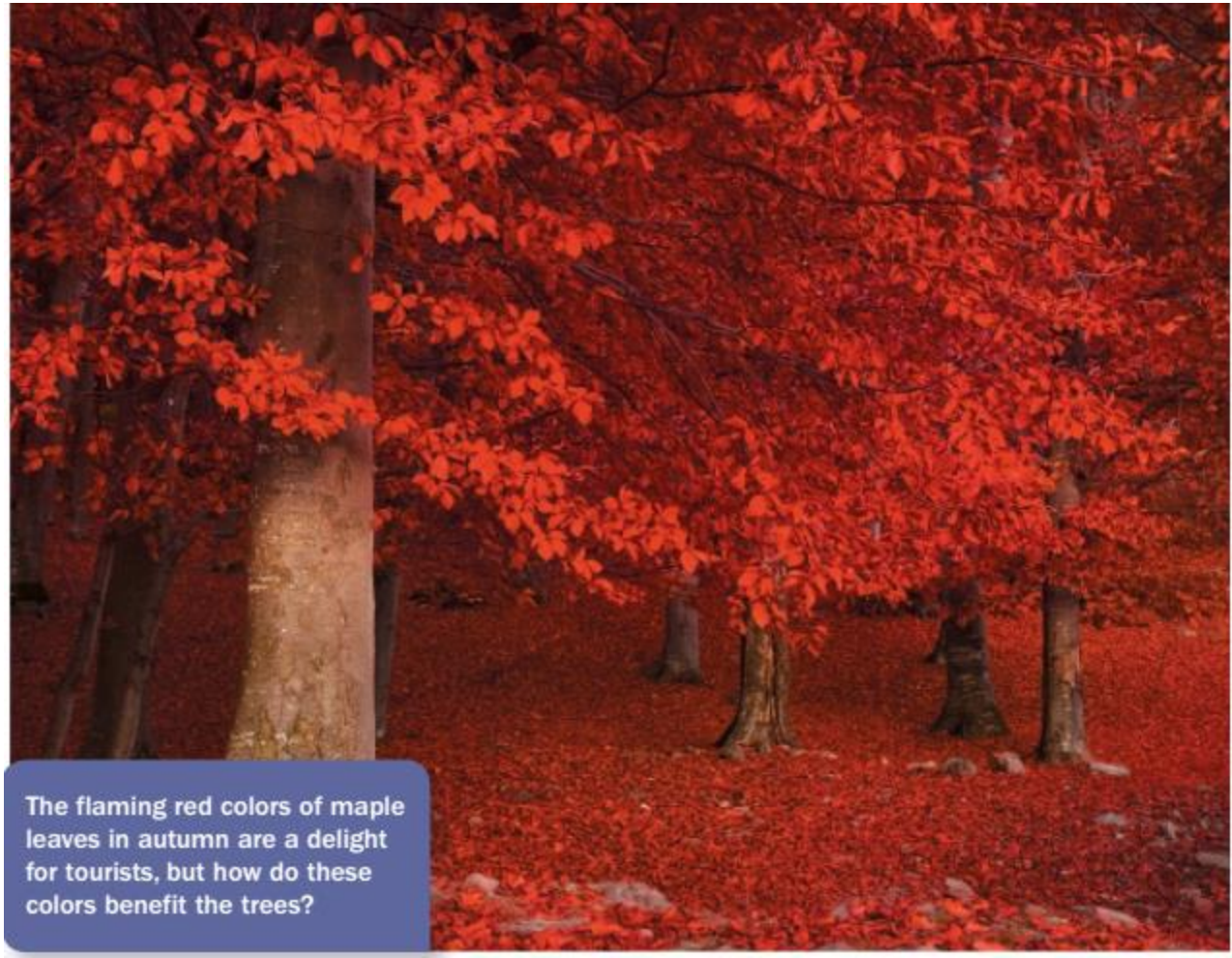
Chapter 43

Plant Anatomy and Nutrient Transport



The flaming red colors of maple leaves in autumn are a delight for tourists, but how do these colors benefit the trees?

Chapter 43 At a Glance

- 43.1 How Are Plant Bodies Organized?
- 43.2 How Do Plants Grow?
- 43.3 What Are the Tissues and Cell Types of Plants?
- 43.4 What Are the Structures and Functions of Leaves?
- 43.5 What Are the Structures and Functions of Stems?

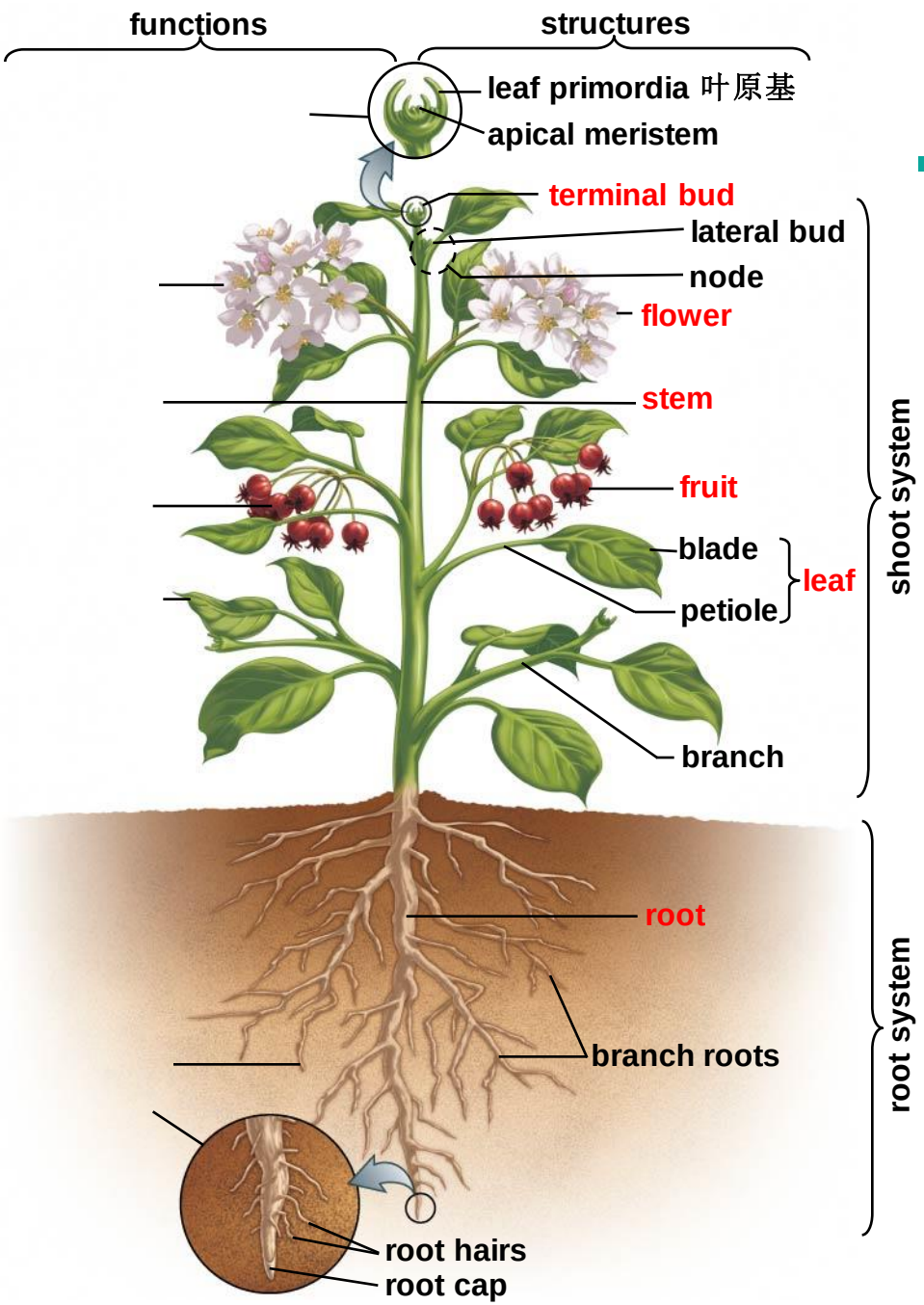
Chapter 43 At a Glance *(continued)*

- 43.6 What Are the Structures and Functions of Roots?
- 43.7 How Do Plants Acquire Nutrients?
- 43.8 How Do Plants Move Water and Minerals from Roots to Leaves?
- 43.9 How Do Plants Transport Sugars?

