their buccal funnel to the side of a fish, rasp a
hole in the body with their tongue, and feed on the body fluids of the fish. Question 9 Which closely related subphylum of chordates does an ammocoete resemble? Class Chondrichthyes (Sharks, Skates, and Rays) Sharks and their relatives (1000 species) are abundant in oceans as predators and scavengers. Their endoskeleton is cartilaginous and the anterior gill arches to process food (fig. 40.18). Like agnathans, their cartilaginous skeleton is not necessarily primitive but is probably derived secondarily from an ancestral bony skeleton. Examine a preserved specimen of Squalus, the dogfish shark (fig. 40.19). Its external anatomy illustrates some advanced features appropriate for a predator. Fin structure Forming neural arch Neural tube Rib Notochord Vertebral body developing around notochord Neural arch Neural anatomy illustrates some advanced features appropriate for a predator. Embryonic development of a vertebra. During the course of evolution, or of development, the flexible notochord is surrounded and eventually replaced by a cartilaginous or bony covering, the centrum. The neural tube is protected by an arch above the centrum. animal swims or moves. 40-11 Survey of the Animal Kingdom 463 Young lamprey migrating downstream to ocean Lamprey feeding on fish in open ocean Ammocoete larva partially buried in sand Gill slits Mouth with teeth Freshwater stream © Heather Angel/Natural Visions (a) Lamprey returning to river for mating (b) Figure 40.17 Lamprey (class Cephalaspidomorphi Petromyzon marinus). (a) Note the sucking mouth attached to aquarium glass and teeth used to feed on other fish. (b) External structure and life history of a sea lamprey. Sea lampreys feed in the open sea; toward the end of their lives lampreys migrate into freshwater streams, where they mate. Females deposite eggs in nests on the stream bottom, and the young larvae hatch 3 weeks later. Skeletal elements Cranium Early jawed fish Gill slits Early jawed fish Gill slits Early jawed fish (a) (b) © Jeff Rotman Photography Figure 40.18 (a) Jaws are believed to have evolved from the first few pairs of skeletal elements forming gill arches that separate gill slits of agnathans. The second pair of gill arches became support structures for the jaws. (b) Head of sand tiger shark, Carcharias sp., showing a series of successional teeth on strong jaws. includes paired pelvic fins (on the ventral surface near the anus) and pectoral fins (behind the gill slits) for stabilization and maneuvering. Jaws are large and powerful and receptors in the nostrils and epidermis are sensitive to smells and electrical currents. A lateral line runs along each side of the body and contains sensory cells to detect slight vibrations. Question 10 a. Which fins of sharks provide power and speed? 464 EXERCISE 40 b. Why is the number of pharyngeal gill slits in sharks fewer than that in lampreys? c. Consider Learning Objective 1 listed at the beginning of this exercise. Is a lateral line Tooth shed Figure 40.19 Sharks and bony fish? How so? 40-12 Caudal fin Spiracle Nostril First dorsal fin Spine Rostrum External gill openings Pectoral fin Second dorsal fin Spiracle Nostril First dorsal fin Spine Rostrum External gill openings Pectoral fin Spine Rostrum External gill openings (class Chondrichthyes). Dogfish shark, Squalus acanthias. Section of lower jaw (inset) shows new teeth developing inside the jaw. These teeth move forward to replace lost teeth. The rate of replacement varies in different species. Question 11 a. How do the number and shape of fins of a bony fish differ from those of a shark? Class Actinopterygi (Bony Fish) Procedure 40.3 Examine the anatomy of a bony fish are available, observe their swimming and "breathing." 3. Examine the external anatomy of a preserved fish (fig. 40.20). 2. Although sharks are built for speed, the maneuverability of bony fishes is much greater. If living fish are available, observe their swimming and "breathing." 3. Examine the external anatomy of a preserved fish (fig. 40.20). 2. Although sharks are built for speed, the maneuverability of bony fishes is much greater. If living fish are available, observe their swimming and "breathing." 3. Examine the external anatomy of a preserved fish (fig. 40.20). 2. Although sharks are built for speed, the maneuverability of bony fishes is much greater. If living fish are available, observe their swimming and "breathing." 3. Examine the external anatomy of a preserved fish (fig. 40.20). 2. Although sharks are built for speed, the maneuverability of bony fishes is much greater. If living fish are available, observe their swimming and "breathing." 3. Examine the external anatomy of a preserved fish (fig. 40.20). 2. Although sharks are built for speed, the maneuverability of bony fishes is much greater. If living fish are available, observe their swimming and "breathing." 3. Examine the external anatomy of a preserved fish (fig. 40.20). 2. Although sharks are built for speed, the maneuverability of bony fishes is much greater. If living fish are available, observe their swimming and "breathing." 3. Examine the external anatomy of a preserved fish (fig. 40.20). 2. Although sharks are built for speed, the maneuverability of bony fishes is much greater. If living fish are available, observe their swimming and "breathing." 3. Examine the external anatomy of a preserved fish (fig. 40.20). 2. Although sharks are built for speed, the maneuverability of bony fishes is much greater. If living fish are available, observe their swimming and "breathing." 3. Examine the external anatomy of a preserved fish (fig. 40.20). 3. Although sharks are built for speed, shown in figure 40.20. b. Fins of a bony fish are the most diverse in shape. Describe the location of a fin present in bony fish but not in sharks. Bony fish include a bony endoskeleton, modified gill arches, and internal air bladders for balance and buoyancy Gills are protected by a movable gill cover called an operculum. Along each side and branching over the head of most fishes is a lateral-line system consisting of sensory pits in the skin. These pits detect water currents and predators or prey that may be moving near the fish. Lateral line d. Does most of the power for movement by a fish come from the tail or from other fins? e. Can fish move water over their gills without moving through the water? What role does the operculum play in this movement? Nostril Partially cut operculum play in this movement? of a shark? Anus Gonad Intestine Liver Pelvic fin f. How does the buoyancy of an air bladder affect the motion of a fish compared to that of a shark? Gills Heart Figure 40.20 Anatomy of a bony fish, class Actinopterygii. 40–13 Survey of the Animal Kingdom 465 Lobe-finned Fish Shoulder Pelvis Humerus Tibia Ulna Femur Fibula Radius (a) © BiologyImaging.com Figure 40.22 A frog (class Amphibia). This poison arrow tree frog (Dendrobates sp.) exhibits strong coloration. These colors advertise its powerfully toxic secretions to predators, which quickly learn the frog's noxious taste. Natives of South America use the frog's noxious taste. stick and holding it over a fire. The heat causes the cutaneous glands to secrete drops of venom, which are scraped into a container and allowed to ferment. Arrows dipped into the poison can paralyze birds and small monkeys. One poison arrow tree frog contains enough toxin to kill about 20,000 mice. Tiktaalik Shoulder Humerus Ulna Radius (b) Early Amphibian Shoulder Pelvis Fibula Femur Tibia Humerus Ulna lay eggs in water (fig. 40.22). The eggs are fertilized externally and each hatches into an aquatic larval stage called a tadpole. Tadpoles undergo a dramatic metamorphosis of body shape as they become adults. Development of legs and the development of lungs in amphibians were major evolutionary events. However, primitive lungs had already developed in some fish. In addition to lungs, the soft moist skin of some amphibians is highly vascularized and accounts for as much oxygen diffusion as the lungs. Question 12 How are the legs of a frog different from the fins of a fish to enable movement on land? Radius (c) Figure 40.21 Transitional forms in the tetrapod lineage. This figure shows two early tetrapod ancestors, a lobe-finned fish and the transitional form Tiktaalik roseae, as well as a descendant, an early amphibian. Recent fossil evidence strongly supports our understanding of the evolutionary transition of ancestral bony fish to a tetrapod body plan of amphibians (fig. 40.21) Class Amphibians were the first land vertebrates, arising from fish with stout, fleshy fins. Most amphibian adults are terrestrial, but they 466 EXERCISE 40 Class Reptilia (Turtles, Snakes, and Lizards) Examine preserved reptiles and note their morphological diversity (fig. 40.23). Reptiles, unlike their ancestors, are independent of aquatic environments and have developed structures for internal fertilization (fig. 40.24). Most reptiles also lay watertight eggs that contain a food source (the yolk) and a series of four membranes—the chorion, the amnion, the annion, the annion, the annion, the egg an independent life-support system. The outermost membrane of the egg, the chorion, allows oxygen to enter the porous shell but retains water within the egg. The amnion encases the developing embryo within a fluid-filled cavity. The yolk sac provides food from the yolk for the embryo via blood vessels connecting to the embryo is gut. The allantois surrounds a cavity into which waste products from the embryo are excreted. 40-14 © BiologyImaging.com Figure 40.23 venomous reptiles; they have a pair of heat-detecting pit organs, one on each side of the head. Pit organs are visible between the eye and the nostril of this copperhead snake. These vipers can locate and strike a motionless warm animal in total darkness by sensing heat from its body. Pit organs are highly sensitive to infrared wavelengths and are especially sensitive to sudden changes of
temperature. Pit organs can detect temperature differences of 0.2°C or less, allowing effective hunting of small animals at night. Reptiles, fish, and amphibians are poikilothermic, meaning that their body temperature depends on the environment. Question 13 a. What is the adaptive significance of internal fertilization. The male injects sperm on the injects sperm on the environment. Question 13 a. What is the adaptive significance of internal fertilization. The male injects sperm on the environment. first terrestrial vertebrates to develop this form of reproduction, which is particularly suited to terrestrial existence. b. How do the legs of a terrestrial tetrapod to be more robust than those of an aquatic organism? Why or why not? Is this true for the reptiles and amphibians that you examined? Albumin Amnion Placenta Embryo Umbilical cord Yolk sac Uterus Yolk Chorion Allantois Uterine cavity Shell © seasoning_17/Shutterstock Air space Figure 40.25 The watertight amniotic egg enables reptiles to live in a wide variety of habitats. This sea turtle is hatching from a typical reptilian egg. The amnion of vertebrate eggs is a sac that encloses the developing embryo of a reptile, bird, or mammal. In an amniotic egg, the embryo is encased in a hard, protective shell, and is supported internally by three membranes—the amnion, allantois, and chorion. Placental mammals also enclose their embryos in an amnion. 40-15 Survey of the Animal Kingdom d. Consider Learning Objective 1 listed at the beginning of this exercise. How could poikilothermy contribute to the evolutionary success of reptiles in their environment? Leading edge Forelimb Wrist Finger 1 Class Aves (Birds) Examine a prepared slide and whole mount of a feather (fig. 40.26). Notice the interlocking structures. Also examinee a prepared slide and whole mount of a feather (fig. 40.26). specimens of birds (fig. 40.27). Birds are the only animals with feathers, and they share the ability to fly with Palm Vane Finger 2 Shaft Shaft Hook Barbule Barb (a) Wing (b) Feather structure (c) Pelicanus occidentalis) (c) © Gilbert S. Grant/Science Source Figure 40.26 Features of the bird wing and feather. (a) The wing is supported by an elongated and modified forelimb with extended fingers. (b) Each feather has a hollow shaft that supports many barbs, which in turn supports many barbs, which in turn support barbules that interlock with hooks to give the feather its form. (c) The bones of a pelican (Pelicanus occidentalis) are hollow but crisscrossed with a honeycomb structure that provides added strength (8×). © BiologyImaging.com (a) (b) © kojihirano/Getty Images Figure 40.27 Birds (class Aves). (a) The flightless cormorant, Phalacrocorax harrisi, lives only on the Galápagos islands and is the only cormorant in the world (out of 30 species) that cannot fly. Ancestors arriving at the islands had no predators and little competition for their feeding niche of bottom-fish, eels, and octopuses. Flight muscles atrophied through the generations, and their sparsely feathered wings have become vestigial. (b) The California condor (Gymnogyps californianus) is the largest land bird in North America. Young condors acquire full adult plumage after 6 years and may live 50 years. They are efficiently adapted to soaring effortlessly in search of carrion. Their bald heads are adapted for reaching deep within the carcass and tearing pieces of meat. Unfortunately, they are in danger of becoming extinct. The remaining three or four wild individuals were captured in 1987. Offspring have been raised in captivity and have been periodically reintroduced into their dwindling habitat. Even efficient survival adaptations of the condor have not prevented a dramatic population decline. habitat. 468 EXERCISE 40 40-16 only a few groups. Eyes of birds are always prominent, and vision is one of their most highly developed senses. Birds are homeothermic, meaning that they maintain a constant body temperature. Other adaptations to flight include a high body temperature for high metabolism, a lightweight skeleton, an efficient respiratory system, and heavy musculature at the breast to move the wings. The evolutionary origin of feathers is hotly debated, but biologists agree that their lineage likely traces back to dinosaur ancestry (fig. 40.28). Question 14 a. What are wings of flying animals other than birds made of? b. Why might birds use keen vision more than reptiles or amphibians do? head wing tail feet wing (a) Archaeopteryx fossil reptile characteristics bird characteristics feathers teeth tail with vertebrae claws (b) (a) © Joe Tucciarone, Interstellar Illustrations Figure 40.28 Transitional fossils. (a) Archaeopteryx was a transitional fossils. (b) © Joe Tucciarone, Interstellar Illustrations Figure 40.28 Transitional fossils. (a) Archaeopteryx was a transitional link between dinosaurs and birds. Fossils indicate that it had feathers and wings with claws, and teeth. Most likely, it was a poor flier. (b) Archaeopteryx also had a feather-covered, bony reptilian-type tail that shows up well in this artist's representation. 