Chapter 35: Plant Structure, Growth and Development - No two Plants Are Alike

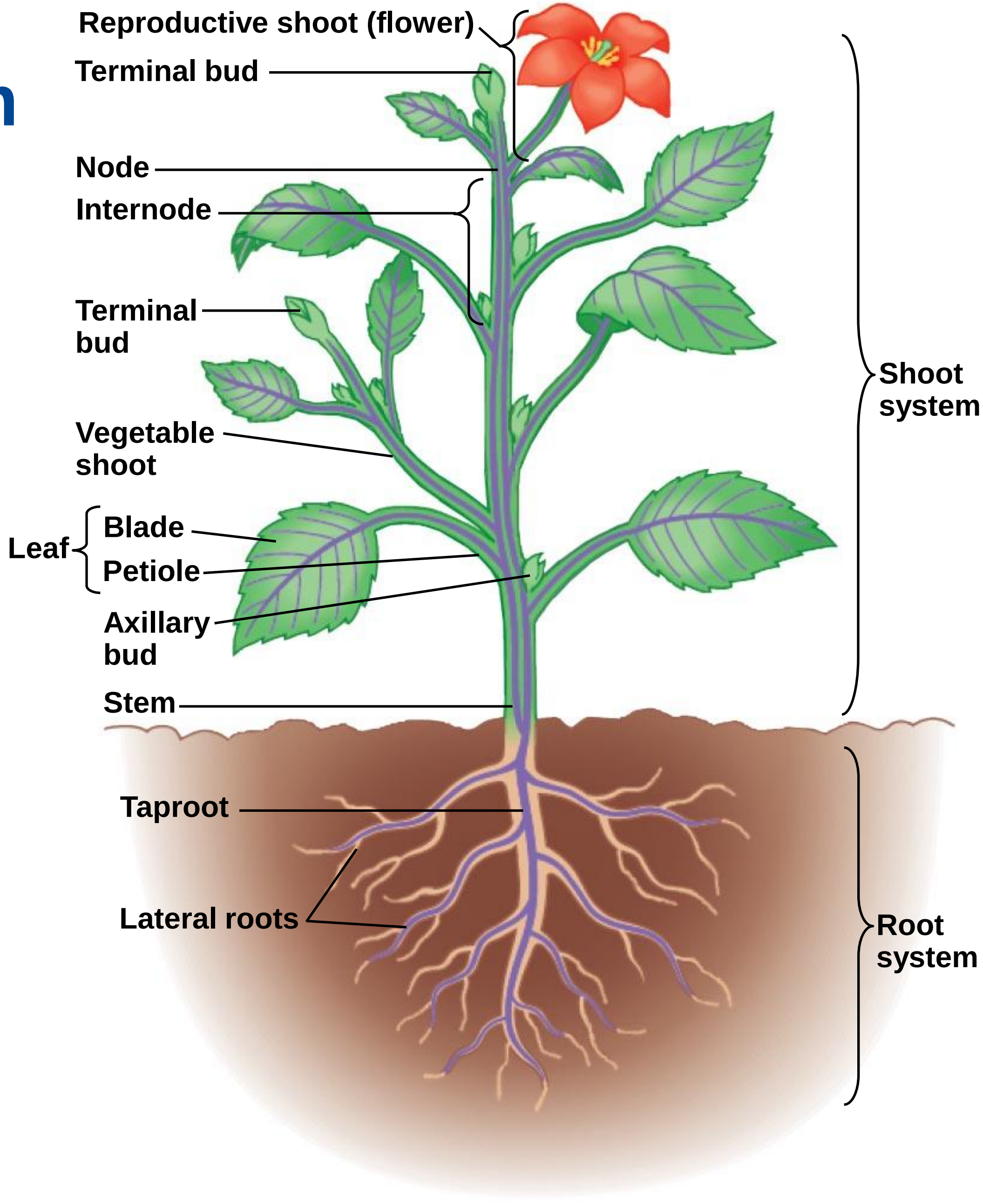
- Plant structure
  - Systems – Root and Shoot system
  - Organs – Roots, Stems, Leaves
  - Tissues – Dermal, Vascular, Ground
  - Cells – parencyma, collenchyma, sclerencyma, xylem and phloem
- Plant growth occurs from **meristems**
  - Apical and lateral meristems
  - Plant tissue organization (Lab!)
  - Primary and secondary growth
- Regulation of plant development
  - Growth – Cell division/expansion, Morphogenesis/pattern formation, Cell differentiation – controlled by gene expression!

The plant body has a hierarchy of organs, tissues, and cells

- Plants exhibit extensive **plasticity** - the ability to alter themselves in response to its environment
- In addition to plasticity, plant species have, by natural selection, accumulated characteristics of morphology that vary little within the species
- Plants, like multicellular animals, have organs composed of different tissues, which are in turn are composed of cells
- The Three Basic Plant Organs: Roots, Stems, and Leaves
- Basic morphology of vascular plants reflects their evolution as organisms that draw nutrients from below-ground and above-ground
- Therefore, they are organized into a root system and a shoot system

Plants are organized into a root system and a shoot system

3 major plant organs:
Roots
Stems
Leaves



Roots

- Functions of roots:
  - Anchoring the plant into the ground
  - Absorbing minerals and water from the surroundings
  - Often storing organic nutrients for times of emergency/drought
- In most plants, absorption of water and minerals occurs near the root tips, where vast numbers of tiny **root hairs** increase the root surface area to increase absorption

Many plants have modified roots

(a) Prop roots – will eventually get into the ground.

(b) Storage roots – store food and water.

Many plants have modified roots

(c) **"Strangling" aerial roots – trees begin to grow in the branches of a larger tree, sending down these roots.**

(d) **Buttress roots – support tall trees in wet environments.**

Many plants have modified roots

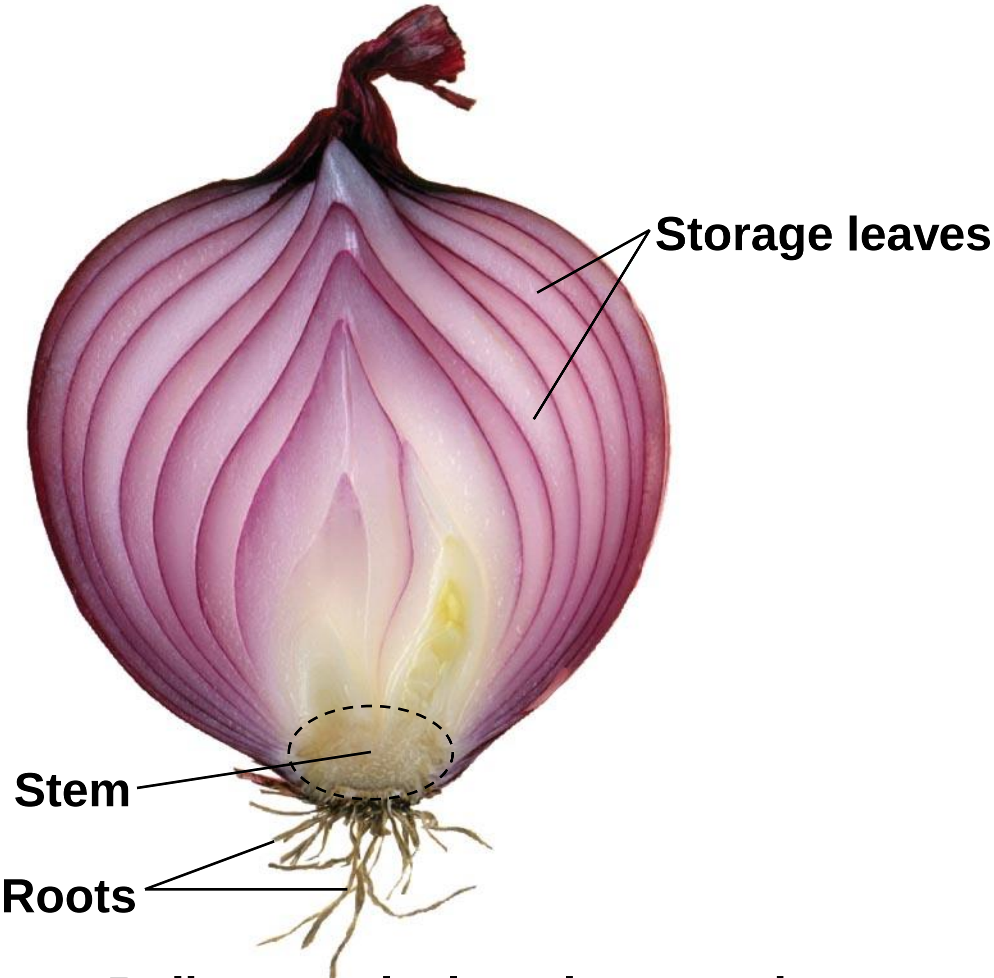
(e) **Pneumatophores – air roots, mangroves have these – they project these roots into the air to get oxygen when growing in thick mud.**

Stems

- A stem is an organ consisting of:
  - An alternating system of nodes, the points at which leaves are attached
  - Internodes, the stem segments between nodes
- An **axillary bud** is a structure that has the potential to form a lateral shoot, or branch
- A **terminal bud** is located near the shoot tip and causes elongation of a young shoot

Many plants have modified stems

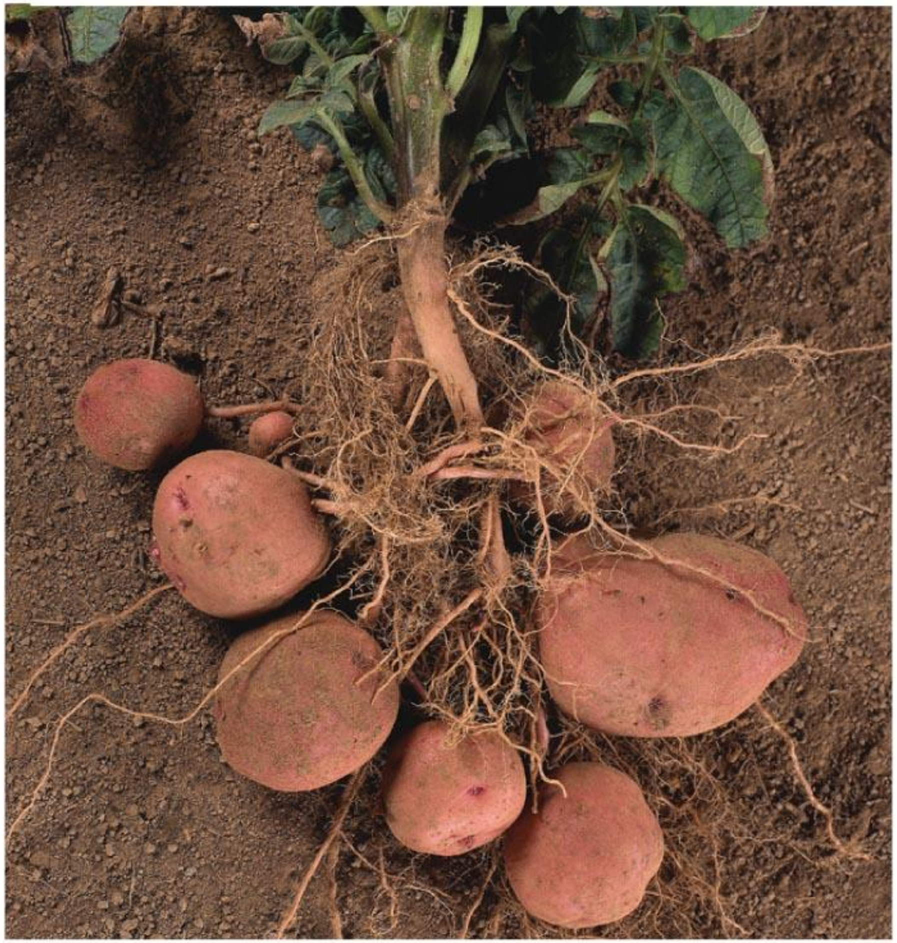
Stolons – horizontal stems that grow as 'runners' along a surface (strawberries).



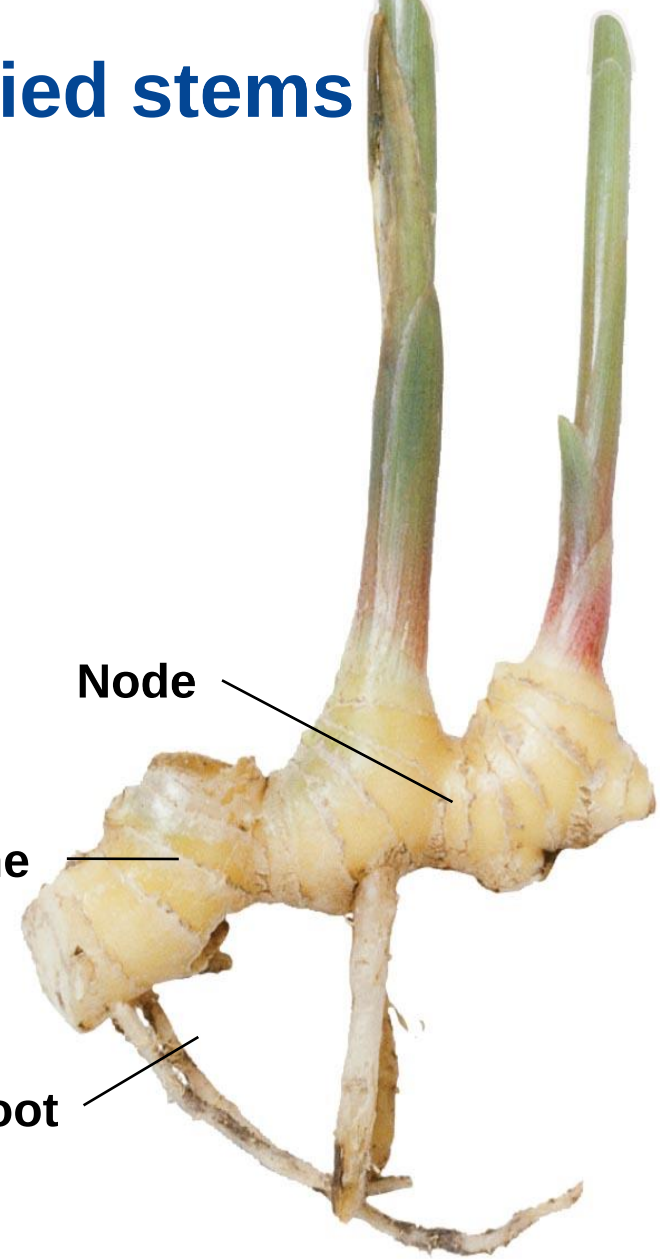
(b)

Bulbs – vertical, underground shoots made up mainly of leaves that store food.

