Chapter 35

Plant Structure, Growth, and Development

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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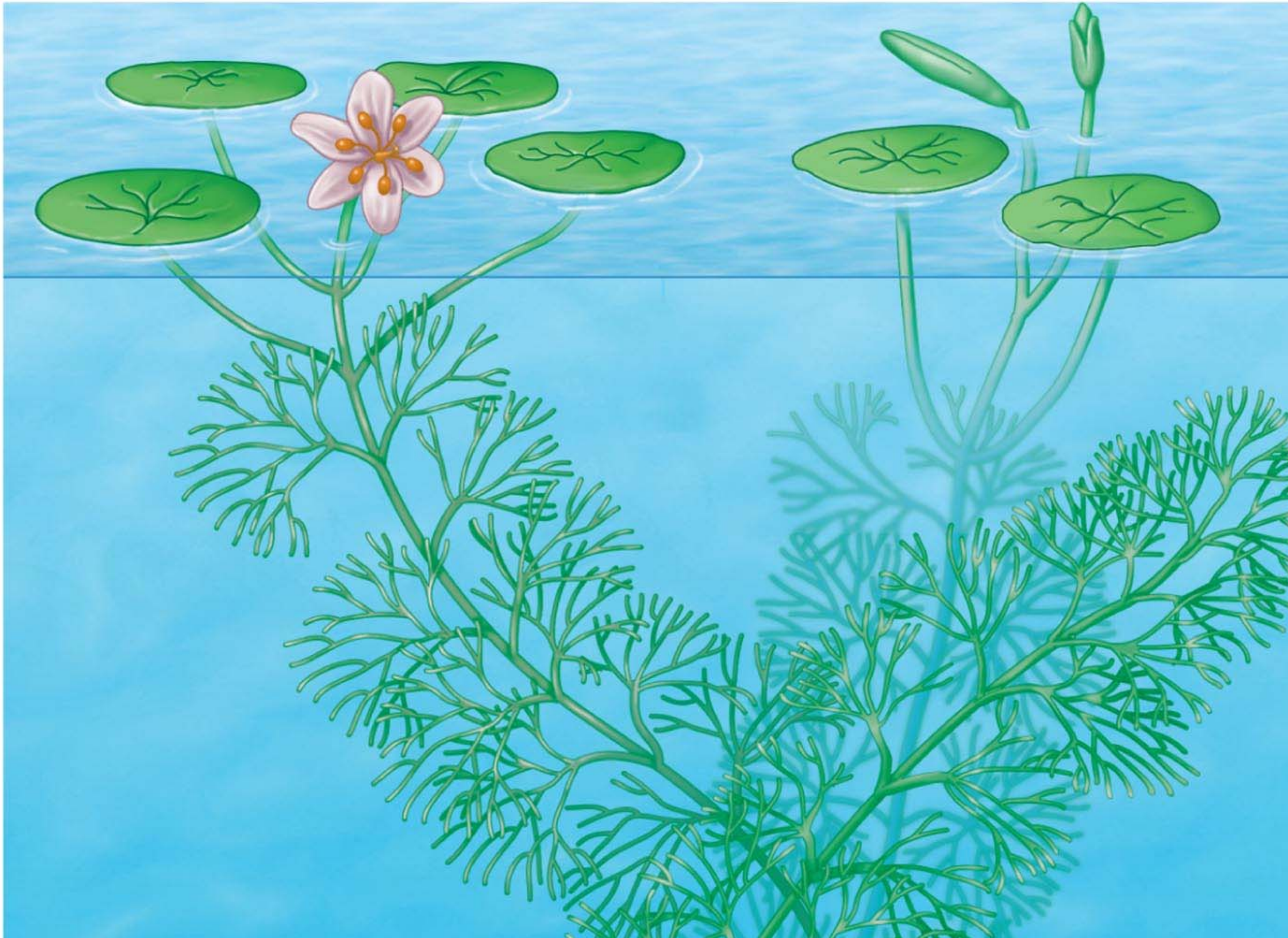
Overview: Plastic Plants?

- To some people, the fanwort is an intrusive weed, but to others it is an attractive aquarium plant
- This plant exhibits *developmental plasticity*, the ability to alter itself in response to its environment

Fig. 35-1



- Developmental plasticity is more marked in plants than in animals
- In addition to plasticity, plant species have by natural selection accumulated characteristics of **morphology** that vary little within the species

Concept 35.1: The plant body has a hierarchy of organs, tissues, and cells

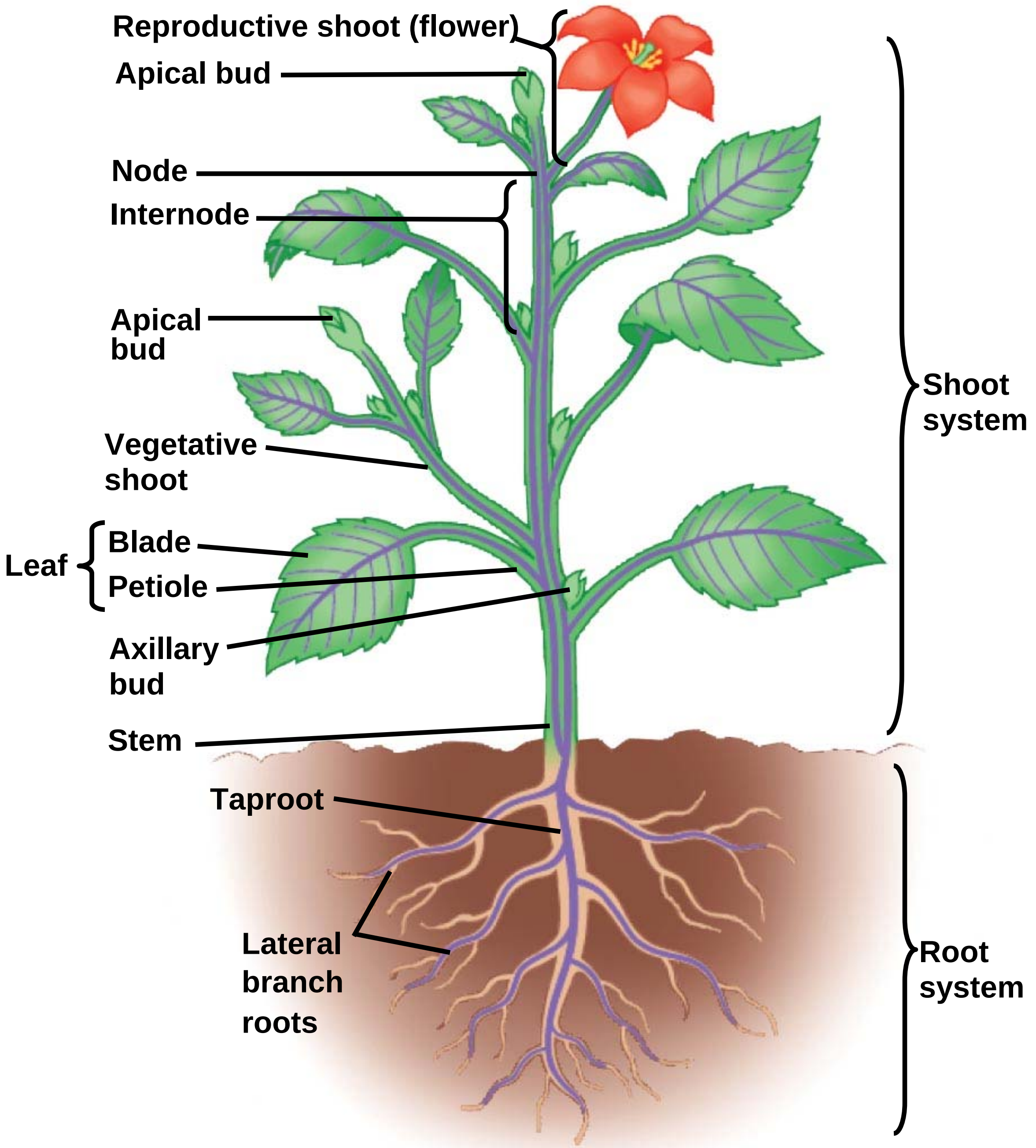
- Plants, like multicellular animals, have **organs** composed of different **tissues**, which in turn are composed of cells

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

- Three basic organs evolved: roots, stems, and leaves
- They are organized into a **root system** and a **shoot system**
- Roots rely on sugar produced by photosynthesis in the shoot system, and shoots rely on water and minerals absorbed by the root system

Fig. 35-2



Reproductive shoot (flower)
Apical bud
Node
Internode
Apical bud
Vegetative shoot
Leaf
Blade
Petiole
Axillary bud
Stem
Taproot
Lateral branch roots
Shoot system
Root system

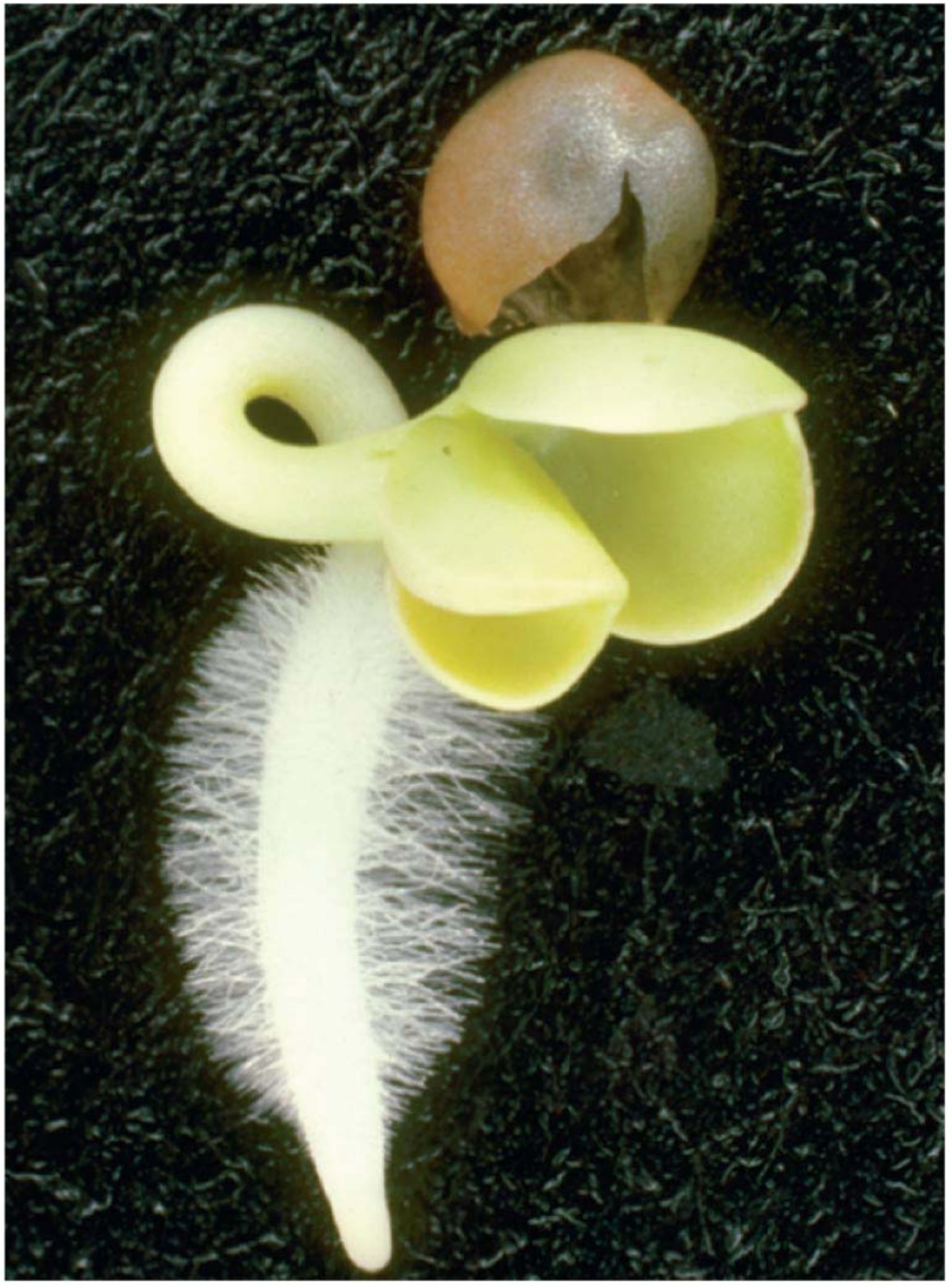
Roots

- **Roots** are multicellular organs with important functions:
  - Anchoring the plant
  - Absorbing minerals and water
  - Storing organic nutrients

- A **taproot** system consists of one main vertical root that gives rise to **lateral roots**, or branch roots
- Adventitious roots arise from stems or leaves
- Seedless vascular plants and monocots have a fibrous root system characterized by thin lateral roots with no main root

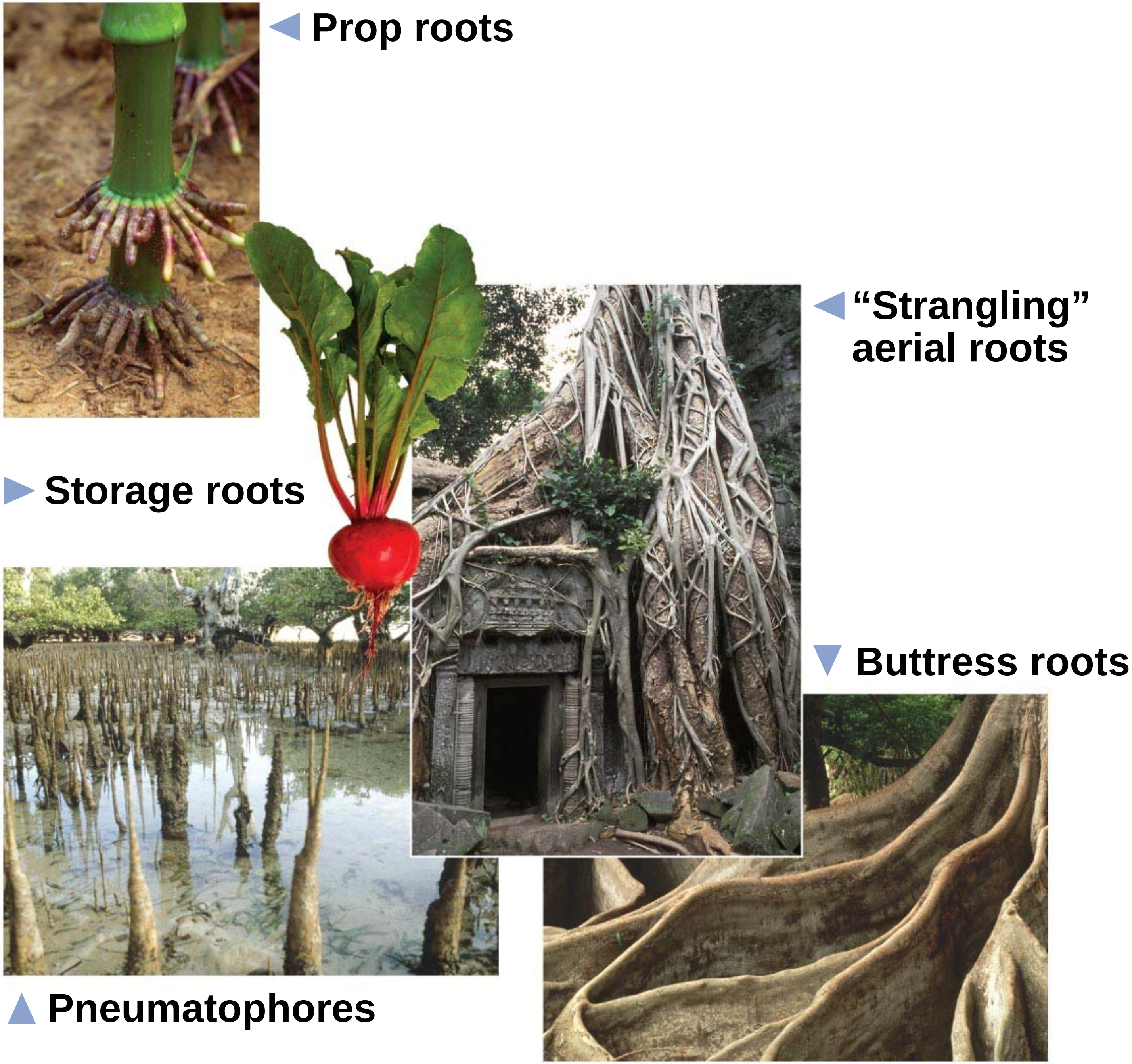
- In most plants, absorption of water and minerals occurs near the **root hairs**, where vast numbers of tiny root hairs increase the surface area

Fig. 35-3



- Many plants have modified roots

Fig. 35-4



Prop roots
Storage roots
"Strangling" aerial roots
Buttress roots
Pneumatophores

Fig. 35-4a

Prop roots

Fig. 35-4b

Storage roots

Fig. 35-4c

“Strangling” aerial roots

Fig. 35-4d

Pneumatophores

Fig. 35-4e

Buttress roots

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
- An **apical bud**, or terminal bud, is located near the shoot tip and causes elongation of a young shoot
- **Apical dominance** helps to maintain dormancy in most nonapical buds

- Many plants have modified stems

Fig. 35-5

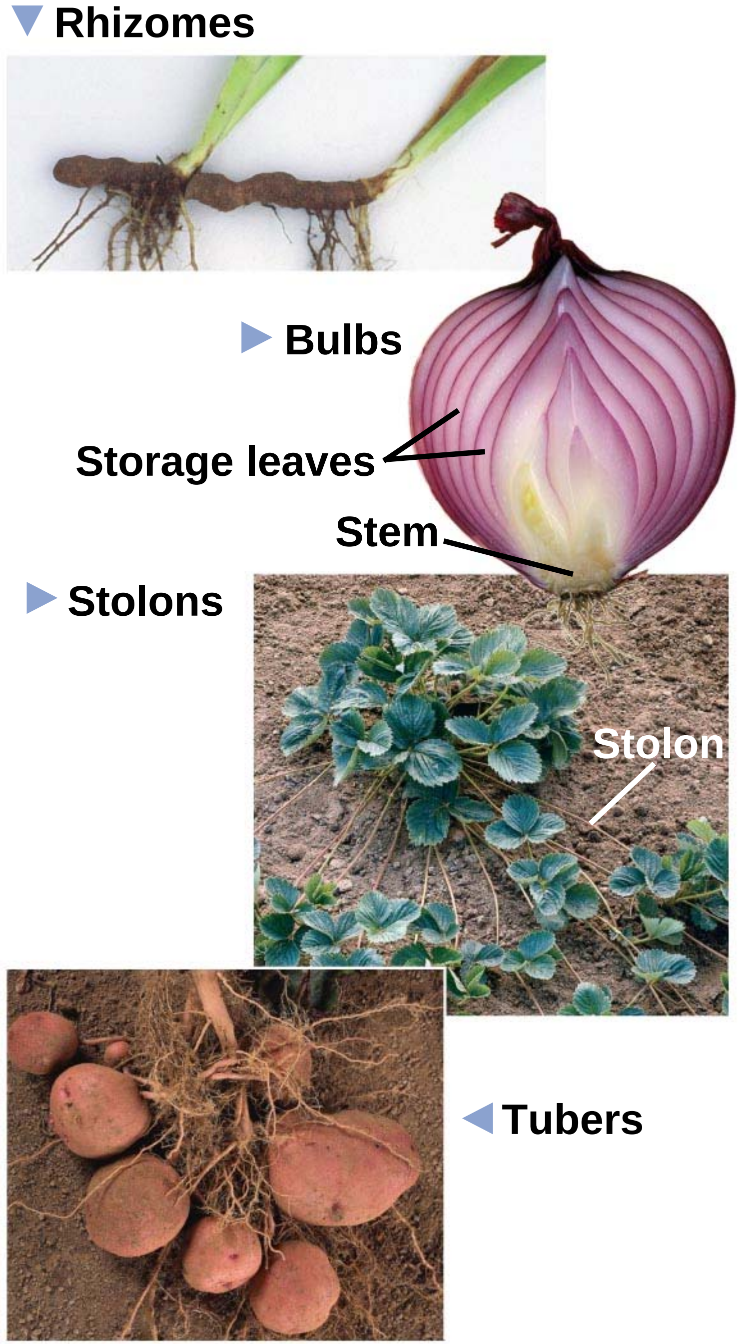
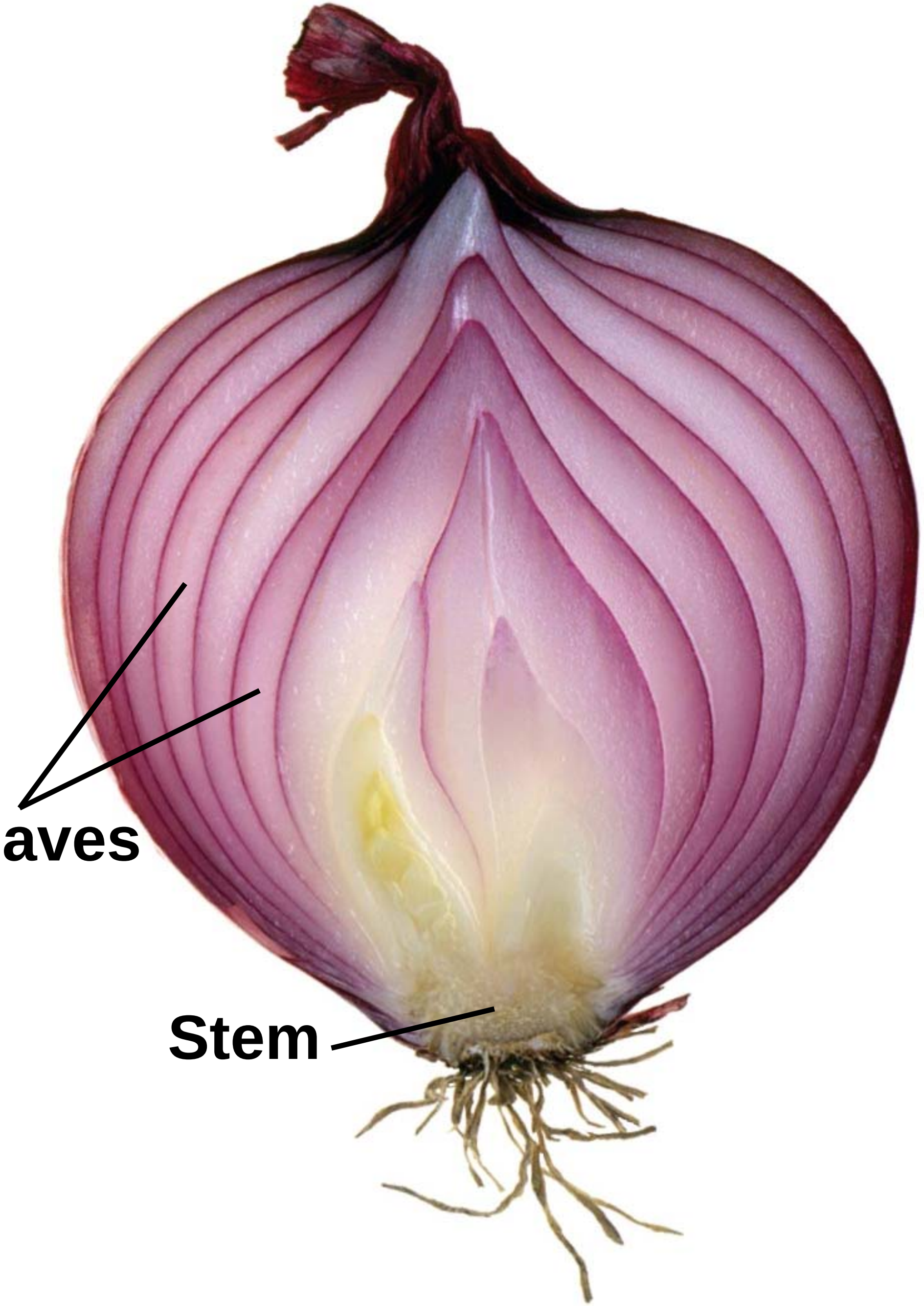


Fig. 35-5a

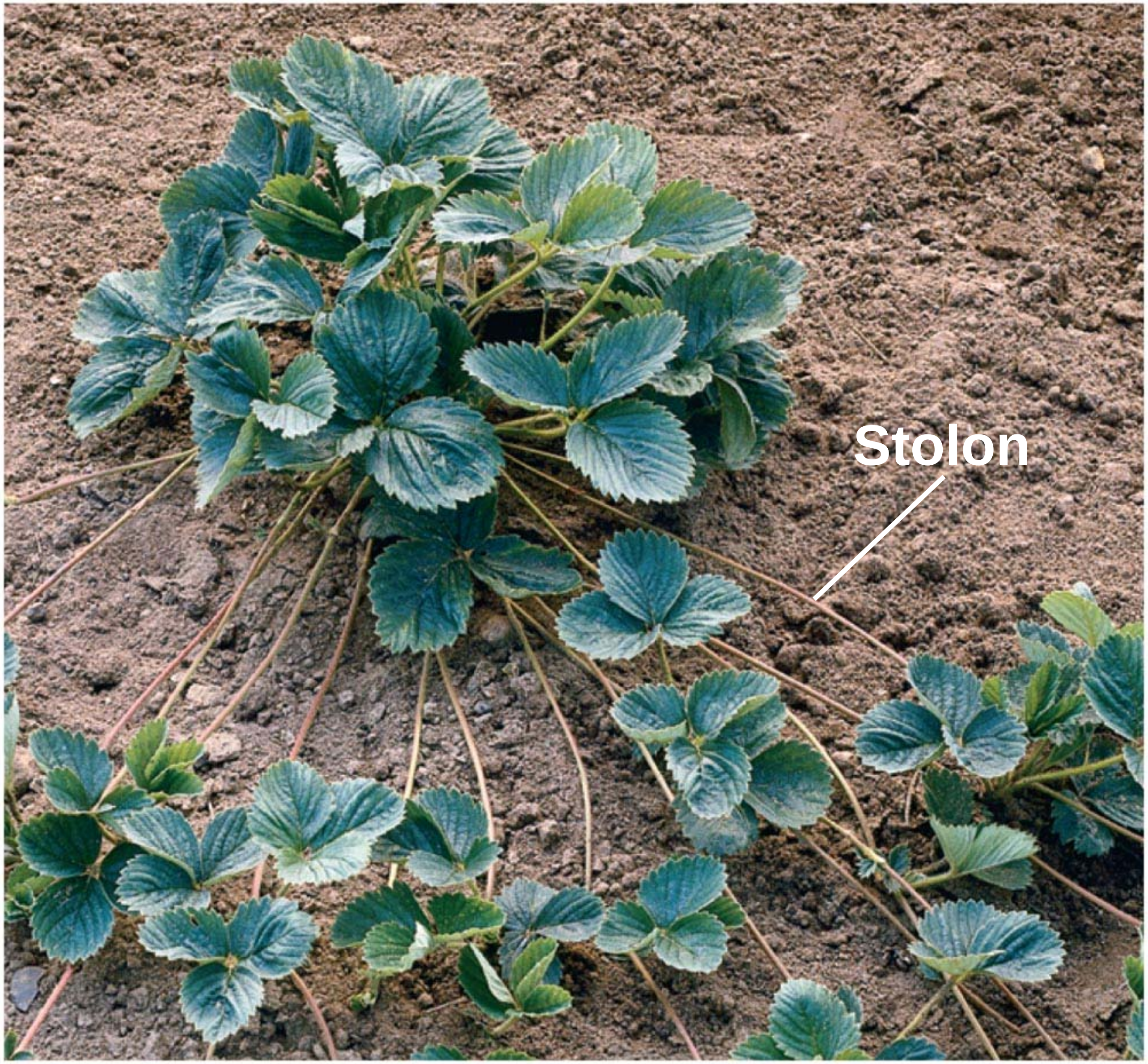
Rhizomes

Fig. 35-5b



Bulb

Fig. 35-5c



Stolons

Fig. 35-5d

Tubers

Leaves

- The **leaf** is the main photosynthetic organ of most vascular plants
- Leaves generally consist of a flattened **blade** and a stalk called 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
  - Most eudicots have branching veins
- In classifying angiosperms, taxonomists may use leaf morphology as a criterion

Fig. 35-6

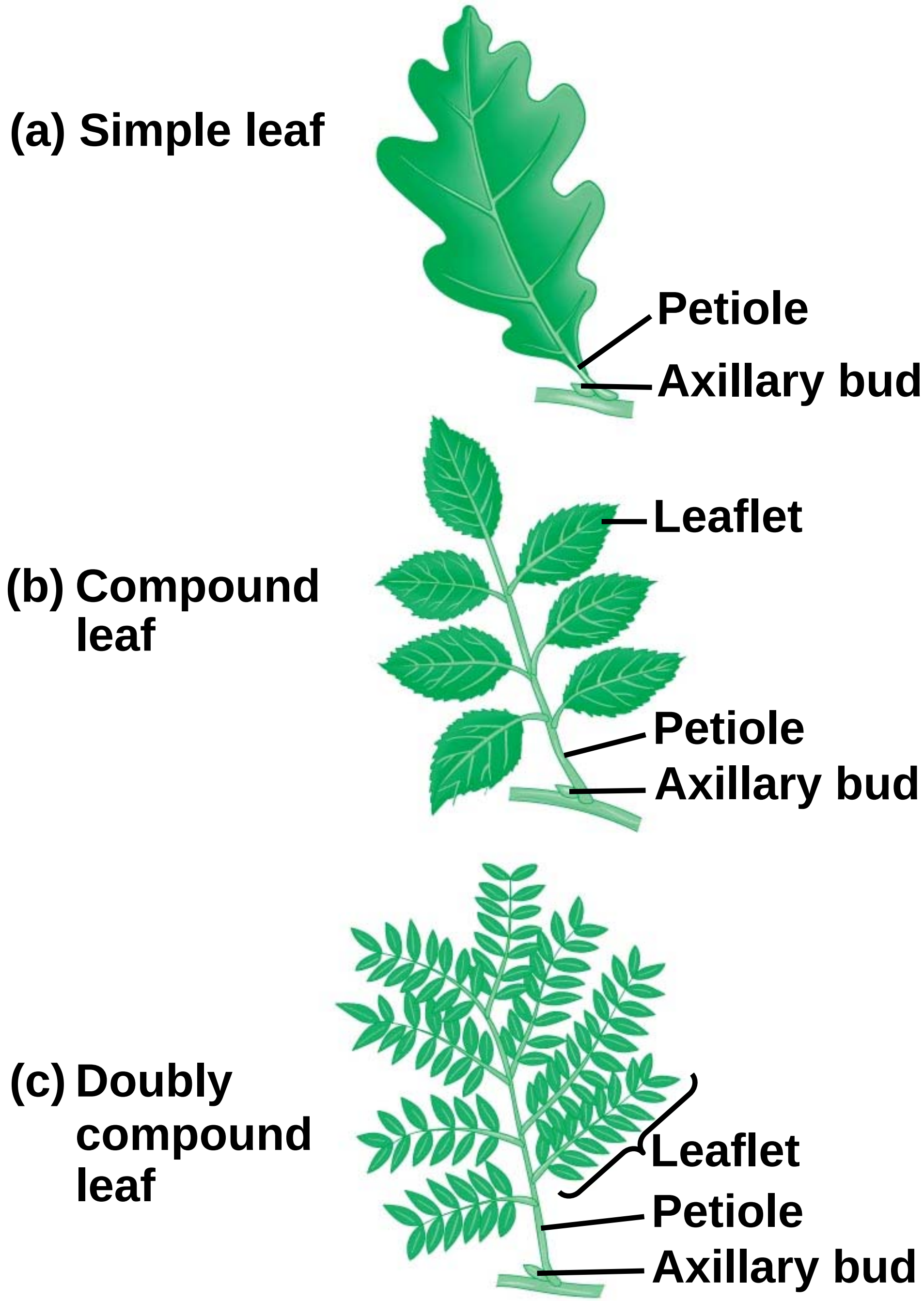

(a) Simple leaf
Petiole
Axillary bud
(b) Compound leaf
Leaflet
Petiole
Axillary bud
(c) Doubly compound leaf
Leaflet
Petiole
Axillary bud