40-17 Survey of the Animal Kingdom 469 c. Consider what you have learned about enzymes in Exercise 11. What might be the adaptive advantage of homeothermy? Fat Circular muscle Connective tissue Milk ducts d. Describe six adaptations of birds to flight. Fat (a) Connective tissue capsule Active mammaly gland Class Mammalia Examine some preserved mammals. Mammals are covered with insulating body fat and hair and maintain a constant body temperature as birds do (fig 40.29). Mammals are active and have a well-developed circulatory system with a four-chambered heart. The circulatory system distributes oxygen, nutrients, and heat. Mammary glands are specialized to secrete milk following the birth of young. (a) Many ducts lead from the glands to a nipple. Parts of the duct system are enlarged to store milk. (b) Some mammaly glands to release milk. (b) Some mammaly ducts. Milk collects in a large cistern prior to its release. Although you are already familiar with the external anatomy of a rat, another representative mammal, in Exercises 47, 48, and 49. As you examine preserved and living mammals, search for common features such as hair distribution, body orientation, and structures for locomotion. Question 15 a. What factors govern the distribution of hair on species such as the human or rat? b. How do the mammals that you are examining vary in body orientation (resting stance and position during movement)? © Magdalena Biskup Travel Photography/Getty Images Figure 40.29 This tarsier (Tarsius syrichia) is a primitive primate (class Mammalia) found in the Philippines. It is the size of a rat, lives in a tree, and eats insects. The position of its eves in the front of its head allows full stereoscopic vision. It has nails instead of claws, which indicates a common ancestry with higher primates. Its large eyes are efficient adaptations for nocturnal activity. The retinase lack cones for detecting color but are extra rich in rods for black/white sensitivity. 470 EXERCISE 40 c. What characteristics of mammals help explain how they can occupy a variety of habitats? 40-18 INQUIRY-BASED LEARNING Would you argue that skeletons of all major groups of vertebrates are similar? Different? Observations: Natural selection shapes available genetic variation into adaptations that boost fitness. Over many generations, characteristics with no adaptive advantages become increasingly frequent. External features interface an organism with its environment and are subject to strong selective pressures. External features serving multiple functions also vary a great deal among the various functions? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 40 from your instructor. b. Obtain and examine the external features of a preserved fish, amphibian, bird, reptile, and mammal. c. Discuss with your group and instructor specific comparisons to make among these vertebrates. Record them on Worksheet 40. d. The table on Works functions in the worksheet table. e. Complete the investigation directed by Worksheet 40. Questions for Further Study and Inquiry 1. Does it surprise you that echinoderms are more closely related to our own phylum (Chordata) than are other phyla? Why would you have thought otherwise? 2. Why are embryological features important for distinguishing the major groups of phyla? 3. Echinoderms lack cephalization. What characteristics of this group deemphasize the need for a head? 4. What problems were associated with colonizing land during the evolution of vertebrates? 5. Why do you suppose four rather than five or six appendages is the rule for vertebrates? 6. A cuticle occurs on the surface of organisms of many phyla and appears to be an advantageous feature. Why have higher organisms not retained this structure? 40-19 Survey of the Animal Kingdom 471 7. What is the difference in the developmental derivation of mandibles among insects, jaws of vertebrates, and the beak of an octopus? 8. Although other groups of vertebrates are more numerous and have existed longer than mammals, mammals are often called the most advanced form of life. Why? 9. Locomotion are superior to those of birds? Why or why not? 10. Compare the origin and function of reptile scales, bird feathers, and mammal hair. How are they similar? How do they differ? 11. Prepare a simple table of all of the taxonomic groups, their common names, their distinguishing characteristics, and all representative genera covered in this exercise. Keep this table with your study notes. 12. Vertebrates have a closed circulatory system, meaning that the blood is always enclosed within vessels and does not fill body cavities. Mollusks (Exercise 38) and arthropods (Exercise 39) have open circulatory systems, meaning that blood. What are the advantages of each type of circulatory system? 13. Two classes of vertebrates (Avessels and does not
fill body cavities, where tissues are surrounded by the blood. and Mammalia) are endothermic. What is meant by this term? Hypothesize some evolutionary advantages of being endothermic. What are some of the costs? WRITING TO LEARN BIOLOGY What external anatomical features of amphibians are associated with their dual life on land and in water? 472 EXERCISE 40 40-20 Vertebrate Animal Tissues Epithelial, Connective, Muscular, and Nervous Tissues E XER CISE 41 Learning Objectives By the end of this exercise you should be able to: 1. Understand the general classification scheme for vertebrate tissues. 2. List examples, functions, and distinguishing features of each type of tissue. that you examine. Please visit connect.mheducation.com to review online resources tailored to this lab. C ells with similar structure and function constitute a tissue, such as the stomach, lungs, and liver composed of several different tissues grouped together and having an integrated function. Organs work together as systems, such as the respiratory system or digestive system (fig. 41.1). Thus, we can define an organism at various levels of biological organization. At the cellular level, vertebrates contain between 50 and several hundred different kinds of cells, depending on how finely you differentiate cell types. These diverse cells are traditionally grouped into four tissues (fig. 41.2). The study of the microscopic anatomy of tissues is called histology. EPITHELIAL TISSUE Epithelial cells protect the body. They cover the exterior of an organism, line the gut and other cavities, and line the coelomic cavity. Specifically, epithelial cells (1) protect underlying tissues from dehydration and mechanical damage, (2) provide a selectively permeable barrier that facilitates or impedes p assage of materials, (3) provide sensory surfaces, and (4) secrete fluids. Epithelial cells are often classified by their layers and shape. Simple refers to a tissue that occurs in one layer. Stratified refers to multiple layers. Pseudostratified refers to a single layer of cells that appear in different positions within the columnar cells (see fig. 41.6). Squamous cells are flat like fried eggs, cuboidal cells are shaped roughly like cubes, and columnar cells are tall and narrow. You will examine three classes of epithelial tissue in lab: simple epithelium, 41-1 Cell Tissue Organ Organ System Figure 41.1 Levels of organization within the body. Similar cell types operate together and form tissues. Tissues functioning together form organs. Several organs working together to carry out a function for the body are called an organ system. The circulatory system is an example of an organ system. Stratified epithelium, and glandular epithelium. As you view each of the slides, summarize what you've learned in table 41.1 at the end of this exercise. Simple Epithelium Simple epithelial tissues are a single cell layer thick and are classified according to the shapes of their cells (fig. 41.3). •• Squamous epithelial cells are irregular and flattened. Thus, one cell layer to diffusion. Squamous epithelial cells are irregular and flattened. major cavities of the body. These cells are relatively inactive and are associated with sites of passive movement of water, electrolytes, and other substances. Vertebrate Animal Tissues 473 Epithelial tissue Nervous tissue Columnar epithelium in epidermis Bone Cuboidal epithelium in kidney tubules Blood Muscle tissue Smooth muscle in intestinal wall Skeletal muscle in voluntary muscles Cardiac muscle in heart Loose connective tissue Figure 41.2 The types of tissues in vertebrates. Cuboidal cells Columnar (a, b) ©Ed Reschke; (c) ©Ed Reschke/Getty Images Figure 41.3 Types of epithelium forms the epithelium lines the artery shown here (200×). The nuclei are flat. The round cells above the epithelium forms the walls of these kidney tubules, seen in cross section (200×) (also see fig. 41.4). (c) Columnar epithelial cells are goblet cells, which secrete mucus (200×) (also see fig. 41.5). 474 EXERCISE 41 41-2 •• Cuboidal and columnar epithelial cells appear fuller than do squamous cells and are shaped as their names imply They line the respiratory and intestinal tracts and ducts such as kidney tubules. Cuboidal cells often have cilia and secrete fluids. Nuclei of simple squamous and cuboidal cells 1. Gently scrape the inside of your cheek with the tip of a clean toothpick and stir the tip in a small drop of methylene blue—it will stain your skin and clothes! Do not scrape your cheek forcefully. Be gentle. 3. If the stain does not readily diffuse under the coverslip, pull the fluid under by touching a dry paper towel to the opposite edge of the coverslip, pull the fluid under by touching a dry paper towel to the opposite edge of the coverslip. 4. Examine your cells under the coverslip. 4. Examine your cells under the coverslip. 4. Examine your cells under the coverslip. Sketch a few cells. Bowman's capsule © BiologyImaging.com Figure 41.4 Kidney tubules (see fig. 41.3b). The squamous cells are seen on edge because they line a narrow cavity. Question 2 a. How thin are the cells, and how does this relate to function? b. What term describes the shape of cheek cells? Question 1 Which cell structures can you identify? c. What is the approximate diameter (in microscopy (Exercise 3) for instructions on measuring cells. d. How does a tissue differ from a cell? From an organ? Examine a prepared slide of a cross section of a kidney. Simple squamous and cuboidal cells are both common in vertebrate kidneys. 8. Refer to figure 41.4. Simple squamous epithelium surrounds Bowman's capsules, and simple cuboidal cells are both common in vertebrate kidneys. cells. 41-3 e. The cuboidal cells in fig. 41.4 are arranged in circles. How can these circles be interpreted as tubes? Vertebrate Animal Tissues 475 Procedure 41.2 Examine columnar epithelium 1. Columnar epithelium 1. Columnar epithelium 1. small intestine and locate the relatively large, fingerlike villi of the inner intestinal wall. 2. Increase the magnification to medium, then high power, focusing on the single layer of columnar epithelial cells of the trachea similar in size and structure to those lining the intestine? b. What is the approximate ratio of length to width for epithelial cells from the surface of the trachea. What are these projections called? Stratified Epithelium © BiologyImaging.com Figure 41.5 Simple columnar epithelium of frog intestine consists of a single layer of elongated cells. The arrow points to a specialized goblet cell that secretes mucus (400×). Examine a slide of a cross section of skin and locate the stratified tissues are several layers thick. Typically, the upper layer is squamous, the m iddle one cuboidal, and the basal (bottom) layer ©Lutz Slomianka ©Ed Reschke Figure 41.6 Pseudostratified ciliated columnar epithelium taken from the trachea. Notice the tuft of cilia at the top of each cell (500×). 476 EXERCISE 41 Figure 41.7 Stratified squamous epithelium, such as this cross section of skin, consists of many layers of cells (120×). The surface of the skin is toward the top. 41-4 columnar. The skin is the most obvious example of stratified epithelium, although "skin" includes tissues other than epithelium. Question 5 a. What fluid do hepatocytes secrete and store in the gallbladder? Question 4 a. Are layers of skin cells distinct, or is there a gradual change in cellular shape from the basal to the surface layers? b. What is the dark spot in the nucleus of a hepatocyte? b. Skin cells produce keratin, a strong fibrous protein found in hair and fingernails. What is the function of keratin? CONNECTIVE TISSUE c. List several functions of skin that relate to the shape and toughness of these epithelial cells. Glandular Epithelium Some glands of the body consist of highly modified epithelial cells that do not function as a protective covering. These cells are more active metabolically than is simple epithelial cells that do not function as a protective covering. Cellular secretions of exocrine glands move to the surface and away from the organ via ducts. Examine a prepared slide of liver. Liver contains many sinuses that carry blood. Note the large nucleus in each hepatocyte (liver cell). Connective tissues support and defend the body and store food. These cells are not tightly packed (as are epithelial cells) and are typically suspended in an extracellular matrix of fibers. Some connective tissues are dispersed and flow in the circulatory system. Classification of connective tissue cells is based as much on function and the nature of the extracellular matrix as on cellular matrix as on cell proper, further divided into loose and dense connective tissues with an abundance of fibers, and (2) special connective tissues, which include blood, cartilage, and bone, each having a characteristic extracellular matrix. Connective tissues, which include blood, cartilage, and bone, each having a characteristic extracellular matrix. ground substance. Examine a slide of subcutaneous tissue, and note the irregular arrangement of fibroblasts and fibers (fig. 41.8). Fibroblasts, which are widely dispersed in vertebrate bodies, are irregular branching Adipose cell: Elastic fiber stores fat Stem cell: divides to produce other types of cells Collagen fiber: unbranched, strong but flexible Collagen fiber Fibroblast (a) ©Ed Reschke Ground substance: fills spaces between cells and fibers Elastic fiber: branched, thin, and forms network White blood cell: engulfs pathogens or produces antibodies (b) Figure 41.8 Loose connective tissue. (a) Subcutaneous, fibrous connective tissue (400×). (b) Cellular and fibrous connective tissue. 41-5 Vertebrate Animal Tissues 477 cells that secrete an extracellular matrix of strong fibrous proteins. The most commonly secreted protein is collagen, which represents 25% of all vertebrate protein (fig. 41.9). If all components of the body except collagen were removed, a
