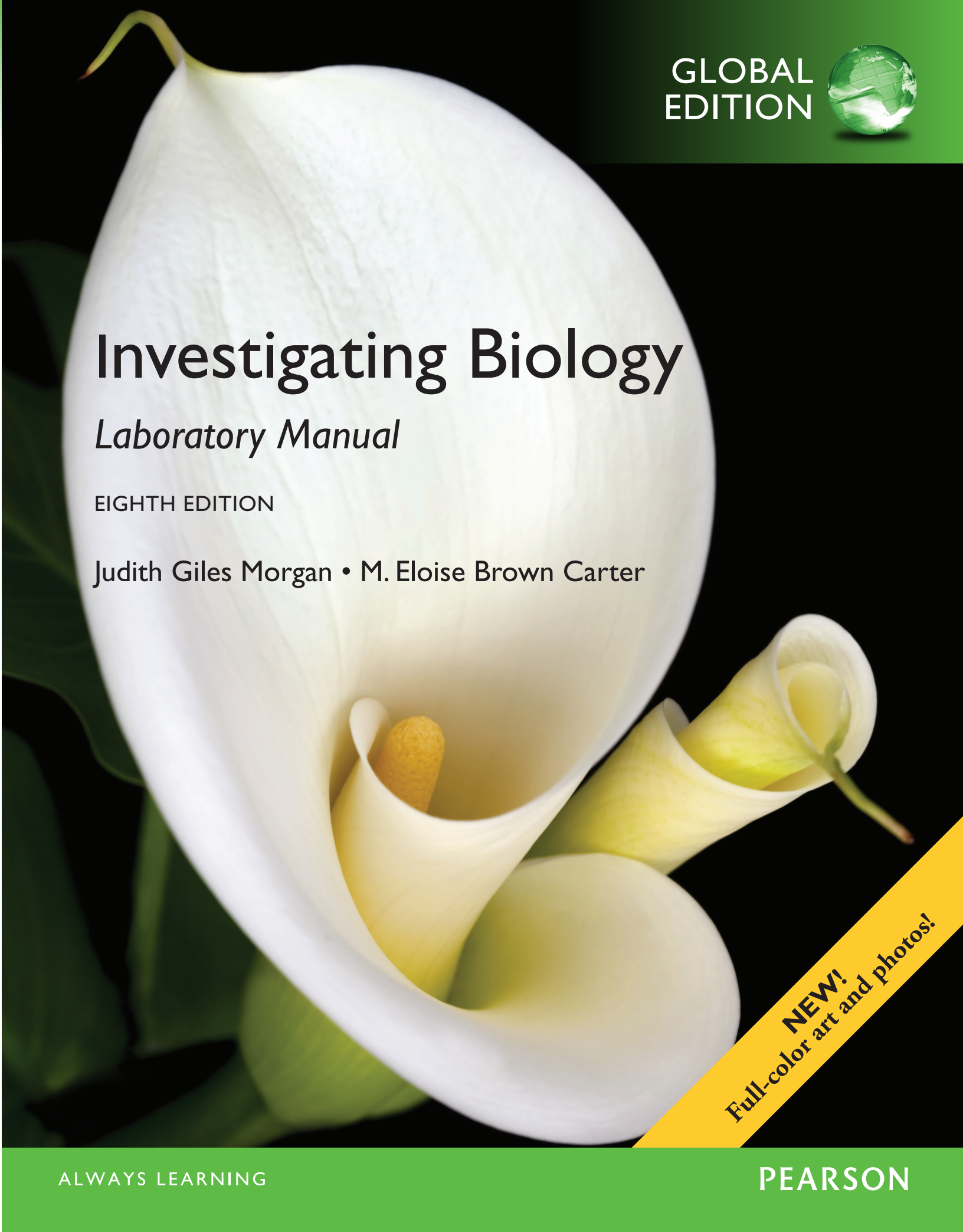
GLOBAL EDITION
Investigating Biology
Laboratory Manual
EIGHTH EDITION
Judith Giles Morgan • M. Eloise Brown Carter
NEW!
Full-color art and photos!
ALWAYS LEARNING
PEARSON

