Supplementary Information

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The original version of this chapter was revised. The correction to this chapter can be found at https://doi.org/10.1007/978-3-319-77315-5_20

R. Crang et al., *Plant Anatomy*, https://doi.org/10.1007/978-3-319-77315-5

Appendix 1: Answers to End-of-Chapter Material

Chapter 1: The Nature of Plants

- **Concept Connections**

1. Crossword puzzle answers:
   Across
   3. Megaphylls
   8. Eudicot
   10. Autotroph
   11. Primary
   12. Cenozoic
   14. Sporophyte
   15. Gametophyte
   16. Coevolution

   Down
   1. Meristems
   2. Fruits
   4. Secondary
   5. Pigment
   6. Monocot
   7. Cellulose
   9. Chlorophyll
   13. Heterotroph

- **Concept Assessment**

2. e
3. c
4. c
5. e
6. c
7. a
8. c
9. a
10. d
11. e

- **Concept Applications**

12. Many scenarios apply here. One could include a variety of plants to ensure a wide variety of types of foods would ensure a complete diet. One might include soybeans in the microcosm as they contain all nine essential amino acids needed by humans. Many plants in the legume (bean) family also help provide nitrogen in the soil with the help of microorganisms, Rhizobium, contained within root nodules. Recycling of human wastes as fertilizer will be necessary.

13. Spices are derived from plant secondary compounds, a broad class of molecules produced by plants mostly for defense.

Chapter 2: Microscopy and Imaging

- **Concept Connections**

1. Crossword puzzle answers:
   Across
   2. Resolution
   4. Scanning
   6. Esau
   7. Grew
   9. Confocal
   10. Hooke
   11. Lens

   Down
   1. Brown
   3. Van Leeuwenhoek
   5. Compound
   6. Electron
   8. Transmission

- **Concept Assessment**

2. a
3. d
4. c
5. a
6. a

7. c

8. c

9. e

10. d

11. d

■ **Concept Applications**

12. Confocal laser scanning microscopy (CLSM) would be the method of choice. Start by isolating a tissue-specific promoter that is only expressed in roots. Ligate to it the gene for the green fluorescent protein (GFP). Transform an oak plant with the chimeric gene—stable transformation is a necessity. The gene should be expressed in the roots only, and GFP should be produced. Use CLSM to localize the GFP inside the root cells. CLSM is rarely used on leaf tissue because fluorescence from the abundant chlorophyll would overwhelm any signal from a fluorescent probe.

13. Scanning electron microscopy could be used to visualize surface structures such as stomata, trichomes, and waxes. Light microscopy could be used to visualize leaf internal structures such as cells, internal air spaces, and vascular strands. Transmission electron microscopy could be used to visualize cellular detail such as chloroplasts, mitochondria, and membranes.

Chapter 3: Plant Cell Structure and Ultrastructure

■ **Concept Connections**

1. Answers:
   proplastid: source of all other plastids, nitrogen fixation
   elaioplast: oil storage in the tapetum
   amyloplast: starch storage, graviperception
   etioplast: plant growth regulator synthesis
   chloroplast: photosynthesis, starch synthesis, amino acid synthesis, protein synthesis, lipid synthesis, pigment synthesis, photorespiration, sulfur assimilation, nitrogen assimilation
   gerontoplast: resource recovery
   chromoplast: seed dispersal

■ **Concept Assessment**

2. d

3. a

4. b

5. c

6. d

7. e

8. e

9. e

10. e

11. a

■ **Concept Applications**

12. Plastids are the primary anabolic organelles in cells, and they are all derived from germinal proplastids. They would need to be transplanted into the animal cells and then develop into the proper type of mature plastid needed by that host tissue.

13. A number of marine animals (mostly sea slugs) extract fully functional chloroplasts from algae and incorporate those chloroplasts into their cells. These stolen plastids are called "kleptoplasts," and the process is known as kleptoplasty. The chloroplasts remain photosynthetically active for an extended period of time

and contribute to the carbon needs of their new host. However, they cannot enter the egg cells and are not passed on to the next generation during sexual reproduction. Newly hatched young must acquire their own set of kleptoplasts.

Chapter 4: Mitosis and Meristems

- **Concept Connections**

1. Matching answers
   - c. Interphase
   - e. Prophase
   - d. Metaphase
   - a. Late anaphase
   - f. Telophase/cytokinesis
   - b. Late cytokinesis

- **Concept Assessment**

2. a
3. a
4. e
5. a
6. d
7. b
8. a
9. e
10. b
11. e

- **Concept Applications**

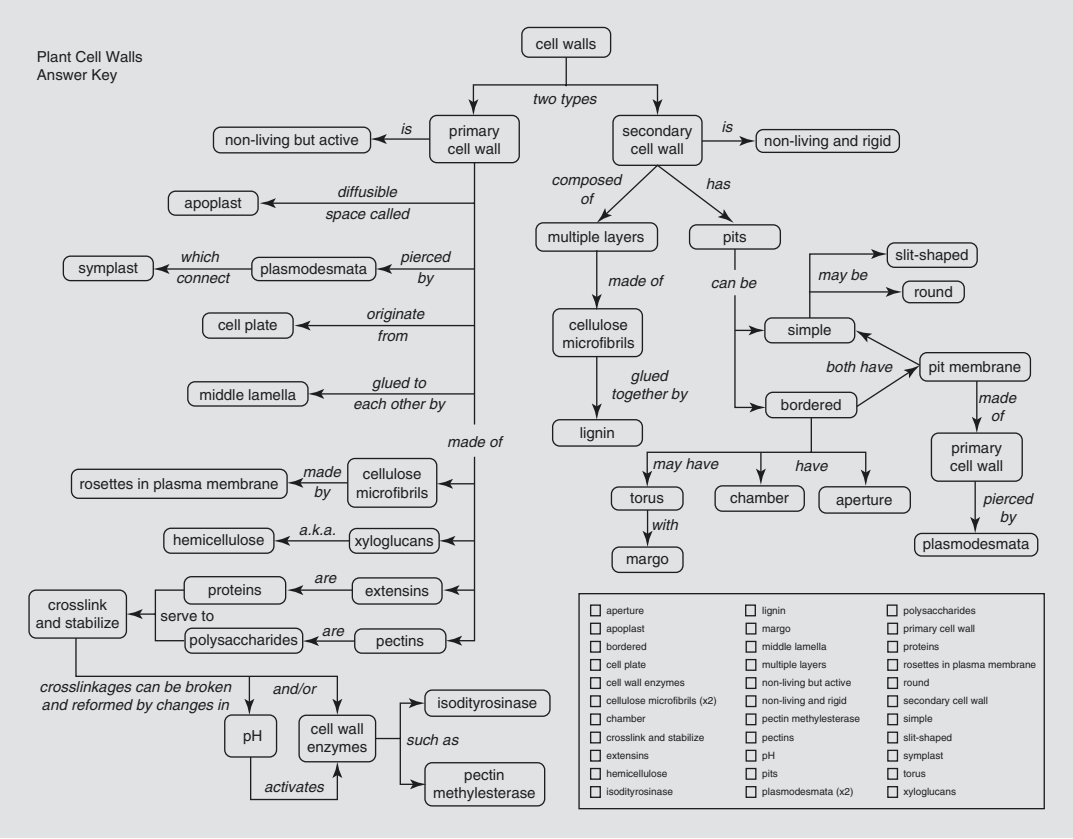
12. Amyloplasts (also called statoliths) in the root cap settle in response to the gravitational field, interact with the endoplasmic reticulum at the "bottom" of the cell, and indicate which direction is down. The root cap cells then send signals to the adjacent root tip cells to induce cellular division and elongation in a directional manner.

13. Shoot lateral organs originate exogenously, whereas lateral root organs must originate endogenously because the shoot is growing through air but the root is growing through soil. If a root produced a lateral root at the tip of a developing primary root, that young lateral root would be torn off as the primary root is pushed downward through the soil. Therefore, lateral roots develop further back on the root, where forward expansion has stopped. The only meristematic tissues available at that part of the root are the internal pericycle. Developing leaves, on the other hand, face no resistance as the shoot tip on which they are borne pushes through the air.

Chapter 5: Cell Walls

■ Concept Connections

1. Concept map answers



■ Concept Assessment

2. c
3. a
4. e
5. a
6. b
7. d
8. e
9. e
10. d
11. e

■ Concept Applications

12. Woody plants would be the plant of choice as they produce more biomass per year. In addition, woody plants keep the carbon sequestered for multiple years, whereas herbaceous plants typically have shorter life spans and their carbon is quickly returned to the atmosphere as they die and decompose.

13. Pectins form the basis of the glue that holds cells together. PMEs break down the pectin, cells detach from one another, and the fruit "softens."

Chapter 6: Parenchyma, Collenchyma, and Sclerenchyma

Concept Connections

1. Answers
   a. Angular collenchyma
   b. Annular collenchyma
   c. Astrosclereids
   d. Brachysclereids
   e. Fibers
   f. Lacunar collenchyma
   g. Lamellar collenchyma
   h. Sclereid (xylem vessel element)

Concept Assessment

2. d
3. b
4. d
5. e
6. a
7. c
8. b
9. d
10. b
11. e

Concept Applications

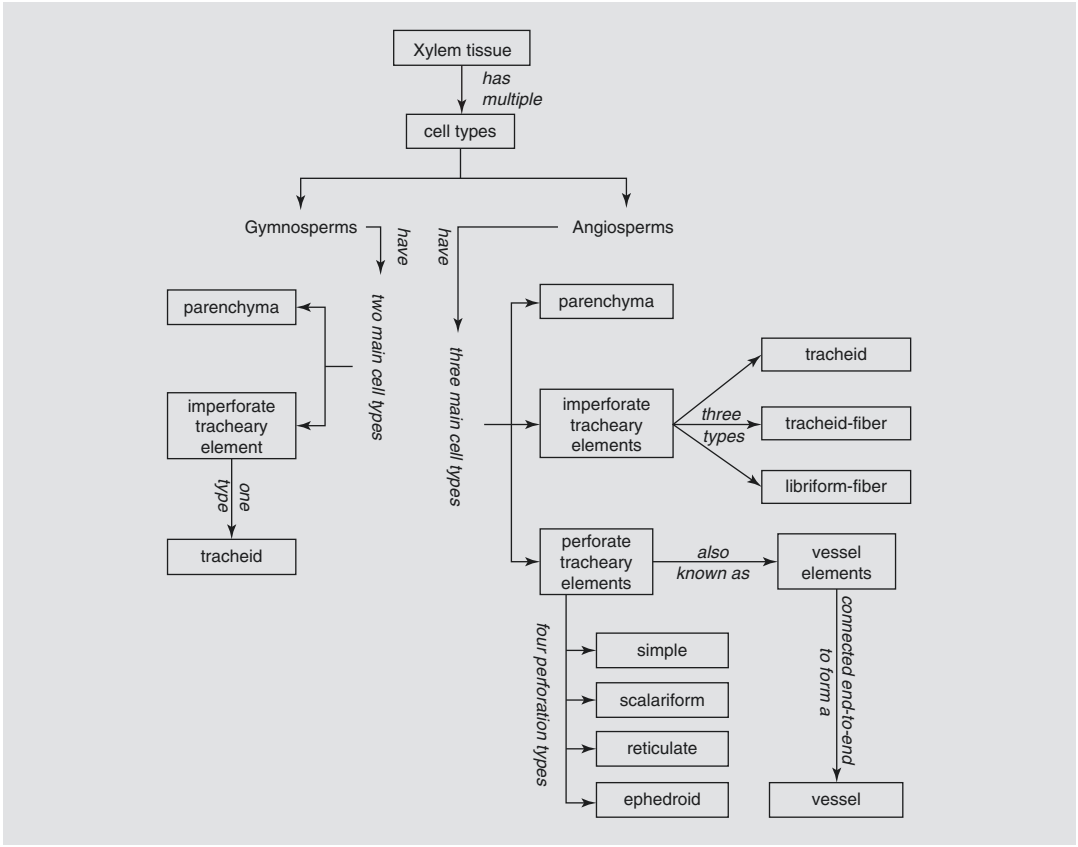
12. Animal body plans, and the names of the tissues, organs, and cells within those body plans, are arranged around "systems." Namely, there is a circulatory system, nervous system, digestive system, excretory system, etc. Each system may have multiple organs such as the esophagus, stomach, small intestine, and large intestine of the digestive system. Animal anatomy is taught from the system standpoint. Plant body plans, on the other hand, are arranged around organs—leaf, stem, root, flower, and fruit—and each organ is composed of a mixture of parenchyma, sclerenchyma, and collenchyma cells. Therefore, understanding plant anatomy is best approached by understanding the characteristics of those three cell types and then integrating them into tissues (dermal, ground, vascular) and then organ.

13. Totipotency is the ability of a cell to develop into multiple different cell types. In humans and other animals, these are typically called "stem cells" and are restricted, for the most part, to cells of the embryo. Once an embryonic stem cell heads down a developmental pathway, it is very difficult or impossible to revert to totipotency. The majority of plant cells are parenchyma, and many of those retain their totipotent ability into maturity. Meristematic cells, which are found in apical meristems, lateral meristems, and open vascular bundles, remain totipotent for the entire life of the plant.

