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Botany

Seventh Edition

An Introduction to Plant Biology

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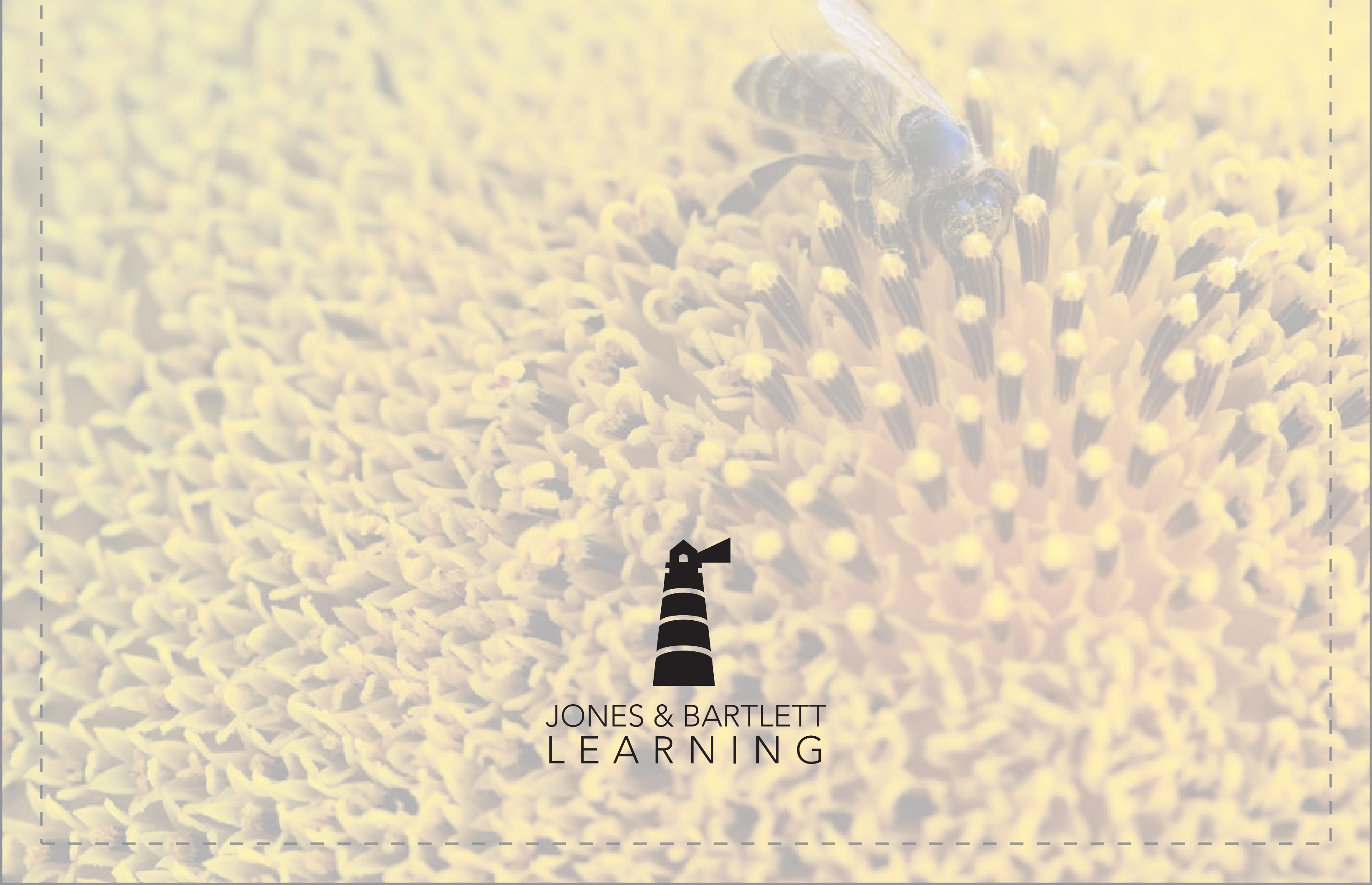
University of Texas at Austin



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PREFACE


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I have read a description of textbooks as "those formidable fossilizers of misconceptions." As a textbook author, this caught my attention. I hope it is not true of me or this textbook, but it is an opinion worth considering.

Do textbooks fossilize misconceptions? Well, they come close to engraving certain ideas and theories in stone. I have always tried to ensure that the ideas I put into this textbook—through its many editions—are correct and will stand the test of time. One goal of authors, editors, publishers, and teachers is that a textbook should be as up-to-date as possible. This is risky: The newest observations, experimental results, and interpretations have not been widely repeated, verified, analyzed, or vetted to determine whether they are something new and important or are instead merely misinterpretations, errors, or exceptional cases that are not representative of most organisms. I would say that it is the duty of a textbook author to specifically avoid including the latest trendy, attention-grabbing tidbits that are in the spotlight at the moment the book is being written. It is our responsibility to give students solid, trustworthy, and reliable information. That means textbooks might always be a bit out-of-date, but the role of a textbook and its author is to give a student a solid foundation.

Another goal of a textbook and its author should be to emphasize how much we do not yet know. If a textbook were to give the impression that its contents were the complete and absolute truth, that would indeed be formidable and discouraging. A textbook is a means by which an author speaks to the newest members of a discipline and shares with them the most important concepts and insights of that discipline, welcoming the readers into the discipline. It is important to convey to students that there is still much work left to be done. Research into plant biology is an ongoing process, and students need not fear that everything will have been done, everything will have been discovered, by the time they graduate.


In the moist conditions of Victoria, British Columbia, this lichen grows rapidly enough to cover mosses and to exceed the formation and shedding of tree bark.

Of course, an author cannot tell readers everything that is currently known; it is necessary to choose core concepts and to make generalizations. It is here where an author might cause a textbook to fossilize misconceptions. We present the most common, most representative cases, but other interesting and valid points are left out. During my years in college, I was bewildered to read certain "facts" that I knew first-hand were not true. For example, I grew up in the Great Basin Desert of eastern Washington State, and I knew that many outcrops of ancient lava were covered in mosses that lived in harsh sun, extreme drought and heat, with bitterly cold winters. But my textbook told me that mosses live in moist forests. The author had given mosses a description that was accurate for most but not all of them. But was that an unforgivable error by the textbook and its author? No. It allowed me to realize that I could take charge of my own education: the book gave me the basics and I could personally fill in some details and nuances. I hope that in this *Seventh Edition*—just like in all previous editions—I have emphasized diversity enough that students will realize they should keep an open mind and expect that variations often exist.

But just in case, let's clear up some botanical misconceptions and break some old fossils:

1. Mosses and ferns live in wet areas . . . and also in dry ones.
2. Lichens grow slowly . . . but in moist areas they grow rapidly, overwhelming mosses and liverworts.
3. Deserts are hot . . . and cold or in between.
4. Wood and bark are dead . . . but only after they die. They are alive while growing, differentiating, conducting. Living cells persist for years throughout sapwood and inner bark.
5. Mosses and ferns reproduce by spores . . . . as do all plants; there are no exceptions. The point is that mosses and ferns reproduce without seeds.
6. The tropics are warm, humid habitats in which life is easy . . . but plants adapted to tundra or deserts would find them stressful.
7. Textbooks are formidable fossilizers of misconceptions. I will let you decide.