LABORATORY SAFETY:

GENERAL GUIDELINES

1. Notify your instructor immediately if you are pregnant, color blind, allergic to any insects or chemicals, taking immunosuppressive drugs, or have any other medical condition (such as diabetes, immunologic defect) that may require special precautionary measures in the laboratory.
2. Upon entering the laboratory, place all books, coats, purses, backpacks, etc. in designated areas, not on the bench tops.
3. Locate and, when appropriate, learn to use exits, fire extinguisher, fire blanket, chemical shower, eyewash, first aid kit, broken glass container, and cleanup materials for spills.
4. In case of fire, evacuate the room and assemble outside the building.
5. Do not eat, drink, smoke, or apply cosmetics in the laboratory.
6. Confine long hair, loose clothing, and dangling jewelry.
7. Wear shoes at all times in the laboratory.
8. Cover any cuts or scrapes with a sterile, waterproof bandage before attending lab.
9. Wear eye protection when working with chemicals.
10. Never pipet by mouth. Use mechanical pipeting devices.
11. Wash skin immediately and thoroughly if contaminated by chemicals or microorganisms.
12. Do not perform unauthorized experiments.
13. Do not use equipment without instruction.
14. Report all spills and accidents to your instructor immediately.
15. Never leave heat sources unattended.
16. When using hot plates, note that there is no visible sign that they are hot (such as a red glow). Always assume that hot plates are hot.
17. Use an appropriate apparatus when handling hot glassware.
18. Keep chemicals away from direct heat or sunlight.
19. Keep containers of alcohol, acetone, and other flammable liquids away from flames.
20. Do not allow any liquid to come into contact with electrical cords. Handle electrical connectors with dry hands. Do not attempt to disconnect electrical equipment that crackles, snaps, or smokes.
21. Upon completion of laboratory exercises, place wall materials in the disposal areas designated by your instructor.
22. Do not pick up broken glassware with your hands. Use a broom and dustpan and discard the glass in designated glass waste containers; never discard with paper waste.
23. Wear disposable gloves when working with blood, other bodily fluids, or mucous membranes. Change gloves after possible contamination and wash hands immediately after gloves are removed.
24. Place gloves, swabs, toothpicks, etc. that may have come in contact with body fluids in a disposable autoclave bag.
25. Leave the laboratory clean and organized for the next student.
26. Wash your hands with liquid or powdered soap prior to leaving the laboratory.

The biohazard symbol indicates procedures that may pose health concerns.

The caution symbol points out instruments, substances, and procedures that require special attention to safety. These symbols appear throughout this manual.

INVESTIGATING BIOLOGY

Laboratory Manual

Eighth Edition
Global Edition

Judith Giles Morgan
Emory University

M. Eloise Brown Carter
Oxford College of Emory University

PEARSON

Boston Columbus Indianapolis New York San Francisco Hoboken
Amsterdam Cape Town Dubai London Madrid Milan Munich Paris Montreal Toronto
Delhi Mexico City São Paulo Sydney Hong Kong Seoul Singapore Taipei Tokyo

The authors and publisher believe that the lab experiments described in this publication, when conducted in conformity with the safety precautions described herein and according to the school's laboratory safety procedures, are reasonably safe for the students to whom the manual is directed. Nonetheless, many of the described experiments are accompanied by some degree of risk, including human error, the failure or misuse of laboratory or electrical equipment, mismeasurement, spills of chemicals, and exposure to sharp objects, heat, bodily fluids, blood, or other biologics. The authors and publisher disclaim any liability arising from such risks in connection with any of the experiments contained in this manual. If students have questions or problems with materials, procedures, or instructions on any experiment, they should always ask their instructor for help before proceeding.

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Preface

Science is a way of thinking much more than it is a body of knowledge.

