PREFACE

In biology, three topics are so fundamental they should permeate every aspect of an introductory botany textbook: *evolution by natural selection, analysis of botanical phenomena,* and *diversity of organisms and their components.*

Emphasis on Evolution by Natural Selection

Evolution by natural selection is the basis of botany and all other fields of biology. It is possible, without understanding natural selection, to memorize botanical terms, to learn enzyme mechanisms and metabolic pathways, to solve problems in genetics, and so on. But without knowledge of evolution by natural selection, it is not possible to fully understand biological structures or processes. As instructors, we teach that the discoveries by Darwin and Wallace revolutionized biology, but it can be difficult to explain to students how powerful the concept of natural selection is. In this book, I introduce natural selection in general, nontechnical terms that students new to biology are able to grasp. I believe students must become familiar with organisms, anatomy, physiology, and genetics before they can truly appreciate the subtleties of evolution, natural selection, selective advantage, and competition. Beginning with Chapter 1, selective advantage and fitness are referred to or discussed in every chapter and on almost every page. Natural selection is covered in detail in Chapter 17, after students have become more familiar with plants and botanical phenomena.

Analysis of Botanical Phenomena and Diversity

Diversity includes not only the kingdoms and divisions of organisms, but also the alternative adaptations, that is, the diversity of ways plants can be adapted to their environments. There are many types of stems, leaves, and flowers; many types of respiration, storage molecules, and methods of transporting material; many types of pollination, rewards for pollinators, and types of seeds and fruits. Instructors can guide students through an analysis of biological phenomena by emphasizing the diversity of microhabitats and microclimates; the numerous pests and pathogens; the many types of stresses, scarcities, and excesses that plants must face. There are several types of stem and leaf structures. Some are selectively advantageous under certain conditions; others are adaptive under different conditions. Many types of pollination have evolved, but each can be analyzed in terms of the selective advantage it offers under particular conditions.

This method of analyzing diversity of structures and metabolisms on the basis of natural selection encourages students to participate in biological inquiry. It is so easy to ask, "What is the selective advantage of this process compared to that process?" that students will soon realize that not everything in biology is known and understood. Students themselves can think about such questions, rather than leaving them for unknown scientists to answer. Students can create their own hypotheses—their own potential explanations—using natural selection as an analytical tool. Simple observations or thought experiments can often indicate whether hypotheses might be feasible and plausible.

Organization

The topics and chapters are organized in a sequence I find to be the easiest to follow, beginning with the most familiar (plant structure) and proceeding to the less familiar (metabolism) then finishing with those topics that are probably least familiar to most beginning students—genetics, evolution (in detail), the diversity of organisms, and ecology. Three initial chapters—chemistry, cell structure, and cell division—are not familiar but are so basic they have been placed early in the book. Because this order may not be preferred by all instructors, sections have been written to be self-contained so they can be taken up in various orders. In courses that emphasize metabolism, the sequence could be Chapters 1, 2, 3, 10–15. Courses emphasizing plant diversity could follow a sequence of Chapters 1, 2, (16, 17), 18–25.

Gene action appears in Chapter 15 of the growth and development section, whereas gene replication is located in Chapter 16 in the genetics section. Although both topics are based on the DNA molecule, it does not seem necessary to cover DNA replication and Mendelian genetics prior to teaching about mRNA, protein synthesis, and gene regulation. These topics, along with the techniques of recombinant DNA analysis, are covered in considerable detail.

New Features of the Fourth Edition

This fourth edition differs from earlier editions in the following ways:

- Diversity and systematics chapters are organized on a cladistic basis
- Added emphasis is given to plant diversity in early chapters on structure and metabolism
- More examples of evolutionary change are included
- A new type of boxed material, **Alternatives**, is present. Within each chapter, various topics have been updated or revised to be more easily understood.

Techniques for sequencing and analyzing DNA and RNA continue to advance rapidly, providing a wealth of data that are enabling us to more fully understand the evolution of genes, physiological processes, anatomical structures, taxa, and interactions between organisms. Virtually all systematics and evolutionary studies are based on phylogenetic analyses, and their results are presented in cladograms. Chapter 18, Classification and Systematics, has been completely rewritten to more fully explain concepts of cladistics and to teach students how to read and interpret cladograms. Similarly, the presentation of organisms in the diversity chapters (19–25) has been revised extensively to include cladograms showing evolutionary relationships and to be consistent with current theories of evolutionary relationships.

