Preface

Welcome to the fourth edition of *Biology: The Dynamic Science*. The book's title reflects the speed with which our knowledge of biology is growing. Although biologists have made enormous progress in solving the riddles posed by the living world, every discovery raises new questions and provides new opportunities for further research. As in previous editions, we have encapsulated the dynamic nature of biology in the fourth edition by explaining biological concepts—and the data from which they are derived—in the historical context of each discovery and by describing what we know now and what new discoveries will be likely to advance the field in the future.

Building on a strong foundation . . .

The first three editions of this book provided students with the tools they need to learn fundamental biological concepts and processes. More important, the previous editions encouraged students to *think like scientists* by applying the process of science. Our approach encourages students to think about biological questions and hypotheses through clear examples of hypothesis development, observational and experimental tests of hypotheses, and the conclusions that scientists draw from data. The many instructors and students who have used previous editions have generously provided valuable feedback that has allowed us to strengthen the elements that enhance student learning. We have also received comments from expert reviewers. As a result of these inputs, every chapter has been revised and updated with recent studies, including many based on genomic and proteomic analyses. In addition, the chapters in Unit One (Molecules and Cells) have been reorganized. This edition also includes new or modified illustrations and photos, as well as some new features.

The fourth edition of *Biology: The Dynamic Science* represents a fully integrated package of print and media that will appeal to today's students. Although the traditional format of the printed text can stand alone for both instructors and students, MindTap, the most engaging and easily personalized online solution in biology, enables instructors to deliver what they know is best for their students. MindTap offers an online version of the text, as well as before-class and in-class exercises, assignable and gradable homework exercises drawn from the book's content, and other resources and features that allow students to assess their learning as they progress through their study of biology.

Emphasizing the big picture . . .

In this textbook, we have applied our collective experience as teachers, researchers, and writers to create a readable and understandable foundation for students who choose to enroll in more advanced biology courses in the future. Where appropriate, we provide straightforward explanations of fundamental concepts from the evolutionary perspective that bind together all of the biological sciences. Recognizing that students in an introductory biology course face a potentially daunting quantity of ideas and information, we strive to provide an appropriate balance between factual and conceptual material, taking great care to provide clear explanations of how scientists draw conclusions from empirical data. Our approach helps students understand how we achieved our present knowledge. Having watched our students struggle to navigate the many arcane details of college-level introductory biology, we constantly remind ourselves and each other to "include fewer facts, provide better explanations, and maintain the narrative flow," thereby enabling students to see the big picture. Clarity of presentation, thoughtful organization, a logical and seamless flow of topics within chapters, and carefully designed illustrations are key to our approach. With this edition, full integration with MindTap engages students with appealing and useful exercises that encourage them to learn biology by thinking like scientists.

Focusing on research to help students engage the living world as scientists . . .

A primary goal of this book is to sharpen and sustain students' curiosity about biology, rather than dulling it with a mountain of disconnected facts. We can help students develop the mental habits of scientists and a fascination with the living world by conveying our passion for biological research. We want to excite students not only with *what biologists know* about the living world but also with *how they know it* and *what they still need to learn*. In doing so, we can encourage some students to accept the challenge and become biologists themselves, posing and answering important new questions through their own innovative research. For students who pursue other careers, we hope that they will leave their introductory—and perhaps only—biology course armed with intellectual skills that will enable them to evaluate future knowledge with a critical eye.

In this book, we introduce students to a biologist's "ways of learning." Research biologists constantly integrate new observations, hypotheses, questions, experiments, and insights with existing knowledge and ideas. To help students engage the world as biologists do, we must not simply introduce them to the current state of knowledge. We must also foster an appreciation of the historical context within which those ideas developed, and identify the future directions that biological research is likely to take.

To achieve these goals, our explanations are rooted in the research that established the basic facts and principles of biology. Thus, a substantial proportion of each chapter focuses on studies that define the state of biological knowledge today. When describing research, we first identify the hypothesis or question that inspired the work and then relate it to the broader topic under discussion. Our research-oriented theme teaches students, through example, how to ask scientific questions and pose hypotheses, two key elements of the scientific process.

Because advances in science occur against a background of research, we also give students a feeling for how biologists of the past formulated basic knowledge in the field. By fostering an appreciation of such discoveries, given the information and theories available to scientists in their own time, we can help students understand the successes and limitations of what we consider cutting edge today. This historical perspective also encourages students to view biology as a dynamic intellectual enterprise, not just a collection of facts and generalities to be memorized.

We have endeavored to make the science of biology come alive by describing how biologists formulate hypotheses and evaluate them using hard-won data; how data sometimes tell only part of a story; and how the results of studies often end up posing more questions than they answer. Although students might prefer simply to learn the "right" answer to a question, they must be encouraged to embrace "the unknown," those gaps in knowledge that create opportunities for further research. An appreciation of what biologists do *not* yet know will draw more students into the field. And by defining *why* scientists do not understand interesting phenomena, we encourage students to think critically about possible solutions and to follow paths dictated by their own curiosity. We hope that this approach will encourage students to make biology a part of their daily lives by having informal discussions and debates about new scientific discoveries.