Carl Sagan

Our knowledge and understanding of the biological world is based on the scientific enterprise of asking questions and formulating and testing hypotheses. Scientists gather data, then evaluate and interpret their results, communicating their findings through papers and presentations. An important aspect of learning biology is participating in the process of science and developing creative and critical reasoning skills. Our goal in writing this laboratory manual is to present a laboratory program that engages students in the scientific process and encourages scientific thinking. We want students to experience the excitement of discovery and the satisfaction of solving problems and connecting concepts. For us, investigating biology is more than just doing experiments; it is an approach to teaching and learning that promotes inquiry.

The laboratory exercises are designed to encourage students to ask questions, to pose hypotheses, and to make predictions before they initiate laboratory work. Students are asked to synthesize results from their observations and experiments, then draw conclusions based on evidence. Whenever possible, students apply their results to new problems and case studies. *Investigating Biology* provides students with many opportunities to design their own open-inquiry investigations as part of the laboratory. In addition, students can pursue independent investigations using the suggestions and extensions provided at the end of lab topics. Scientific writing and communication are emphasized throughout the laboratory manual and supported by an appendix that includes instructions for writing each section of a scientific paper, obtaining information from primary sources, and preparing oral and poster presentations. Instructors are given suggestions for organizing a laboratory writing program.

Investigating Biology uses a stepwise approach to developing scientific knowledge and skills, as students in early lab topics practice asking questions, developing hypotheses, and designing experiments. Early laboratory experiences build on knowledge (e.g., how cells and enzymes function, genetics, and then biodiversity as an expression of variation and evolution). At the same time, students are developing laboratory and thinking skills, such as pipetting, using instruments, analyzing results, organizing and managing teams, and developing systematic approaches to experimental design and problem solving. Lab topics are a mixture of directed inquiry and open inquiry, with more directed investigations in the initial lab topics and increasing opportunities for open inquiry in subsequent lab topics. In the open-inquiry investigations, students are presented with a topic and preliminary experiment, then encouraged to develop their own questions, design their investigations, and write their proposals before implementing their own investigations. They must then collect and interpret their data. We use a similar approach for scientific writing. Students write individual sections of a scientific paper for initial lab topics, receiving feedback and the opportunity to revise. Then, for open-inquiry investigations, they are prepared to use their writing expertise to write a complete scientific paper.

This incremental approach to knowledge, skills, and disciplined ways of thinking is a hallmark of our approach throughout the lab manual and is adaptable to programs with large laboratory sections or small groups of students. *Investigating Biology* provides a comprehensive introduction to the diverse topics and subdisciplines in the biological sciences, always with an emphasis on scientific investigation.

We are convinced that involving students in the process of science through investigating biological phenomena is the best way to teach. The organization of this laboratory manual with a mix of directed-inquiry and open-inquiry investigations complements this approach to teaching and learning.

New in the Eighth Edition

The eighth edition of *Investigating Biology* offers enhanced opportunities for students to participate in science. You will find two newly designed lab topics for protists and fungi, new and revised open-inquiry exercises, suggestions for extending lab topics with independent investigations, new case studies for practicing problem solving, a revised section on student media, two new appendices on instrumentation and techniques and for metric measurement, and a revised appendix to support scientific writing in the laboratory. Adopters of the eighth edition will notice an enhanced emphasis on recurring themes in biology, including structure and function, unity and diversity, transmission of genetic information, energy transformations, and the overarching theme of evolution. These themes are developed across hierarchical levels from cells to organisms to ecosystems.

The eighth edition includes major revisions that reflect new molecular evidence and our current understanding of phylogenetic relationships for plants, invertebrates, protists, and fungi. The new Lab Topic 17 Fungi provides extensive coverage of the major fungi groups, including lichens. Lab Topic 13 Protists has been revised and expanded with additional examples of all the major clades. Now both newly revised lab topics include suggestions and exercises for open-inquiry investigations. In addition, the sequence of the lab topics has been reorganized to reflect the closer relationship of the fungi and animal kingdoms.