ghostly mesh of fibers would remain as the framework of the body and its organ systems. Collagen is not the only fiber produced by fibroblasts. Elastin fibers have protein molecules arranged so that the fibers can stretch. Examine a slide of tissue having reticulin fibers taken from a lymph gland (fig. 41.10). Reticular fibers that support glands such as the spleen and lymph nodes. Reticular fibers also compose junctions between several other kinds of tissues. Loose connective tissue also includes macrophages, the immune system's first defense against invading organisms. Macrophage connective tissue consists of many relatively small, round cells. Macrophages are defensive cells that engulf and digest cellular debris, invading bacteria, and foreign particles (fig. 41.11). Macrophages may move individually in the circulating fluids of the body or remain fixed in an organ such as the liver or spleen. Examine a prepared slide of liver tissue. Macrophages of this tissue may contain small black particles of India ink that they engulied before the tissue was fixed and preserved. Reticular fibers ©Dennis strete Figure 41.10 Reticular connective tissue was fixed and preserved. Reticular fibers @Dennis strete Figure 41.10 Reticular fibers @Dennis indicate individual macrophages. Question 6 Review lysosomes in Exercise 4, The Cell. Why are macrophages rich in lysosomes? Adipose cells are found in loose connective tissue and comprise adipose cells are found in loose connective tissue and comprise adipose cells are found in loose connective tissue. For best contrast, keep the light intensity of the microscope low. Each adipose cells contains a droplet of fat (triglycerides). To generate energy, the adipose cells in an adult is generally fixed. When a person gains weight, the cells become larger, and when weight is lost, the cells shrink. © J. Gross/Biozentrum, University of Basel/Science Source Question 7 a. Why do adipose cells appear empty? Figure 41.9 Scanning electron micrograph of collagen strands and is very strong (5000×). 478 EXERCISE 41 41-6 in structure to tendons. Notice the lack of apparent blood vessels in your prepared slide of tendon. Low vascularization makes tendons and ligaments slow to heal. Question 8 a. How can a fibroblast produce a fiber many times its own length? b. In what areas of the body would the elasticity of elastin fibers be advantageous? ©McGraw-Hill Education/Al Telser, photographer Figure 41.12 Adipose tissue cells contain large droplets of fat that push the nuclei close to the plasma membranes. The arrow points to a nucleus (200×). b. Of what use is the reserve of oil in adipose cells? c. Which tissues in the body require the greatest strength? Explain your answer. d. Are all the fibers in a tendon oriented in the same direction? Of what importance is this? Dense connective tissue contains tightly packed c ollagen fibers; these fibers make dense connective tissue stronger than loose connective tissue stronger than loose connective tissue aprepared slide of a ligament if one is available. Tendons connect muscle to bone and derive their strength from this regular, longitudinal arrangement of bundles of collagen fibers. Ligaments bind bone to bone and are similar Special Connective Tissues Blood cells and their intercellular fluid matrix called plasma perform a variety of tasks in the vertebrate body, Fibroblasts Collagenous fiber bundles ©Ed Reschke Figure 41.13 Tendon. Dense fibrous connective tissue is a strong tissue that forms tendons, which attach muscle to bone. Bundles of collagen fibers are oriented in the same direction to increase strength (400×). 41-7 Vertebrate Animal Tissues 479 Red blood cells Intercellular fluid (plasma) Platelet White blood cell ©McGraw-Hill Education/Al Telser, photographer Figure 41.14 Blood tissue consists of red blood cells, white blood cells, and platelets suspended in an intercellular fluid called plasma (800×). including maintaining proper pH and transporting oxygen and carbon dioxide. Practically every type of substance used by cells is dissolved in plasma. Blood cells are classified as erythrocytes (red blood cells), leukocytes (white blood cells), or platelets (enucleated fragments of large bonemarrow cells). Hemoglobin protein with 4 subunits Blood vessel Plasma Procedure 41.3 Examine a prepared slide of a human blood smear (fig. 41.14). 2. The most numerous blood cells are erythrocytes, or red blood cells. They produce hemoglobin (fig. 41.15), which binds and transports oxygen. Notice the uniform shape of erythrocytes; these cells have lost their nuclei and become packets of hemoglobin. 3. Locate some leukocytes as defensive connective tissue. 4. Platelets, which appear as small dark fragments, sequester (collect and store) chemicals and enzymes essential for clotting blood cells and contrast their structure with that of human blood cells. In the following space, draw some of these subunit of hemoglobin. Question 9 a. Is a nucleus visible in each blood cell? Are nuclei apparent in white blood cells? 41-8 b. The shape of nuclei in leukocytes? Chondrocytes in lacunae Chondrin matrix c. What is the ratio of leukocytes to erythrocytes? d. Do frog blood cells have nuclei? © BiologyImaging.com Figure 41.16 Hyaline cartilage cells called chondrocytes are located in lacunae surrounded by a chondrin matrix of intercellular material and fine collagenous fibers (250×). Cartilage is found in skeletal joints and derives its resilience and support from an extracellular gelatinous matrix of chondrin. Chondrin of cartilage may be impregnated with fibers of collagen. This matrix is secreted by cells called chondrocytes. As in most connective tissue, cells of cartilage are rather isolated within the extracellular matrix. Chondrocytes in cartilage reside in cavities called lacunae. Examine a slide of hyaline cartilage, which cushions bone surfaces between joints (fig. 41.16). Also examine a slide of elastic cartilage, which commonly occurs in the external ear and in the epiglottis of the voice box (larvnx) (fig. 41.17). Elastic cartilage is more flexible than is hvaline cartilage is more flexible than is hvaline cartilage. function of cartilage? © BiologyImaging.com Figure 41.17 Elastic cartilage contains fine collagenous fibers and many dark elastic fibers in its intercellular matrix with fibers (fig. 41.18). Collagen fibers of bone are also surrounded by hard crystals of calcium salts rather than the flexible matrix of chondrin in cartilage. This fibrous and crystalline matrix is maintained by bone cells called lamellae forming Haversian systems, or osteons. Lamellae form a series of tubes around narrow channels called Haversian canals, which align parallel to the long axis of the bone. Haversian canals surround blood vessels and nerve cells throughout bone and communicate with bone cells in lacunae through canaliculi. 41-9 Ouestion 11 Why is an elaborate system of canals needed in bone more than in cartilage? MUSCLE TISSUE The distinctive feature of muscle is its ability to contract. which results from the interaction of actin and myosin filaments. These proteins occur in other eukaryotic cells but not in such abundance and uniform orientation. Bundles of these contractile filaments, called myofibrils, occur within Vertebrate Animal Tissues 481 Hyaline cartilage (articular cartilage) Chondrocytes in lacunae Growth plate Spongy bone (contains red bone marrow) Compact bone Compact bone Osteocyte in lacuna Medullary cavity (contains yellow bone marrow) Concentric lamellae Osteocyte Canaliculus Central canal Lacuna Osteocyte Nucleus Osteon Thin radiating Haversian canals Osteocytes in lacunae Periosteum Blood vessel Spongy bone Blood vessels (a, b) ©Ed Reschke; (c) ©Biophoto Associates/Science Source Figure 41.18 Anatomy of a long bone. Bone shown at three levels of detail. Some parts, such as marrow, are spongy and have a more open lattice. Most red blood cells are formed in marrow. New bone is formed by cells called osteocytes, which secrete collagen fibers as sites for deposition of hard calcium-phosphate crystals. Bone is deposited in thin, concentric layers called lamellae. Lamellae form a series of tubes around narrow channels called Haversian canals, which run parallel to the length of the bone. Haversian canals are interconnected and contain nerves and blood vessels. 482 EXERCISE 41 41-10 a single muscle cell, and their uniform contraction produces considerable force and movement (fig. 41.20). Skeletal Muscle Review in your textbook how skeletal muscle contracts. Then examine a prepared slide of skeletal muscle (fig. 41.20a). Skeletal (striated) muscles are attached to the skeleton and are controlled voluntarily (i.e., they Muscle fasciculus Nuclei Muscle microfilaments arranged as sarcomeres that slide along their lengths and contract the muscle. Units of these microfilaments form myofibrils, which are bundled into muscle fibers. These fibers are surrounded by a membranous network that distributes the stimulus for contraction along the surface of the muscle (b) Smooth muscle (c) Cardiac muscle (a) Skeletal muscle (c) Cardiac muscle (c) © Biology Pics/Science Source Figure 41.20 Three types of muscle. (a) Skeletal (400×). (b) Smooth (400×). (c) Cardiac (400×). "cell" is a long fiber of regularly arranged contractile units with many nuclei scattered at the periphery (outer boundaries) of the fiber. The strength and speed of contraction is enhanced by having the contents of many cells coalesced (merged) into a fiber rather than functioning as individual cells. The stacked array of actin and myosin filaments within the fibers gives striated muscle its banded (i.e., striated) appearance (fig. 41.20a). Smooth Muscle Examine a prepared slide of smooth muscle (fig. 41.20b). Smooth muscle (fig. 41.20b). controlled involuntarily. Smooth muscle is organized into sheets of cells that contract slowly and rhythmically. The uterus and intestine are examples of organs
with smooth muscle is striated, as is skeletal muscle, but its contraction is involuntary. Unlike

skeletal muscle, cardiac muscle fibers are composed of chains of single, uninucleate cells. However, these cells have specialized junctions called intercalated disks between cells that organize them 41-12 Figure 41.21 Anatomy of a neuron. Neurons are specialized to transmit nerve impulses. A neuron axon receives nerve impulses from other neurons, whereas a dendrite transmits the nerve impulse to subsequent neurons (600×). Axon Cell body Dendrites c. Of the three types of muscle, which contracts without voluntary thought? © Science Photo Library/Alamy Stock Photo into rather continuous functional fibers similar to those of skeletal muscle. Thus, cardiac cells depolarize and contract more as a unit than do sheets of loosely associated cells of smooth muscle. Question 12 a. Can you distinguish the small striations perpendicular to the axis of a muscle cell? NERVOUS TISSUE The fourth major class of vertebrate tissue is nervous tissue. Nervous tissue consists of (1) neurons, cells specialized for transmitting nerve impulses and (2) supporting cells called glia, including Schwann cells, which help propagate the nerve impulse and provide nutrients to neurons. b. Of the three types of muscle, which contracts most swiftly? Table 41.1 A Comparison and Organization of Vertebrate Body Function Tissue Examined Location in the Vertebrate Body Function Vertebrate Animal Tissues 485 Cell body Dendrite Direction of conduction Myelin sheath Axon terminal Node of Ranvier Axon (a) Motor neuron (multipolar) Muscle fiber Axon Cell body Direction of conduction Myelin sheath Axon terminal Node of Ranvier Axon (b) Key (figst a shear of nervous tissue (figst a shear of nervous tissue) 41.21, 41.22). Neurons consist of (1) a cell body containing a nucleus and (2) cytoplasmic extensions that conduct nerve impulses toward the cell body from other cells or sensory systems. Axons are long extensions that usually carry impulses away from the cell body. An axon may carry an impulse to a muscle to make it contract or to the dendrites of another neuron. Because cell bodies occur only in the brain and spinal cord, some axons and dendrites must be a meter long to reach distant parts of the body. Axons and dendrites must be a meter long to reach distant parts of the body. and organs of the vertebrate body (fig. 41.23). To review all of the available examples of animal tissues, briefly reexamine each prepared slide. As you view each type of tissue, record in table 41.1 the tissue's location and function. Question 13 What is the difference between a nerve, such as that found in an arm or leg, and a neuron? (b) Sensory neuron (unipolar) Myelin sheath Skin Axon Cell body Dendrite (c) Interneuron (multipolar) (a) © Scott Camazine/Alamy Stock Photo; (c) © Don W. Fawcett/Science Source Figure 41.22 Neuron anatomy. (a) Motor neuron. Note the branched dendritelike and the single, long axon, which branches only near its tip. (b) Sensory neuron with dendritelike and the single structures projecting from the peripheral end of the axon. (c) Interneuron (from the cortex of the cerebellum) with very highly branched dendrites. 486 EXERCISE 41 ©Ed Reschke/Getty Images Figure 41.23 Cross section, many myelinated neuron axons are visible, each looking somewhat like a severed hose (400×). 