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# PREFACE

The preparation of this *Sixth Edition of Botany* had two objectives: first, to emphasize the interactions between plants and other organisms, and second, to make plant biology more accessible and relevant to students and other readers.

The emphasis on plant interactions with the biosphere began several editions ago, as the reality of global climate change became clear. Previous editions explored the role of plants in the removal of greenhouse gases and also the loss of many forests by human activities. While thinking about the interrelationships of plants and people, I suspected that students would be interested in the ways in which plants interact with all other organisms. I believe it is more realistic and engaging to examine plant biology as one aspect of the set of all the interactions of organisms and Earth. To take a reductionist view of plant biology as just the anatomy, metabolism, and evolution of isolated plants is to miss out on many of the richest aspects of plant biology.

Consequently, in this *Sixth Edition*, a new *Chapter 26: Community Ecology* has been added to introduce students more fully to interactions between plants and their surroundings. Also, several existing chapters have had new material added to emphasize these interactions; for example, there is a new discussion about ways in which plants detect attacks by fungi in *Chapter 14: Development and Morphogenesis*.

Making plant biology more accessible to students and everyone else was the reason I originally began writing this book 30 years ago. It has also been a primary concern in every new edition. Some reviewers and professors have felt that previous editions of *Botany* were too difficult for their students, and, to address their concerns, I have added a new *Chapter 2: Overview of Plant Life*. This is structured to provide a broad introduction to topics such as plant structure, metabolism, genetics, diversity, evolution, and ecology. An entire chapter was dedicated to this so that fundamental principles could be presented with just enough depth and breadth that any student or reader would obtain enough of an overview to feel ready to tackle any other part of the text. Many students will already be so familiar with plants that certain portions of *Overview* will be unnecessary, but they might benefit from other parts. For some students, all of *Overview* may be a valuable aid. Either way, it is meant to welcome everyone into the world of plant biology. I want all people to feel included in this book; I do not want any part to be a barrier to anyone.

Several other elements make this *Sixth Edition* more accessible. First, a *Pronunciation Guide* has been added for

those words that have made many of us feel uncertain: people will feel more comfortable with *xylem*, *allele*, or *Rosaceae* if they are confident they are pronouncing these words correctly. Also, every chapter now opens with two new elements, a list of *Learning Objectives* and a few *Did You Know?* facts. The first is designed to allow students to see the important topics immediately, the second is designed to attract their interest. All chapters now end with a new section entitled *At the Next Level*, which presents more advanced topics that some students might want to explore on their own.

A new *Chapter 24: Ethnobotany: Plants and People* has been added to both emphasize interactions between plants and other organisms (us humans) and to make the book more relevant to each reader's life. Among the typical topics such as food and fibers, *Box 24-3 Plants and People: Natural Drugs, Endangered Species, and Women's Rights* discusses modern ethnobotanical problems that result from our increasing knowledge of plants and the cures they may provide. This new chapter does not replace the numerous *Plants and People* boxes that have been developed in previous editions; those are all still present here.

One of the aims of this book is to encourage students to think about the intersection between the scientific world and themselves, including their religious beliefs. This has been an important part of *Botany* from the very first edition with the sections *The Scientific Method* and *Areas Where the Scientific Method is Inappropriate*. In this *Sixth Edition*, *Box 2-4 Botany and Beyond: Noah's Flood and Population Biology* points out that studies of the *Bible* led directly to the establishment of two critically important scientific disciplines: population biology and demography. *Box 17-1 Botany and Beyond: Species Are Populations, Not Types* discusses how our modern concept of species has changed from our original concept that had been based on *Genesis*. The relationships between science and religion are touched on only occasionally, but I do not want students to think there is a complete gulf between their biology classes and their religious lives. Perhaps some instructors will use these sections of *Botany* to lecture more expansively on science and religion.

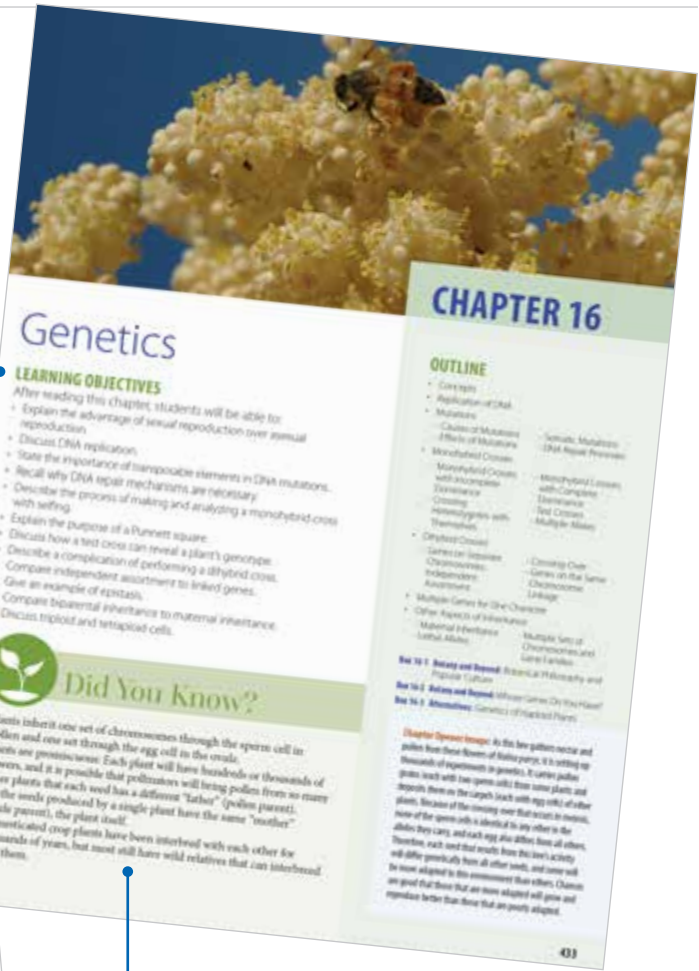
My ultimate goal is to teach about life in general. Every topic mentioned in this book should help the reader to more fully understand human biology, indeed to understand all of biology. No organism exists isolated from all others; instead we all share one biology that encompasses all organisms. We are all in this together.

# THE STUDENT EXPERIENCE

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

## New to This Edition

**Learning Objectives** New to this edition, 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.



### Genetics

#### LEARNING OBJECTIVES

- After reading this chapter, students will be able to:
- Explain the advantage of sexual reproduction over asexual reproduction.
  - Discuss DNA replication.
  - State the importance of transposable elements in DNA mutations.
  - Recall why DNA repair mechanisms are necessary.
  - Describe the process of making and analyzing a monohybrid cross with selfing.
  - Explain the purpose of a Punnett square.
  - Discuss how a test cross can reveal a plant's genotype.
  - Compare independent assortment to linked genes.
  - Give an example of epistasis.
  - Compare biparental inheritance to maternal inheritance.
  - Discuss triploid and tetraploid cells.



#### Did You Know?

- Plants inherit one set of chromosomes through the sperm cell in pollen and one set through the egg cell in the ovule.
- Plants are promiscuous: Each plant will have hundreds or thousands of other plants that each seed has a different "father" (pollen parent).
- All the seeds produced by a single plant have the same "mother" (ovule parent), the plant itself.
- Domesticated crop plants have been interbred with each other for thousands of years, but most still have wild relatives that can interbreed with them.