43.1 How Are Plant Bodies Organized?

- **Adaptations that allow plants to thrive**
  - Plants cannot move to seek food or water, to escape predators, to avoid winter, or to find a mate
- The bodies of flowering plants consist of two major parts: the root system and the shoot system
  - The **root system** consists of all the roots of a plant
  - The **shoot system** (茎轴系统) is usually located **aboveground**

Figure 43-1 The structures and functions of a typical flowering plant



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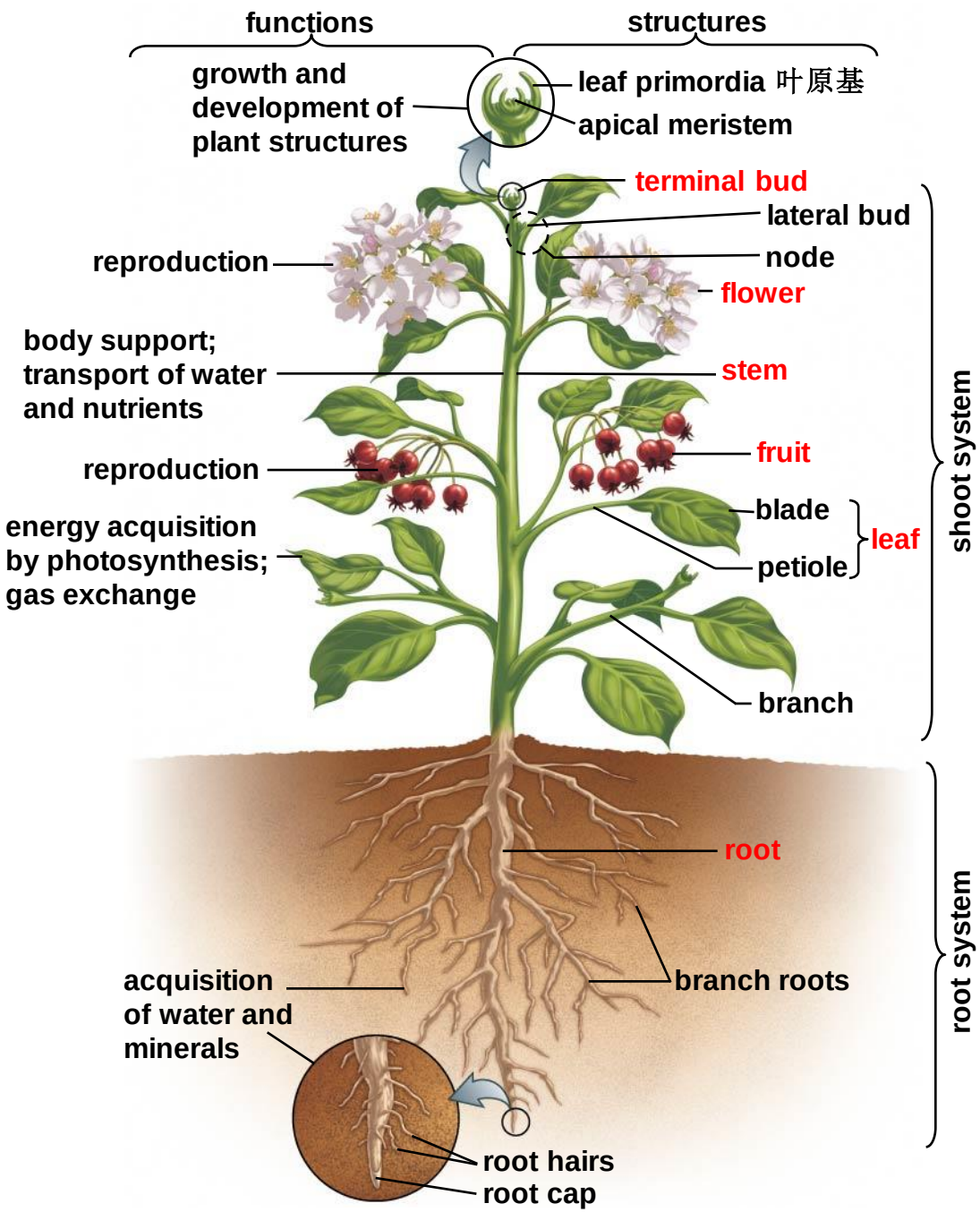


43.1 How Are Plant Bodies Organized?

- **Roots** are usually embedded in the soil, and carry out **six** major functions

1. Anchor the plant in the ground
2. Absorb water and minerals from the soil
3. Transport water, minerals, sugars, and hormones to and from the shoot
4. Store surplus sugars and starches
5. Produce hormones
6. Interact with soil fungi and bacteria, getting nutrients

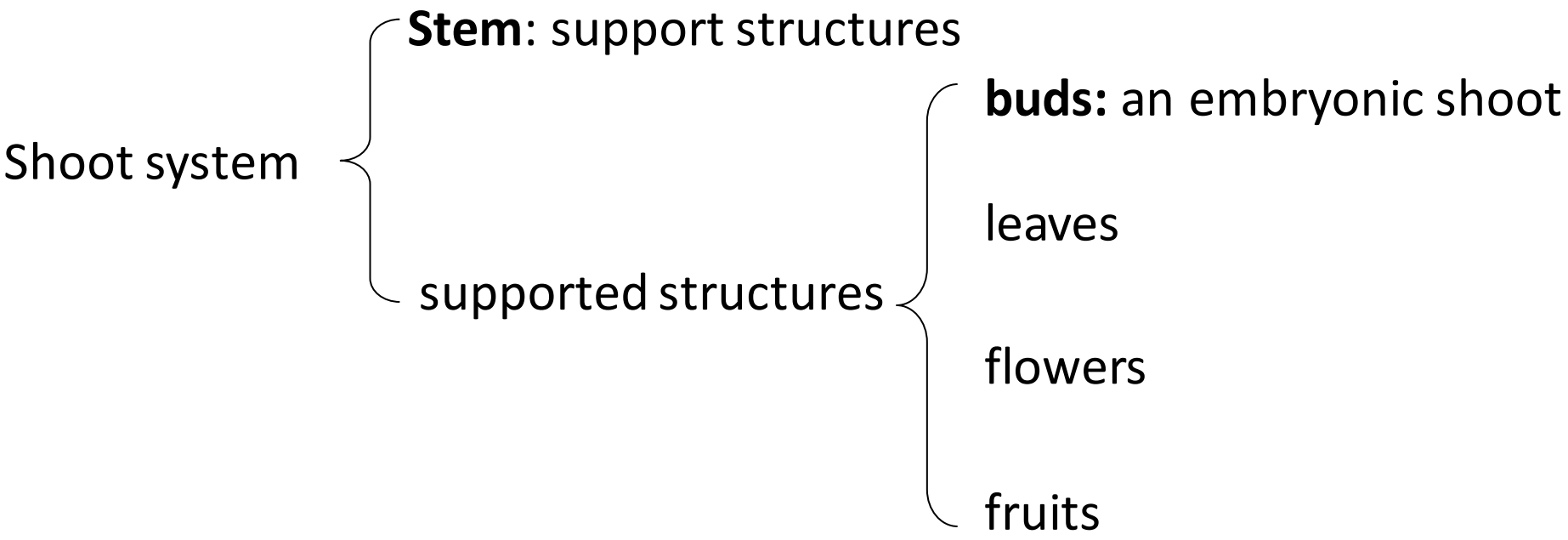
43.1 How Are Plant Bodies Organized?