41-14 Where do stem cells come from? With the right stimulation, stem cells can produce a variety of tissues with great therapeutic value. Even a whole organism can be produced from properly treated stem cells! The fate of stem cells is undetermined until their genetic program and an appropriate microenvironment stimulate their differentiation into specialized tissue. But not all stem cells are the same. Human embryonic stem cells are the same. Human embryonic stem cells are the same. Blastocyst 5-6 days Gastrula 14-16 days begin to specialize, stem cells of therapeutic value must be harvested from early embryos. These embryonic and adult tissues), but the bioethics of harvesting them from human embryos is controversial. Alternatively, adult stem cells found in areas of rapid cell division (such as bone marrow and reproductive organs) in mature organisms also have great utility, but they do not have the potential to develop into as many different cell types as do embryonic stem cells. Inner cell mass yields stem cells that have the ability to form any cell type in the body Develops into skin, neurons, eyes, ears Develops into bone marrow, muscle, blood vessels Develops into pancreas, liver, lung, bladder (a) Embryonic stem cells (produces blood and immune system cells) Stromal stem cells (b) Adult stem cells Vertebrate Animal Tissues 487 INQUIRY-BASED LEARNING Can the visibility of cellular structures be enhanced? Observations: Cells are so small and transparent that their structures are difficult to see, even at high magnifications. Stains with dissolved pigments will adhere to some organelles more than others and thereby increase contrast and visibility. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 41 from your instructor. b. Discuss with your group a well-defined question. Record your question on Worksheet 41. c. Ask your instructor which common cellular stains are available in the lab. d. Outline on Worksheet 41 your experimental design and supplies needed to answer your question. Ask your instructor to review your proposed investigation. e. Conduct your procedures, record your data, answer your questions, hypotheses, or procedures. Repeat your work as needed Questions for Further Study and Inquiry 1. Why are vertebrate animal tissues difficult to classify into a single consistent system? 2. If a compound microscope produces an image in only two dimensional shape of a cell? 3. How many animal tissues and cell types might be in a typical hamburger? 4. All living cells maintain a polarized membrane, meaning that positive and negative ions are separated on either side of the membrane. What role does this polarization play in the function? 6. What aspects of a neuron's structure enhancement of a neuron's structure enhancement. its function? 7. What structural components of cartilage promote its function as a pliable, yet tough, material? WRITING TO LEARN BIOLOGY Does the presence of nuclei in mammalian blood cells is an "advanced" characteristic? Why or why not? 488 EXERCISE 41 41-16 E XER CISE 42 Human Biology The Human Skeletal System Learning Objectives By the end of this exercise you should be able to: 1. Identify the major bones of the human skeleton and the different types of joints. 2. Understand human morphology and how age influences bone structure. Please visit connect.mheducation.com to review online resources tailored to this lab. T he human body consists of 206 bones that make up about 15% of our body-weight. Most bones are parts of larger structures and systems; for example, the skull has 22 bones, the vertebral column 26 bones, and the ribcage 24 bones. The skeletal system, along with the muscular system (see Exercise 43), determines the shape of an organism, supports other organs, and allows for movement. Bones are held together by ligaments, which are made of dense connective tissue that is slightly elastic. Bones are attached to muscles by tendons. In this exercise, you will study bones of the human body? 1. Examine the articulated skeleton in the lab. The human skeleton consists of the axial skeleton (skull, vertebrae, sternum, and ribs) and appendicular skeleton (shoulder, arm, hip, and legs). 2. Use your textbook or other books in lab to identify the bones of the skeleton, paying particular attention to the shapes of the bones, the textures of the bones, and the planes in which the joints can move (figs. 42.1, 42.2). 3. Identify and label the bones in figure 42.3. For each bone, list whether it is part of the axial or appendicular skeleton. Also identify these bones. In figure 42.3. For each bone, list whether it is part of the axial or appendicular skeleton. In solution were than 270 bones. In figure 42.3. For each bone, list whether it is part of the axial or appendicular skeleton. Also identify these bones in your body. adults, the skeleton accounts for 15% of our body weight. The smallest bone in humans is the stapes, which is a stirrup-shaped bone in our ears that is critical for hearing. The stapes is full size at birth. We have 12 pairs of ribs. Approximately 4% of people have an extra pair. Ribs are attached to the sternum (or breastbone), which is a long, flat bone shaped like a necktie in the center of the chest. Bones in our bodies are approximately 48% water, our lungs are 84% water, our lungs are 84% water, our lungs are 84% water. THE APPENDICULAR SKELETON (126 BONES) The appendicular skeleton consists of the shoulders, the upper limbs (in humans, commonly called arms, forearms, and hands), the pelvic girdle (pelvis), and lower limbs (in humans, commonly called arms, forearms, and hands), the pelvic girdle (pelvis), and lower limbs (in humans, commonly called arms, forearms, and hands), the pelvic girdle (pelvis), and lower limbs (in humans, commonly called arms, forearms, and hands), the pelvic girdle (pelvis), and lower limbs (in humans, commonly called arms, forearms, and hands), the pelvic girdle (pelvis), and lower limbs (in humans, commonly called arms, forearms, and hands), the pelvic girdle (pelvis), and lower limbs (in humans, commonly called arms, forearms, and hands), the pelvic girdle (pelvis), and lower limbs (in humans, commonly called arms, forearms, and hands), the pelvic girdle (pelvis), and lower limbs (in humans, commonly called arms, forearms, and hands), the pelvic girdle (pelvis), and lower limbs (in humans, commonly called arms, forearms, and hands), the pelvic girdle (pelvis), and lower limbs (in humans, commonly called arms, forearms, and hands), the pelvic girdle (pelvis), and lower limbs (in humans, commonly called arms, forearms, and hands), the pelvic girdle (pelvis), and lower limbs (in
humans, commonly called arms, forearms, and hands), the pelvic girdle (pelvis), and lower limbs (in humans, commonly called arms, forearms, and hands), the pelvic girdle (pelvis), and lower limbs (in humans, commonly called arms, forearms, and hands), the pelvic girdle (pelvis), and lower limbs (in humans, commonly called arms, forearms, and hands), the pelvic girdle (pelvis), and lower limbs (in humans, commonly called arms, forearms, and hands), the pelvic girdle (pelvis), and lower limbs (pelvis), and lower l Biology 489 Slightly Movable Joints Immovable Joint Fibrous Joints Bone Suture Fibrous connective tissue Fibrous joints (a) Cartilaginous Joints Freely Movable Joint Fibrous capsule Synovial fluid Intervertebral disk Synovial membrane Articular cartilage (b) Articular cartilage (c) Figure 42.1 Joints are classified functionally on the extent of movement they permit. (a) The sutures of the skull are immovable joints. (b) Freely movable joints, such as a finger joint. (c) Slightly movable joints, such as a finger joint. (c) Slightly movable joints are synovial joints, such as a finger joint. Scapula—shoulder blade Arm Humerus—upper arm; is on the side of the little finger Radius—shorter of the two bones in the forearm; is on the side of the thumb Carpals—eight bones in the wrist bound by strong connective tissue Metacarpals—five bones in the hand Phalanges—bones of the fingers Question 1 What bones form the raised knobs of your knuckles? 2. Flex your forearm. Question 2 a. What is your "funny bone"? How did it get this name? Procedure 42.2 Identifying bones in your body 1. Clench your fist. 490 EXERCISE 42 42-2 Ball-and-Socket (a) Hinge Joint (b) Gliding Joint (c) Combination Joint Figure 42.2 Synovial joints are the most common and most movable type of joint. (a) Ball-and-socket joints, such as the term implies, allows movement in only one plane. Examples include elbows and knees. (c) Gliding joints are well represented by the lateral vertebral joints (not the central ones) that enable one surface to slide on another. (d) Combination joints have features of more than one type of joint. The example shown here is a mammalian jaw joint that allows rotation and side-to-side sliding. (d) 3. Use your left hand to hold your right forearm near the elbow. Now rotate your right wrist from palm up to palm down. What is this motion called? Question 3 What bone is stationary, and which bone sof the feet Phalanges—bones of the toes; two in the big toe and three in each of the other toes 4. Bend your leg at the knee and feel your patella. Then feel the lump just below your patella. Question 4 What bone forms that lump? What might be an adaptive function for that lump? What might be an adaptive function for that lump? What might be an adaptive function for that lump? Biology 491 492 EXERCISE 42 42-4 Figure 42.3 Ventral view of the human skeleton. Question 5 What are the functions of your legs? Ankles? Feet? AXIAL SKELETON (80 BONES) The axial skeleton is formed by the vertebral column, part of the rib cage, and the skull. In humans, the axial skeleton maintains our upright posture. Sternum breastbone Ribs—normally 24 bones (i.e., 12 pairs of ribs); increase in length from the first through seventh ribs, then decrease in length to the twelfth rib. Vertebrae—26 bones, including six bones of the middle ear. Most bones of the skull are fused with immovable joints called sutures that appear as wavy lines (the head also includes six auditory ossicles) Hyoid—a single, small, U-shaped bone suspended at the front of the throat above the pharynx. The hyoid bone does not articulate with (i.e., touch) any other bone. Question 6 If the human skull is made of bone, how does it enlarge as we age? Extension—straightening parts at a joint so that the angle between them increases and the parts move farther apart (straightening the lower limb at the knee) Hyperextension—excess extension of parts at a joint, beyond the anatomical position (bending the head back beyond the upright position) Abduction moving a part away from the midline (lifting the upper limb from the body) Adduction—moving a part toward the midline (returning the upper limb from the body). Adduction—moving a part around an axis (twisting the head from side to side). movement toward the midline, whereas lateral rotation involves movement in the opposite direction. Circumduction—turning the hand so the palm is upward or facing anteriorly (in anatomical position) Pronation—turning the hand so the palm is downward or facing posteriorly (in anatomical position) Eversion-turning the foot so the sole faces medially Protraction-moving a part forward (thrusting the chin forward) Retraction-moving a part backward (pulling the chin backward) Elevation-raising a part (shrugging the shoulders) Depression—lowering a part (drooping the shoulders) 2. Demonstrate and draw one or two examples of each movement. Procedure 42.3 Vocabulary of joints and skeletal 1. Examine the disarticulated human skeleton in the lab. Note the relative sizes and shapes of the major bones. 2. Work with your lab partner(s) to assemble the skeleton. 1. Examine the following terms describing the movement of synovial joints. Flexion—bending parts at a joint so that the angle between them decreases and the parts of synovial joints. human adults have about 300 joints, which are points at which bones meet (fig. 42.2). Most of these joints are synovial joints, such as elbows, knees, and knuckles. 42–5 Re-examine the basic structure of bone (fig. 41.18). Parts of bones are dense and strong, whereas other parts, such as elbows, knees, and knuckles. marrow. Bones are built by cells called osteoblasts, Human Biology 493 which secrete collagen fibers as sites for the deposited in thin, concentric layers called lamellae (fig. 41.18). When muscles are developed by exercise, the bones they pull against also become thicker and stronger. This is why exercises such as weight lifting increase the mass of bone is continually maintained by bone remodeling, the ongoing replacement of old bone tissue. As osteoblasts produce collagen and other organic components they become trapped in these secretions. Soon they mature and are called osteocytes. Bone is broken down by large cells called osteoclasts in a process called bone resorption. In humans, bone remodeling replaces bones as many as 10 times during an average lifetime. Bone remodeling is a balance between bone deposition. If too much mineral is deposited in the bone, the surplus bone tissue often forms thick bumps called bone spurs that can interfere with movement of joints. If too much bone is resorbed, the bones become weak and overly susceptible to fracture. Question 7 a. What causes osteoporosis? b. What factors increase a person's chances of getting osteoporosis? c. What can help prevent the development of osteoporosis? Osteoporosis? Affects the Bones of Millions of People Osteoporosis is a progressive bone-disease that reduces both the mineral and organic portions of bone, thereby increasing the risk of fracture (fig. 42.4). This disease affects four times as many women as men and occurs when the normal balance between bone formation and bone breakdown is disrupted. A common cause of osteoporosis is prolonged disuse of muscles. The force produced by active skeletal muscle contractions helps maintain bone mass. When muscles are not used due to paralysis or illness, bone mass declines. Osteoporosis can also result from hormonal imbalances. Hormones such as estrogen stimulate bone formation. When a woman' reproductive cycles cease (menopause), estrogen levels decline and bone density may decrease and heighten the risk of bone fractures. In contrast, some hormones can demineralize bone to cause osteoporosis. Osteoporosis itself has no symptoms; its main consequence is the increased risk of bone fractures. Osteoporosis is slowed by adequate calcium and vitamin D intake along with weight-bearing exercise and, in some cases, hormone replacement therapy for postmenopausal women. Osteoporosis is the most prevalent bone disease in the United States, affecting 55% of Americans older than 50 years of age, and costing our nation approximately \$15-\$20 billion in hospital and other expenses. © Michael Klein/Getty Images Figure 42.4 In osteoporosis, the loss of calcium weakens bones. The vertebra on the left is normal, and the vertebra on the right has been weakened by osteoporosis. 494 EXERCISE 42 42-6 Spinal Curvatures Chronic pain can result from misalignment and curvature of the spine. Lordosis (hollow back) is an exaggeration of the conceve curve of the thoracic region, resulting in a hunchback condition. Scoliosis (see figures below is an abnormal lateral and rotational curvature of the vertebral column, which is often accompanied by secondary abnormal curvatures, such as kyphosis. ©Princess Margaret Rose Orthopaedic Hospital/Science Source HOW DO THE SKELETONS OF HUMANS COMPARE WITH THOSE OF OTHER MAMMALS? Examine the skeletons of other mammals available in lab. Give special attention to the relative sizes, locations, and functions of each bone. Many bones—for example, those in our arms and in birds' wings—are homologous bones always have the same function? Explain your answer. ©Lester V. Bergman/Getty Images INQUIRY-BASED LEARNING How are vertebrates' skeletons adapted for strength versus protection? Observations: No organ system is more versatile in function than the skeleton and its adaptive features. Strength and protection are critical for highly mobile vertebrates. Question: To what extent are vertebrate skeletons adapted for strength versus protection? a. Establish a working lab group and instructor. 42-7 b. Discuss with your group and instructor. 42-7 b. Discuss with your group and instructor. both. Record them on Worksheet 42. c. Obtain and examine the features of a human skeleton. Record your observations and assessments of skeletal features. d. Complete the