Fig. 35-6a

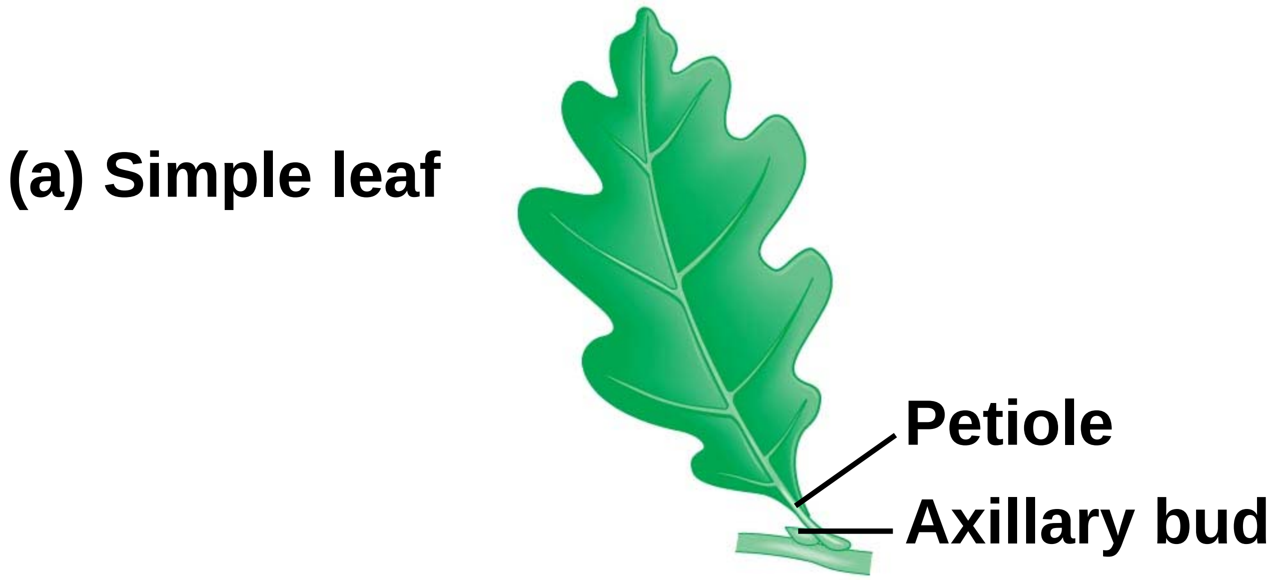


Fig. 35-6b

(b) Compound leaf

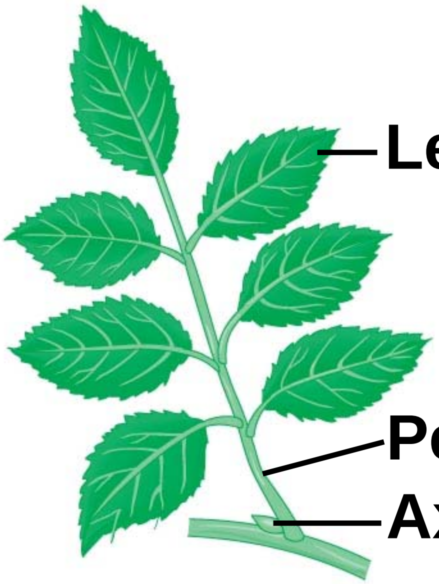
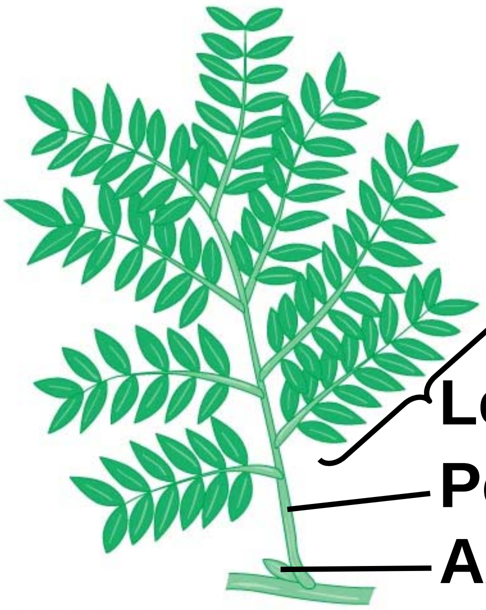


Fig. 35-6c



(c) Doubly compound leaf

- Some plant species have evolved modified leaves that serve various functions

Fig. 35-7

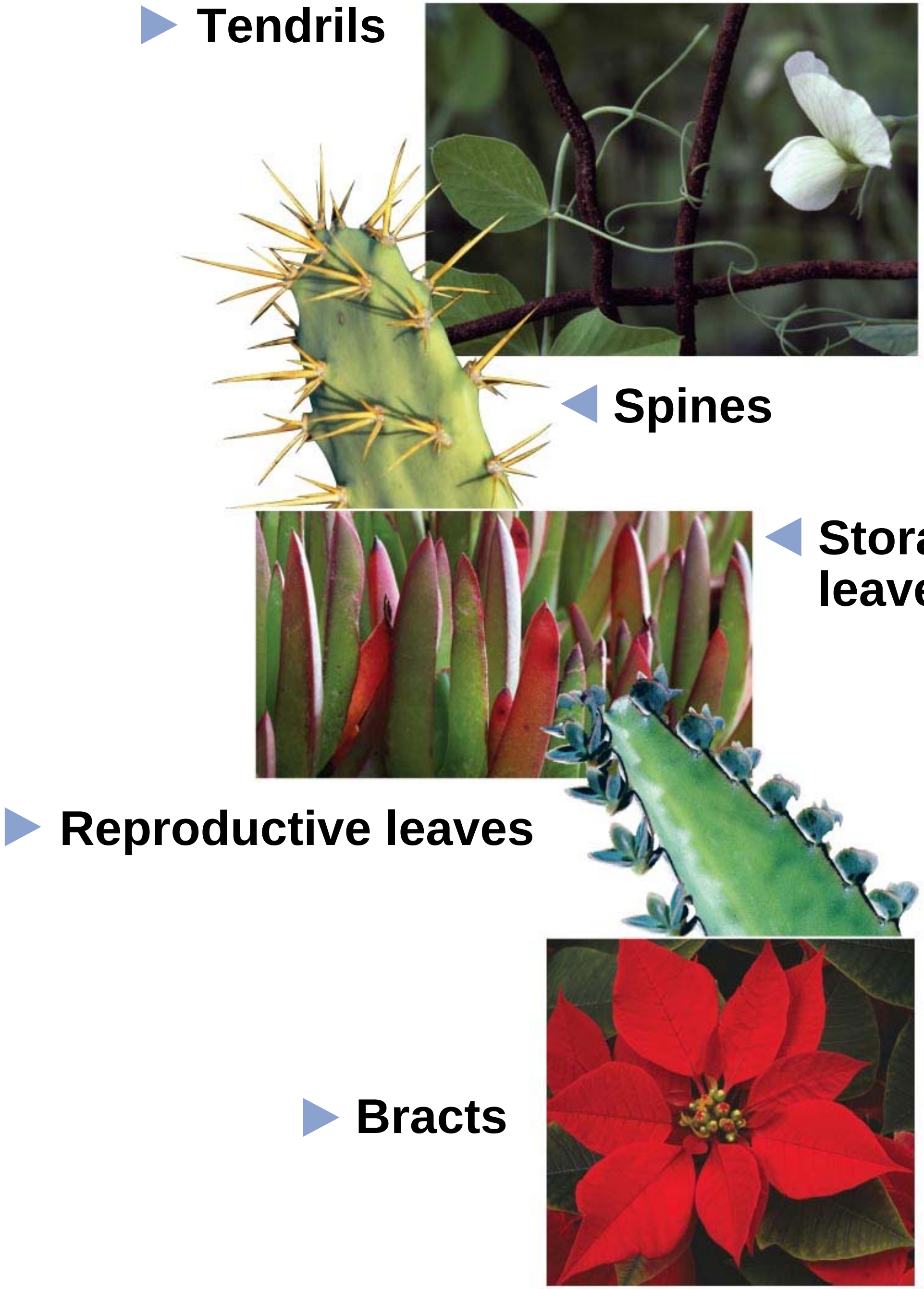
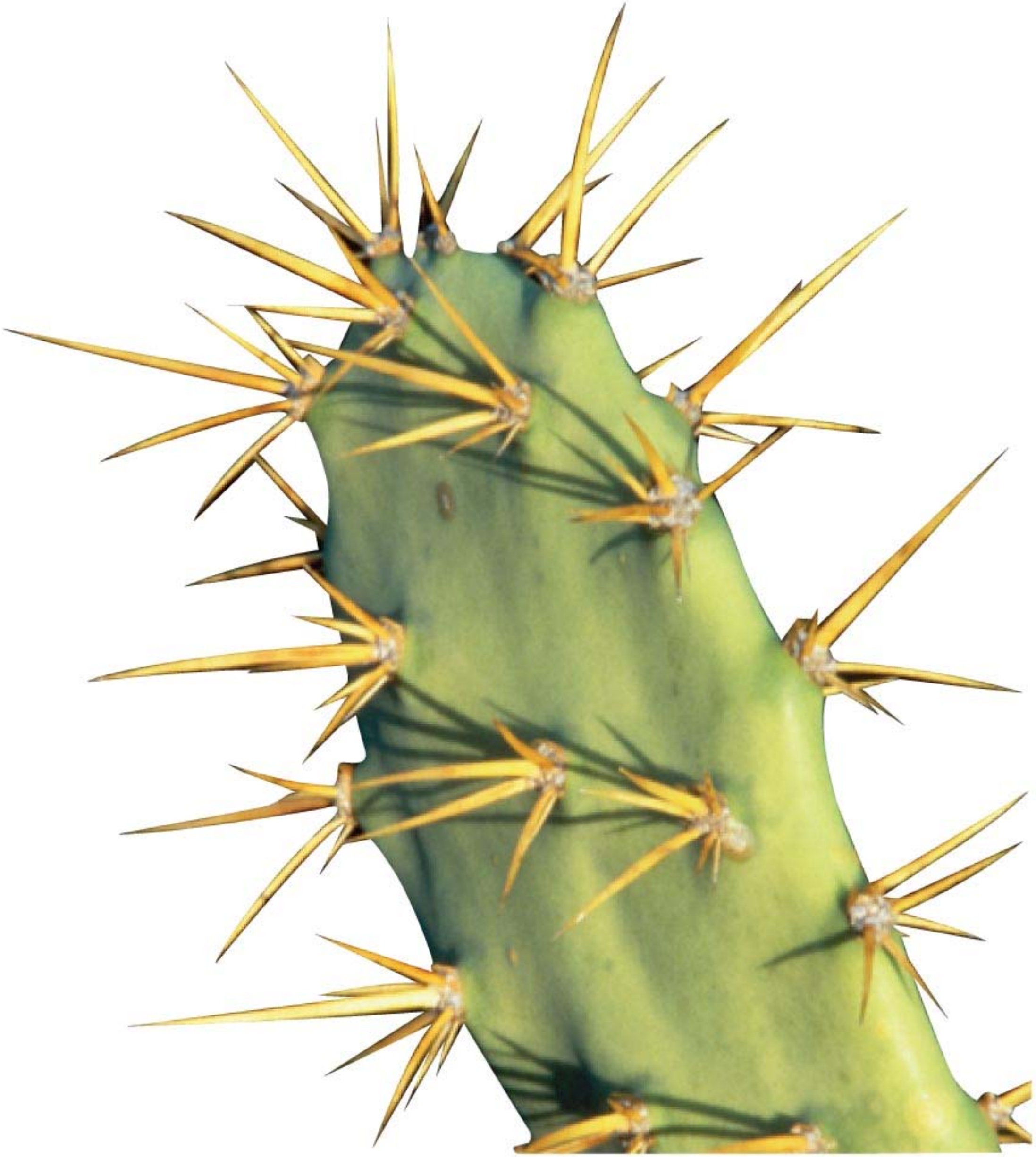

Tendrils
Spines
Storage leaves
Reproductive leaves
Bracts

Fig. 35-7a

Tendrils

Fig. 35-7b

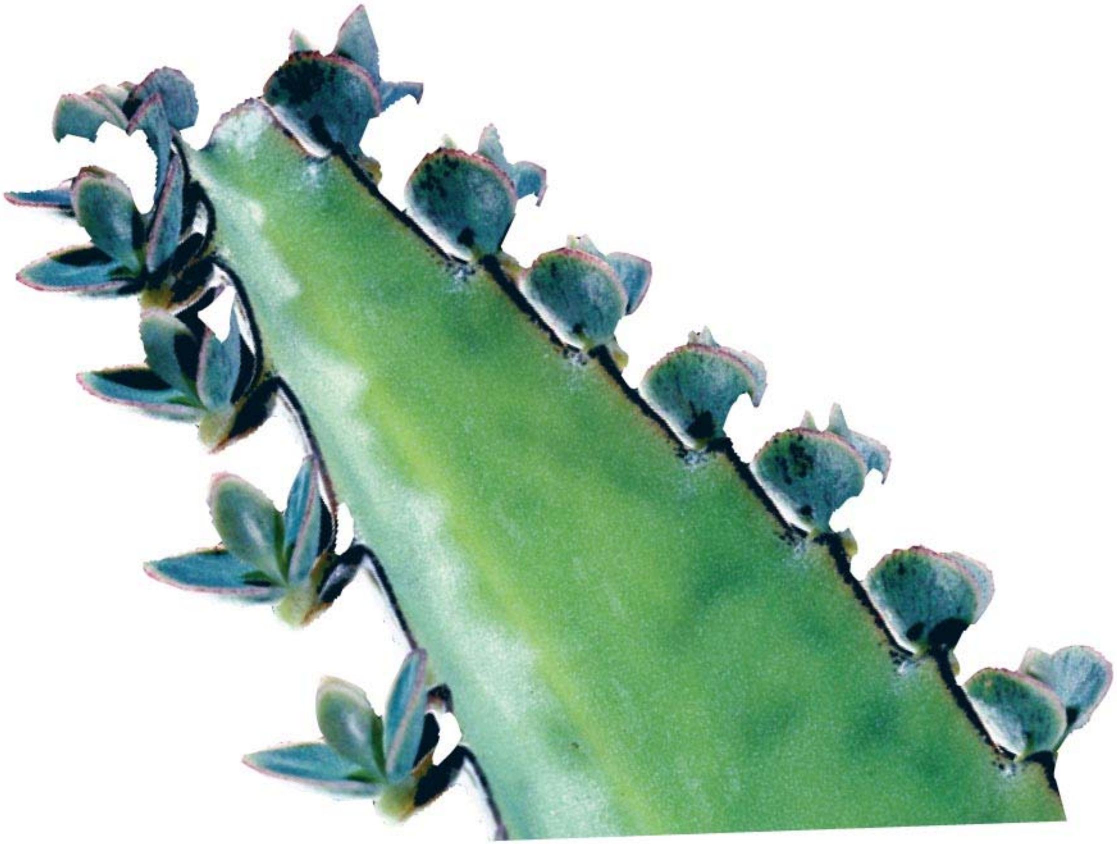


Spines

Fig. 35-7c

Storage leaves

Fig. 35-7d



Reproductive leaves

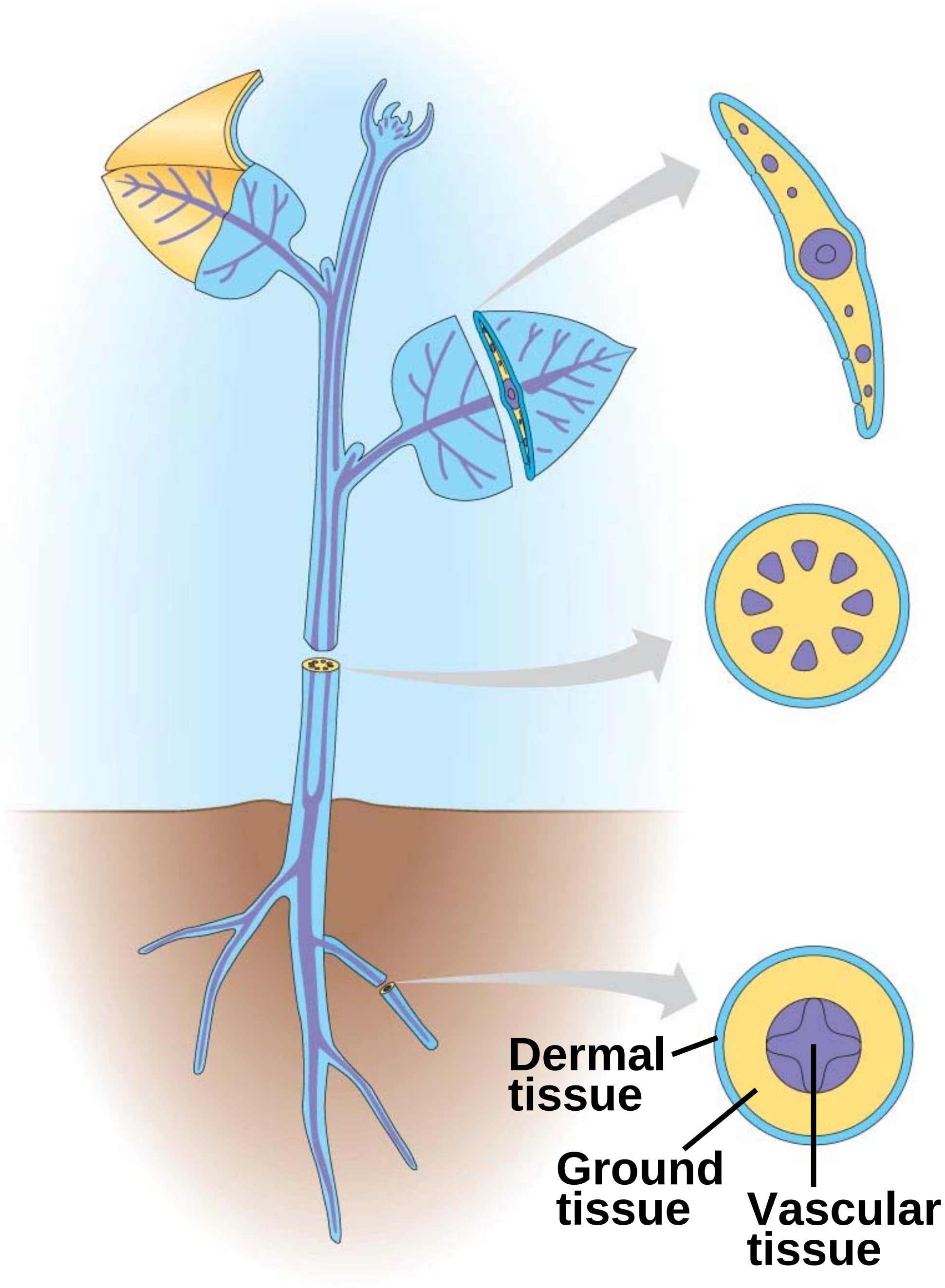
Fig. 35-7e

Bracts

Dermal, Vascular, and Ground Tissues

- Each plant organ has dermal, vascular, and ground tissues
- Each of these three categories forms a **tissue system**

Fig. 35-8



- In nonwoody plants, the **dermal tissue system** consists of the **epidermis**
- A waxy coating called the **cuticle** helps prevent water loss from the epidermis
- In woody plants, protective tissues called **periderm** replace the epidermis in older regions of stems and roots
- *Trichomes* are outgrowths of the shoot epidermis and can help with insect defense

Fig. 35-9

EXPERIMENT

Very hairy pod (10 trichomes/ mm^2)	**Slightly hairy pod (2 trichomes/ mm^2)**	**Bald pod (no trichomes)**

RESULTS

Very hairy pod: 10% damage	**Slightly hairy pod: 25% damage**	**Bald pod: 40% damage**

- 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 to where they are needed

- 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 internal to the vascular tissue is **pith**; ground tissue external to the vascular tissue is **cortex**
- Ground tissue includes cells specialized for storage, photosynthesis, and 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

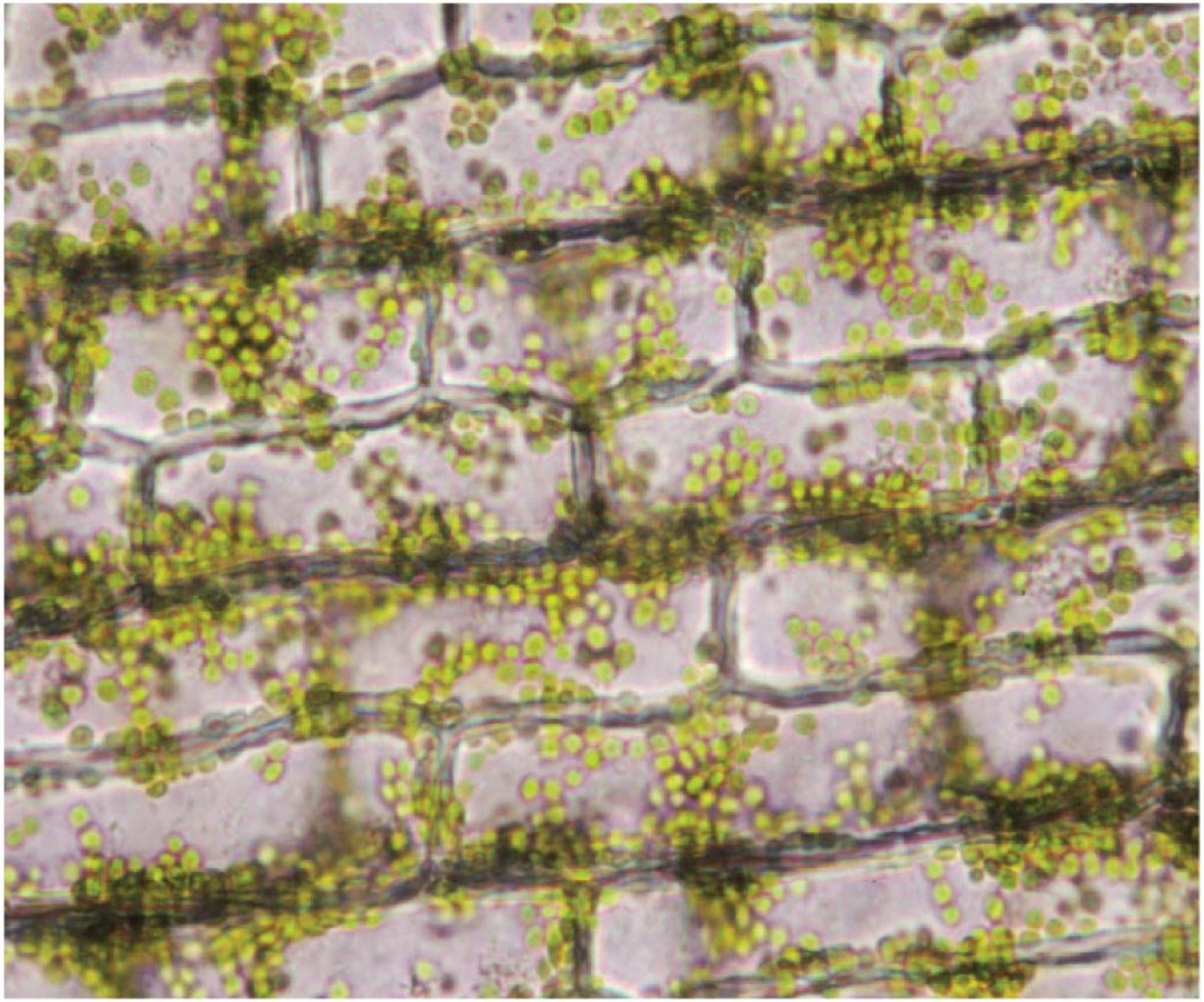
- Some major types of plant cells:
  - Parenchyma
  - Collenchyma
  - Sclerenchyma
  - Water-conducting cells of the xylem
  - Sugar-conducting cells of the phloem

Parenchyma Cells

- Mature **parenchyma cells**
  - Have thin and flexible primary walls
  - Lack secondary walls
  - Are the least specialized
  - Perform the most metabolic functions
  - Retain the ability to divide and differentiate

PLAY BioFlix: Tour of a Plant Cell

Fig. 35-10a



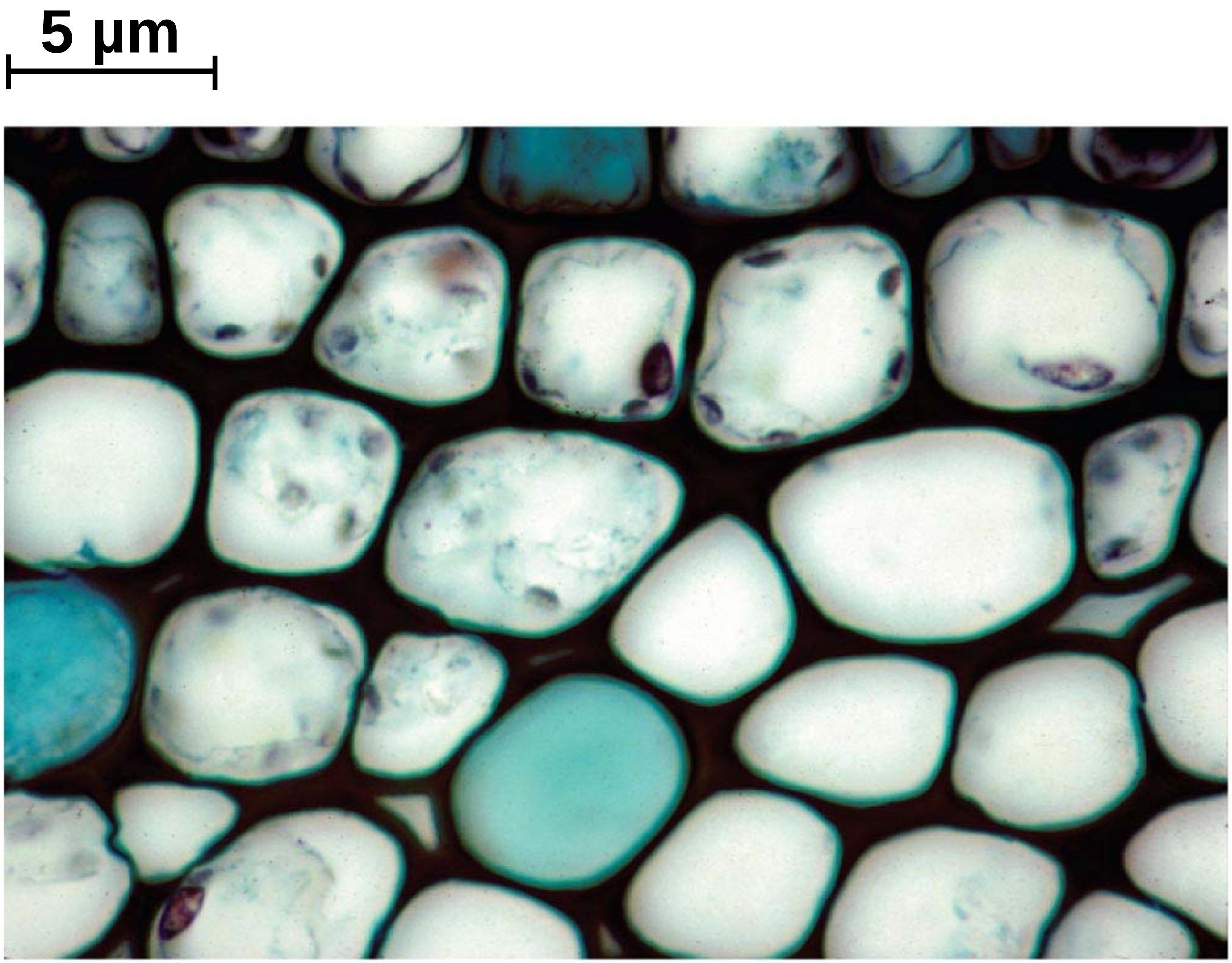
Parenchyma cells in *Elodea* leaf, with chloroplasts (LM)

60 µm

Collenchyma Cells

- **Collenchyma cells** are grouped in strands and help support young parts of the plant shoot
- They have thicker and uneven cell walls
- They lack secondary walls
- These cells provide flexible support without restraining growth