Chapter 7: Xylem

■ Concept Connections

1. Concept map answers



■ Concept Assessment

2. e
3. b
4. c
5. d
6. e
7. a
8. b
9. d
10. a
11. b

■ Concept Applications

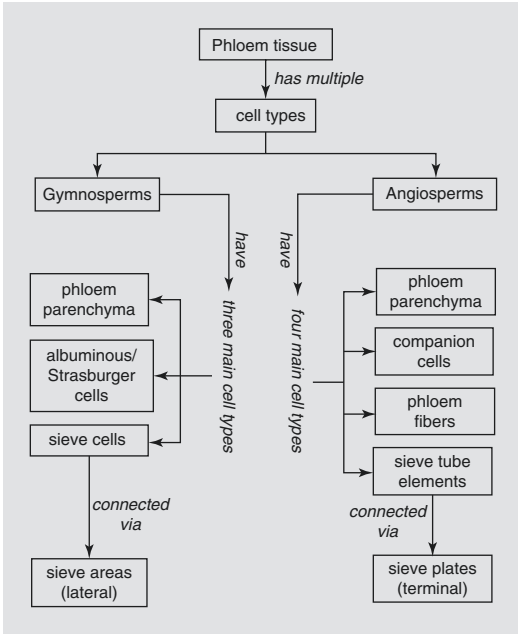
12. Angiosperm secondary xylem consists of three types of imperforate tracheary elements (tracheid, tracheid-fiber, libriform-fiber) and perforate tracheary elements (vessel elements) and xylem parenchyma. Gymnosperm secondary xylem has one type of imperforate tracheary element (tracheid) and xylem parenchyma. All of the tracheary elements function, to smaller or greater degrees, in water conduction and support. The parenchyma cells serve roles in storage and water balance. The cells perform similar functions in both angiosperms and gymnosperms, but the greater diversity of tracheary elements in angiosperms allows them to occupy a greater diversity of ecological niches.

13. Water is cohesive. Therefore, water exits the stoma via transpiration and in turn draws water from the leaf mesophyll, leaf vasculature, petiole, stem, root, and eventually soil. Because the water is being pulled, not pushed, it is always under tension during times of active transpiration (typically daytime). Water adheres to the inner surfaces of the tracheary elements and does not drain back to the roots when transpiration stops (typically nighttime). Cavitation is the formation of bubbles of water gas and occurs when the water column is pulled too hard (because the air or soil, or both, is dry). Cavitation events block water flow through that tracheary element and have been a powerful driver of tracheary element evolution.

Chapter 8: Phloem

■ Concept Connections

1. Concept map answers



■ Concept Assessment

2. e
3. c
4. d
5. a
6. e
7. c
8. d
9. b
10. e
11. a

■ Concept Applications

12. Angiosperm secondary phloem is composed of sieve tube elements (STE, responsible for translocation of photosynthate), companion cells (STE metabolic support, phloem loading/unloading), phloem parenchyma (storage and water balance), and phloem fibers (support). Gymnosperm secondary phloem contains sieve cells (SC, translocation) and albuminous/Strasburger cells (SC metabolic support, loading/unloading).

13. Phloem sap movement (translocation) as described by the Münch pressure flow hypothesis is osmotically driven. Osmotically active photosynthate molecules (sugars) are actively loaded into the STE in the source tissue, which decreases the water potential of the phloem sap. This causes an influx of water via osmosis (supplied by the adjacent xylem tissue) and a pressurization of the STE. The phloem sap is then forced toward the sink cells, where the sugars are actively unloaded, water follows the

osmolytes, and the pressure drops. A water potential gradient is established between the source tissues (higher pressure) and the sink tissues (lower pressure). Therefore, the sugar molecules being translocated are responsible for creating the water potential gradient that drives their own transport.

Chapter 9: Epidermis

■ Concept Connections

1. Matching answers:
   i. (j) Anomocytic stomatal complex (*Betula papyifera* leaf)
   ii. (i) Pavement cells (*Acer negundo* leaf)
   iii. (e) Multicellular non-glandular trichome (*Solanum tuberosum* leaf)
   iv. (f) Epidermal waxes (*Phaseolus vulgaris* leaf)
   v. (h) Glandular trichome (*Juglans nigra* fruit)
   vi. (g) Silica bodies (*Setaria* sp. leaf)
   vii. (a) Hypostomatous leaf (*Epipactis* sp. leaf)
   viii. (c) Paracytic stomatal complex (*Eichhornia crassipes* leaf)
   ix. (b) Non-glandular trichomes (*Cucurbita* sp. leaf)
   x. (d) Amphistomatous leaf (*Lactuca* sp. leaf)

■ Concept Assessment

2. d
3. a
4. c
5. a
6. e
7. c
8. e
9. a
10. e
11. a

■ Concept Applications

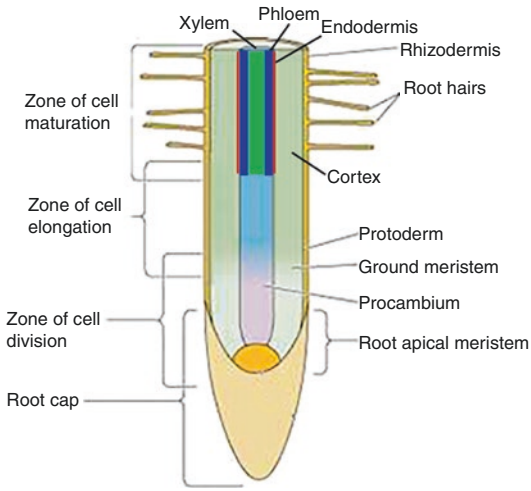
12. Chaparral is an ecosystem of shrubs and heaths found in the southwestern USA and the northern Baja of Mexico. It is characterized by a Mediterranean climate of hot, dry summers and cool, wet winters. Chaparral plants develop thick waxy cuticles to preserve moisture during the summer droughts. Many of the species are drought deciduous and shed their leaves in the summer. The chaparral ecosystem has evolved to withstand fires on a 10–20-year cycle. Fire repression by humans generates a multiyear accumulation of dry, wax-coated leaf litter which represents a significant "fuel load." In such areas, fires can be extremely severe and have devastating impacts.

13. Stomatal density is somewhat sensitive to the carbon dioxide concentration present during leaf development, with fewer stomata under high CO_2 levels. Scientists have quantified stomatal densities on fossil leaves and used those values as a proxy for the $[CO_2]$ at the time the leaf was fossilized.

Chapter 10: Roots

■ Concept Connections

1. Labeled as ◘ Fig. 10.3 a. The procambium gives rise to the xylem, phloem, and pericycle. The ground meristem gives rise to the cortex and the endodermis. The protoderm gives rise to the rhizodermis which gives rise to the root hairs.



■ Concept Assessment

2. b
3. d
4. c
5. c
6. b
7. a
8. d
9. e
10. c
11. b

■ Concept Applications

12. Stem cuttings work because stems have nodes from which more stem, leaves, and adventitious roots can develop. Roots do not have nodes and cannot produce stems or leaves.

13. The roots respond normally; they grow downward. So do the shoots, they grow upward. However, because the roots are constrained by the bottom of the bucket, they are forced to grow laterally and, to a certain degree, up the insides of the container. The shoots are pulled down by their weight and the weight of the fruit, even though the shoot tips point upward. It is a completely artificial orientation, but as long as the roots can get water and the shoots can get light, the plant will survive.

Chapter 11: Stems

■ Concept Connections

1. Answers to matching:
   a. Rhizome = storage, perennation, and asexual reproduction
   b. Corm = perennation and storage
   c. Stolon = asexual reproduction
   d. Cladode = photosynthesis
   e. Tendril = attachment

■ Concept Assessment

2. d
3. d
4. e
5. a
6. b
7. a
8. e
9. c
10. a
11. d

■ **Concept Applications**

12. Palms and bamboo take advantage of the ability of each vascular bundle to generate fibers to both the interior (adaxial) and exterior (abaxial). Each of the hundreds of vascular bundles in the stem ("trunk") becomes heavily sclerified which imparts great strength to the stem.

13. The primary thickening meristem covers the stem apex. At its center, the divisions are perpendicular to the stem axis and contribute to the length of the stem. As the apex grows in length, those meristematic cells are pushed and reoriented to the side where they divide in a plane parallel to the stem axis and contribute to the width (girth) of the stem.

Chapter 12: Leaves

■ **Concept Connections**

1. Answers to matching:
   a. Foliage = ii. photosynthesis = f. *Rosa* sp.
   b. Leaf sheath = i. support = *c.* many grasses
   c. Cataphyll = v. protection = *h.* bud scales
   d. Frond = iv. photosynthesis = *g.* ferns and duckweeds
   e. Pseudostem = i. support = *k. Musa* sp.
   f. Scutellum = absorption = *d.* monocotyledon seed
   g. Needle = vi. photosynthesis = *i.* conifers
   h. Spine = iii. antiherbivory = *b.* cacti
   i. Cotyledon = vii. food storage = *a. eudicotyledon* seed
   j. Hypsophyll = viii. floral structures = *e.* flowering plants
   k. Tendril = x. attachment = *j. Clematis* sp.

■ **Concept Assessment**

2. c
3. a
4. b
5. e
6. c
7. d
8. b
9. d
10. b
11. a

■ **Concept Applications**

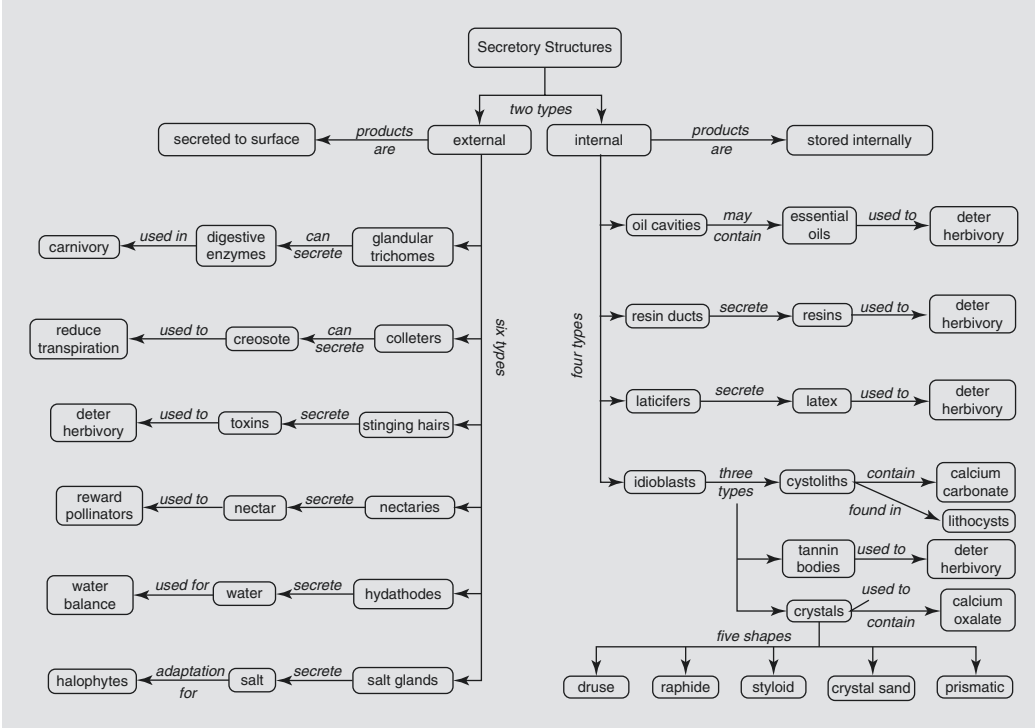
12. Leaves of the xeromorphic *Nerium oleander* leaf have a thick cuticle, stomatal crypts, and numerous trichomes extending into the crypt. All of these features are adaptations of the leaf epidermis. The cuticle prevents water loss through the epidermis. The stomatal crypts and trichomes create a dead-air space to which the stomata are exposed, thus reducing transpiration.

13. Most gymnosperms are "evergreen," meaning they retain their leaves for multiple growing seasons. The period of the year between the favorable growing seasons is usually cold and dry (ground water is frozen and in the solid state). Therefore, their leaves have xeromorphic adaptations as mechanisms for surviving the "drought" of winter.

Chapter 13: Secretory Structures

■ Concept Connections

1. Concept map answers



■ Concept Assessment

2. e
3. b
4. a
5. e
6. b
7. c
8. a
9. d
10. e
11. b

■ Concept Applications

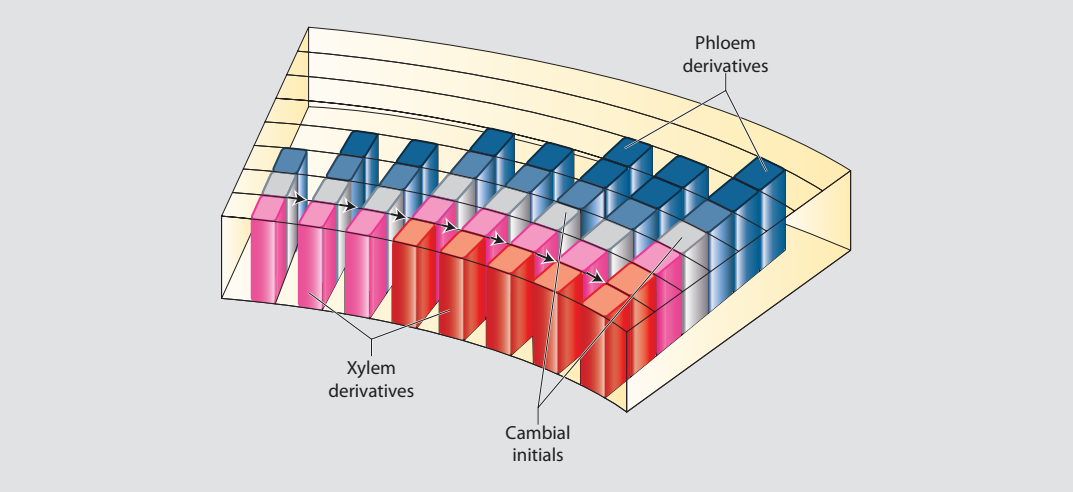
12. Antiherbivory structures include stinging hairs, laticifers, oil glands, resin ducts, crystal-containing idioblasts, and glandular trichomes. They all serve to deter feeding by stinging, trapping, or poisoning animals—mostly, but not exclusively, insects.