### CHAPTER 16

#### OUTLINE

- Cell Cycle
- Apoptosis (AKA Cell Death)
- Mutations
  - Causes of Mutations
  - Effects of Mutations
  - Genetic Drift
  - Genetic Bottleneck
  - Founder Effect
  - Gene Flow
  - Genetic Isolation
  - Speciation
  - Adaptive Radiation
  - Convergent Evolution
  - Divergent Evolution
  - Sympatric Speciation
  - Allopatric Speciation
  - Polyploidization
  - Hybridization
  - Gene Duplication
  - Gene Loss
  - Gene Conversion
  - Horizontal Gene Transfer
  - Endosymbiosis
  - Gene Transfer
  - Gene Duplication
  - Gene Loss
  - Gene Conversion
  - Horizontal Gene Transfer
  - Endosymbiosis
  - Gene Transfer
- Mendelian Genetics
  - Monohybrid Crosses
  - Dihybrid Crosses
  - Test Crosses
  - Multiple Alleles
  - Polygenic Inheritance
  - Epistasis
  - Incomplete Dominance
  - Codominance
  - Multiple Alleles
  - Multiple Genes for One Character
  - Other Aspects of Inheritance
  - Maternal Inheritance
  - Lethal Alleles
  - Multiple Sets of Chromosomes and Gene Duplication

- Box 16.1: Botany and Society: Botanical Classification and Plant Culture
- Box 16.2: Botany and Society: Botanical Classification and Plant Culture
- Box 16.3: Botany and Society: Botanical Classification and Plant Culture

**Chapter Opening Image:** As this bee gathers nectar and pollen from these flowers of *Malva parviflora*, it is setting up thousands of experiments in genetics. It carries pollen grains (each with two genes) to other plants, and it deposits these on the large (each with egg cells) of other plants. Because of the way the genes are passed on, the offspring of the gene cells is a blend of its own father's and mother's genes. Each seed that results from this bee's activity will differ genetically from all other seeds, and some will be more adapted to this environment than others. Chances are good that those that are more adapted will grow and reproduce better than those that are poorly adapted.

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#### At the Next Level

1. **Extreme modification of shoots.** All seed plants have the same basic organization of their shoots, but in nature, the various tissues are highly modified. Although cacti appear to be exceptional, they have all the normal parts presented in this chapter; you now know enough to understand papers about their anatomy. Parasitic plants that live entirely within their hosts usually have such highly modified bodies that some organs and tissues are missing or barely recognizable. Species you might find informative are *Rafflesia arnoldii*, *Trochilium ophifolium*, *Yucca minima*, and *Hyalocoma africana*. If you really want to go to the next level, look up the family Podostemaceae (sometimes called Podostemaceae). These are flowering plants in which almost all aspects of anatomy are abnormal.
2. **Evolution and ecology of xylem.** All organisms must obtain, transport, and conserve water. Many studies have analyzed the ways in which alternative types of xylem cells affect a plant's adaptation to its habitat. Also

the evolution of xylem—from a few simple tracheids in the first plants to the many diverse types of cells present in angiosperm xylem—has been studied extensively and is well-documented. Searching on the key words "xylem evolution" and "xylem ecology" is a good way to start.

3. **Ant plants (myrmecophytes).** A surprising number of plants have stem modifications, such as hollow chambers with tunnels leading to the shoot surface, that provide shelter for animals such as ants and termites. The structures are called domatia (sing: domatium; pronounced doe-MAY-shum) and the insects that occupy them typically provide some sort of benefit to the plant. For example, ants often patrol the plant and kill any other insects that would attack the plant, and some even clean fungal cells of the plant. Many also irrigate and deliver in plant with nitrogen fertilizer. Search on these keywords: ant plant, myrmecophyte, domatium, Hydophyton, Myrmecodia, Solanopsis (and check the index of this book).

#### SUMMARY

1. Cells must be arranged in the proper patterns and with the proper interrelationships in order to function efficiently.
2. All angiosperms have roots, stems, and leaves, although each can be highly modified in particular environments.
3. Virtually all stems function in producing and supporting leaves and transporting water, minerals, and sugars between leaves, buds, and roots. Other stems are involved in storage, reproduction, dissemination, and surviving stress.
4. All stems consist of nodes and internodes, and they have leaves and axillary buds. Numerous types of stems exist, and individual plants have two or three types of shoots, most individual plants have two or three types of shoots, and the three basic types of plant cells, based on walls, are parenchyma (responsible for most metabolism), collenchyma (plastic support), and sclerenchyma (elastic support).
4. The vascular tissues are xylem and phloem. Tracheids consist of vessel elements (with perforations). Sieve tubes consist of sieve cells (with small sieve pores) and sieve tube members (with large sieve pores on the end walls).
7. Vessels of all angiosperms have end walls, and in collateral vascular bundles, in basal angiosperms and dicots, the bundles occur as one ring surrounding the pith, whereas in monocots, they have a complex distribution in impunctate tissue.
8. Parenchyma and protophloem form while an organ is elongating and therefore must be extensible. Metaxylem and metaparenchyma form after elongation ceases.
9. Both primary xylem and primary phloem are complex tissues with a variety of cell types, not just conducting cells.

