Preface

Welcome to the third 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 the prior two editions, we have encapsulated the dynamic nature of biology in the third 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 two editions of this book provided students with the tools they need to learn fundamental biological concepts, processes, and facts. More important, they enabled students to think like scientists. 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 their data. The many instructors and students who have used the book have generously provided valuable feedback about the elements that enhanced student learning. We have also received comments from expert reviewers. As a result of these inputs, every chapter has been revised and updated, and some units have been reorganized. In addition, the third edition includes new or modified illustrations and photos as well as some new features.

Emphasizing the big picture . . .

In this textbook, we have applied our collective experience as teachers, researchers, and writers to create a readable and understandable introduction that provides a foundation for students who choose to enroll in more advanced biology courses in the future. We provide straightforward explanations of fundamental concepts presented, where appropriate, from the evolutionary perspective that binds the biological sciences together. Recognizing that students in an introductory biology course face a potentially daunting amount of material, we strive to provide an appropriate balance between facts and concepts, taking great care to provide clear explanations while maintaining the narrative flow. In this way students not only see the big picture, but they 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.

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 discoveries with a critical eye.

In this book, we introduce students to a biologist's "ways of knowing." 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 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 xiii.

- The chapter openers, entitled *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 . . .* 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 entitled *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.
- Each chapter includes a short, boxed essay entitled *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 *Insights* focus on a single study and include sufficient detail for its content to stand alone.
- Many chapters are further supplemented with one or more short, boxed essays involving three different aspects of research. *Focus on Basic Research* essays describe how research has provided understanding of basic biological principles. *Focus on Applied Research* essays describe research designed to solve practical problems in the world, such as those relating to health or the environment. *Focus on Model Research 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 and test specific hypotheses 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 the scientific method, cloning a gene, 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 important. Our illustration program provides an exceptionally clear supplement to the narrative in a style that is consistent throughout the book. Graphs and anatomical drawings are annotated with interpretative explanations that lead students, step by step, through the major points they convey.

For the second edition, we undertook a rigorous review of all the art in the text. The publishing team identified the key elements of effective illustrations. In focus groups and surveys, instructors helped us identify the "Key Visual Learning Figures" covering concepts or processes that demand premier visual learning support. Each of these figures was critiqued by our Art Advisory Board to ensure its usability and accuracy. For the third edition, we again evaluated each illustration and photograph carefully and made appropriate changes to improve their use as teaching tools. New illustrations for the edition were created in the same style as existing ones.

For the third edition, important figures were developed as *Closer Look* figures; a Summary and a concluding *Think Like a Scientist* question are designed to enhance student learning. Many *Closer Look* figures involve key biological processes, such as meiosis, transcription, muscle contraction, the cohesion-tension mechanism of water transport in plants, ecological interactions between predators and prey, and the haplodiploidy genetic system in social insects.

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 . . .

The third edition of *Biology: The Dynamic Science* includes a new 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 ends of *Experimental Research* figures, *Observational Research* figures, *Closer Look* figures, *Insights from the Molecular Revolution* boxes, and *Unanswered Questions.*

The new edition also includes *Think Outside the Book,* an active learning feature introduced in the second edition. *Think Outside the Book* activities have been designed to encourage students to explore biology directly or through electronic resources. Students may engage in these activities either individually or in small groups.

Supplementary materials at the end of each chapter 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.
- *Understand & Apply* includes five 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) *Test Your Knowledge* is a set of 10 questions (with answers in an appendix) that focus on factual material; (2) *Discuss the Concepts* involves open-ended questions 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; (4) *Interpret the Data* questions help students develop analytical and quantitative skills by asking them to interpret graphical or tabular results of experimental or observational research experiments for which the hypotheses and methods of analysis are presented; and (5) *Apply Evolutionary Thinking* asks students to answer a question in relation to the principles of evolutionary biology.

Helping students master key concepts throughout the course . . .

Teachers know that student effort is an important determinant of student success. Unfortunately, most teachers lack the time to develop novel learning tools for every concept—or even every chapter—in an introductory biology textbook. To help address this problem, we are pleased to offer **Aplia for Biology,** an automatically graded homework management system tailored to this edition. For students, Aplia provides a structure within which they can expand their efforts, master key concepts throughout the course, and increase their success. For faculty, Aplia can help transform teaching and raise productivity by requiring more—and more consistent—effort from students without increasing faculty workloads substantially. By providing students with continuous exposure to key concepts and their applications throughout the course, Aplia allows faculty to do what they do best—respond to questions, lead discussions, and challenge the students.