13. The connection between carnivory and high light has to do with competition. Noncarnivorous plants do not grow well in the low-nutrient environments to which carnivorous plants are adapted. Therefore, carnivory provides a competitive advantage and allows such plants to grow where others will not.

Chapter 14: Vascular Cambium

- **Concept Connections (Springer to Redraw)**

1. Labeled drawing



- **Concept Assessment**

2. c
3. b
4. d
5. b
6. b
7. a
8. c
9. c
10. e
11. a

- **Concept Applications**

12. Closed vascular bundles lack a vascular cambium and cannot generate new vascular tissues. That is to say, they cannot contribute to secondary growth, only primary growth. Open bundles have a vascular cambium and can contribute to secondary growth.

13. Holoparasites rely on the host plant for water (via a xylem connection) and photosynthate (via a phloem connection). They get all of their nutrition from the host and do not need to photosynthesize.

Chapter 15: Wood – Economics, Structure, and Composition

- **Concept Connections**

a. *Sassafras albidum*
b. *Quercus rubra*
c. *Carya illinoinensis*
d. *Diospyros virginiana*
e. *Juglans cinerea*
f. *Ilex opaca*
g. *Malus domesticus*
h. *Albania julibrissin*
i. *Cornus florida*
j. *Magnolia virginiana*

■ Concept Assessment

2. b
3. d
4. b
5. e
6. e
7. b
8. e
9. b
10. c
11. c

■ Concept Applications

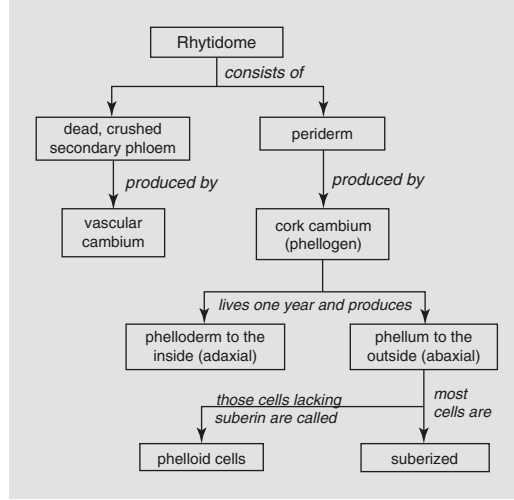
12. For the boat building industry engineer, select for slow growth (strength) and tyloses. For the furniture industry engineer, select for slow growth (strength), maximum heartwood (color), and different patterns of vessel element distribution (to generate figure). For the paper industry engineer, select for fast growth (maximum production, easier to chip) and minimal lignin (easier to digest or macerate).

13. Students might access the following websites for their minute paper:
Forest Stewardship Council – ► https://ic.fsc.org
Weyerhaeuser – ► https://www.weyerhaeuser.com/timberlands/forestry/sustainable-forestry/
Georgia Pacific – ► https://www.gp.com/Company/Sustainability/Forestry
World Resources Institute – ► http://sustainableforestproducts.org/

Chapter 16: Periderm

■ Concept Connections

1. Concept map



■ Concept Assessment

2. d
3. a
4. c
5. e
6. c
7. b
8. d
9. e
10. d
11. b

■ Concept Applications

12. The cork removed from the cork oak (*Quercus suber*) is only the dead outer bark. The living, inner bark is left intact. Overharvesting just the outer bark would do little damage, but the yield would be low and result in a lower quality of cork. Removing the vascular

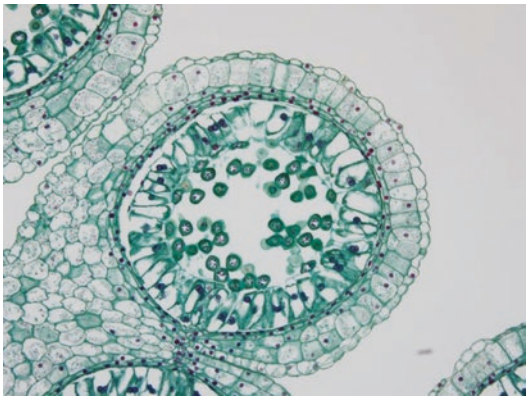
cambium, the living secondary phloem, or the inner bark (vascular cambium, living secondary phloem, and phellogen) would kill the tree.

13. Both the vascular cambium and the cork cambium generate cells that make up the rhytidome. The vascular cambium persists for the entire life of the tree. It produces secondary xylem to the interior and secondary phloem to the exterior. A growing season's worth of secondary xylem accumulates each year and forms annual tree rings. The secondary phloem, which consists of conducting cells and fibers, is crushed each year, and those dead cells intermingle with the periderm cells to form the rhytidome. The phellogen (usually) arises from the cells of the cortex, produces the periderm (phelloderm to the interior and phellem to the exterior), and ceases activity at the end of the growing season. A new phellogen arises the next year, or multiple phellogens may arise in a single growing season.

Chapter 17: Floral Development and Male Reproduction

Concept Connections

1. epidermis (1), connective (2), tapetum (3), and developing microspores (4).



Concept Assessment

2. c
3. a
4. e
5. c
6. a
7. e
8. c
9. e
10. e
11. b

Concept Applications

12. While both genera are within the same plant family (Asteraceae), the goldenrod pollen has evolved a sticky pollen to facilitate dispersal by insects. In contrast, ragweed has evolved to be buoyant in the air.
13. The evolution of exine structure appears to be related to how the pollen is physically dispersed between plants. For example, terrestrially dispersed pollen has a thicker exine than amphibiously dispersed pollen. Pollen from hypohydrophilous plants that are underwater has very thin exine and may be coated with remnants of the tapetum.

Chapter 18: Female Reproduction and Embryogenesis

Concept Connections

1. Crossword puzzle answers:
    1. Cordate
    2. Axile
    3. Funiculus
    4. Cotyledon
    5. Integument
    6. Inferior
    7. Suspensor
    8. Endosperm
    9. Proembryo

10. Double
11. Superior
12. Basal
13. Chalaza
14. Megagametogenesis

■ **Concept Assessment**

2. c
3. b
4. b
5. e
6. e
7. a
8. c
9. a
10. c
11. a

■ **Concept Applications**

12. The evolution of double fertilization was likely due to the efficiency of providing for offspring (producing endosperm) only when embryos were developing. Hence, less waste occurs as nutrients are only produced for offspring when needed.

13. Pollination is a process that occurs prior to fertilization. It takes time for sperm cells within the pollen tube of an angiosperm to get to the egg cells within the embryo sac. Given that the number of ovules within a flower is limited, the sperms must compete with those from other pollen grains in fertilizing egg cells, resulting in pollen tube competition. Thus, we see natural selection occurring at the level of the gametophyte.

Chapter 19: Fruit, Seeds, and Germination

■ **Concept Connections**

1. Identify
   a. Emerging leaves
   b. Hypocotyl hook
   c. Cotyledon
   d. Seed coat
   e. Hypogeal (even though a bit of the cotyledon is visible above the soil)
   f. Eudicot (mung bean—*Vicia faba*)

■ **Concept Assessment**

2. d
3. b
4. a
5. b
6. a
7. e
8. c
9. d
10. d
11. a

■ **Concept Applications**

12. a. The Tariff Act of March 3, 1883, declared that a tax be paid on vegetables imported to the USA. Fruits were excluded from the act. John Nix was an importer of fruits and vegetables in New York City. The tax collector of the Port of New York, Edward Hedden, had assessed taxes on Mr. Nix's imported tomatoes, claiming they were vegetables, and therefore subject to the Tariff Act. Nix sued Hedden to recover the tariffs paid on the basis that tomatoes are (botanically) fruit and should therefore be exempt from the act. Nix lost.

b. When tomatoes were introduced to Europe in the 1500s, they were seen as exotics and cultivated and eaten by aristocrats more so than the common person. Aristocrats could afford to use pewter plates, those of lesser classes could not. Pewter is an alloy of lead and tin. Tomatoes are naturally acidic. Serving a tomato dish on pewter plates extracts the lead from the pewter, which can lead to lead poisoning.

c. In 1753 Carolus Linnaeus applied the name *Solanum lycopersicum* to tomato, the same genus as potato. In 1768, Philip Miller moved the plant to a different taxon and changed the name in to *Lycopersicon esculentum*. It was not until the 1990s—over 200 years—before the error was corrected and the designation by Linnaeus was recognized as valid.

13. a. An aggregate fruit is a made of multiple individual carpels on a single flower, each of which generates an individual fruit. All of the individual fruits remain attached to the same receptacle. A multiple fruit is composed of the ovaries of multiple individual flowers fused together.

b. A drupe is a fleshy fruit derived from a single carpel. All three pericarp layers (exocarp, mesocarp, and endocarp) are fleshy. An achene is a dry, indehiscent fruit in which all the pericarp layers are sclerified and fused together.

c. In epigeal germination, the cotyledons (and the first internode to which they are attached) are pushed above the soil surface. In hypogeal germination, the cotyledons (and the first internode to which they are attached) remain below the soil surface.

Glossary

abaxial Facing away from the axis of stem or root (as opposed to adaxial). Also, typically the lower surface of leaves.

abscisic acid A plant growth regulator involved in abscission, germination, flowering, senescence, and other processes.

abscission The dropping of leaves, fruits, or floral structures upon maturation or at the end of a growing season.

abscission zone The layer of cells which transverses the structure (e.g., petiole) which is separated in the process of abscission.

accessory fruit A fruit composed primarily from tissues other than the ovary.

acicular crystal Typically, a calcium oxalate crystal which is elongated into a needle shape, such as raphides and styloids.

acropetal Directed toward the apex of an organ, e.g., the tip of a stem or root.

achene A dry, indehiscent fruit with a single carpel characterized by the fusion of the exocarp, mesocarp, and endocarp into a thin, hard layer which is not fused to the seed, for example, sunflower and strawberry.

actin A globular protein often organized into two filamentous strands wound around each other. An important component of the cell cytoskeleton.

actinostele A protostele that is star-shaped in cross-sectional view.

adaxial Facing toward the axis of stem or root (as opposed to abaxial). Used to describe the upper surface of leaves.

adnation Fusion of stamens, pistils, or petals in a flower involving different whorls.

adventitious Anomalous growth of tissues or organs as in the growth of roots directly from stems and/or leaves.

aerenchyma Parenchymatous tissue characterized by air spaces between cells.

aggregate fruit A fruit developing from a single flower but with multiple carpels.

albedo The white, air-filled mesocarp of a hesperidium. See flavedo.

albuminous cells Found in gymnosperm phloem where cells which are functionally and structurally similar to companion cells exist but do not originate from the same precursors as do the companion cells in angiosperms. Same as a **Strasburger cell**.

aleurone layer The outermost layer of the endosperm in grass seeds which are characterized by large protein deposits and enzymes which can degrade the endosperm.

alternation of generations A life cycle characteristic of higher plants that have both haploid and diploid phases.

aliform xylem parenchyma A pattern of xylem parenchyma in which the parenchyma forms winglike extensions around the vessels.

amphicribral vascular bundle A concentric vascular bundle in which the phloem surrounds the xylem tissue.

amphiphloic siphonostele A stele in which the vascular system appears as a tube with the phloem located on both the external and internal sides of the xylem.

amphistomatous leaves Having stomata on both adaxial and abaxial surfaces of a leaf.

amphivasal vascular bundle A vascular bundle in which the xylem surrounds the phloem.

amyloplast A colorless plastid containing starch grains, involved in starch storage and graviperception.

anabolism Utilizing energy to synthesize molecular structures. See catabolism.

anaphase That phase of mitosis or meiosis in which the separation of chromatids takes place in the opposite poles of the cell.

anatropous A configuration of an ovule in which it is bent downward with the micropyle adjacent to the funiculus.

androecium Collectively, all of the stamens in the flower of a seed plant.

anemophilous Pollinated by wind.

angiosperm Higher plants in which seeds are borne within a mature ovary.

angular collenchyma Collenchyma cells in which the primary wall is thickened at intercellular sites with adjacent cells.

anomalous vascular cambium Unusual growth (usually of secondary nature) from vascular cambium.

annual plant A plant that completes its life cycle in 1 year and then dies.

annual ring The growth of xylem tissues formed in a single growing season as observed in transectional view.

annular cell wall thickenings Secondary wall thickenings appearing as rings in xylem tracheary cells.

annular collenchyma Collenchyma cell in which the primary wall is uniformly thickened.

antechamber A recessed space beneath the stomatal opening.