Fig. 35-10b

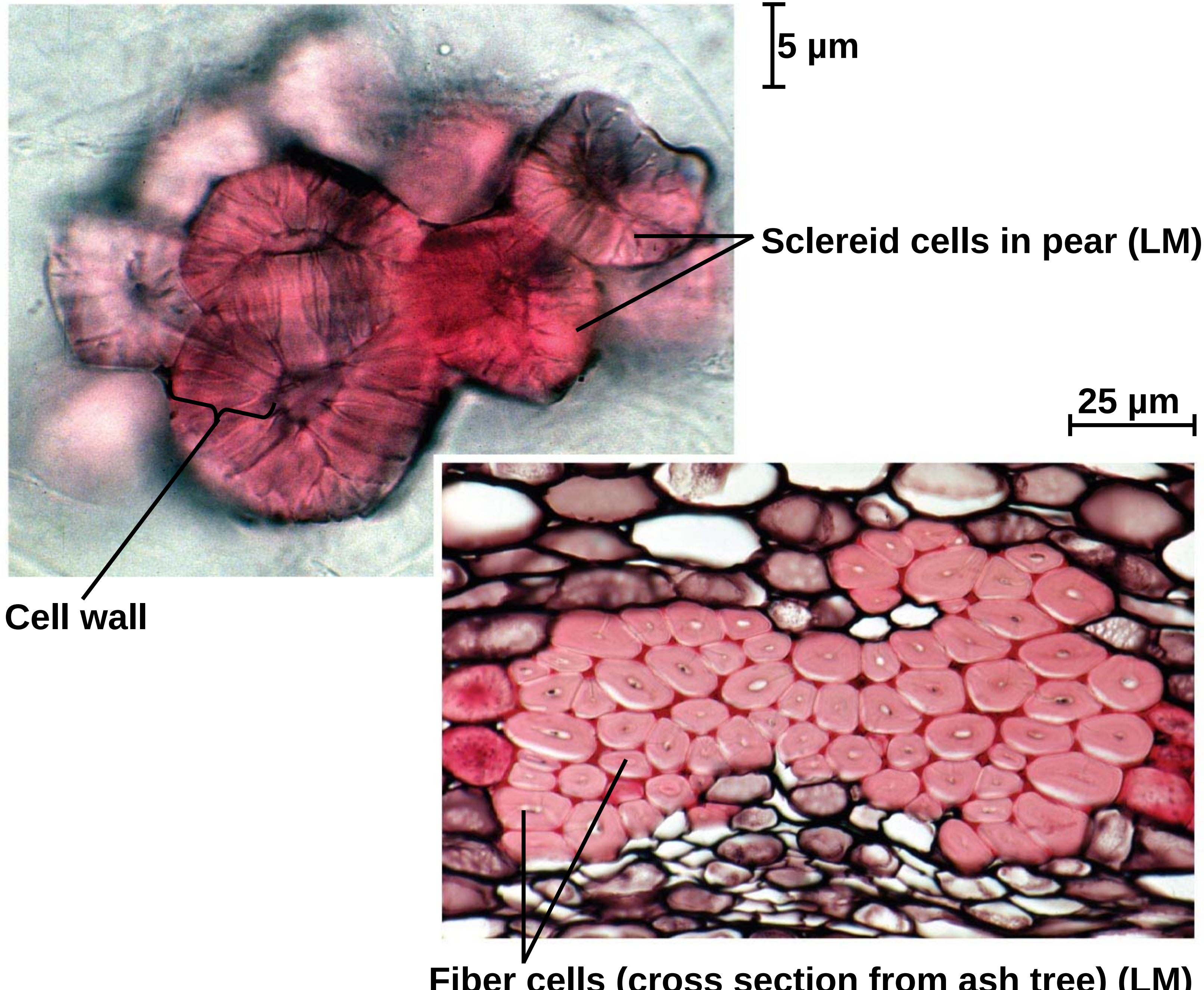


Collenchyma cells (in *Helianthus* stem) (LM)

Sclerenchyma Cells

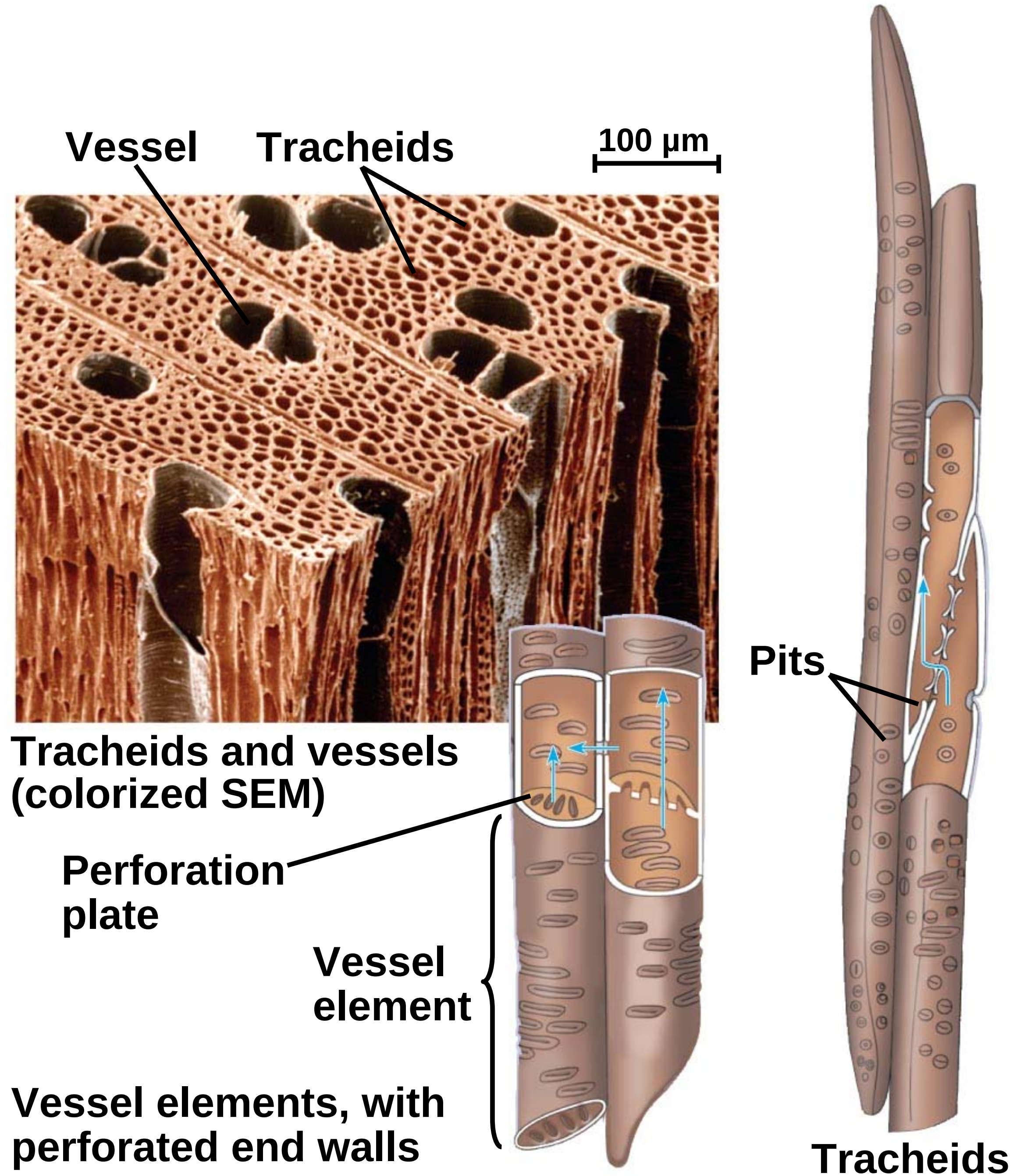
- **Sclerenchyma cells** are rigid because of thick secondary walls strengthened with lignin
- They are dead at functional maturity
- There are two types:
  - **Sclereids** are short and irregular in shape and have thick lignified secondary walls
  - **Fibers** are long and slender and arranged in threads

Fig. 35-10c



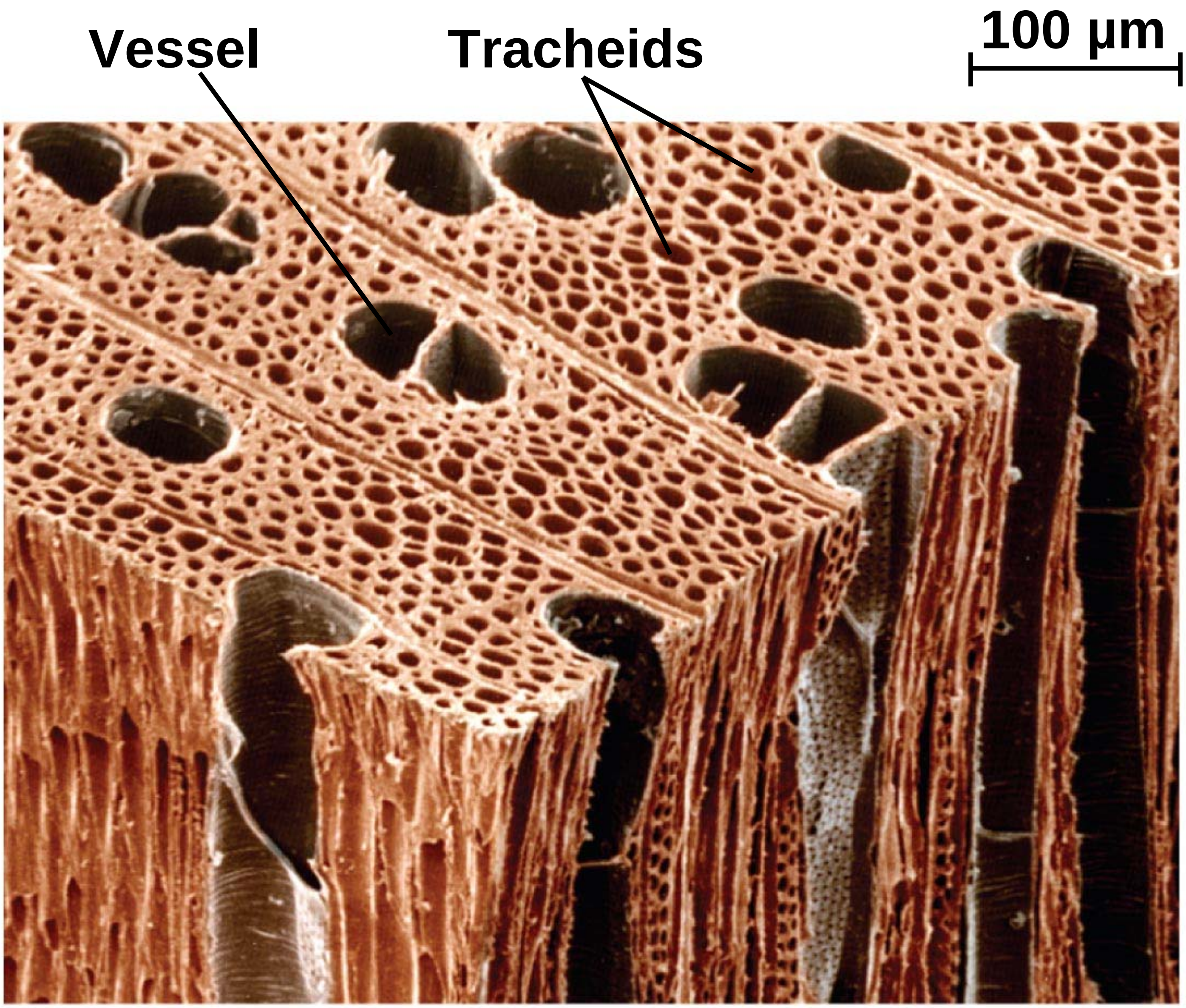
5 µm
Sclereid cells in pear (LM)
Cell wall
25 µm
Fiber cells (cross section from ash tree) (LM)

Fig. 35-10d



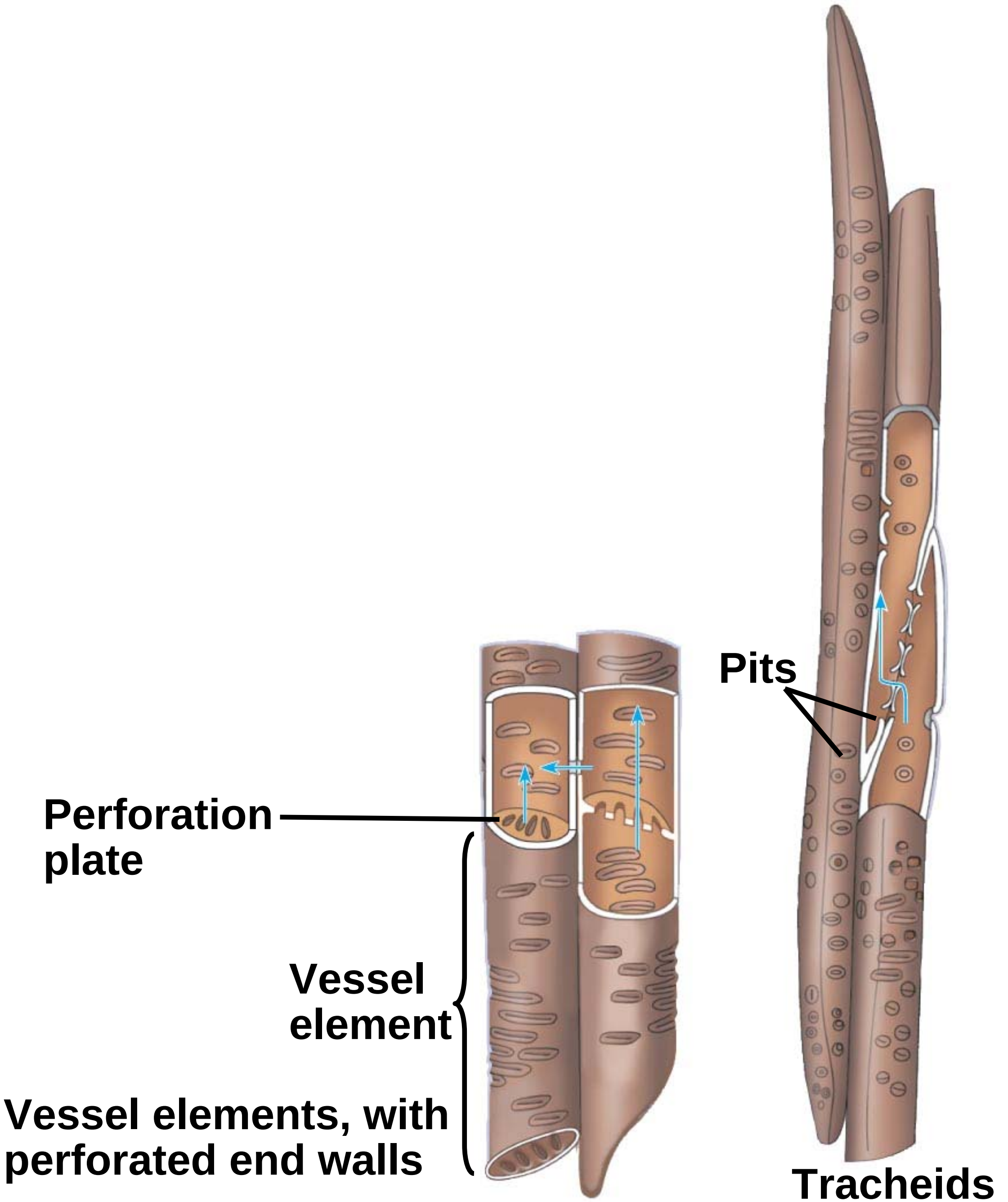
Vessel
Tracheids
100 µm
Tracheids and vessels (colorized SEM)
Perforation plate
Vessel element
Vessel elements, with perforated end walls
Pits
Tracheids

Fig. 35-10d1



Tracheids and vessels (colorized SEM)

Fig. 35-10d2



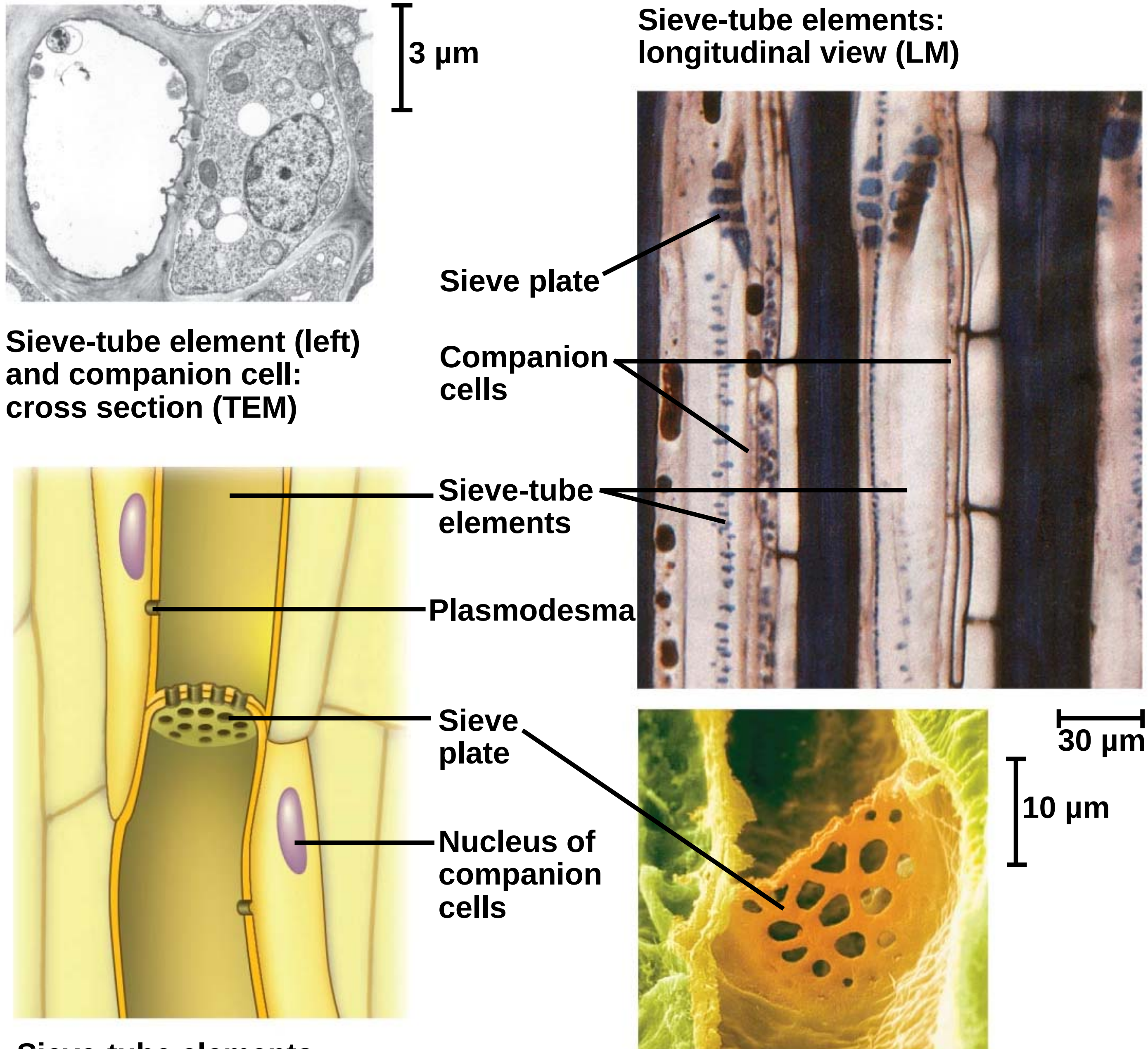
Pits
Perforation plate
Vessel element
Vessel elements, with perforated end walls
Tracheids

Water-Conducting Cells of the Xylem

- The two types of water-conducting cells, **tracheids** and **vessel elements**, are dead at maturity
- Tracheids are found in the xylem of all vascular plants

- Vessel elements are common to most angiosperms and a few gymnosperms
- Vessel elements align end to end to form long micropipes called **vessels**

Fig. 35-10e

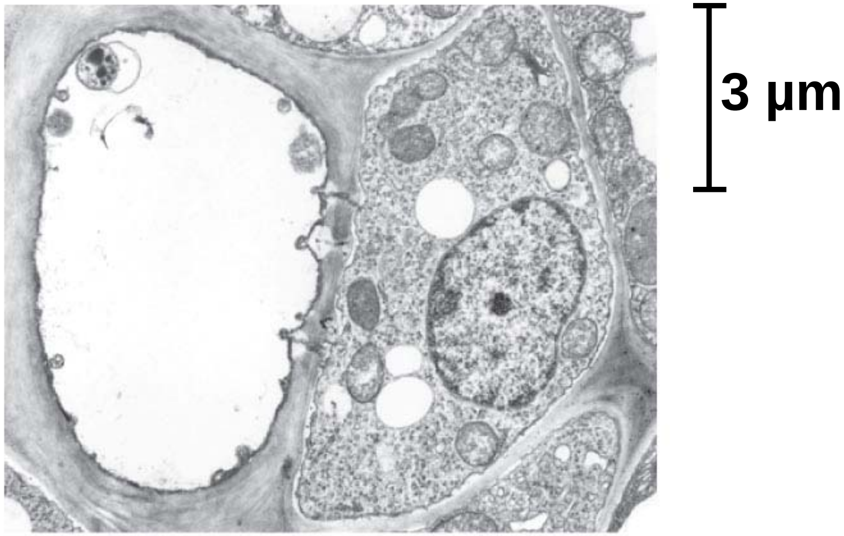


Sieve-tube element (left) and companion cell: cross section (TEM)

Sieve-tube elements: longitudinal view

Sieve plate with pores (SEM)

Fig. 35-10e1



Sieve-tube element (left) and companion cell: cross section (TEM)

Sugar-Conducting Cells of the Phloem

- **Sieve-tube elements** are alive at functional maturity, though they lack organelles
- **Sieve plates** are the porous end walls that allow fluid to flow between cells along the sieve tube
- Each sieve-tube element has a **companion cell** whose nucleus and ribosomes serve both cells

Fig. 35-10e2

Sieve-tube elements: longitudinal view (LM)

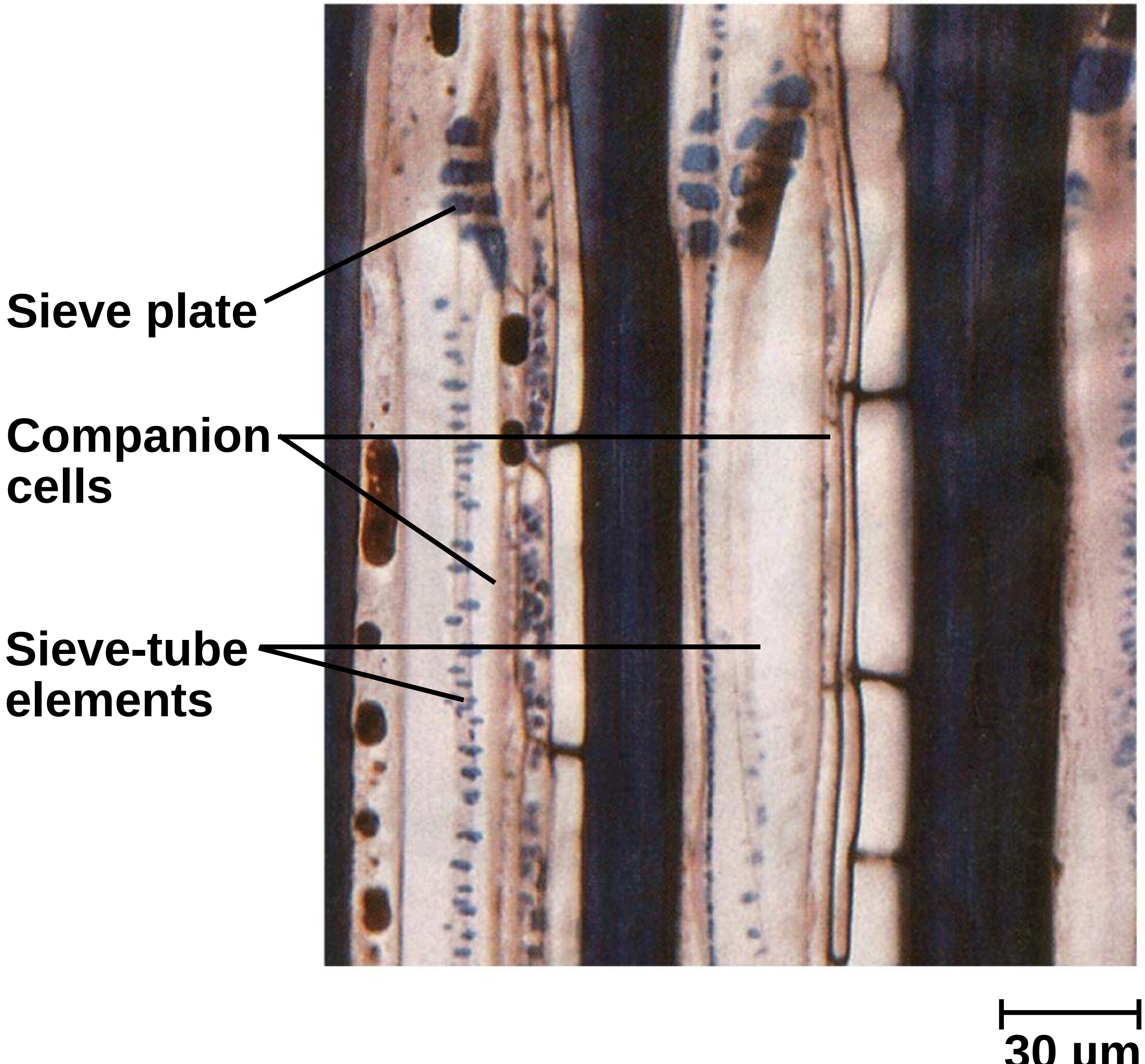
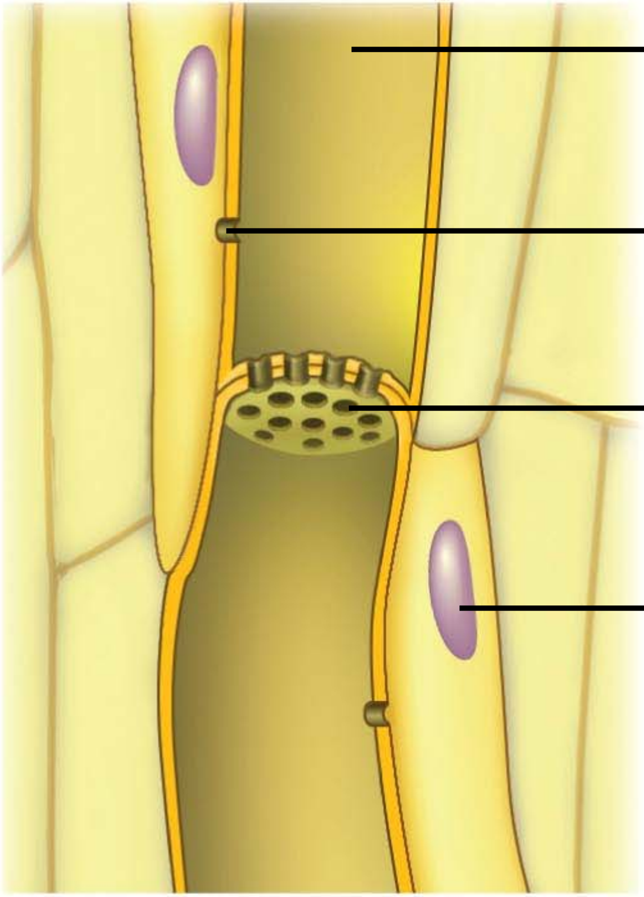
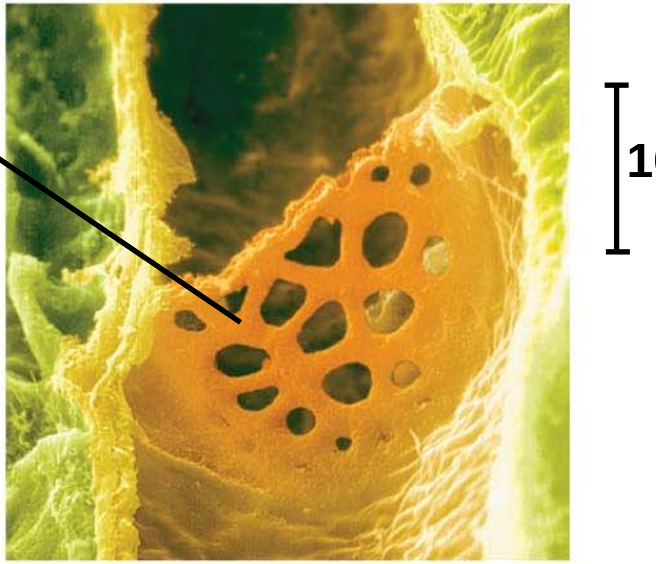


Fig. 35-10e3



Sieve-tube elements: longitudinal view



Sieve plate with pores (SEM)

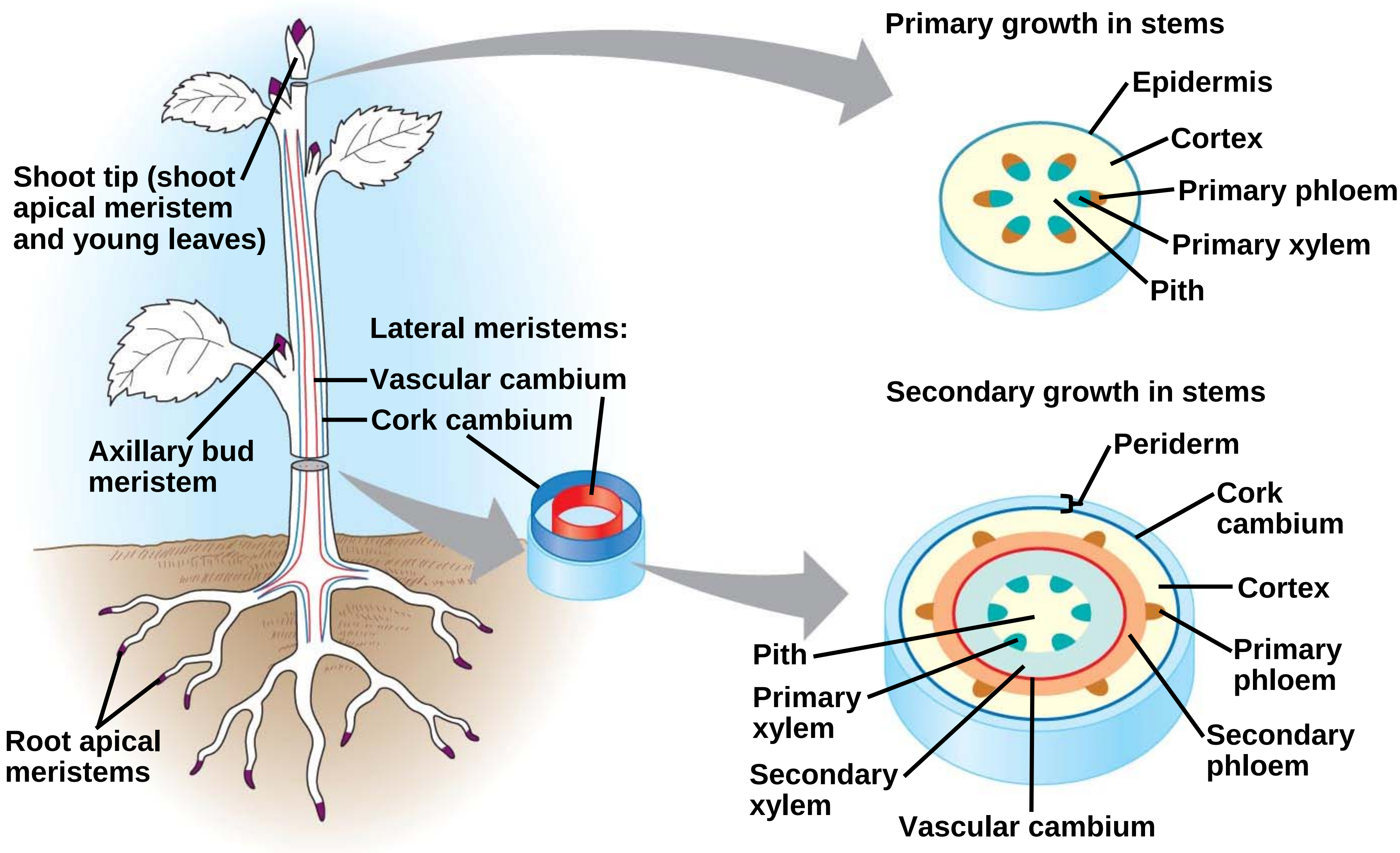
Concept 35.2: Meristems generate cells for new organs