investigation directed by Worksheet 42. Human Biology 495 Questions for Further Study and Inquiry 1. How many bones are in the body of an adult human? How many are in a human infant? Why is there a difference? 2. What is the difference between a ligament and a tendon? 3. How does a tibia differ from a femur? 4. What bones? 6. Osteoporosis affects 35 million elderly and middle-aged people in the United States. About 80% of these people are women. Why do older women suffer more from osteoporosis than men? 7. What are some examples of bone disease? WRITING TO LEARN BIOLOGY What health problems affect joints? Describe how these ailments are treated. 496 EXERCISE 42 42-8 E XER CISE 43 Human Biology Muscles and Muscle Contraction Learning Objectives By the end of this exercise you should be able to: 1. Identify the major muscles of your body. 2. Describe how muscles can flex or extend a joint. 3. Describe how muscles can flex or extend a joint. 3. Describe how muscles can flex or extend a joint. 3. Describe how the use of a muscle causes fatigue. structures specialized for contraction. Contrary to what many people think, muscles cannot actively lengthen; they can only contract (shorten). Some other force (e.g., gravity or the contraction of another muscle) is necessary to return the muscle to its original (uncontracted) length. Muscles are ineffective without something rigid or antagonistic to pull against. Sometimes the antagonistic structure is another muscle, but usually bone is the rigid surface against which a muscle by an object is muscle load. For example, a 4-kg object would exert a muscle load of 4 kg when being lifted. Muscle tension is the force a contracting muscle exerts on an object. Muscle load and muscle tension are opposing forces. If the tension produced by a muscle tension must exceed muscle load. There are two primary types of muscle contractions: isotonic and isometric. Isotonic contractions are contractions in which the muscle shortens while the load is constant. For example, if you use your arm and lift a 10-lb weight, then (fig. 43.1) your biceps muscle shortens as you lift, but the weight (load) is 10 lb at all times. This is an isotonic contraction contraction of the shortens as you lift. Isometric contractions occur when muscles develop tension but do not shorten. For example, if you push against an immovable wall, your muscles develop tension but do not shorten significantly. This is an isometric contractions? Isometric contractions? B. Which type of contraction develops more muscle tension: isotonic or isometric? Explain why. In both types of contract, the more fibers are stimulated by a nerve impulse to contract, the greater the tension. Muscle tone is a state of moderate to slight tension that is maintained continuously by a muscle or group of muscles. For example, our posture relies on the muscle tone important? Most joints are movable; they will move in one, two, or three planes, depending on the joint. Movement results from contraction of a skeletal muscle that connects a nonmoving Human Biology 497 Bone Tendon Skeletal muscle fascicle (with many muscle fibers) Nuclei Striations Plasma membrane ©Ryan McVay/Photodisc/Getty Images Muscle fibers, and a large-to-small view of myofilaments in muscle fibers. bone (i.e., the origin) to a moving bone (i.e., the insertion) across a joint. In this exercise, you will study how muscles flex or extend joints. The extension of a joint, such as when you bend your arm at the elbow, decreases the angle between two bones. More specifically, the contraction of your biceps muscle flexes your forearm. In this example, as is true throughout most of your biceps muscle extends your forearm. In this example, as is true throughout most of your biceps muscle flexes your forearm. this exercise, you will also study the major groups of skeletal muscles. You'll also study the mechanics of skeletal muscle cell biology in Exercise 41. 498 EXERCISE 43 Muscles by the Numbers Our body has 639 skeletal muscles accounting for 42% of a male's body mass and 36% of a female's mass. Muscle tissue is 15% denser than fat. Thirty of our muscles are facial muscles that provide us with remarkable subtlety of expression. Eye muscles are the busiest of our muscles; we blink as much as 100,000 times a day! They are also notably large and strong considering how small our eyeballs are. Research shows them to be 100times stronger than needed. Our strongest muscle is the masseter or jaw muscle. It can bite with a force of 4300 Newtons. A Newton is the force that gravity exerts on approximately 102 g (equal to a small apple). 43-2 MAJOR GROUPS OF MUSCLES The following terms help biologists describe the structure and function of muscles (fig. 43.2): Extensor—muscle that straightens a joint Flexor—muscle that straighten in the lab to identify the following groups of muscles. After locating these muscles on yourself or your partner, label figures 43.3 and 43.4. Shoulder and Trunk Deltoid is the outer muscle along the upper third of the humerus. When the arm is raised, the deltoid is the hard short, thick deltoid raises the upper arm to horizontal or slightly higher. This motion away from the body midline is abductors. Pectorals—large, triangular muscle covering the upper part of the chest. Inserts on the humerus; originates from the clavicle ribs, and sternum. Contractions move the arms toward the body midline (i.e., adduction). If your arm is fixed, such as Origins, fixed ends, or heads of biceps (two heads) brachii (belly) Scapula during climbing, the pectoral helps pull the chest upward. The pectorals are the "breast" of poultry and are the main flight muscles of birds. Trapezius—inserts on the clavicle and along the scapula; originates along the upper dorsal midline. Aids in lifting with the arms or carrying loads on shoulders. Latissimus—large sheet of muscle in back. Inserts on the upper part of the humerus, and originates along the middorsal line. Moves the arm downward. The latissimus is a primary muscle used in a swimming stroke or in bringing the arm forcibly downward. Arm Triceps brachii—inserts on the scapula and humerus. The triceps brachii—inserts on the scapula. The biceps brachii—inserts on the scapula and humerus. flexes the forearm at the elbow and is the primary muscle for doing a biceps curl or raising a glass to your mouth. Procedure 43.1 What muscles flex and extend the forearm? 1. Find a partner. 2. Position your or your partner's elbow comfortably on the table top with the palm up. 3. Feel the muscles of the upper arm as the forearm? flexed. 4. Repeat this exercise with a heavy weight in the hand. 5. Repeat this exercise with the elbow pointed at the ceiling. Question 3 a. What muscle flexes the forearm? Flexion b. What is its origin? Its insertion? Tendon Extension Ulna Radius Insertion, or mobile end, of biceps brachii on radial tuberosity Origins, fixed ends, or heads of triceps (three heads) brachii on scapula and humerus Humerus d. What is its origin? Its insertion? Insertio humerus. The biceps brachii inserts onto the radial tuberosity and onto nearby connective tissue. The triceps brachii inserts onto the olecranon process of the ulna. 43-3 c. Which muscle extends the forearm? Wrist extensors—muscles on the ventral side of the lower arm that bends the hand at the wrist. Human Biology 499 Figure 43.3 Ventral view of superficial muscles of the human body. 500 EXERCISE 43 43-4 Figure 43.4 Dorsal view of superficial muscles of the human body. 500 EXERCISE 43 43-4 Figure 43.4 something heavy. Finger flexors and extensors—similar to those of the wrist. Identify these muscles and the long tendons that attach to them by clenching and extending your fingers. The tendons are crossed from extensor muscles and the long tendons that attach to them by clenching and extending your fingers. The tendons are crossed from extensor muscles to the middle and ring fingers. c. What muscle flexes the lower leg? Procedure 43.2 How does the structure of your hand affect its movement? 1. With your finger also. Question 4 Did your ring finger also go higher? Why or why not? d. What are its origins? Its insertions? 2. Repeat the previous observation for your or your partner's lower leg. Question 6 a. What muscle group extends the foot? Skull Masseter—the main muscle at your temples and on either side of your cheekbone. Leg Hamstring—a set of three muscles on the back of the thigh that bend the leg at the knee. Originate on the coxal bone and femur; insert on the fibula. You can feel the hamstring's tendons at the back of your knee butchers use these tendons to hang up hams. Quadriceps—large muscles on the anterior part of the thigh that originate on the coxal bone and insert on the tibia. The quadriceps extends the knee and enables you to stand from a squatting position. Also provides much of the power for kicking a ball. Gastrocnemius—the calf muscle; originates on the femur and inserts (by the Achilles tendon) on the heel bone (a tarsal). The gastrocnemius—the calf muscle; originates on the femur and inserts (by the Achilles tendon) on the heel bone (a tarsal). and extend your foot. Toe flexors and extensors—several muscles in the lower leg that curl or extend the toes. Tendons from the extensors are visible atop your foot when you raise your toes. Procedure 43.3 What muscles flex and extends the lower leg against an externally applied force. 502 EXERCISE 43 b. What are its origins? Its insertions? c. What muscle flexes the foot? d. What are its origins? Its insertions? e. What common activities involve contraction of the gastrocnemius? Procedure 43.4 Can any tendons be manipulated manually? Your Achilles tendon connects your heel to muscles of your lower calf. This tendon, the largest tendon in the human body, can withstand forces exceeding 1000 lb. Grab your answer. Hip Gluteus—large, powerful muscle in the posterior pelvic region. Inserts on the femur and originates from the coxal
bone. The gluteus supports the pelvis and trunk on the femur (you can show this by standing on one leg and feeling the muscle). Used in climbing, cycling, jumping, and regaining an erect position after bending forward. 43–6 Do not do the following exercises if you have heart or lung problems. Stop immediately if you feel faint. Procedure 43.5 How fast do muscles fatigue? Work with two lab partners as you do this procedure. 1. Squeeze a tennis ball as rapidly as possible with one hand. While you squeeze, a partner will count and record your number of contractions during each 15-sec period. 0-15 sec contractions 15-30 sec contractions 30-45 sec contractions 45-60 sec contractions 120-135 sec contractions 120-135 sec contractions 120-165 sec sec contractions 15-30 sec contractions 30-45 sec contractions 45-60 sec contractions 120-135 se your results: 0-15 sec contractions 15-30 sec contractions 30-45 sec contractions 43-7 Number of contractions 43-7 defecation. 40 0 0 15 30 45 60 75 90 105 120 135 150 165 180 Time (seconds) Figure 43.5 Decline in the number of contractions contractions contractions contractions contractions contractions 4. On figure 43.5, graph the number of contractions versus time for each trial. Connect the data points with a straight line for each trial. Question 7 a. Did you produce the same number of contractions in crease during the experiment? Explain your answer. b. Is there are same number of contractions in crease during the experiment? slope of the line constant in the experiments? What do you conclude from this? c. What causes muscle fatigue? Human Biology 503 INQUIRY-BASED LEARNING How long does it take a fatigued muscle to recover? Observation: If given enough rest, muscles recover from fatigue? Automatication and the state a fatigued muscle fatigue? Establish a working lab group and obtain Inquiry-Based Learning Worksheet 43 from your instructor. b. Discuss with your group a well-defined question relevant to the preceding observation and question. Record it on Worksheet 43. c. Translate your question into a testable hypothesis and record it. d. Suggest one way to measure recovery time. Outline on Worksheet 43 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your procedures, record your data, answer your questions, hypotheses, or procedures. Repeat your work as needed. Questions for Further Study and Inquiry 1. What would happen if both muscles of an antagonistic pair? 5. Many people takes are there? 