- The **shoot system** is usually located aboveground and performs five major functions

1. Capture sunlight energy and synthesize sugars during photosynthesis
2. Transport materials to and from various parts of the plant
3. Store surplus sugars and starches
4. Reproduce
5. Produce hormones

43.1 How Are Plant Bodies Organized?

- the shoot system (of flowering plants)

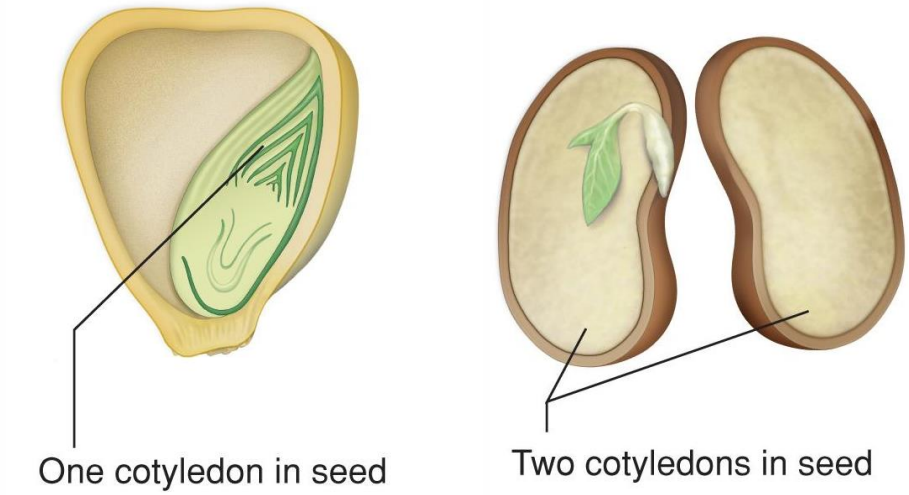


Different types and locations of buds may produce **branches, flowers, or additional growth at the top of an existing stem**

43.1 How Are Plant Bodies Organized?

- Flowering plants can be placed into one of two large groups called monocots (单子叶) and dicots (双子叶)
  - characteristic that gives the groups their names is the number of ***cotyledons*** (子叶)
    - Monocots have a single cotyledon and dicots have two

Seed



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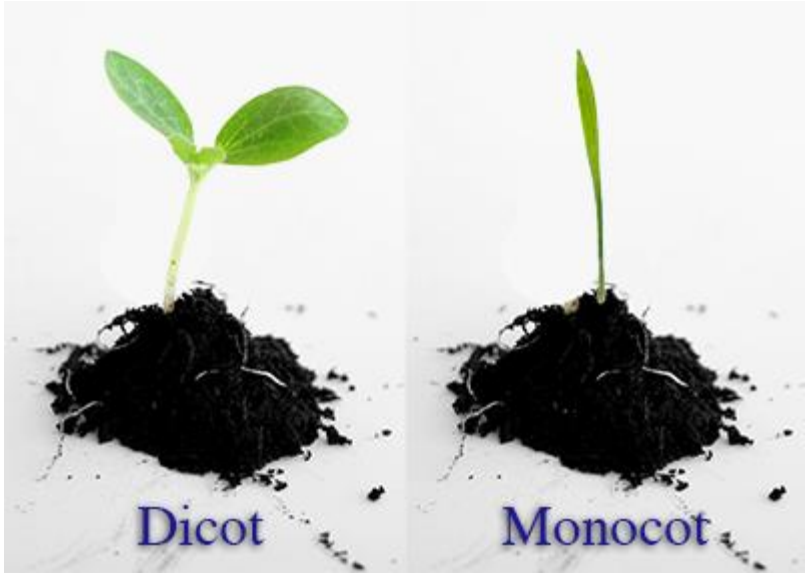
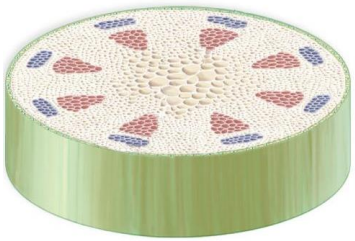
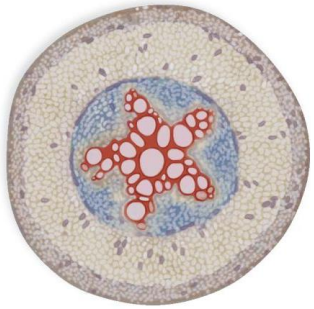


Figure 43-2 Characteristics of monocots and dicots

Leaf veins form
a parallel pattern

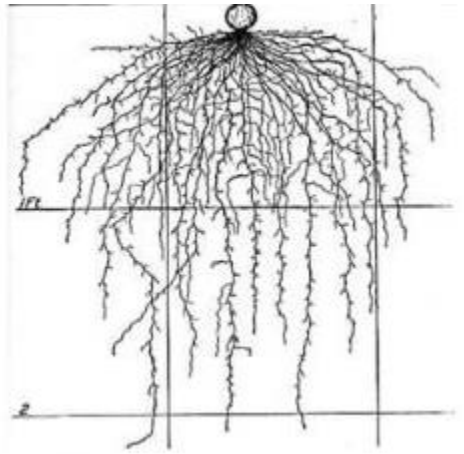


Vascular bundles
in a distinct ring

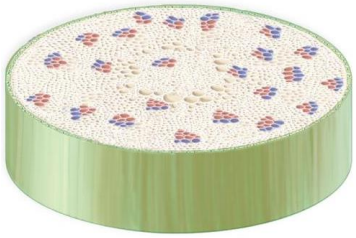


Root phloem between
arms of xylem

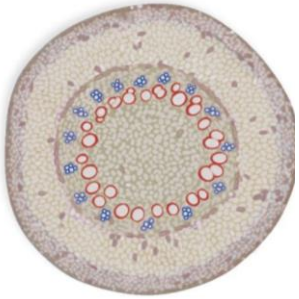
Flower parts in threes
and multiples of three