anther The pollen sack typically at the terminus of a stamen.

anthesis The time period during which the flower is open and available to release and/or accept pollen.

anthocyanin A red, purple, or reddish-blue water-soluble pigment found in the cell vacuole.

anthropogenic Of human origin or cause.

anticlinal A plane of growth or development at right angles to the nearest surface.

antiherbivory compounds Any one of hundreds of secondary compounds produced by plant leaves, stems, or roots that serve to deter herbivory.

antipodals In angiosperms, the cells at the opposite end of the embryo sac from the site of the zygote.

aperture A thin plate of exine covering an opening through which the pollen tube may emerge (in pollen). May also be an opening into a pit from the interior of a cell.

apical cell A cell found at the apex which is typically the origin, or initial, of a meristem.

apical dominance Situation in which the central stem grows more vigorously than the lateral branches.

apical meristem A group of mitotically dividing cells found in the apical region of a root or shoot and which give rise to primary tissues.

apical tip growth Growth at the pollen tube tip.

apocarpy The lack of fusion between carpels in a flower (also free carpels).

apoplast Region of the plant body outside of the living cell contents, typically limited to the cell wall and intercellular spaces.

apoplastic loading The process of phloem loading seen in some plants in which the photosynthate is exported from the companion cell to the apoplast and then taken up by sieve tube elements. See symplastic loading.

apotracheal xylem parenchyma That parenchyma in wood which is not closely associated with vessel members.

apposition Growth of cell wall by successive deposition of layers of wall material.

areole A leaf mesophyll region limited by vascular tissues around it.

articulated laticifer Fusion of two or more cells in a laticifer in which the partitioning walls are partly or wholly lacking.

aspirated pit A bordered pit in gymnosperm wood in which the pit membrane is displaced to one side and the torus blocks the aperture.

astrosclereid A branched sclereid.

atactostele A stele with the vascular bundles scattered throughout the ground tissue.

atrichoblast A rhizodermal cell that does not give rise to a root hair.

autotroph An organism capable of making its own food substances from (usually) light energy and producing organic material from CO_2 as a raw material.

autumnal senescence In leaves, a genetically controlled process of resource recovery that takes place in the fall and ends in leaf abscission.

axial parenchyma That parenchyma found in the vertical axis of a plant, not associated with rays.

axial vascular system Secondary vascular cells derived from cambial initials and with their axis running parallel with the axis of the stem or root.

axial tracheid Tracheids in the axial system of secondary xylem, in contrast to ray tracheids.

axis The upper (and usually smaller) angle between a stem and the petiole of a leaf.

axile placentation A form of placentation in which ovules are attached at the center (the axis) of a compound ovary.

axillary bud A bud found in the axil of a leaf.

axillary meristem The meristematic region in the axil of a leaf that gives rise to an axillary bud.

banded xylem parenchyma A pattern of xylem parenchyma in which the parenchyma appears as large bands.

bark A general term for all tissues outside of the vascular cambium.

basal placentation A form of placentation in which ovules are attached at the base of the ovary.

bast fiber Any fibrous tissue outside of the xylem, primarily phloem fibers.

berry A fleshy fruit with multiple carpels characterized by a papery exocarp and fleshy mesocarp and endocarp, for example, tomato.

bicollateral vascular bundle A vascular bundle with phloem on two sides of the xylem.

biennial plant Higher plants that require 2 years to complete their growth cycle; the first year is vegetative growth and the second year reproduction and death.

bifacial initials Secondary growth at two sites, e.g., cork cambium is producing cork while vascular cambium is producing vascular tissues.

bifacial leaf Leaf with palisade mesophyll on one side of the leaf (within the epidermis) and spongy mesophyll on the other.

birefringence Having a refractive property to light that alters its pathway, often characteristic of crystals.

biforine cell An idioblast in the leaf or stem of plants in the Araceae containing a bundle of raphide crystals.

biseriate ray A vascular tissue ray that is two cells wide.

bordered pit A pit in the secondary wall which overarches the pit membrane.

bordered pit-pair The pairing of bordered pits from adjacent cells.

boundary layer resistance The resistance imposed on leaf gas exchange by still air on the leaf surface.

brachysclereid A thick-walled sclereid that is nearly isodiametric.

branch root A root arising from the pericycle of the primary root. Same as **lateral root**.

Brownian movement Microscopic random movement of small particles due to bombardment of surrounding molecules.

bulliform cell In grasses, it appears as a large epidermal cell arranged in a row that may regulate the rolling or unrolling of the leaf.

bundle sheath One or more layers of cells which enclose a vascular bundle in a leaf. While usually parenchyma cells comprise the bundle sheath, they may also be composed of sclerenchyma cells.

bundle sheath chloroplast In C_4 plants, chloroplasts in the bundle sheath are agranal and lack photosystem II activity.

bundle sheath extension An extension of the bundle sheath cells that extends to one or both of the epidermal layers in a leaf.

C_3 photosynthesis Plants that only use the Calvin cycle to produce carbohydrates but also undergo photorespiration.

C_4 photosynthesis Plants that convert CO_2 by means of a two-stage process into a four-carbon molecule and do not have photorespiration.

callose Depositions of ß-1,2 glucan (a carbohydrate which can be hydrolyzed to glucose residues) on sieve plates in phloem, as partitions in pollen tubes, and occasionally in parenchyma cells.

callosic wall A temporary cell wall, made of callose, that forms around developing pollen grains.

calyptrogen Meristematic cells (histogen) of the root tip which give rise to the root cap. Characteristic of monocots.

calyx Collectively, all the sepals of a flower.

cambial initials Cells of the vascular cambium which give rise through periclinal divisions to either phloem or xylem (fusiform initials) or to rays (ray initials).

cambial zone While technically only a single layer of cells that produces both xylem and phloem, it is a region of cells that may include both tissues due to inability to accurately distinguish the individual cells.

cambium Lateral meristematic cells of either vascular cambium or cork cambium.

candelabra trichome A highly branch trichome.

capsule A dry, dehiscent fruit type characterized by multiple capsules. See also poricidal, loculicidal, and septicidal fruit.

carotenoid Naturally occurring plant pigments appearing red, orange, and yellow for the most part.

carpel Highly modified leaflike organs in angiosperm flowers that produce one or more ovules.

caryopsis A dry, indehiscent fruit with a single carpel characterized by the fusion of the exocarp, mesocarp, and endocarp into a thin, hard layer which are fused to the seed and seed coat, for example, maize and wheat.

Casparian strip Deposits of suberin and lignin on the radial and transverse anticlinal walls of the root endodermis which limit the flow of water and solutes through the apoplast.

catabolism The breakdown of larger molecules to form smaller ones while releasing energy. See anabolism.

cataphyll A leaf modified to perform functions other than photosynthesis such as protection of an immature bud.

cavitation The process by which liquid water will undergo a phase change to gaseous water within the xylem of gymnosperms and angiosperms. Occurs most frequently under conditions of high transpirational demand (high tension).

cell cycle The process of cell division, typically mitosis, giving rise to daughter cells.

cell plate The partition of cell wall material that appears during the latter stages of mitosis and which becomes the new primary cell wall that separates the daughter cells.

cell wall The nonliving materials deposited outside of the plasmalemma which give rigidity, form, and protection to the cell. Typically composed of cellulose and other organic materials that may contain extracellular enzymes and other substances. See primary cell wall and secondary cell wall.

cellular endosperm An endosperm divided into multiple cells, due to cytokinesis following mitosis. See nuclear endosperm.

cellulose A polysaccharide component of primary cell walls consisting of a glucan polymer of indeterminate length, typically gathered into bundles forming microfilaments. A principal component of primary cell walls and the scaffolding for secondary walls.

cellulose synthase complex A transmembrane protein complex responsible for the production of cellulose microfibrils.

central cell A large binucleate cell of the megagametophyte that will develop into endosperm after double fertilization.

central mother cell Dominant cell that gives rise to meristematic initials in multiple directions; in root tip, it is covered by the root cap.

centrarch xylem A pattern of xylem development in which xylem is initiated in the center and matures in an outward direction. Only found in early (extinct) land plants.

centric Morphology of monocot leaves that are cylindrical in cross-sectional view.

centrifugal Refers to movement or development progressively away from the center.

centripetal Refers to movement or development progressively toward the center.

chalaza The site of an ovule opposite the micropyle and adjacent to the stalk region.

chemoautotrophic An autotrophic organism which uses energy from chemical degradation as opposed to light energy. Found among microorganisms.

chlorenchyma Any parenchyma tissue containing chloroplasts.

chlorophyll Any of several closely related green pigments that capture light energy used in the initial steps of photosynthesis.

chloroplast A photosynthetically active organelle with chlorophyll pigments organized into thylakoid membranes usually arranged in stacks. The organelle is typically bounded by two membranes and is found in eukaryotic plants.

chromatin DNA and associated protein of a cell which is (typically) not in a chromosomal state, i.e., in an interphase nucleus. May be euchromatin or heterochromatin.

chromoplast A plastid containing pigments other than chlorophyll, usually carotenoids.

chromosome Rodlike structure containing units of genetic information as DNA in association with histone proteins. Formed within the nucleus of eukaryotic cells.

circular bordered pit A bordered pit with a circular aperture.

cis face The forming face of a dictyosome.

cladode A stem whose primary function is photosynthesis. Those more stemlike may be called a "pad" (as in cactus). Those more leaflike are called a **cladophyll**, **phyllode**, or **phylloclade**.

cladogram A branching diagram depicting the successive point of species divergence from common ancestral lines.

cladophyll A flattened stem, functioning and appearing much as a leaf. Another name for **cladode, phyllode**, and **phylloclade**.

closed minor vein A minor leaf vein that does not have direct symplastic connections (via plasmodesmata) to the adjacent leaf mesophyll cells. Photosynthate is transferred apoplastically. See open minor vein.

closed vascular bundle A vascular bundle with no cambium tissue.

coenocyte Refers to usually large, multinucleate cells in plants.

coevolution A situation in which two or more species affect each other's structural evolution.

cohesion-adhesion-tension model The model that utilizes the properties of water to explain transpiration.

coleoptile In grasses, a leafy sheath which encloses the epicotyl of the embryo.

coleorhiza In grasses, a sheath that encloses the radicle of the embryo.

collateral vascular bundle A vascular bundle with phloem on the abaxial side of the xylem. The most common situation.

collenchyma Elongated cells with uneven primary cell walls and containing no lignin. Usually found in early development of stems and leaf petioles.

colleter A multicellular trichome of a leaf or bud scale that produces a sticky secretion.

columella The central part of a root cap in which the parenchyma cells are arranged in a series of columns. Involved in gravisensing.

commissural vein A small vascular bundle which connects the larger, parallel vascular bundle of grass leaves.

companion cell A living phloem parenchyma cell in angiosperms which is associated with a sieve tube member and was derived from the same mother cell.

compound light microscope An optical instrument designed for producing magnified images of objects using two or more glass lenses.

compound middle lamella A general term referring collectively to the middle lamella and the primary cell walls of two adjacent cells.

compound sieve plate A sieve plate composed of several patchy sieve areas.

compression wood A reaction wood in conifers characterized by dense structure at the lower side of limbs due to stress.

confluent xylem parenchyma A pattern of xylem parenchyma in which the parenchyma surrounding a vessel (called vasicentric parenchyma) extends to and coalesces with the parenchyma surrounding adjacent vessels.

confocal A type of light microscopy in which a point of illumination is projected or rastered over a specimen, and the reflected illumination is screened through an exit aperture in order to eliminate light from out-of-focus planes.

conjunctive tissue Secondary growth in which scattered vascular bundles are found within a parenchyma tissue.

connective A band of parenchyma cells that unites the lobes of an anther.

cork Nonliving cells with suberized walls and formed from cork cambium (phellogen). Also known as phellem.

cork cambium A lateral meristem producing cork centripetally in stems and sometimes roots.

corky layer In leaf abscission, a layer of cork cells formed where the petiole attaches to the stem. Also called separation layer.

corm A round, underground perennating organ. Commonly known as a bulb.

corolla Refers to all the petals of a single flower.

corpus A mass of meristematic cells in the apical meristem of roots and shoots which is covered by a less meristematically active tunica and in which divisions occur in various planes.

cortex Region found between the epidermis and the vascular system in roots and stems.

cotyledon The first leaf/leaves generated from a plant embryo. Function in food storage or absorption. See **scutellum**.

crassulae Ridgelike thickenings of the compound middle lamellae in tracheids of certain conifers. Appear near bordered pits, normally.

crista(e) The infolding(s) of the inner mitochondrial membrane possessing the electron transport mechanism.

cross-linking glycans Polysaccharides found in the primary cell wall that cross-link the cellulose fibrils. Formerly known as hemicelluloses

cross section Same as a transverse section.

cryptochrome Flavoprotein sensitive to blue light and functional in attracting pollinators as well as in regulating circadian rhythms.

crystal An accumulation of almost pure calcium oxalate formed in the vacuoles of idioblasts. Several shape variants are found; all are birefringent.

crystal sand Calcium oxalate crystals shaped like sand grains.

cuticular ledge The ending of the cuticle covering guard cells that provides an opening to the stoma.

cuticular membrane A layer of water-impervious material (cutin) deposited on the outer surfaces of epidermal cell walls, particularly in leaves. Often referred to as the cuticle.

cuticular transpiration The movement of gasses across the epidermal cuticle.