4. What is an example of a muscle sheletal muscles are there? 4. What is an example of a muscle sheletal muscles are there? 4. What is an example of a muscle sheletal muscle she dietary supplements to improve their strength and endurance. Do these supplements "work"? What is the evidence? 6. Review the information presented in Exercise 42. How do muscles and bones work together? 7. Do invertebrates without bones have something rigid for their muscles to pull against? How so? WRITING TO LEARN BIOLOGY What is muscle fatigue? How could you delay the fatigue of a muscle? 504 EXERCISE 43 43-8 E XER CISE 44 Human Biology Breathing. 2. Measure or compute your vital capacity, tidal volume, inspiratory reserve volume, and expiratory reserve volume, and understand how these volumes relate to one another. 3. Measure how exercise and hyperventilation affect your breathing. Please visit connect.mheducation.com to review online resources tailored to this lab. I n Exercise 12 you studied how cells oxidize sugars to release energy for their activities. This process is called c ellular respiration, and in humans and most other organisms it requires oxygen (fig. 44.1). To get this oxygen for respiratory system in which ventilation and gas exchange occur in specialized organs called lungs. We promote gas exchange by forcing air into and out of our lungs as we breathe. The importance of breathing can't be overestimated— every day we breathe about 25,000 times. If our rate of breathing slows too much, we either faint or suffocate. Air moves in response to pressure gradients produced by a complex anatomy (fig. 44.2). This is true for large masses of air, such as cold and warm fronts that sweep into town, and for relatively small masses of air that move into and out of our lungs. Air always moves from inside the balloon, where pressure is high, to the outside of the balloon, where pressure is lower. Air moving into and out of our bodies as we breathe also moves in response to pressure gradients. As you'll learn in this exercise, we expend much energy to create pressure gradients that help us breathe. Our lungs are in our thoracic (chest) cavity. We inhale by expanding our lungs, which creates a negative pressure gradients. This suction pulls air into our lungs. Expanding our lungs is more complicated than it seems because lung tissues lack skeletal muscles. •• The diaphragm is a sheetlike muscle separating the abdomen from the chest cavity. It is the primary muscle used 44-1 in breathing; when the diaphragm contracts, it flattens and expands the chest cavity. This expansion of our chest creates a negative pressure (i.e., a partial vacuum), thereby pulling air into our nostrils, mouth, and lungs. •• Intercostal muscles are located between the ribs (fig. 44.3). When these muscles contract, they expand the chest cavity, and decreases the pressure pulls air into our lungs. Contracting your chest cavity, so as it expands, your lungs also expand. This expansion decreases the pressure in the lungs and causes air to move into the lungs. Relaxing the diaphragm and intercostal muscles shrinks the chest cavity, thereby increasing the pressure in © Rex Brown/Getty Images Figure 44.1 We humans promote gas exchange by forcing air into and out of our lungs as we breathe. In cold weather, we see condensed water vapor in air exhaled from our lungs. Human Biology 505 Nasal cavity Nostril Mouth Pharynx Air Larynx Connective tissue Mucus Trachea Left lung Right bronchus Left bronchus Left bronchus Trachea Left lung Right bronc Tracheal lining Capillaries Alveolus Blood flow Branch of pulmonary vein Branch of pulmonary artery Bronchiole End of one bronchiole End of one bronchiole End of one bronchiole Alveolar type I cell O2 CO2 Interstitium (connective tissue) Alveolar type I cell O2 CO2 Interstitiu Cross section of an alveolar cluster, with enlarged region Figure 44.2 The mammalian respiratory system. (a) In this overview, the ribs and intercostal muscles and the muscular diaphragm. For simplicity, external and internal intercostal muscles are not indicated separately. (b) Ciliated epithelial cells and mucus-producing goblet cells line the trachea. The mucus toward the mouth, where it can be swallowed. (c) The bronchioles deliver air to the clusters of alveoli. Note the smooth muscle cells around the bronchioles, which can cause the bronchioles to constrict or dilate. Capillaries surround the alveoli. Red represents oxygenated blood; blue r Sternocleidomastoid muscles contract (for forced inhalation) Air Intercostal muscles contracts (a) Expiration Air Intercostal muscles contracts (a) Expiration Air Intercostal muscles contracts (b) Figure 44.3 How a human breathes. (a) Inhalation. The diaphragm contracts and the walls of the chest cavity expand, increasing the volume of the chest cavity and the lungs. As a result of the larger volume, air is drawn into the lungs through the trachea. Note that inhalation can be forced by contracting accessory respiratory muscles (such as the sternocleidomastoid), and exhalation can be forced by contracting the abdominal muscles. 44-3 Human Biology 507 Air Exhalation (a). When the diaphragm" (a) (b) (c) Figure 44.4 A simple experiment that shows how we breather. In the jar is a balloon (a). When the diaphragm (b) (c) Figure 44.4 A simple experiment that shows how we breather. is pulled down, as shown in (b), the balloon expands; when it is relaxed (c), the balloon contracts. In the same way, air is taken into the lungs because and air is expelled. the lungs because air out of the lungs because pressure there exceeds that in the atmosphere. To better understand breathing movements, use your fingertips on
your chest and then abdomen to feel the difference in your body movements as you breathe while holding your rib cage steady and using only your diaphragm. Then feel your body movements when using only rib intercostal muscles, and then when using both rib intercostals and diaphragm. Next, examine the lung model, a simple device that helps demonstrate the principles underlying inhalation. The model represents air passages, the balloons represent the lungs, the space represents the thoracic cavity, and the rubber sheet at the base of the model represents the diaphragm. Rhythmically pull and push the diaphragm is pulled down? When it is pushed back? Why? 508 EXERCISE 44 b. What would happen if the seal at the base of the jar was broken? c. What causes a collapsed lung? d. Is a collapsed lung functional? Why or why not? Don't do the following procedures, and stop immediately if you feel faint. 44-4 Procedure 44.1 Measure differences in chest diameter during breathing 1. Wrap a tape measure snugly under your chest diameter: cm 2. Now take a deep breath, hold it, and measure your chest diameter: cm 2. Now take a deep breath, hold it, and measure your chest diameter: cm 2. Now take a deep breath and a round the fullest part of your chest diameter: cm 2. Now take a deep breath and a round the fullest part of your chest diameter: cm 2. Now take a deep breath and a round the fullest part of your chest diameter: cm 2. Now take a deep breath and a round the fullest part of your chest diameter: cm 2. Now take a deep breath and measure your chest diameter: cm 2. Now take a deep breath and a round the fullest part of your chest diameter: cm 2. Now take a deep breath and measure your chest diameter: deep breath without expanding both your chest and abdomen? Why or why not? 6. Exhalation occurs by relaxing your diaphragm and intercostal muscles. Place your hand near your belly button and force as much air out of your lungs as possible. Question 5 a. What happened to your abdominal muscles when you exhaled? b. What caused your chest to enlarge? c. What is the significance of this change? 3. Place your hand at the bottom of your sternum (chest bone) and take a deep breath. Question 3 a. What direction did your hand at the bottom of your sternum (chest bone) and take a deep breath. LUNG CAPACITY Your lungs hold several liters of air. This volume of air has several subvolumes (fig. 44.5). b. When you exhaled? 4. Place your hands on your chest. Describe what you feel. Total lung capacity Expiratory reserve volume Tidal volume Vital capacity Inspiratory reserve volume Figure 44.5 Pulmonary volumes and capacities. 44-5 Human Biology 509 •• Tidal volume (TV) is the volume of air inhaled or exhaled during a single breath and is the amount of air necessary to maintain the oxygen supply to your tissues. Tidal volume is about 500 mL for an average adult. •• Expiratory reserve volume (ERV) is the amount of air that can be exhaled after a normal, quiet exhalation. Expiratory reserve volume (IRV) is the amount of air that can be exhaled after a normal, quiet exhalation. Expiratory reserve volumes range from 2500 to 3500 mL. •• Residual volume (RV) is the air that cannot be exhaled from the lungs. Residual volume is about 1200 mL. •• Vital capacity is the total of tidal volume amount of air that can be inhaled after maximum exhalation. Vital capacity is sometimes used to indicate pulmonary function. A significant decrease in vital capacity is often associated with emphysema, pneumonia, and other lung diseases. Measuring Lung Capacity The volumes change as you age, and they vary from individual to individual. The normal adult breathes about 12 breaths per minute. In the following procedures, record all of your results in table 44.1. Procedure 44.2 Measure your tidal volume (TV) 1. Set the dial of the spirometer at zero. Place a sterile mouthpiece over the stem of the spirometer. Insert the mouthpiece into your mouth with the spirometer's dial facing upward. 2. Inhale through your nose and exhale through your mouth for five normal breathing cycles. ©Phipps & Bird, Inc., Richmond, VA. Used with Permission. Figure 44.6 A spirometer is used to measure lung capacity. 3. After five breathing cycles, observe the dial reading. Divide the reading by five to determine your tidal volume for one breath. 4. Record this volume, according to the units on the spirometer, as the first of three tidal volume measurements in table 44.1. 5. Repeat steps 2-3 twice and record this average of the resulting three values and record this average of the resulting three values and record the second three tidal volume measurements in table 44.1. 5. Repeat steps 2-3 twice and record the second three values and record th contribute equally to breathing? Observation: Breathing involves the combined action of the diaphragm and intercostal muscles to breathing? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 44 from your instructor. b. Discuss with your group a well-defined question relevant to the preceding observation and question, and relate it to your inspiratory reserve volume and/or tidal volume. Record it. d. Outline on Worksheet 44 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your proposed investigation. e. Conduct your procedures, record your data, answer your questions, hypotheses, or procedures. Repeat your work as needed. 44-6 Procedure 44.3 Measure your expiratory reserve Breathing by the Numbers 1. Reset the dial of the spirometer to zero. 2. Place your mouth on the tube. Inhale normally through your nose, then exhalation volume. 3. From this maximal exhalation volume. 3. From this maximal exhalation volume. 3. 44.2). 4. Record this value in table 44.1 as the first of three ERV values. 5. Repeat steps 2-4 twice and record it in table 44.1. 6. Calculate your average ERV and record it in table 44.1. The interior surface of 500 m2, whereas that of a rabbit is only 5.9 m2. A parking space for a car is 10 m2. Our lungs have an inner surface equal to 9 parking spaces! In each breath, we inhale/exhale about 500 mL. For comparison, a horse exhales 7500 mL. For comparison, a horse exhales 7500 mL. several deep breaths and exhale completely after each. Then take as deep a breath as possible and exhale slowly and evenly through the spirometer. 3. Record this value in table 44.1. 5. Calculate your average value your your average value your average value your you VC and record it in table 44.1. Procedure 44.5 Compute your inspiratory reserve volume (IRV) Your instrument is not set up to measure your inspiratory reserve = capacity volume wL Procedure (mL) volume mL Procedure (mL) volume mL Procedure (mL) volume mL Procedure 44.5 44.6 Measure the effect of exercise on your tidal volume = mL Question 6 a. How do these values compare with your "at rest" values (table 44.1)? b. How do you explain this difference? 2. Stop exercising and continue to measure your tidal volume every 30 sec for 10 min. Graph your results (fig. 44.7). The normal adult's vital capacity for men is about 5200 mL, whereas that for women is about 4000 mL. Tidal volume is affected strongly by exercise. Table 44.1 Measurements of Lung Volumes Tidal Volume (TV) Expiratory Reserve Volume (IRV) Vital Capacity (VC) 1st 1st 2nd 2nd 3rd 3rd Average Average Average 44-7 Inspiratory Reserve Volume (IRV) Calculated value = Human Biology 511 dioxide in your blood. Slowing your breathing rate slows the release of carbon dioxide into the lungs, thereby increasing the amount of carbon dioxide in the blood. The average adult breathes about 12 times per minute, compared to an elephant's 10 breaths per minute. A giraffe maintains alveolar ventilation by breathing about 8 to 10 times per minute. the long trachea, must be filled with air. The resting tidal volume of the giraffe is about 4 L. Question 7 What is your recovery time? 3. When you've finished the experiment, place the disposable mouthpiece in the collecting bag. BODY SIZE AND VITAL CAPACITY A normal adult's vital capacity varies with body size. To show this, use a meterstick to measure your height: cm Write your height, gender, and vital capacity on the chalkboard in the lab. Graph all of the data for your class on figure 44.8. Your instructor may ask you to graph the data for your class on figure 44.8. Measure your breathing rate 1. Determine your breathing rate at rest. 2. Breathe deeply and rapidly for 12 breaths (i.e., hyperventilate). Try not to move your shoulders as you hyperventilate. Simply increase the rate and depth of breathing. Question 9 Does deep breathing rate at rest. 2. Breather deeply and