- A plant can grow throughout its life; this is called **indeterminate growth**
- Some plant organs cease to grow at a certain size; this is called **determinate growth**
- **Annuals** complete their life cycle in a year or less
- **Biennials** require two growing seasons
- **Perennials** live for many years

- **Meristems** are perpetually embryonic tissue and allow for indeterminate growth
- **Apical meristems** are located at the tips of roots and shoots and at the axillary buds of shoots
- Apical meristems elongate shoots and roots, a process called **primary growth**

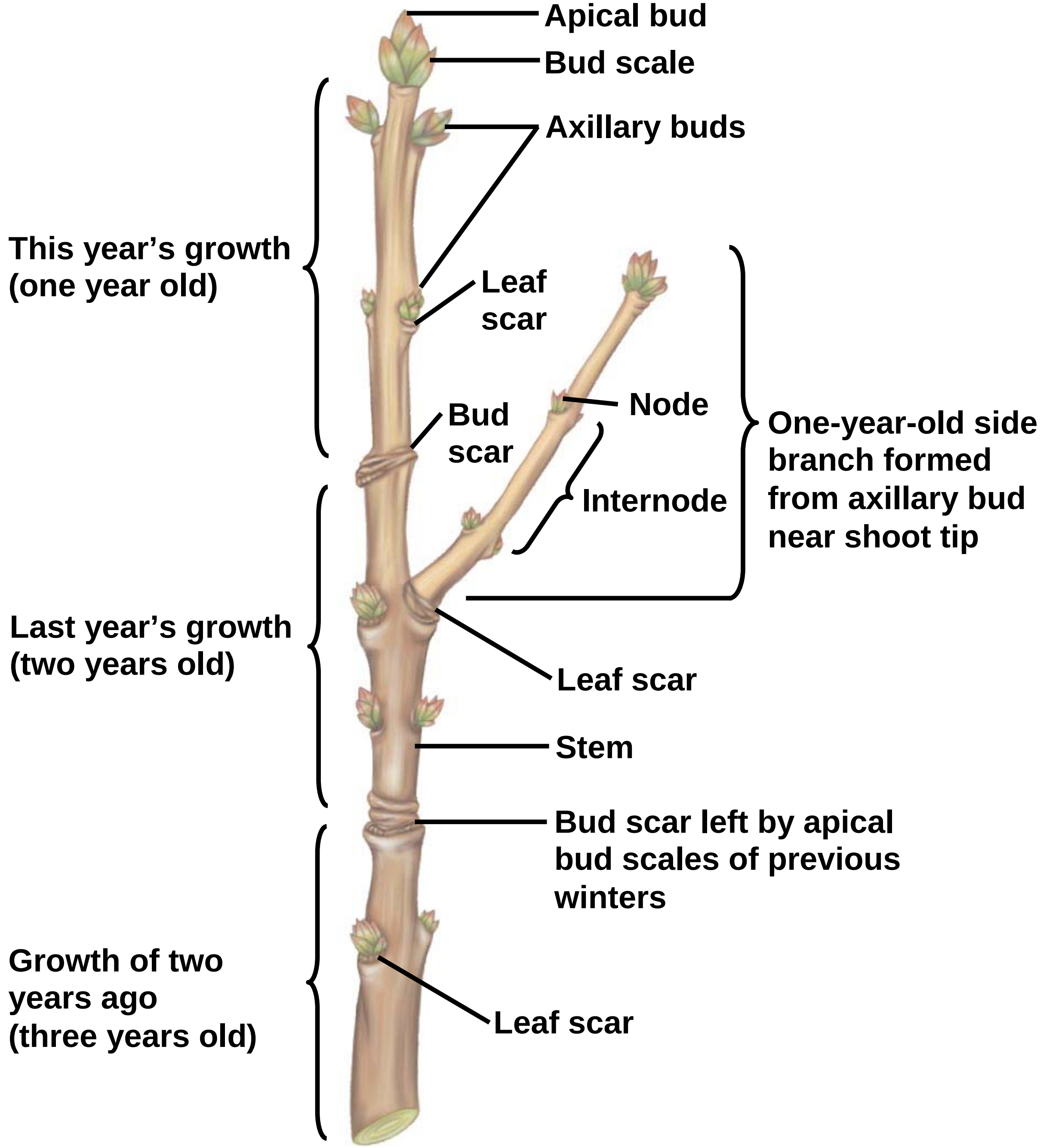
- **Lateral meristems** add thickness to woody plants, a process called **secondary growth**
- There are two lateral meristems: the vascular cambium and the cork cambium
- The **vascular cambium** adds layers of vascular tissue called secondary xylem (wood) and secondary phloem
- The **cork cambium**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

Fig. 35-11


Shoot tip (shoot apical meristem and young leaves)
Axillary bud meristem
Root apical meristems
Lateral meristems:
Vascular cambium
Cork cambium
Primary growth in stems
Epidermis
Cortex
Primary phloem
Primary xylem
Pith
Secondary growth in stems
Periderm
Cork cambium
Cortex
Primary phloem
Secondary phloem
Vascular cambium
Secondary xylem
Primary xylem
Pith

- Meristems give rise to *initials*, which remain in the meristem, and *derivatives*, which become specialized in developing tissues
- In woody plants, primary and secondary growth occur simultaneously but in different locations

Fig. 35-12


Apical bud
Bud scale
Axillary buds
This year's growth
(one year old)
Leaf
scar
Bud
scar
Node
Internode
One-year-old side
branch formed
from axillary bud
near shoot tip
Last year's growth
(two years old)
Leaf scar
Stem
Bud scar left by apical
bud scales of previous
winters
Growth of two
years ago
(three years old)
Leaf scar

Concept 35.3: Primary growth lengthens roots and shoots

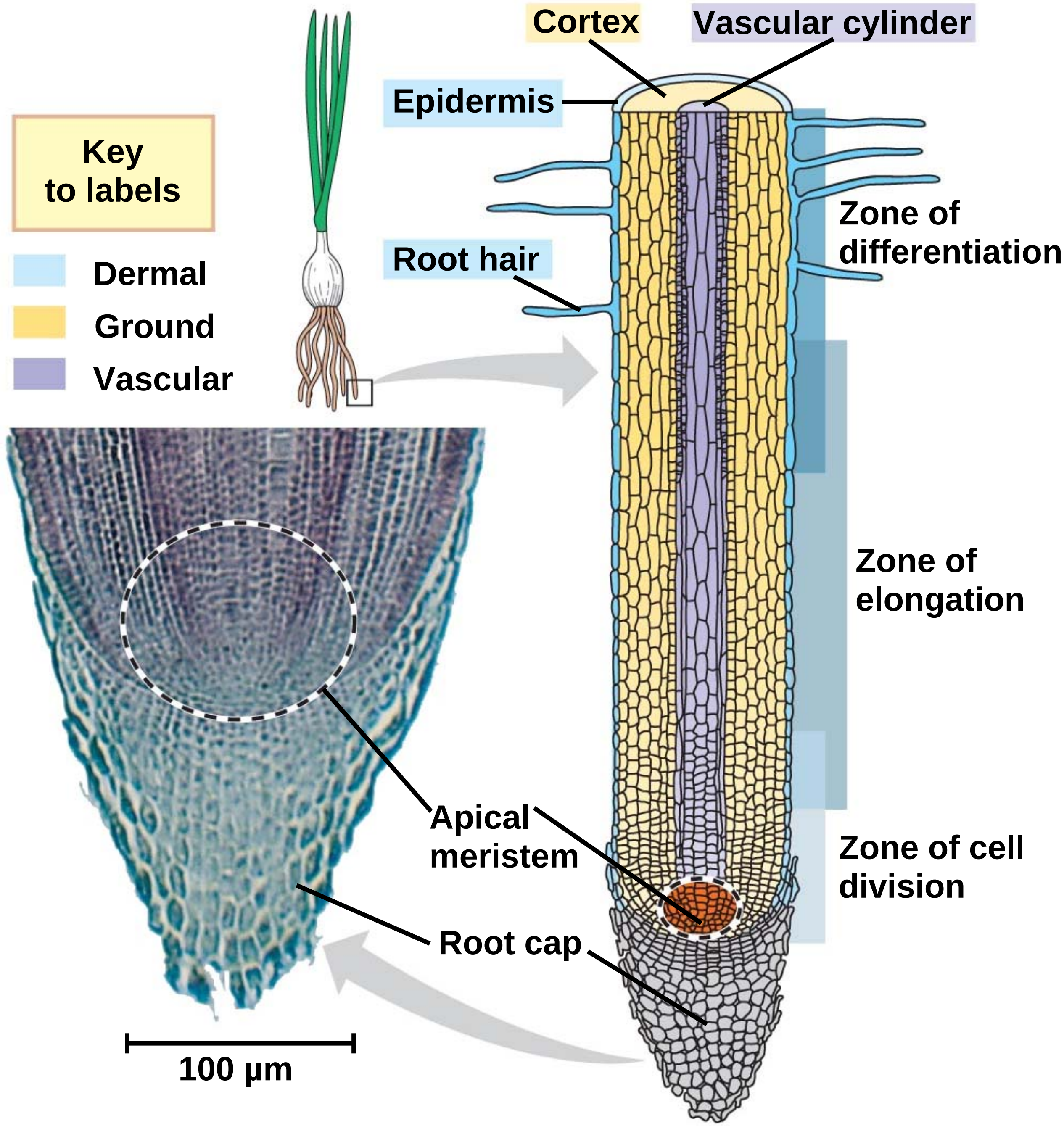
- Primary growth produces the **primary plant body**, the parts of the root and shoot systems produced by apical meristems

Primary Growth of Roots

- 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

PLAY Video: Root Growth in a Radish Seed (Time Lapse)

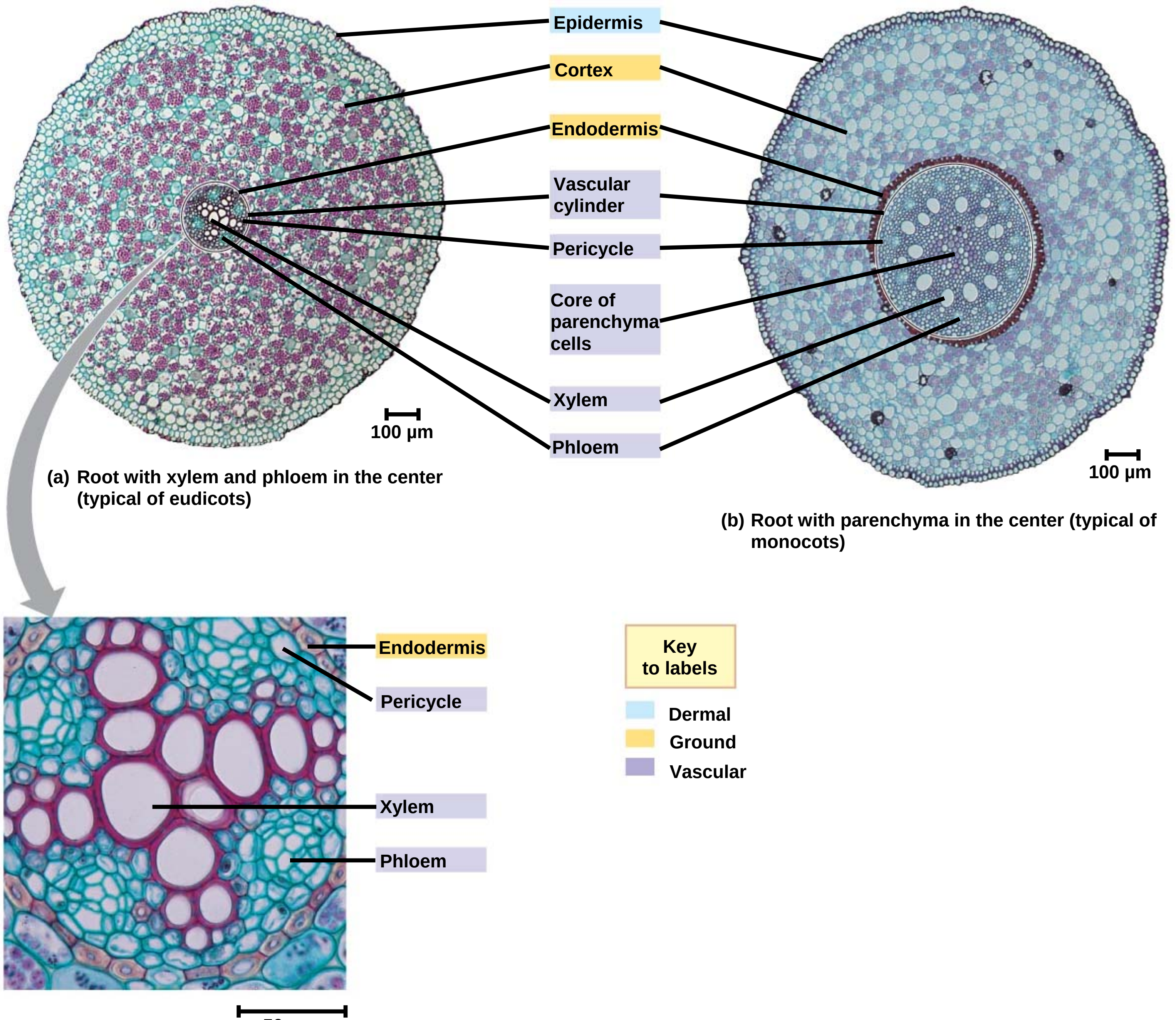
Fig. 35-13



Key to labels
Dermal
Ground
Vascular
Cortex
Vascular cylinder
Epidermis
Root hair
Zone of differentiation
Zone of elongation
Zone of cell division
Apical meristem
Root cap
100 µm

- 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**

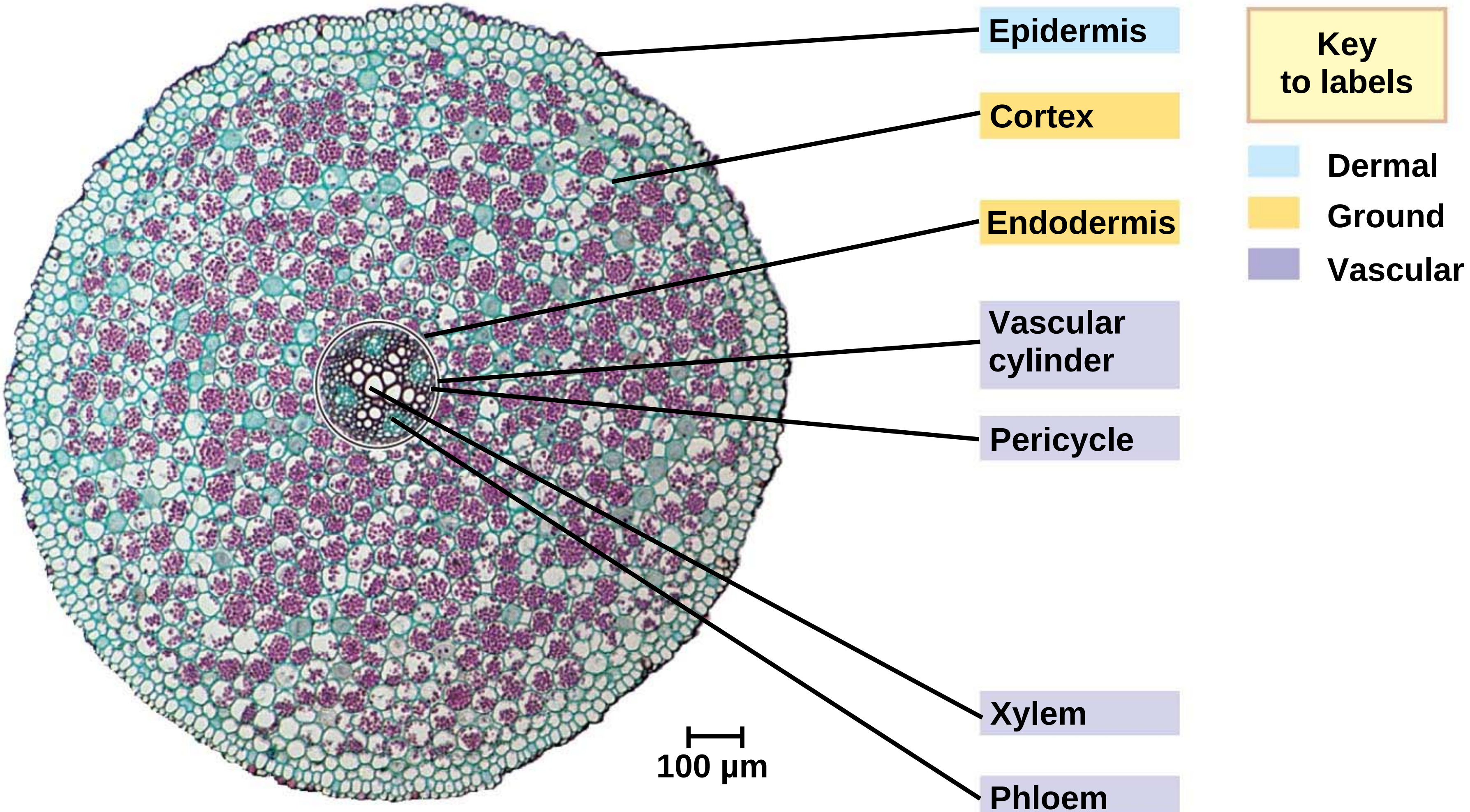
Fig. 35-14



(a) Root with xylem and phloem in the center (typical of eudicots)

(b) Root with parenchyma in the center (typical of monocots)

Fig. 35-14a1



(a) Root with xylem and phloem in the center (typical of eudicots)

Fig. 35-14a2

(a) Root with xylem and phloem in the center (typical of eudicots)

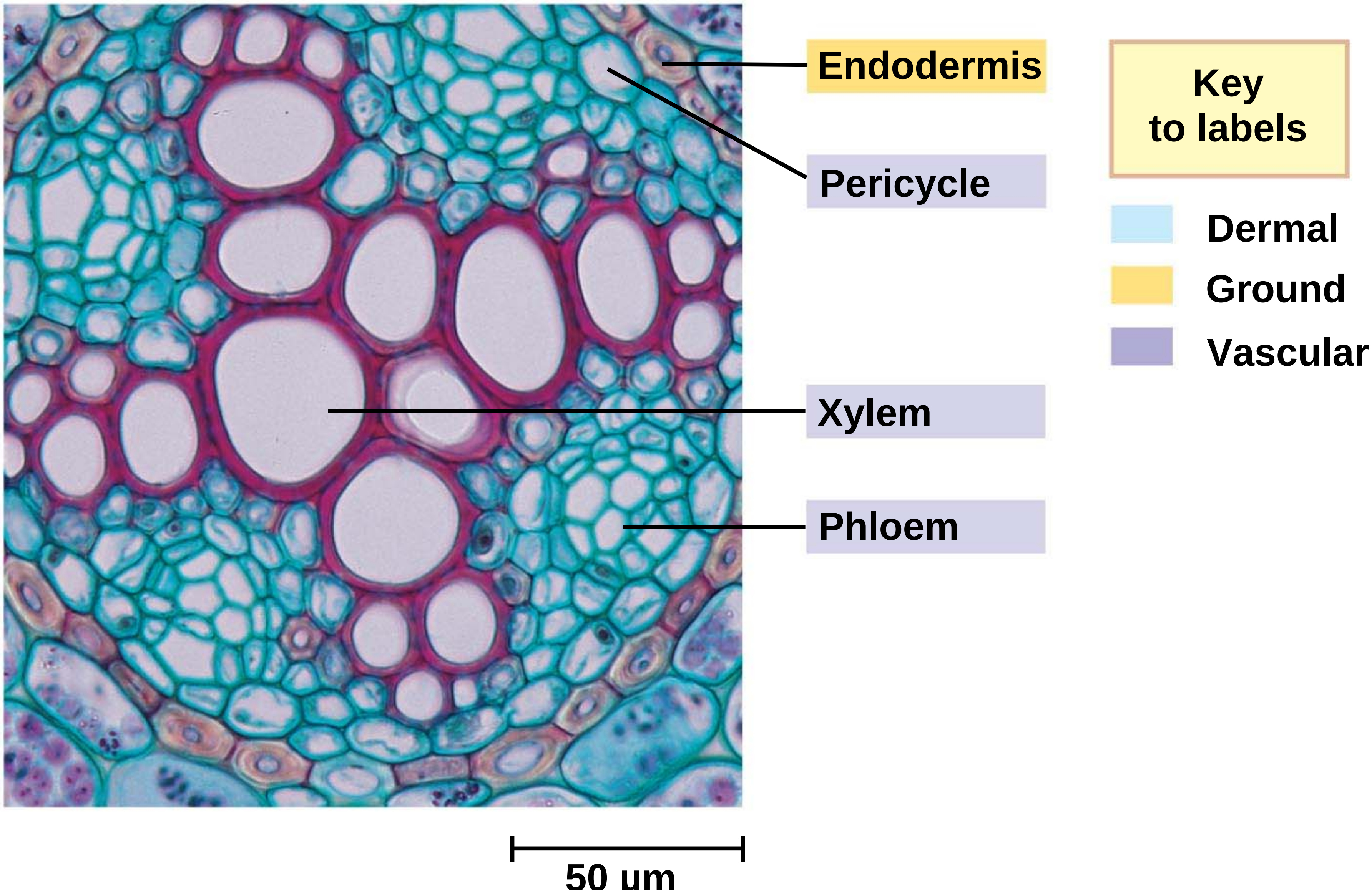
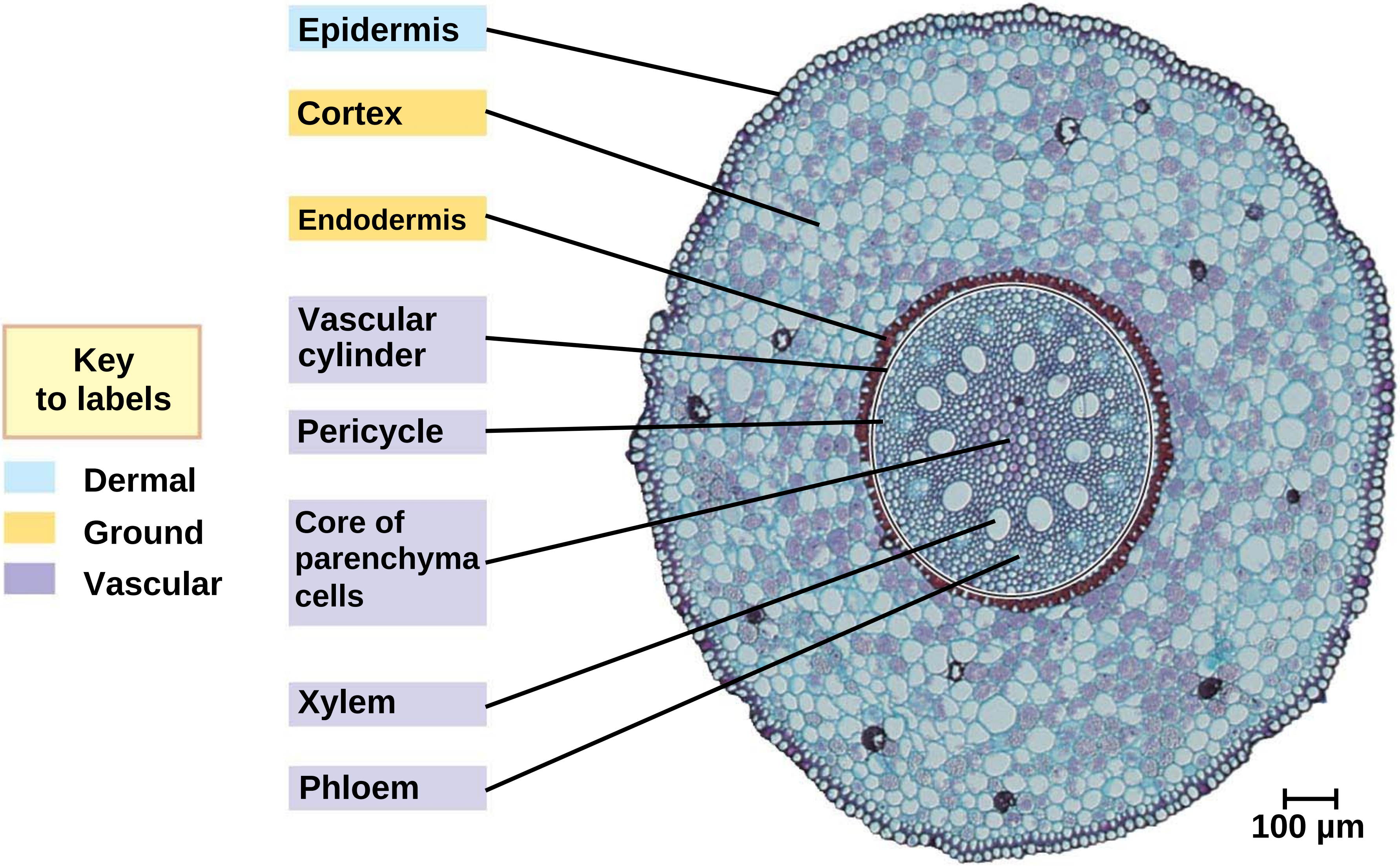


Fig. 35-14b



(b) Root with parenchyma in the center (typical of monocots)

- Lateral roots arise from within the **pericycle**, the outermost cell layer in the vascular cylinder

Fig. 35-15-1

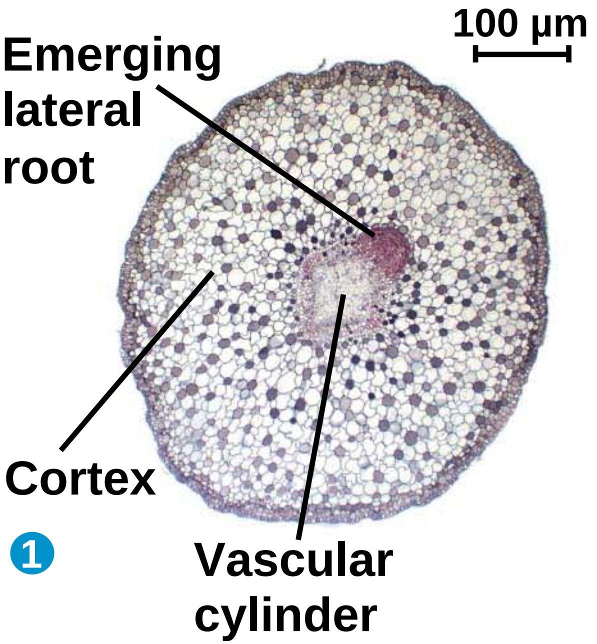


Fig. 35-15-2

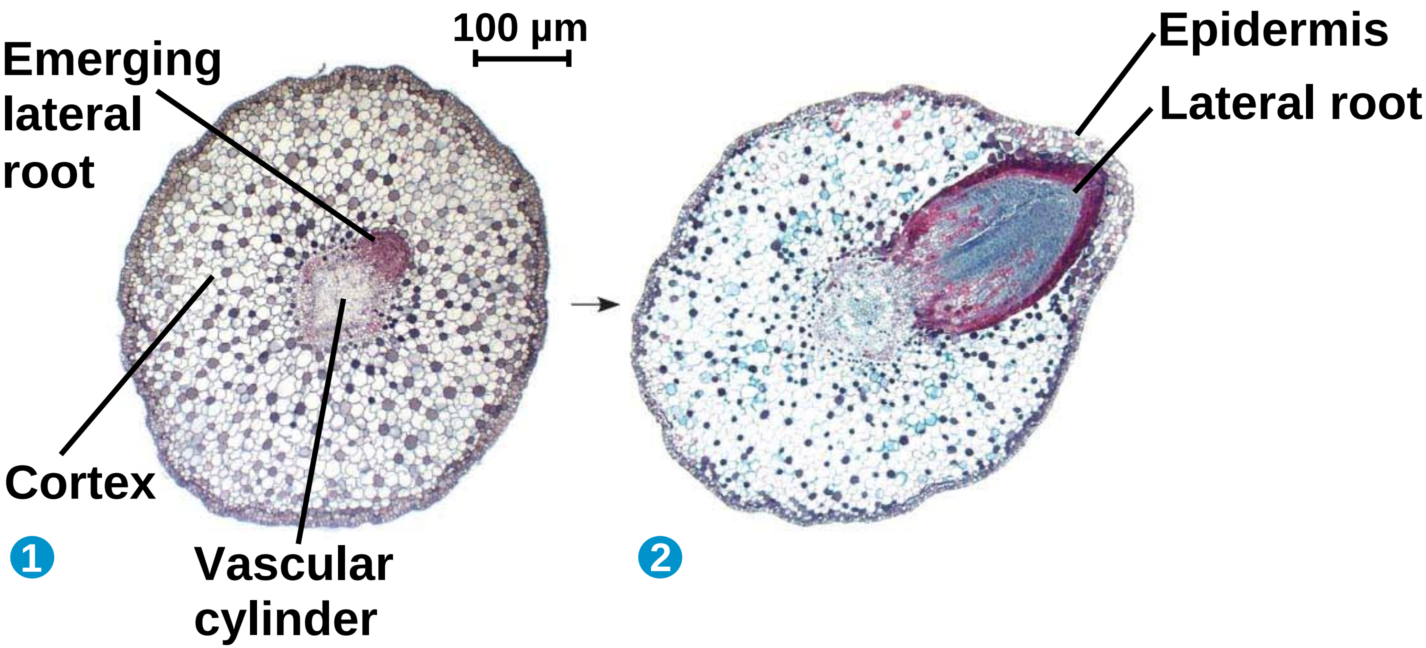
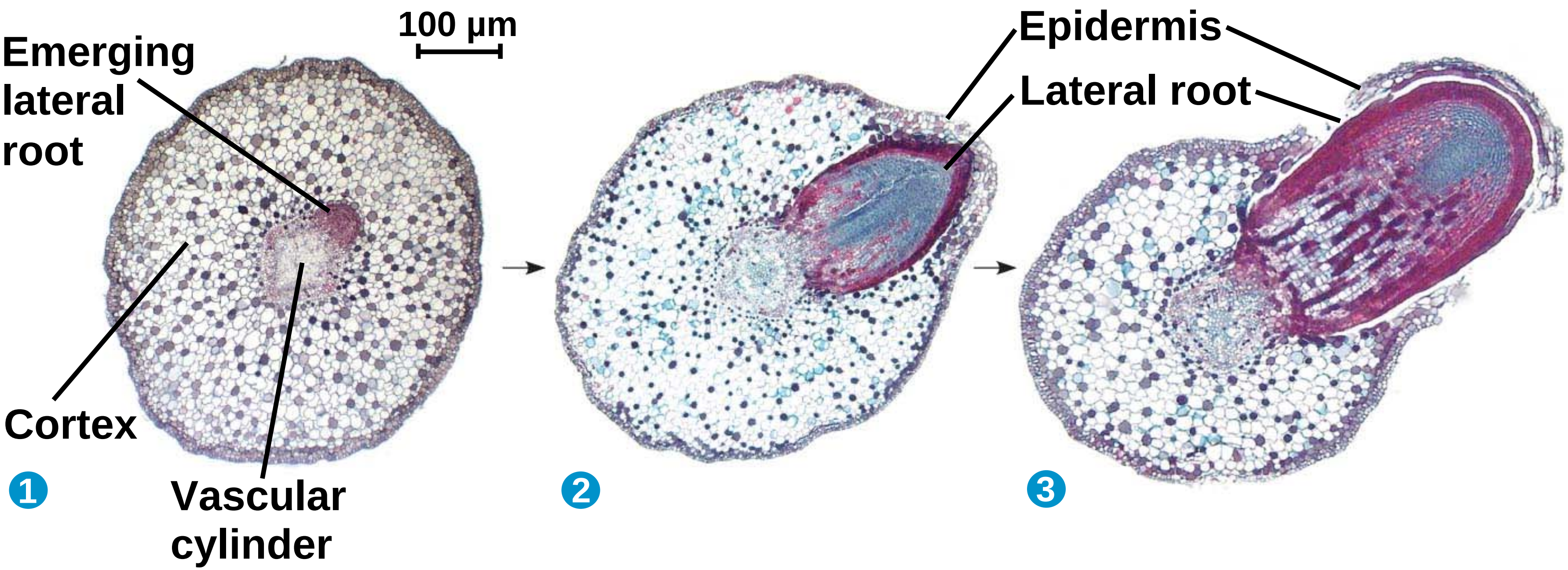