Many plants have modified stems



(c) **Tubers – Enlarged ends of rhizome stems that store food.**

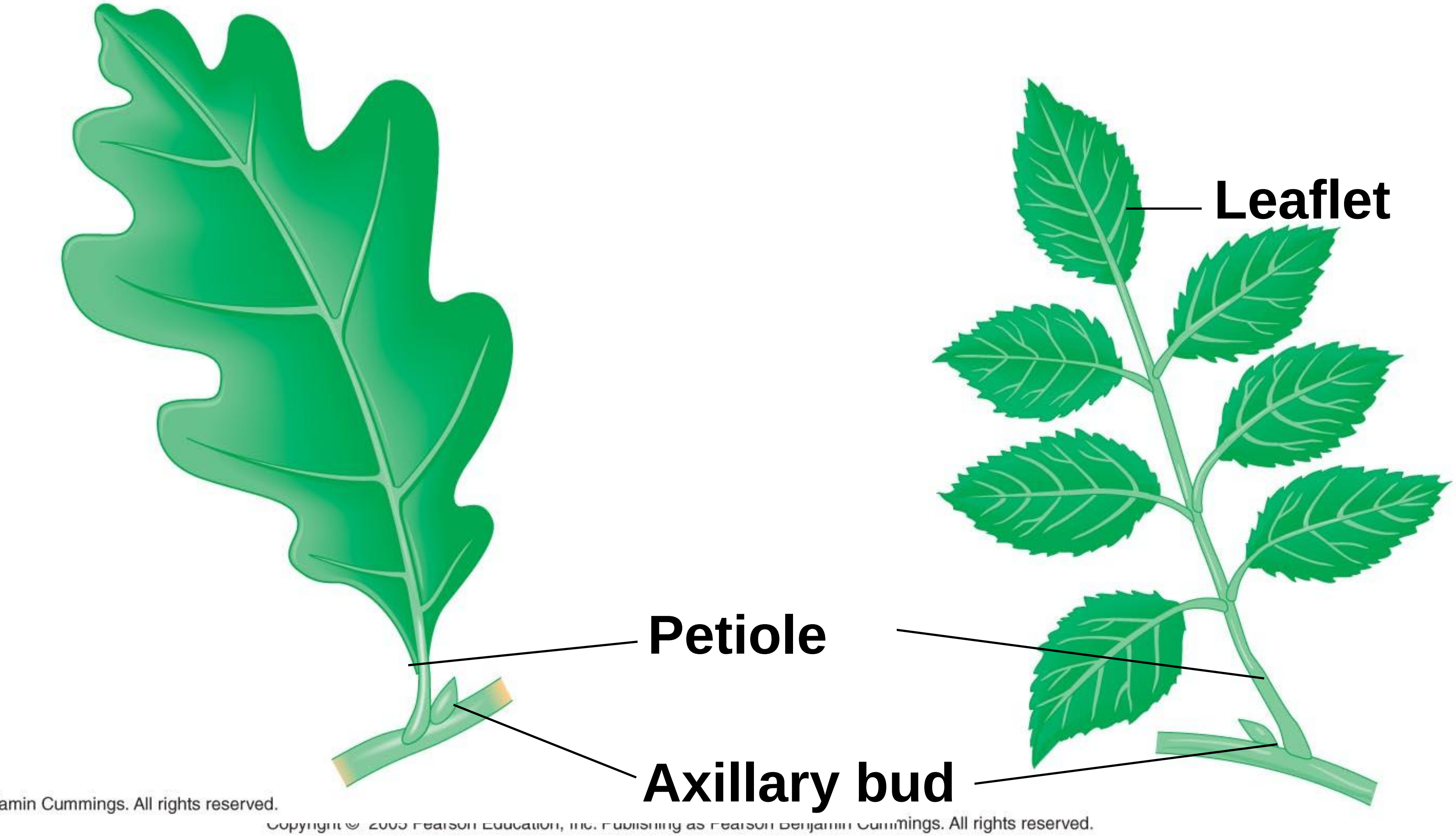


Rhizomes – horizontal stems that grow just below the surface.

Leaves

- The **leaf** is the main photosynthetic organ of most vascular plants
- Leaves generally consist of
  - A flattened blade and a stalk
  - The **petiole**, which joins the leaf to a node of the stem
- Monocots and eudicots differ in the arrangement of veins, the vascular tissue of leaves
  - Most **monocots** have parallel veins in a leaf
  - Most **eudicots** have branching veins in a leaf
- There are two main types of leaves – Simple and Compound
- In classifying angiosperms, taxonomists may use leaf morphology as a criterion

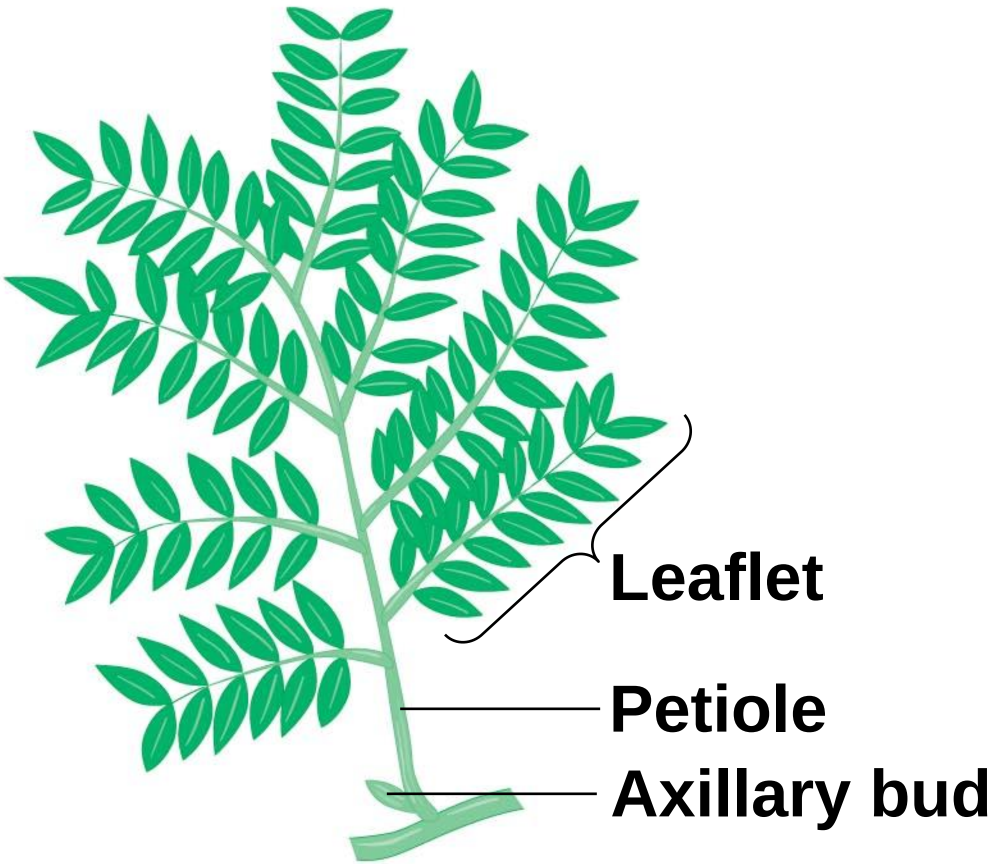
Simple and Compound Leaves – both eudicots!



Simple leaf

Compound leaf

Doubly compound leaf



Some plants have modified leaves

Tendrils – leaves that grow for attachment - peas.

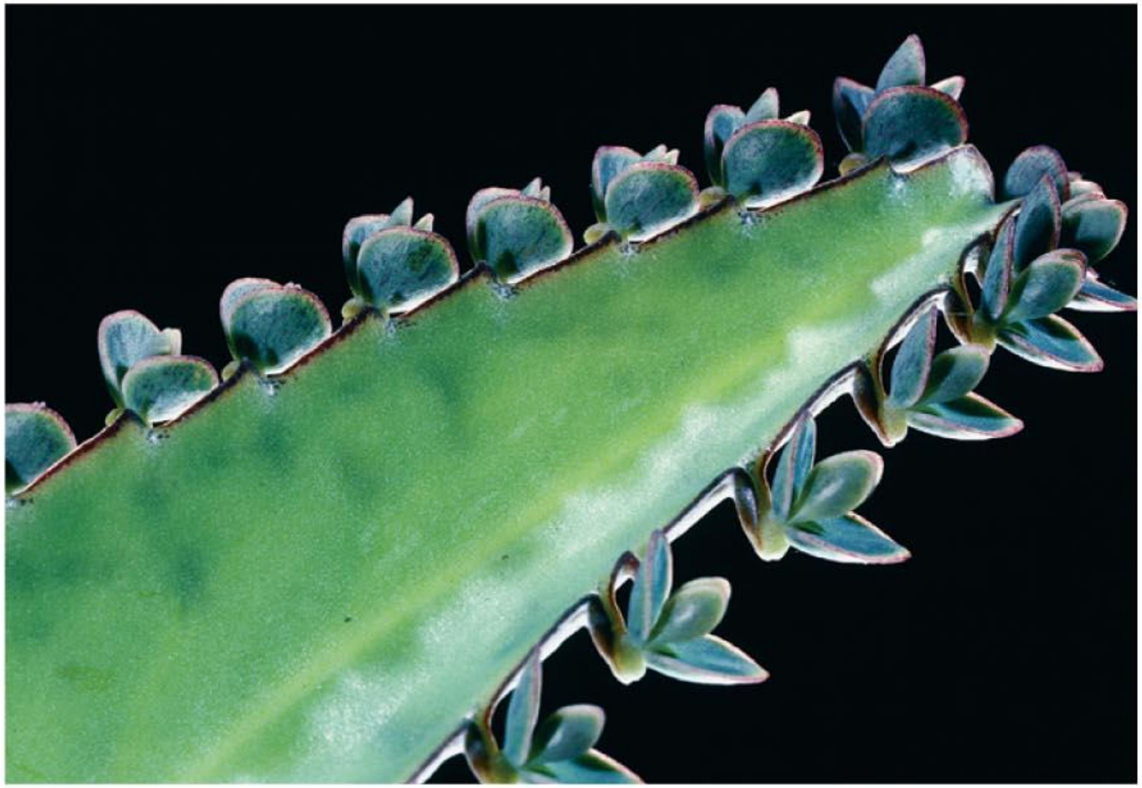
Spines – on cacti are actually leaves.

Some plants have modified leaves

Storage leaves – function to store sugar or water.

Bracts – surround groups of flowers to attract insects.

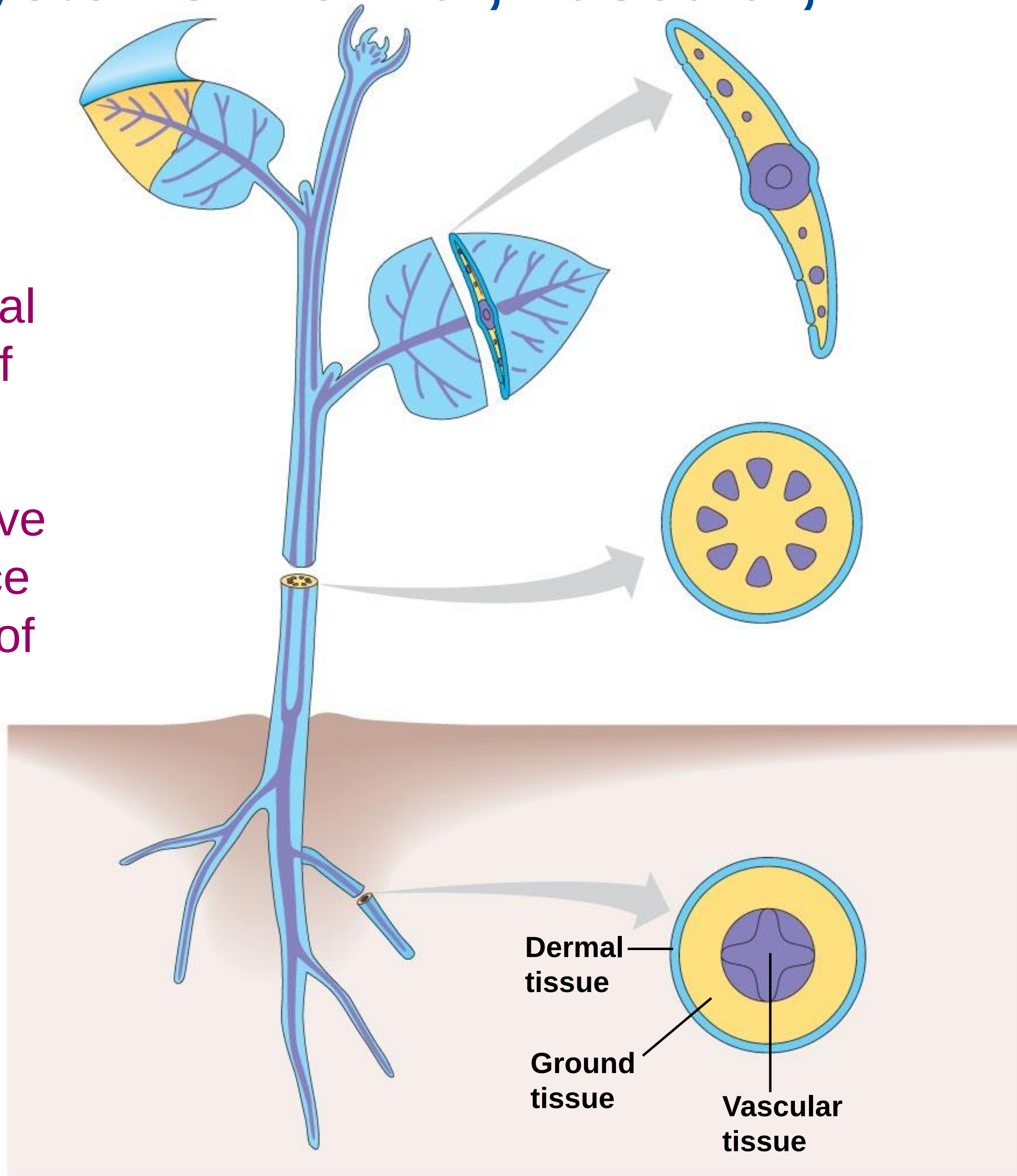
Some plants have modified leaves



Reproductive leaves – produce small plants that fall off and root into the soil.