Presenting the story line of the research process . . .

In preparing this book, we developed several special features, all of which are included in MindTap, to help students broaden their understanding of the material presented and of the research process itself. A Visual Tour of these features and more begins on page xiv.

- The chapter openers, titled *Why it matters . . .*, are engaging, short vignettes designed to capture students' imaginations and whet their appetites for the topic that the chapter addresses. In many cases, this feature tells the story of how a researcher or researchers arrived at a key insight or how biological research solved a major societal problem, explained a fundamental process, or elucidated a phenomenon. The *Why it matters . . .* feature also provides a brief summary of the contents of the chapter.
- To complement this historical or practical perspective, each chapter closes with a brief essay titled *Unanswered Questions,* prepared by an expert or experts in the field. These essays identify important unresolved issues relating to the chapter topic and describe cutting-edge research that will advance our knowledge in the future.
- Most chapters include a short, boxed essay titled *Molecular Insights* (formerly called *Insights from the Molecular Revolution*), which describes how molecular tools allow scientists to answer questions that they could not have posed even 30 years ago. Most *Molecular Insights* focus on a single study and include sufficient detail for their content to stand alone.
- Many chapters are further supplemented with one or more short, boxed essays called *Focus on Research.* Each essay focuses on one of three different aspects of research. *Focus on Research: Basic Research* essays describe how research has provided understanding of basic biological principles. *Focus on Research: Applied Research* essays describe research designed to solve practical problems in the world, such as those relating to health or the environment. *Focus on Research: Model Organisms* essays introduce model research organisms—such as *Escherichia coli, Drosophila, Arabidopsis, Caenorhabditis,* the mouse, and *Anolis*—and explain why they are used as subjects for in-depth analysis.
- Three types of specially designed *research figures* provide more detailed information about how biologists formulate specific hypotheses and test them by gathering and interpreting data. The research figures are listed on the endpapers at the back of the book. *Experimental Research* figures describe specific studies in which researchers used both experimental and control treatments—either in the laboratory or in the field—to test hypotheses or answer research questions by manipulating the system they studied. *Observational Research* figures describe specific studies in which biologists have tested hypotheses by comparing systems under varying natural circumstances. *Research Method* figures provide examples of important techniques, such as light and electron microscopy, the polymerase chain reaction, making a knockout mouse, DNA microarray analysis, plant cell culture, producing monoclonal antibodies, radiometric dating, and cladistic analysis. Each *Research Method* figure leads a student through the purpose of the technique and protocol and describes how scientists interpret the data it generates.

Integrating effective, high-quality visuals into the narrative . . .

Today's students are accustomed to receiving ideas and information visually, making the illustrations and photographs in a textbook and the fully integrated online resources critically important. From the first edition, our illustration program has provided an exceptionally clear supplement to the narrative in a style that is consistent throughout the book. Graphs

and anatomical drawings are annotated with interpretive explanations that lead students, step by step, through the major points they convey.

Over subsequent editions, we have enhanced the illustration program, focusing on features that reviewers and users of the book identified as the most useful pedagogical tools. For this most recent edition, we focused explicitly on helping students to think like scientists. A revised Figure 1.14 illuminates the intellectual steps that collectively lead researchers to new scientific discoveries. These steps—observation, hypothesis, prediction, experiment, and interpretation—represent the fundamentals of our "think like a scientist" theme in this book.

In revising the text, we reevaluated each illustration and photograph and made appropriate changes to improve their utility as teaching tools. New illustrations for the fourth edition were created in the same style as existing ones. In addition, some illustrations of key biological processes were recast as *Closer Look* figures in which a Summary and a concluding *Think Like a Scientist* question enhance student learning.

Organizing chapters around important concepts . . .

As authors and college teachers, we understand how easily students can get lost within a chapter. When students request advice about how to read a chapter and learn the material in it, we usually suggest that, after reading each section, they pause and quiz themselves on the material they have just encountered. After completing all of the sections in a chapter, they should quiz themselves again, even more rigorously, on the individual sections and, most important, on how the concepts developed in the different sections fit together. Accordingly, we have adopted a structure for each chapter to help students review concepts as they learn them.

- The organization within chapters presents material in digestible sections, building on students' knowledge and understanding as they acquire it. Each major section covers one broad topic. Each subsection, titled with a declarative sentence that summarizes the main idea of its content, explores a narrower range of material.
- Whenever possible, we include the derivation of unfamiliar terms so that students will see connections between words that share etymological roots. Mastery of the technical language of biology will allow students to discuss ideas and processes precisely. At the same time, we have minimized the use of unnecessary jargon.
- *Study Break* questions follow every major section. These questions encourage students to pause at the end of a section and review what they have learned before going on to the next topic within the chapter. Short answers to these questions appear in an appendix.

Encouraging active learning, critical thinking, and self-assessment of learning outcomes . . .