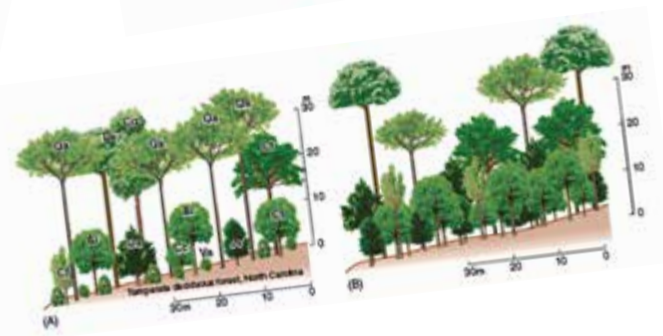
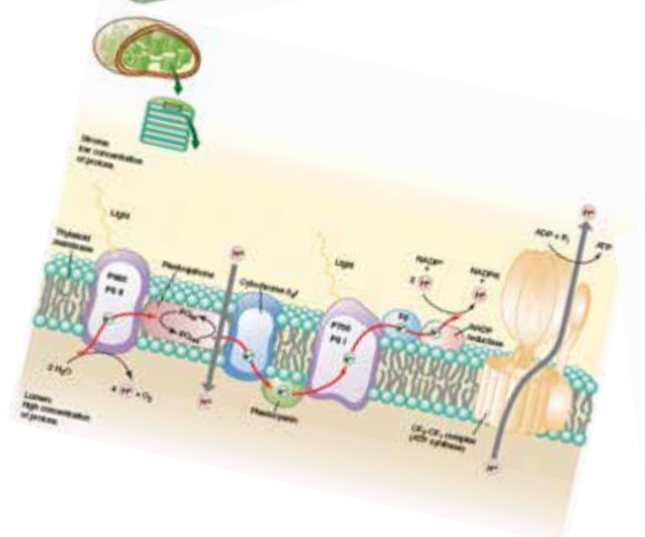
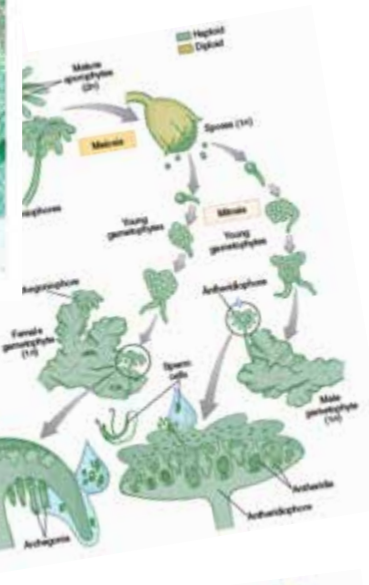
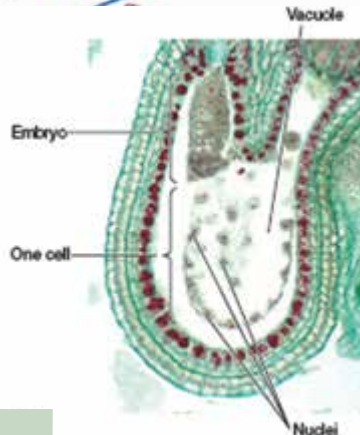
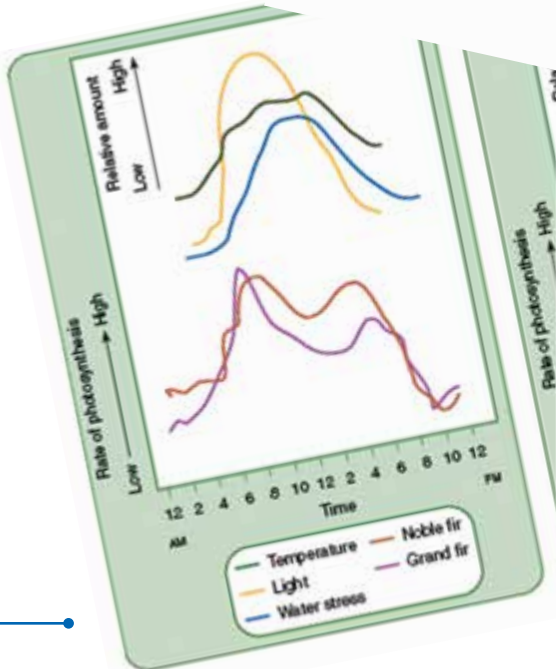
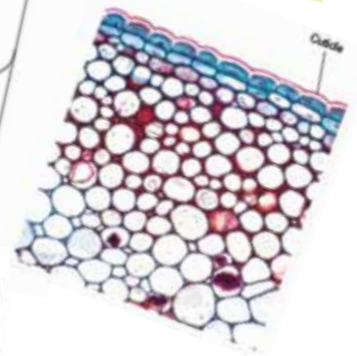
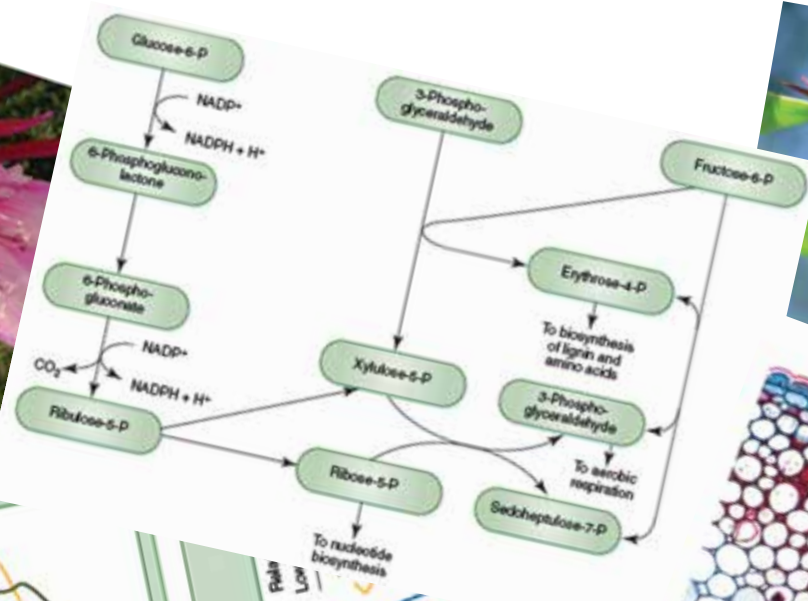
#### IMPORTANT TERMS

- |              |                  |                  |                        |                        |                   |                 |              |
|--------------|------------------|------------------|------------------------|------------------------|-------------------|-----------------|--------------|
| angiosperm   | axillary bud     | basal angiosperm | bulb                   | vascular bordered pits | collenchyma cells | companion cells | axeren       |
| axillary bud | basal angiosperm | bulb             | vascular bordered pits | collenchyma cells      | companion cells   | axeren          | axillary bud |
| axillary bud | basal angiosperm | bulb             | vascular bordered pits | collenchyma cells      | companion cells   | axeren          | axillary bud |

- outside epidermis
- endocuticle
- fibers
- ground meristem

**At the Next Level** New *At the Next Level* feature closes every chapter and provides opportunities for students to expand their understanding of the key botanical concepts they just learned. This feature is especially helpful for higher-level botany courses and biology majors.

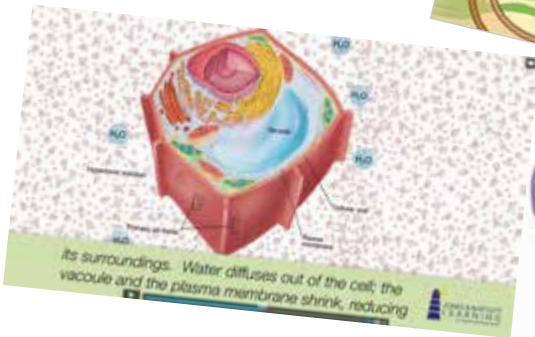
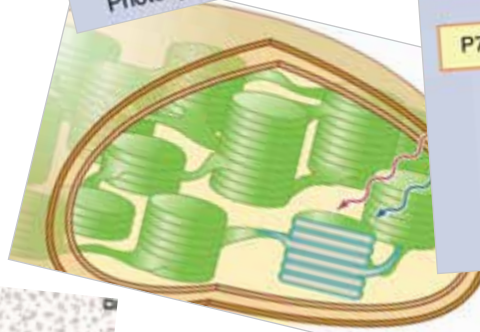
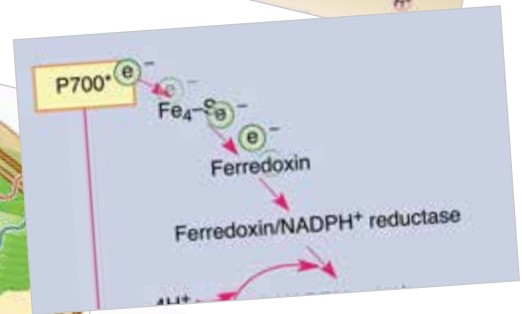
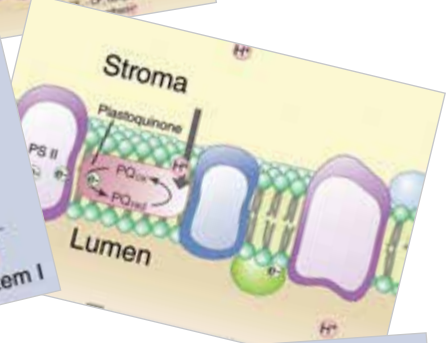
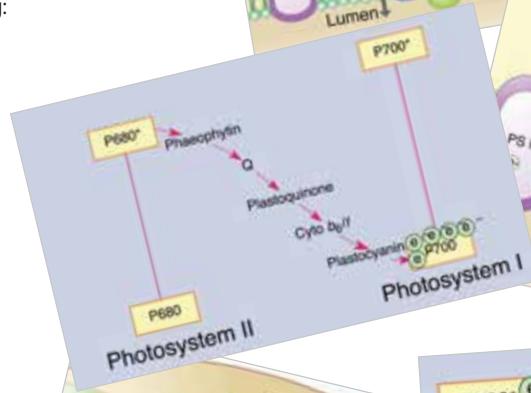
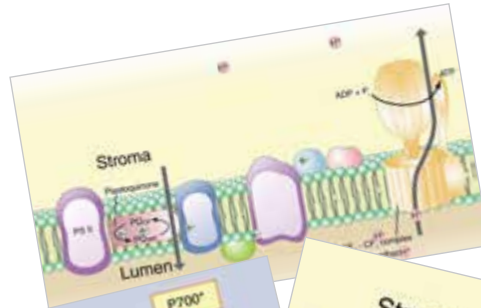