The Three Tissue Systems: Dermal, Vascular, and Ground

- Each plant organ has dermal, vascular, and ground tissues
- In nonwoody plants, the dermal (skin) tissue system consists of the epidermis
- In woody plants, hard protective tissues called **periderm** replace the epidermis in older regions of stems and roots



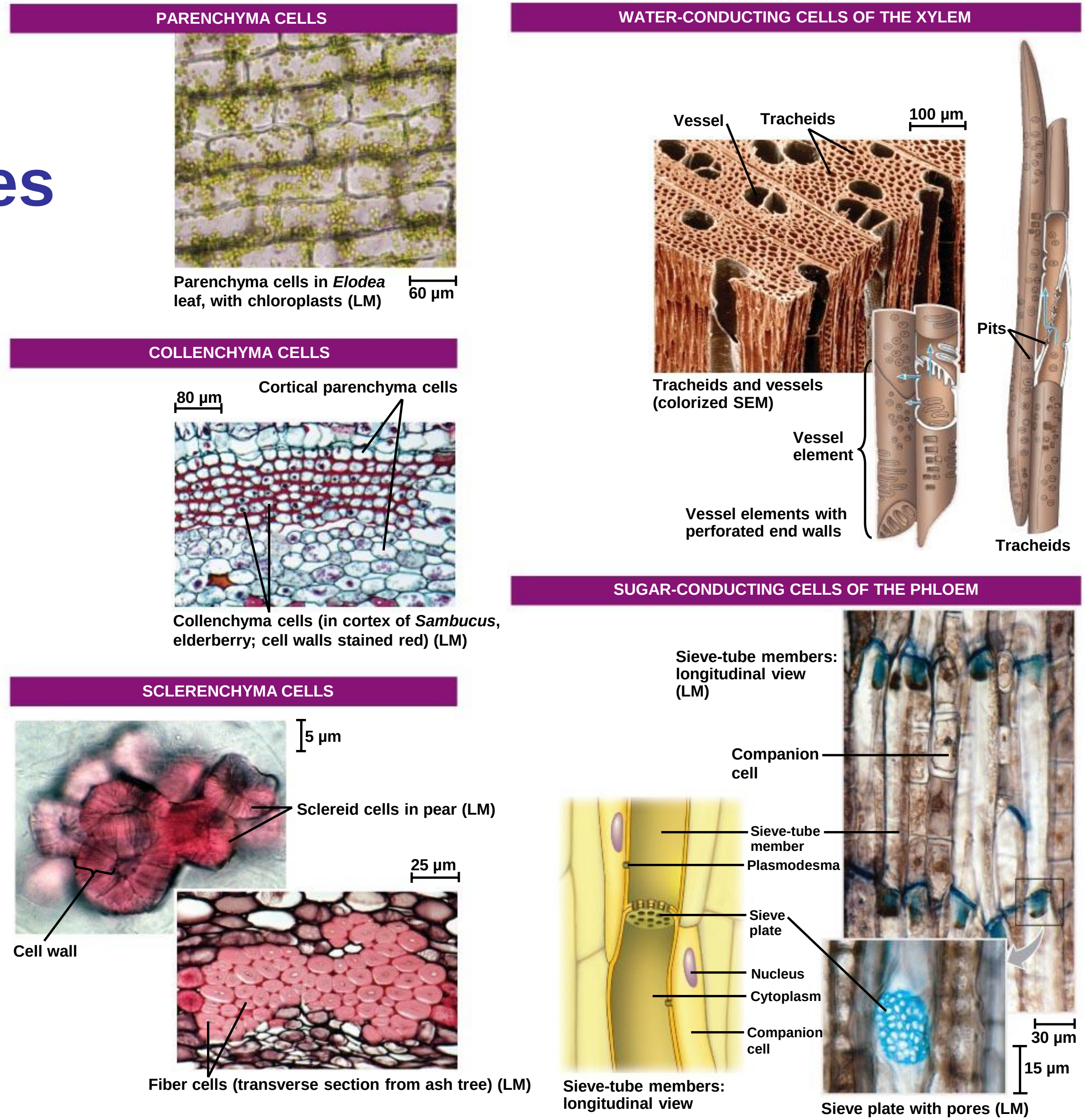
The plant vascular system

- The vascular tissue system carries out long-distance transport of materials between roots and shoots
- The two vascular tissues are **xylem** and **phloem**
  - **Xylem** conveys water and dissolved minerals upward from roots into the shoots
  - **Phloem** transports organic nutrients from where they are made by photosynthesis in the leaves to where they are needed throughout the plant
- The vascular tissue of a stem or root is collectively called the **stele**
- In angiosperms, the stele of the root is a solid central vascular cylinder
- The stele of stems and leaves is divided into vascular bundles, strands of xylem and phloem
- *Tissues that are neither dermal nor vascular are the ground tissue system*
- Ground tissue includes cells specialized for storage of macromolecules, photosynthesis, and structural support

Common Types of Plant Cells

- Like any multicellular organism, a plant is characterized by **cellular differentiation**, the specialization of cells in structure and function
- Some major types of plant cells:
  - **Parenchyma** – perform metabolic functions of a plant
  - **Collenchyma** – Mainly for support of young plants
  - **Sclerenchyma** – Rigid cells that provide strong support for non-growing areas
  - Water-conducting cells of the xylem – dead cells provide water and mineral transport up the plant from the roots
  - Sugar-conducting cells of the phloem – cells are alive, and they transport sugar down the plant from the photosynthetic leaves

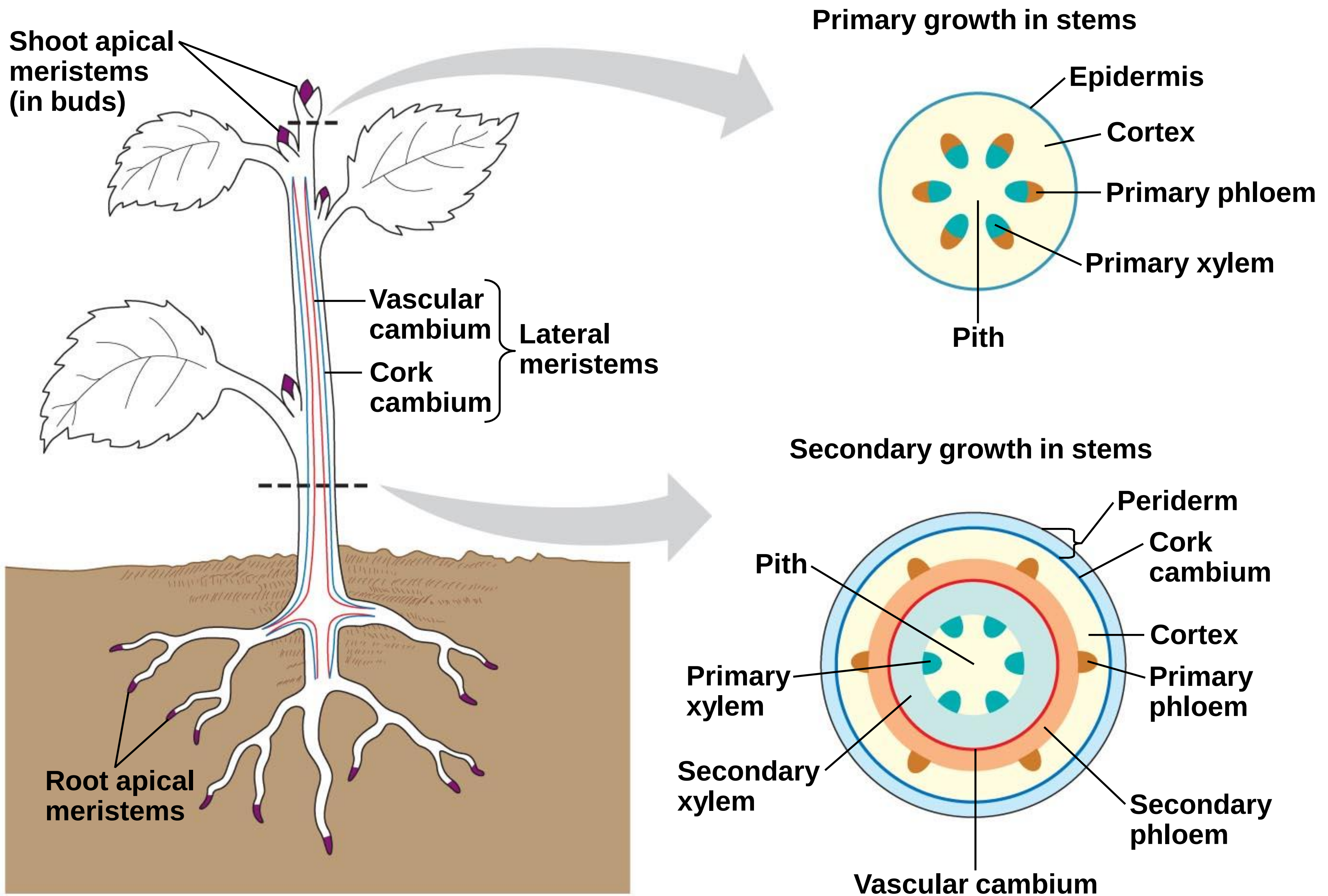
Common Types of Plant Cells



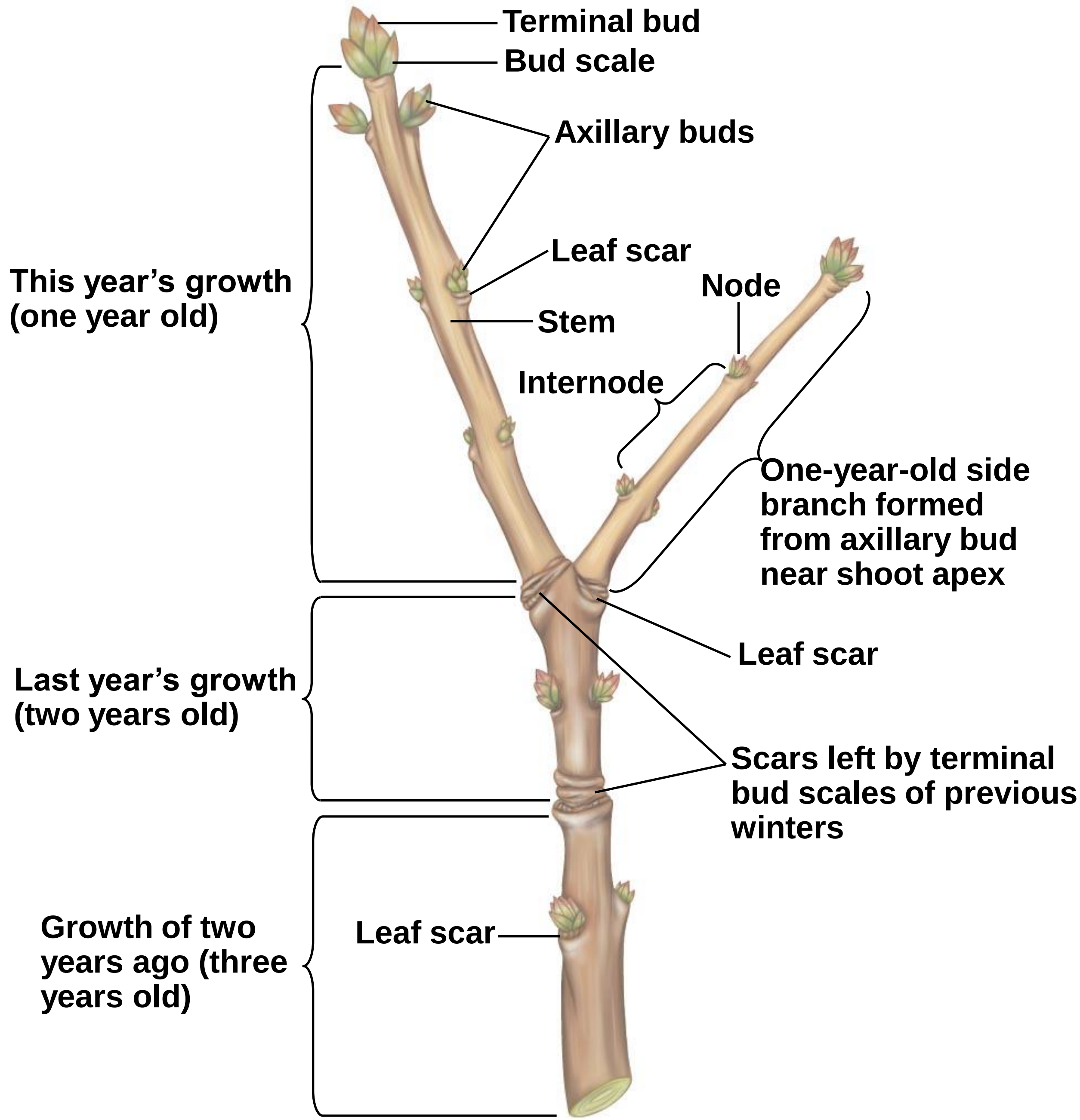
Meristems generate cells for new organs

- **Apical meristems** are located at the tips of roots and in the buds of shoots
  - Apical meristems elongate shoots and roots, a process called **primary growth**
- **Lateral meristems** add thickness to woody plants, a process called **secondary growth**
  - There are two lateral meristems: the **vascular cambium** and the **cork cambium**
    - The **vascular cambium** adds layers of vascular tissue called secondary xylem (wood) and secondary phloem
    - The **cork cambium** replaces the epidermis with periderm, which is thicker and tougher