Lab Topic 1 Scientific Investigation has been completely revised with a return to an investigation of cardiovascular fitness. Students have additional options to design the experiment, as they choose among dependent variables and select the parameters for the experimental procedure. We have included new ways of measuring pulse/heart rate utilizing technology available on iPads and iPhones. The lab topic continues to emphasize the scientific process and establishing a fundamental way of working and thinking that will be featured in the continuing laboratory program.

In a previous edition we introduced a new laboratory, Lab Topic 16 Bioinformatics: Molecular Phylogeny of Plants. This lab topic connects organismal biology, molecular genetics, and evolution, using the techniques of computer science to analyze nucleotide sequences and develop phylogenetic trees. We have provided suggestions for teaching, additional analysis tools, and new questions that involve "tree thinking."

In the eighth edition, population genetics is covered in one lab topic with new problems and examples that connect ecology, evolution, and genetics.

Two new appendices have been added: Appendix B The Metric System and Appendix C Instrumentation and Techniques. Appendix C includes information and procedures for the use of pipettors, micropipettes, calipers, and both digital and electronic spectrophotometers.

We have continued to revise and propose ideas for the student-designed investigations in Lab Topic 5 Cellular Respiration, Lab Topic 11 Population Genetics, Lab Topic 13 Protists, Lab Topic 21 Plant Growth, Lab Topic 26 Animal Behavior, and Lab Topic 28 Ecology II. These open-inquiry laboratory experiences allow students to independently investigate questions, thus providing team research opportunities in the introductory laboratory program. For almost all other lab topics, we have further developed the open-inquiry section: "Investigative Extensions." For programs interested in providing independent or team research opportunities, students may pursue these investigations. Additional support for the investigations is provided in the *Preparation Guide for Investigating Biology Laboratory Manual* available to instructors. In Appendix A Scientific Writing and Communication, we updated a section on oral and poster presentations to introduce students to other formats for scientific communication.

The most dramatic innovation in the eighth edition is the use of full-color photographs and figures incorporated throughout the laboratory manual. Students will better visualize the procedures, structures, organisms, and life cycles within the context of their reading, thinking, and investigating. For example, students will find color photographs located in the text as they are observing the stages of mitosis or the diversity of plants and animals. Life cycles and stages of development are color coded to provide information that is essential to understanding processes and structures.

Other changes are more subtle but represent fine-tuning based on our experiences and those of instructors and students who used the first seven editions. We have revised and added to the questions at the end of each lab topic. Questions in "Reviewing Your Knowledge" allow students to test their knowledge and comprehension. Questions in "Applying Your Knowledge" allow students to apply their understanding to new problems that feature current research and societal issues. These questions reinforce the investigative approach of the laboratory manual in which students develop their skills in analyzing results, synthesizing, and communicating as they participate in the scientific process. We have integrated new scientific knowledge from molecular biology that has changed and invigorated areas of study in systematics and evolution. We have updated taxonomic classifications to be consistent with *Biology: A Global Approach,* 10th edition, Global Edition. However, we recognize that these will continue to change as new research reveals evolutionary relationships.

With increasing use of technology in the laboratory by instructors and students, we have provided all data tables in Excel format at *masteringbiology .com* under the Study Area. These tables can be modified and used in open-inquiry investigations, to teach data analysis, and as models for developing independent projects. All websites have been updated, and new Web sources and resources are included. We continue to support the use of media and technology with the section in each lab topic called "Student Media: BioFlix, Activities, Investigations, Videos, and Data Tables," which coordinates with *Biology: A Global Approach* student media materials.

The *Preparation Guide* has been revised to coordinate with and support the laboratory manual.

Writing and scientific communication continue to be a strong component of the laboratory manual. In the eighth edition, we enhanced support for the writing program by reorganizing and revising Appendix A Scientific Writing and Communication with easily located information on each section of the scientific paper, notes for successful writing, suggestions for locating appropriate references, and a "Plan for Writing a Scientific Paper." We provide tips for preparing and presenting oral papers and posters and encourage instructors to include poster presentations to report findings from open-inquiry investigations. The writing program is supported by materials in the *Preparation Guide* as well as coordinating with Web resources and the latest editions of guides to scientific writing and presentations.