Phylogenetic relationships among protistans are now so well-understood that I decided to give more emphasis to organisms that are closely related to true plants (embryophytes) and their algal forerunners. Chapters on algae, bryophytes, vascular cryptogams, and seed plants have been moved forward; chapters on prokaryotes and fungi have been moved to the end of the diversity section. Consequently, the chapter on classification and systematics is now followed immediately by chapters on algae (19) and embryophytes (20-23). With this new placement, I revised the discussions of algae and bryophytes to use them as a means of developing the ideas and vocabulary of cladistics the students learned in the preceding chapter.

Early chapters on structure and metabolism have been revised to provide more examples of plant diversity and evolutionary change. Plant biology is the biology of all plants, not just the most familiar flowering plants of north temperate regions; any extant taxon is as closely related to the first true plants as any other. Mosses and ferns may have fewer apomorphies than flowering plants, but they are not "lower plants." Students certainly need to know about photosynthesis, but they should also be aware that some plants are completely heterotrophic. Water absorption by roots is a central topic in introductory botany, but storing and conserving water are critical features for desert plants—and the world has many deserts and many desert-adapted plants.

I believe students understand ordinary plant biology more fully if they are given examples of extra-ordinary types of biology. This was the reason for adding the "**Plants Do Things Differently**" boxes in the third edition; they present contrasts between plant biology and animal (especially human) biology. In this fourth edition, I have created a new set of "**Alternatives**" boxes with the objective of discussing differences that occur among plants themselves. I want to show students that the typical plant biology taught to freshman and sophomores is not the only type. For example, Chapter 3 presents typical plant cell biology, and its Alternatives box gives examples of cells that function with multiple nuclei, no nuclei or while dead; Chapter 5 deals with the stems and tissues of a typical plant and its Alternatives box points out that hornworts and many liverworts never have any of the organs or tissues just described as being so functional. Other Alternatives boxes discuss bacterial photosynthesis (not only as an alternative to the Z-scheme of chloroplasts, but also as an alternative to using intelligent design to explain the origin of the Z-scheme); heterotrophic, non-photosynthetic plants (discusses how plants evolve when natural selection no longer favors leaves); the genetics of haploid plants (bryophytes, with very simple Punnett squares); and so on. This material was placed in boxes to make it more reader-friendly.

Features of This Edition

The following features are used throughout Botany to help students learn.

Part Openers Each of the book's four parts is introduced by a brief summary of all the chapters in that part. The opener ties together the main themes and shows how botany is a unified science, not just a body of facts to memorize.

Concepts Each chapter opens with a section on concepts that will set the stage for the main topics and themes covered in the chapter. It provides an overview and outline of what is to follow.

Alternatives Boxes The objective of Alternatives boxes is to show students they should think expansively. While the text describes the most common, typical aspects of plant biology, there are alternative types that are more advantageous in certain conditions.

Chapter 3 Unusual cells
Chapter 4 Rates of Growth
Chapter 5 Simple Plants
Chapter 6 Photosynthesis Without Leaves
Chapter 7 Photosynthesis in Bacteria and Cyanobacteria
Chapter 11 Respiration in Prokaryotes
Chapter 11 Heterotrophic Plants
Chapter 12 Desert Plant Biology
Chapter 14 Simple Bodies and Simple Development in Algae
Chapter 16 Genetics of Haploid Plants

Plants Do Things Differently Boxes These boxes compare plant biology with human biology. All of us—students, instructors, and lay people—are familiar with how our own bodies work. We understand our blood circulation, we are aware that our skeleton can grow despite being strong enough to support our weight, and we know that good nutrition requires a balanced diet of carbohydrates, fats, proteins, vitamins, and minerals. The same phenomena in plants—circulation, support and nutrition—can appear to be completely different from the processes occurring within our bodies: rather than circulate, water moves one way in xylem, and the same is true of sugar transport in phloem. Plant nutrition mostly involves having enough dirt and water, not proteins and vitamins. In many cases, as students study a botany textbook, they might assume they are misunderstanding what they are reading about plants—plant biology just seems too exotic, too different from the students' own metabolism. The new boxes reassure students that they are understanding their reading correctly—plants really are doing things very differently from the way we do them—and the boxes go on to show students that they should not expect plants, and humans to carry out these processes in the same ways. But the boxes also explain that the plant-type of biology is functional and adaptive for plants whereas our animal type of biology would not be. As an example, Calcium: Strong Bones, Strong Teeth, But Not Strong Plants (Plants and People, Chapter 3) helps students understand the plant support/skeletal system of lignified cell walls by comparing them with the biology of an animal system of calcium-strengthened bones.