100 µm
Emerging lateral root
Cortex
Vascular cylinder
1
2
Epidermis
Lateral root

Fig. 35-15-3

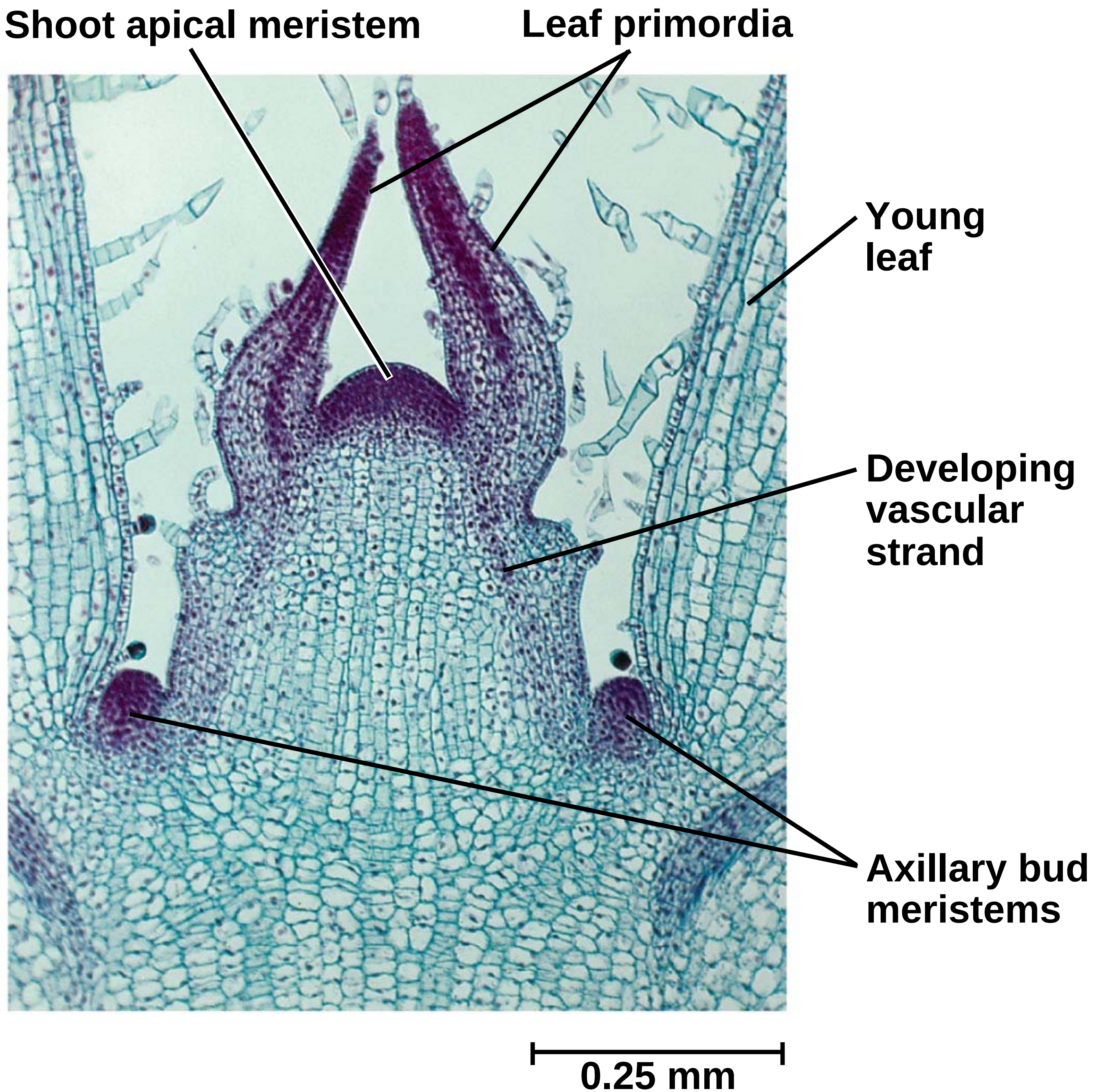


Emerging lateral root
100 µm
Epidermis
Lateral root
Cortex
Vascular cylinder
1
2
3

Primary Growth of Shoots

- A shoot apical meristem is a dome-shaped mass of dividing cells at the shoot tip
- Leaves develop from **leaf primordia** along the sides of the apical meristem
- Axillary buds develop from meristematic cells left at the bases of leaf primordia

Fig. 35-16

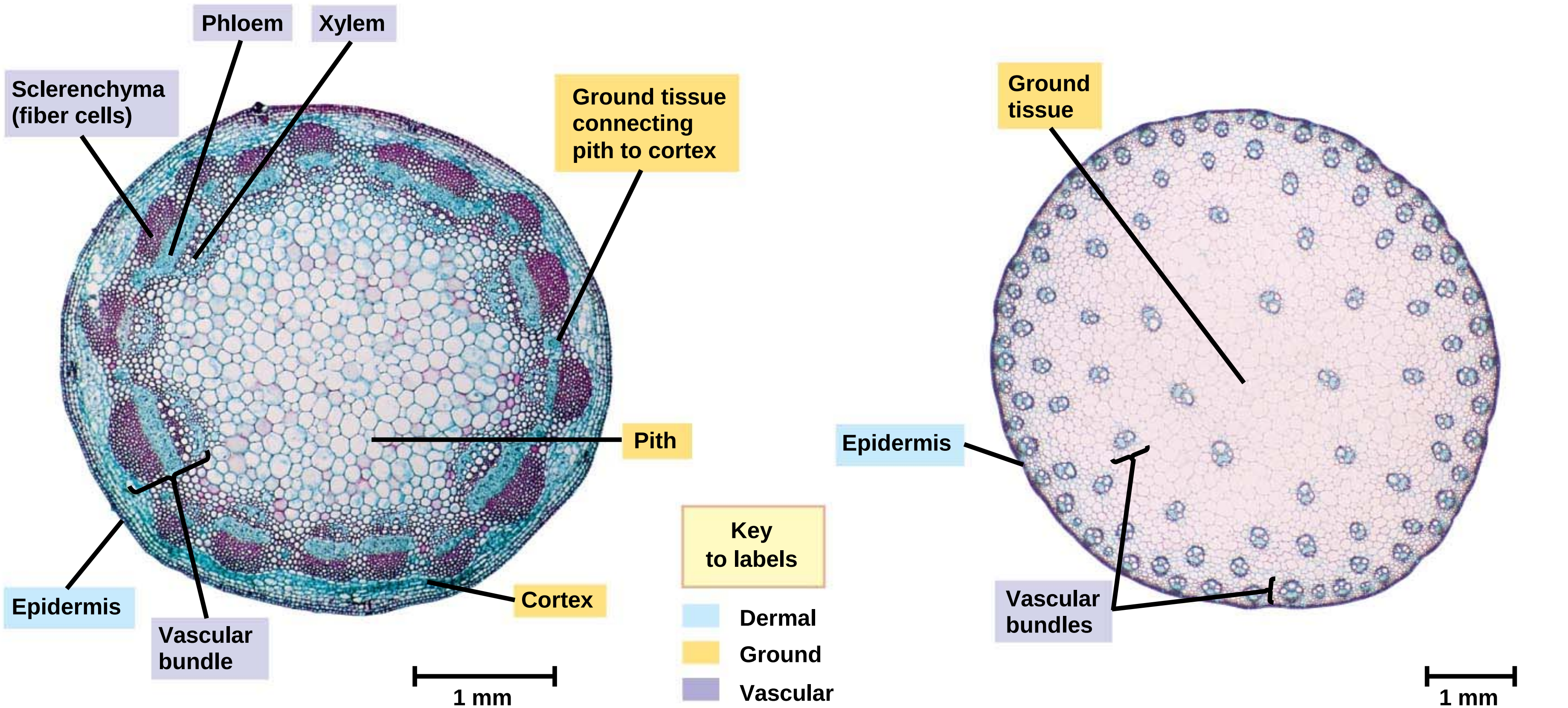


Shoot apical meristem
Leaf primordia
Young leaf
Developing vascular strand
Axillary bud meristems
0.25 mm

Tissue Organization of Stems

- Lateral shoots develop from axillary buds on the stem’s surface
- In most eudicots, the vascular tissue consists of vascular bundles that are arranged in a ring

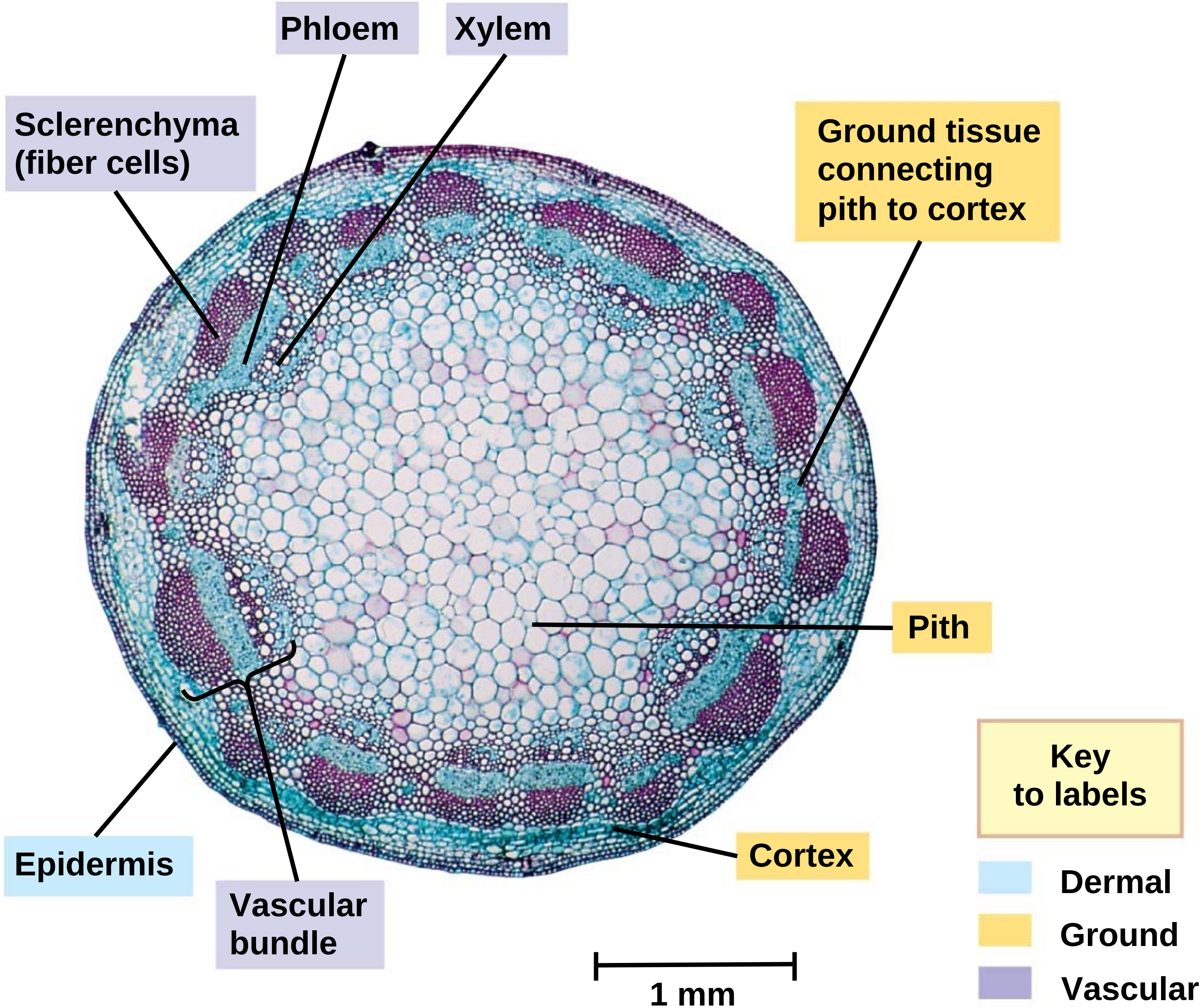
Fig. 35-17



(a) Cross section of stem with vascular bundles forming a ring (typical of eudicots)

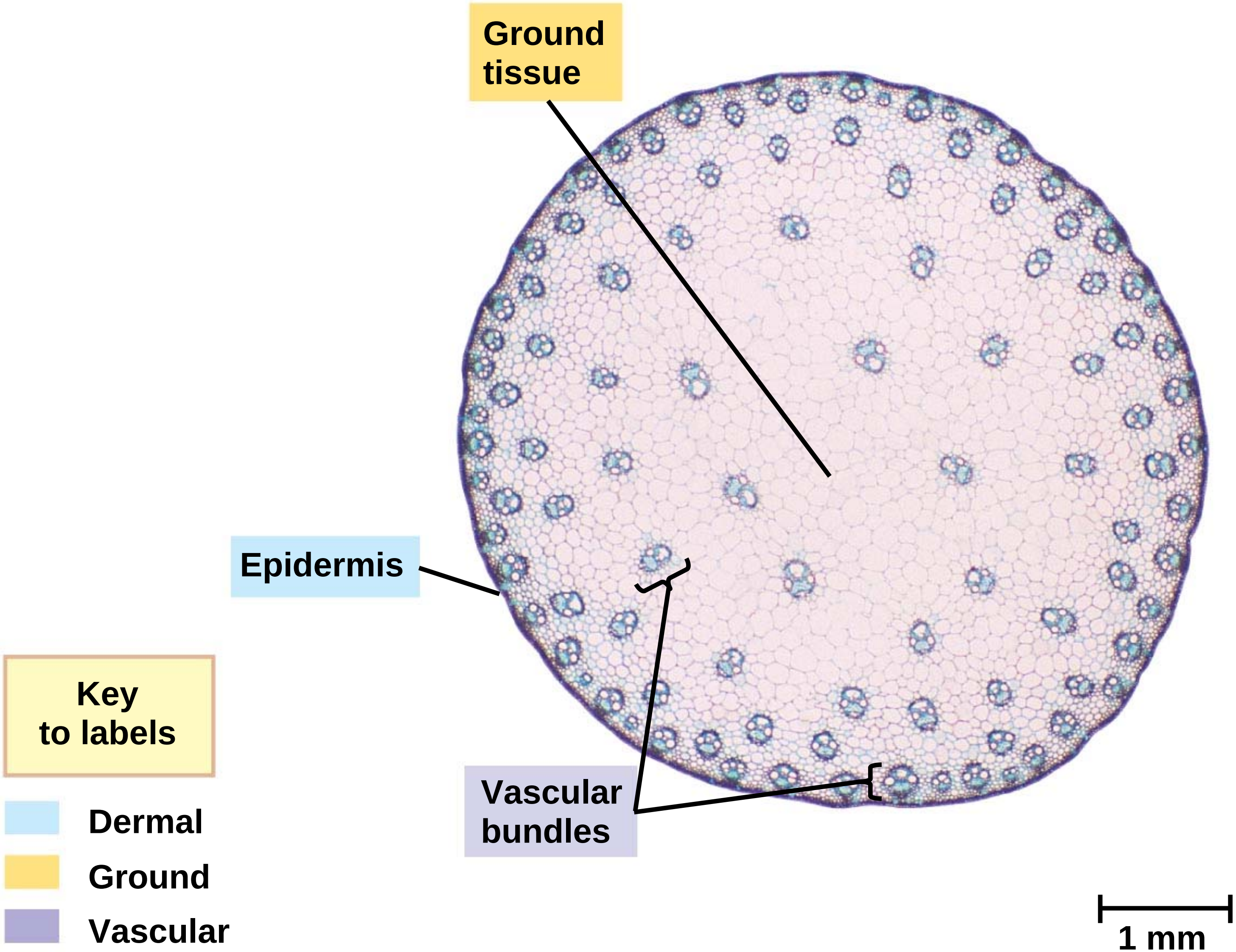
(b) Cross section of stem with scattered vascular bundles (typical of monocots)

Fig. 35-17a



(a) Cross section of stem with vascular bundles forming a ring (typical of eudicots)

Fig. 35-17b



(b) Cross section of stem with scattered vascular bundles (typical of monocots)

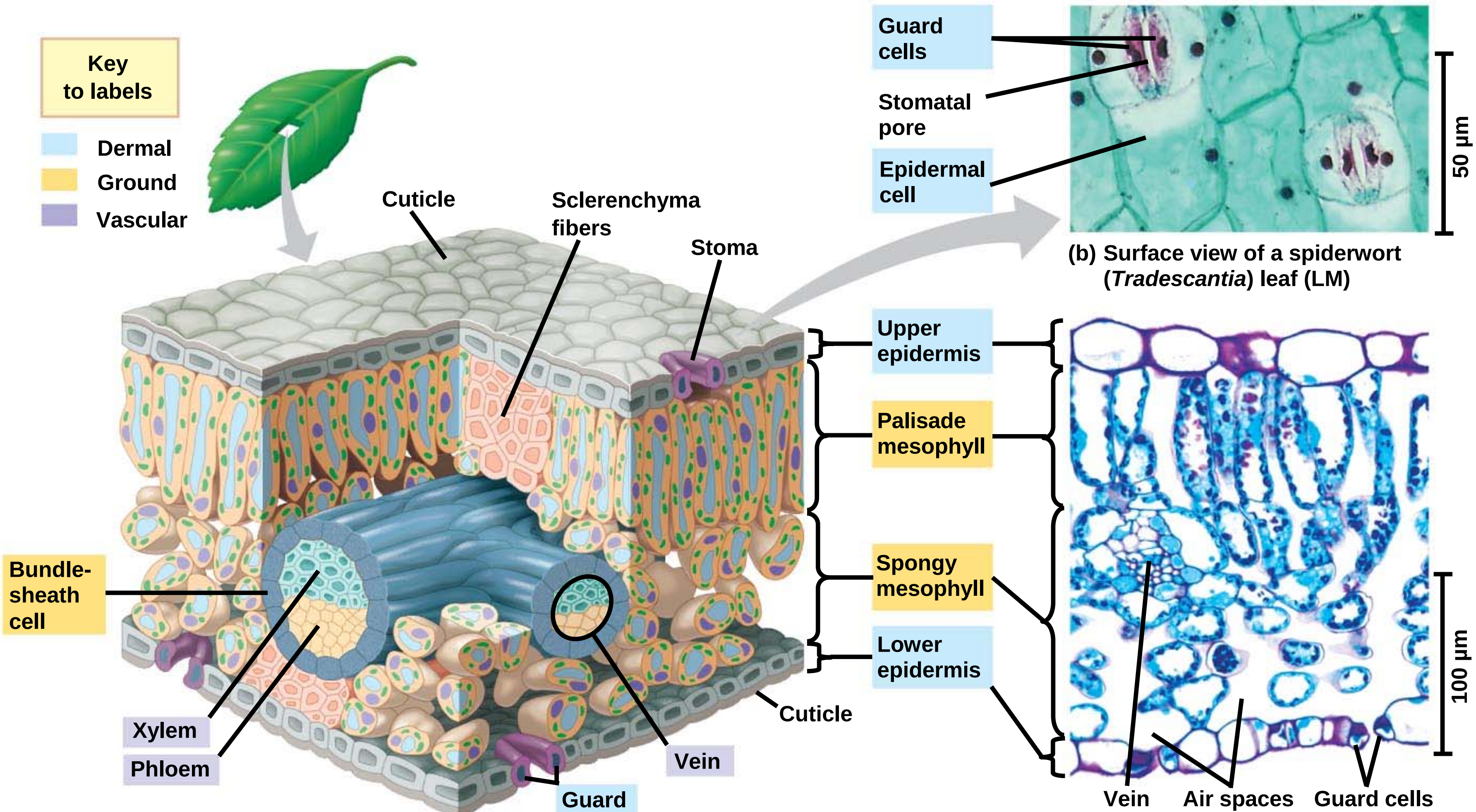
- In most monocot stems, the vascular bundles are scattered throughout the ground tissue, rather than forming a ring

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
- Each stomatal pore is flanked by two **guard cells**, which regulate its opening and closing
- The ground tissue in a leaf, called **mesophyll**, is sandwiched between the upper and lower epidermis

- Below the *palisade mesophyll* in the upper part of the leaf is loosely arranged *spongy mesophyll*, where gas exchange occurs
- The vascular tissue of each leaf is continuous with the vascular tissue of the stem
- Veins are the leaf's vascular bundles and function as the leaf's skeleton
- Each vein in a leaf is enclosed by a protective bundle sheath

Fig. 35-18

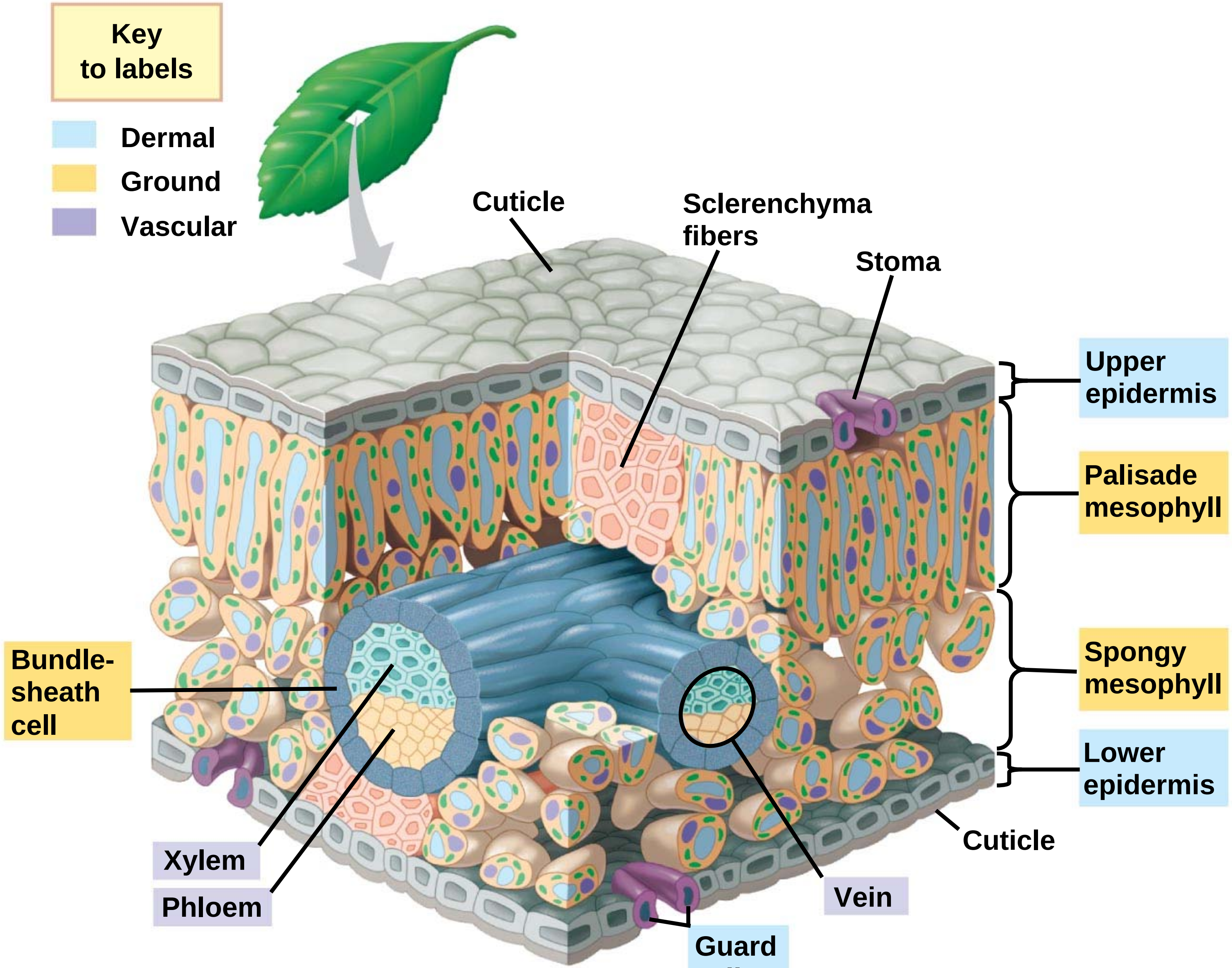


(a) Cutaway drawing of leaf tissues

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

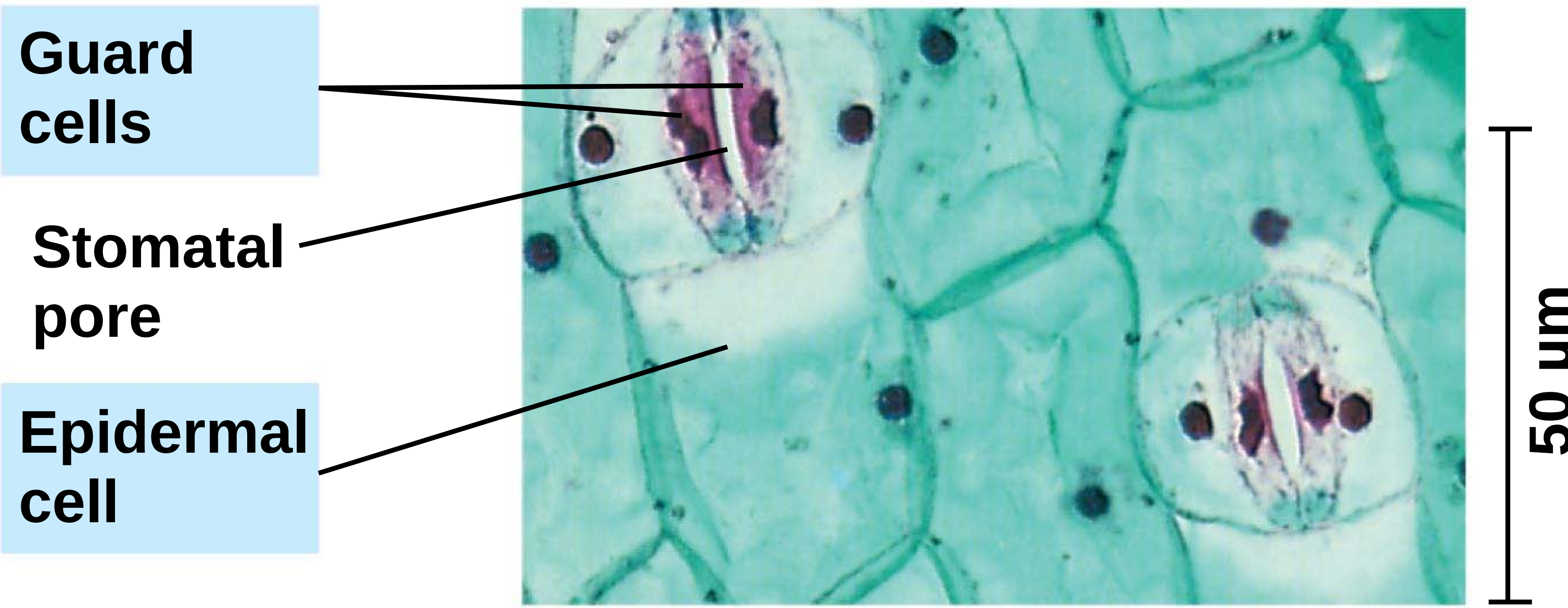
(c) Cross section of a lilac (*Syringa*)) leaf (LM)