• **Market-Leading Art and Photos** This edition has received a complete overhaul to its art package. It features a visually stunning design with over 550 new and revised figures, including new photographs (most of which were taken by James Mauseth) and thoroughly revised, detailed illustrations that unlock complex topics and biological processes.

**Botany in Action** No text connects structure to function better than Mauseth's *Botany*. Building on this strength and new to the *Sixth Edition* is *Botany in Action*, a collection of high-quality animations on market-selected topics, including:

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



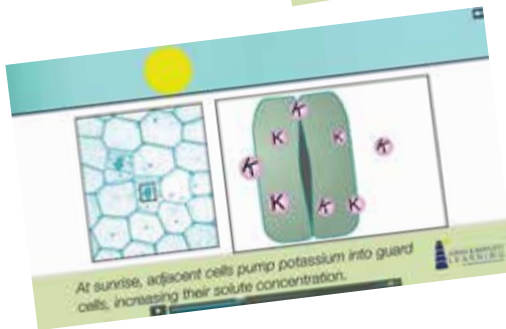
its surroundings. Water diffuses out of the cell; the vacuole and the plasma membrane shrink, reducing



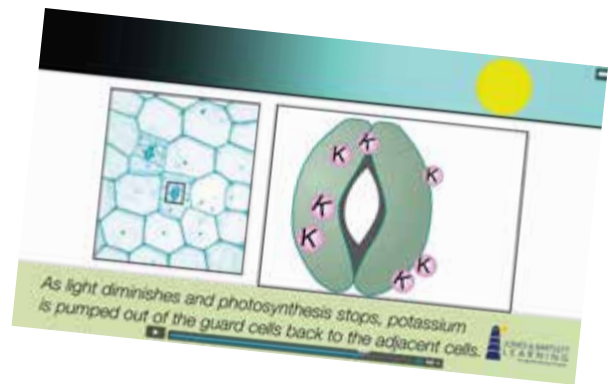
Meanwhile, haploid megasporocytes in the ovules undergo meiosis, developing into four megaspores.



the sperm, one of which fertilizes the egg. The new diploid zygote grows by mitosis, forming an embryo.



At sunrise, adjacent cells pump potassium into guard cells, increasing their solute concentration.



As light diminishes and photosynthesis stops, potassium is pumped out of the guard cells back to the adjacent cells.

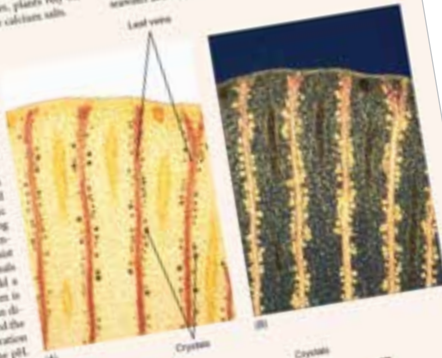


## Plants Do Things Differently

### BOX 3-2 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. Seashells are often protected by mineral 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 they can chew through almost anything, plants rely on thick, tough cell walls, whereas animals use calcium salts.

Would it be possible for plants to use bone-like material? We can see the consequences. The present alternative—wood—consists of cellulose fibers 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 absorbing shells, bones, or teeth has a broad impact on cell physiology. Cells consist of calcium carbonate, and as animals use carbonate ion ( $\text{CO}_3^{2-}$ ) to build a shell, the acidity of the protoplasm is altered. Furthermore, animals can do calcium elsewhere, and this liberation of carbonate will again affect the pH. This is tolerable for marine organisms



**FIGURE 33-2** (A) A leaf showing of vascular tissue (stained), showing several small, clear leaf veins that conduct water out of the leaf. Each vein is the largest of other vascular tissues. (B) The same leaf, as in (A), but with calcium carbonate crystals in the vascular bundles. (C) The same leaf, as in (A), but with calcium carbonate crystals in the vascular bundles. The crystals are stained. (D) The same leaf, as in (A), but with calcium carbonate crystals in the vascular bundles. The crystals are stained. (E) The same leaf, as in (A), but with calcium carbonate crystals in the vascular bundles. The crystals are stained.

**Plants Do Things Differently Boxes** Retained by popular demand, these boxes help students understand and compare plant biology with human biology. Plants really are doing things very differently from the way we do them.

**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 15-1 Genetic Engineering and Evolution

An important area of genetic engineering is the production of herbicide-resistant crop plants. The concept is to engineer the plant so that it can be sprayed with the herbicide to kill weeds without harming the crop itself. There are arguments for and against the basic idea of using herbicides rather than using organic gardening, but for the moment, let us consider just the genetic engineering aspect.

An extremely effective herbicide called **glyphosate** became available in the 1970s (acid with the trade name Roundup). Glyphosate has many favorable features. First, it inhibits an enzyme necessary for the synthesis of three aromatic amino acids (tryptophan, tyrosine, and phenylalanine), thus those would make it deadly by blocking protein synthesis and thus, glyphosate is used to other essential plant pathways. Glyphosate is especially lethal. Second, the enzyme that animals must obtain from their diet, the enzyme glyphosate rarely poisons water because it binds so strongly to soil that it does not wash into ground water or streams. Third, fact, it is applied by spraying it onto leaves rather than mixing it with soil. Finally, it breaks down quickly into harmless products.

Why would the plant enzyme be so fundamental. How could an entire new enzyme or whole new pathway evolve in a short period of time? But glyphosate-resistant weeds have appeared already in many parts of the world, and not because they have a new enzyme. Instead, plants are variable in their capacity to transport glyphosate through phloem. Most transport glyphosate throughout their body, and a few (we do not know which) that cause them to transport glyphosate to leaf tips—it leaves the rest of the plant. In natural environments, this glyphosate did not cause glyphosate-resistant weeds. In a naturally variable population of plants, it is just that those plants suddenly are more adapted because glyphosate is part of their environment; they will become a greater part of the population as susceptible plants are killed.