In the third edition we introduced an active learning feature, *Think Like a Scientist,* which is designed to help students think analytically and critically about research presented in the chapter. *Think Like a Scientist* questions appear at the end of *Experimental Research* figures, *Observational Research* figures, *Closer Look* figures, *Molecular Insights* boxes, and *Unanswered Questions.* In this new edition, *Experimental Research* figures and *Observational Research* figures include a new icon that identifies the particular step in the process of science that the *Think Like a Scientist* question addresses: Observe, Hypothesize, Predict, Experiment, or Interpret. (Sample shown.)

This edition also continues the popular *Think Outside the Book* active learning feature. *Think Outside the Book* activities have been designed to encourage students to explore biology directly or through electronic resources, working either individually or collaboratively.

Supplementary materials at the end of each chapter—all of which are fully integrated into MindTap—help students review the material they have learned, assess their understanding, and think analytically as they apply the principles developed in the chapter to novel situations. Many end-of-chapter questions also serve as good starting points for class discussions or out-of-class assignments.

Review Key Concepts provides a summary of important ideas developed in the chapter, referencing specific figures and tables in the chapter. These *Reviews* are no substitute for reading the chapter, but students may use them as a valuable outline of the material, filling in the details on their own.

Test Your Knowledge includes four types of end-of-chapter questions and problems that focus on the chapter's factual content while encouraging students to apply what they have learned: (1) Multiple-choice questions (with answers in an appendix) focus on factual material; (2) *Discuss Concepts* questions involve open-ended issues that emphasize key ideas, the interpretation of data, and practical applications of the material; (3) *Design an Experiment* questions help students hone their critical thinking skills by asking them to test hypotheses that relate to the chapter's main topic; and (4) *Apply Evolutionary Thinking* questions ask students to answer a question in relation to the principles of evolutionary biology.

In this edition, *Test Your Knowledge* questions are organized according to Bloom's taxonomy into three sections: Remember/Understand, Apply/Analyze, and Evaluate/Create. This structure allows students to review the material in a sequence that moves from the basic knowledge of factual material to more challenging and sophisticated applications of that knowledge to novel situations.

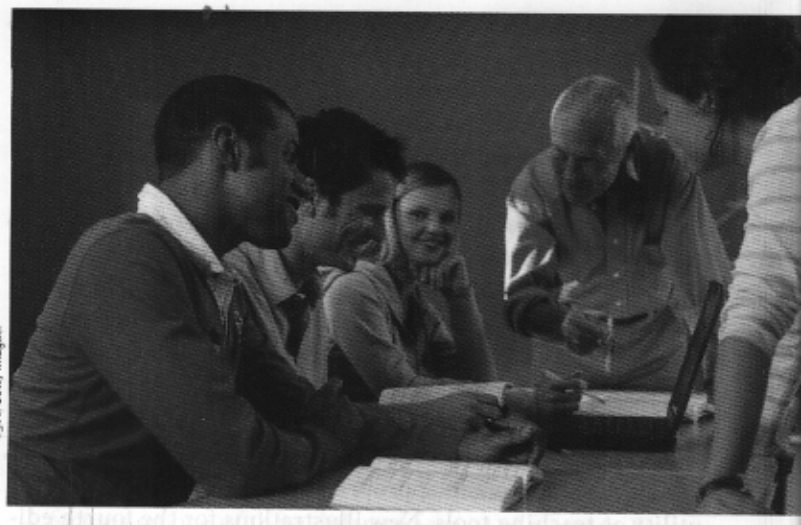
Interpret the Data questions, highlighted in a distinctive format, help students develop analytical and quantitative skills by asking them to interpret graphical or tabular results of experimental or observational research studies for which the hypotheses and methods of analysis are presented.

Effectively introducing digital solutions into your classroom—online or in class—is now easier than ever . . .

The fourth edition of *Biology: The Dynamic Science* represents a fully integrated package of print and media, providing comprehensive learning tools and flexible delivery options. In preparing this edition we conducted extensive research to determine how instructors prefer to present online learning opportunities. The result of this research is a new MindTap course organized around the instructor's preferred workflow. Instructors can now select just the content they want to assign, chosen from a comprehensive set of learning materials provided with the course for each chapter. Many types of learning activities are assignable and offer students immediate feedback and automated instructor assessment.

Research also indicates that online content is most effective when it enhances conceptual understanding through the use of relevant applications. In this edition, we have developed three new assessable, online learning activities that align with important book features and provide students the opportunity to explore and practice biology the way scientists practice biology:

- The *Interpret the Data* feature at the end of every chapter is enhanced by an additional online exercise to further develop student quantitative analysis and mathematical reasoning skills.



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- Many *Experimental Research* and *Observational Research* figures now include an additional activity to help students engage with the scientific process.
- The end-of-chapter *Design an Experiment* feature is presented online as a guided learning activity that takes the student through the process of designing an experiment.

The *Instructor Resource Center* provides everything you need for your course in one place. This collection of lecture and class tools is available online for instructors only via www.cengage.com/login. There you can access and download PowerPoint presentations, images, the *Instructor's Manual,* videos, and more.

We hope you agree that we have developed a clear, fresh, and well-integrated introduction to biology as it is understood by researchers today. Just as important, we hope that our efforts will excite students about the research process and the biological discoveries it generates.

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