Fig. 35-18a



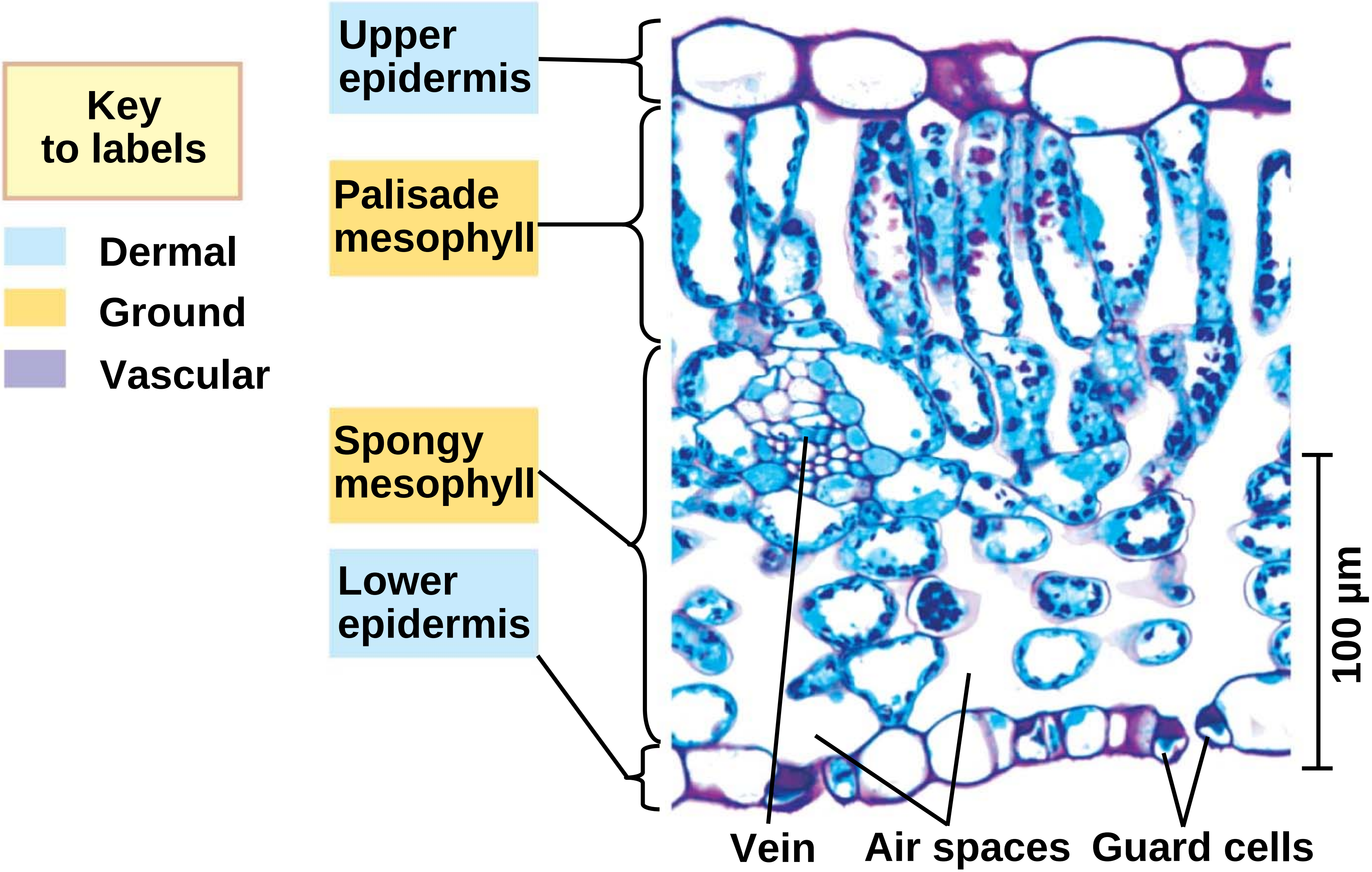
(a) Cutaway drawing of leaf tissues

Fig. 35-18b



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

Fig. 35-18c

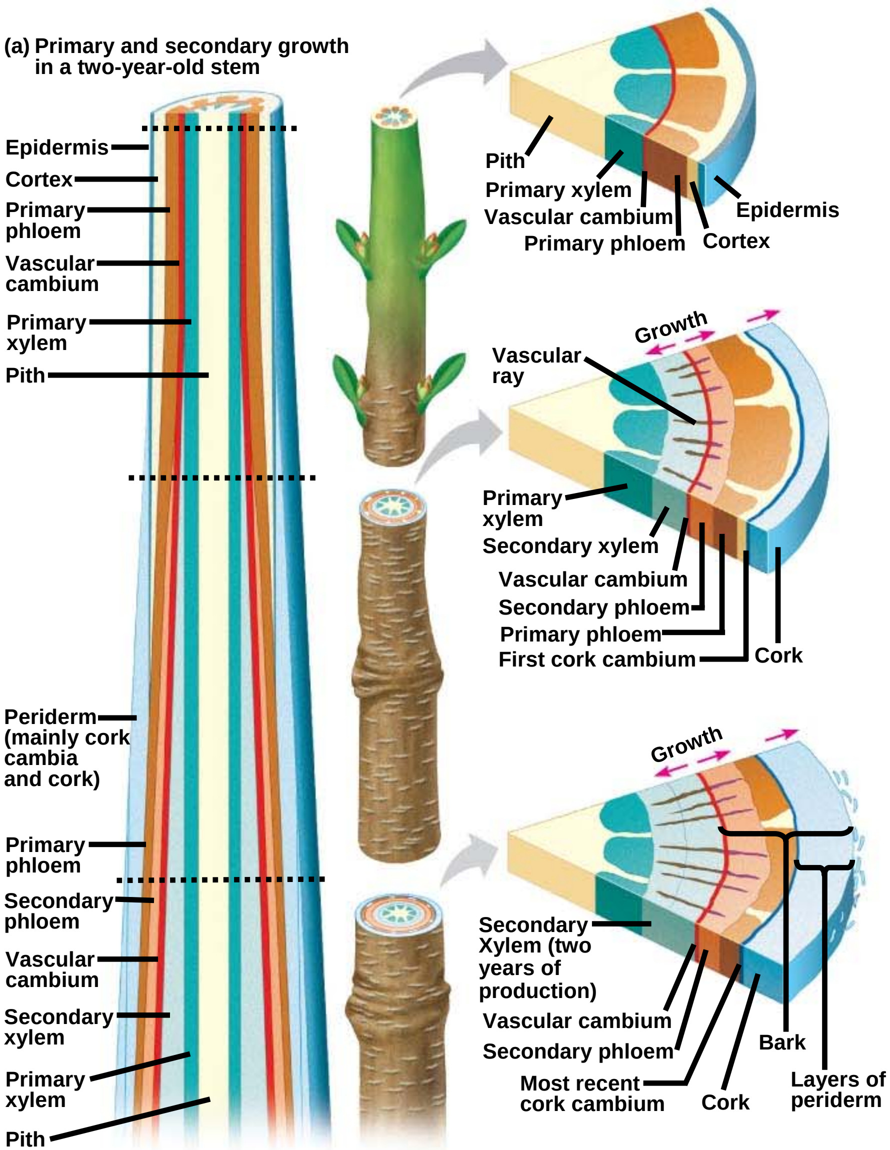


(c) Cross section of a lilac (*Syringa*) leaf (LM)

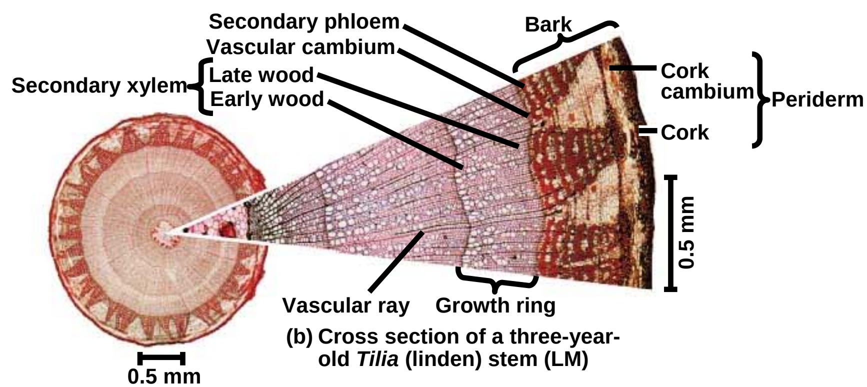
Concept 35.4: Secondary growth adds girth to stems and roots in woody plants

- 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 is characteristic of gymnosperms and many eudicots, but not monocots

Fig. 35-19



(a) Primary and secondary growth in a two-year-old stem



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

Fig. 35-19a1

(a) Primary and secondary growth in a two-year-old stem

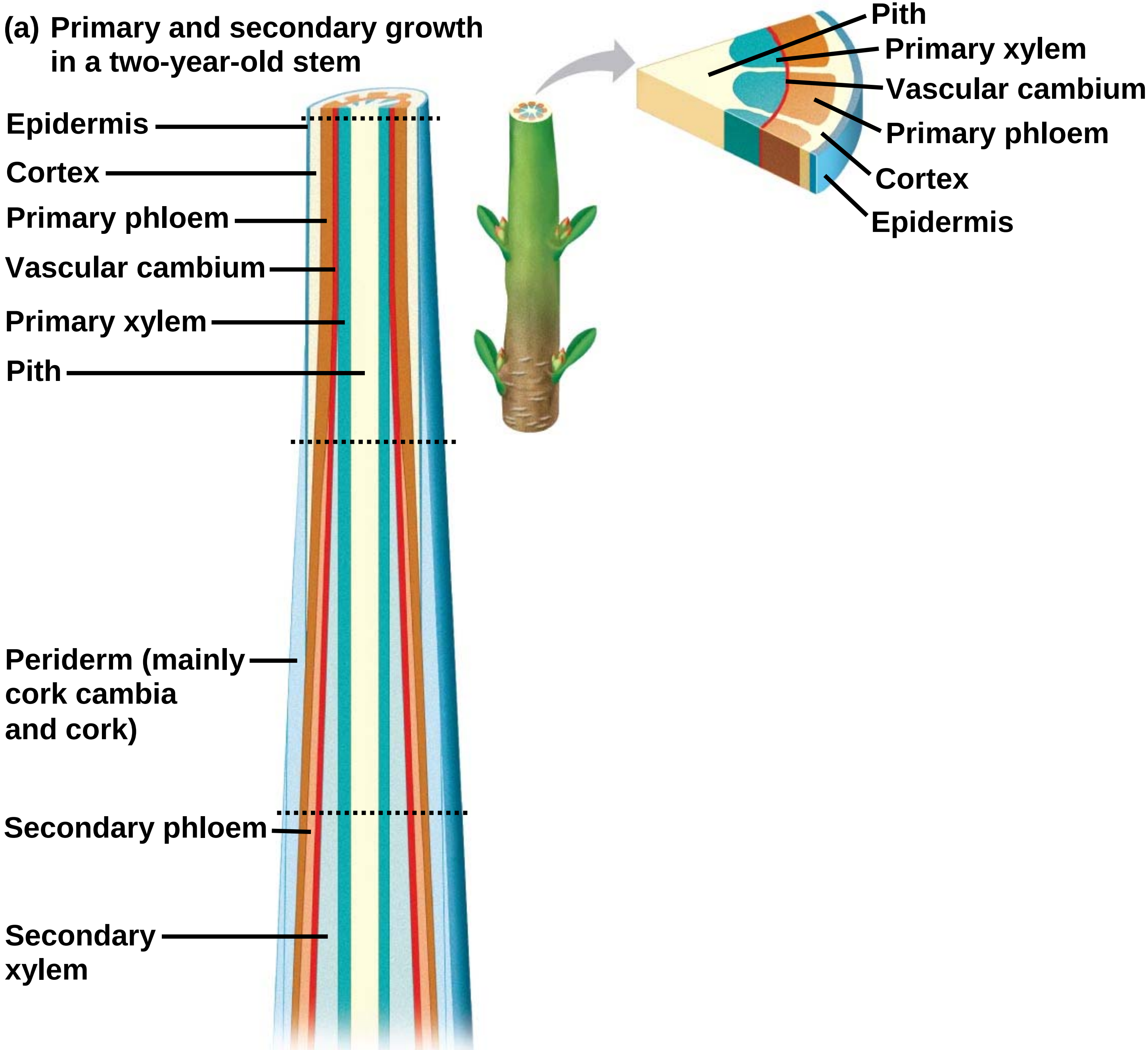
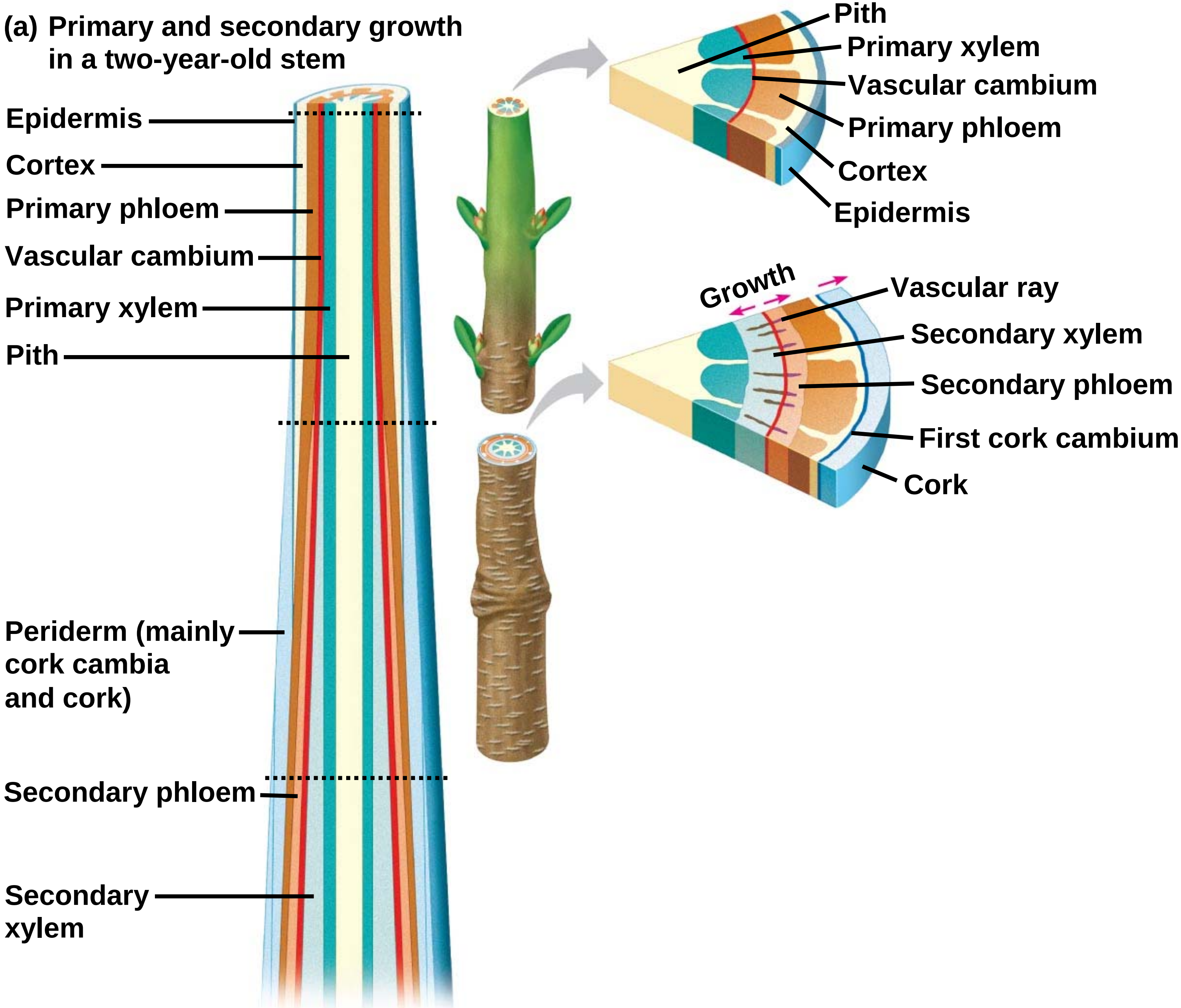
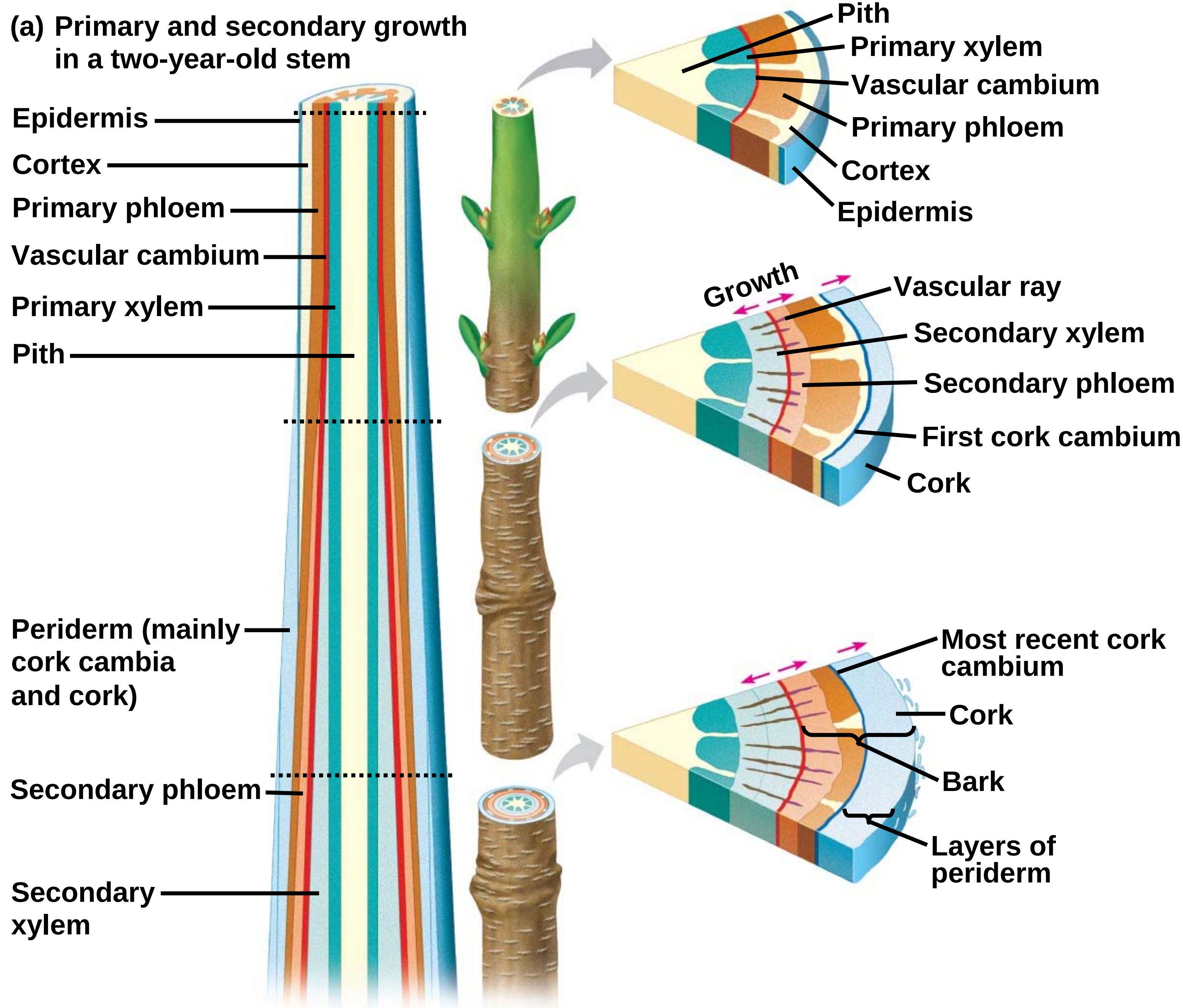


Fig. 35-19a2



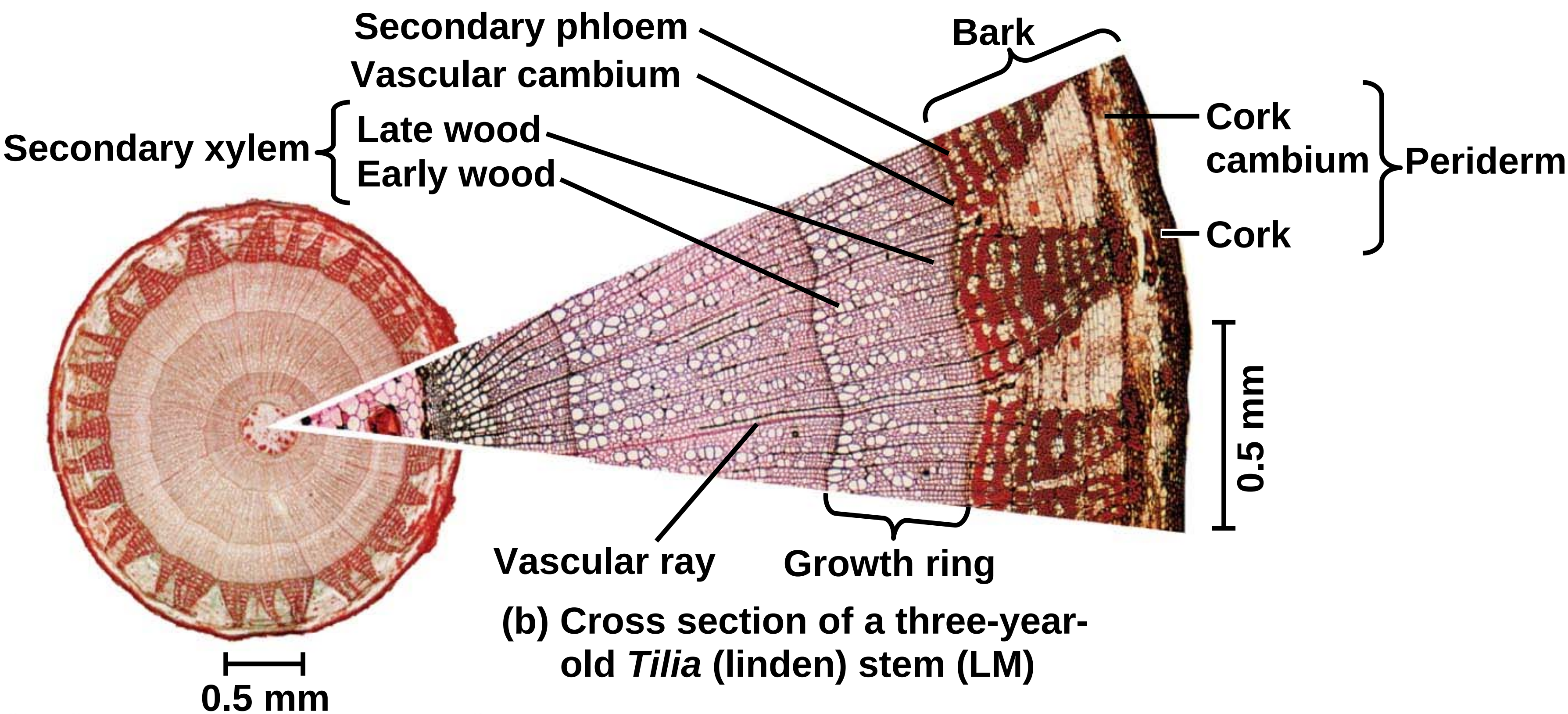
(a) Primary and secondary growth in a two-year-old stem
Epidermis
Cortex
Primary phloem
Vascular cambium
Primary xylem
Pith
Periderm (mainly cork cambia and cork)
Secondary phloem
Secondary xylem
Pith
Primary xylem
Vascular cambium
Primary phloem
Cortex
Epidermis
Growth
Vascular ray
Secondary xylem
Secondary phloem
First cork cambium
Cork

Fig. 35-19a3



(a) Primary and secondary growth in a two-year-old stem
Epidermis
Cortex
Primary phloem
Vascular cambium
Primary xylem
Pith
Periderm (mainly cork cambia and cork)
Secondary phloem
Secondary xylem
Pith
Primary xylem
Vascular cambium
Primary phloem
Cortex
Epidermis
Growth
Vascular ray
Secondary xylem
Secondary phloem
First cork cambium
Cork
Most recent cork cambium
Cork
Bark
Layers of periderm

Fig. 35-19b



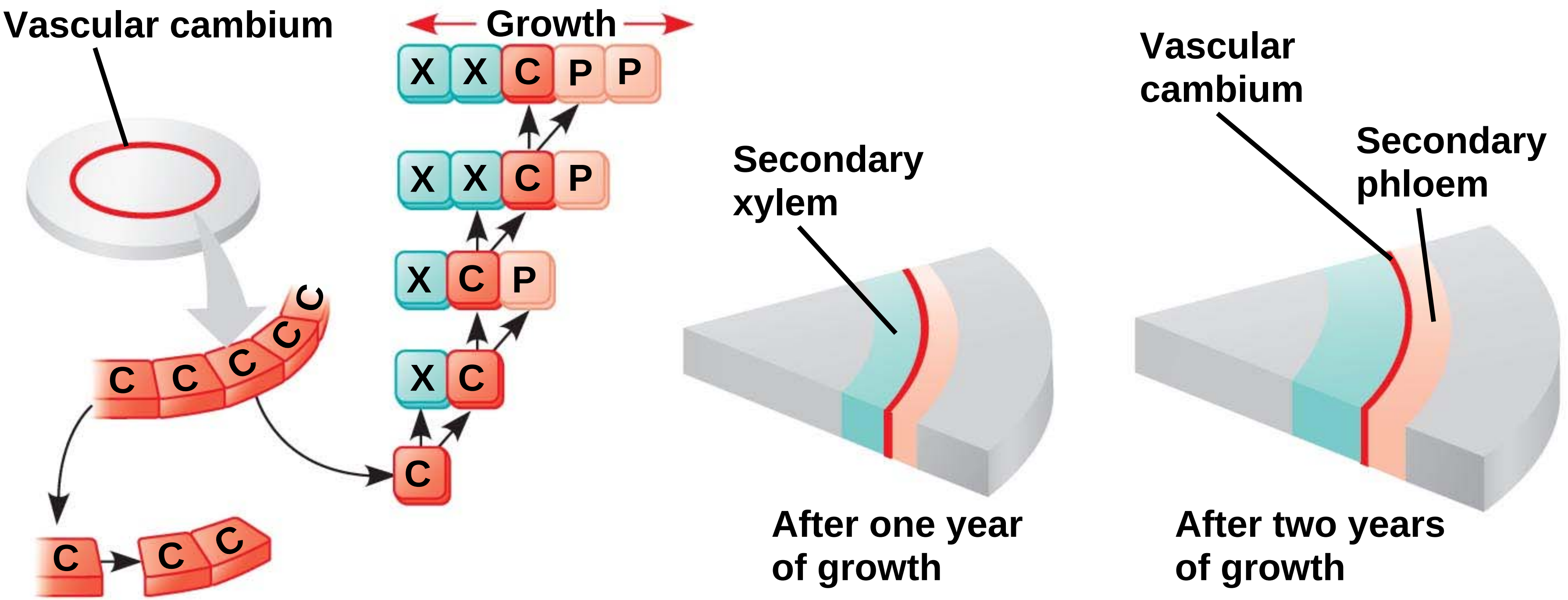
(b) Cross section of a three-year-old *Tilia* (linden) stem (LM)

The Vascular Cambium and Secondary Vascular Tissue

- The vascular cambium is a cylinder of meristematic cells one cell layer thick
- It develops from undifferentiated parenchyma cells

- In cross section, the vascular cambium appears as a ring of initials
- The initials increase the vascular cambium’s circumference and add secondary xylem to the inside and secondary phloem to the outside

Fig. 35-20



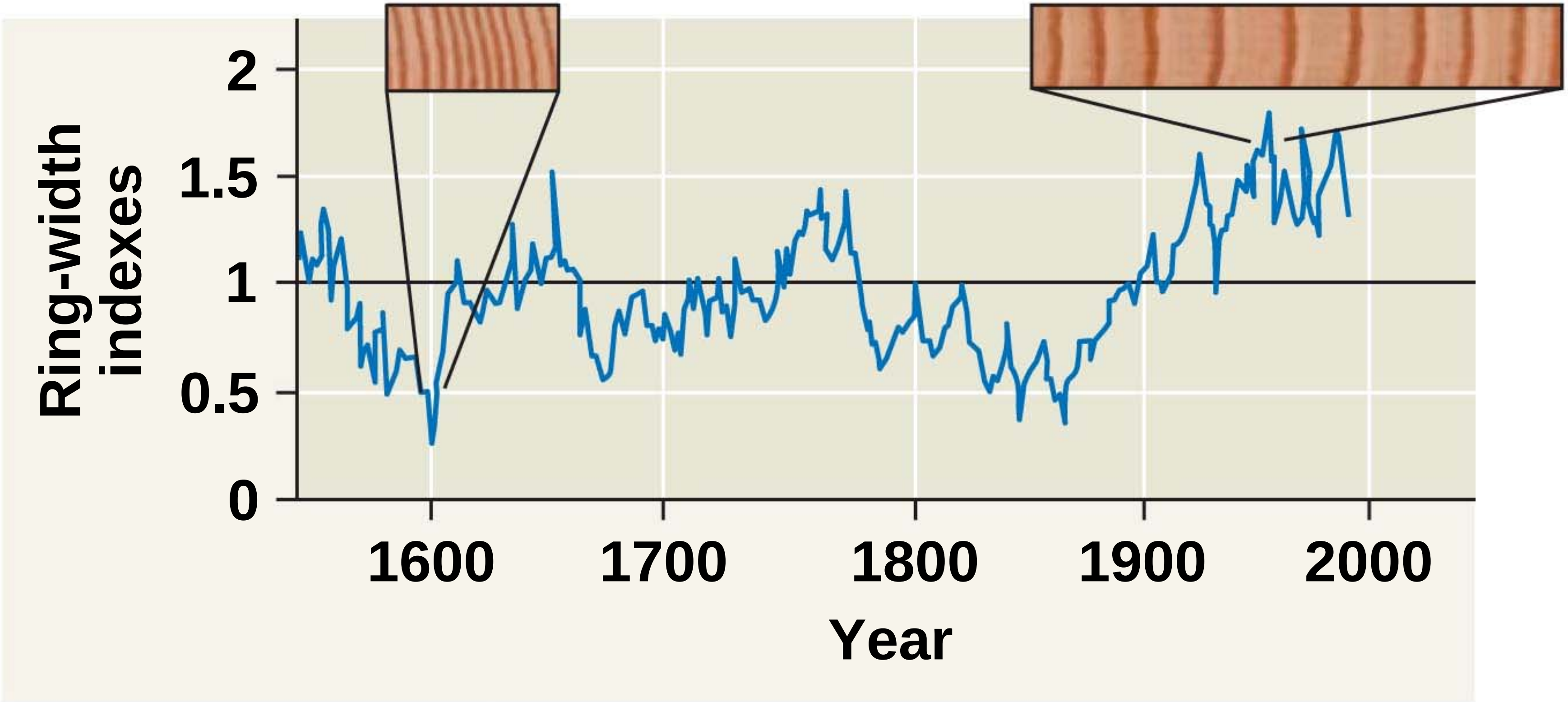
Vascular cambium
Growth
X X C P P
X X C P
X C P
X C
C
C C C C C
C C C
Secondary xylem
Vascular cambium
Secondary phloem
After one year of growth
After two years of growth

- Secondary xylem accumulates as wood, and consists of tracheids, vessel elements (only in angiosperms), and fibers
- Early wood, formed in the spring, has thin cell walls to maximize water delivery
- Late wood, formed in late summer, has thick-walled cells and contributes more to stem support
- In temperate regions, the vascular cambium of perennials is dormant through the winter

- Tree rings are visible where late and early wood meet, and can be used to estimate a tree’s age
- *Dendrochronology* is the analysis of tree ring growth patterns, and can be used to study past climate change

Fig. 35-21

RESULTS



- 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
- Older secondary phloem sloughs off and does not accumulate