In all of these changes and modifications, our objective has been to provide laboratory experiences that are challenging to students and allow them to participate in authentic scientific investigations. We are keenly aware of the constraints on laboratory programs, including number of students and sections, preparation of laboratories and instructors, and the expense and mentoring that are required to teach inquiring young scientists. We hope we have provided choices and options that can meet the needs of a wide range of programs and instructors.

Laboratory Topics

The laboratory topics build on information and techniques in previous exercises. Various laboratory exercises incorporate a combination of directed and open-ended procedures. There are basically three types of lab topics included in the manual:

1. *Directed-Inquiry Investigations,* in which exercises have been constructed to involve students in the process of science. We have organized these lab topics to include introductory information from which students develop hypotheses and then predict the results of their experiments. They collect their data and summarize the data in tables and figures of their own construction. The students must then accept or reject their hypotheses, based on their results. Examples of these directed-inquiry investigations include Lab Topic 3 Diffusion and Osmosis, Lab Topic 4 Enzymes, and Lab Topic 6 Photosynthesis.
2. *Key Theme Investigations,* in which laboratory exercises have been designed and reorganized with a focus on key themes of biology, for example, the unity and diversity of life. In these thematic exercises, students summarize and synthesize their results and observations connecting to the key themes. They use their observations as evidence in support of these major concepts and apply their understanding to new problems. Examples of these laboratories (and their underlying themes) include Lab Topic 2 Microscopes and Cells (unity and diversity of life);

Lab Topics 14 and 15 Plant Diversity I and II (adaptation to the land environment); and Lab Topics 22 to 24 Vertebrate Anatomy I, II, and III (structure and function).

3. *Open-Inquiry Investigations,* in which students generate their own hypotheses and design their own experiments. These exercises begin with an introduction and a simple experiment that demonstrates procedures. Then students are given suggestions and encouraged to develop their own questions and methodologies for further investigation. Examples of these open-inquiry investigations include Lab Topic 5 Cellular Respiration and Fermentation, Lab Topic 11 Population Genetics, Lab Topic 13 Protists, Lab Topic 17 Fungi, Lab Topic 21 Plant Growth, Lab Topic 26 Animal Behavior, and Lab Topic 28 Ecology II.

Lab topics are designated as *Directed-Inquiry, Key Theme,* or *Open-Inquiry Investigations* in the table of contents.

Scientific Communication: Writing and Presenting

Scientists communicate their results in writing and in presentations to research groups and at meetings. Undergraduates need instruction in writing and an opportunity to practice these skills; however, instructors do not have the time to critique hundreds of student research reports for each exercise. Throughout this lab manual, teams of students work together on improving their skills. They are asked to organize and present their results to their peers during the discussion and summary sessions in the laboratory. Students are also required to write as part of each laboratory. They summarize and discuss their results and then apply information to new problems in the questions at the end of the laboratory.

We have also incorporated a scientific writing program into our lab manual in a stepwise fashion. Students must answer questions and summarize results within the context of the laboratory exercises. For directed-inquiry investigations, students are required to submit one section of a scientific paper. For example, they might submit the Results section for one experiment in Lab Topic 3, and the Discussion section for one experiment in Lab Topic 4. Once students have experience writing each section, they write at least one complete scientific paper for an open-inquiry investigation, for example, Lab Topics 13, 17, 21, and 26. Instructions for writing a scientific paper, developing an oral presentation, and creating a poster are included in Appendix A, which also contains suggestions for developing an organized writing program.

Instructors may also choose to organize a session for oral or poster presentations similar to scientific meetings. Appendix A includes advice and references for these other forms of scientific communication.

See Appendix A for additional information on scientific writing and presentations.