cutan A hydrophobic hydrocarbon polymer that makes up a minor portion of the cuticle. It differs chemically from cutin.

cutin A hydrophobic polyester polymer that is the primary material of the cuticle.

cystolith Inorganic deposits (usually calcium carbonate) on the inner surface of the cell walls of lithocysts.

cytokinesis The division of the remaining cytoplasmic substances in a cell aside from the nuclear events of mitosis.

cytoplasm All the living contents of a cell aside from the nucleus. Does not include vacuole or cell wall substances.

cytoplasmic sleeve Cytoplasmic content of a plasmodesma surrounding the desmotubule.

cytoplasmic streaming The movement of cytoplasm around the plant cell carrying a variety of substances and organelles.

cytoskeleton A network of protein filaments (microfibrils and microtubules) that give eukaryotic cells shape and movement. Are involved in directing chromosome movement, cell plate formation, orientation of chloroplasts, etc.

deciduous Plants with a loss of foliage at the end of a growing season.

decussate A leaf arrangement on stems in which alternating leaves are at right angles to one another.

deep-seated phellogen A phellogen that develops inside the organ, such as in the pericycle of a root. See superficial phellogen.

dehiscence The process of splitting open to release enclosed spores, seeds, or other reproductive structures.

dehiscent fruit Fruits which open spontaneously upon maturity and drying.

dendritic wood Vessel distribution in wood that appears to have a branched pattern when viewed in cross section.

dendrochronology The use of annual tree rings to reconstruct past climatological and meteorological conditions and date archeological artifacts.

denticulate fruit A dry, dehiscent, capsule-type fruit with a single carpel. Characterized by a large opening at the top ring by teeth at the top of the capsule. Ex: campion.

derivative A cell which comes from a meristem and undergoes differentiation into a specialized tissue. The sister cell from the mitosis in the meristem may or may not also become a derivative.

desmotubule A cylindrical membrane within a plasmodesma that connects the endoplasmic reticulum system of adjacent cells.

determinate growth Development to a point characterized by a fixed number of leaves or other lateral organs.

diarch Primary xylem of the root showing two strands or poles of protoxylem in cross-sectional view.

dichotomous venation Branching of veins within a leaf blade resulting in two new veins from each existing one. Found in ferns and in Ginkgo. See also dichotomous venation and reticulate venation.

dictyosome A functional unit of a Golgi apparatus. Characterized by a stack of membranes involved with secretory activities.

dictyostele Vascular system in which the phloem surrounds the xylem in anastomosing strands defined by a series of leaf gaps.

diffuse porous wood Wood characterized by a relatively uniform distribution of xylem vessels in the annual rings, so that the change from 1 year to the next is not easily distinguished.

diffuse secondary growth The differentiation of parenchyma cells scattered through the trunk into xylem and phloem in palm trees.

diffuse xylem parenchyma A pattern of xylem parenchyma in which the parenchyma is spread throughout the xylem in no apparent pattern.

dimorphic chloroplasts In C_4 plants, the mesophyll and bundle sheath chloroplasts vary in appearance and functionality.

dissected siphonostele A variant of stele architecture in which multiple leaf gaps result in a netlike arrangement. Also called a dictyostele.

distal The position of an object farthest away from the site of attachment or origin.

distichous The arrangement of leaves in two vertical rows on a stem.

discontinuous growth ring A temporary, but perhaps multiyear, cessation of the activity of the vascular cambium. No annual growth rings are produced during that time but the vascular cambium remains alive.

dormancy A period of growth and development is stopped.

dorsiventral A leaf characterized by having palisade mesophyll on one side and spongy mesophyll on the opposite side.

double fertilization The process of two sets of nuclear fusions in an embryo sac occurring at the same time, involving the fusion of egg and sperm as well as the fusion of a second male gamete with the two polar nuclei.

drought deciduous plant A plant that drops (abscises) its leaves during the dry season.

drupe A fleshy, single-carpel fruit characterized by a papery exodermis, fleshy or stringy mesocarp, and a hard, thick endocarp. Also called a stone fruit, for example, almond and peach.

druse Calcium oxalate crystals with a globular shape, usually with many spikelike processes on the surface.

early wood The same as springwood, which is formed first in the growing season and is often characteristically distinctive from the late (or summer) wood.

ectophloic siphonostele A stele characterized by xylem enclosing a pith region and with phloem outside of the xylem.

egg apparatus A group of three cells in the angiosperm egg sac consisting of one egg cell and two synergids.

elaioplast An oil-containing plastid found most prominently in the tapetum and involved in pollen maturation.

embryo A small, multicellular individual plant, enclosed in a seed, that upon germination will develop into a mature plant.

embryo sac In angiosperms, the female gametophyte which is multinucleate/multicellular. Also known as the **egg sac**.

enation Outgrowths of the stem in simple, primitive land plants. May be called microphylls to distinguish them from megaphylls which are true primitive leaves derived from a system of branches.

endarch xylem A xylem system in which the progression of development occurs to a direction away from the axial center. Typical of most seed plants.

endocarp The innermost layer(s) of the pericarp.

endodermis The innermost layer of ground tissue in a root representing modified cortex and possessing a Casparian strip on its anticlinal walls.

endogenous Arising from a deep tissue in the plant's organization, such as the development of branch roots from the pericycle of a primary root.

endoplasmic reticulum A series of (usually) flattened saclike membranes that extend throughout the cytoplasm of cells. Site of lipid and lipoprotein production. May be rough (with ribosomes attached) or smooth (with no ribosomes).

endosperm Typically a 3n tissue in the seeds of angiosperms formed by the fusion of a sperm nucleus with the two polar nuclei in an embryo sac. The endosperm is rich in proteins and carbohydrates that serve as a food substance for the early growing embryo.

endosymbiosis The concept of evolution from invasion of prokaryote cells into eukaryotic ones.

endothecium In anthers, it is a wall layer adjacent to the tapetum that lines the locules (or pollen sacs) and is characterized by secondary wall thickenings.

endothelium The innermost layer of the integument lining an embryo sac.

entomophylous Pollinated by insects.

epiblem The "epidermis" of a root, also called rhizodermis.

epicotyl The shoot of an embryo above the cotyledons.

epicuticular wax Wax deposits on the outer surface of epidermal cuticle in stems and leaves.

epidermis The outer layer of cells of a plant body derived from protoderm.

epigeal Growth of an embryo plant characterized by having the cotyledon(s) raised above the level of the ground.

epigyny A flower structure organized with the petals, sepals, and stamens above the ovary. In this case, the ovary is said to be inferior.

epiluminescence Illumination for microscopy in which the light source is above the specimen. Commonly used in confocal microscopy.

epistomatal cavity In gymnosperms, a cavity to the exterior of the guard cells and overarched by epidermal subsidiary cells.

epistomatic leaves Possessing stomata only on the upper (adaxial) surface of a leaf.

epithelium Parenchyma cells lining a duct or cavity, which are typically secretory in nature.

epithem Modified leaf mesophyll cells between minor vein endings and a hydathode pore. Cells may form a structure as transfer cells.

erect ray cell A cell at the periphery of a ray that is elongated in the axial direction.

etioplast A plastid developed in the dark or under very low light levels and having a prolamellar body with no chlorophyll.

eudicotyledonous plants Members derived from the Magnoliopsida that possess two cotyledons. Believed to be ancestral to monocotyledonous plants.

eumetazoan The major clade of animals, based on having a tissue level of organisms. Includes all multicellular animals except sponges.

eustele A stele in which the primary vascular tissues are arranged in strands around the pith.

exalbuminous seed A mature seed lacking endosperm.

exarch xylem A xylem in which the oldest members are located away from the axis, as in most roots.

exine The outer, rather rigid and resistant wall of pollen grains, primarily composed of sporopollenin.

exocarp The outer layer of pericarp.

exocytosis The release of vesicular materials to the outside of a cell. The opposite of endocytosis.

exodermis The outer layer of root cortex cells functioning as a hypodermis.

exogenous Developing from superficial tissue, as in the development of leaves and flowers at the shoot apical meristem.

external phloem Primary phloem located outside, or external to, the primary xylem.

extrafloral nectary A nectary occurring outside of a flower. Compare to floral nectary.

extraxylary fibers Fibers found in regions outside of the xylem.

fascicle A bundle, usually vascular.

fascicular cambium That vascular cambium derived from a vascular bundle.

fertilization The fusion of male and female gametes to produce a 2n (diploid) zygote.

fiber An elongated narrowly tapered sclerenchyma cell with thickened cell wall and typically no living cytoplasm at maturity.

fiber tracheid A cell intermediate between a fiber and a tracheid, with characteristics of both.

fibrillin Proteins in chloroplasts that help maintain plastoglobuli structure.

fibrous roots Roots characterized by many similar branching roots of common length and thickness. Generally not highly adapted for food storage.

fibrovascular bundle Another name for a vascular bundle and accompanying fibers.

filament The stalk of a stamen which supports the anther.

filiform apparatus Threadlike extensions of the synergid cell walls thought to play a role in increasing the rate of transport of molecules into and out of the synergids.

filling tissue Loose tissue formed by a lenticel phellogen toward the outside.

flavedo The colored exocarp of a hesperidium fruit. See albedo.

floral nectary A nectary situated within the flower. Compare to extrafloral nectary.

follicle A dry, dehiscent, fruit derived from a single carpel, dehiscent along a single axis.

free central placentation A form of placentation similar to axile placentation in which ovules are attached at the center (the axis) of a compound ovary. However, the placenta is not attached to the ovary wall.

frond A large divided leaf, typically associated with ferns and palms. May also be used to describe the photosynthetic body found in the Lemnaceae.

fruit A mature ripened ovary containing seeds in angiosperms. May also include associated floral tube.

funiculus The stalk of an ovule.

fusiform initial A cambial cell which is characteristically elongated with tapering end walls.

gamete Haploid reproductive cells (egg or sperm) produced in plants by mitosis from a gametophyte.

gametophyte That plant generation which gives rise to the gametes by means of mitosis. Typically haploid.

gap In a siphonostele, the parenchymatous region in the vascular cylinder above the position where the leaf trace (or branch trace) enters a leaf (or branch).

gelatinous fiber/layer A non-lignified fiber which appears gelatinous-like with light microscopy. Layers of such fibers comprise reaction wood.

generative cell The smaller haploid cell in a pollen grain that divides (most often in the pollen tube) to form two sperm cells.

gerontoplast A type of chromoplast typically found in senescent cells.

gibberellic acid A plant growth regulator active in fruit set and seed germination.

girdling The removal of a ring of live bark around a tree trunk that includes all tissues down to the secondary xylem (wood).

glandular trichome A trichome with an enlarged unicellular or multicellular secretory cells, at the terminus. May be stalked or unstalked.

glaucous A gray or gray-blue surface color on fruits such as grapes caused by epidermal waxes.

glyoxisome A type of microbody largely found in the cells of germinating seeds and containing enzymes that convert stored lipids to carbohydrates.

Golgi apparatus A system of interconnected dictyosomes of similar function in a cell.

grafting Joining two or more related plants together by fitting one or more scions onto a rootstock.

granum(a) Stack(s) of chloroplast thylakoids.

gravitropism A directional growth response to the influence of gravity. Induced by mechanical and hormonal (plant growth regulator) influences.

gravisensing The process of growth toward or away from the direction of gravity. Mostly used in root response, but some responses are noted in shoots.

ground cell(s) Cells other than vascular, epidermal, or periderm.

ground meristem Primary meristem derived from the apical meristem.

growth ring A circular layer of secondary xylem (or, in some cases, secondary phloem) which is the result of seasonal growth in perennial stems or roots. Typically observed in cross-sectional view.

guard cells A specialized pair of epidermal cells surrounding and adjusting the size of a stomatal pore.

guttation The exudation of liquid water from hydathodes fed by vascular xylem traces.

gynoecium All of the carpels in a flower or that part of the flower in which megasporogenesis occurs.

half-bordered Referring to pit-pairs in which one is bordered and the adjacent one is simple.

halophyte A plant adapted to living in salty or brackish conditions.

haplostele A variant of stele architecture in which a central core of xylem is surrounded by phloem.

hardwood General non-specific term for the wood of eudicotyledons.