Fig. 35-22

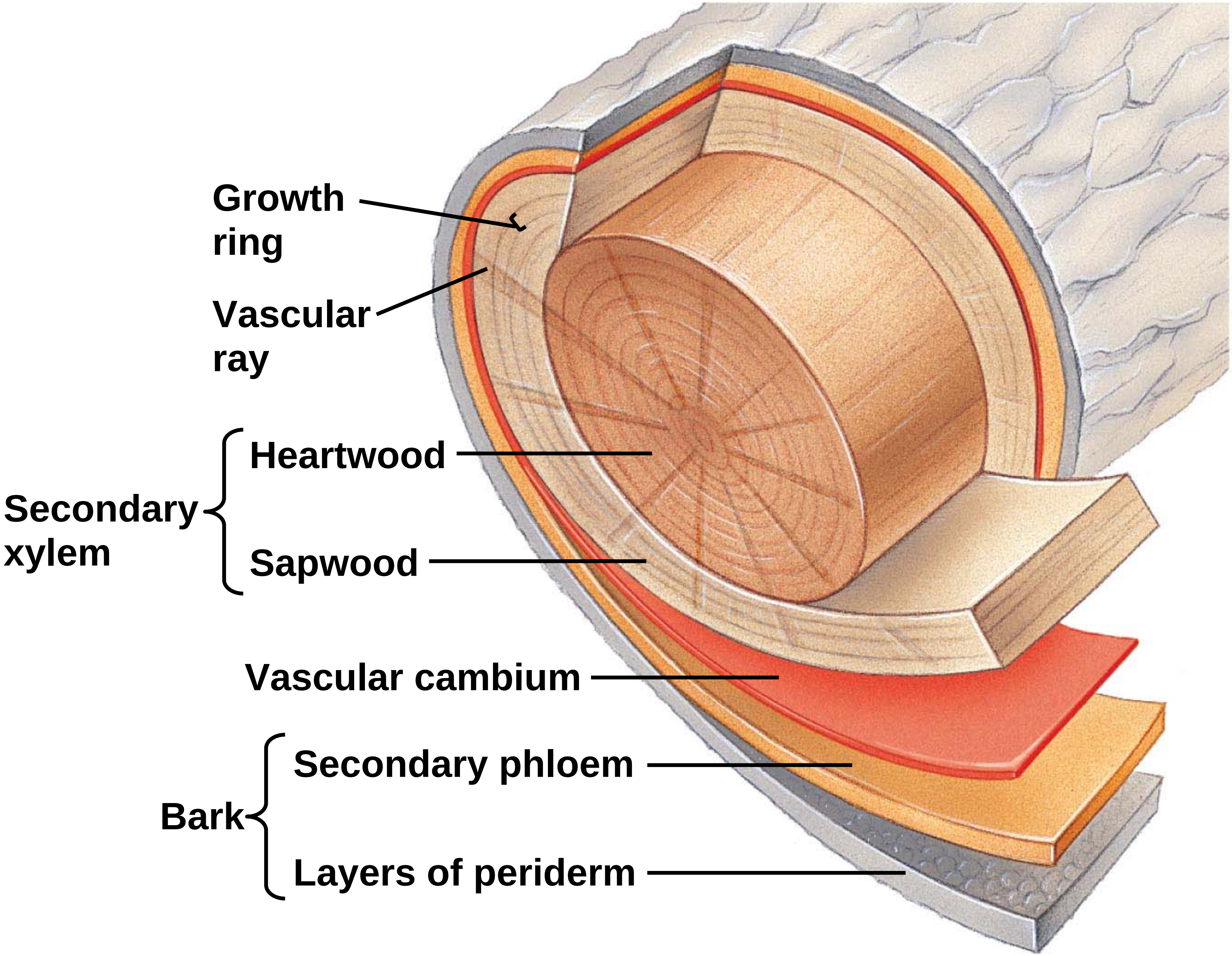

Growth ring
Vascular ray
Heartwood
Sapwood
Secondary xylem
Vascular cambium
Secondary phloem
Layers of periderm
Bark

Fig. 35-23

The Cork Cambium 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
- **Lenticels** in the periderm allow for gas exchange between living stem or root cells and the outside air

Concept 35.5: Growth, morphogenesis, and differentiation produce the plant body

- **Morphogenesis** is the development of body form and organization
- The three developmental processes of growth, morphogenesis, and cellular differentiation act in concert to transform the fertilized egg into a plant

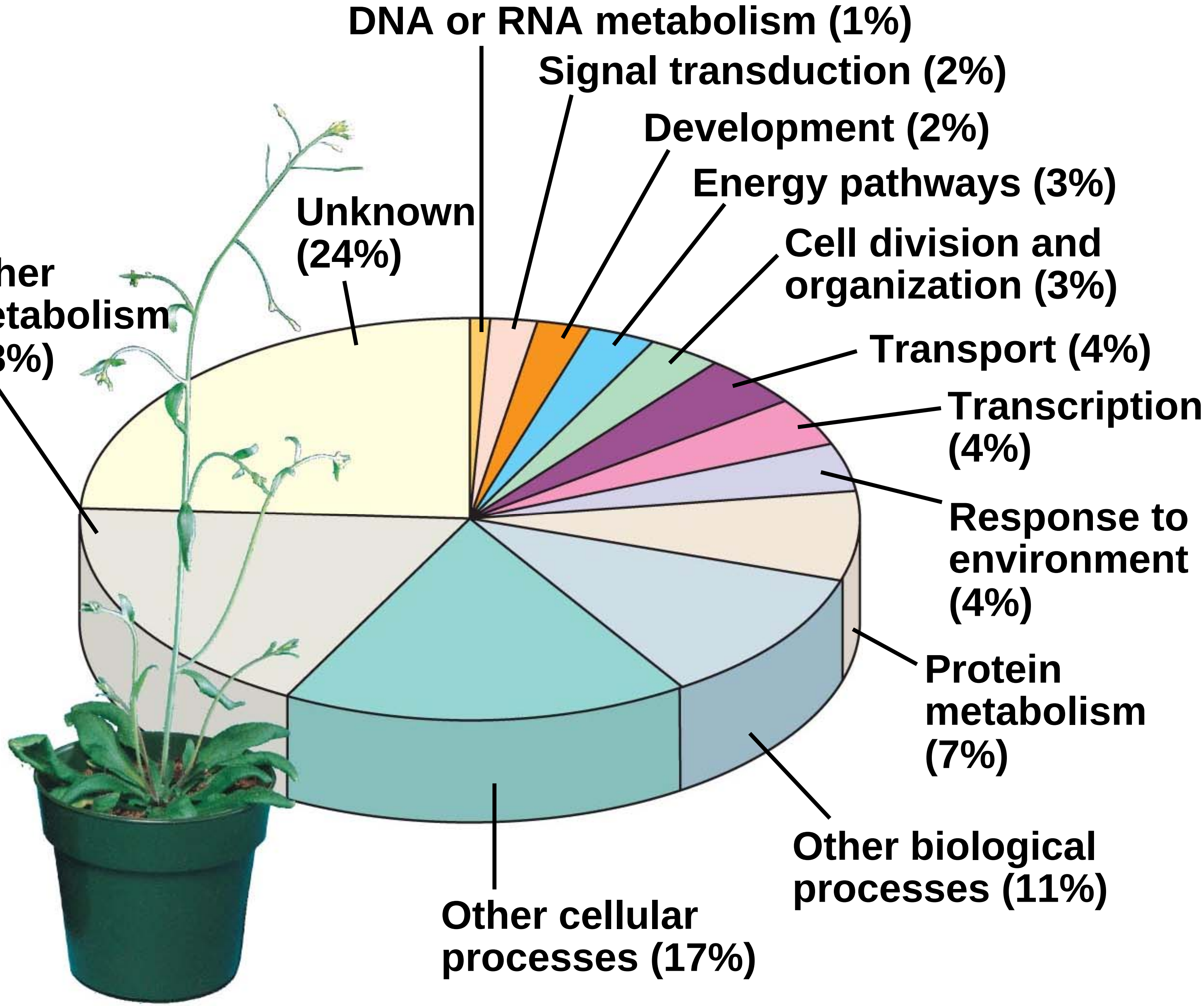
Molecular Biology: Revolutionizing the Study of Plants

- New techniques and model systems are catalyzing explosive progress in our understanding of plants

- *Arabidopsis* is a model organism, and the first plant to have its entire genome sequenced

- Studying the genes and biochemical pathways of *Arabidopsis* will provide insights into plant development, a major goal of systems biology

Fig. 35-24


DNA or RNA metabolism (1%)
Signal transduction (2%)
Development (2%)
Energy pathways (3%)
Cell division and organization (3%)
Transport (4%)
Transcription (4%)
Response to environment (4%)
Protein metabolism (7%)
Other biological processes (11%)
Other cellular processes (17%)
Other metabolism (18%)
Unknown (24%)

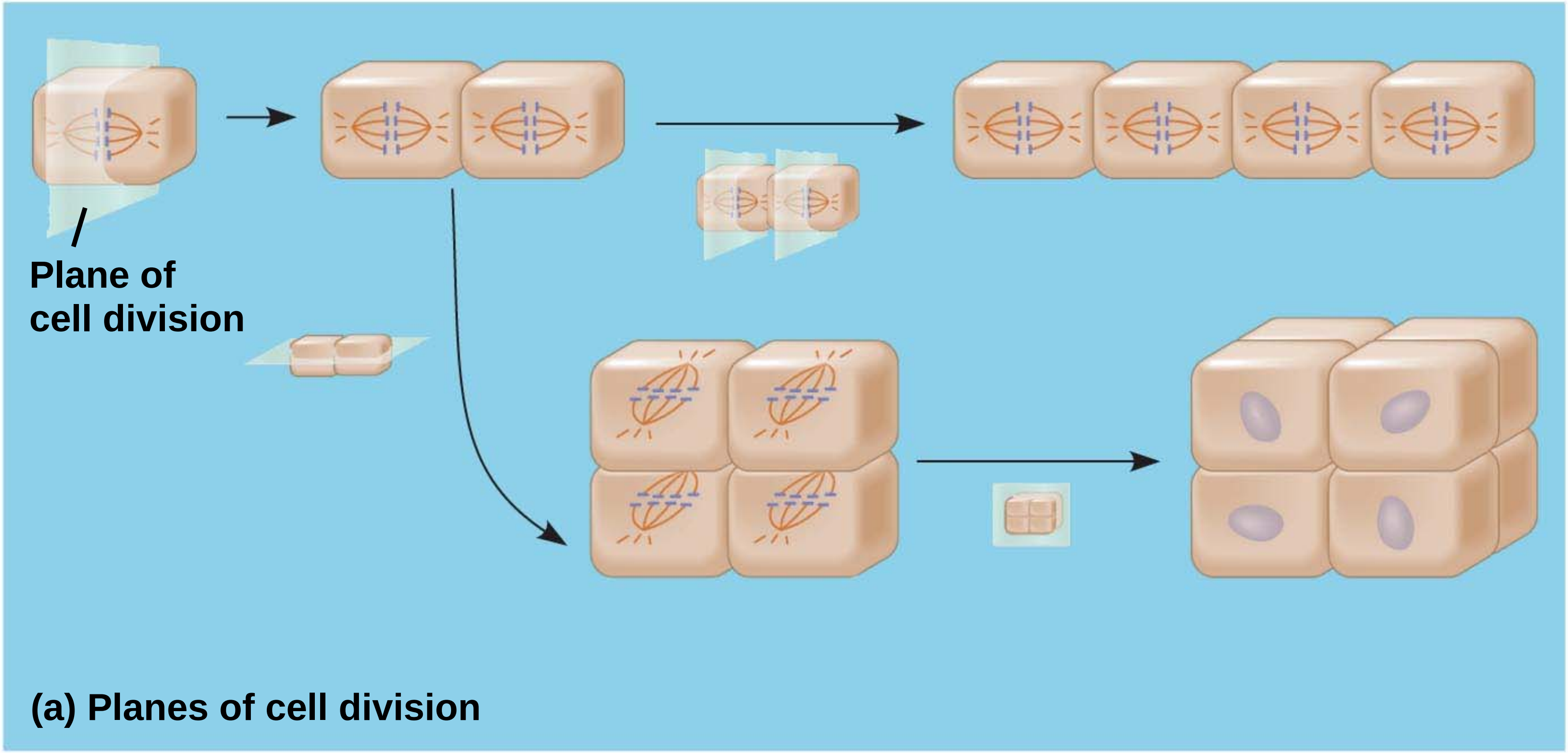
Growth: Cell Division and Cell Expansion

- By increasing cell number, cell division in meristems increases the potential for growth
- Cell expansion accounts for the actual increase in plant size

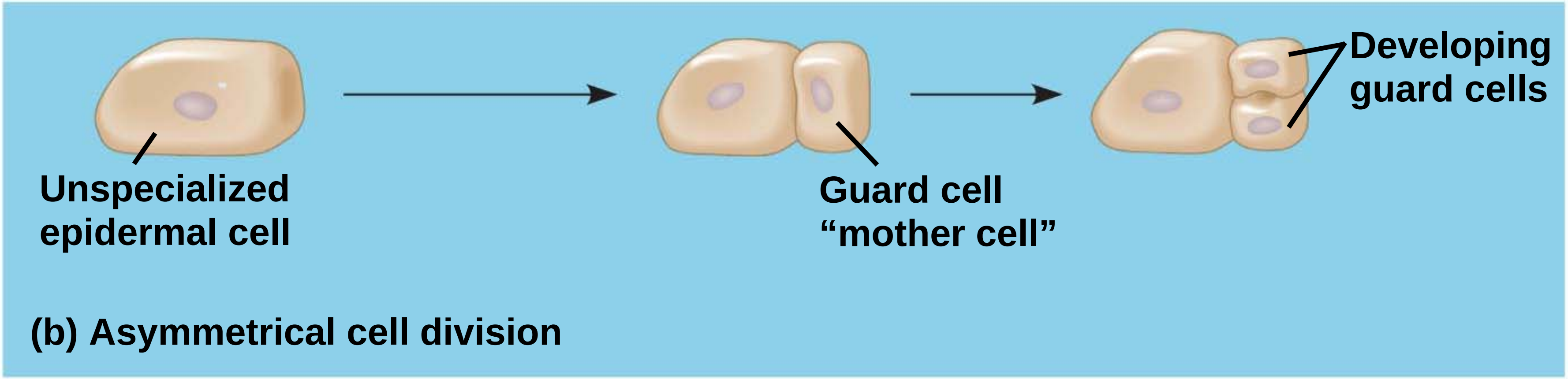
The Plane and Symmetry of Cell Division

- 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 of cells is produced

Fig. 35-25

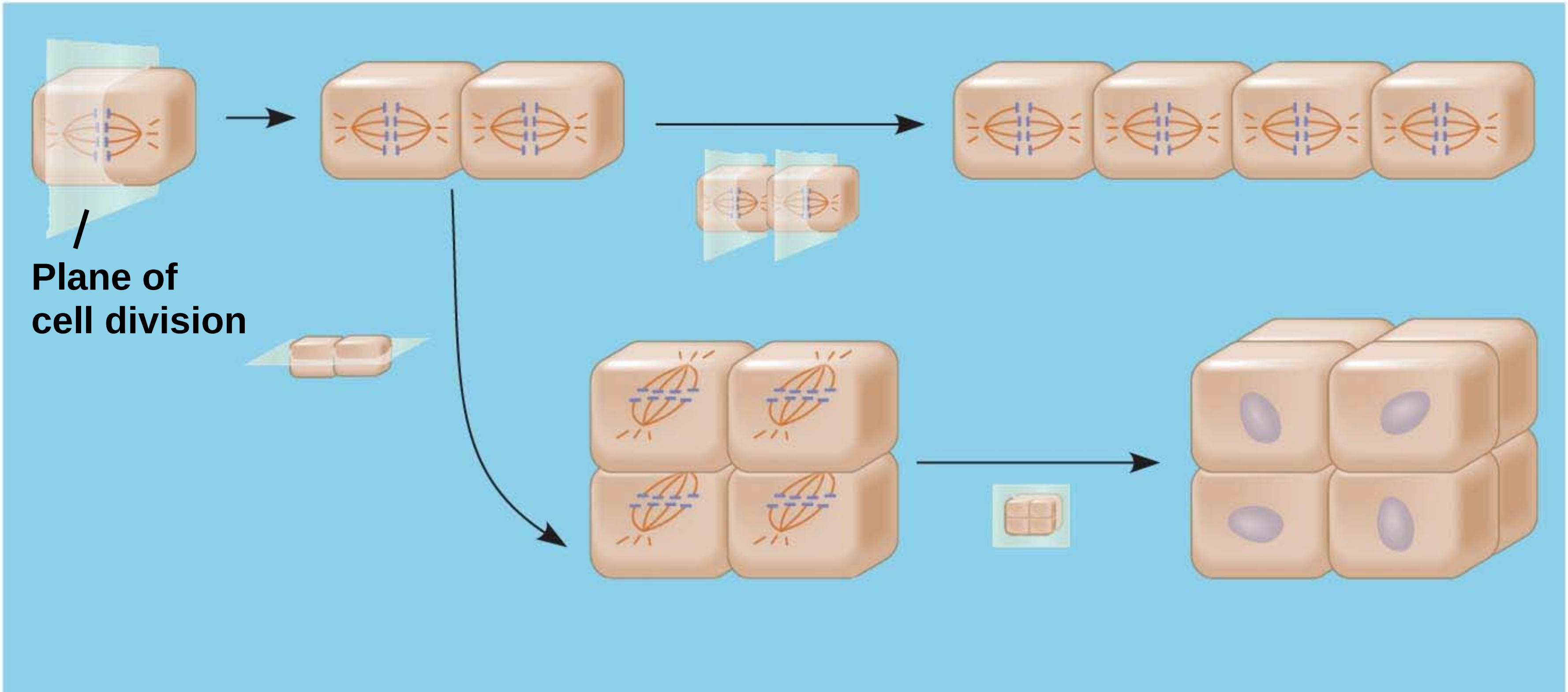


Plane of
cell division
(a) Planes of cell division



Developing
guard cells
Unspecialized
epidermal cell
Guard cell
“mother cell”
(b) Asymmetrical cell division

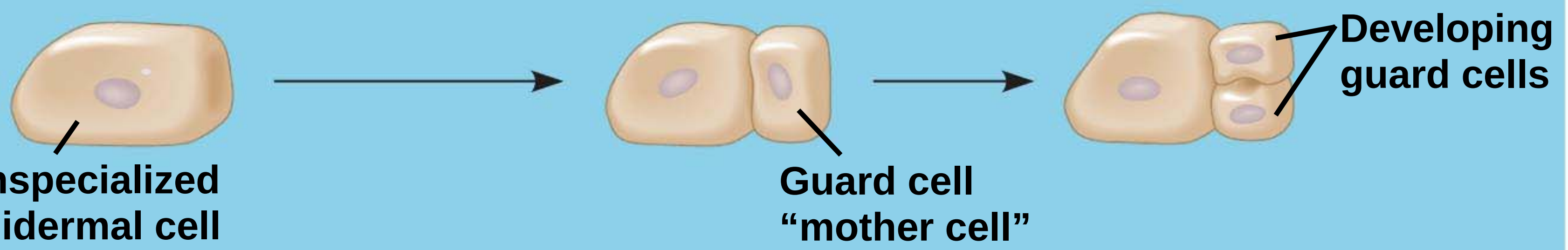
Fig. 35-25a



(a) Planes of cell division

- If the planes of division vary randomly, asymmetrical cell division occurs

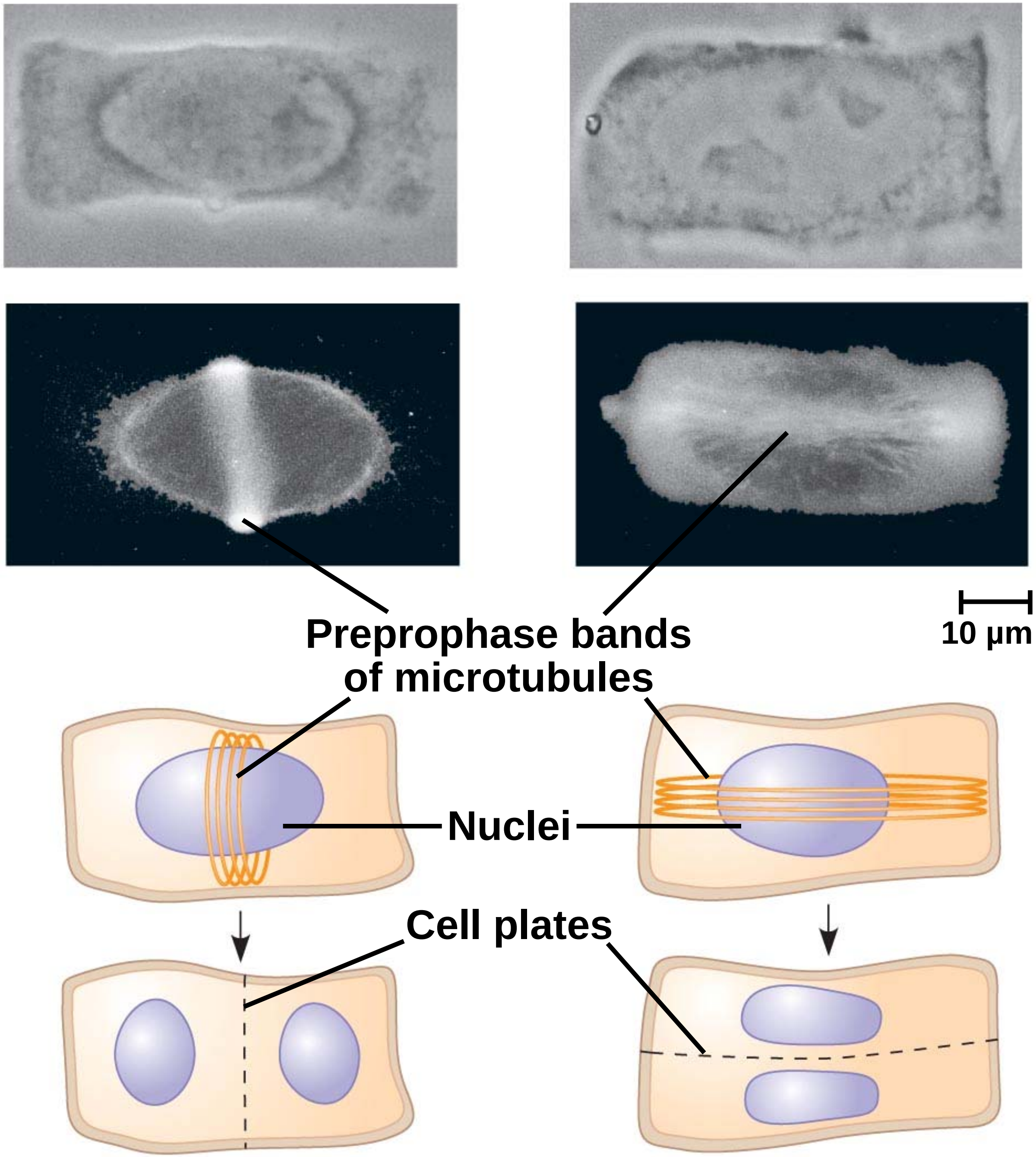
Fig. 35-25b



(b) Asymmetrical cell division

- The plane in which a cell divides is determined during late interphase
- Microtubules become concentrated into a ring called the **preprophase band** that predicts the future plane of cell division

Fig. 35-26

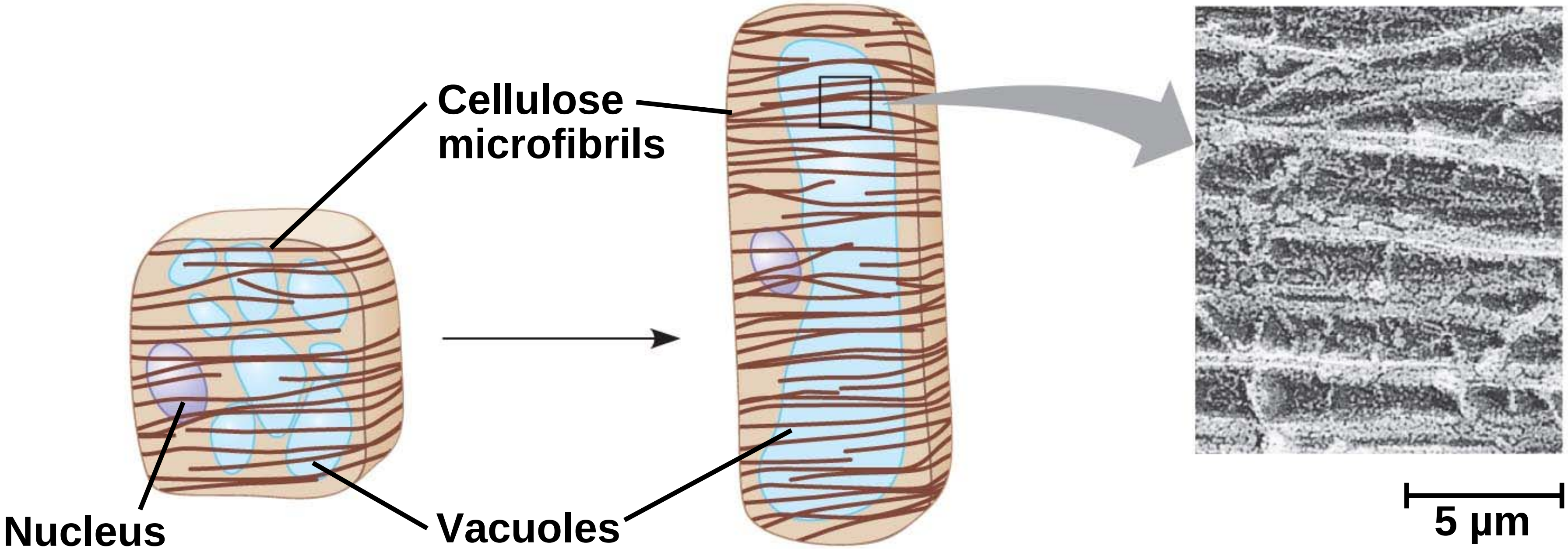


Preprophase bands of microtubules
10 µm
Nuclei
Cell plates

Orientation of Cell Expansion

- Plant cells grow rapidly and “cheaply” by intake and storage of water in vacuoles
- Plant cells expand primarily along the plant’s main axis
- Cellulose microfibrils in the cell wall restrict the direction of cell elongation

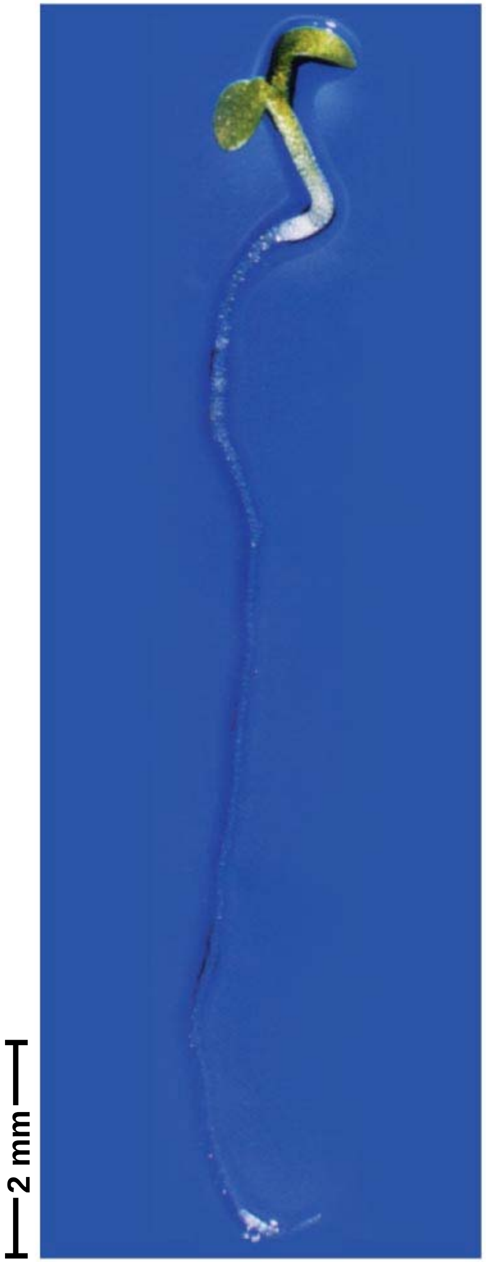
Fig. 35-27

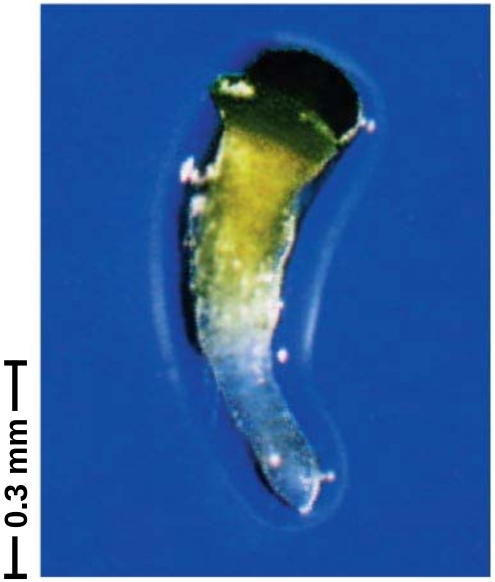


Microtubules and Plant Growth

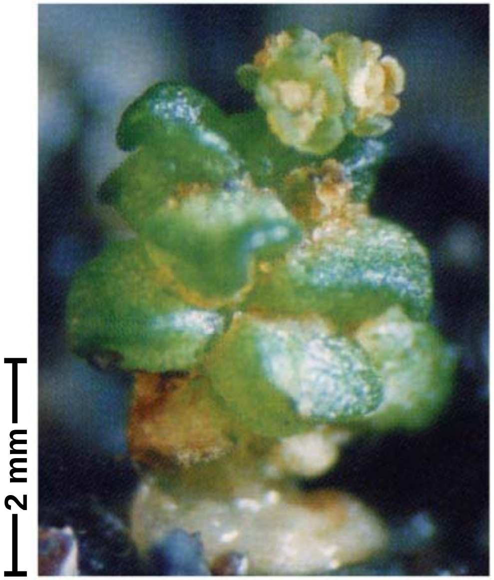
- Studies of *fass* mutants of *Arabidopsis* have confirmed the importance of cytoplasmic microtubules in cell division and expansion

Fig. 35-28





(b) ***fass*** **seedling**



(a) Wild-type seedling

(c) Mature ***fass*** **mutant**

Morphogenesis and Pattern Formation

- **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
- Positional information may be provided by gradients of molecules
- **Polarity**, having structural or chemical differences at opposite ends of an organism, provides one type of positional information

- Polarization is initiated by an asymmetrical first division of the plant zygote
- In the *gnom* mutant of *Arabidopsis*, the establishment of polarity is defective