—James D. Mauseth

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THE STUDENT EXPERIENCE

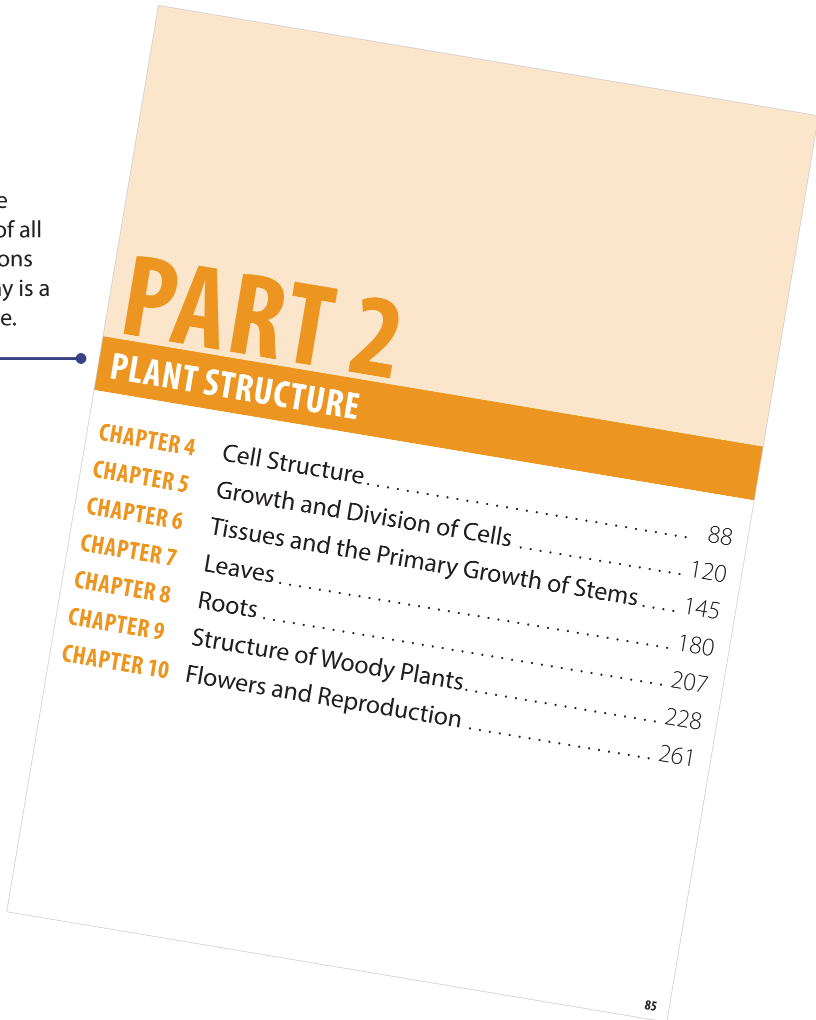
What's New?

We have made a few key improvements to the text as part of the *Seventh Edition*. As always, all of the content was thoroughly reviewed and updated as needed to reflect changes in the field of botany. Structurally, the major change was moving the chapter "Ethnobotany: Plants and People" forward to become Chapter 3, and so we have created a new Part 1 called "Welcome to Botany." The boxed features have always been popular with both students and instructors, so we have added a new type of box, *Thinking About Thinking*. These boxes are designed to emphasize critical-thinking skills such as evidence-based decision making, clean sheet thinking, etc. Other new boxes have been added as well for a total of 20 new features. Almost all of the At the Next Level features have been expanded with new topics as well.

The Student Experience

Botany: An Introduction to Plant Biology, Seventh Edition was designed with the student in mind and is packed full of features and elements to help engage, elaborate, and enhance the learning experience.

PART OPENING INTRODUCTIONS Each of the book's five parts is introduced by a brief summary of all the chapters in that part. These opening introductions tie together the main themes and show how botany is a unified science, not just a body of facts to memorize.



PART 2

PLANT STRUCTURE

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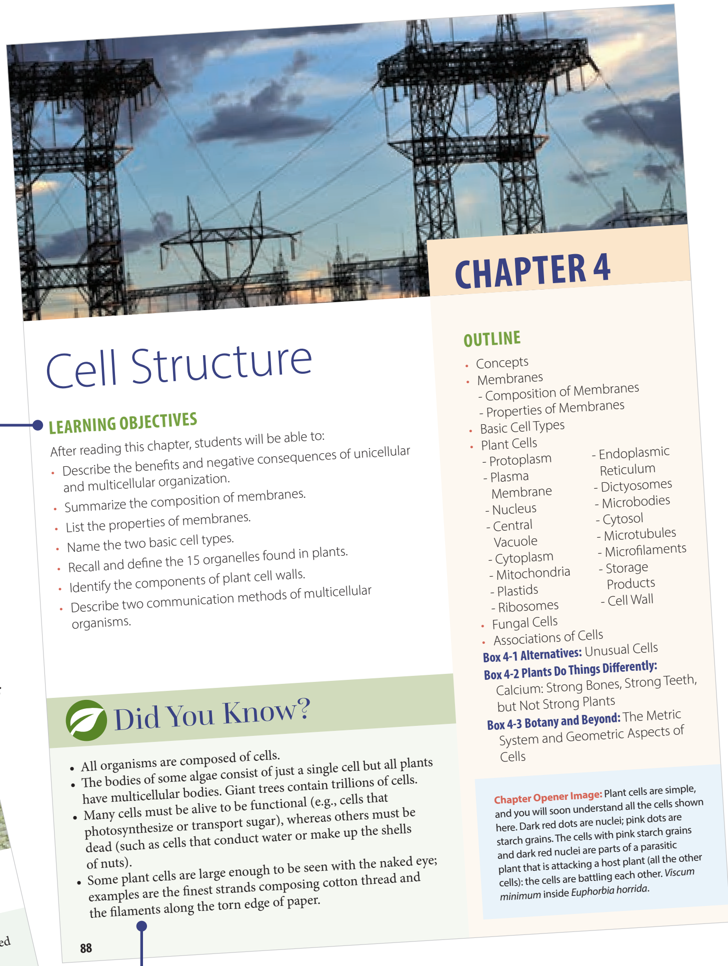
LEARNING OBJECTIVES Every chapter opens with a list of learning objectives that allow students to review the important concepts they will encounter in the chapter. Students should review this list prior to digging into the chapter to help guide their focus. As they progress through the material they should periodically flip back to the Learning Objectives to ensure they are fully grasping that chapter's key botanical concepts.



CHAPTER 4

Cell Structure

LEARNING OBJECTIVES

After reading this chapter, students will be able to:

- Describe the benefits and negative consequences of unicellular and multicellular organization.
- Summarize the composition of membranes.
- List the properties of membranes.
- Name the two basic cell types.
- Recall and define the 15 organelles found in plants.
- Identify the components of plant cell walls.
- Describe two communication methods of multicellular organisms.