## Botany and Beyond

### BOX 4-3 Chloroplast Division During Leaf Growth

Elegant studies have been done of the growth and division of leaves plastids in relationship to growth and development of leaves in spinach. In very small leaves, 1 mm long or less, plastid DNA constitutes 7% of the total cell DNA, and an average of 76 DNA circles are present in each plastid (TABLE 4-3). As the leaf doubles in size to 2 mm long, plastid DNA is replicated at approximately the same rate as nuclear DNA. As the leaf continues to expand to 20 mm long, plastid DNA is replicated much more rapidly than nuclear DNA and increases to 23% of total cellular DNA. At the same time, the number of plastids per cell triples from 19 to 59, and thus, neither plastid nor plastid DNA replication is controlled. At this point, each plastid has 190 DNA circles, and each cell has a total of 5.5 billion. In the next stage of leaf growth, to 100 mm long, no sprouting of DNA occurs, and no new cells form. Instead, those already present expand; however, plastids continue to divide even though they are not making any more DNA. Consequently, the number of DNA circles per plastid

drops from 190 to 32, whereas the number of plastids per cell increases from 29 to 171. From these data, it is reasonable to form the hypothesis that plastid growth, DNA replication, division, and development are correlated predominantly with tissue or organ development rather than with the cell cycle.

Leaf Size	1 mm	2 mm	20 mm	100 mm
Genome copies per plastid	76	76	190	32
Plastids per cell	19	59	25	171
Genome copies per cell	796	4,464	4,750	5,472
Plastid DNA as percentage of total	7%	8%	23%	23%

Data from Govil, N. S., and J. V. Pospisil. 1982. Changes in chloroplast DNA levels during growth of spinach leaves. *J. Experimental Bot.* 33: 1759-67.

### Division of Chloroplasts and Mitochondria

Mitochondria and plastids are constructed similarly to prokaryotes; they also contain circles of naked DNA that become

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

## SUMMARY

- All information required to specify protein primary structure—the sequence of amino acids—is stored in the sequence of deoxyribonucleotides in DNA.
- Cell differentiation is based largely on differential activation of genes and control of the processing of heterogeneous nuclear RNA into messenger RNA.
- The exact details of the mechanisms by which a plant hormone induces differential activation of other nuclear or organellar genes are not known. Binding of a hormone to its receptor results in the formation of transcription factors that bind to DNA promoter regions.
- The genetic code consists of triplets of nucleotides, each triplet coding for only one amino acid, or for STOP or START. The code is degenerate, each amino acid being coded by several codons.
- Genes consist of a promoter region that usually contains both exons and introns.
- In transcription, RNA polymerase attaches to the promoter region, moves to a start site, and then polymerizes RNA, being guided by base pairing in a short region of single-stranded DNA. Both introns and exons are transcribed.
- Heterogeneous nuclear RNA is processed to mRNA and then transported to the cytoplasm where it binds to ribosomes. Each ribosome has a large and a small subunit, four molecules of rRNA, and approximately 60 proteins.
- Amino acids are carried to ribosomes as part of an activated tRNA, each of which has an anticodon complementary to the codon for the amino acid it carries. All tRNAs have similar structures.
- Restriction endonucleases cut DNA at specific sequences; the resulting pieces can be methylated to the single-stranded state. Single-stranded nucleic acids from different sources can be mixed and allowed to hybridize, either as a means of their isolation or as part of the construction of a new molecule of DNA.
- Specific sequences of DNA can be synthesized artificially by incorporating one copy into a vector and then inserting the vector into a bacterium. As the bacterium reproduces, the sequence of DNA is reproduced as well.
- Most viruses are short pieces of DNA or RNA that contain a few genes closely related to normal host genes. Most plant viruses have RNA, not DNA, and a coat of just one type of protein.
- Viruses infect plants through wounds and then divert the plant's nucleic acid and protein-synthesizing machinery to the synthesis of more virus molecules, which they self-assemble into complete virus particles.

## IMPORTANT TERMS

antibiotic	eukaryotic initiation factors (eIFs)	restriction map
bacteriophage	exon	retrovirus
chromatin	expression profiling	reverse transcriptase
codon	gene	ribosomal RNA (rRNA)
complementary DNA (cDNA)	genome	ribosome
differential activation of genes	intron	start codon
DNA cloning	messenger RNA (mRNA)	stop codon
DNA denaturation	palindromes	structural region (of a gene)
DNA hybridization	polymerase chain reaction (PCR)	transcription
DNA ligase	promoter region (of a gene)	transfer RNA (tRNA)
DNA microarray	recombinant DNA techniques	yeast artificial chromosome (YAC)
	restriction endonucleases	

## REVIEW QUESTIONS

- Plants are composed of numerous types of cells that are all unique because they have distinct metabolisms. What are these metabolisms based on?
- The information needed to construct each type of protein is stored in \_\_\_\_\_.
- Because an organism grows by duplication division, all its cells have (choose one: identical, unique) genes.
- What is meant by the differential activation of genes? Explain how this affects the synthesis of cutin and P-protein.
- Cutin, lignin, and chlorophyll are not proteins. How is it possible for genes to control the synthesis of these polymers?
- A gene is made up of (choose one: RNA, protein, DNA, carbohydrate).

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**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** 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. Every chapter includes 30 to 50 thought-provoking questions.

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

## GLOSSARY

Numbers after definitions are the chapters where the principal discussion occurs. Italicized terms are defined elsewhere in the Glossary.