Leaf veins form
a net pattern



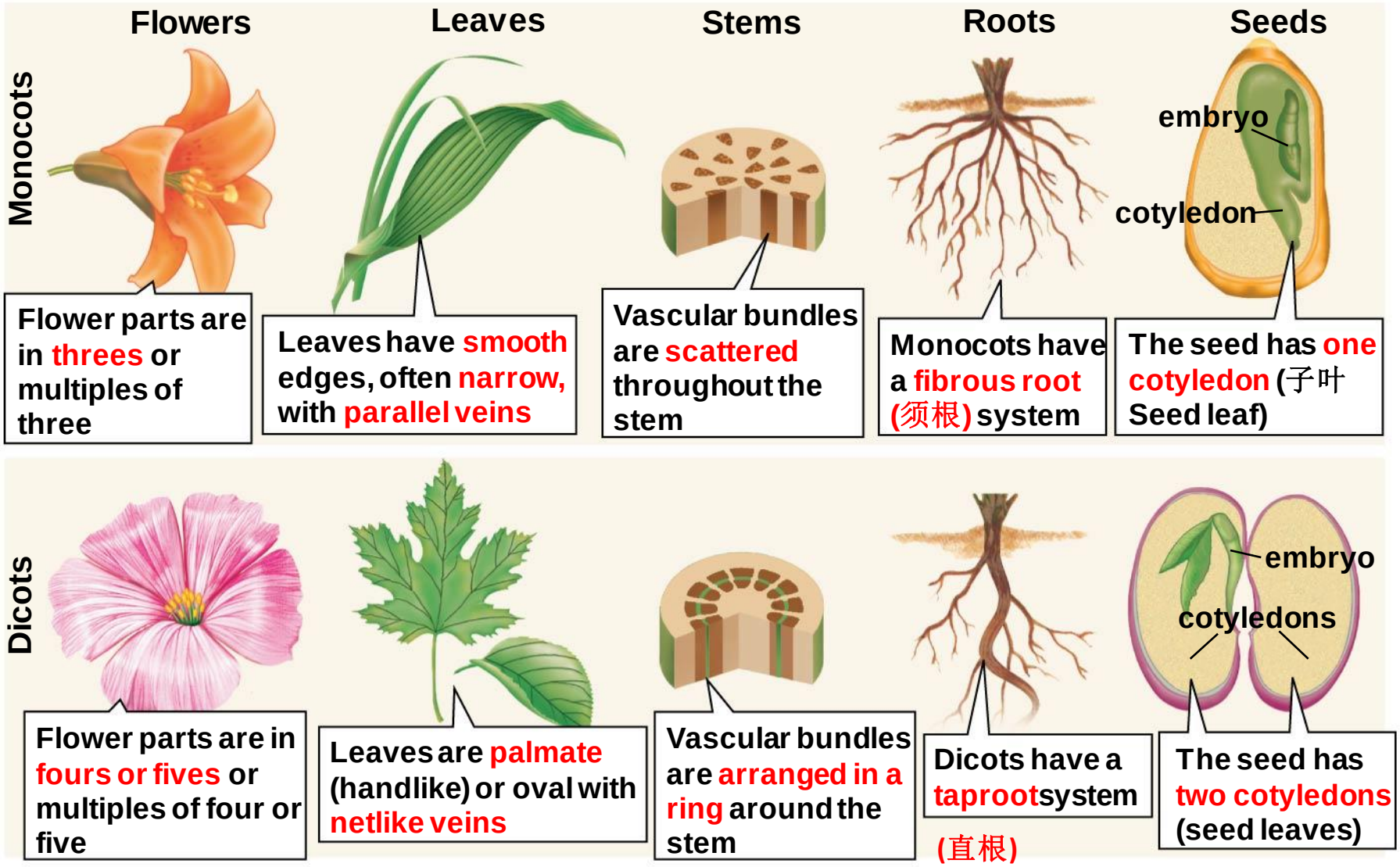
Vascular bundles
scattered in stem



Root xylem and
phloem in a ring

Flower parts in fours or
fives and their multiples

Figure 43-2 Characteristics of monocots and dicots

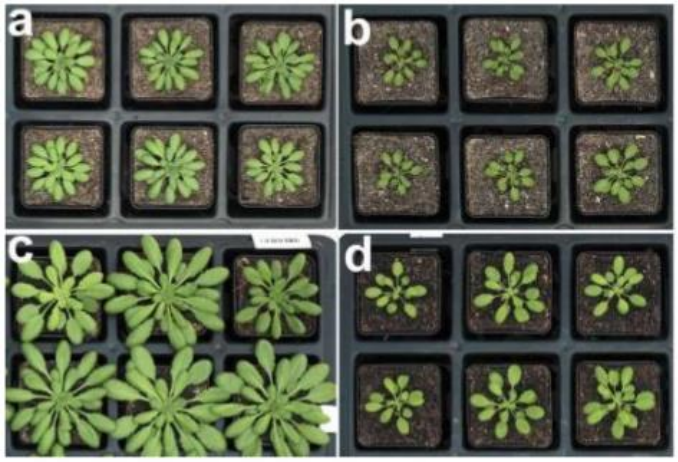


Summary I

- How are plant body organized?
  - Root
  - Shoot (stem, buds, leaves…)
- Two main category of plants:
  - Monocots
  - Dicots

43.2 How Do Plants Grow?

- Animals and plants **develop in dramatically different ways**

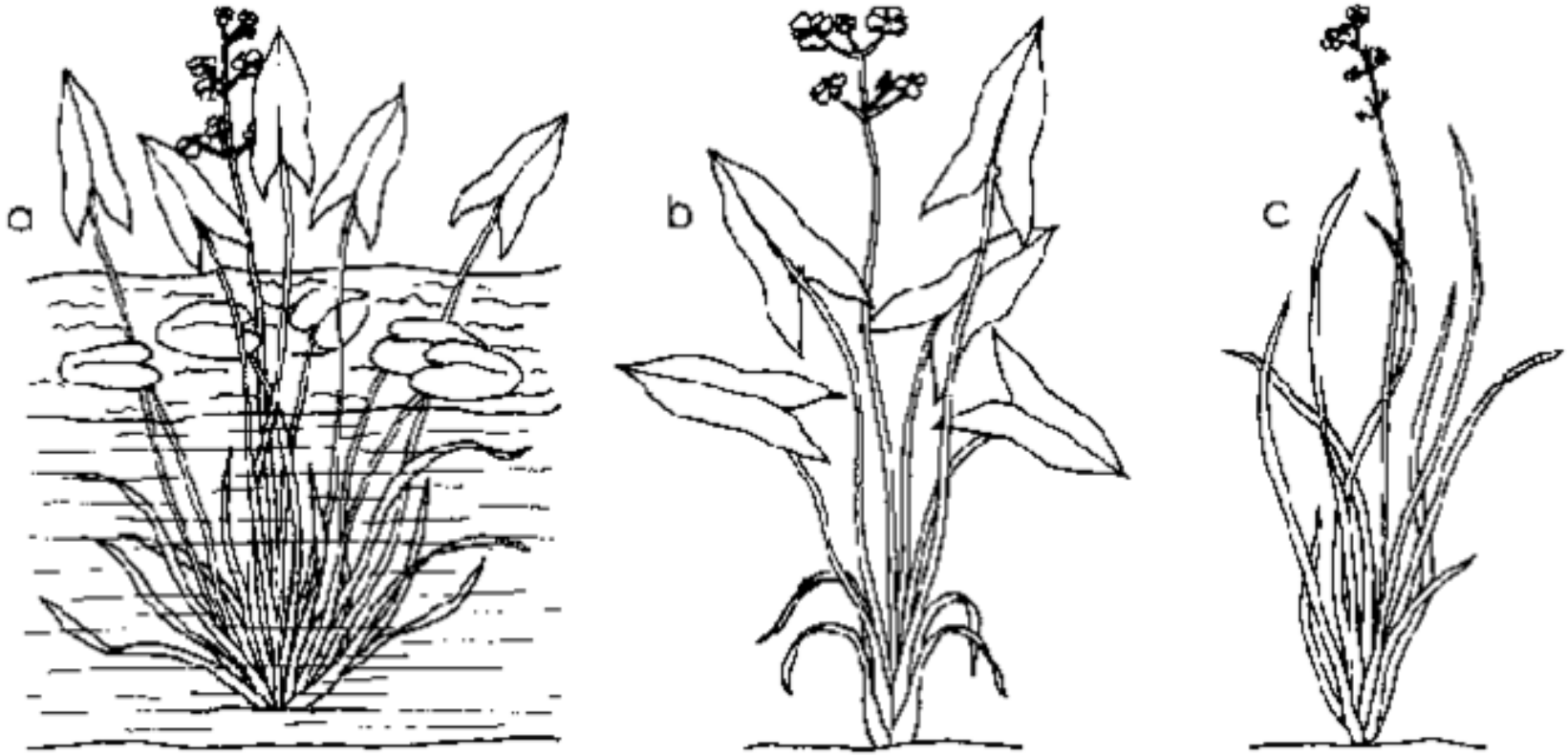


43.2 How Do Plants Grow?

- Animals and plants **develop in dramatically different ways**
  - In animals, newborns closely resemble adults, except, of course, in **size**
    - All parts of a newborn's body become larger as the newborn grows, until it reaches its adult size
  - Flowering plants grow throughout their lives, **never reaching a stable adult body size or a stable body shape**

Mapping Phenotypic Plasticity of a Count Trait

Arthur Berg
Department of Statistics, University of Florida



Caption: Marsh plant (*Sagittaria sagittifolia*) that is **(a)** partially submerged, **(b)** completely terrestrial, **(c)** completely submerged.
From Developmental Plasticity and Evolution by David W. Pfennig

43.2 How Do Plants Grow?

- Plants are composed of two fundamentally different types of cells: **meristem cells** (分生组织细胞) and **differentiated cells**
  - **Meristem cells**, like the **stem** cells of animals, are unspecialized and are capable of mitotic cell division
  - Some of their daughter cells lose the ability to divide and become **differentiated** cells, with specialized structures and functions
- Plants grow as a result of the division of meristem cells found in two general locations in the plant body