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.

New to This Edition

The enhancements we have made in the third edition of *Biology: The Dynamic Science* reflect our commitment to provide a text that introduces students to new developments in biology while fostering active learning and critical thinking. As a part of this effort, we have added *Closer Look* figures that integrate a major concept into a highlighted visual presentation. The key concept is stated briefly at the top, shown in detail through one or more illustrations, and summarized at the bottom. A *Think Like a Scientist* question invites students to apply the figure concept(s) to a related problem or issue. We have also incorporated *Think Like a Scientist* questions into *Insights from the Molecular Revolution* and *Unanswered Questions*, as well as into *Experimental Research* and *Observational Research* figures.

We have also made important changes in coverage to follow recent scientific advances. A new Chapter 19, Genomes and Proteomes, introduces methods of genomics and proteomics along with examples of new discoveries and insights. In addition, we now devote two chapters to plant diversity, discussing seedless plants in Chapter 28 and seed plants in Chapter 29. Finally, we've consolidated our treatment of animal behavior into a single Chapter 56 (Animal Behavior), which integrates various approaches to this subfield of biology. Beyond these major organizational changes, we have made numerous improvements to update and clarify scientific information and to engage students as interested readers and active learners, as well as responsive scientific thinkers. The following sections highlight some of the new content and organizational changes in this edition.

Unit One: Molecules and Cells

To make molecular and cellular processes easier to grasp, this unit incorporates explanatory material into many more illustrations. For example, in Chapter 3 (Biological Molecules: The Carbon Compounds of Life), Table 3.1 now presents more information on the roles of functional groups of organic molecules and a new Figure 3.3 clarifies the concept of stereoisomers. In Chapter 5 (The Cell: An Overview), we have combined the diagrams of animal and plant cells in Figure 5.9 and labeled functions of the organelles. In Chapter 8 (Harvesting Chemical Energy: Cellular Respiration), a new overview diagram of glycolysis (Figure 8.7) helps students understand basic concepts. Chapter 10 (Cell Division and Mitosis) features a new discussion and illustration of the tight pairing of chromatids (sister chromatid cohesion) during mitosis.

New references to molecular aspects of evolution have been integrated into Unit One chapters to emphasize evolution as the theme unifying the subfields of the biological sciences. For example, in Chapter 5 (The Cell: An Overview), the discussion of the mitochondrial matrix now highlights how equivalent structures in bacteria led scientists to propose and develop the endosymbiotic theory. In Chapter 6 (Membranes and Transport), we point out that the close similarity of bilayer membranes in all cells—prokaryotic and eukaryotic—is evidence that the basic structure of membranes evolved during the earliest stages of life on Earth, and has been conserved ever since. In Chapter 9 (Photosynthesis), a new section, *Evolution of Photosynthesis and Cellular Respiration*, summarizes the evolutionary development of these processes.

Unit Two: Genetics

Chapter 11 (Meiosis: The Cellular Basis of Sexual Reproduction) includes fuller descriptions of homologous chromosomes and sex chromosomes. Extensive revision and expansion of Chapter 16 (Regulation of Gene Expression) provides more thorough coverage of gene regulation and the operon model. We now introduce the role of DNA-binding proteins in prokaryotic as well as eukaryotic gene regulation and include more detail on the activation of regulatory molecules. We have also added detail on combinatorial gene regulation, along with a figure showing a specific example, and have added new information and an illustration of how growth factors and growth-inhibiting factors affect cell division. Chapter 17 (Bacterial and Viral Genetics) includes new information on how horizontal gene transfer contributes to genome evolution in prokaryotes, and evidence of its possible contribution to eukaryotic genome evolution.

A new Chapter 19 (Genomes and Proteomes) focuses on the methods of genomics and the information it generates. This chapter describes how genome sequences are determined and annotated, how genes in genomes are identified and characterized, and how studies have generated new information on the evolution of genes and of genomes. It also includes examples of how genomics has become a source of new discoveries in many fields, including human physiology and evolutionary biology.

Unit Three: Evolutionary Biology

In Chapter 21 (Microevolution: Genetic Changes within Populations), *Observational Research* Figure 21.11 now shows more clearly how opposing forces of directional selection produce stabilizing selection. Plant speciation by alloploidy and polyploidy is shown in parallel illustrations in one figure (22.16), allowing easy comparison. In Chapter 23 (Paleobiology and Macroevolution), Figure 23.15 clarifies our understanding of the rise and fall of plant lineages through evolutionary time. Chapter 24 (Systematics and Phylogenetics: Revealing the Tree of Life) includes a new example of how systematists construct phylogenetic trees

with genetic distance data and includes a clarified discussion of statistical methods used to construct phylogenetic trees. Reworked phylogenetic trees throughout Chapter 24 are now fully consistent in presentation.