Chapter 2 Vitamins: Plants and Human Health
Chapter 3 Calcium: Strong Bones, Strong Teeth, But Not Strong Plants
Chapter 5 Plants and People Grow Differently
Chapter 5 Organs: Replace Them or Reuse Them?
Chapter 7 Plants and People and Having a Weight Problem
Chapter 8 Having Multiple Bodies in One Lifetime
Chapter 11 Plants, Babies, and Heat
Chapter 13 Plants Eat Dirt; Animals Eat Protoplasm

Plants and People Boxes These boxes discuss ways in which plants and people influence each other. Some plants influence people by producing poisonous or irritating compounds; others produce food, medicine, and beauty. In the other direction, human activities influence plants either directly by habitat destruction and the farming of "wastelands" or by producing acid rain and global climate change. Less obviously, plants have affected the way we humans think by being the organisms in which we discovered cells, mineral nutrition, genes, genetics, artificial selection, and so on.

Chapter 1 Plants and People, Including Students
Chapter 1 Life, Death, and the Exploration of the Solar System

Chapter 2 Toxic Compounds
Chapter 4 Controlled Growth Versus Cancerous Growth
Chapter 6 Leaves, Food, and Death
Chapter 8 Dendrochronology—Tree Ring Analysis
Chapter 9 Flowers, Fruits, Seeds, and Civilization
Chapter 10 Photosynthesis, Global Warming, and Global Climate Change
Chapter 11 Fungal Respiration—A Prehistoric Industrial Revolution
Chapter 12 Farming "Wastelands"
Chapter 13 Acid Rain
Chapter 13 From Fertility Gods to Fertilizers
Chapter 15 Genetic Engineering and Evolution
Chapter 17 Zoos, Botanical Gardens, and Genetic Drift
Chapter 18 Development of Concepts of Evolution and Classification
Chapter 18 Identifying Unknown Plants
Chapter 23 Maintaining Genetic Diversity
Chapter 26 Niches in the Jet Age

Botany and Beyond Botany and Beyond boxes elaborate on subjects that, while not essential to the study of botany, help make the material more relevant and accessible. Some of the topics include the structure of wood in three dimensions, resin casting—a new method for studying cell shapes—and a key to identifying unknown plants.

Chapter 3 The Metric System
Chapter 4 Chloroplast Division During Leaf Growth
Chapter 5 Resin-casting
Chapter 6 Leaf Structure, Layer by Layer
Chapter 8 Wood in Three Dimensions
Chapter 12 Water and Ecology
Chapter 16 Botanical Philosophy and Popular Culture
Chapter 18 Cacti as Examples of Evolutionary Diversity
Chapter 21 Molecular Studies of the Evolution of Early Land Plants
Chapter 21 Form Genera
Chapter 25 The "Misclassification" of the Blue-Green Algae
Chapter 27 Measuring Ancient Continental Positions and Climates

Illustrations The botanical world is full of color, and so is this text. Figure illustrations have been chosen to illuminate points made in the text and to show many of the plants under discussion. Many of the drawings have been redone and are both beautiful and botanically accurate. Photographs have been added where our adopters or reviewers have indicated a need for greater variety or multiple views. For this edition, many new photographs have been added to provide superior visual aids. Extensive labels have been added to many photographs to clarify the features or structures shown. Many of the micrographs are introduced with either diagrams or low-magnification micrographs to help the reader understand the orientation of the tissues in the high-magnification illustration. Selected light and electron micrographs are accompanied by interpretive line drawings to make the photographs more understandable to students.

Additional Features

Summary The summary at each end of the chapter consists of numbered points that succinctly list the major topics and concepts discussed.

Important Terms This feature gives a list of terms that should be understood after completing study of the chapter. Students can now review these terms online at BotanyLinks.

Review Questions The study questions at the end of each chapter have been designed to act as a study guide, to lead students to the most important points, and to focus students' efforts on mastering the most significant concepts. "Fill-in-the-blank" questions are sentences taken verbatim from the text. The objective is for students to go back into the chapter and find the sentence: The words that correspond to the blanks are key words involving a critical concept they should pay attention to.