Figure 43-3 Meristems

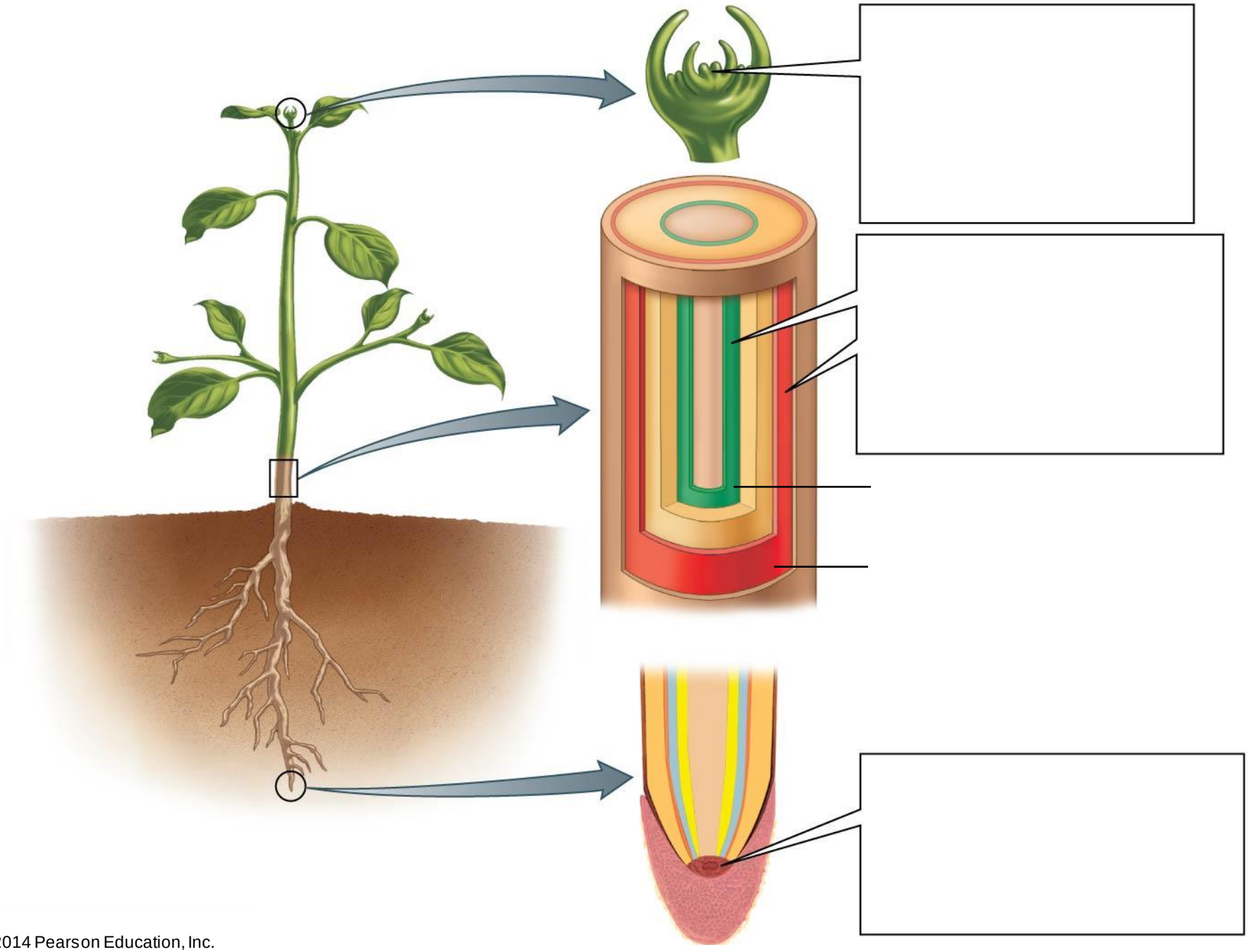
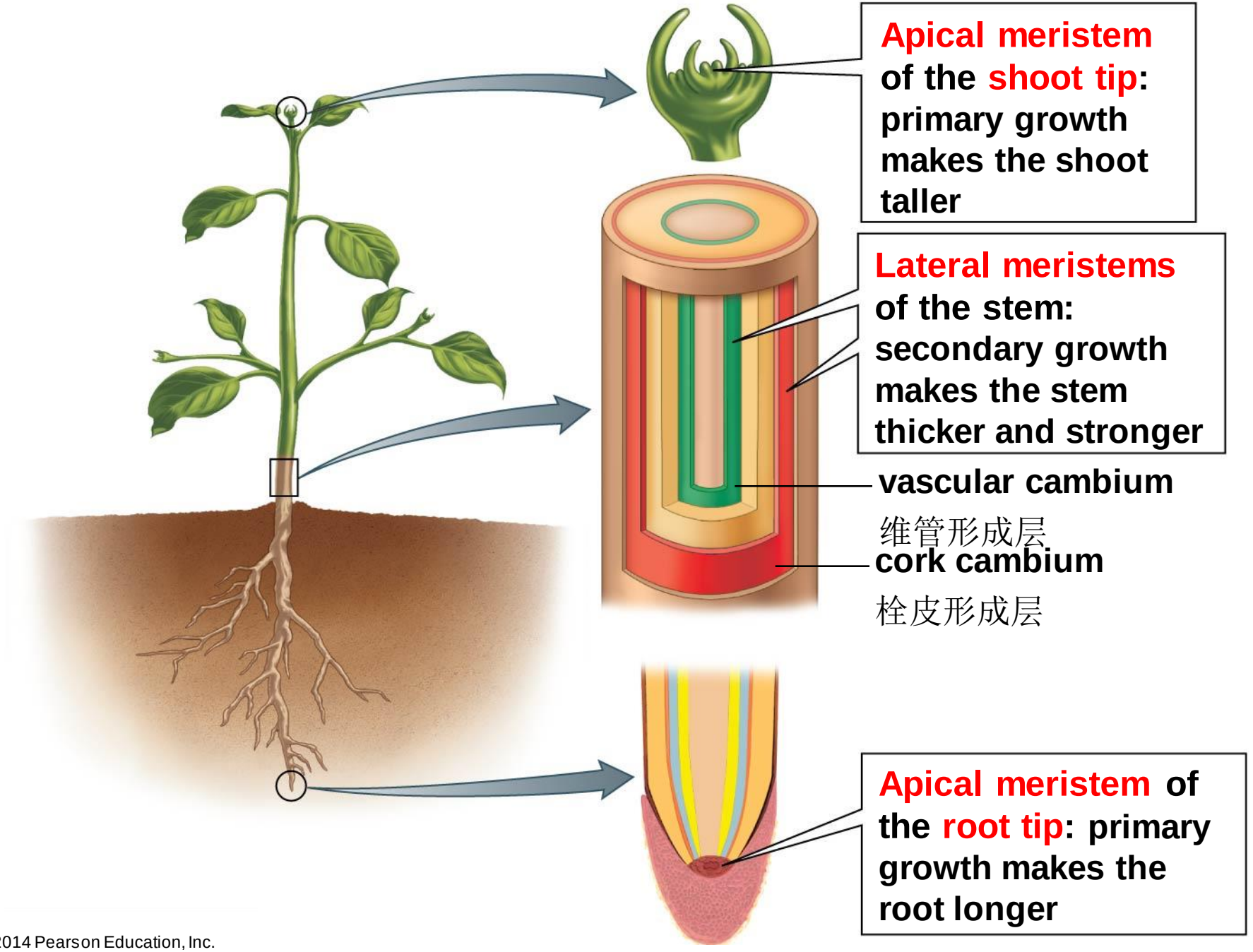


Figure 43-3 Meristems



43.2 How Do Plants Grow?

- **Apical meristems** (顶端分生组织) are located at the tips of **roots and shoots**
- Growth produced by apical meristem cells is called **primary growth** (初级生长): an increase in the **height or length** of a shoot or root, and the development of **specialized parts** of the plant, such as leaves and buds

43.2 How Do Plants Grow?

- **Lateral meristems** (侧生分生组织) are concentric cylinders of meristem cells
  - *cork cambium* (栓皮形成层)
  - *vascular cambium* (维管形成层)
  - Cell division in lateral meristems and the differentiation of the resulting daughter cells produce **secondary growth** (次级生长), typically an increase in the **diameter and strength** of roots and shoots