Integration of Other Sciences and Mathematics

Students often view biology as a separate and isolated body of knowledge. We have attempted to integrate biology, chemistry, some physics, and geology whenever possible. For example, in Lab Top 16 Bioinformatics: Molecular Phylogeny of Plants, students must use bioinformatics to analyze their data from molecular biology. Students use computer models to understand relationships and test hypotheses in Lab Topic 11 Population Genetics: The Hardy-Weinberg Principle and Lab Topic 28 Ecology II: Computer Simulations of a Pond Ecosystem. We also provide opportunities for students to quantify observations, analyze and summarize results in tables and figures, and, ultimately, to use these data to construct arguments in support of their hypotheses.

Special Features

Reviewing Your Knowledge: Students recall terminology and content by describing and explaining fundamental concepts. Students examine their results and then use evidence as they evaluate their understanding and knowledge. (Bloom's Taxonomy Level I: Knowledge and Comprehension)

Applying Your Knowledge: As instructors, we want our students to be challenged to think and to develop critical thinking skills. Throughout this manual, students are asked to work logically through problems, critique results, and modify hypotheses. To emphasize these skills further, we have developed a section in each laboratory topic called Applying Your Knowledge, in which students are asked to apply their knowledge to new problems and to make connections between topics. The questions encourage students to use their knowledge as they solve problems developed from current research as well as issues in science, medicine, and society. (Bloom's Taxonomy Level II: Application and Analysis; Synthesis and Evaluation)

Excel Tables: All data tables used for recording and analyzing results are available in Excel format for modification and use in the laboratory. These tables are designated in the table title and can be downloaded to laboratory computers for student use at www.masteringbiology.com in the Study Area.

Images and Data: Full-color images and figures are integrated throughout the lab manual. Lab Topic 16 Bioinformatics: Molecular Phylogeny of Plants is supported by images in the text as well as the masteringbiology.com website. Folders found under the Study Area contain images of the plants used in the investigation along with the edited and ready-to-use nucleotide sequences for each species. These can be downloaded to laptops or accessed on the website.

Investigative Extensions and Case Studies: Students and instructors have expressed interest in extending laboratory topics to open-inquiry investigations or simply to pursue additional questions that connect the topic to current research and issues. At the end of most lab topics, we have provided questions to prompt student-designed investigations. For a few, we provide case studies that build on the lab topic and require additional reading and research.

Student Media and Web Resources: Providing media and Web resources can enhance teaching and learning in the laboratory. For students, we have included references to videos that connect to their laboratory activities. These are designated in the text with a media icon. Also, at the end of each lab topic, we have included the section **Student Media: BioFlix, Activities, Investigations, Videos, and Data Tables,** which directs students to the website for **activities** and **investigations** that can be used to prepare for the laboratory or review and practice after the laboratory. These media resources are available at www.masteringbiology.com under the Study Area.

Safety Considerations: Safety concerns are noted in the text by the use of icons for general safety and for biohazards. Note the **Laboratory Safety Guidelines** printed on the inside front cover.

Notes to Students: To assure student success, cautionary reminders and notes of special interest are also highlighted in the text.

Appendixes: Information needed in several laboratory topics is included in the appendixes: scientific writing and communication, instrumentation and techniques, the metric system, using chi-square analysis, and dissection terminology.

Instructional Support

The *Preparation Guide* provides valuable suggestions and essential information for the successful implementation of the laboratory topics.

Preparation Guide: A detailed *Preparation Guide for Investigating Biology* accompanies the laboratory manual. It contains materials lists, suggested vendors, instructions for preparing solutions and constructing materials, schedules for planning advance preparation, and suggestions for organizing materials in the lab. Also, the new edition includes sources for a new, hardier strain of mutant *Drosophila* flies for sepia/aldehyde oxidase developed for Lab Topic 9 Mendelian Genetics II: *Drosophila*. The *Preparation Guide* is essential for successfully preparing and teaching these investigative laboratories. It is available electronically at masteringbiology.com. Instructors can download preparation and ordering lists as needed and customize these for their program.