Meristems generate cells for new organs



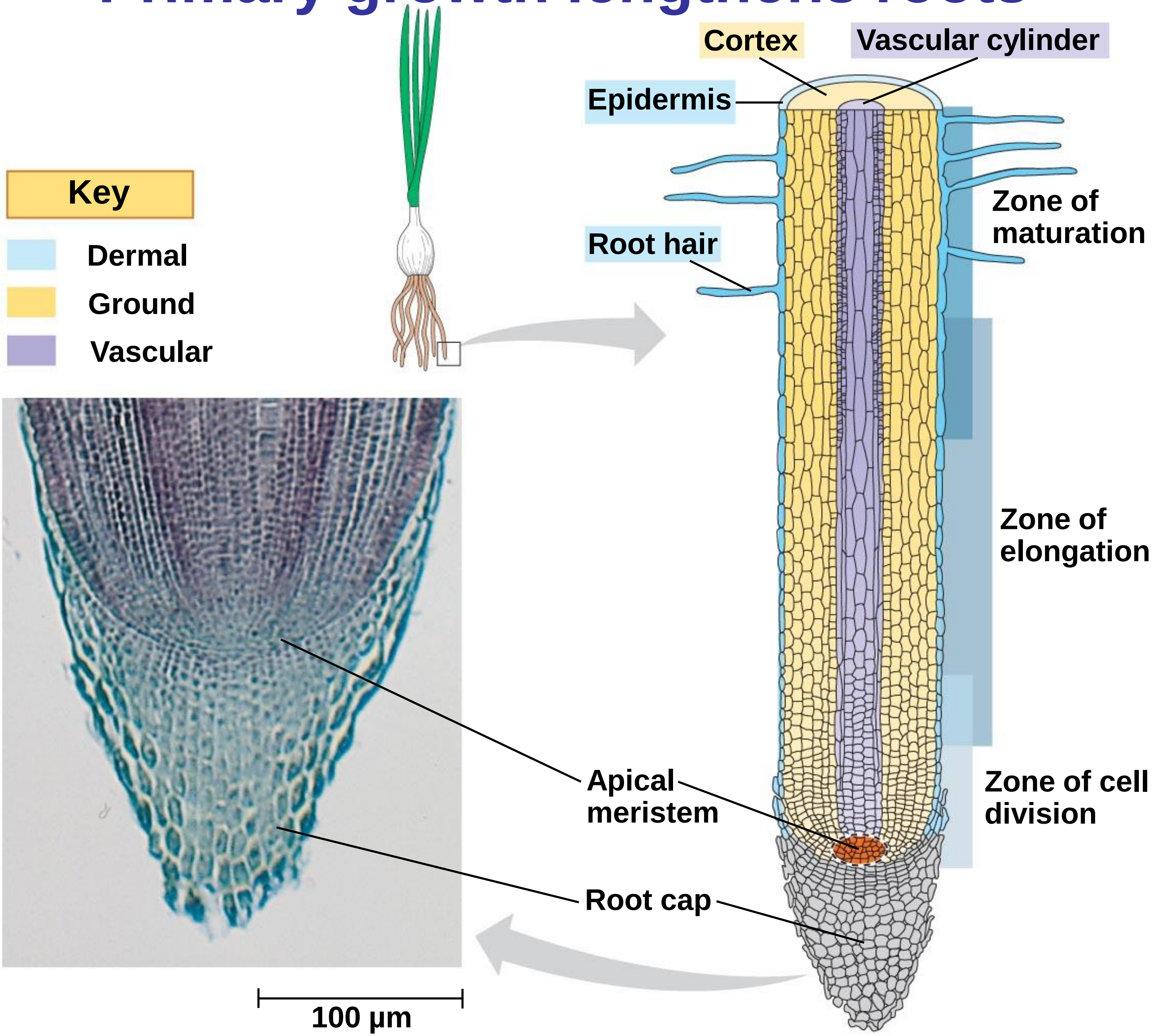
- In woody plants, primary and secondary growth occur simultaneously but in different locations



Primary growth lengthens roots and shoots

- Primary growth from the apical meristems produces the primary plant body, the parts of the root and shoot systems
- The root tip is covered by a root cap, which protects the apical meristem as the root pushes through soil
- Growth occurs just behind the root tip, in three zones of cells:
  - Zone of cell division
  - Zone of elongation
  - Zone of maturation

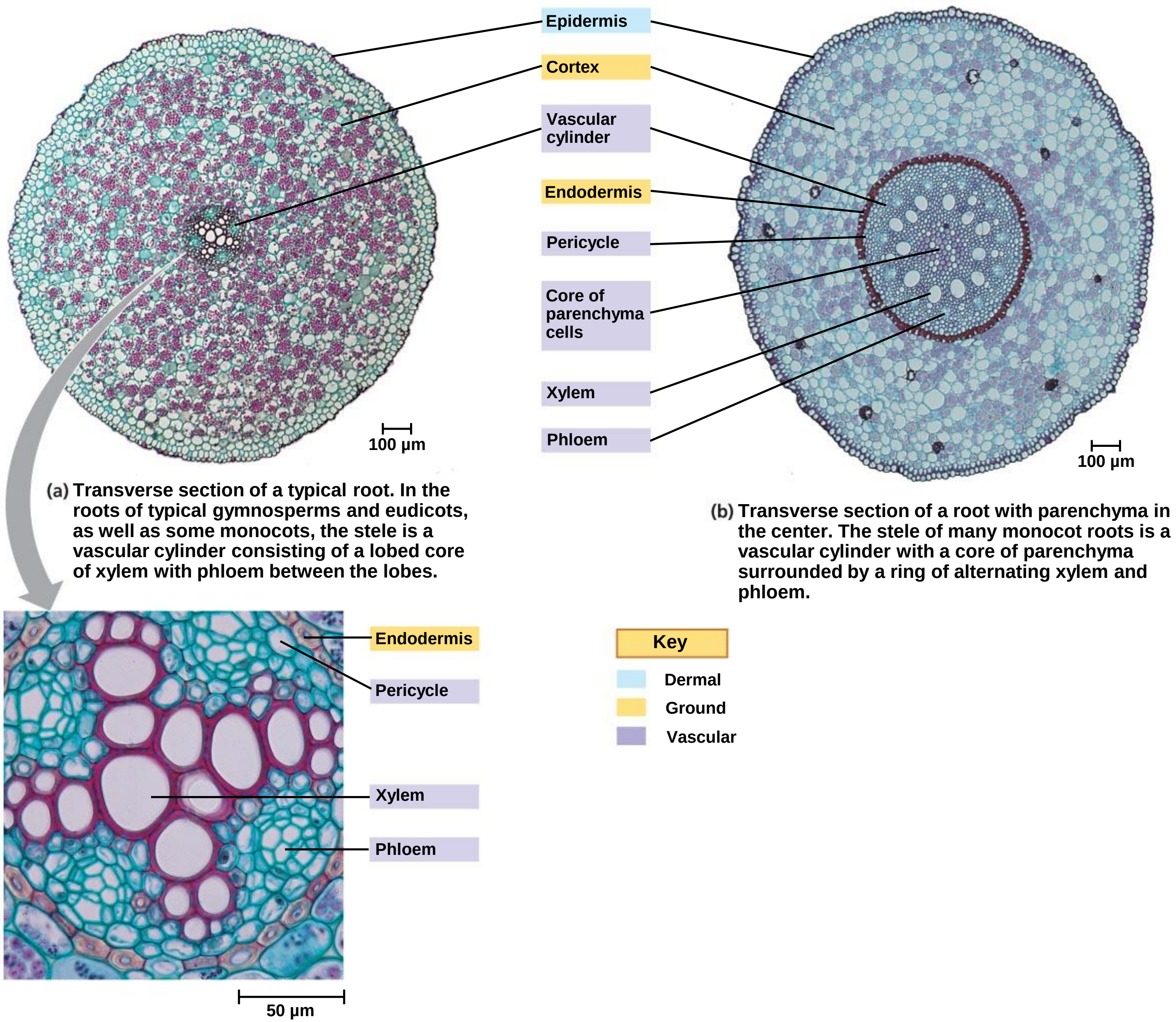
Primary growth lengthens roots



Primary growth lengthens roots

- The primary growth of roots produces the epidermis, ground tissue, and vascular tissue
- In most roots, the stele is a vascular cylinder
- The ground tissue fills the **cortex**, the region between the vascular cylinder and epidermis
- The innermost layer of the cortex is called the endodermis

Views of roots

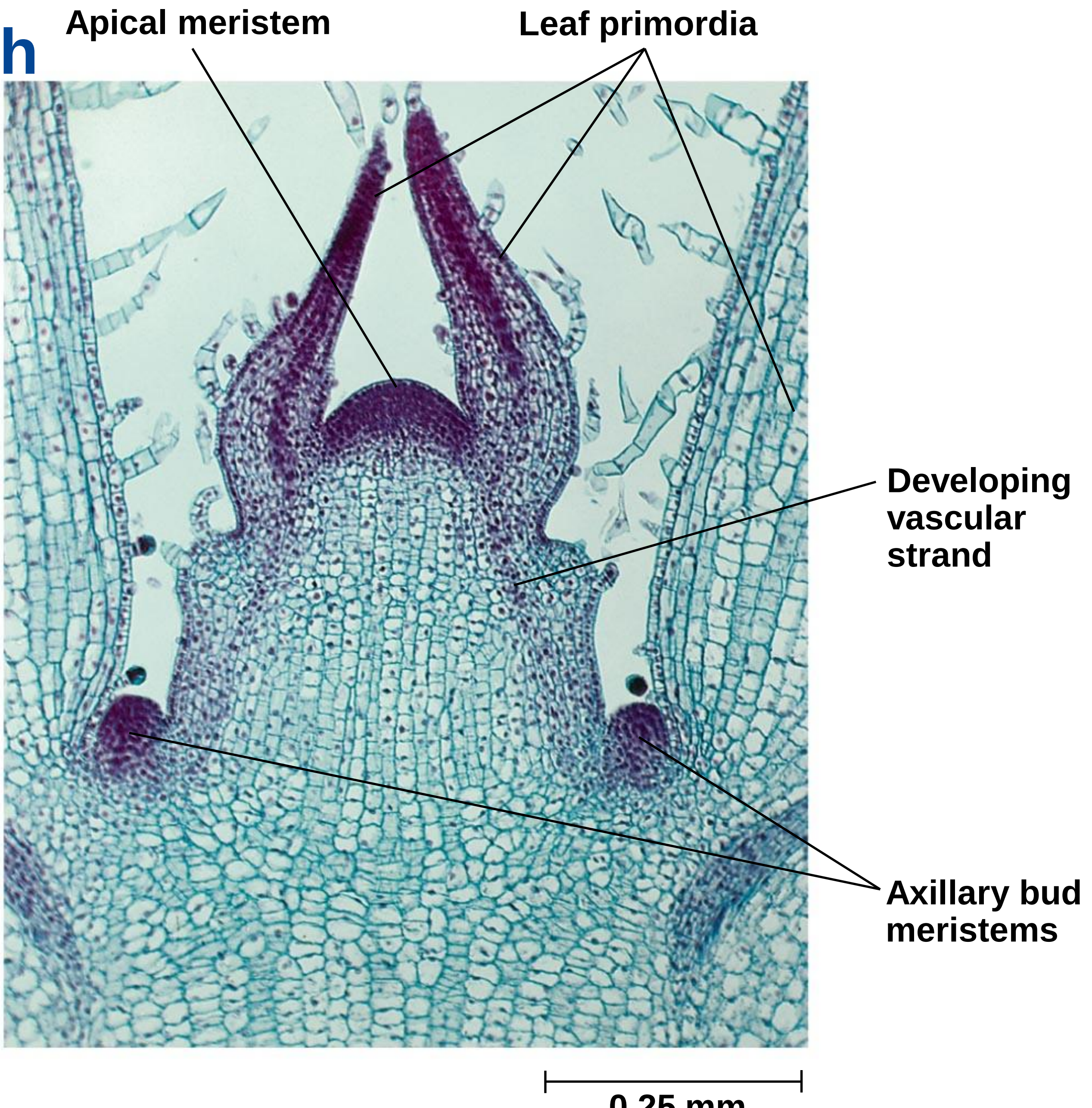


(a) Transverse section of a typical root. In the roots of typical gymnosperms and eudicots, as well as some monocots, the stele is a vascular cylinder consisting of a lobed core of xylem with phloem between the lobes.

(b) Transverse section of a root with parenchyma in the center. The stele of many monocot roots is a vascular cylinder with a core of parenchyma surrounded by a ring of alternating xylem and phloem.