rapidly for 12 breaths (i.e., hyperventilate). Try not to move your shoulders as you hyperventilate. predicted? Why or why not? BREATHING RATE Your rate of breathing is controlled by many factors, the most important of which is the concentration of carbon 3. After hyperventilating, hold your breath again as long as you can. Again record how long you held your breath: sec 5. Repeat this exercise three more times. 7.0 3000 6.0 Vital capacity (liters) Tidal volume (mL) 2600 2200 1800 1400 5.0 4.0 1000 600 200 0 1 2 3 4 5 6 7 8 9 10 3.0 120 130 Time (minutes) Figure 44.7 Change in tidal volume during recovery from exercise. 512 EXERCISE 44 140 150 160 170 180 190 200 210 Height (cm) Figure 44.8 The relationship between lung vital capacity and a person's height. 44-8 asbestos fiber Pneumonia Alveoli fill with thick fluid, making gas exchange difficult. Pulmonary Fibrosis Fibrous connective tissue builds up in lungs, reducing their elasticity. tubercle Pulmonary Tuberculosis Tubercles encapsulate bacteria, and elasticity of lungs is reduced. mucus Emphysema Alveoli burst and fuse into enlarged air spaces. Surface area for gas exchange is reduced. Asthma Airways are inflamed due to infection (acute) or due to an irritant (chronic). Coughing brings up mucus Common bronchial and pulmonary diseases. Exposure to infectious pathogens and/or polluted air, including tobacco smoke, causes the diseases and disorders shown here. Question 10 a. What pattern do you see in the results? 44-9 b. How do you explain these data? That is, how is this response adaptive under these condi and pus. Figure 44.9 Human Biology 513 6. Rest until your respiratory rate returns to normal. Then run vigorously in place for 3 min. Stop and hold your breath for as long as possible. Record your time: sec b. What do you think causes the breathing rate to increase of CO2 in the blood or the depletion of O2? How could you test your answer? Question 11 a. How does this time compare with others you recorded? Explain your results. c. A large surface area is critical for efficient breathing. Review figure 44.9. What is the clinical significance of vital capacity? 2. How does smoking affect the various aspects of lung capacity? 3. How would you measure the effects of exercise on vital capacity? WRITING TO LEARN BIOLOGY Who do you think would have a shorter recovery time after exercising, a well-conditioned athlete or an out-of-shape professor? Explain your answer. 514 EXERCISE 44 44-10 E XER CISE 45 Human Biology Circulation and Blood Pressure Learning Objectives By the end of this exercise you should be able to: 1. Describe the path of blood flow in a four-chambered heart. 2. Describe the structure and function of red blood cells, white blood cells, white blood cells, and arteries. 4. Describe the structure and function of red blood cells, white blood cells, white blood cells, white blood cells, white blood cells, and arteries. pressure and pulse rate. Please visit connect mheducation.com to review online resources tailored to this lab. The cells of multicellular organisms are linked by an elaborate circulatory system. In humans, this circulatory system is based on a fast-flowing river of blood that delivers materials, food, and oxygen to cells (see fig. 49.7). Our circulatory system also removes waste products such as carbon dioxide from cells. The circulatory system in humans and other vertebrates is a closed system, meaning that blood is enclosed at all times within vessels and does not fill body cavities. The circulatory system in humans consists of a pumping heart, blood, and blood vessels. In this exercise, you'll examine the structure and function of your circulatory system. You'll also make some diagnostic measurements of your circulatory system, including your pulse rate and blood pressure. HEART Your heart is a muscular organ that weighs 200-400 g (7-15 ounces) and is slightly larger than your fist. Every day, a person's heart beats about 100,000 times and pumps about 7570 liters (2000 gallons) of blood. A human heart has four chambers: a left and right atrium, and a left and right ventricle. These chambers are separated by one-way valves that help control blood flow. The left and right ventricle. the mammalian heart (see fig. 45.1; also fig. 45.1; also fig. 49.9). •• Oxygen-poor and CO2-rich blood from the superior vena cava enter the right atrioventricular (tricuspid) valve to the right ventricle. 45-1 •• The right ventricle then pumps blood through the pulmonary semilunar valve into the pulmonary trunk and the two pulmonary arteries to the left atrium pumps blood through the left atrium. •• The left atrium pumps blood through the left atrium arteries to the left atrium pumps blood through the semilunar valve into the aorta to the body. Examine a heart from a cow. Use your fingers to trace the path of blood flow. Question 1 a. Which chamber has the thickest wall? b. How does this relate to the function of that chamber? Circulation and Blood Pressure by the Numbers of the function of the funct blood throughout our bodies. This means that during an average lifetime, our heart pumps about 48 million gallons of blood, which would fill more than 70 Olympic-size swimming pools. Human Biology 515 The human heart weighs about 300 g; that's comparable to the weight of an empty stomach, but is only one-fifth that of our liver. For comparison, the heart of a lion weighs about 750 g, while that of a sparrow weighs only 0.4 g. If all of the veins, arteries, and capillaries in a human body were stretched end-to-end, they would span more than 2.5 times. Our bodies produce more than 100 billion red blood cells per day; each of these cells lives about 120 days. For comparison, cells lining our stomach and small intestine live an average of only 2 days, and cells in our lungs, has a diameter of 2.4 cm. For comparison, our capillaries have a diameter of about 8 um. Typical blood pressure in humans is 120/80 mm Hg, which is similar to that in rabbits (110/80) and chimps (135/80). Frogs have a lower blood pressure (32/20), while giraffes have a higher blood pressure (32/20), while giraffes have a higher blood pressure (32/20). Left subclavian artery Left common carotid artery Brachiocephalic artery Brachiocephalic artery Superior vena cava Aortic arch Aorta Each beat of the heart produces a characteristic sound. The first sound is a low-pitched "lub" made by the left atrioventricular (also called the bicuspid) valves closing when the ventricles start to contracted. In both cases, blood falling back on the cuplike valves snaps these valves closed, much like wind snaps open a parachute. If any of the valves do not close completely, there is a turbulence in the heart murmur. Heart murmur. Heart murmur. the stethoscope against the fifth or sixth rib, slightly left of center. To hear the "lub" sound, press the stethoscope against the second rib. Figure 45.1 External anatomy of the human heart is located near the center of our chest. It is about the size of a large fist, has a mass of 200-400 g, and is enclosed in a protective sac called the pericardium. The aorta and pulmonary veins attach to the left side of the heart, and the venae cavae and pulmonary trunk attach to the right pulmonary artery O2-poor blood, and colored red if they carry O2-poor blood, and colored red if they carry O2-poor blood, and colored red if they carry O2-poor blood. Right pulmonary veins Left atrium Left cardiac vein Right atrium Right coronary artery Left ventricle Inferior vena cava Apex 516 EXERCISE 45 45-2 Question 2 a. About how fast is your heart beating? f. What are some diseases of blood? What are the symptoms of these diseases? b. Why can't you hear these sounds when you press the stethoscope against your neck or leg? g. Red blood cells lack nuclei. How might this improve their ability to function? BLOOD Blood vessels Recall from Exercise 41 that blood is a type of connective tissue (see fig. 41.14). About 55% of blood is a type of connective tissue (see fig. 41.14). cells, or erythrocytes. Red blood cells are biconcave disks 7-8 um in diameter (fig. 17.4a). There are about 250,000 erythrocytes in a drop of blood. Red blood cells are made by red bone marrow. Use the low, then high, magnification lenses of your microscope to examine a prepared slide of human blood. The pink cells lacking nuclei are red blood cells. The larger cells stained bluish-purple are white blood cells, or leukocytes, like erythrocytes, are made by red bone marrow. Blood vessels include arteries, capillaries, and veins (fig. 45.2). Arteries carry blood away from the heart. Arteries consist of four concentric layers: an outer layer of connective tissue, a middle layer of smooth muscle, an elastic layer, and an inner layer of epithelial cells. Examine a prepared slide of an artery. Question 3 a. What is the function of the cells? d. What is the function of each kind of blood cell? e. What is the approximate ratio of red blood cells to white blood cells in human blood? 45-3 Question 4 a. Which of the layers is thickest? b. What does this tell you about the function of the arteries? c. Plaque is a buildup of cholesterol, white blood cells, calcium, and other substances in the walls of arteries. How would the deposition of plaque in an artery affect the function of the artery? Veins carry blood to the heart. Veins have the same three layers that arteries have. Examine a prepared slide of a vein. Question 5 a. Which of the layers is thickest? b. How is this different from an artery? Human Biology 517 Large vein Large artery Few layers of smooth muscle and connective tissue Few elastic layers Wide lumen Endothelium Artery Many lavers of smooth muscle and connective tissue Several elastic lavers Inferior vena cava Aorta Endothelium Venule Lumen Arteriole Vein Lumen Arteriole Vein Lumen 4.3 mm Smooth muscle fibers Endothelium Endothelium Endothelium Endothelium Connective tissue ©Ed Reschke/Getty Images Endothelium
Endothelium Endothelium Connective tissue Continuous capillary pores Continuous capillary Figure 45.2 Comparative features of blood vessels. Sizes are not drawn to scale. Inset: Light micrograph (12×) of a medium-size artery near a vein. Note the difference between the artery and vein in wall thickness and lumen diameter. c. What does this tell you about the functioning of veins? c. Which has the thinnest wall? Capillaries connect arteries and veins and have a diameter slightly larger than that of a single red blood cell. Collectively, capillaries form an elaborate lattice of narrow, thinwalled tubes. Humans have about 97,000 km of capillaries form an elaborate lattice of narrow, thinwalled tubes. Examine a prepared slide of an artery, vein, and capillary. d. What does the absence of muscle tissue in capillaries suggest about the function of this part of the circulatory system? Blood Circulation in Goldfish b. Which has the smallest diameter? 518 EXERCISE 45 Use a net to catch a goldfish from the aquarium. Let the tail protrude from the aquarium. Let the tail protrude from the goldfish in cotton. Place the fish in a petri dish and examine the tail with a dissecting microscope. Note the moving blood. Gently return the goldfish to the aquarium. Act quickly and decisively to minimize stress on the goldfish. 45-4 Question 7 a. Is the blood moving at a steady rate and in the same direction? Superficial temporal artery b. What does this tell you? Axillary artery Brachial artery common carotid artery? Radial artery Femoral artery d. How do you know? Popliteal artery (behind knee) HUMAN PHYSIOLOGY Do not do the following exercises if you have heart or lung problems. Stop immediately if you feel faint. Dorsalis pedis artery Pulse During an average lifetime, the human heart beats approximately 2.5 billion times. With each beat, the heart forces blood into arteries. This surge of blood stretches the artery coming from the heart. Surge after surge of blood from your beating heart produces waves of blood are known as pulses. The pulse rate indicates the number of heart contractions per minute. Typical pulse rates usually range from 65 to 80 contractions per minute, but well-conditioned athletes may have rates as low as 40 contractions per minute. Many arteries are well positioned for measuring your pulse by placing your second and third fingers on the thumb side of your inner wrist (this is where the radial artery passes into the hand). Press down slightly. Count your pulse for 15 sec: beats in 15 sec 2. Multiply this number by 4 to convert this to beats per minute: Beats in 15 sec 4 = beats per minute: Beats per Question 8 How does this pulse rate compare with that measured at your breath for 15 sec. Then measure your pulse for another 15 sec. Then measure your breath affect your breath for 15 sec. Then measure your results. Record your average resting pulse rate: beats per minute 45-5 Human Biology 519 Do not do the following exercises if you have heart or lung problems. Stop immediately if you feel faint. Question 11 a. Is blood pressure the same throughout the circulatory system? 6. Run vigorously in place for 5 min. Then sit down and immediately measure your pulse rate. Question 10 a. How does exercising affect your pulse rate? b. How do you explain this? Blood Pressure stee blood through arteries, veins, and capillaries. The increased pressure that results from blood leaving the heart is the systolic pressure. When the heart relaxes, the arteries return to their original diameter and, in the process, squeeze blood forward through the cardiovascular system. This pressure when the heart relaxes is the diastolic pressure. INQUIRY-BASED LEARNING How do minor movements affect our pulse rate? Observation: Pulse rate changes quickly and is highly sensitive to minor movements and exercise. Question: Do minor movements such as sitting and standing affect pulse rate? How long does it take for pulse rate to recover from these changes in position? a. Establish a working lab group and obtain Inquiry-Based Learning Worksheet 45 from your instructor. b. Discuss with your group and instructor a specific question relevant to the preceding observation and question, consider magnitude of change in pulse rate as well as recovery time. Record your question into a testable hypothesis and record it. d. Outline on Worksheet 45 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your proposed investigation. e. Conduct your procedures, record your data, answer your questions, hypotheses, or procedures. Repeat your work as needed. 