Hartig net In ectomycorrhizae, hyphae which penetrate between the outermost root cells where they form a mycelium

haustorium A modified root that penetrates host tissues for the purpose of absorbing nutrient materials.

heartwood Inner, non-functional wood characterized by a darker color than the surrounding sapwood. Often becomes prone to decay or degradation by biotic agents.

helical cell wall thickening A helical pattern of secondary cell wall thickening found in xylem vessel elements.

hemicelluloses Soluble and loosely organized polysaccharides in the cell wall matrix.

hemiparasite A photosynthetic plant parasite that only gets water and minerals from the host. See holoparasite.

hemitropous A half-inverted ovule.

herbaceous A plant with only primary growth. Non-woody.

hesperidium A fleshy fruit with multiple carpels, a leathery exocarp (flavedo), spongy mesocarp (albedo), and papery endocarp, for example, all citrus.

heterobaric leaf A leaf in which vascular bundle extensions segregate the internal air spaces into separate compartments.

heterocellular ray A vascular ray composed of more than one type of cell.

heterotrophic An organism incapable of producing organic compound from inorganic materials and thus must rely on other living or dead organisms for its food supply.

hilum Seed scar where the funiculus was once attached. Serves as a one-way water valve in some species. Also may designate the central part of a starch grain.

histogen An older term for root or shoot apical meristems, which are initials that form definite tissue systems in the plant body. See also primary meristem.

holoparasite A parasite that cannot complete its life cycle without a suitable host. Usually non-photosynthetic.

homobaric leaf A leaf in which all of the air spaces are internally connected (see heterobaric leaf).

homocellular ray A vascular ray composed of only one type of cell.

hydathode Pore in the margin of a leaf through which the exudation of water in liquid form takes place, usually by the process of guttation.

hydrophyte A plant adapted to growing in or under the surface of water.

hypanthium A ringlike, cup-shaped, or tubular structure of a flower on which the sepals, petals, and stamens are borne, as in the flowers of the rose or cherry.

hypocotyl That part of the embryo or seedling located below the site of cotyledon attachment.

hypodermis One or more layers of cells beneath the epidermis of the leaf, root, or stem and distinctly different from the cortex or other ground tissues.

hypogeal Type of germination in which the cotyledons remain beneath the surface of the ground.

hypogyny Floral structure in which the sepals, petals, and stamens are attached below the ovary (which is said to be superior).

hypophysis The top cell of a suspensor which gives rise to the development of the root in the embryo of angiosperms.

hypsophylls Leaves located at high levels on the stem resembling floral bracts.

hypostomatous Having stomata only on the abaxial surface of a leaf.

idioblast An unusual cell in a tissue which is distinctly different in form, size, or content from the surrounding cells.

included phloem Phloem tissue that is completely surrounded by secondary xylem or wood.

imperfect flower Flower lacking in either stamens or carpels.

imperforate tracheary element A tracheary element lacking perforations. Typically referred to as a tracheid. Found in both gymnosperms and angiosperms.

indehiscent fruit Fruits which do not open spontaneously and release their seeds upon maturity and drying.

indoleacetic acid (IAA) A plant growth regulator that stimulates growth in stem and roots. Often used in the development of asexual cuttings.

inferior ovary Floral structure in which the sepals, petals, and stamens are attached above the ovary.

initial cell A cell which normally gives rise to two cells, one of which remains in the meristem and the other is added to the plant body.

inner bark Region in stems or roots from vascular cambium through cork cambium. Includes living tissues.

integument Cell layers enveloping the nucellus of an ovule and which will become the seed coat.

intercalary meristem Meristematic tissue located at some distance away from the meristem that gave rise to it.

interfascicular cambium Vascular cambium that develops between the sites of vascular bundles and in the ground tissue.

intermediate filament A non-force-generating, structural, proteinaceous component of the plant cell cytoskeleton.

interphase The non-divisional stages of the cell cycle. Although mitotic activity and cytokinesis do not occur in interphase, replication of DNA does.

internal cuticle A layer of cuticle on the interior periclinal walls that border substomatal cavities.

internal phloem Primary phloem located internally from the primary xylem.

internode Regions of a stem between nodes.

intine The inner wall of a pollen grain which does not contain sporopollenin.

intrusive growth Growth of cells which invade between existing ones by interpositioning themselves.

isobilateral leaf Leaf in which the palisade mesophyll occurs on both adaxial and abaxial sides.

isodiametric Essentially uniform in diameter.

isolateral see isobilateral

kinesin Motor proteins that move along microtubule filaments and powered by ATP.

Kranz anatomy Radially oriented mesophyll cells which surround the vascular bundles in plants with C_4 pathway of photosynthesis (Kranz = wreath).

lacuna A hole or space.

lacunar collenchyma Collenchyma cells with intercellular spaces adjacent to cell wall thickenings.

lamellar collenchyma Collenchyma cells with cell wall thickenings on the tangential surfaces. Also sometimes designated as "plate collenchyma."

lamina The flattened portion of a leaf blade.

late wood Secondary xylem that forms late in the growing season. Sometimes called summer wood.

lateral meristem Those meristems, such as vascular cambium or cork cambium, which are located in a cylinder around the periphery or parallel to it.

latex Milky-like fluid produced in laticifers.

laticifer(s) One or more cells containing latex.

laticiferous cell A non-articulated laticifer.

laticiferous vessel An articulated laticifer in which the cell walls between cells are partially or wholly lacking.

leaf buttress The initial formation of a leaf primordium characterized by a protrusion of tissues below the shoot apical meristem.

leaf gap A region where a portion of the vascular materials connecting the stem to the leaf is interrupted.

leaf scar The scar left on a stem after leaf abscission.

leaf sheath The base of a monocot leaf that wraps completely around the stem.

leaf trace The vascular bundle connecting the vasculature of the stem with that of the leaf. There may be multiple leaf traces per leaf.

leaves The most transient and variable vegetative organ of higher plants. Typically adapted for photosynthesis, they also include cotyledons.

legume A dry, dehiscent, single-carpel fruit, for example, beans and peas.

lenticel An opening, usually characterized as an eruption of the periderm through which gaseous exchange may occur in stems.

liana A woody climbing plant, usually tropical, that hangs from trees.

libriform fiber A very long xylem fiber with thick walls and simple pits.

lignification The process of depositing lignin in cell walls, primary or secondary.

lignin Mixed organic polymers of complex structure with units derived from phenylpropane and other complex phenolics. A component of many plant cell walls—especially in secondary wall structure.

lithocyst A cell, usually epidermal, that contains a calcium carbonate and cell wall accretion known as a **cystolith**.

locule An opening or cavity within a sporangium, as in anthers and ovules.

loculicidal fruit A dry, dehiscent, capsule-type fruit with multiple carpels. Characterized by the release of seeds via splitting of the locules. See poricidal and septicidal fruit.

maceration The breakdown of a tissue into individual cells through the digestion, or hydrolysis, of the middle lamella with chemical or enzymatic agents.

macrosclereid An elongated sclereid with randomly thickened secondary walls.

marginal placentation A form of placentation in which ovules are attached to the margin of the ovary.

margo The pit membrane around the torus in bordered pits of conifers.

medulla Pith.

medullary bundles Vascular bundles distributed in the pith.

medullary ray An extension of the medulla (pith) that reaches from the center of the stem to the cortex, through the vascular region. Same as a pith ray.

megagametogenesis The process of forming a female gamete, and egg, through mitotic division.

megagametophyte The female gametophyte which is the embryo sac in angiosperms.

megaphyll A foliage leaf in ferns and seed plants that has branched or parallel vascular bundles within the lamina and is associated with a leaf gap.

megasporangium The plant structure that produces megaspores.

megaspore A haploid cell that develops into a female gametophyte.

megaspore mother cell Same as a megasporocyte

megasporocyte The diploid cell that gives rise by meiosis to four haploid megaspores, of which only one survives to become a megaspore. Also called the megaspore mother cell.

megasporogenesis Process of forming the female megaspore as a consequence of meiosis.

meiosis Cell division in which the number of chromosomes is reduced to half the number and four cells are produced.

membranes Partitional structures limiting the surface of cells and comprising the structural organization of most organelles of cells. Typically comprised of a bilayer of lipids with various protein and glycoprotein components.

mericarp A fruit. One portion (carpel) of a schizocarp.

meristem Region of actively dividing cells giving rise to new tissues.

mesarch xylem Xylem strand in which the protoxylem is in the center and metaxylem differentiates from the center.

mesocarp The central layer of a pericarp.

mesogenous Ontogeny in stomatal complexes where there is a common developmental origin between subsidiary cells and guard cells of the epidermis.

mesoperigenous Ontogeny in stomatal complexes where there is a partial common origin of subsidiary cells and neighboring guard cells in epidermis.

mesophyll Leaf parenchyma cells active in photosynthesis and located within the two epidermal layers.

mesophyte A plant living in a temperate environment and receiving average amounts of moisture.

mestome sheath An inner layer of cells around vascular bundles of grass leaves characterized by sclerenchyma cells.

metaphase That phase of mitosis or meiosis in which the chromosomes are aligned on an equatorial plane prior to separation of the chromatids. Chromosomes are at their shortest length during this phase.

metaphloem That phloem which matures after the establishment of the protophloem and before the secondary phloem.

metaxylem That xylem which matures after the establishment of the protoxylem and before the secondary xylem.

microbody A small subcellular organelle, enclosed with a single membrane, and containing a variety of non-hydrolytic enzymes. See glyoxisome and peroxisome.

microfibril A grouping of cellulose molecules in the cell wall.

microfilament Long, thin proteinaceous fibers in the cytoplasm which serve multiple structural roles in the cell. Other proteins use the microfilaments to generate force.

microgametogenesis The formation of male gametes (sperm) through mitosis.

microgametophyte The male gametophyte—pollen grains in seed plants.

micrometer Same as micron, 1000 of a millimeter.

microphyll A type of leaf in which there is one single unbranched leaf vein.

micropyle The opening in the integument of an ovule through which the pollen tube may pass and enter the embryo sac.

microscope An optical instrument capable of producing a magnified image of an object. Also adapted as electron, X-ray, and sonic microscopes, among others.

microsporangium A sporangium in which microspores are formed—the anther in angiosperms.

microspore A haploid spore that develops into the male gametophyte, e.g., the first stage of a pollen grain.

microspore mother cell Same as a microsporocyte.

microsporocyte Diploid cell that undergoes meiosis and forms four haploid microspores. Same as microspore mother cell.

microsporogenesis Process of forming haploid male microspores through meiosis.

microtubules Proteinaceous tubules in the cytoplasm of cells which appear hollow and are approx. 25 nm in diameter. These structures form to guide chromosomes in nuclear divisions, establish the cell plate, and provide a framework for the cell prior to cell wall establishment.

middle lamella A "cementing" layer of pectic materials holding together the primary cell walls of adjacent cells.

mitochondrion Double-membrane-limited subcellular organelle actively involved in functions of aerobic respiration.

mitosis Division of the cell's nucleus into two daughter nuclei—each with the same number of chromosomes as the original parent nucleus.

monocarpic A plant that dies soon after setting seed. May be an annual or a perennial plant.

mucigel A mucopolysaccharide produced by the root cap. Functions to lubricate the root tip as it is pushed through the soil and serves as a medium to support the growth of microbes beneficial to the plant.

mucilage Gums and other carbohydrates which swell in water.

multiple epidermis Two or more layers of epidermal tissue derived from protoderm.

multiple fruit Fruit composed of several matured ovaries, each from a separate flower.

multiseriate ray A phloem or xylem ray which is several cell layers in width.

mycorrhiza The symbiotic association of fungi with roots of higher plants.

nectary A glandular structure in flowers (floral nectary) or on vegetative structures (extrafloral nectary) that secretes insect-attracting substances, usually containing sugars.

nitrogen fixation A process carried out by free-living or symbiotic bacteria in which atmospheric N_2 gas is reduced to the level of ammonia.

node The position on a stem at which one or more leaves are attached.

non-articulated laticifer A single, often multinucleate cell that may be branched and transport latex.

non-endospermic storage A form of seed storage in which the food reserves are stored in the cotyledons. Also called cotyledonary storage.

non-storied Typically, secondary growth in which the cells and rays are not found to be synchronously developed in tiers.

non-stratified Same as non-storied (see above).

nucellus The internal region of an ovule in which the embryo sac develops.

nuclear endosperm A multinucleate endosperm not divided into multiple cells, due to lack of cytokinesis following mitosis. See cellular endosperm.

nuclear envelope The double membranes limiting the boundary of a nucleus in eukaryotic cells.

nucleolus An irregularly dense region of a nucleus responsible for the development of ribosomes.

nucleus The double-membrane-limited organelle of eukaryotic cells which contains the hereditary materials.

numerical aperture Measure of a microscope objective lens to gather light and to resolve fine detail at a fixed distance.

obturator A growth in the style or its canal that brings the pollen tubes and conducting tissue near to the micropyle.

oil cavity A cavity, usually in the leaf or stem, in which oils produced by the epithelium accumulate.

ontogeny The development of an individual from embryo to maturity.

open minor vein A minor leaf vein that has direct symplastic connections (via plasmodesmata) to the adjacent leaf mesophyll cells. See closed minor vein.

open vascular bundle Vascular bundles found in eudicots in which fascicular cambium is found between the xylem and phloem.

operculum A portion of the pollen wall that covers the aperture through which the pollen tube will grow.

organ A unique structure composed of tissues which possess common functions, e.g., leaves, stems, and roots are vegetative organs.

organelle Characteristic subcellular structures, usually membrane-limited, that have a specific function within the cell.

orthic tetrakaidecahedron A 14-sided geometric three-dimensional figure often considered to represent the average cell form of closely compacted parenchyma cells.

orthotropous An ovule that is upright or not bent over.

osteosclereid A bone-shaped sclereid, swollen at the ends.

outer bark The "dead" bark lying outside of the phellogen or cork cambium.

ovary Basal region of a carpel or simple pistil containing ovules and developing into a fruit.

ovule Structure in the flower which contains the female gametophyte and which develops into a seed.