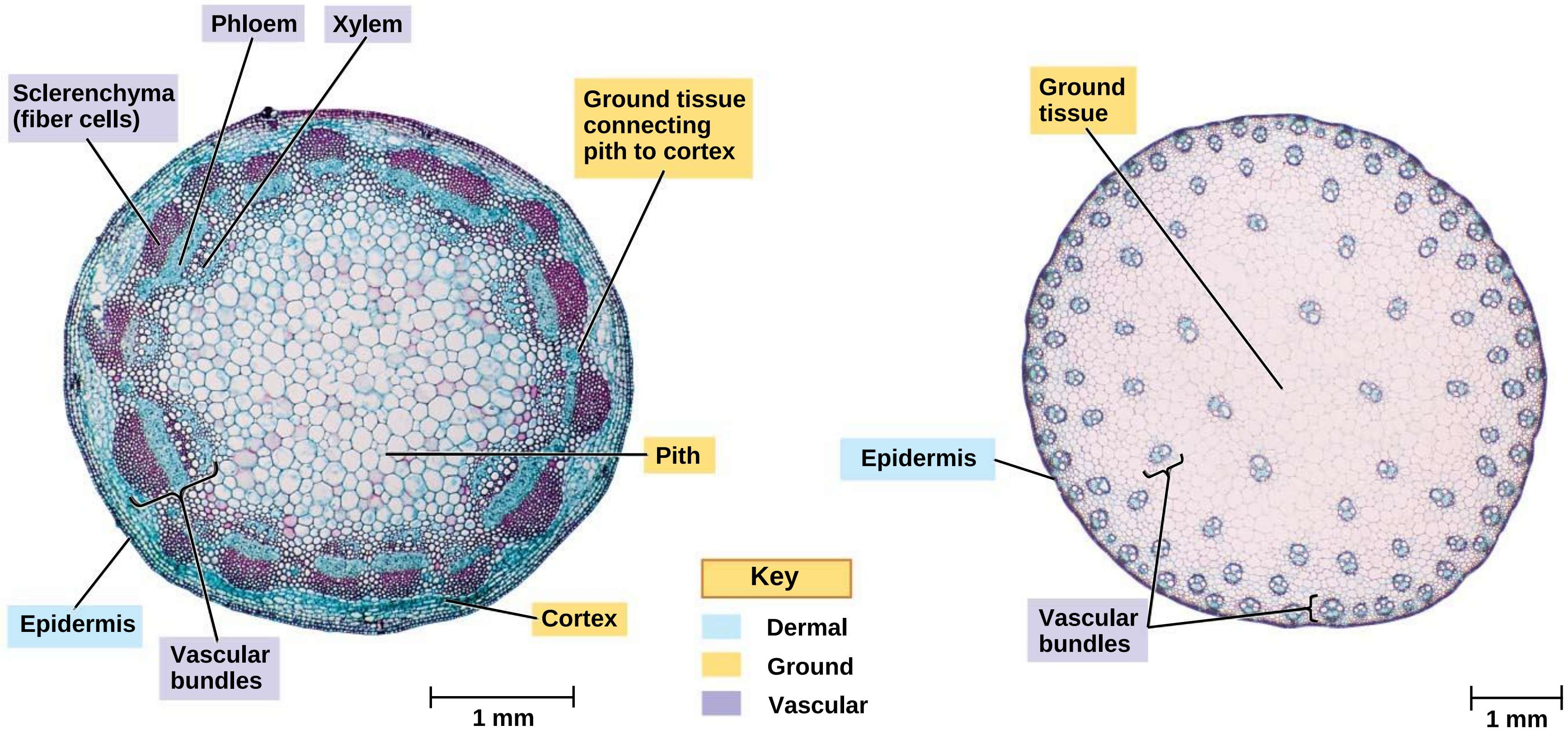
Primary Growth of Shoots

- A shoot apical meristem is a dome-shaped mass of dividing cells at the tip of the terminal bud
- It gives rise to a repetition of internodes and leaf-bearing nodes



Tissue Organization of Stems

- In gymnosperms and most eudicots, the vascular tissue consists of vascular bundles that are arranged in a ring
- In most monocot stems, the vascular bundles are scattered throughout the ground tissue, rather than forming a ring



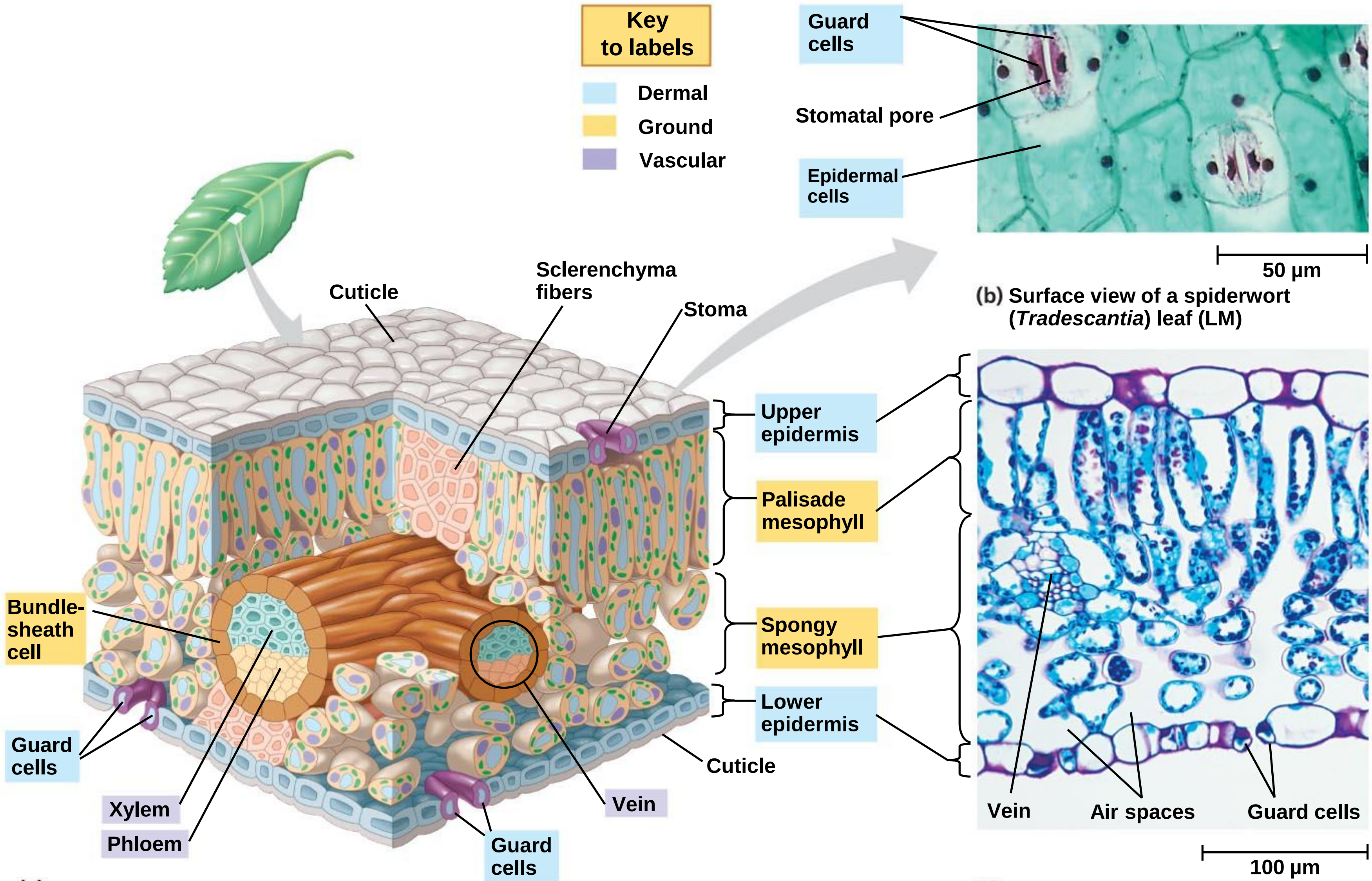
(a) A eudicot (sunflower) stem. Vascular bundles form a ring. Ground tissue toward the inside is called pith, and ground tissue toward the outside is called cortex. (LM of transverse section)

(b) A monocot (maize) stem. Vascular bundles are scattered throughout the ground tissue. In such an arrangement, ground tissue is not partitioned into pith and cortex. (LM of transverse section)

Tissue Organization of Leaves

- The epidermis in leaves is interrupted by stomata, which allow CO_2 exchange between the air and the photosynthetic cells in a leaf
- The ground tissue in a leaf is sandwiched between the upper and lower epidermis
- The vascular tissue of each leaf is continuous with the vascular tissue of the stem

Tissue Organization of Leaves



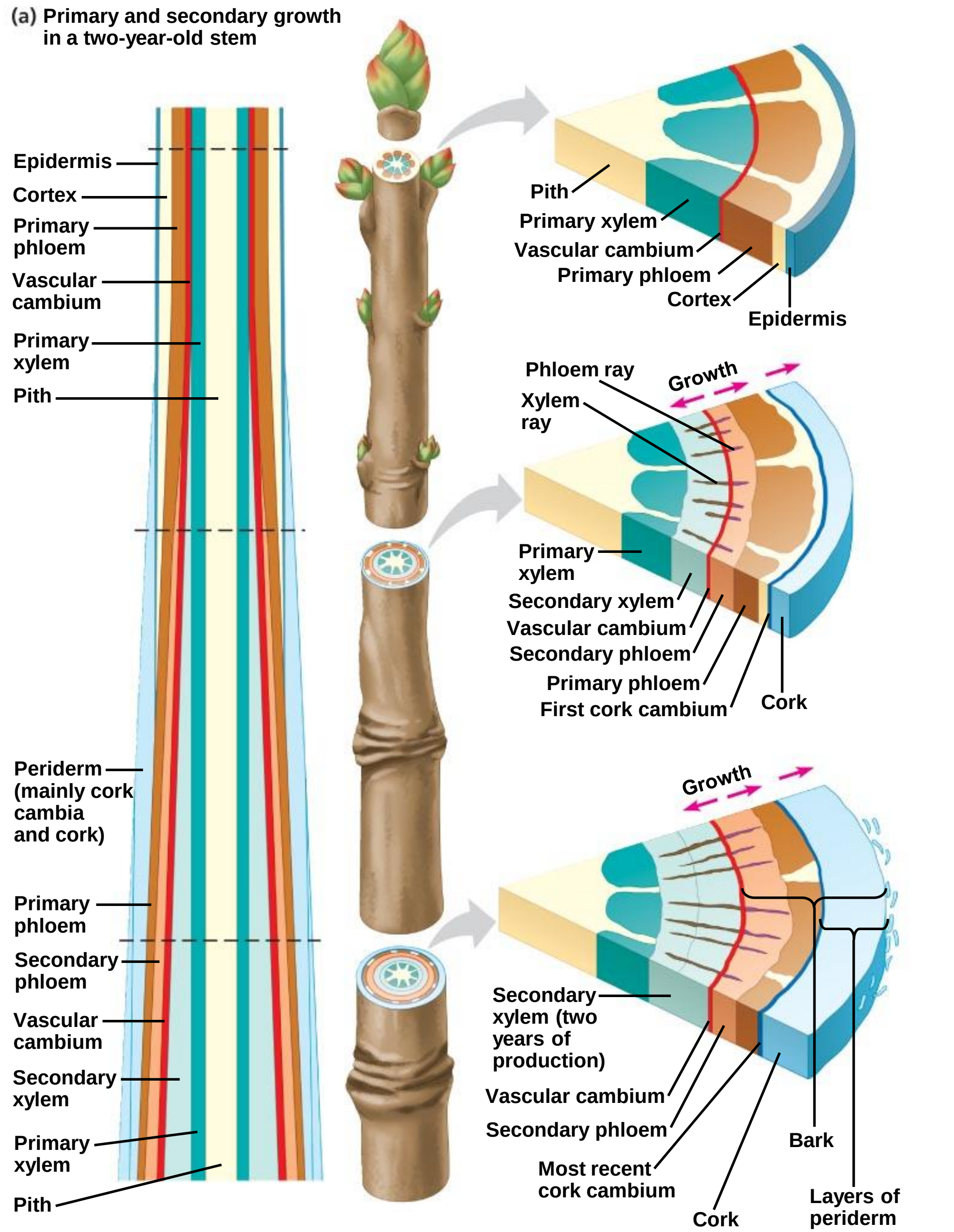
(a) Cutaway drawing of leaf tissues

(b) Surface view of a spiderwort (*Tradescantia*) leaf (LM)