Did You Know?

- All organisms are composed of cells.
- The bodies of some algae consist of just a single cell but all plants have multicellular bodies. Giant trees contain trillions of cells.
- Many cells must be alive to be functional (e.g., cells that photosynthesize or transport sugar), whereas others must be dead (such as cells that conduct water or make up the shells of nuts).
- Some plant cells are large enough to be seen with the naked eye; examples are the finest strands composing cotton thread and the filaments along the torn edge of paper.

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OUTLINE

- Concepts
- Membranes
  - Composition of Membranes
  - Properties of Membranes
- Basic Cell Types
- Plant Cells
  - Protoplasm
  - Plasma Membrane
  - Nucleus
  - Central Vacuole
  - Cytoplasm
  - Mitochondria
  - Plastids
  - Ribosomes
  - Endoplasmic Reticulum
  - Dictyosomes
  - Microbodies
  - Cytosol
  - Microtubules
  - Microfilaments
  - Storage Products
  - Cell Wall
- Fungal Cells
- Associations of Cells

Box 4-1 Alternatives: Unusual Cells

Box 4-2 Plants Do Things Differently: Calcium: Strong Bones, Strong Teeth, but Not Strong Plants

Box 4-3 Botany and Beyond: The Metric System and Geometric Aspects of Cells

Chapter Opener Image: Plant cells are simple, and you will soon understand all the cells shown here. Dark red dots are nuclei; pink dots are starch grains. The cells with pink starch grains and dark red nuclei are parts of a parasitic plant that is attacking a host plant (all the other cells): the cells are battling each other. *Viscum minimum* inside *Euphorbia horrida*.

ALTERNATIVES BOXES The *Alternatives* boxes 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.

Alternatives

BOX 6-3 Simple Plants

Three groups of plants have much simpler bodies than those described in this chapter. **Hornworts** (Anthocerotophyta) are a rather rare group of tiny plants whose bodies look like bits of green cellophane, often no larger than 2 to 5 mm in diameter and only a few cells thick. They have no epidermis, no stomata, no collenchyma, no sclerenchyma, no cortex, no pith, no xylem, and no phloem. Instead, they are small ribbon- or disk-shaped sheets of parenchyma cells, most of which have a single chloroplast. Each cell absorbs water and minerals, carries out its own photosynthesis, and is relatively self-reliant. When the plant reproduces, hornlike structures grow upward, break open, and release spores (there are no flowers). During this stage, nutrients are transported from chlorophyllous cells to spore-producing cells, but only by means of plasmodesmata, not phloem.

Many **liverworts** (Hepatophyta) are about as simple as hornworts. Plants of *Pallavicinia*, *Sphaerocarpos*, and *Riccia* also consist of just small green ribbons or disks of chlorophyllous cells. Bodies of *Fossombronia* and *Petallophyllum* appear leafy and more complex, but in fact they are just ribbons whose edges are puckered. The bit of complexity present in these bodies is merely that the central portion of the ribbon is several cells thick, whereas the margins are unistratose. As in hornworts, no epidermis or vascular tissue is present.

Other liverworts such as *Asterella* and *Marchantia* have thicker, more complex bodies. The ventral side (the "belly" side facing the soil) is several layers of compact parenchyma with few chloroplasts, and the dorsal side (the "backbone" side facing the air) consists of intersecting sheets of cells that form air chambers (like the intersecting sheets of cardboard that form a six-pack carton for beer). The term "epidermis" is used for surface cells; dorsal epidermis has stomalike air pores. Ventral epidermis has trichomes (called rhizoids) that attach the body to soil or tree bark. The most complex liverworts have "leaves" and are called leafy liverworts, but their bodies are composed of just parenchyma. As in hornworts, liverworts transfer nutrients through plasmodesmata from chlorophyllous cells to spore-producing tissues when they reproduce: Liverworts do not have vascular tissue. Despite their simplicity, all liverworts grow by means of organized apical meristems.

Mosses (Bryophyta) are a bit more complex than either hornworts or liverworts. Mosses always have a stem with leaves, and in those with taller stems or larger leaves some cells deposit a thicker wall and resemble sclerenchyma fibers. However, these walls do not contain lignin and probably have a separate evolutionary origin, so they are called stereides instead of fibers to avoid confusion. Many mosses conduct water, but along the outside of their bodies, not inside and not with xylem: Their numerous leaves are so tiny and close to the stems they form capillary spaces and act like a wick. A number of mosses do have an internal system of conducting cells in their green, leafy stems; cells called hydroids conduct water, and others called leptoids conduct carbohydrates and other nutrients. These should never be called "xylem" or "phloem" because they differ in significant ways from those two tissues.

What are some consequences of having such simple bodies? The simplicity of hornworts, liverworts, and some mosses limits their ability to survive in some habitats. Lacking conducting tissues, they must remain short, thin, or prostrate, and many quickly die in dry air. On the other hand, this same simplicity *enables* them to survive in many habitats because just a few weeks of cool moist weather is enough to allow their spores to germinate and grow into tiny, mature plants. They do not need to photosynthesize long enough to produce all the carbohydrates that a vascular plant needs for its larger, more complex body. Even deserts have rainy periods and shaded spots that stay moist for weeks; such spots will almost always have some nonvascular plants thriving there.

FIGURE A Plants of hornworts (*Phaeoceros*); the bodies are just thin, green sheets of parenchyma. The columns ("horns") are reproductive structures.

FIGURE B Plants of this liverwort (*Riccia fluitans*) grow in quiet streams. Each shoot is less than 1 mm thick and consists of parenchyma cells and grows from an apical meristem that occasionally divides in two.

Internal Organization of Stems: Arrangement of Primary Tissues 163

DID YOU KNOW? This "fun fact" style feature opens every chapter and illuminates the direct application of plants to students' lives. This list of interesting facts stimulates curiosity of the fascinating botanical world around us, making plant biology more accessible and relevant to students.

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PLANTS DO THINGS DIFFERENTLY BOXES
Retained by popular demand, these boxes help students understand and compare plant biology with human biology. Having an understanding of human biology, students might assume they are misunderstanding what they are reading about plants—plant biology seems too different from their own metabolism. This feature reassures students that they are understanding their reading correctly. Plants really are doing things very differently from the way we do them.

Plants Do Things Differently

BOX 4-2 Calcium: Strong Bones, Strong Teeth, but Not Strong Plants

Most plants and animals need hard parts. Wood is strong enough to support the weight of a tree, and bones play a similar role in animals. Seeds are often protected by resistant shells such as those of walnuts and almonds, and animal shells protect clams and oysters. Our teeth are so tough that they can chew through almost anything. Although plants and animals use hard parts for similar roles, plants rely on thick, tough cell walls, whereas animals use calcium salts.