Unit Four: Biodiversity

In Chapter 26 (Prokaryotes: Bacteria and Archaea), a new *Insights from the Molecular Revolution* describes how changes in gene expression in the bacterium that causes gingivitis help govern its transition from a free-living state to a biofilm. A revised and expanded section discusses the five subgroups of proteobacteria. In Chapter 27 (Protists), we've added the nucleariids to the Opisthokont group, along with evidence that they may be more closely related to fungi than to animals.

Plant diversity is now covered in two chapters. Chapter 28 (Seedless Plants) describes trends in land plant evolution and the characteristics of bryophytes and seedless vascular plants, and Chapter 29 (Seed Plants) focuses on adaptations and distinguishing features of gymnosperms and flowering plants. Chapter 28 also includes a new *Unanswered Questions* essay, and Chapter 29 presents a new *Insights from the Molecular Revolution* feature on plant genome evolution. Chapter 30 (Fungi) presents an updated discussion of the evolution of multicellular animals and fungi from different opisthokont ancestors. Changes to Chapter 31 (Animal Phylogeny, Acoelomates, and Protostomes) include color-coding of anatomical illustrations of invertebrates to distinguish structures arising from endoderm, mesoderm, and ectoderm, and a new Table 31.1 providing a phylogenetic overview of the phyla presented in the chapter. In Chapter 32 (Deuterostomes: Vertebrates and Their Closest Relatives), a new *Insights from the Molecular Revolution* feature describes a study of the evolutionary gains and losses of genes that code for olfactory receptor proteins in various clades of mammals. Figure 32.38, which shows timelines for the species of hominins, has been updated with recently discovered fossils. The discussion of human evolution includes recent genomic studies of the relationship between Neanderthals and modern humans.

Unit Five: Plant Structure and Function

Chapter 33 (The Plant Body) features clearer illustrations of plant growth. Chapter 34 (Transport in Plants) has more focused discussions and illustrations of water movements in roots and the physiology of stomatal function. A new *Unanswered Questions* explores research in plant metabolomics. Chapter 36 (Reproduction and Development in Flowering Plants) includes refined diagrams of floral whorls and self-incompatibility, an updated *Insights from the Molecular Revolution* on trichome development, and an updated *Experimental Research* figure on studies of floral organ identity genes. Chapter 37 (Plant Signals and Responses to the Environment) begins with a new *Why It Matters* essay presenting the diverse adaptations of creosote bush *(Larrea tridentata)* to environmental challenges such as extended drought. The chapter also has been reorganized, with the discussion of signal transduction pathways and second messenger systems now included in the introduction to plant hormones. New art illustrates current thinking on different signal transduction mechanisms in plant cells.

Unit Six: Animal Structure and Function

In Chapter 43 (Muscles, Bones, and Body Movements), a new *Insights from the Molecular Revolution* presents experiments on exercise training in racehorses. We have updated and clarified the discussion of immunity in Chapter 45 (Defenses against Disease) and added new material on how microbial pathogens are detected and how pathogens may sometimes escape recognition by the immune system. In Chapter 47 (Animal Nutrition), we have added detail on absorption in the small intestine. Chapter 48 (Regulating the Internal Environment) has expanded coverage of mammalian kidney function and the role of countercurrent heat exchanges in maintaining body temperature. In Chapter 50 (Animal Development), we have revised and expanded Section 50.5, The Cellular Basis of Development, including new information on apoptosis during development and on molecular mechanisms of induction.

Unit Seven: Ecology and Behavior

In Chapter 51 (Ecology and the Biosphere), improved illustrations clarify the effects of latitudinal and seasonal variations in incoming solar radiation. In Chapter 52 (Population Ecology), we have updated Figures 52.22 and 52.23 on human population growth. In Chapter 53 (Population Interactions and Community Ecology), we have improved Figure 53.22 showing the food web. We have also added informative labels to Figure 53.25, which shows the effects of storms on corals. Chapter 55 (Biodiversity and Conservation Biology) features a new Figure 55.16 illustrating the species–area relationship. A unified Chapter 56 (Animal Behavior) concludes the text, integrating the discussions of genetic and experiential bases of animal behavior, the neurophysiological and endocrinological control of specific behaviors, and the ecology and evolution of several broad categories of animal behavior.