Fig. 35-29

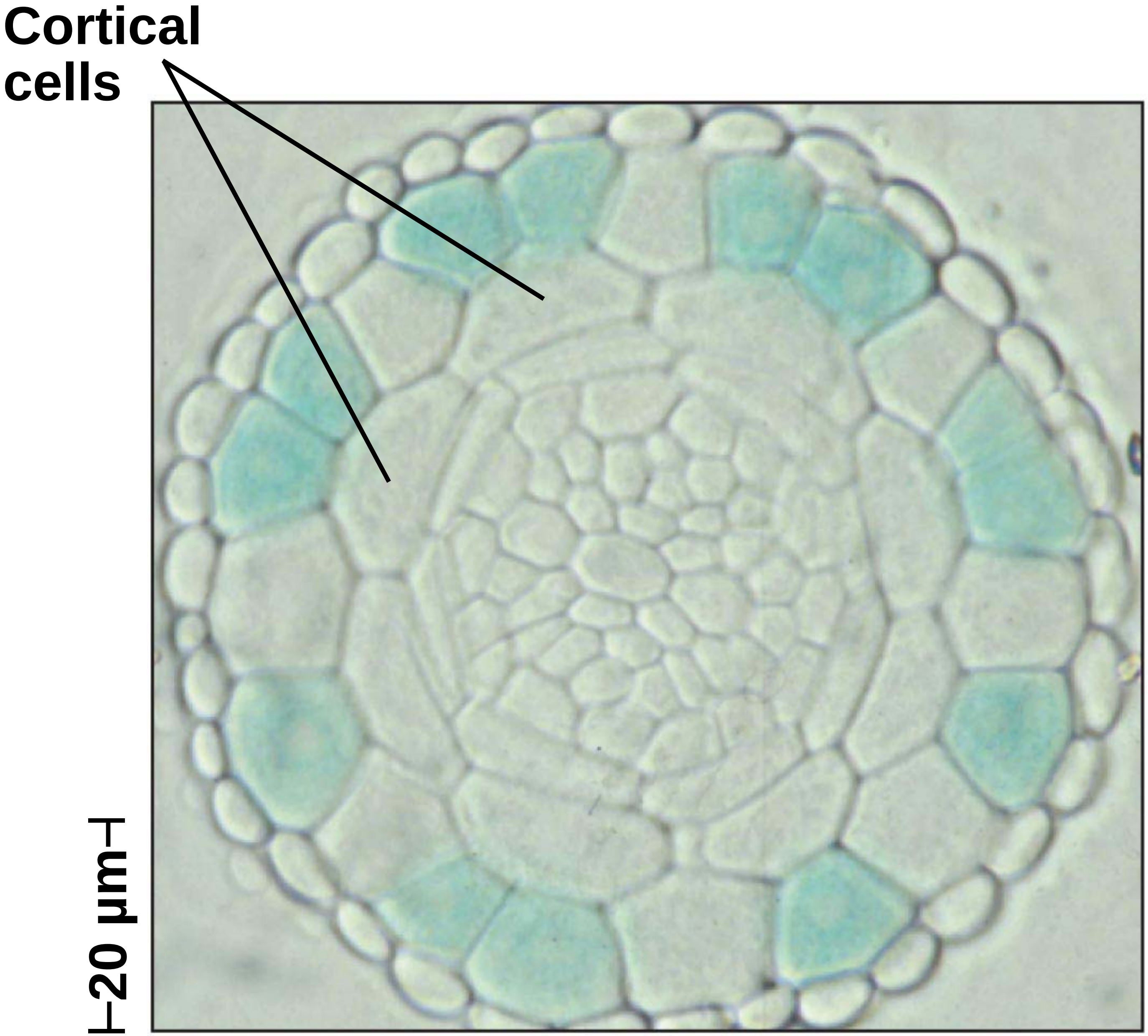
- Morphogenesis in plants, as in other multicellular organisms, is often controlled by homeotic genes

Fig. 35-30

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
- Cellular differentiation to a large extent depends on positional information and is affected by homeotic genes

Fig. 35-31



Location and a Cell's Developmental Fate

- Positional information underlies all the processes of development: growth, morphogenesis, and differentiation
- Cells are not dedicated early to forming specific tissues and organs
- The cell's final position determines what kind of cell it will become

Shifts in Development: Phase Changes

- Plants pass through developmental phases, called **phase changes**, developing from a juvenile phase to an adult phase
- Phase changes occur within the shoot apical meristem
- The most obvious morphological changes typically occur in leaf size and shape

Fig. 35-32

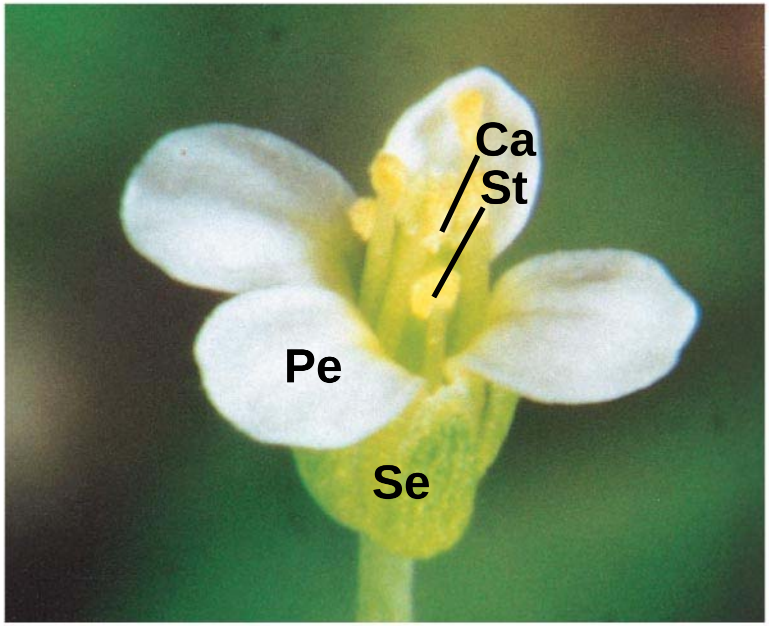

Leaves produced by adult phase of apical meristem
Leaves produced by juvenile phase of apical meristem

Genetic Control of Flowering

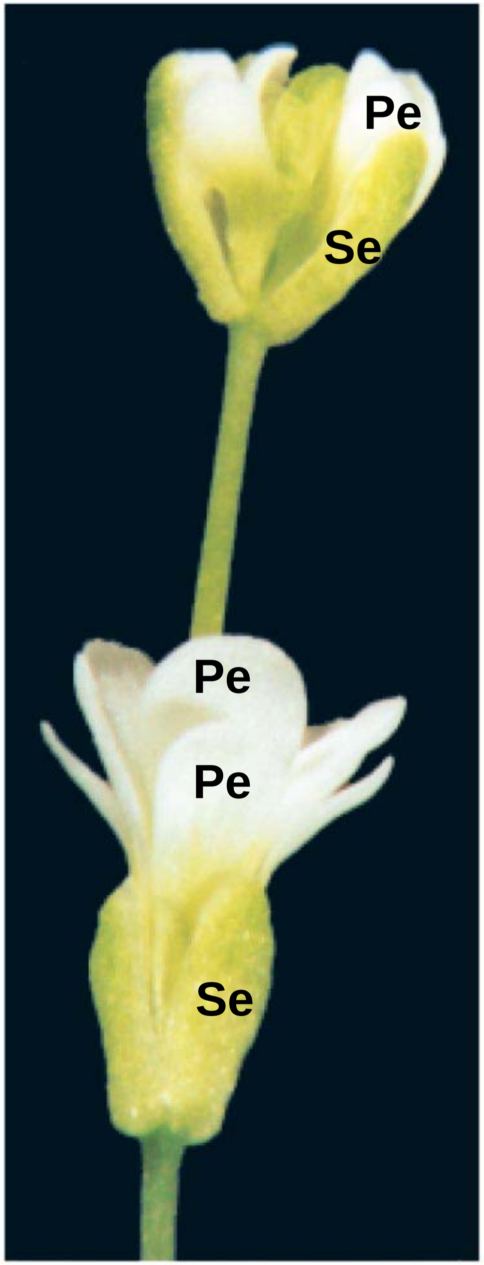
- Flower formation involves a phase change from vegetative growth to reproductive growth
- It is triggered by a combination of environmental cues and internal signals
- Transition from vegetative growth to flowering is associated with the switching on of floral **meristem identity genes**

- Plant biologists have identified several **organ identity genes** (plant homeotic genes) that regulate the development of floral pattern
- A mutation in a plant organ identity gene can cause abnormal floral development

Fig. 35-33



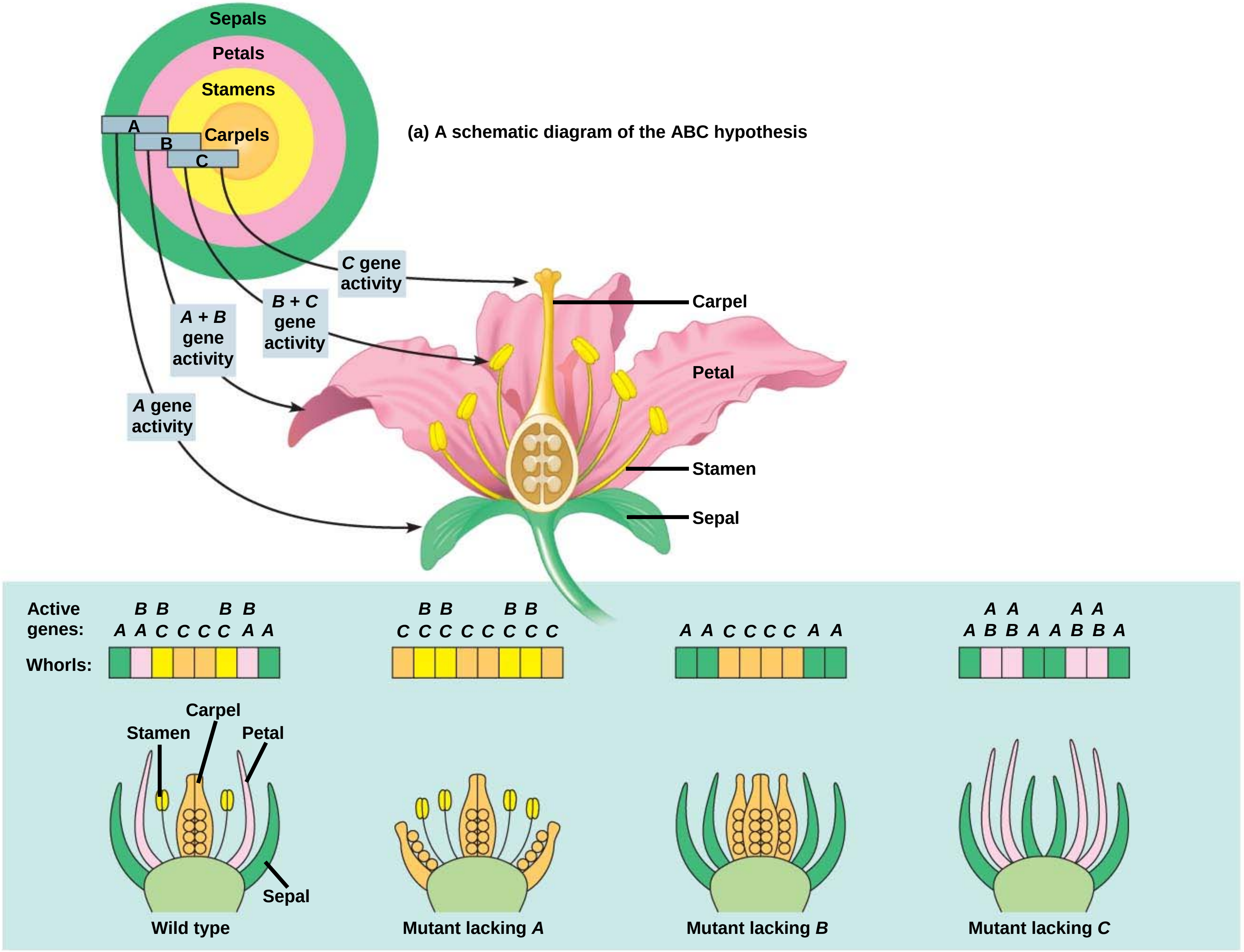
(a) Normal *Arabidopsis* flower



(b) Abnormal *Arabidopsis* flower

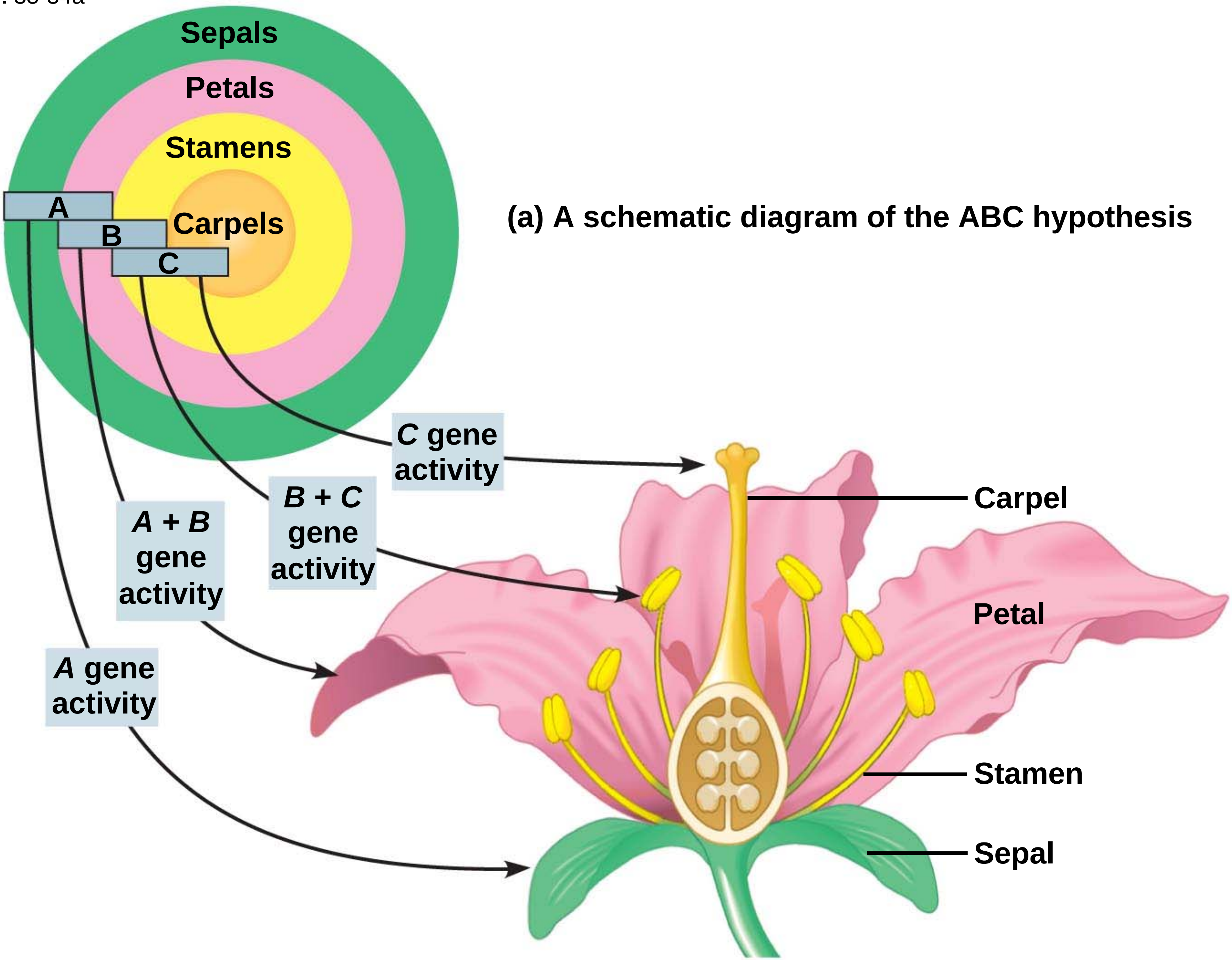
- Researchers have identified three classes of floral organ identity genes
- The **ABC model** of flower formation identifies how floral organ identity genes direct the formation of the four types of floral organs
- An understanding of mutants of the organ identity genes depicts how this model accounts for floral phenotypes

Fig. 35-34



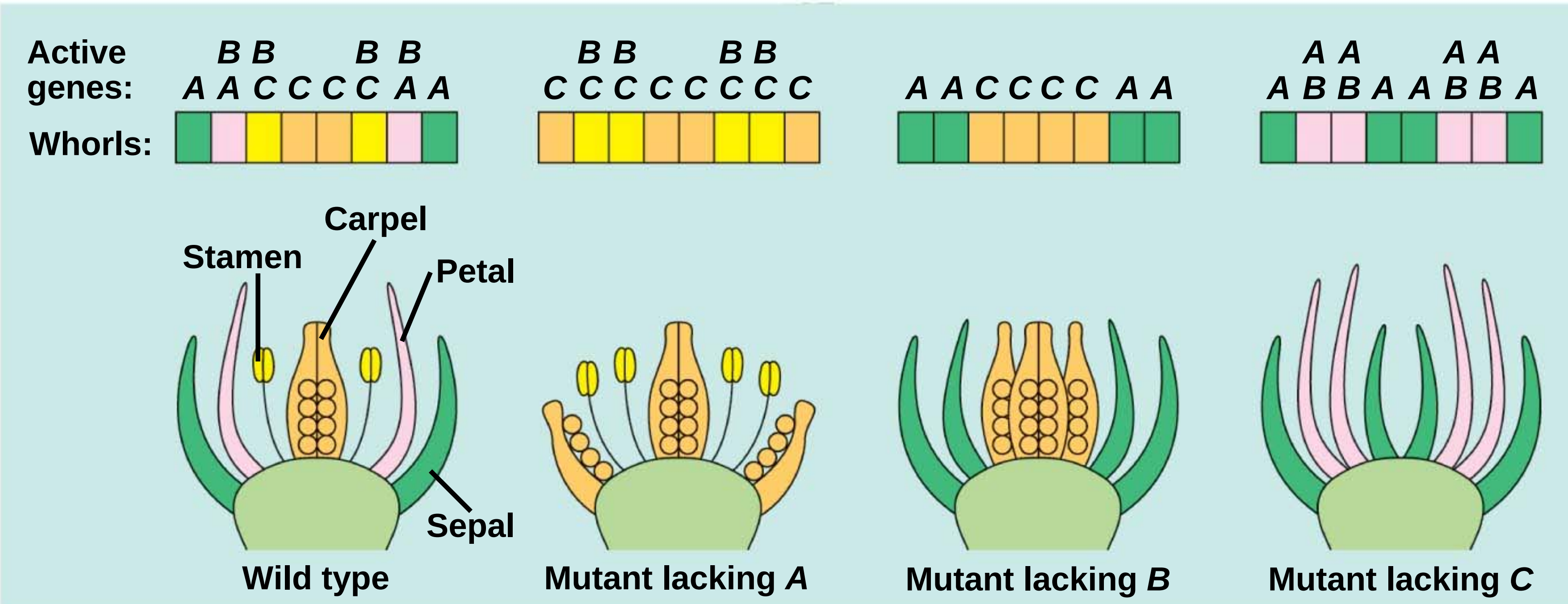
(b) Side view of flowers with organ identity mutations

Fig. 35-34a



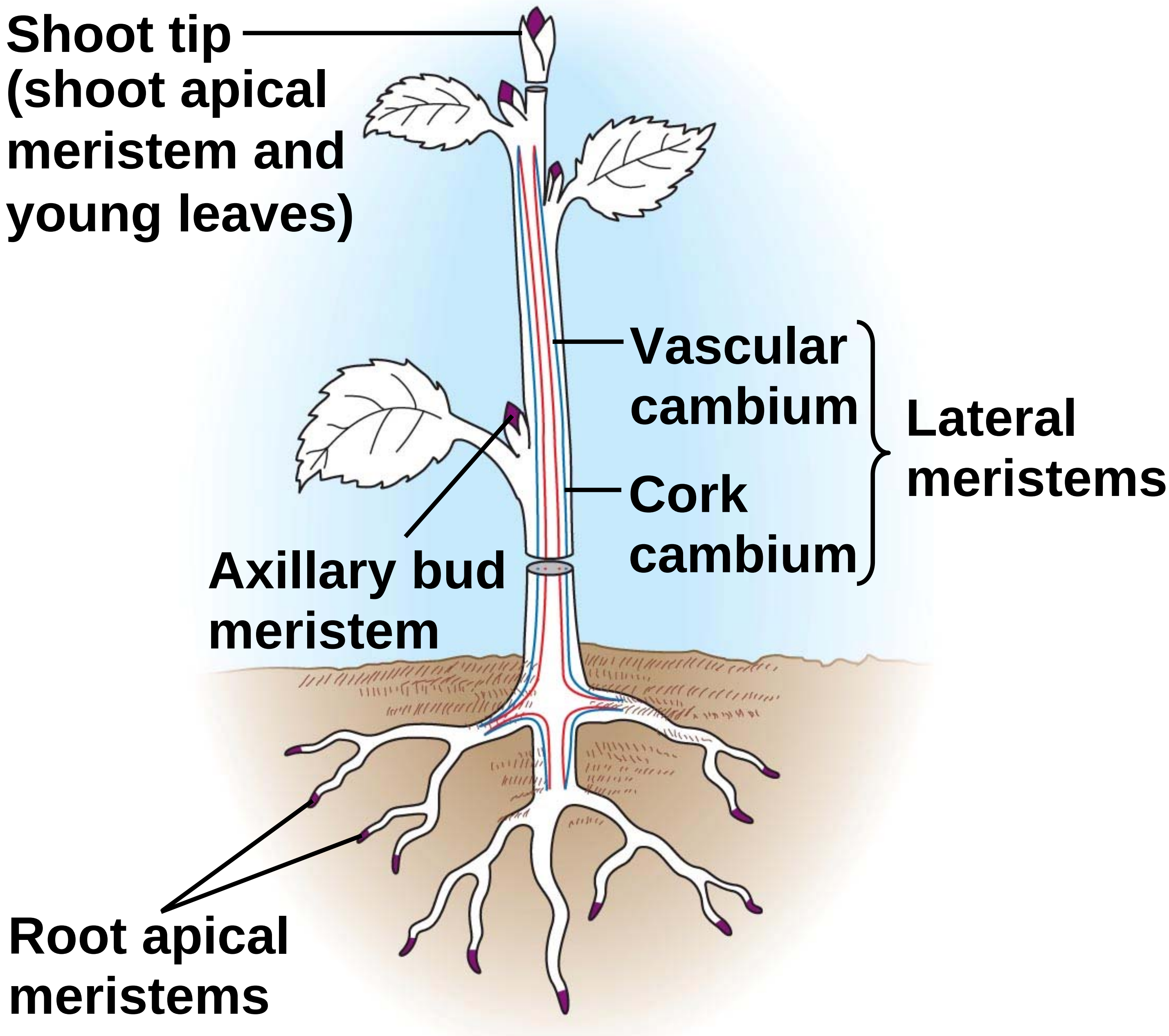
(a) A schematic diagram of the ABC hypothesis

Fig. 35-34b



(b) Side view of flowers with organ identity mutations

Fig. 35-UN1



Shoot tip
(shoot apical
meristem and
young leaves)
Vascular
cambium
Cork
cambium
Lateral
meristems
Axillary bud
meristem
Root apical
meristems

Fig. 35-UN2

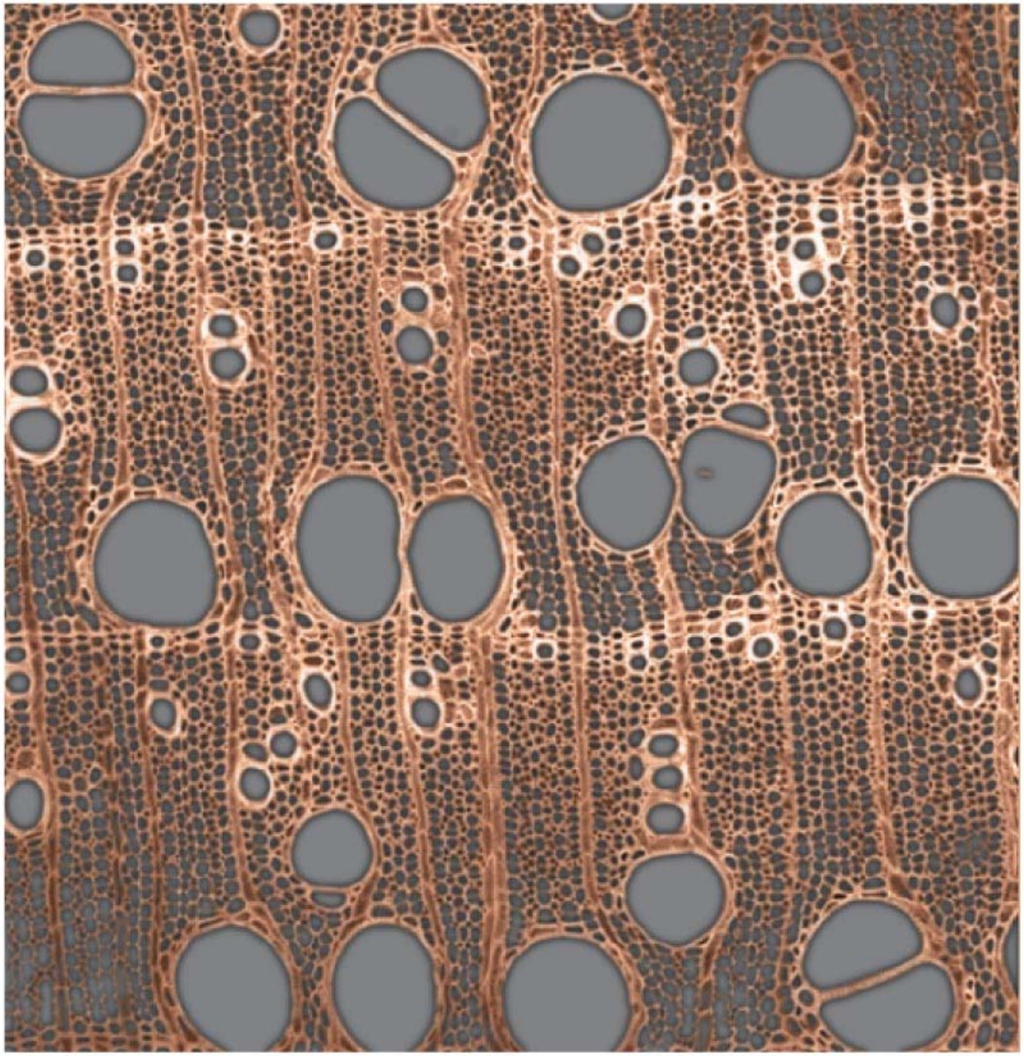
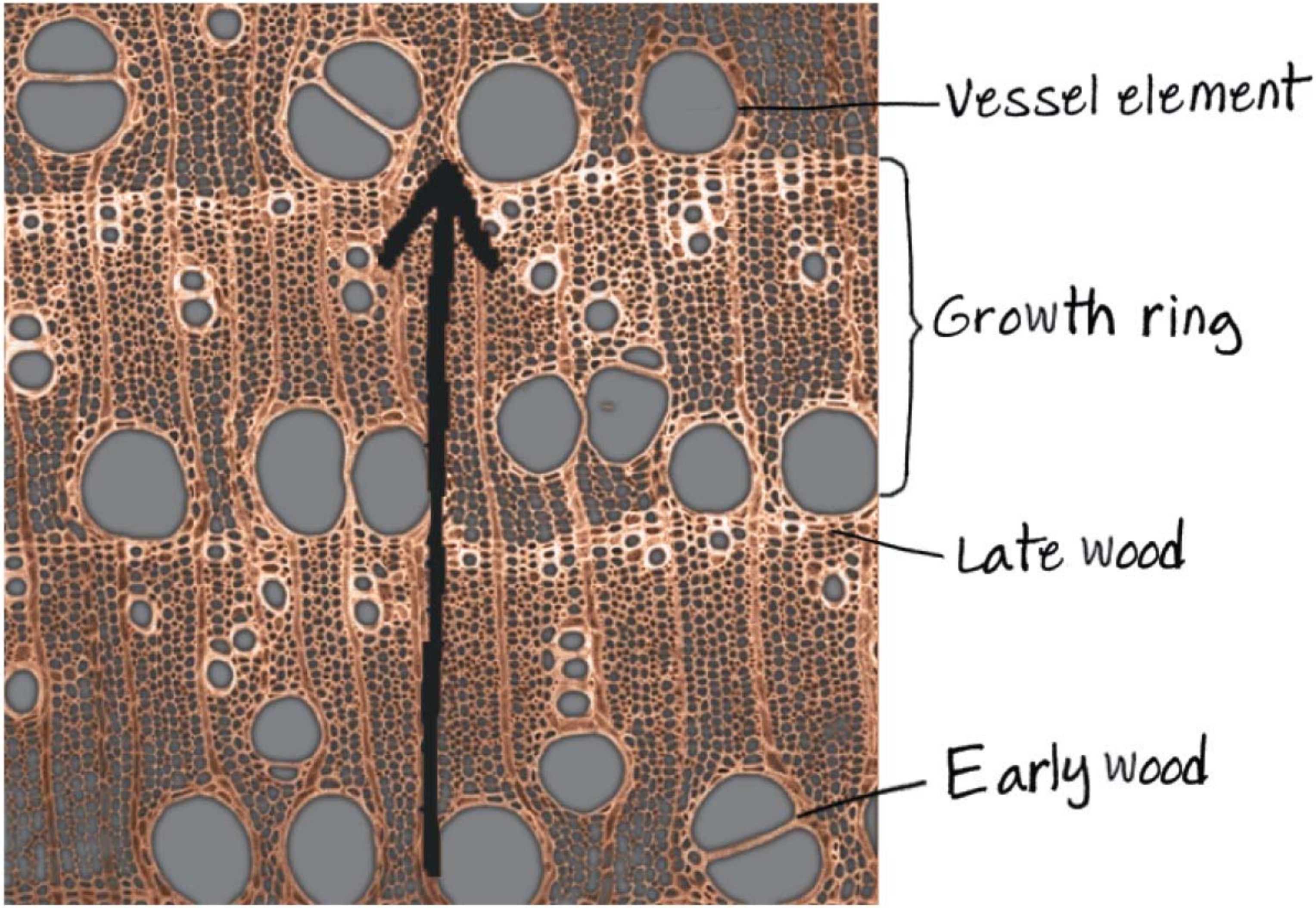


Fig. 35-UN3



You should now be able to:

1. Compare the following structures or cells:
   - Fibrous roots, taproots, root hairs, adventitious roots
   - Dermal, vascular, and ground tissues
   - Monocot leaves and eudicot leaves
   - Parenchyma, collenchyma, sclerenchyma, water-conducting cells of the xylem, and sugar-conducting cells of the phloem
   - Sieve-tube element and companion cell

2. Explain the phenomenon of apical dominance
3. Distinguish between determinate and indeterminate growth
4. Describe in detail the primary and secondary growth of the tissues of roots and shoots
5. Describe the composition of wood and bark

6. Distinguish between morphogenesis, differentiation, and growth

7. Explain how a vegetative shoot tip changes into a floral meristem