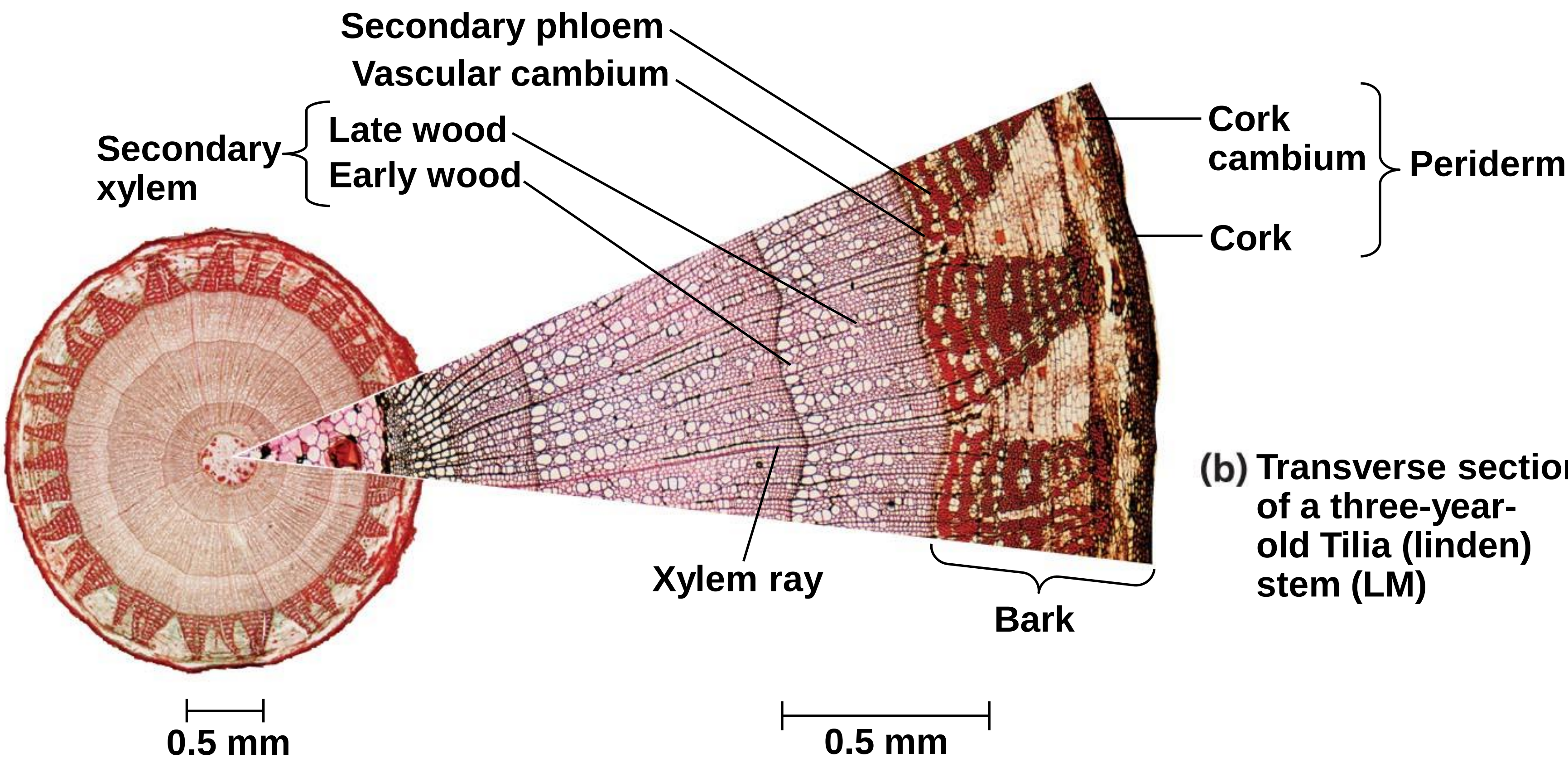
(c) Transverse section of a lilac (*Syringa*) leaf (LM)

Secondary growth adds girth to stems and roots in woody plants

- Secondary growth occurs in stems and roots of woody plants but rarely in leaves
- The secondary plant body consists of the tissues produced by the vascular cambium and cork cambium



Secondary growth adds girth to stems and roots in woody plants

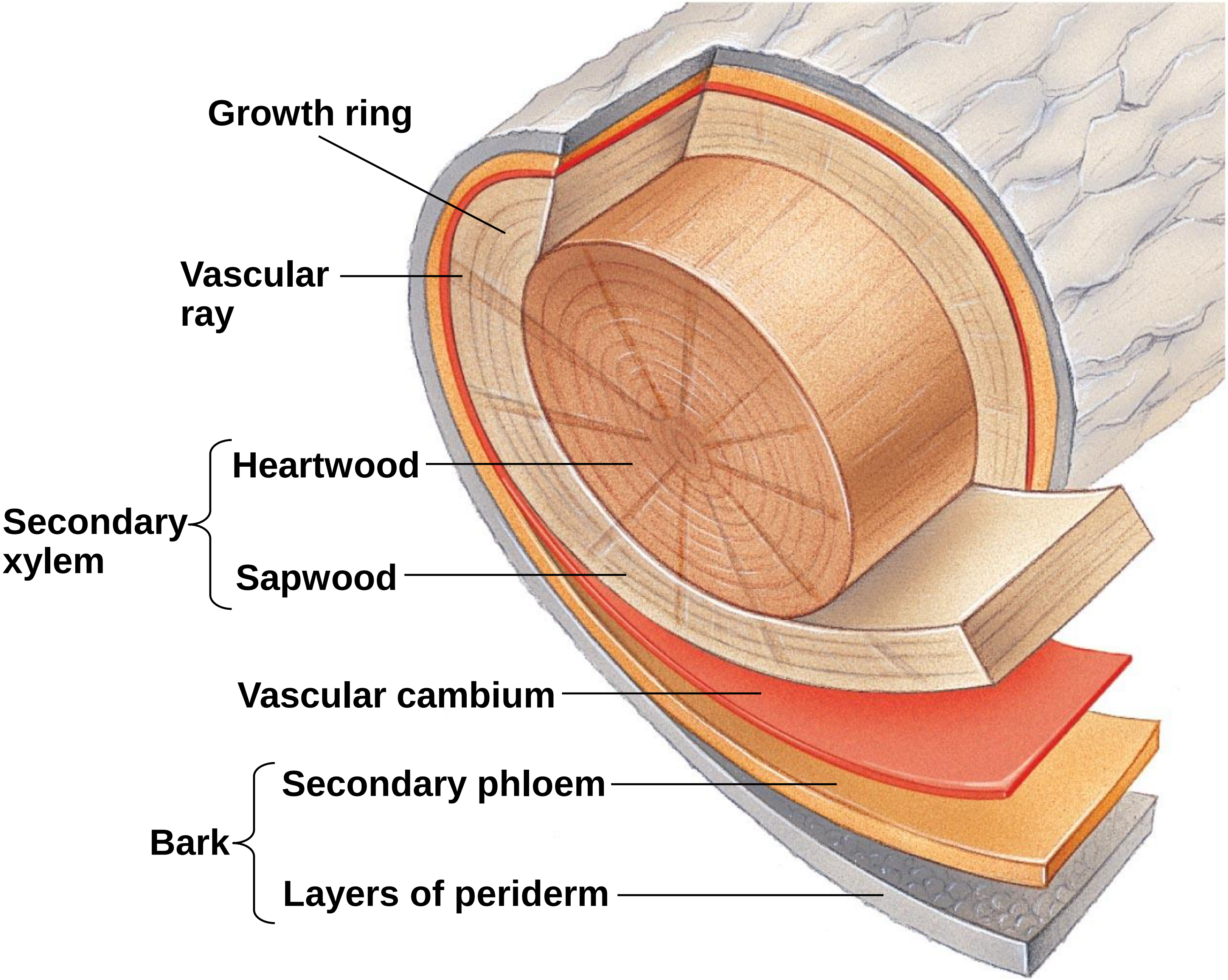


(b) Transverse section of a three-year-old Tilia (linden) stem (LM)

The Vascular Cambium and Secondary Vascular Tissue

- The **vascular cambium** is a cylinder of meristematic cells one cell thick
- It develops from undifferentiated cells and parenchyma cells that regain the capacity of divide
- In transverse section, the vascular cambium appears as a ring, with regions of dividing cells called fusiform initials and ray initials
- The initials increase the vascular cambium’s circumference and add secondary xylem to the inside and secondary phloem to the outside
- As a tree or woody shrub ages, the older layers of secondary xylem, the **heartwood**, no longer transport water and minerals
- The outer layers, known as **sapwood**, still transport materials through the xylem

Anatomy of a tree trunk



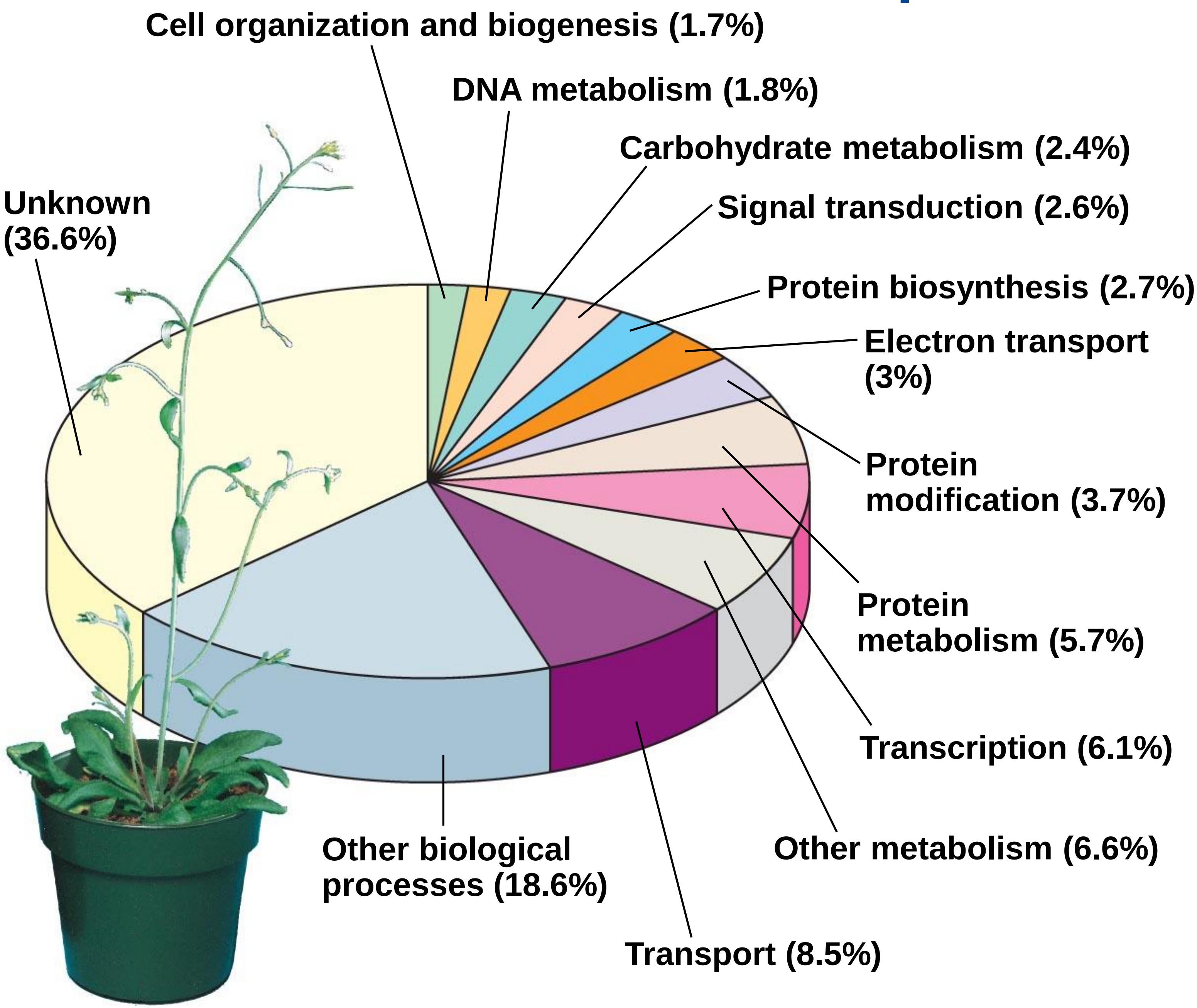
Cork Cambia and the Production of Periderm

- The **cork cambium** gives rise to the secondary plant body's protective covering, or **periderm**
- Periderm consists of the cork cambium plus the layers of cork cells it produces
- Bark consists of all the tissues external to the vascular cambium, including secondary phloem and periderm

Growth, morphogenesis, and differentiation produce the plant body

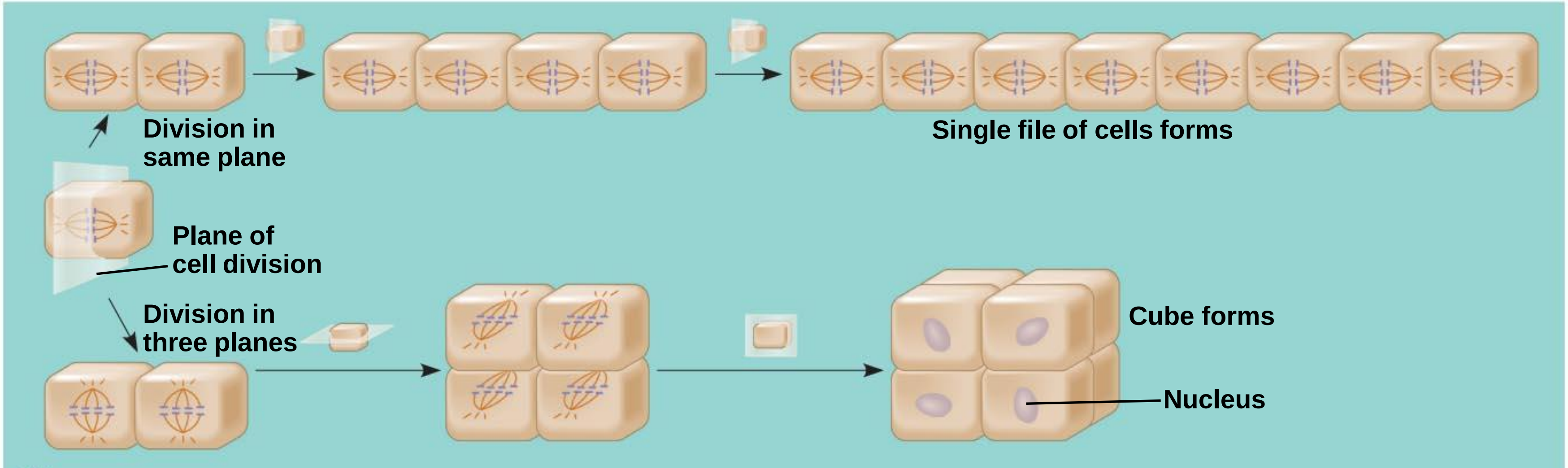
- The three developmental processes of growth, morphogenesis, and cellular differentiation act in concert to transform the fertilized egg into a plant
- New techniques and model systems are catalyzing explosive progress in our understanding of plants
- *Arabidopsis* is the first plant to have its entire genome sequenced
- The sequenced genes revealed the functions of the genes in the plant

Gene functions in Arabadopsis



Growth: Cell Division

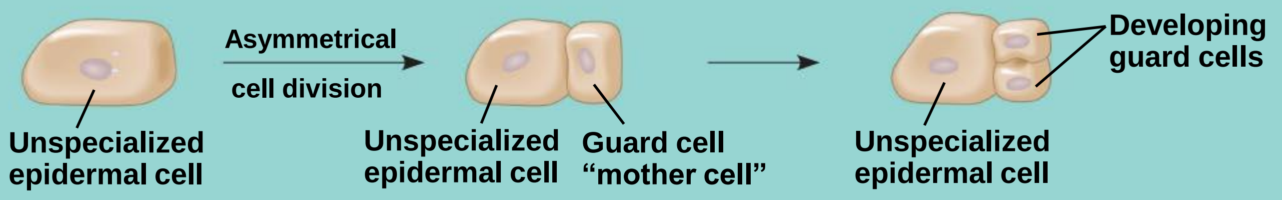
- By increasing cell number, cell division in meristems increases the potential for growth
- Cell division accounts for the actual increase in plant size = growth!
- The plane (direction) and symmetry of cell division are immensely important in determining plant form
- If the planes of division are parallel to the plane of the first division, a single file row of cells is produced



(a) Cell divisions in the same plane produce a single file of cells, whereas cell divisions in three planes give rise to a cube.