Would it be possible for plants to use bonelike material? We can analyze this as a set of alternatives and their consequences. The present alternative—wood—consists of cellulose and a chemical called lignin. Both are carbohydrates that a plant itself makes through photosynthesis, and thus they are readily available. And both are remarkably inert, having little impact on other aspects of the plant's metabolism. In contrast, calcium and its salts participate in many metabolic pathways, and building or resorbing shells, bones, or teeth has a broad impact on cell physiology. Shells consist of calcium carbonate, and as animals use carbonate ion (CO_3^{2-}) to build a shell, the acidity of the protoplasm is altered. Furthermore, animals can digest part of their shells if they need the calcium elsewhere, and this liberation of carbonate will again affect the pH. This is tolerable for marine organisms because they use carbonate from the surrounding seawater rather than from their own protoplasm so their pH is not affected. If the shell is resorbed later, the liberated carbonate is likewise dumped outside the animal into the seawater.

Animals like us—with an internal skeleton—use calcium phosphate in our bones and teeth. Calcium carbonate's tendency to alter pH is too dangerous for us, and our skeleton cannot use seawater as a carbonate reservoir. The phosphate ion (PO42-) that we use has little effect on a cell's acidity, and, furthermore, if we resorb bone for some reason, the liberated phosphate is a resource for many other metabolic reactions. It is not a liability at all.

Plants, too, must be careful with calcium and its salts. Calcium carbonate's disturbance of cell acidity is just as dangerous for plants as it is for us, but plants do not use calcium phosphate either, perhaps because it requires too much phosphate. Most soils have just marginal amounts of phosphate and not quite enough to let plants grow optimally. If plant cells had walls made of bone, they would need much more phosphate than is available in soil.

Like animals, plants must carefully control the concentration of dissolved calcium within their cells. The concentration must be kept at extremely low levels; otherwise, it would interfere with metabolism. Roots block the entry of calcium, but so much leaks in accidentally that the plant must get rid of the excess somehow. Plants crystallize the calcium by producing oxalic acid. Calcium and oxalic acid react to form calcium oxalate, which is insoluble and forms crystals. Crystallized calcium is more or less inert and cannot interfere with the plant's metabolism. Calcium oxalate forms only tiny individual crystals rather than big bone-like structures.

Wood with lignin is not as strong as bones or teeth, but its synthesis does not affect cell acidity. Plants can make all of the wood they need without relying on rare minerals from the soil. Plants and animals may do things differently, but there are sound biological principles underlying the differences.

FIGURE A A leaf clearing of maidenhair tree (*Ginkgo*), showing several red-stained leaf veins that conduct sugars out of the leaf. Such veins are the targets of aphids and other sucking insects (×15).

FIGURE B The same tissu... in polarized light (×15).

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.

Plants and People

BOX 7-1 Leaves, Food, and Death

Leaves impact our lives every day. Examples that come to mind readily are leafy foods such as artichokes (*Cynara scolymus*), cabbage (*Brassica oleracea* variety *capitata*), celery (petioles; *Apium graveolens*), lettuce (*Lactuca sativa*), onions (*Allium cepa*), and spinach (*Spinacia oleracea*). Also important are numerous herbs and spices: basil (*Ocimum basilicum*), bay leaves (*Laurus nobilis*), marjoram (*Origanum majorana*), oregano (*Origanum vulgare*), parsley (*Petroselinum crispum*), sage (*Salvia officinalis*), tarragon (*Artemisia dracunculus*), thyme (*Thymus vulgaris*), and the flavorings mint (several species of *Mentha*), spearmint (*Mentha spicata*), and peppermint (*Mentha piperita*) (FIGURES A–C).

The flavors and pungency of these are due to chemicals located within the leaves themselves or in trichomes of the leaf epidermis. Most of these chemicals probably serve as antiherbivore defensive compounds, causing animals other than humans to avoid the plants. Many classes of antiherbivore chemicals have evolved, ranging from only mildly effective ones, such as these flavors, to others that are much more powerful, such as alkaloids, many of which are toxic in small amounts and kill quickly. The alkaloids in poison hemlock and death camas are particularly effective.

An alkaloid of the leaves of one plant in particular is of interest to us—it is quite lethal but acts only slowly: nicotine in the leaves of tobacco (*Nicotiana tabacum*) (FIGURE D). If tobacco leaves are eaten, they cause vomiting, diarrhea, and even death caused by respiratory failure; however, most tobacco leaves are smoked, of course. Americans smoked an all-time high of 4,345 cigarettes per capita in 1963. Since then, consumption has declined for white males but recently has increased for other groups. Tobacco leaves contain between 0.6% and 9.0% nicotine, and an ordinary filter cigarette has 20 to 30 mg of the alkaloid, approximately 10% of which is absorbed by the lungs. Nicotine dissolves readily into our mucous membranes and passes quickly into our bloodstream. Because it is transferred across the placenta, women who smoke during pregnancy may give birth to babies addicted to nicotine. Blood-borne nicotine also affects the heart, causing coronary problems: People who smoke a pack or more a day are over three times more likely than nonsmokers to die of heart disease. After nicotine is taken into the cells of the mouth and lungs of a smoker, it can cause cancer—of the lungs especially, but also of the throat, larynx, and mouth. If detected early enough, nicotine-induced lung cancer can be combated with surgery and chemotherapy, but after the cancer has spread to the lymph system, the prognosis is not good. Lung cancer causes more than 400,000 deaths per year in the United States. Vaping also supplies dangerous nicotine.

FIGURE A Basil ...

BOTANY AND BEYOND BOXES
Modernized to suit a new generation of learners, the popular *Botany and Beyond* boxes elaborate on subjects that, although not essential to the study of botany, help make the material more relevant and accessible.

Botany and Beyond

BOX 7-4 Are Some Cacti the Fastest Growing Plants in the World?

This is a serious question, not a trick. My objective is to call your attention to two things: (1) diversity within plants and (2) understanding how things are measured.

We picture cacti as hardy, spiny, desert-dwellers that take years to show even a bit of growth. But the cactus family contains about 1,500 species, and although many are adapted to slow growth in dry desert conditions, others are at home in mesic grasslands or wet rainforests, and some even live high in the Andes Mountains of South America in cold conditions near snow drifts. One group of South American cacti, in the genus *Cleistocactus*, inhabits dry habitats that receive enough rain from time to time to allow ordinary trees, shrubs, and herbs to grow. A plant of *Cleistocactus* can sit quietly, conserving water for months, but when there is enough rain it grows rapidly—more rapidly than other cacti, more rapidly than surrounding trees, perhaps more rapidly than any other type of plant in the world.

Various definitions of growth are possible depending on what a person is trying to understand. During your teenage years, you increased irreversibly in height; that was one type of growth. As an embryo develops within an egg, the chick undergoes organogenesis and becomes more complex; that is another type of growth. If we place dry bean seeds into moist soil, they will take up water in the first few days and become heavier, but they are only hydrating desiccated cells: no new cells or leaves are being made during the first day or two. This is not growth, it is just water absorption.