Summary II

- How do plants grow?
  - **Meristem cells**
    - Apical meristem at tips (root and shoot apical meristem)→ **primary growth**→ grow tall and generate new parts of plant
    - Lateral meristem (cork and vascular cambiam)→ **secondary growth**→ increase in diameter

43.3 What Are the Tissues and Cell Types of Plants?

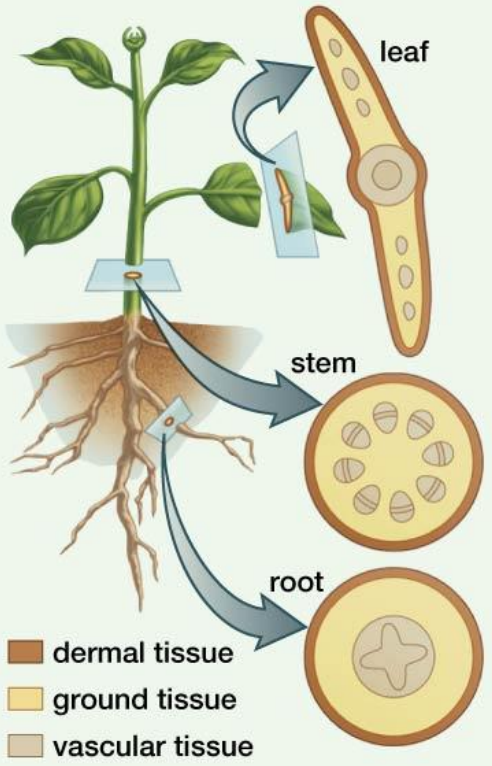
- When one or more specialized types of cells work together to perform a **specific function**, such as conducting water and minerals, they form a **tissue (组织)**
- Functional groups of **more than one tissue** are called **tissue systems**

Table 43-1 Tissue Systems of Plants

TABLE 43-1 Tissue Systems of Plants

Type	Tissues Within the Tissue System	Functions
Dermal tissue system 皮组织系统	Epidermis	Protects the plant body
	Periderm (secondary growth) 周皮	Regulates the movement of O_2, CO_2, and water vapor between the air and the plant
Ground tissue system 基本组织系统	Parenchyma 薄壁组织	Photosynthesizes; principally in leaves and young stems; secretes hormones
	Collenchyma 厚角组织	Stores nutrients; principally in stems and roots
	Sclerenchyma 厚壁组织	Supports the plant body, as strengthening fibers in both xylem and phloem
Vascular tissue system 维管组织系统	Xylem 木质部	Transports water and dissolved minerals from root to shoot
	Phloem 韧皮部	Transports sugars and other organic molecules, such as amino acids, proteins, and hormones throughout the plant body

Locations of the Tissue Systems



43.3 What Are the Tissues and Cell Types of Plants?

- The dermal tissue system covers the plant body
  - The **epidermis** (表皮) is the dermal tissue system formed during primary growth
    - The epidermis is the outermost cell layer covering the leaves, stems, and roots of **young plants** and new growth in older plants
    - Epidermis also covers flowers, seeds, and fruit

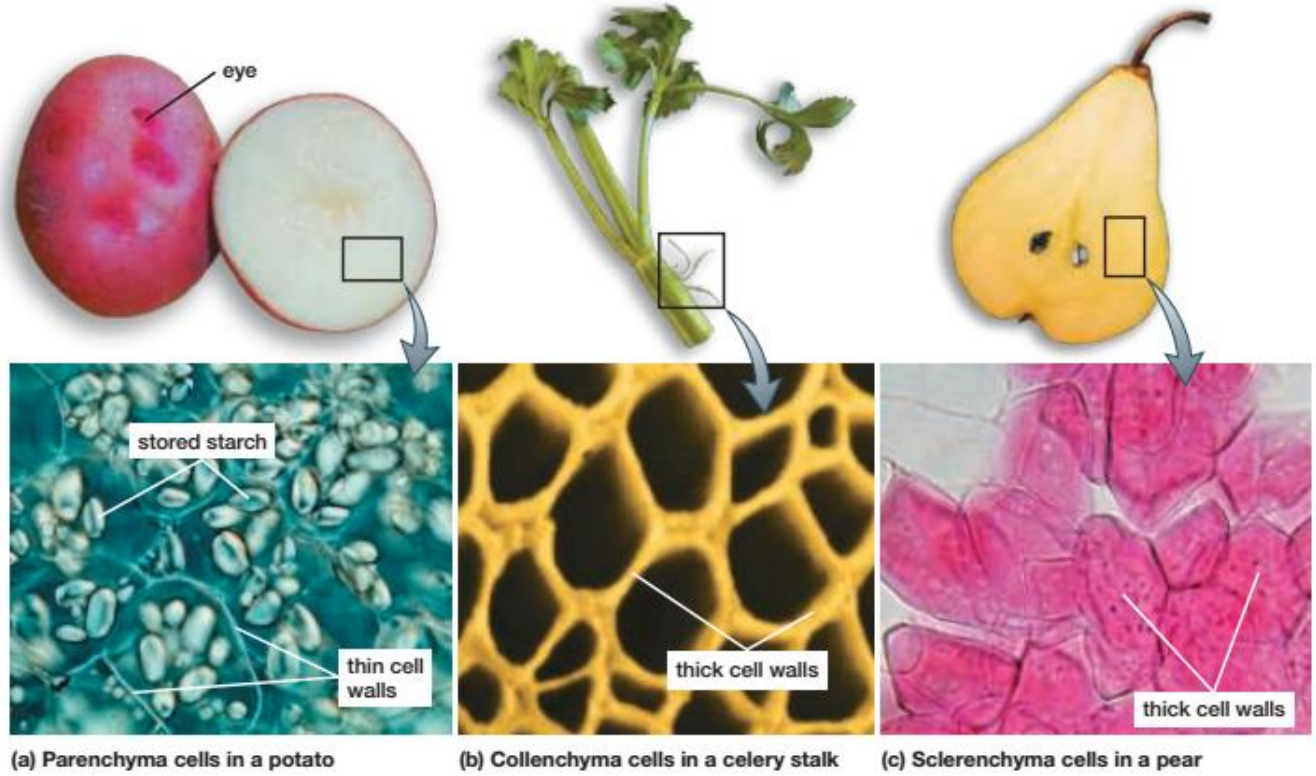
43.3 What Are the Tissues and Cell Types of Plants?

- **Aboveground parts** of a plant epidermis are generally composed of tightly packed, thin-walled cells, covered with a waterproof, waxy **cuticle** (角质层)
- Root epidermis is **not** covered with cuticle, which would prevent the roots from absorbing water and minerals
  - In **wood plants**, **periderm (**周皮**)** is the dermal tissue that replaces epidermis on roots and stems as they undergo secondary growth

43.3 What Are the Tissues and Cell Types of Plants?

- The **ground tissue system** consists of all of the tissues of the plant body **except** dermal and vascular tissues

- ✓ parenchyma tissue (软细胞组织, 薄壁组织),
- ✓ collenchyma tissue (厚角组织)
- ✓ sclerenchyma tissue (厚壁组织)