Other questions are long, with multiple parts designed to take the students through a complex process step by step. These questions have many hints to let the students know where there

are concepts that are easily misunderstood or whose importance is easily overlooked. Many of these questions draw on the students' knowledge of their own bodies.

Glossary A comprehensive glossary defines major botanical and general biological terms. Each definition is keyed to the chapter where the principal discussion occurs.

Web Exercises Included at the end of most chapters, original Web-integrated activities invites students to explore topics in greater depth on the Web, while encouraging the use of their critical thinking skills. Jones and Bartlett's extensive botany home page at **http://biology.jbpub.com/botany** provides the links to help them in their research along with brief introductions to place the links in context. Students can hand-in or email answers to their instructor at the instructor's discretion. Jones and Bartlett monitors the links regularly to ensure that there will always be a working and an appropriate site.

Ancillaries

http://biology.jbpub.com/botany In addition to the Web Exercises, the Web site developed exclusively for an *Introduction to Botany* contains a variety of resources to assist in the study of Botany. The **On-Line Glossary** and the **Animated Flashcards** provide students with help for definitions of important botany terms. The flashcards correspond to the Important Terms found at the end of most chapters of the text. BotanyLinks point to Web sites that have relevance to a particular topic in each chapter. **Botany and Beyond** links go to sites that elaborate on topics not vital to understanding botany but are interesting and noteworthy. Information found here will deepen your understanding of botany by providing details on subjects such as leaf structure, acid rain, and classifying unknown plants. **Plants and People** links go to sites with information on human and plant biology comparisons. Exploring the differences between human and plant biology will give you a firmer grasp of plant structure and function. **Lecture outlines** review chapter material point by point. Finally, a **Directory of Organizations** lists associations relevant to botany.

Instructor's ToolKit CD-ROM

The Instructor's ToolKit CD-ROM, compatible with Windows and Macintosh platforms, provides adopters with the following traditional ancillaries.

- The *PowerPoint Image Bank* provides the illustrations, photograph, and tables (to which Jones and Bartlett Publishers holds the copyright or has permission to reprint digitally) inserted into PowerPoint slides. With the Microsoft PowerPoint program, you can quickly and easily copy individual image slides into your existing lecture slides. If you do not own a copy of Microsoft PowerPoint or a compatible software program, a Microsoft PowerPoint Viewer is included on the CD-ROM.
- The *Instructor's Manual* contains key chapter outlines, lecture suggestions, and laboratory exercises. It also has a wealth of supplemental information that can be included in lectures to provide extra motivation for students.
- A *Test Bank* of multiple-choice, true/false, matching, and short essay questions.
- *Unlabeled Art* consists of approximately 39 illustrations. These can be used as part of a labeling exercise in an exam or can be photocopied and given to students for taking notes. Instructors can add their own labels to customize them to their course.
- Solutions to Review Questions. The files for *Solutions to Review Questions* contain answers to all of the end-of-chapter review questions inthe text.

A Final Word, Just To Students

Plants are of vital importance to all of us in everyday life, providing not only food and oxygen, of course, but also lumber, medicines, fibers, and even protection against high-energy radiation from space. But plants are important to biologists in other, more subtle, interesting ways: Most of the early discoveries of cell biology, including the discovery of cells themselves, were made in studies of plants, and many enzyme systems were first isolated from plants and were later confirmed to be present in animals as well. Even at present, when thousands of scientists analyze human metabolism and structure in ever greater detail, studies of plant metabolism and structure are essential as a means of truly understanding human biology. For example, when we are cold, we generate heat by shivering—a rapid contraction and relaxation of muscle cells that

converts mechanical energy to heat energy. But certain plants have an unusual type of respiration (thermogenic respiration) that generates heat more directly and efficiently.

Would such a metabolism be beneficial to us? What kinds of changes would have to occur for humans to have thermogenic respiration? Similarly, all humans use only 20 types of amino acids in building proteins, but some plants have hundreds of types of amino acids: If we ate such plants, our bodies would try to build our new proteins with those exotic amino acids and we would die. But the plants can somehow tell the difference and are not killed by those amino acids in their cells. How do the plants distinguish between safe and poisonous amino acids? What does our inability to distinguish between them tell us about our protein-synthesizing metabolism—one of our most fundamental metabolisms? By understanding plant biology we can more completely and fully understand and appreciate the details of human biology.

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