But after a few days of being moist, seeds become metabolically active, cell division begins, and the shoot apical meristem starts making new leaf primordia, new nodes and internodes; the root apical meristem produces new root cells. There is both an increase in complexity and an irreversible increase in weight. For many studies of plants, counting new leaves is the preferred way to measure growth because we do not have to harm the plant to do our counting. If we measure growth as an increase in weight, we must dig up the plants and weigh them, which causes damage.

Counting leaves in cacti is very easy. Most cactus leaves are microscopic, causing many people to say they are leafless (which is never true), but each tiny foliage leaf produces an axillary bud, and that bud is very visible. Bud scales in cacti are not scale-shaped and do not fold over the buds; instead, they grow

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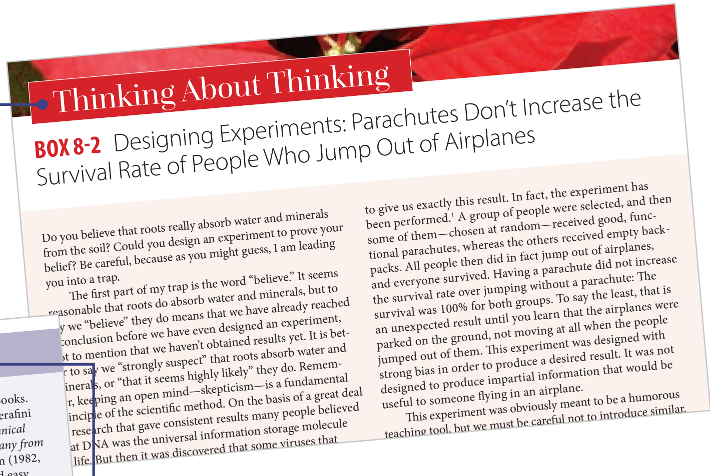
THINKING ABOUT THINKING BOXES
Learning the material for any given topic is naturally the focus of most courses, but it is just as important for students to learn how to think critically and logically so that they can continue to learn after the course is over. This is a new feature for the *Seventh Edition*.



Thinking About Thinking

BOX 8-2 Designing Experiments: Parachutes Don't Increase the Survival Rate of People Who Jump Out of Airplanes

Do you believe that roots really absorb water and minerals from the soil? Could you design an experiment to prove your belief? Be careful, because as you might guess, I am leading you into a trap.

The first part of my trap is the word "believe." It seems reasonable that roots do absorb water and minerals, but to … y we "believe" they do means that we have already reached … conclusion before we have even designed an experiment, … ot to mention that we haven't obtained results yet. It is bet… r to say we "strongly suspect" that roots absorb water and … inerals, or "that it seems highly likely" they do. Remem… r, keeping an open mind—skepticism—is a fundamental … inciple of the scientific method. On the basis of a great deal … research that gave consistent results many people believed … at DNA was the universal information storage molecule … life. But then it was discovered that some viruses that

to give us exactly this result. In fact, the experiment has been performed.[1] A group of people were selected, and then some of them—chosen at random—received good, functional parachutes, whereas the others received empty backpacks. All people then did in fact jump out of airplanes, and everyone survived. Having a parachute did not increase the survival rate over jumping without a parachute: The survival was 100% for both groups. To say the least, that is an unexpected result until you learn that the airplanes were parked on the ground, not moving at all when the people jumped out of them. This experiment was designed with strong bias in order to produce a desired result. It was not designed to produce impartial information that would be useful to someone flying in an airplane.

This experiment was obviously meant to be a humorous teaching tool, but we must be careful not to introduce similar.

At the Next Level

1. *Independent, advanced study.* The purpose of these At the Next Level boxes is to suggest to you information that would be relevant to a more advanced understanding of the topics of the current chapter. Because Chapter 1 is an introductory chapter, most of its topics will be developed later in this text, and if you would like to read ahead now, just check the table of contents and find topics that appeal to you. Also, leaf through the book and read various boxes or figure legends: these are short enough that you can easily read through those you find interesting and skip the others.
2. *The development of our current concepts.* We are familiar with concepts of cells, plants, life, gravity, energy, motion, and many other phenomena. But our present understanding is the result of thousands of years of trying to understand the world. I recommend reading a bit of the history of science, especially the history of biology. You will be amazed to learn that concepts we assume have always been known had to be discovered; other concepts that most of us have never heard of had been widely accepted but had to be disproven and discarded. I recommend three books. Two, *The Epic History of Biology* by Anthony Serafini (1993, Perseus Publishing) and *History of Botanical Science: An Account of the Development of Botany from Ancient Times to the Present Day* by A. Morton (1982, Academic Press), are shorter, more direct, and easy to follow. The third book, *The Growth of Biological Thought: Diversity, Evolution, and Inheritance* by Ernst Meyer (1985, Belknap Press), is more detailed and parts will be difficult for a freshman or sophomore, but it is a book that any biologist should read; it is a book you will want to have for the rest of your life.
3. *Science and ethics.* The scientific method cannot deal with things that are not tangible or physical, and certainly plants never face ethical or moral dilemmas, but we humans do. Ethics and morality are not my specialty, and I will not recommend any particular book or article, but I do strongly suggest that you think about ethics and search out information on your own. An internet search is a good place to start, and book reviews on Amazon.com are excellent guides as to which books might be of value to you.

SUMMARY

1. It is difficult to define a plant. It is more important to develop a familiarity with plants and understand how they differ from animals, fungi, protists, and prokaryotes. The differences are presented in later chapters.
2. The scientific method requires that all information be gathered through documented, repeatable observations and experiments. It rejects any concept that can never be examined, and it requires that all hypotheses be tested and be consistent with all relevant observations. It is based on skepticism.
3. Science and religion address completely different kinds of problems. Science cannot solve moral problems; religion cannot explain physical processes.
4. Living organisms have evolved by natural selection. As organisms reproduce, mutations cause some offspring to be less fit, some to be more fit. Those whose features are best suited for the environment grow and reproduce best and leave more offspring than do those that are poorly adapted.
5. For any particular environment, several types of adaptation can be successful.
6. Our knowledge of the world is incomplete and inaccurate; as scientific studies continue, incompleteness diminishes and inaccuracies are corrected.
7. Two simple questions are powerful analytical tools: (1) What are the alternatives, and (2) what are the consequences?