43.3 What Are the Tissues and Cell Types of Plants?

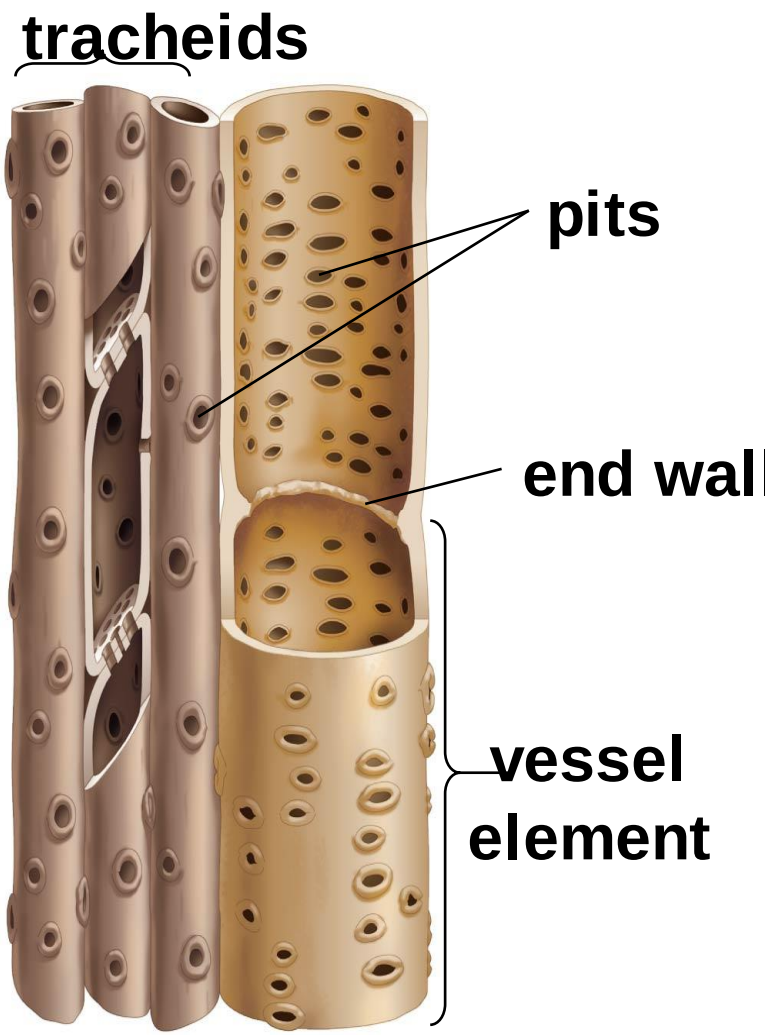
- The vascular tissue system transports water and nutrients
  - The vascular tissue system of plants conducts water and dissolved substances throughout the plant body
  - The vascular tissue system consists of two conducting tissues, **xylem (木质部)** and **phloem (韧皮部)**, **together with sclerenchyma and parenchyma cells**

43.3 What Are the Tissues and Cell Types of Plants?

– Xylem transports **water and dissolved minerals** from the **roots to the rest of the plant**

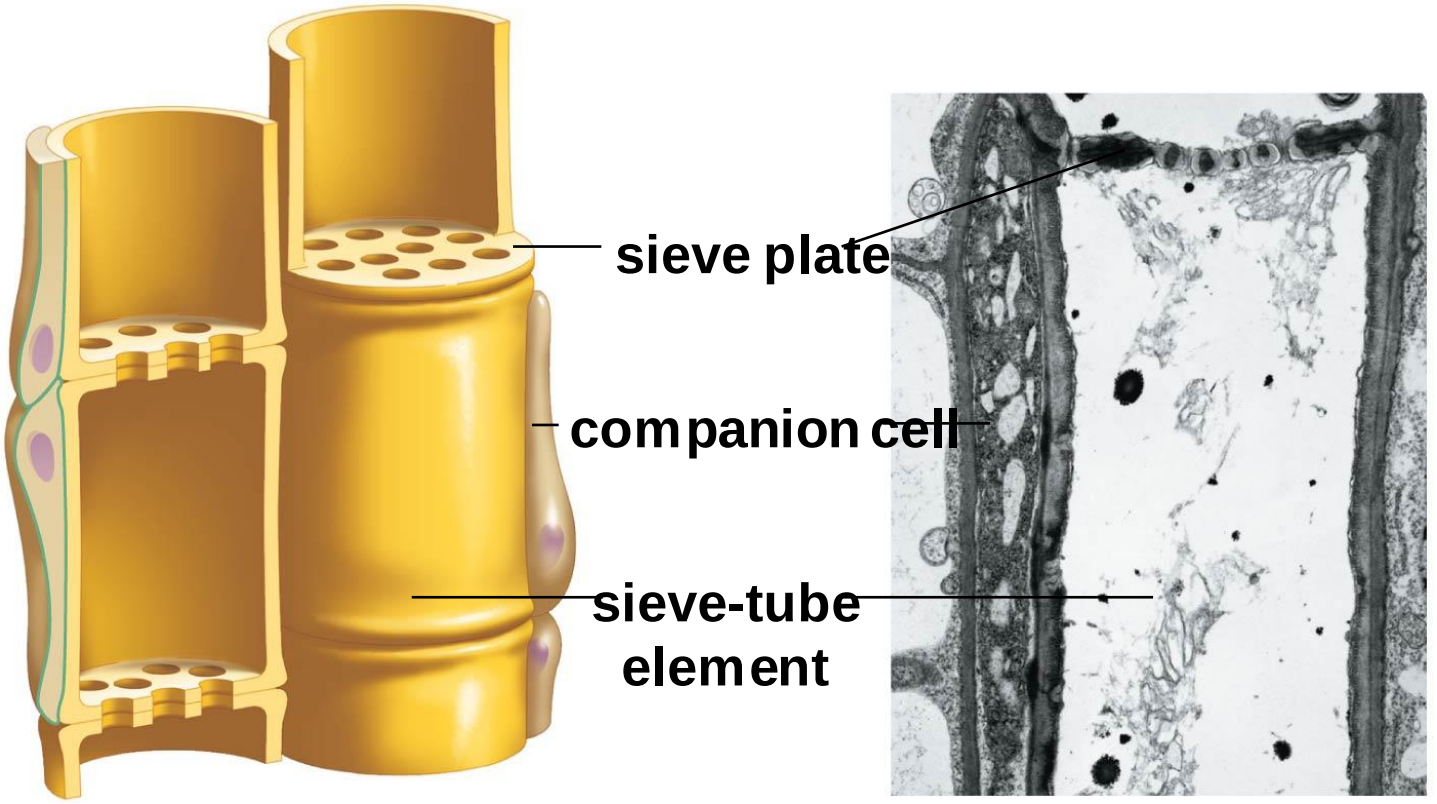
Xylem contains two types of conducting sclerenchyma cells:

✓ **tracheids (管胞)**
✓ **vessel elements (导管分子)**



43.3 What Are the Tissues and Cell Types of Plants?

- **Phloem** transports **sugars and other organic molecules (amino acids, hormones)** throughout the plant body
  - **sieve-tube elements** (筛管分子) and **companion cells** (伴胞)



Summary III

- What Are the Tissues and Cell Types of Plants?

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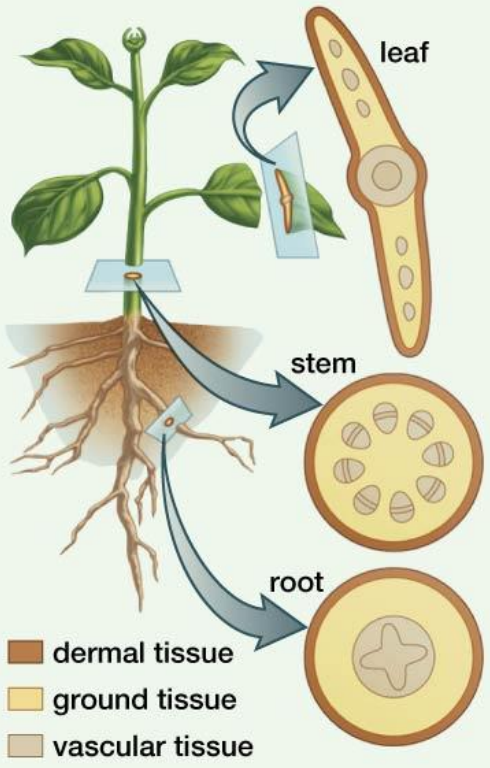
Locations of the Tissue Systems