520 EXERCISE 45 b. How do you know? Blood pressure, like barometric pressure, is measured in units called millimeters of mercury (mm Hg). This unit is based on a measuring device called a manometer, an inverted tube of liquid mercury. Pressure against the mercury reservoir at the base of the tube raises the column of mercury—the more pressure, the higher the column. Thus, the greater the number of millimeters of mercury, the greater the pressure of 100 mm Hg would raise a column of mercury 100 mm, whereas a pressure of 160 mm Hg would raise a column of mercury 160 mm. Blood pressure is usually measured in the brachial artery just above the elbow (fig. 45.3, also see fig. 45.5). Systolic pressure there typically ranges from 100 to 140 mm Hg, with the average being near 120. Diastolic pressure is "120 over 80" (expressed as 120/80). The difference between systolic and diastolic pressure is pulse pressure—this is what you feel in arteries when you touch your skin (fig. 45.4). Blood pressure is affected by many factors, including a person's intake of salt, the volume of blood, age, and the elasticity of blood vessels. Blood pressure is affected by many factors, including a person's intake of salt, the volume of blood, age, and the elasticity of blood vessels. inflatable cuff attached to a pressure gauge. The principle is simple: You first tighten the cuff until blood flow through the artery. Then you slowly deflate (i.e., loosen) the cuff and use a stethoscope to determine when blood flow resumes through the artery (fig. 45.5). Procedure 45.2 on blood pressure Measure the effect of exercise 1. Do all of the following experimenter. Have your lab partner lie down and relax for 2 min. Attach the cuff around his/her arm above the elbow. Tuck the flap of the bag under the fold. 2. Inflate the cuff to about 200 mm Hg. Because this pressure exceeds the subject's systolic pressure, the brachial artery in the arm collapses, thus stopping blood flow 45-6 140 Systolic pressure 60 40 20 Aorta Arteries Arterioles Capillaries Venules, veins Parts of circulatory pathway Figure 45.4 The changing pressures associated with the pulse wave in the human circulatory system. Column of mercury indicating pressure in mm Hg 190 170 150 80 mm Hg 130 110 90 70 Sound first heard Korotkoff sounds Sound disappears NO SOUND 50 30 10 4.0

Stethoscope Pressure cuff 5. Elbow Arm Air valve Squeezable bulb Figure 45.5 Measurement of blood pressure is recorded as two numbers separated by a slash; the first number is the systolic pressure, and the second number is the diastolic pressure. For a healthy 20-year-old college student at rest, a typical blood pressure is 120/80. 45-7 6. 7. through the artery. You'll feel no pulse in your partner's wrist when pressure in the cuff is 200 mm Hg. Place the bell of the stethoscope under the cuff and over the brachial artery just above the elbow. Again inflate the cuff to a pressure of about 200 mm Hg. Place the bell of the stethoscope under the cuff and over the brachial artery just above the elbow. pressure falls below the systolic pressure, blood spurts through the artery. This flow of blood occurs quickly and produces vibrations and turbulence that can be heard with a stethoscope as loud, tapping sounds. The pressure at which you hear these so-called Korotkoff sounds is the systolic pressure. As the pressure drops, the sounds become louder and more distinct as more blood flows through the artery. At this point, the flow of blood is continuous but still turbulent. When the cuff pressure, blood flow is normal (i.e., nonturbulent) and the sounds disappear. diastolic pressure. Repeat this pressure until you obtain consistent measurements. However, do not keep the cuff inflated around your partner's arm for more than a minute or so at a time. Record the average blood pressure: mm Hg When you stand up, gravity causes arterial pressure to decrease in the upper parts of your body and increase in the lower parts of your body. Indeed, standing up from a prone position has an effect on brachial artery blood pressure equivalent to losing about 500 mL of Human Biology 521 Table 45.1 The Effect of Posture on Blood Pressure (mm Hg) (systolic pressure/diastolic pressure) Pulse Rate (beats/sec) Prone Standing (10 sec after rising) Standing (5 min after rising) Standing (7 min after rising) Standing (9 min after rising) Question 12 How did your partner's plood. Measure your partner's plood pressure (mm Hg) blood. Measure his or her pulse rate and blood pressure immediately and 5, 7, and 9 min after rising. Record your results in table 45.1. 200 180 160 140 120 100 80 0 9. Have your partner lie down again and continue to measure your partner's blood pressure at 2-min intervals until it returns to normal. Plot these blood pressures on figure 45.6. 1 2 3 4 5 6 7 8 9 10 Time (minutes) Figure 45.6 Graph of systolic blood pressure on the x-axis. The data you plot on this graph will describe the recovery of systolic blood pressure after exercise. Question 13 a. How does exercise affect blood pressure? d. What was your partner's recovery time? That is, how long did it take for your partner's blood pressure to return to normal? b. Which is affected more, systolic pressure? e. What other physiological changes occurred as your partner put his? or her hand in cold (5°C) water for 1-2 minutes. Then remeasure the blood pressure. 522 EXERCISE 45 45-8 Question 14 a. How does cold affect blood pressure? b. Why would you expect such a difference? b. Are systolic and diastolic pressures affected similarly? Procedure 45.4 Locate valves in veins c. Compare your data with those of your classmates. What is the average blood pressure for your class? Venous Blood pressure slowly and at low pressure through capillaries, there is no mechanism (e.g., heart) to pump and increase the blood pressure slowly and at low pressure through capillaries. the blood under such low pressure from flowing backward. 1. Compress the vessels near your right elbow until the veins stand out. 2. Lay the index finger of your left hand on a vein near your wrist. 3. Move your thumb along and on top of the vein toward your elbow (i.e., toward your left hand on a vein near your wrist. 3. Move your thumb along and on top of the vein toward your elbow (i.e., toward your left hand on a vein near your wrist. 3. Move your thumb along and on top of the vein toward your elbow (i.e., toward your left hand on a vein near your wrist. 3. Move your thumb along and on top of the vein toward your elbow (i.e., toward your elbow (i.e., toward your left hand on a vein near your wrist. 3. Move your thumb along and on top of the vein toward your elbow (i.e., toward your elbow until the veins stand out. 2. Lay the index finger of your left hand on a vein near your wrist. 3. Move your thumb along and on top of the vein toward your elbow (i.e., toward your elbow (i.e., toward your elbow (i.e., toward your elbow until the veins stand out. 2. Lay the index finger of your elbow (i.e., toward your elbow until the veins stand out. 3. Lay the index finger of your elbow (i.e., toward your elbow (i.e., toward your elbow until the veins stand out. 3. Lay the index finger of your elbow (i.e., toward your elbow (i.e., toward your elbow (i.e., toward your elbow until the veins stand out. 3. Lay the index finger of your elbow (i.e., toward your elbow until the veins stand out. 3. Lay the index finger of your elbow (i.e., toward your elbow until the veins stand out. 3. Lay the index finger of your elbow until the veins stand out. 3. Lay the index finger of your elbow until the veins stand out. 3. Lay the index finger of your elbow until the veins stand out. 3. Lay the index finger of your elbow until the veins stand out. 3. Lay the index finger of your elbow until the veins stand out. 3. Lay the index finger of your elbow until the veins stand out. 3. Lay the index finger of your elbow until the veins stand out. vein. If blood refills all of the vein, repeat the experiment by placing your finger where the thumb reached. Continue until you reach a point at which the blood does not return toward the finger when the thumb is lifted. Question 17 What blocks the backflow of blood in veins? Procedure 45.3 Blood flow in veins 1. Hang your hands down at your side. Note the veins on the back sides of your hands. 2. Raise your hands above your head. Question 15 What happens to the veins? Why? 3. Have your partner's hand, the height where the veins disappear is the venous pressure measured in centimeters (cm) of water. Convert this measurement to mm Hg = cm water × 0.73 = Question 16 a. How does blood pressure in veins compare with that in the brachial artery? 45-9 Blood Pressure and Your Health Your blood pressure is relatively constant when you are sitting down and resting. Optimal blood pressure occurs when systolic pressures are less than 120 mm Hg and diastolic pressures are between 80 and 89 mm Hg. 118/75 is an example of an optimal blood pressures are between 120 and 129 mm Hg. and/ or when diastolic pressures are between 80 and 89 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 and 129 mm Hg. and/ or when diastolic pressures are between 80 and 89 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 and 129 mm Hg. and/ or when diastolic pressures are between 80 and 89 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 and 129 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 and 129 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 and 129 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 and 129 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 and 129 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 mm Hg. 118/75 is an example of an optimal blood pressure are between 120 mm Hg. probably develop hypertension if they do nothing to lower their blood pressure. Hypertension, or high blood pressures exceed 129 mm Hg and/or when diastolic pressures exceed 90 mm Hg. A blood pressure of 145/96 is an example of hypertension. The American Heart Association estimates that approximately 50 million Americans have hypertension, and at least 30% of them do not know it. If left untreated, hypertension increases the risk of health problems such as stroke, heart attack, kidney damage, and heart failure. Smoking, obesity, stress, and a poor diet can contribute to hypertension, and regular exercise can help lower blood pressure (fig. 45.7). Although hypertension has no symptoms, it kills more than 50,000 people per year in the United States. Human Biology 523 The Unhealthy Circulatory System ANEMIA ARRHYTHMIA Anemia is a decrease in the oxygen-carrying capacity of blood. Anemia can result from red blood cells that are too small, contain too little hemoglobin, are manufactured too slowly, or die too guickly. Iron deficiency is the most common cause of anemia; sickle cell disease (see fig. 17.4) is a type of inherited anemia. An arrhythmia is an abnormal heartbeat. Some arrhythmias originate in the atria, causing transient flutters or racing that lasts only a few seconds. An electronic pacemaker implanted under the skin is a common treatment. In ventricular fibrillation, the ventricles contract wildly, causing sudden cardiac arrest. Death may occur within minutes. ATHEROSCLEROSIS ANEURYSM Fatty deposits inside coronary arteries reduce flow to the heart muscle. for "paste," and sclerosis meaning "hardness"). A cross section of a partially clogged artery is shown in the upper right corner. Atherosclerosis can so weaken the wall of an artery that a region of the vessel forms a pulsating, enlarging sac called an aneurysm. If it bursts, blood loss may be great, HEART ATTACK Smoking is the most common preventable cause of death. Cigarette smoke damages the lungs, impairing their ability to deliver O2 to the heart (and increasing both heart rate and blood pressure. Nicotine also damages blood vessels and stimulates the formation of blood clots, increasing the risk of stroke. Blocked blood flow in a coronary artery kills part of the myocardium, the heart muscle. This is a heart attack (myocardial infarction), and it may come on suddenly. A common treatment for a blocked coronary artery kills part of the myocardial infarction) and it may come on suddenly. vessel taken from the patient's chest or leg onto the blocked artery. THE EFFECTS OF SMOKING ON CARDIOVASCULAR HEALTH Fat deposits Endothelium 524 EXERCISE 45 45-10 Organizations such as the American Heart Association provide much useful information about health and blood pressure. If your blood pressure is high, or if you'd like to learn more about how blood pressure affects your health and well-being, study their websites (e.g., .americanheart.org) and visit your physician. AN ANALYSIS OF YOUR RISK OF CARDIOVASCULAR DISEASE A number of factors are suspected or proven to influence your risk of developing heart disease. Factors such as exercise, diet, persistent emotional stress, race, salt intake, obesity, age, family history, and smoking are clearly associated with the probability of suffering from cardiovascular disease later in life, even though no single factor is a guaranteed predictor. To assess your risk, complete the following questionnaire provided by the The University of Arizona's Sarver Heart Center. To complete the questionnaire, simply record the number of points assigned to each level of risk. Although this is not a definitive test, it will heighten your self-awareness of the consequences of your lifestyle. The University of Arizona's Sarver Heart Center's Heart Disease Risk Assessment1 DIRECTIONS: Note your score for the various risk factors. Total your points at the end and find your risk of having a heart attack or stroke during the next 10 years. BP = blood pressure © McGraw-Hill Education/Gary He, photographer Figure 45.7 Regular exercise can help you lower your blood pressure. Question 18 a. Hypertension is the most important modifiable risk factor for stroke, the #3 killer, and a leading cause of severe, long-term disability in the United States. How could hypertension affect someone's health? b. Why is hypertension called a "silent killer"? RISK FACTOR AGE Male 45-55 Male 56-65 Male 56-65 Male 56-65 Female 66-75 Female 55-65 Female 66-75 Female 55-65 Female 66-75 Female 55-65 Female 66-75 Female 55-65 Female 55-65 Female 55-65 Female 55-65 Female 52 3 4 5 2 3 5 0 1 2 3 ©The University of Arizona Sarver Heart Center. Reprinted by permission. 45-11 Human Biology 525 RISK FACTOR SMOKING Never smoked or nonsmoker for 5 or more years Nonsmoker for less than 5 years Current smoker for