IMPORTANT TERMS

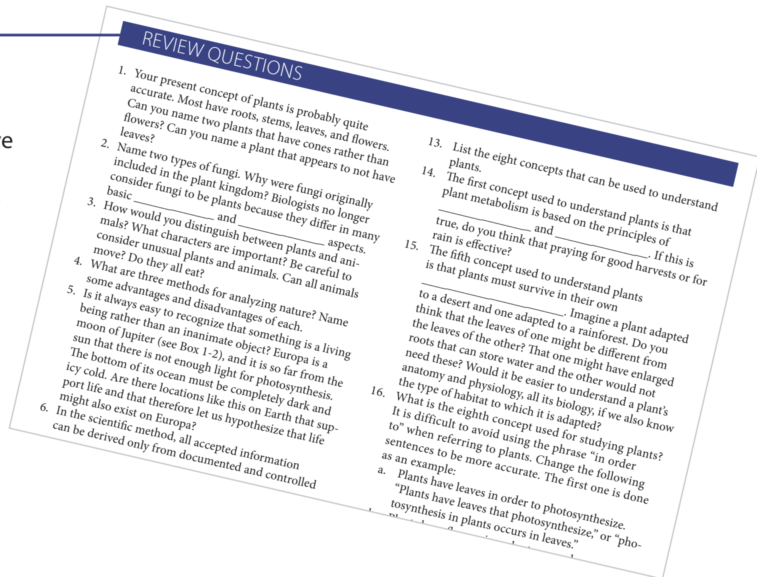
anthropomorphism
apomorphic features
botany
derived features
domains
hypothesis
interpretations
natural selection
observations
plesiomorphic features
relictual features
scientific method
teleology
theory

Important Terms 19

AT THE NEXT LEVEL This feature closes every chapter and provides opportunities for students to expand their understanding of the key botanical concepts they just learned. Most of these have had new topics added for the *Seventh Edition*. This feature is especially helpful for higher-level botany courses and biology majors.

CHAPTER SUMMARIES To ensure students thoroughly grasp the important concepts, each chapter concludes with a comprehensive chapter summary. Students can review the summary before digging into the chapter to direct their study and can also use it as a study tool to prepare for course lectures and exams.

IMPORTANT TERMS A list of important terms is included at the end of every chapter. Furthermore, the terms in the chapter appear in bold to draw the reader's attention. Students should refer to the Important Terms as part of their study to assess their understanding of chapter material.



REVIEW QUESTIONS

1. Your present concept of plants is probably quite accurate. Most have roots, stems, leaves, and flowers. Can you name two plants that have cones rather than flowers? Can you name a plant that appears to not have leaves?
2. Name two types of fungi. Why were fungi originally included in the plant kingdom? Biologists no longer consider fungi to be plants because they differ in many basic ________ and ________ aspects.
3. How would you distinguish between plants and animals? What characters are important? Be careful to consider unusual plants and animals. Can all animals move? Do they all eat?
4. What are three methods for analyzing nature? Name some advantages and disadvantages of each.
5. Is it always easy to recognize that something is a living being rather than an inanimate object? Europa is a moon of Jupiter (see Box 1-2), and it is so far from the sun that there is not enough light for photosynthesis. The bottom of its ocean must be completely dark and icy cold. Are there locations like this on Earth that support life and that therefore let us hypothesize that life might also exist on Europa?
6. In the scientific method, all accepted information can be derived only from documented and controlled

13. List the eight concepts that can be used to understand plants.
14. The first concept used to understand plants is that plant metabolism is based on the principles of ________ and ________. If this is true, do you think that praying for good harvests or for rain is effective?
15. The fifth concept used to understand plants is that plants must survive in their own ________. Imagine a plant adapted to a desert and one adapted to a rainforest. Do you think that the leaves of one might be different from the leaves of the other? That one might have enlarged roots that can store water and the other would not need these? Would it be easier to understand a plant's anatomy and physiology, all its biology, if we also know the type of habitat to which it is adapted?
16. What is the eighth concept used for studying plants? It is difficult to avoid using the phrase "in order to" when referring to plants. Change the following sentences to be more accurate. The first one is done as an example:
    a. Plants have leaves in order to photosynthesize. "Plants have leaves that photosynthesize," or "photosynthesis in plants occurs in leaves."

REVIEW QUESTIONS These questions 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.

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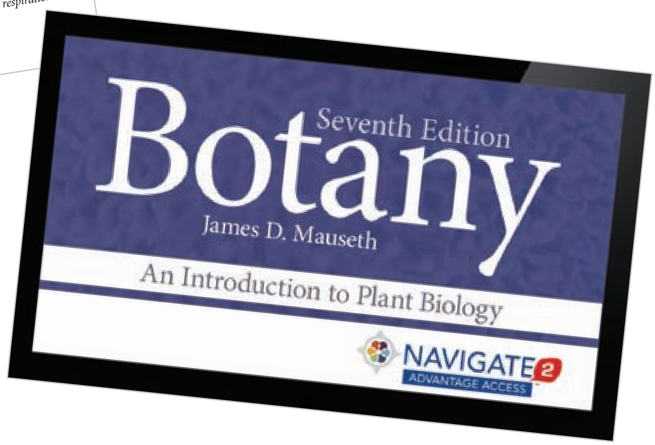
PRONUNCIATION GUIDE Previously part of the front matter, the Pronunciation Guide has been moved to the end of the book near the glossary for easy reference. Students can feel confident that they are correctly pronouncing certain botanical words such as xylem, allele, and Rosaceae.

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



INTERACTIVE EBOOK INCLUDING WEB LINKS
Every new print copy of this *Seventh Edition* includes access to a complete and interactive ebook with embedded enhancements such as Web Links and ungraded Knowledge Checks to reinforce key concepts.

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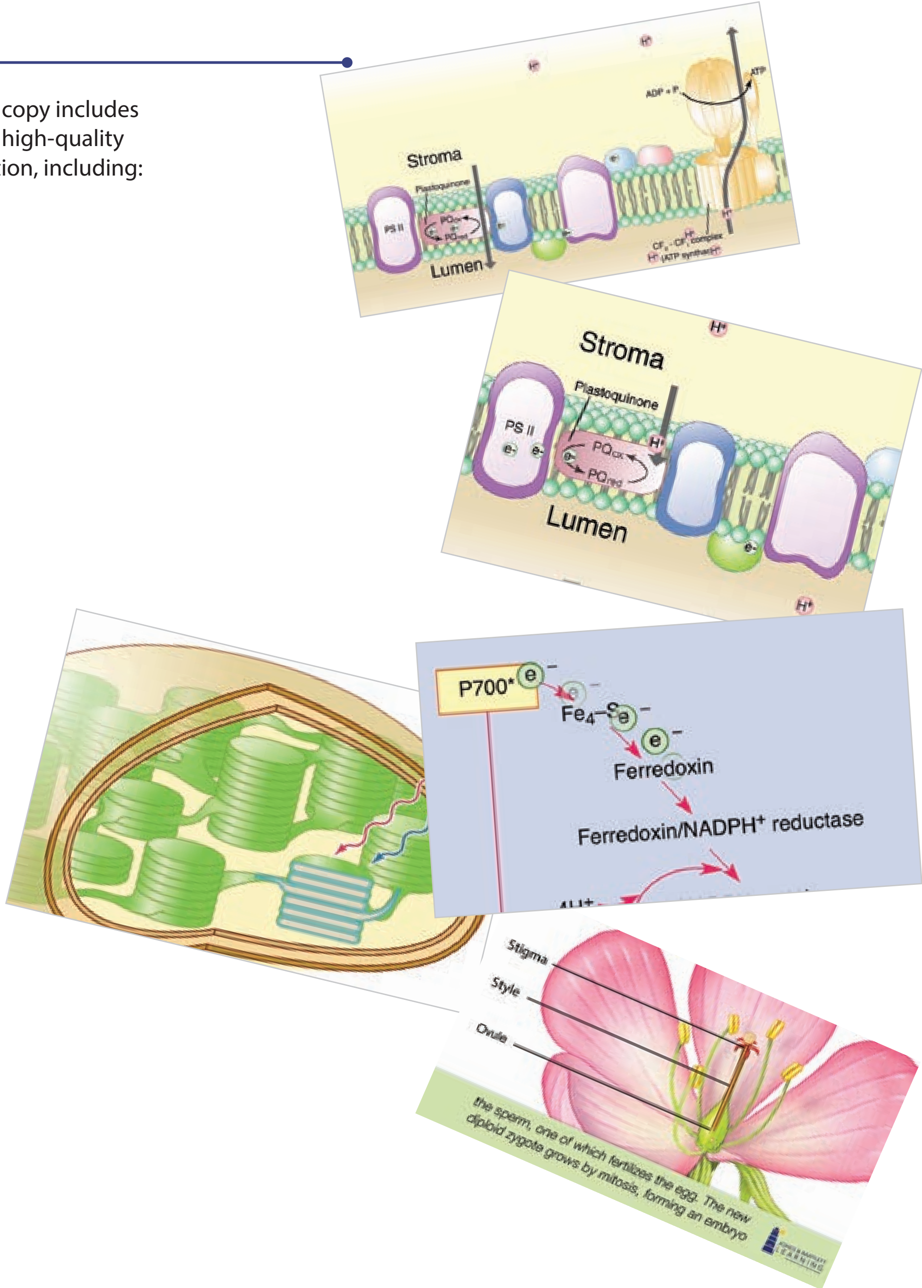
BOTANY IN ACTION Every new print copy includes an interactive eBook with a collection of high-quality animations to connect structure to function, including:

- Photosynthesis
- Water Movement
- Calvin Cycle
- Respiration
- Flowers and Reproduction
- Growth of Wood
- Primary and Secondary Growth
- Pressure Laws Sequence



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TEACHING TOOLS

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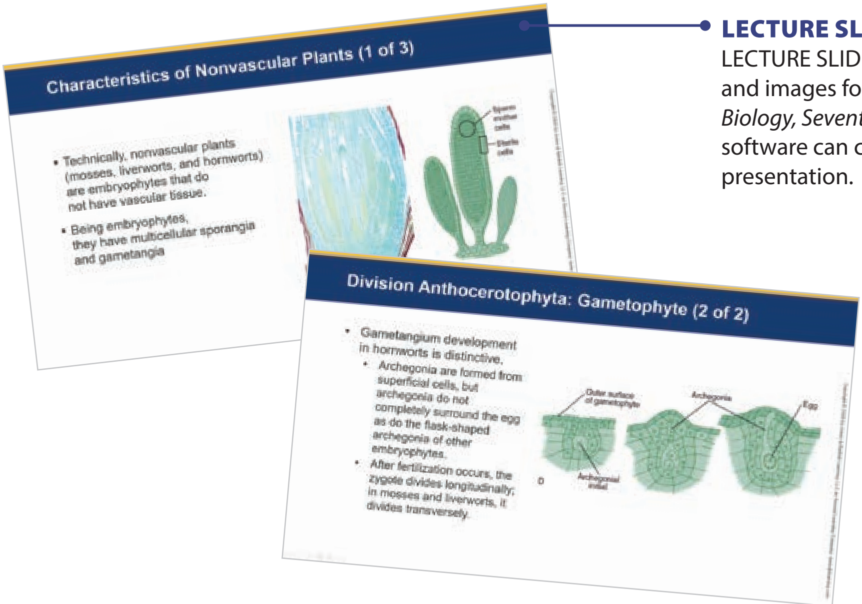
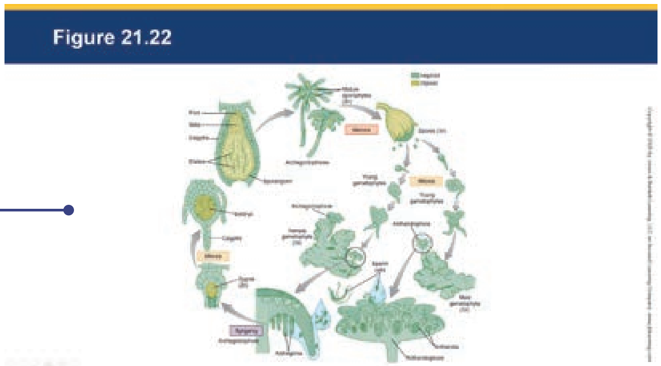
Jones & Bartlett Learning has provided a variety of Teaching Tools to assist instructors with preparing for and teaching their courses. For information on how to access these resources, please contact your Jones & Bartlett Learning Sales Representative at go.jblearning.com/findmyrep.

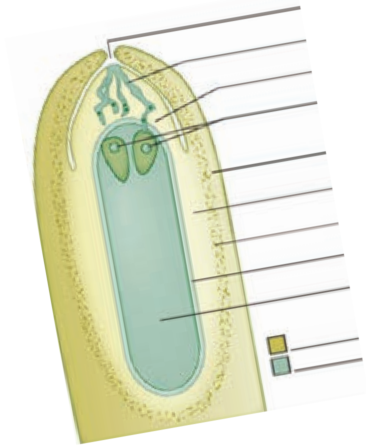


LECTURE SLIDES IN POWERPOINT FORMAT The LECTURE SLIDES in PowerPoint format provide lecture notes and images for each chapter of *Botany: An Introduction to Plan Biology, Seventh Edition.* Instructors with Microsoft PowerPoint software can customize the outlines, art, and order of presentation.

INSTRUCTOR'S MANUAL The INSTRUCTOR'S MANUAL, provided as a text file, includes lecture outlines and teaching tips. We have also included a sample syllabus as an example of how to approach a Plant Biology course.

SOLUTIONS TO REVIEW QUESTIONS These files contain answers to all of the end-of-chapter review questions found in the text.