### A

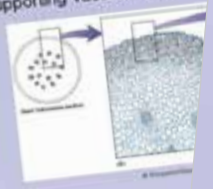
- A channel** The groove in the ribosome small subunit in which the five amino acid-carrying tRNA occurs. *Alternative: Peptide.* 15
- A horizon** The uppermost soil layer, the zone of leaching. 25
- abiotic** Refers to things that are not and never have been alive. *Compare: biotic.* 25
- abscisic acid** A hormone involved in resistance to stress conditions, stomatal closure, and other processes. 14
- abscission zone** The region at the base of an organ, such as a leaf or fruit, in which cells die and tear, permitting the organ to fall cleanly away from the stem with a minimum of damage. 6
- absorption spectrum** A graph of the relative ability of a pigment to absorb different wavelengths of light. *Compare: action spectrum.* 10
- accessory fruit** A fruit that contains nonovarian tissue. *Synonym: false fruit. Alternative: true fruit.* 9
- accessory pigment** A pigment that has an absorption spectrum different from that of chlorophyll *a* and that transfers its absorbed energy to chlorophyll *a*. 10
- acid-free paper** Paper produced by the kraft method of separating and delignifying fibers; acid-free paper is durable and long lasting. 24
- acid rain** Rain that has become acidic due to air pollution. It can damage plant cuticle as well as speed the leaching of minerals from soil. 15
- actinomorphic** *Synonym for regular flower; radially symmetrical.* 9
- action spectrum** A graph of the relative rates of reaction of a process as influenced by different wavelengths of light. *Compare: absorption spectrum.* 10
- active transport** The forced pumping of molecules from one side of a membrane to the other by means of molecular pumps located in the membrane. 3, 12
- adaptive radiation** Divergent evolution in which a species rapidly diversifies into many new species. 17
- adenosine triphosphate (ATP)** A cofactor that contributes either energy or a phosphate group or both to a reaction; as it does so, it loses either one or two phosphate groups, becoming either ADP or AMP. 10, 11
- adult plant** A plant that is mature enough to flower. *Alternative: juvenile plant.* 14
- adventitious** Refers to an organ that forms in an unusual place; refers primarily to roots that form on leaves, nodes, or cuttings rather than on another root. 7
- agamospermy** A set of methods of asexual reproduction that involve cells of the ovule and result in seeds and fruit. 9
- aggregate fruit** A fruit that develops from the crowding together of several separate carpels of one flower. *Alternative: single fruit and multiple fruit.* 9
- albuminous cell** In gymnosperm phloem, a nurse cell connected to and controlling an unlabeled sieve cell. *Compare: companion cell.* 3
- albuminous seed** A seed that contains large amounts of endosperm. *Alternative: eulabrous seed.* 9
- all-or-none response** A situation in which an organism either responds to a stimulus or does not respond; the level of response is not correlated with the level of stimulus. *Alternative: dosage-dependent response.* 14
- allele** Versions of a gene that differ from each other in their nucleotide sequences. 16
- allochemic** See allelopathy. 25
- allelopathy** The inhibition of germination or growth of one species by chemicals (allelochemicals) given off by another species. 25
- allopatric speciation** Speciation that occurs when two or more populations of one species are physically separated such that they cannot interbreed. *Alternative: sympatric speciation.* 17
- alternation of generations** A type of plant life cycle in which a diploid spore-forming plant gives rise to haploid gamete-forming plants, which in turn give rise to more diploid spore-forming plants. The generations may be similar morphologically (isomorphic) or dissimilar (heteromorphic). 9, 19–22
- amino acid** A small molecule containing an amino group and a carboxyl group; the monomers of proteins. 2, 15

# TEACHING TOOLS

A variety of Teaching Tools assist instructors with preparing for and teaching their courses. These resources are available via digital download and multiple other formats.


**Collenchyma**

- Collenchyma cells have a thin primary wall that becomes thickened in other areas.
- This allows plasticity.
- Collenchyma tends to exist:
  - Beneath the epidermis
  - Supporting vascular bundles



**Division Bryophyta: Sporophyte**

- Moss gametophytes are both large and photosynthetic, and they support the sporophyte throughout its entire life.
- All moss sporophytes form from the zygote and have 3 basic components at maturity: foot, capsule (where spores are produced), and seta.
- None is ever branched or has leaves, bracts, or buds of any kind.



**Lecture Outlines in PowerPoint format** The *Lecture Outlines in PowerPoint* format provide lecture notes and images for each chapter of *Botany: An Introduction to Plant Biology, Sixth 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.

**Solutions to Review Questions** These files contain answers to all of the end-of-chapter review questions found in the text.

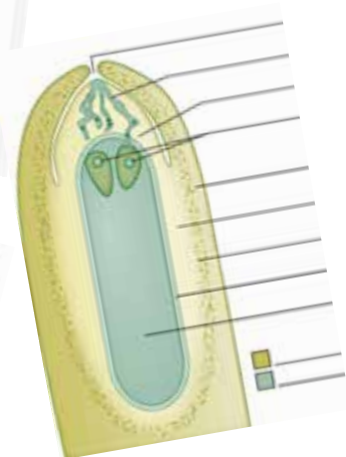
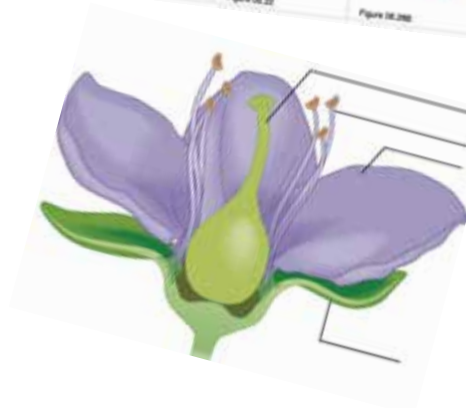
**KEY IMAGE REVIEW**

Jump to Chapter:  Go

Chapter 6: Leaves

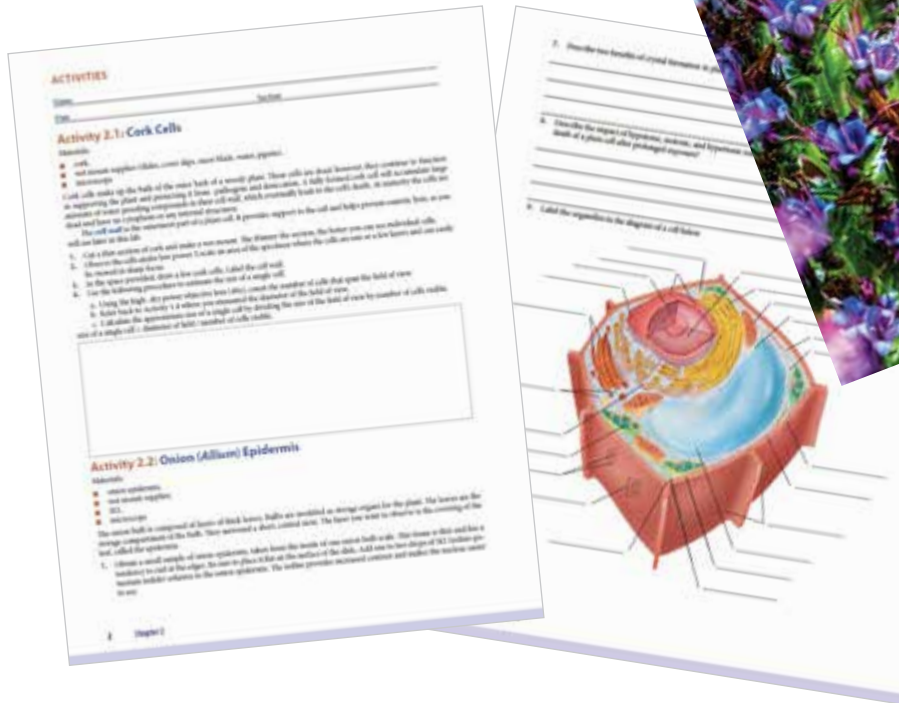
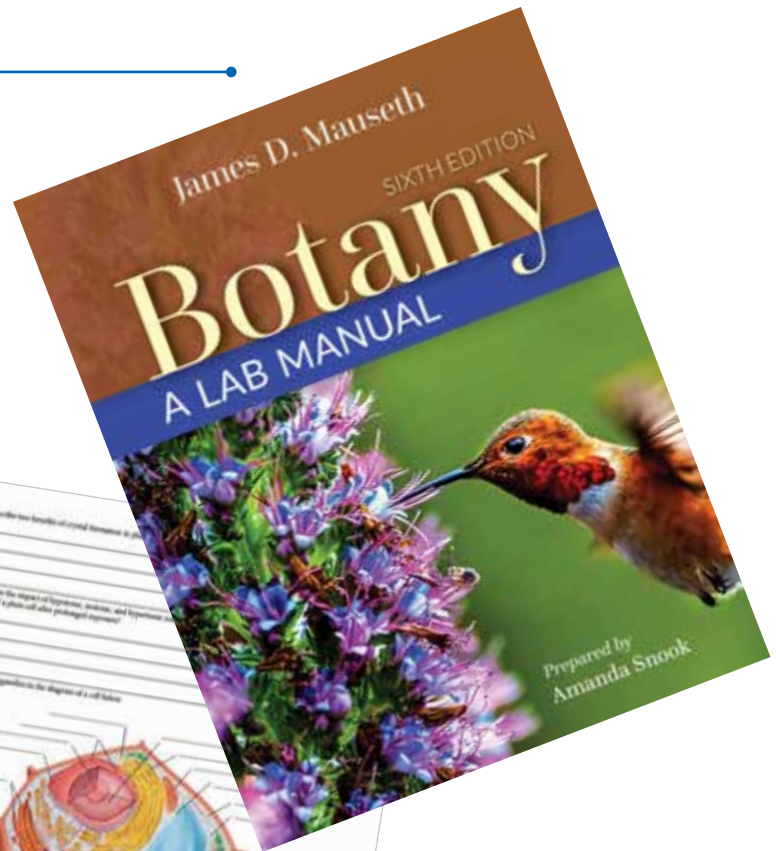