P-protein A network of protein filaments found in sieve tube elements. Formerly called "slime." Palmate radiating from a point, as fingers radiating from the palm of a hand.

palisade mesophyll Columnar, photosynthetic cells found toward the adaxial surface in many eudicot leaves.

palynology The study of plant pollen, both living and fossilized.

papilla A non-lignified modified trichome appearing as a protuberance on an epidermal (usually leaf or petal) cell.

paradermal Refers to a plane of sectioning that is parallel to the epidermal layer (or surface of the leaf).

parallel venation A pattern of leaf venation in which the vascular bundles run parallel to each other. Most often seen in monocot leaves. See dichotomous venation and reticulate venation.

parasitic plant A plant deriving some or all of its nutrients from a host plant. Incapable of surviving without the host and often lacking sufficient chlorophyll to produce sugars through photosynthesis.

paratracheal xylem parenchyma Wood parenchyma associated in some form with vessel members.

parenchyma cell An unspecialized plant cell which usually has thin walls with no secondary wall development.

parietal placentation A form of placentation in which ovules are attached to the outer wall of a compound ovary.

parthenocarpy Development of a fruit (typically seedless) without fertilization.

passage cell Endodermis cell that remains thin-walled when others in the tissue are thick-walled. Still has Casparian strip.

pavement cells Ground cells of an epidermis, not a part of a stomatal complex or trichome.

pectic substances Carbohydrate compounds which are an important part of the middle lamella and which are derived from polygalacturonic acid.

pedicel The stalk of an individual flower.

peduncle The stem of an inflorescence.

peltate trichome A flattened disc-shaped plate of cells that may or may not have a stalk for attachment to an epidermal layer.

pentarch A pattern of root vascular in which the xylem is arranged in a star-shaped arrangement with five arms or poles

pepo A fleshy fruit with multiple carpels with a papery exocarp, fleshy mesocarp, and a fleshy or stringy endocarp, for example, cucumber and squash.

perennating organ A plant part—usually rhizome or corm—that is used to survive unfavorable growing conditions.

perennation The process of persisting for multiple growing seasons.

perennial A species that persists for multiple growing seasons.

perfect flower Flower containing both stamens and carpels.

perforate tracheary element A tracheary element with large holes (perforations) at the end walls and, occasionally, side walls. Commonly known as vessel elements. Only found in angiosperms, not present in gymnosperms.

perforation plate That region of a cell wall which is perforated and found in a vessel member.

perianth Collectively, the petals and sepals (or tepals) of a flower.

pericarp The wall of a fruit which was derived from an ovary wall.

periclinal A plane of division or cell wall establishment which is parallel with the surface of the organ.

pericycle A tissue of roots which is found between the endodermis and the phloem and which gives rise to branch roots.

periderm A secondary tissue that replaces epidermis in roots and stems and which consists of phellem, phellogen, and phelloderm.

perigenous Ontogeny in stomatal complexes where there is no common origin of guard and subsidiary cells.

perigyny Floral structure in which the sepals, petals, and stamens are attached at the level of the ovary (which is said to be half inferior).

perimedullary region The outer layer of the stem pith, in which those cells are distinctly different than the inner pith cells.

periplasmodial tapetum A form of tapetum in which the cell walls break down, generating a multinucleate plasmodium that secretes the components needed for pollen maturation. See secretory tapetum.

perivascular fiber A fiber, not of phloem origin, which is located at the outer periphery of a vascular cylinder or even toward the margin of a stem.

peroxisome An organelle enclosed by a single membrane and contained large amounts of catalase and peroxidase to degrade long-chain fatty acids and complex molecules.

petal A nonreproductive modified leaf which is a component of the corolla of a flower.

petiole Stalk of a leaf which is the attachment to a stem.

phellem Corky tissues characterized by nonliving suberized cells produced in a centrifugal manner by the cork cambium (phellogen).

phelloderm Parenchyma-like cells produced in a centripetal manner (to the inside) by the cork cambium (phellogen).

phelloid Idioblasts of the phellem that may be sclerified or contain other wall materials than suberin.

phellogen The cork cambium which produces cork to the outside (centrifugal manner) and phelloderm to the inside (centripetal manner).

phloem Food-conducting tissue of a plant composed of sieve elements, companion cells, and various parenchyma and fibers

phloem ray A vascular ray found in the secondary phloem.

phloem sap The aqueous sap of the phloem. Contains photosynthate, amino acids, hormones, and, occasionally, viruses.

photoautotrophic Capable of synthesizing food products (based on molecules of carbon) using light energy.

photoinhibition Light-induced damage to photosystem II.

photorespiration The production of glycolic acid in chloroplasts in the light. The glycolic acid may be oxidized by enzymes of peroxisomes.

photosynthate Reduced carbon compounds that are the product of photosynthesis.

phragmoplast A disk or platelike structure composed of microtubules and microfilaments which define the site of new wall formation following mitosis or meiosis.

phylloclade A flattened stem that resembles a leaf and performs photosynthesis. Another name for **phyllode**, **cladode**, and **cladophyll**.

phyllode A flattened stem that resembles a leaf and performs photosynthesis. Another name for **phylloclade**, **cladode**, and **cladophyll**.

phyllotaxy The pattern of leaf arrangement on a stem.

phylogeny The sequence of evolutionary changes that have occurred in the development of a species or taxonomic group.

phytochrome A light-sensitive blue-green pigment responding to red and far-red light that regulates plant development such as seed germination, stem growth, etc.

pigment Natural coloring of chemical agents in plant tissues, many of which are significant in growth, photosynthesis, and other processes.

pinna (pinnae) One extension of a frond.

pistil A gynoecium composed of ovary, style, and stigma.

pistillate flower Referring to having pistil(s). A female flower.

pit A small region of the cell wall in which the primary wall is not covered with secondary wall material. See simple pit and bordered pit.

pit aperture Opening into a pit from the interior of a cell.

pit membrane The compound middle lamella separating two pits.

pit-pair Two adjacent pits from opposing cells sharing a common pit membrane.

pith Ground tissue in the center of a root or stem originating from ground meristem.

pith ray An extension of the pith (medulla) that reaches from the center of the stem to the cortex, through the vascular region. Same as a medullary ray.

placenta Site of attachment of the ovule to the ovary wall.

plasma membrane The outer limiting membrane of a cell.

plasmalemma Synonymous with cell membrane or plasma membrane.

plasmodesma The connecting strands of protoplasm between the cytoplasm of adjacent cells which form canals through the cell walls. It may contain a desmotubule which links the endoplasmic reticulum of the adjacent cells.

plastid A family of developmentally and ontogenetically related cellular organelles containing photosynthetic and/or ancillary pigments in internal membranes and limited by a pair of membranes.

plastoglobule Oil-containing droplets in the stroma of a plastid, often associated with senescence.

plectostele A variant of stele architecture in which interconnected platelike regions of xylem surrounded by and immersed in phloem tissue.

plumule The immature leaves on an angiosperm embryo.

pluripotency Cells that can give rise to all functional cells in a plant. Often considered to be plant stem cells.

polar nuclei The two central nuclei which migrated from the opposite poles of an embryo sac.

pollen grain A mature microspore in a seed plant with a distinctive cell wall exine and containing sperm.

pollen sac The locule in an anther containing pollen grains.

pollen tube A hypha-like germination tube from a pollen grain that transmits the male (micro)gametophytes to an embryo sac in an ovule.

pollenkitt An adhesive molecule on the surface of pollen grains. See also tryphine.

pollination The transfer of pollen from an anther to the stigma of the same species.

polyarch The primary xylem of a root with many protoxylem strands.

polyderm A multilayered protective tissue found in the roots and rhizomes of some plants and consisting of alternating layers of suberized and non-suberized cells.

pome A fleshy fruit with multiple carpels, a papery exocarp, a thick mesocarp, and a papery endocarp, for example, apple and pear.

poricidal fruit A dry, dehiscent, capsule-type fruit with multiple carpels. Characterized by release of seeds via pores that form at the top of the capsule, for example, poppy. See loculicidal and septicidal fruit.

pre-prophase band An array of microtubules that form a band in plant cells prior to prophase of mitosis.

primary cell wall Cell wall developing during the growth of a cell in which the wall microfibrils are layered in various, often random, orientations.

primary endosymbiosis A situation in which a prokaryotic organism is engulfed by a eukaryote that may then become an autotrophic organism.

primary growth Plant growth derived from the tissues of apical meristems.

primary meristems Root or shoot apical meristems which form definite tissue systems in the plant body. See histogens (older term).

primary phloem Phloem derived from procambium and divided into the earlier protophloem and the latter metaphloem.

primary pit field A thin area of a primary wall in which a number of pits develop as the secondary wall is deposited.

primary thickening meristem A meristem that increases the girth of a monocot stem.

primary xylem Xylem derived from procambium and divided into the earlier protoxylem and the latter metaxylem.

primexine An early exine wall stage in which sporopollenin is deposited over the stretching wall.

prismatic crystal Calcium oxalate crystals with a prismatic shape. Often found in cells of the bundle sheath.

procambium That primary meristem which develops into primary vascular tissue.

procumbent ray cell A secondary vascular ray cell with its long axis in the horizontal (ray) direction.

proembryo A very early stage of plant embryo development, before protoderm and suspensor are formed.

prophase The first recognizable stage of mitosis or meiosis when the structural organization of chromosomes becomes visually evident with light microscopy.

prokaryotic Organisms whose cells have no membrane-limited nucleus or organelles. Mostly, bacteria and cyanobacteria.

prop roots Aerial adventitious roots which usually provide support.

proplastid The early stage of plastid development.

protoderm The primary meristem that gives rise to epidermis.

protophloem Initial phloem elements produced in primary growth.

protoplasm All of the living contents of a cell, including the cytoplasm and nucleus.

protoplast All cell components but lacking the cell wall.

protostele A simple stele with phloem outside of a solid column of xylem.

protoxylem The first formed primary xylem.

pseudostem A false stem made of a series of concentric leaf sheaths, as in banana.

pubescence A hairy or downy plant surface.

quiescent center That region of apical meristems, particularly in roots, in which there is relatively little (or no) mitotic activity.

radial micellation A pattern of primary cell wall thickening seen in guard cells that causes the cells to bend upon the uptake of water.

radial section A longitudinal section along a radial plane directly through the plant axis.

radicle An embryonic root.

ramiform pit A pit that is branched due to two or more simple pits being fused.

raphides Calcium oxalate crystals with a slender, needle-like shape.

ray Tissue extending radially in the secondary xylem and phloem.

ray initial A small isodiametric cell in the vascular cambium that gives rise to a radial file of cells forming a ray.

ray parenchyma Parenchyma cells of a ray.

reaction wood Wood showing stress formations due to leaning or uneven growth of a stem. See **compression wood** and **tension wood**.

receptacle A modified stem upon which the floral organs are borne.

refractive index The speed of light in a vacuum as opposed to its speed in a medium. Also measured as the sine of the angle of bending from one medium to another.

resin canal A duct formed by the breakdown of cell walls of end members, lined with epithelial cells, and transporting resin in wood.

resin duct A duct formed by the breakdown of cell walls of end members, lined with epithelial cells, and transporting resin. Also referred to as a resin canal in wood.

resolution The finest detail observable with an optical device. Often defined as the ability to observe two object points very close to one another. The measure of the finest distance between the points is referred to as the resolution of an instrument.

resolving power The ability of a microscope to see fine detail, often measured by the narrowest distance between two small objects.

reticulate venation A pattern of leaf venation having the appearance of a net. Most often seen in eudicot leaves. See dichotomous venation and parallel venation.

reticulate cell wall thickenings Secondary wall thickenings having a netlike pattern in xylem tracheary cells.

rhizodermis Primary surface layer of the root, similar to epidermis but of different origin and function. Also called the epiblem.

rhizome A stem that grows underground. Often used for storage.

rhytidome Outer bark.

ribosome A very small non-membranous cell organelle composed of protein and RNA that is the site of protein synthesis and is found in the nucleus, cytoplasm, mitochondria, and plastids of a cell.

ring porous wood Secondary wood of hardwood species which have large diameter vessel elements located primarily in the early wood.

root apical meristem A region of actively dividing cells just behind the root cap that give rise to future growth.

root hair An extension of cells of the rhizodermis, increasing surface area for absorption.

root cap The mass of cells covering and protecting the root apical meristem.

rootstock An underground stem or rhizome. In grafting, the rootstock is the lower portion of the stem or trunk onto which the apical portion (scion) is mounted.

root(s) The (typically) underground vegetative organ of plants derived from the root apical meristem. Capable of storage, support, mutualistic associations with microorganisms, and secondary growth in many cases.

rough endoplasmic reticulum Endoplasmic reticulum with membrane-bound ribosomes that may assemble a variety of protein molecules.