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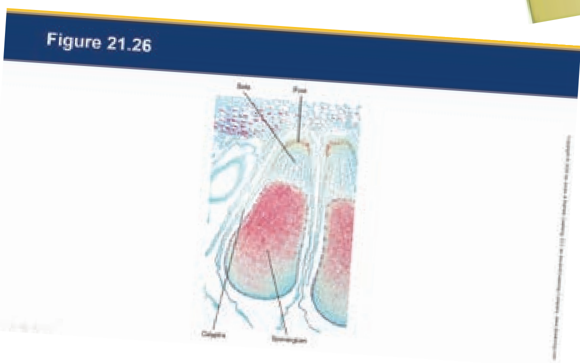

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LAB MANUAL

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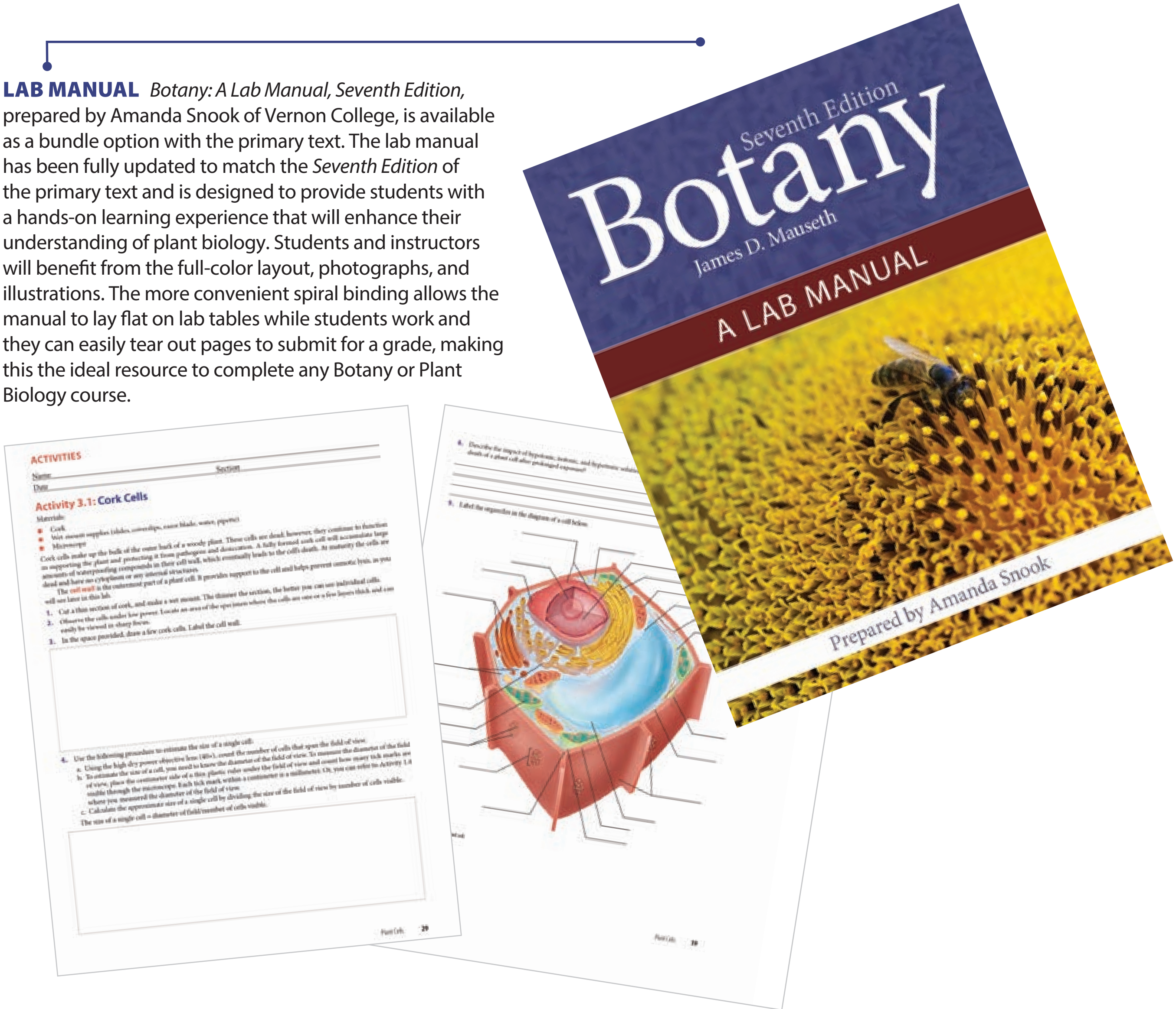
LAB MANUAL *Botany: A Lab Manual, Seventh Edition,* prepared by Amanda Snook of Vernon College, is available as a bundle option with the primary text. The lab manual has been fully updated to match the *Seventh Edition* of the primary text and is designed to provide students with a hands-on learning experience that will enhance their understanding of plant biology. Students and instructors will benefit from the full-color layout, photographs, and illustrations. The more convenient spiral binding allows the manual to lay flat on lab tables while students work and they can easily tear out pages to submit for a grade, making this the ideal resource to complete any Botany or Plant Biology course.



Lab Manual ISBN-13: 978-1-284-15739-0
Main Text + Lab Manual Bundle ISBN-13: 978-1-284-20124-6

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Just like the initial production of a textbook, the preparation of a new edition is not by any means the sole effort of the author. I am fortunate to have benefited from the many contributions of numerous talented individuals through the various editions. The current editorial staff at Jones & Bartlett Learning is one of the best and most skillful. I especially thank Laura Pagluica, Audrey Schwinn, Vanessa Richards, John Rusk, and Troy Liston for their intelligent, creative solutions to many problems that had to be solved in preparing the *Seventh Edition*.

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I had the good fortune to prepare part of the *Seventh Edition* while visiting California Polytechnic State University in San Luis Obispo, California. I was invited there to teach Plant Anatomy in their Biology Department during winter quarter, 2019. The intellectual atmosphere at CalPoly was stimulating due to faculty, staff, and students. I especially thank Drs. Jenn Yost, Matt Ritter, and Ken Hillers.

Once again, I thank my husband Tommy Navarre. He has given me support, encouragement, and confidence ever since I began writing the first edition of this book, so many years ago. I am sorry to report that he died of lung cancer just before I began preparing this revision, and his passing taught me that biology has many unhappy aspects. However, I am glad to say that he still gives me support, courage, and confidence.

—James D. Mauseth
San Luis Obispo, California, and Austin, Texas

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ABOUT THE AUTHOR

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Jim Mauseth was born in eastern Washington state and spent his childhood on his family's irrigated farm, tending wheat, potatoes, corn, and other crops. Adjacent to the farm was an undisturbed sagebrush desert with a sparse but rich variety of wildflowers. He studied botany at the University of Washington in Seattle, and hiked in the cool, rainy Cascade Mountains, the Olympic Rainforest, and on Mount Rainier. The rocky coast of Puget Sound, with its abundant algae and invertebrates, was also a favorite place.

In 1975, he obtained his PhD and became a professor at the University of Texas and has lived in Austin ever since. The vegetation around Austin includes pine woodland, oak–juniper forest, mesquite scrubland, and open grassland. Representatives of all major groups of plants are present within an hour or two, and the streams contain *Chara*, an alga closely related to true plants. The swamps of Louisiana and the desert of Big Bend National Park are nearby.

Jim's research at UT centers on the anatomy and evolution of plants that have highly unusual bodies, such as cacti and parasitic plants. Many of these occur in Latin America, and Jim has traveled extensively in South America to study plants. He believes that one of the best ways to observe plants is from the seat of a bicycle, and he has cycled through many parts of the United States (coast to coast once), across Alaska, and through much of Europe.

As a professor, he has taught both Introductory Botany as well as Plant Anatomy every year since 1975. Many students, both graduates and undergrads, have assisted in his research. He knows from this long experience that students today are just as talented, capable, and interested as students half a century ago.

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