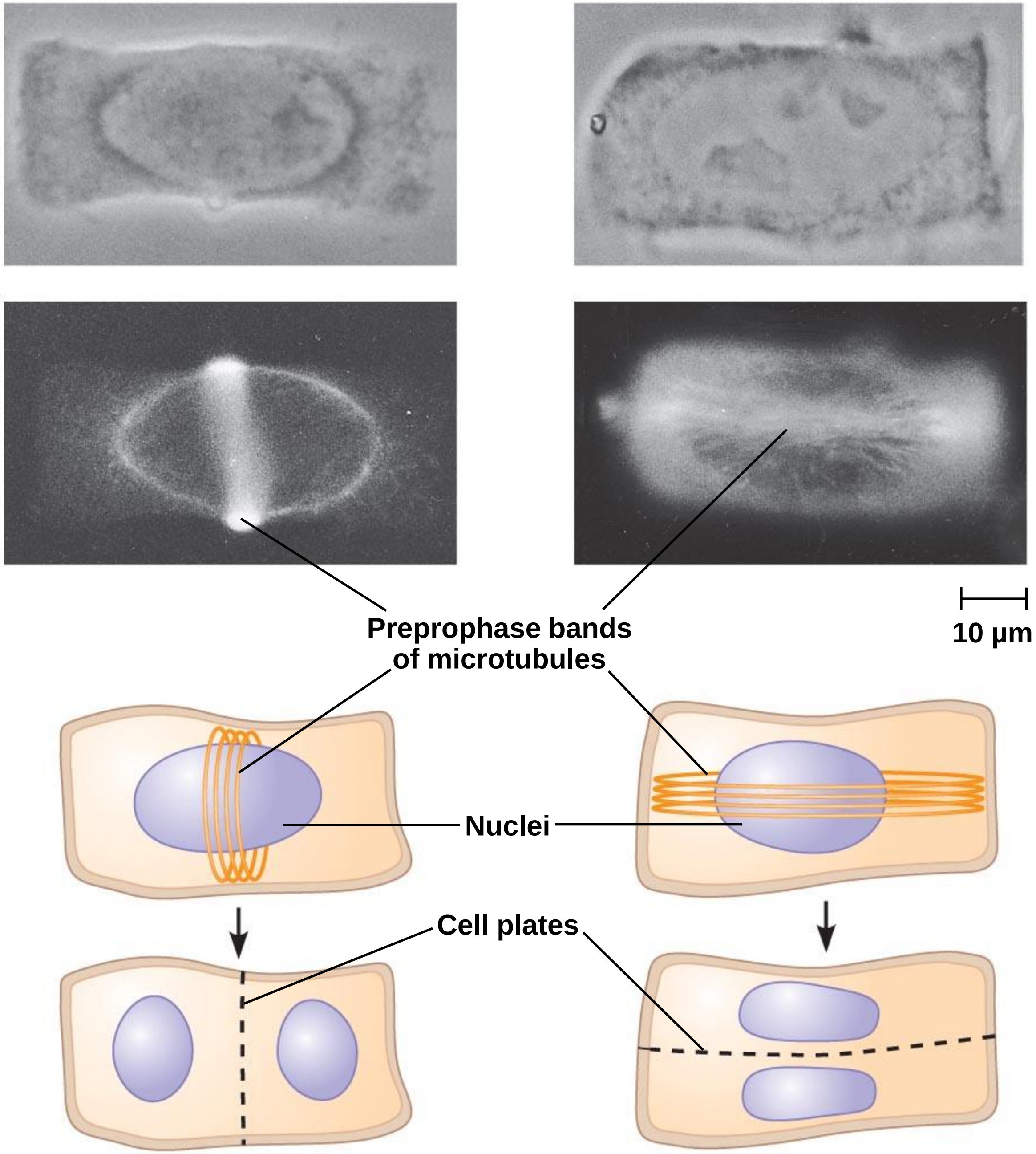
Growth: Cell Division

- If the planes of division vary randomly, asymmetrical cell division occurs
- The plane in which a cell divides is determined during late interphase
- Microtubules become concentrated into a ring called the preprophase band



(b) An asymmetrical cell division precedes the development of epidermal guard cells, the cells that border stomata (see Figure 35.17).

Cell Division

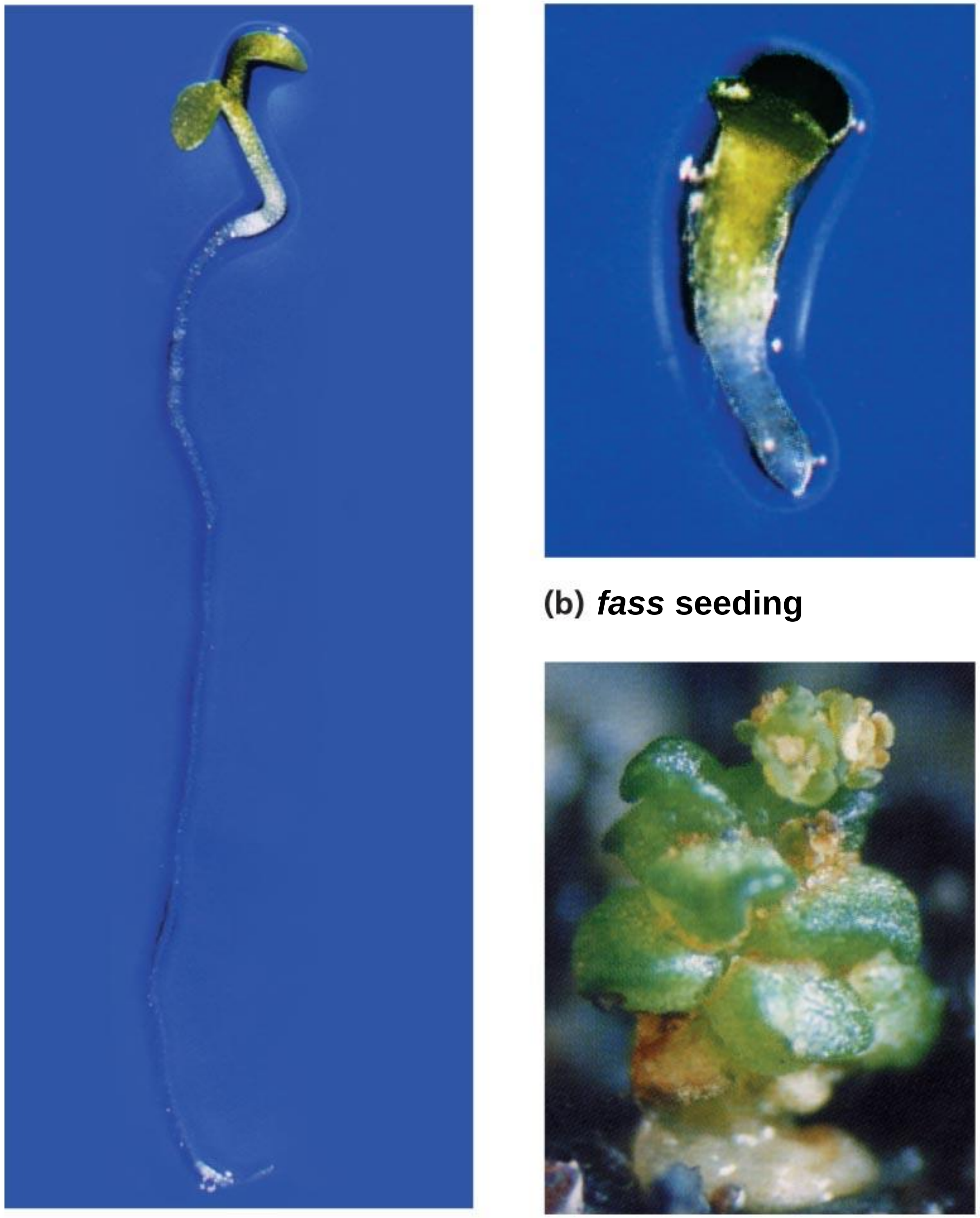


Orientation of Cell Expansion/Division

•Plant cells rarely expand (divide) equally in all directions

•Orientation of the cytoskeleton affects the direction of cell elongation by controlling orientation of cellulose microfibrils within the cell wall

•Studies of *fass* mutants of *Arabidopsis* have confirmed the importance of cytoplasmic microtubules in cell division and expansion



(b) *fass* seeding

(a) Wild-type seeding

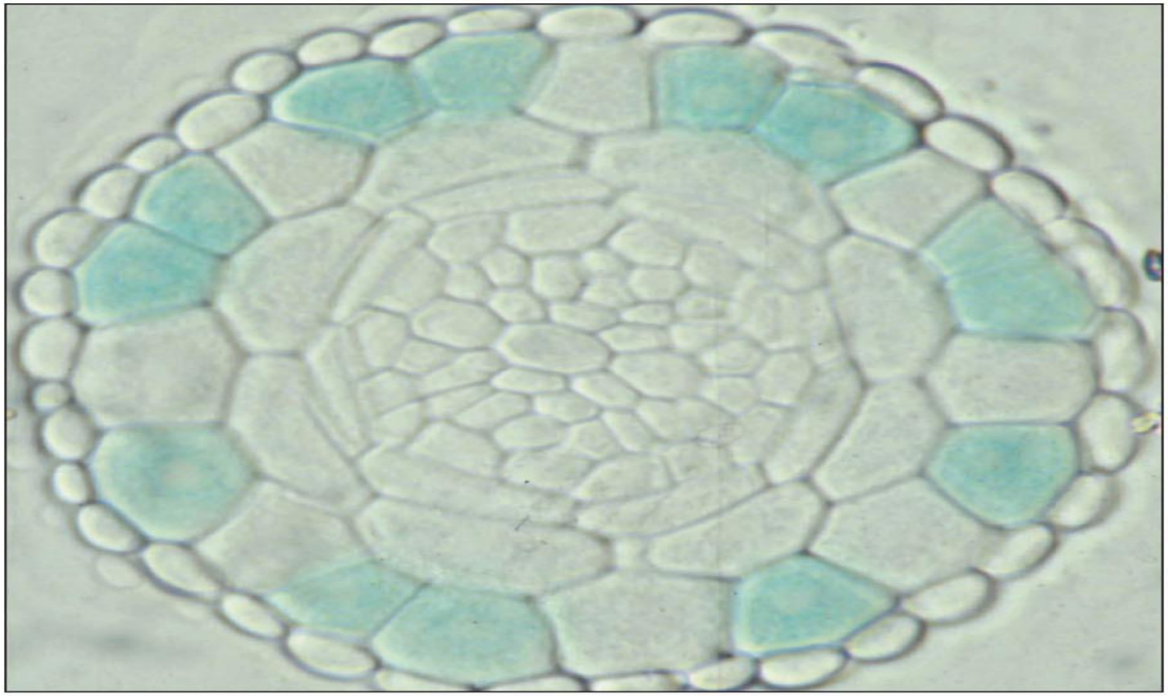
(c) Mass *fass* mutant

Morphogenesis and Pattern Formation

- Morphogenesis/pattern formation is the development of specific structures in specific locations
- It is determined by positional information in the form of signals indicating to each cell its location
- Polarity is one type of positional information
- In the *gnom* mutant of *Arabidopsis*, the establishment of polarity is defective