Rubisco Ribulose *bis*phosphate carboxylase/oxygenase. The primary carbon-fixing enzyme in the C_3 photosynthetic pathway and the most abundant protein on Earth.

salt gland A gland on the surface of the leaves of some halophytes that excretes salts taken up via the transpiration stream.

samara A dry, indehiscent, single-carpel fruit characterized by the development of large flat wings that aid in wind dispersal. Sometimes called "helicopters," for example, maple.

sapwood The outer part of the secondary xylem which still contains some living cells and in which water conduction takes place.

scalariform Having a ladderlike organizational pattern.

scalariform xylem parenchyma A pattern of xylem parenchyma that appears as bands (or ladder rungs) spanning between xylem rays.

scion In grafting, the upper part of the graft that is mounted on the rootstock.

schizocarp A dry fruit found in the Apiaceae (celery and parsnip family) that, upon maturity, splits into individual mericarps.

sclereid A relatively short sclerenchyma cell characterized by thick lignified secondary walls with many simple pits.

sclerenchyma A tissue composed of sclerenchyma cells which have thick, lignified cell walls and may or may not have living contents.

sclerophyllous leaf A heavily sclerified, "leathery" leaf.

scutellum A modified cotyledon found in monocots that absorbs nutrients from the endosperm during germination.

secondary cell wall Cell wall material formed after the cell ceases to enlarge and in which the wall microfibrils have one or more sets of parallel orientation.

secondary endosymbiosis A case in which a living eukaryotic cell engulfs another living eukaryotic cell that becomes dependent upon the larger cell and cannot live independently.

secondary growth Growth originating from a vascular cambium and/or phellogen that gives rise to an increase in girth.

secondary phloem Phloem derived from vascular cambium.

secondary thickening meristem A meristem that increases the girth of a root or stem.

secondary xylem Xylem derived from vascular cambium.

secretory cell A cell that produces and exports various types of secretions and may be an idioblast or a part of a specific morphological and anatomical structure.

secretory tapetum A tapetum in which the cells remain intact and cooperate in a coenocytic fashion to secrete the components needed for pollen maturation. See periplasmodial tapetum.

seed A ripened ovule containing a multicellular embryo plant, an endosperm, and a protective seed coat.

seed coat The outer coat, or testa, of a seed that is derived from the integument.

semi-ring porous wood Secondary wood of hardwood species which has large diameter vessel elements located mostly, but not exclusively, in the early wood.

sepals Outermost vegetative organs of a flower, collectively called a calyx.

separation layer In leaf abscission, a layer of weak cells formed where the petiole attaches to the stem. Also called corky layer.

septicidal fruit A dry, dehiscent, capsule-type fruit with multiple carpels. Characterized by the release of seeds via splitting of the septa separating the locules, for example, lily. See also poricidal and loculicidal fruit.

sessile A leaf lacking a petiole or a flower lacking a pedicel.

shade chloroplast Chloroplasts from leaves in the shade. They typically have larger grana than sun chloroplasts.

shade leaf Leaves that develop in the shade that are larger in area, are thinner, and have a thin cuticle. See sun leaf.

shoot The aboveground portion of a plant which typically includes stem and leaves and later flowers.

shoot apical meristem (SAM) Region of actively dividing cells at the apex of a stem which give rise to stem tissues as well as regenerating itself.

sieve area A pitlike area in the wall of a sieve element whose pores are lined with callose.

sieve cell A type of sieve element with undifferentiated sieve areas and no sieve plates. Common in gymnosperms.

sieve plate Wall of a sieve element with sieve areas.

sieve pores Openings in a sieve plate or sieve area.

sieve tube A series of sieve elements arranged end to end and interconnected with sieve plates.

sieve tube element A phloem cell involved with food conduction, a.k.a. a sieve tube member.

sieve tube member A cell component of a sieve tube, a.k.a. sieve tube element.

silica body Inorganic silicon structures of various shapes and sizes that may add to plant rigidity, strength, and fungal resistance. Also known as phytoliths.

silica cell An epidermal cell containing silica bodies.

silvichemicals A class of chemicals derived from wood or wood products.

simple pit A pit in which the cavity remains uniform in width or gradually becomes either wider or narrower during growth in thickness of the secondary wall.

siphonostele A stele in which the vascular cylinder has a core of pith.

slime A viscous secretion of various composition, mostly rich in protein.

smooth endoplasmic reticulum Cytoplasmic membranes devoid of ribosomes that function largely in the synthesis of lipids.

softwood That wood lacking vessel members and fibers, typically used to refer to gymnosperm wood.

solenostele A variant of stele architecture in which the vascular cylinder forms a more or less continuous ring around the pith.

sperm Male gametes formed by mitosis in plants.

spindle apparatus/fibers An aggregation of microtubules that aid in the movement of chromosomes during mitosis or meiosis.

spiral cell wall thickening A spiral pattern of secondary cell wall thickening found in xylem vessel elements.

spongy mesophyll Leaf parenchyma cells of irregular shape and with large air spaces surrounding it. Primary function is in gaseous exchange.

sporophyte The diploid phase of the life cycle of plants that gives rise to the production of spores by means of meiosis. In higher plants, it is the dominant phase of the life cycle.

sporopollenin The highly resistant material comprising the exine of a pollen grain.

springwood Same as early wood.

stamen Floral organ producing pollen and typically composed of a filament and an anther.

staminate flower Referring to having stamens. A male flower.

statocyte A term sometimes applied to the cells of the endodermis and root cap that are involved in gravisensing.

statolith Starch or carbonate-containing structure (often plastids) in a root cap cell believed to be involved in sensing gravitational pull.

stele The vascular system of a plant body and its associated ground tissues.

stellate trichome Star-shaped trichome.

stigma The terminal portion of a style morphologically adapted to holding and germinating pollen.

stigmatoid tissue Tissue of the style which provides a pathway and nutrition for growing pollen tubes.

stinging hairs Secretory cells on the surface of leaves, petioles, and stems, usually with silica-rich walls, that act like hypodermic needles to inject an irritant into the soft parts of herbivores.

stipule A small, leaflike appendage typically found in pairs at the base of the petiole.

stolon A stem that grows across the soil surface. May generate adventitious roots at the nodes.

stoma/stomata An opening in an epidermal layer (usually in leaves and stems) which is bordered by two guard cells.

stomatal complex The arrangement of stoma and epidermal cells that form any of several patterns on leaf surfaces.

stomatal crypt A leaf depression in which the stoma(ta) and guard cells are found.

stomography The study of stomata.

stomium An opening, often slit-like, in an anther that dehisces upon drying to release pollen.

stone cell See brachysclereid.

storied Stratified (often found in cambium, wood, and rays).

Strasburger cell Found in gymnosperm phloem where cells which are functionally and structurally similar to companion cells exist but do not originate from the same precursors as do the companion cells in angiosperms. Same as **albuminous cell**.

style A filamentous portion of the ovary through which pollen tubes may grow.

styloid crystal Calcium oxalate crystals with a slender, pointed shape.

suberin A fatty substance found in the cell wall of cork cells and the Casparian strip of endodermis tissue.

subsidiary cell A morphologically distinguishable cell associated with a stoma and its guard cells. A part of the stomatal complex.

substomatal cavity The space immediately proximal to the stoma.

successive cambium An anomalous situation in which successive layers of cambium are organized concentrically. Also called supernumerary cambium.

succulence A characteristic of mostly xerophytic plants in which leave or stem cells have large central vacuoles for water storage.

summer wood That secondary xylem formed late in the growth season for temperate plants. Also called "late wood." Suspensor A cellular filament that anchors the embryo into the endosperm.

sun chloroplast Chloroplasts from leaves in the sun. They typically have smaller grana than shade chloroplasts.

sun leaf Leaves that develop in direct sunlight that are smaller in area, are thicker, and have a thick cuticle. See shade leaf.

sunken stomata Stomata that are sunken a few micrometers to aid in the preservation of water. Found in desert plants and in many gymnosperms, such as pine.

superficial phellogen A phellogen that develops near the organ surface. See deep-seated phellogen.

superior ovary Floral structure in which the sepals, petals, and stamens are attached below the ovary.

supernumerary cambium An anomalous situation in which successive layers of cambium are organized concentrically. Also called successive cambium.

suspensor A short column of cells that connect the developing embryo to surrounding tissues.

symplast The living cell contents of tissues (which may be connected from cell to cell by plasmodesmata).

symplastic loading The process of phloem loading seen in some plants in which the photosynthate moves from companion cell to sieve tube elements via plasmodesmatal connections. See apoplastic loading.

syncarpy A floral arrangement in which all the carpels are fused into one.

synconium A floral arrangement in which the carpels are fused but remain separated by a thin septum.

syncytium A single cell containing multiple nuclei.

synergids A pair of "sister" cells associated with the egg at the micropylar end of an embryo sac.

tabular cells Early cells of an abscission zone in a leaf petiole which possess a rectangular outline.

tangential section A plane of sectioning at right angles to the radial plane or parallel to the surface of a flattened structure (as a leaf or stem).

tannin Any of a group of polyphenolic compounds used in tanning and dyeing. Typically makes a strong preservative solution in water.

tannosome Tiny organelles that are formed in chloroplasts but in development filled with tannins.

tapetum A layer of (often binucleate) cells lining the locules of anthers and which provide nutrition to the developing pollen. May become coenocytic (see **secretory tapetum**) or plasmodial (see **periplasmodial tapetum**) in later stages of development. Also see elaioplast.

taproot A root that is not highly branched and may be adapted for food storages.

telophase The divisional stage when chromosomes have moved to opposite poles of the cell and have begun to decondense.

tendril A modified stem or leaf used for attachment primarily by twining.

tension wood A type of reaction wood formed on the upper side of limbs in eudicotyledons in which there is less lignification and more gelatinous fibers.

tepal Units of calyx and corolla that cannot be differentiated from each other.

terminal xylem parenchyma Parenchyma at the end of a xylem vessel.

terpene Volatile unsaturated hydrocarbons found in essential oils of plants.

testa Seed coat.

tetracytic stoma A stoma with four subsidiary cells.

tetrarch Primary xylem of a root with four protoxylem poles.

thylakoid A membrane element, usually in stacked orientation, within the stroma of a plastid, usually a chloroplast.

tissue Groups of cells associated in large numbers and of common origin, common structure, and common function.

tissue culture The growth of living cells in an artificial medium.

tonoplast The limiting membrane surrounding a vacuole.

torus A central thickened portion of a pit membrane in a bordered pit of gymnosperms.

totipotency The growth and development of an entire plant from a single cell containing all necessary genomics.

tracheary elements Cells of the xylem involved with water conduction. May be tracheids or vessel members.

tracheid A tracheary element with no perforations and often intermediate between a vessel member and a fiber.

trans face The secretory side of the cisternae in a dictyosome.

transfer cell Parenchyma cell with primary cell wall invaginations that aid in the transfer of solutes.

transfusion tissue Tracheids and parenchyma cells that surround the vascular tissues in leaf veins of gymnosperms.

translocation The method by which photosynthate and other solutes move through the phloem from the source tissues to sink tissues.

transpiration The evaporation of water from plant leaves.

transport protein A membrane-bound protein that assists the movement of specific solutes across the membrane.

triarch Primary xylem of a root in which there are three protoxylem poles.

trichoblast A rhizodermal cell that develops a root hair.

trichome A hair or scale, usually multicellular, of a leaf or stem epidermis that may be glandular.

tryphin An adhesive molecule on the surface of pollen grains. Found exclusively in the Brassicaceae. See also pollenkitt.

tubulin A globular polypeptide which, in the dimer form, represents the building block of microtubules.

tunica In stem apices, it is a layer (or sheath) of cells that divide perpendicular to the stem axis.

tunica-corpus Concept of the two-layered structural organization of a shoot tip in angiosperms.

tylosis An outgrowth of a parenchyma cell extending through a pit cavity into a tracheary cell. It usually blocks the lumen of the vessel and therefore the movement of materials.

unifacial leaf A leaf in which one face, typically the adaxial face, has fused, so that both faces are abaxial, as in the *iris*.

uniseriate ray A ray (xylem and/or phloem) that is only one cell in thickness (width).

upright ray cell A cell at the periphery of a ray that is elongated in the axial dimension. Also called an erect ray cell.

vacuole Nonliving region within a cell that is membrane-bound and is filled with water, storage, and waste products. Bound by the tonoplast.

vasicentric xylem parenchyma Xylem parenchyma that surrounds a vessel in wood.

vascular bundle A strand of xylem and phloem originating from primary meristems. See open vascular bundle and closed vascular bundle.

vascular cambium Lateral meristem which gives rise to secondary vascular tissues in stems and roots.

vascular cylinder Same as stele but excluding associated ground tissues.

vegetative cell The larger haploid cell of a pollen grain that forms the pollen tube.

vein A strand of vascular tissue in a flat organ such as a leaf.

velamen Multiple epidermises found on aerial roots of tropical orchids.

vesicles Small membrane-limited bodies often derived from dictyosomes and carrying structural or enzymatic materials for deposition at a more remote location, such as the cell surface or cell plate.

vessel A tubelike series of vessel members which have perforations in their common end walls.

vessel member (element) A single cellular component of a vessel.

vestured pit A pit in the secondary cell wall that has multiple, small ingrowths into the pit chamber.

warty layer Small deposits on the inner walls of the S3 layer in secondary walls. Believed to be derived from final decomposition of the protoplast.

wax Long-chain hydrocarbons containing alkanes, fatty acids, alcohols, and aldehydes. They are typically epicuticular.

wood The secondary xylem of seed plants.

woody A type of plant with secondary growth.

X-ray elemental microanalysis An analytical method that uses a beam of electrons to cause a sample to emit characteristic X-rays. The energy of the X-rays is used to identify and map the elements on the surface of the specimen.

xeromorphic leaves Leaves with special structural adaptations to living in a dry environment.

xerophyte A plant adapted to growth and survival in a dry environment.

xylary fiber A fiber cell associated with the xylem. See extraxylary fiber.

xylem The tissue in vascular plants that conducts water and dissolved nutrients upward from the root to the stem and leaves. Also provides support and comprises the woody portions of the stem and root.

xylem initial A cambial cell that provides one or more xylem cells through periclinal divisions. Also known as a xylem mother cell.

xylem ray That portion of a vascular ray which is found in the xylem.

xylem ray initial A cell of the vascular cambium that will produce a xylem derivative.

zygote The diploid cell produced after an egg cell is fertilized. Beginning of the new sporophyte plant.

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