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# LAB MANUAL

**Lab Manual** *Botany: A Lab Manual, Sixth 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 *Sixth 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 new, 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: 978-1-284-11184-2**  
**Main Text + Lab Manual Bundle ISBN-13: 978-1-284-11819-3**

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- Chapter 1 Introduction to Botany and Microscopy
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- Chapter 4 Plant Tissues and Herbaceous Stems
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- Chapter 6 Roots
- Chapter 7 Secondary Meristems and Woody Growth
- Chapter 8 Photosynthesis

- Chapter 9 Cellular Respiration and Fermentation
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- Chapter 21 Community Interactions
- Chapter 22 Ethnobotany

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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 Matt Kane, Audrey Schwinn, Alex Schab, Troy Liston, Kristin Parker, and Jamey O'Quinn for their intelligent, creative solutions to many problems that had to be solved in preparing the *Sixth Edition*. This edition benefits particularly from Matt's vision to expand the treatment of environmental issues and ethnobotany, Audrey's artistic skills in designing the overall book and chapter elements, and Alex's ability to manage the thousands of details that arise in the actual production of each and every page. I also thank my husband Tommy Navarre for his never-ending (33 years so far) support, encouragement, and confidence.

James D. Mauseth, PhD  
Austin, Texas

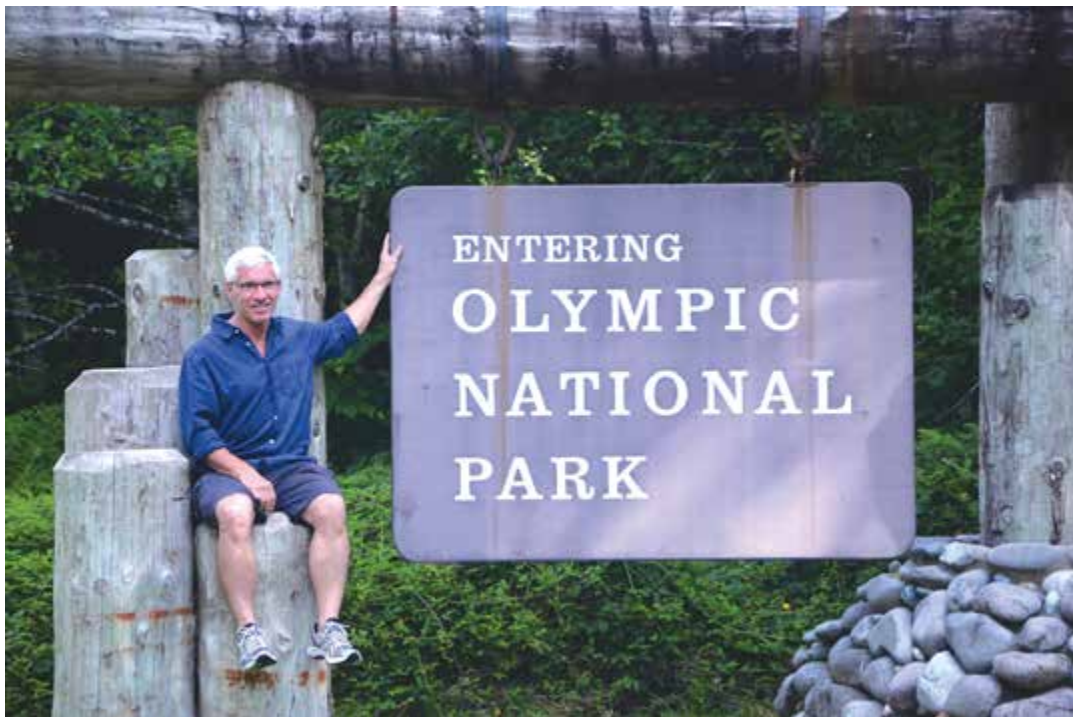
# ABOUT THE AUTHOR

**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 travelled 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.



# PRONUNCIATION GUIDE

**abiotic** ..... AY bye otic  
**abscisic (acid)** ..... ab SIZE ick ..... or ab SIZ ick (SIZ as in sizzle)  
**actinomorphic** ..... ack tin oh MORE fick  
**adenosine** ..... a DEN oh seen ..... (a as in adverse)  
**adventitious** ..... ad ven TI shush  
**allele** ..... al EEL ..... (the final e is silent;  
not al EEL ee)  
**allelochemic** ..... al eel oh KEM ick  
**allelopathy** ..... al EEL oh pathy ..... or al eel oh PATH ee  
**androecia** ..... an droh EE see uh  
**androecium** ..... an droh EE see um  
**angiosperm** ..... AN gee oh sperm  
**angiospermous** ..... an gee oh SPERM us  
**anion** ..... AN eye on ..... (not AN yun)  
**anisogamy** ..... AN eye so gam ee ..... or an eye SAW gam ee  
**antheridia** ..... anther ID ee uh  
**antheridiophore** ..... anther ID ee oh for  
**antheridium** ..... anther ID ee um  
**antipodal** ..... an TI poad uhl ..... (poad like road)  
**apomorphy** ..... AP oh more fee ..... (ap as in apple)  
**apoplast** ..... A po plast ..... (a as in adverse)  
**archaebacterium** ..... ar key bact IR ee um  
**archegonia** ..... arch eh GON ee uh  
**archegoniophore** ..... arch eh GON ee oh four  
**archegonium** ..... arch eh GON ee um  
**aril** ..... AIR ill  
**atactostele** ..... ay TACT oh steel  
**axoneme** ..... AX oh neam ..... (neam as team)  
**biome** ..... BUY ohm  
**biotic** ..... buy AW tick  
**biotroph** ..... BUY oh troph ..... (troph as in loaf)  
**bryophyte** ..... BRY oh fight ..... (bry as in dry)  
**calyces** ..... KAY li sees or KAL i sees  
**calyx** ..... KAY licks  
**cation** ..... CAT eye on  
**charophyte** ..... KAR oh fight  
**chiasma** ..... key AHS muh  
**chitin** ..... KAI tin