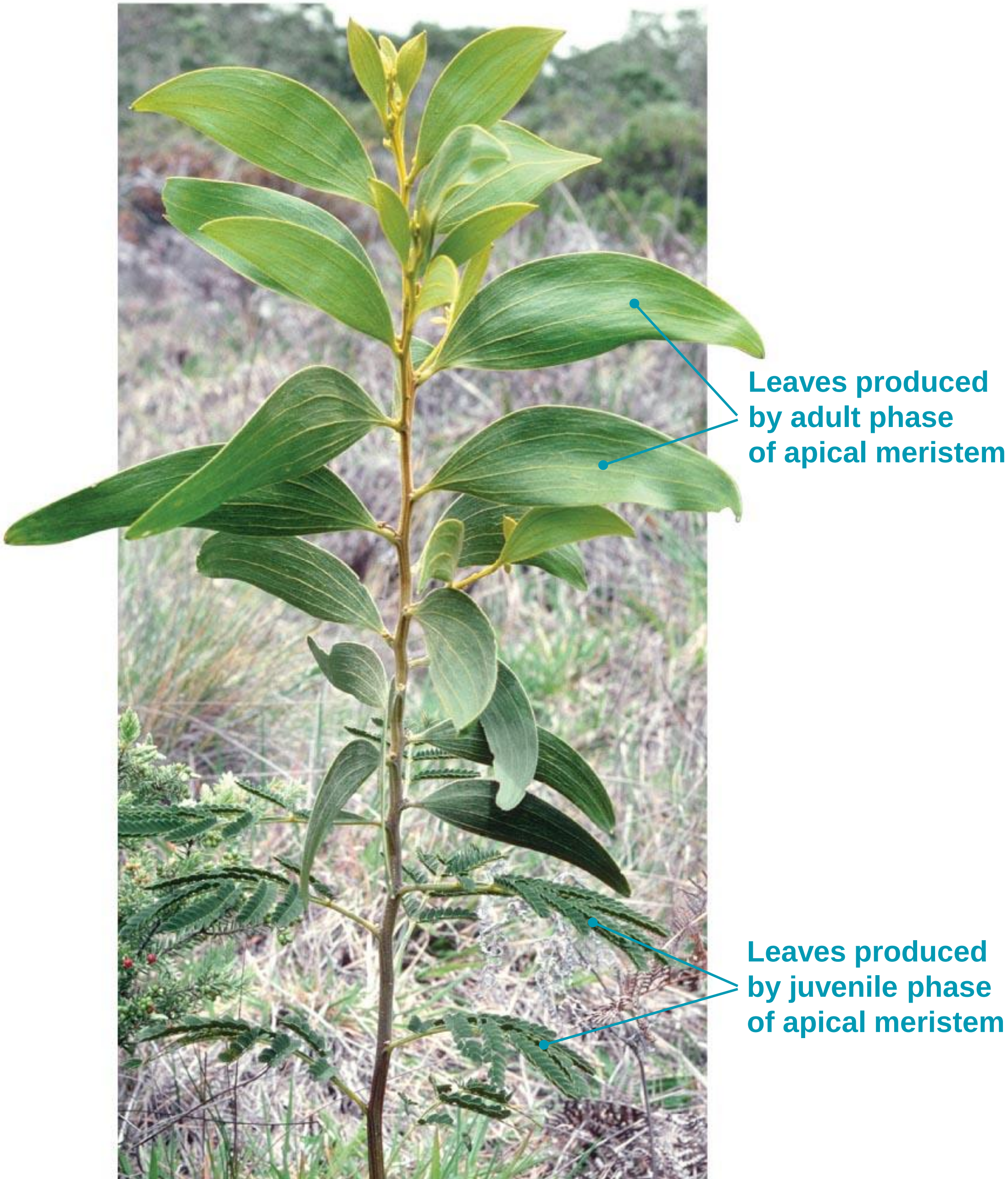
Gene Expression and Control of Cellular Differentiation

- In **cellular differentiation**, cells of a developing organism synthesize different proteins and diverge in structure and function even though they have a common genome – they become different from each other
- Cellular differentiation to a large extent depends on positional information and is affected by the expression of **homeotic genes** – genes that control the growth of cells of an organism



Location and a Cell's Developmental Fate

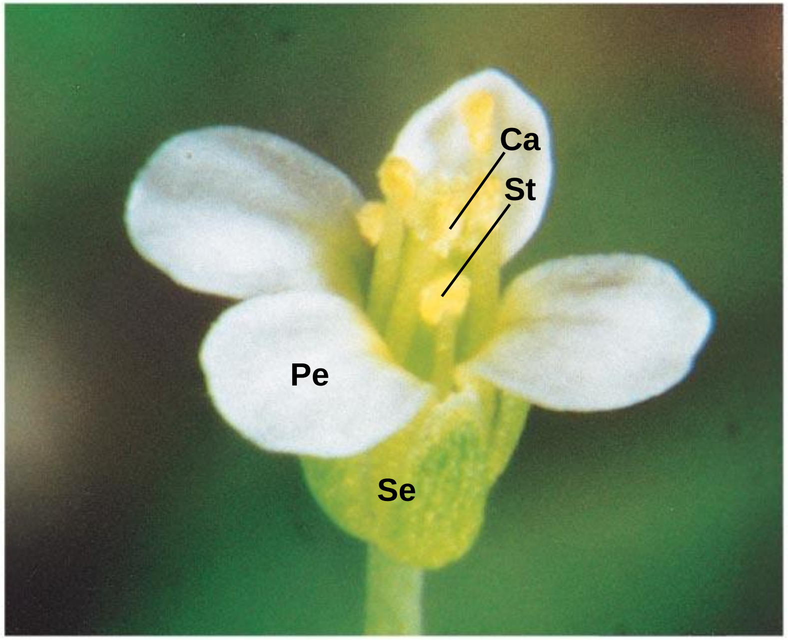
- A cell's position in a developing organ determines its pathway of differentiation
- Plants pass through developmental phases, called phase changes, developing from a juvenile phase to an adult phase
- The most obvious morphological changes typically occur in leaf size and shape



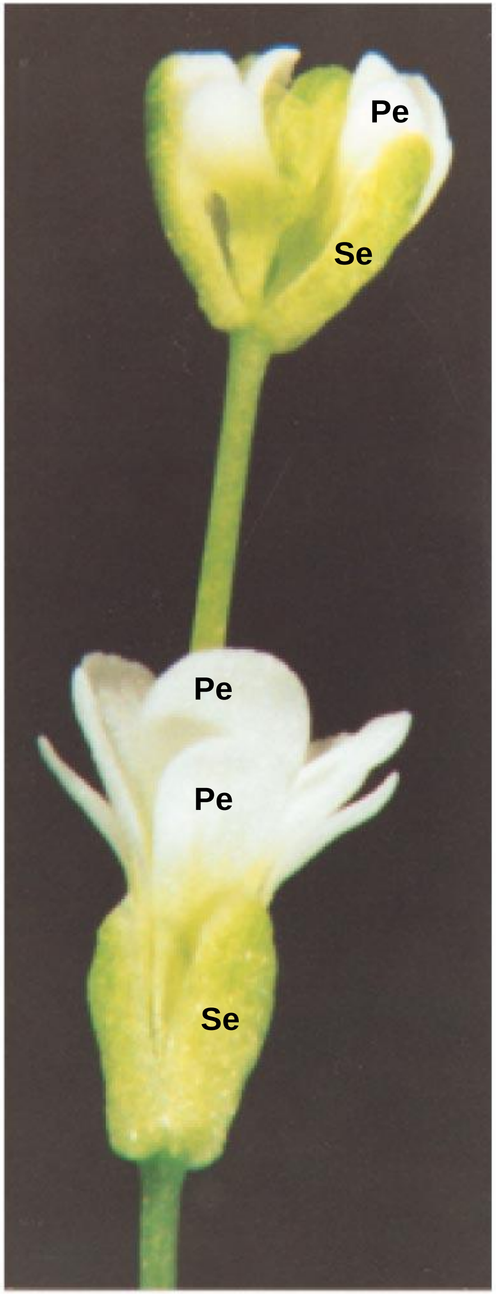
Genetic Control of Flowering

- Flower formation involves a phase change from vegetative growth to reproductive growth
- It is triggered by a combination of environmental cues and internal signals
- Transition from vegetative growth to flowering is associated with the switching-on of floral meristem identity genes
- Plant biologists have identified several organ identity genes that regulate the development of floral pattern

Genetic Control of Flowering

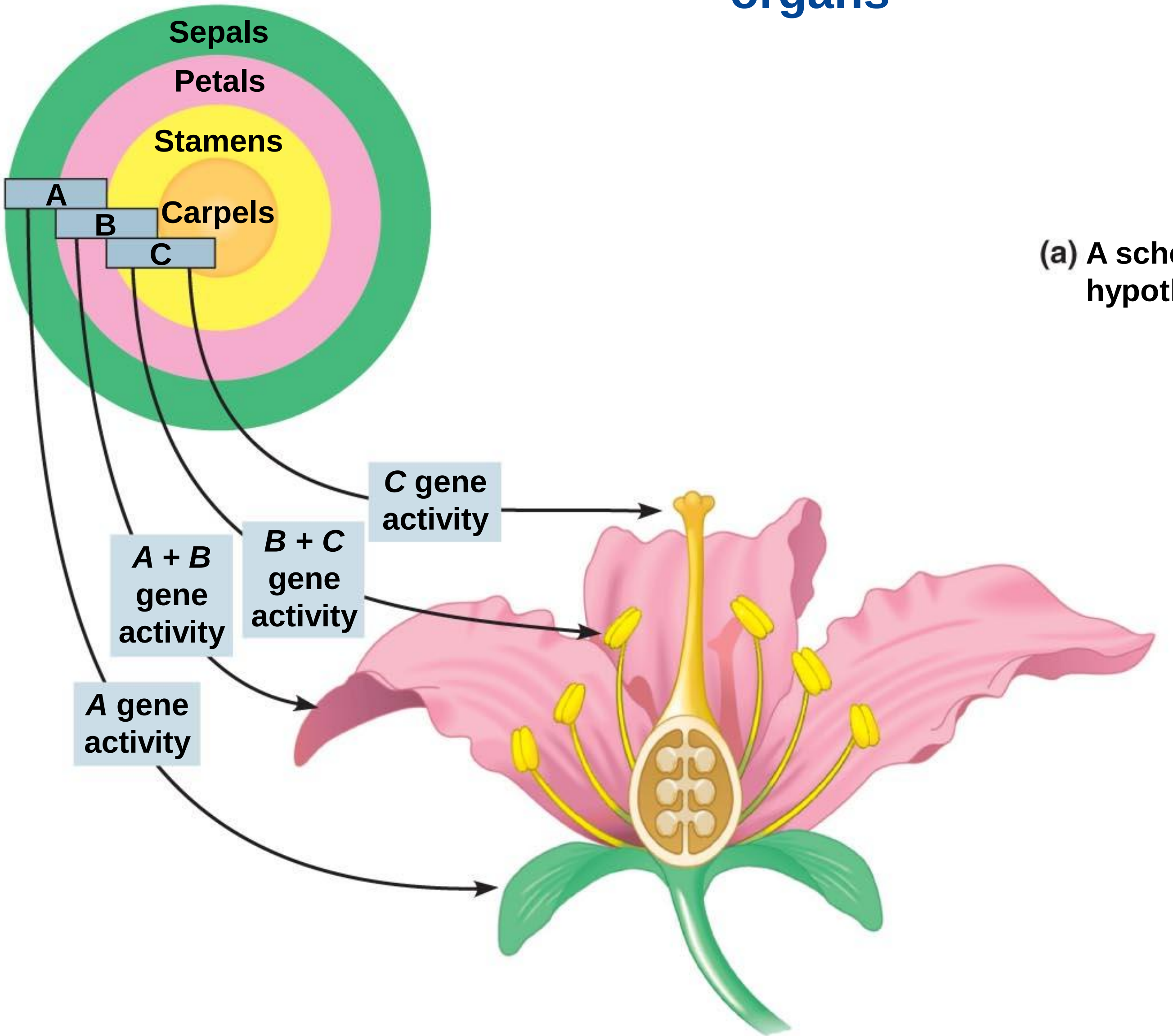


(a) Normal *Arabidopsis* flower. *Arabidopsis* normally has four whorls of flower parts: sepals (Se), petals (Pe), stamens (St), and carpels (Ca).



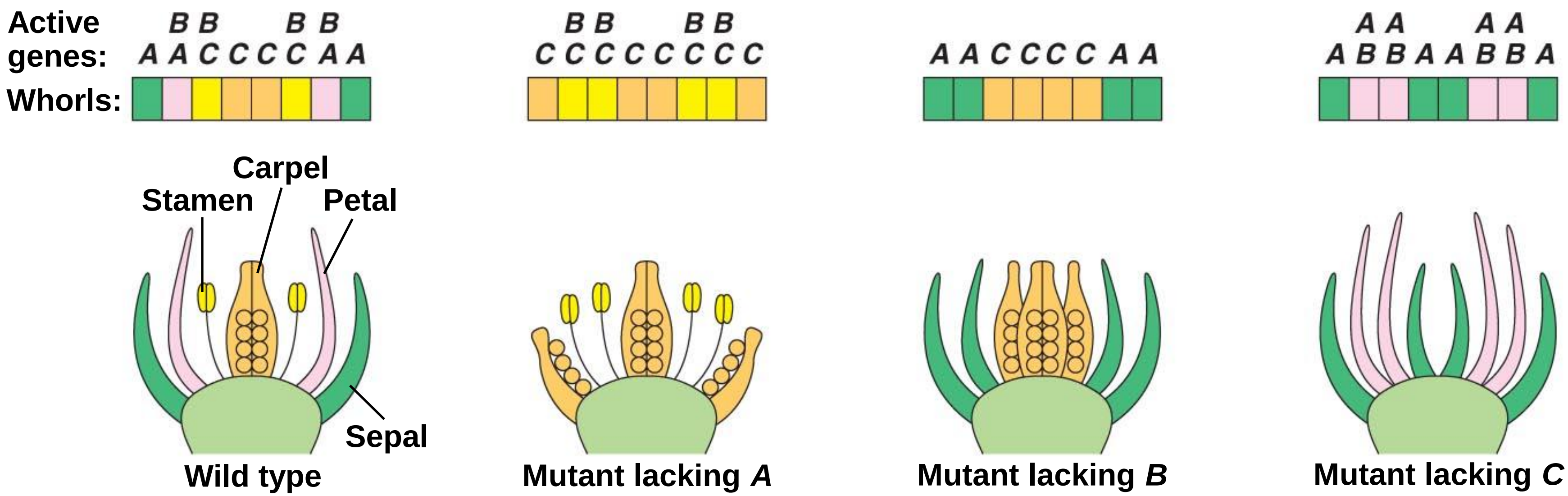
(b) Abnormal *Arabidopsis* flower. This flower has an extra set of petals in place of stamens and an internal flower where normal plants have carpels.

The ABC model of flower formation identifies how floral organ identity genes direct the formation of the four types of floral organs



(a) A schematic diagram of the ABC hypothesis

An understanding of mutants of the organ identity genes depicts how this model accounts for floral phenotypes



(b) Side view of organ identity mutant flowers