**chlamydospore** ..... klam IH doh spoar  
**cilia** ..... SILLY uh  
**cilium** ..... SILL ee um  
**circadian** ..... sur KAY di un  
**coenocyte** ..... SEEN oh sight  
**coenzyme** ..... KOH en zyme  
**coevolution** ..... koh ev ol OU shun  
**coleoptile** ..... coal ee OP tile  
**collenchyma** ..... kol EN kim uh  
**crista** ..... KRIS tah  
**cristae** ..... CHRIS tee  
**cuticle** ..... KIU tih kl  
**cutin** ..... KIU tin  
**cytokinesis** ..... sight oh kai NEE sis  
**cytokinin** ..... sight oh KAI nin  
**dibiontic** ..... dye bye ON tik  
**dichotomous** ..... dye KOT oh mus  
**dicot** ..... DYE kot  
**dioecy** ..... dye EE cy  
**endophyte** ..... END oh fight  
**epiphyte** ..... EPI fight  
**eudicot** ..... you DIE kot  
**eukaryote** ..... you KAR ee oat  
**euphyllophyte** ..... you FILL oh fight  
**eustele** ..... YOU steel  
**flagellum** ..... fla- GEL um  
**gamete** ..... GAM eat  
**gametophore** ..... gam EAT oh four  
**gametophyte** ..... gam EAT oh fight  
**gene** ..... jean  
**genera** ..... GEN er uh  
**genome** ..... JEAN ohm  
**genotype** ..... JEAN oh type  
**genus** ..... JEAN us or GEE nus  
**gibberellin** ..... jib er ILL in  
**gymnosperm** ..... JIM no sperm  
**gynoecium** ..... jah een EE see um  
**hila** ..... HIGH lah

<b>hilum</b> .....	HIGH lum	<b>rachis</b> .....	RAY kis
<b>homeotic</b> .....	home ee AH tik	<b>rachises</b> .....	RAY kis ease
<b>hypha</b> .....	HIGH fuh	<b>raphe</b> .....	RAY f
<b>hyphae</b> .....	HIGH fee	<b>raphide</b> .....	ray FIE d . . . . . (fie as in pie)
<b>isogamy</b> .....	eye SAW gam ee	<b>rhizoid</b> .....	RYE zoid . . . . . (zoid as in Boyd)
<b>leucoplast</b> .....	LOU koh plast	<b>rhizome</b> .....	RYE zoam . . . . . (zoam as in foam)
<b>lignophyte</b> .....	LIG noh fight	<b>ribose</b> .....	RYE bose . . . . . (bose as in gross)
<b>lysis</b> .....	LIE sis	<b>saprotroph</b> .....	SAP row troph. . . . . (troph as in loaf)
<b>lysosome</b> .....	LIE soh soam	<b>sclereids</b> .....	SKLER ee id . . . . . or SKLER eed
<b>manoxylic</b> .....	man oh ZY lik	<b>sclerenchyma</b> .....	skler EN kim uh
<b>meiosis</b> .....	my OH sis	<b>scutellum</b> .....	skee u TEL um
<b>mitosis</b> .....	my TOE sis	<b>seta</b> .....	SEAT uh
<b>monoecy</b> .....	mon EE see	<b>setae</b> .....	SEAT ee
<b>mycorrhiza</b> .....	my koh RYE zuh	<b>statocyte</b> .....	STAT oh sight
<b>mycorrhizae</b> .....	my koh RYE zee	<b>statolith</b> .....	STAT oh lith
<b>niche</b> .....	NI ch (as in rich) or KNEE ch	<b>stele</b> .....	STEAL
<b>oogamy</b> .....	OH oh gam ee . . . . . or oh AH gam ee (each "o" is pronounced)	<b>stigma</b> .....	STIG muh
<b>oogonia</b> .....	oh oh GON ee uh	<b>stipe</b> .....	STY p
<b>oogonium</b> .....	oh oh GON ee um	<b>stipule</b> .....	STIP you'll
<b>pangaea</b> .....	pan GEE uh	<b>stolon</b> .....	STOW lon
<b>paramylon</b> .....	pair AM ill on	<b>stoma</b> .....	STOW muh
<b>parenchyma</b> .....	par EN kim uh	<b>stomata</b> .....	stow MA ta . . . . . or STOW ma ta
<b>perigynous</b> .....	pair IH jen us	<b>strobilus</b> .....	STROW bil us . . . . . (strow as in grow)
<b>phage</b> .....	FAY jj	<b>stroma</b> .....	STROW muh . . . . . (strow as in grow)
<b>phellem</b> .....	FELL em	<b>stromatolite</b> .....	strow MAT oh light
<b>phelloderm</b> .....	FELL oh derm	<b>taxis</b> .....	TAX sis
<b>phellogen</b> .....	FELL oh jen	<b>taxon</b> .....	TAX on
<b>phenotype</b> .....	FEE noh type	<b>telome</b> .....	TEAL ohm
<b>phloem</b> .....	FLOW em . . . . . ("o" and "e" are distinct)	<b>thylakoid</b> .....	THIGH la koid
<b>phyletic</b> .....	fi LET ik . . . . . ("fi" as in high)	<b>ti plasmid</b> .....	TEA EYE plasmid
<b>phyllode</b> .....	FILL oad . . . . . (oad as in toad)	<b>tracheary</b> .....	TRAKE ee ary . . . . . (trake as in rake)
<b>phyllotaxy</b> .....	FILL oh tax ee	<b>tracheid</b> .....	TRAKE ee id . . . . . (trake as in rake)
<b>phylogenetic</b> .....	fi low jen ET ik	<b>trichogyne</b> .....	TRICK oh jyn . . . . . (jyn as in mine)
<b>phytoalexins</b> .....	fight oh al EX inz	<b>trichome</b> .....	TRI comb
<b>phytochrome</b> .....	FIGHT oh chrome . . . . . or fight oh CHROME	<b>tropic response</b> .....	TROPE ick . . . . . (trope as in rope; not as in Tropic of Cancer)
<b>phytoferritin</b> .....	FIGHT oh fer it in	<b>tyloses</b> .....	tie LOW sees
<b>pleiotropic</b> .....	ply oh TROH pic	<b>tylosis</b> .....	tie LOW sis
<b>pneumatocyst</b> .....	new MAT oh sist	<b>vacuole</b> .....	VAK you ol . . . . . (ol as in hole)
<b>poikilohydry</b> .....	poy kil oh HIGH dree	<b>valance</b> .....	VAY lance . . . . . (vay as in way; not as in valley)
<b>prokaryote</b> .....	pro CARRY oat	<b>violaxanthin</b> .....	vi ol uh ZAN thin
<b>protonema</b> .....	pro tow NEEM uh	<b>xerophyte</b> .....	ZERO fight
<b>protostele</b> .....	PRO tow steel	<b>xylem</b> .....	ZY lem
<b>protoxylem</b> .....	pro tow ZY lem	<b>zoospore</b> .....	ZOH oh spore . . . . . (zoh as in mow, tow, go)
<b>pycnoxylic</b> .....	pik noh ZY lik	<b>zygote</b> .....	ZIGH goat . . . . . (zigh as in sigh)