43.4 What Are the Structures and Functions of Leaves?

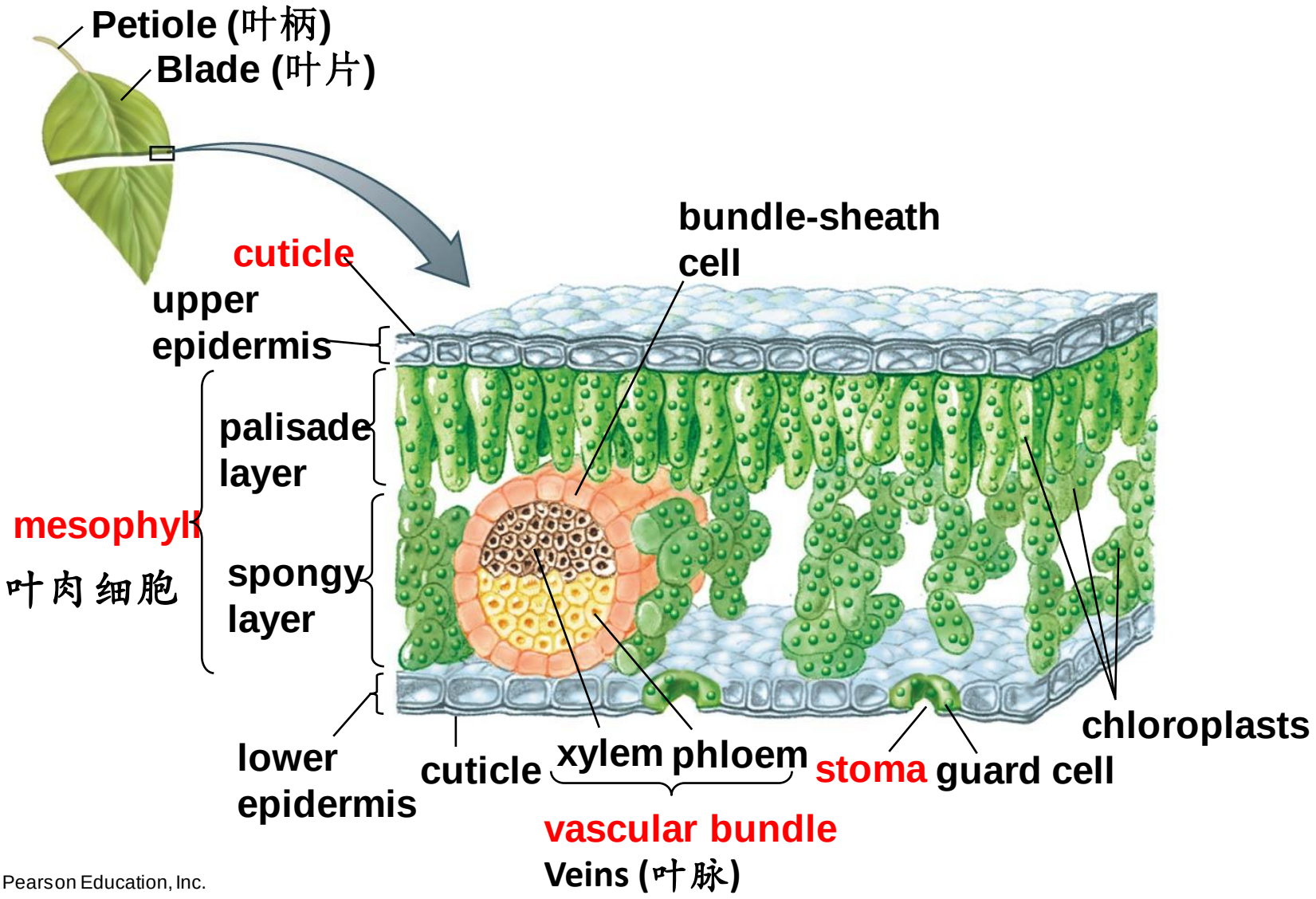
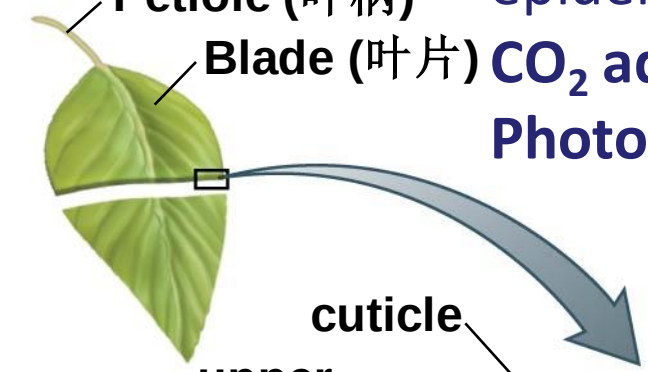
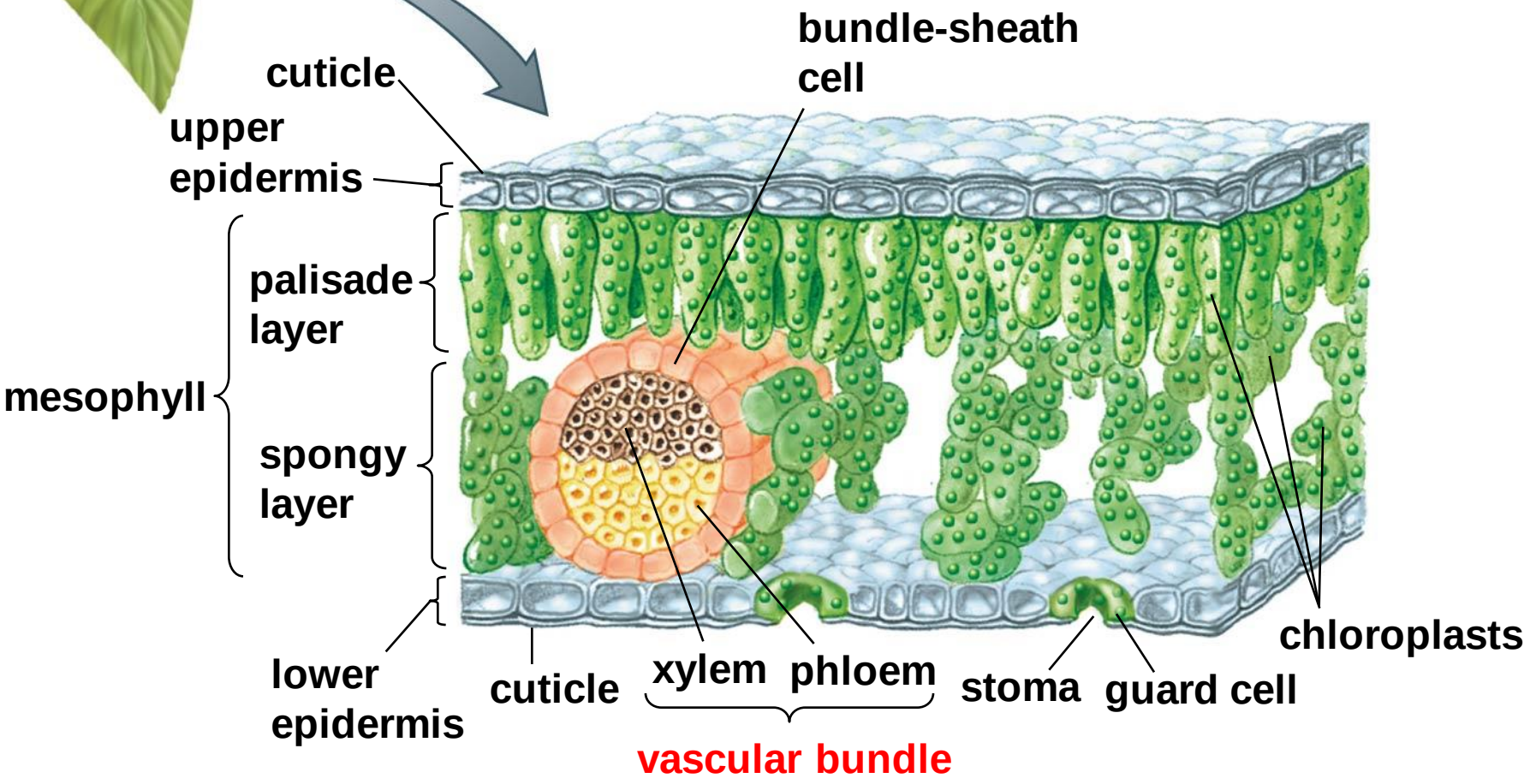


Figure 43-7 A typical dicot leaf

Water conservation:
epidermis (transparent, waxy cuticle), stomata(气孔)
CO_2 admit: stomata (two guard cells)
Photosynthesis: mesophyll (叶肉细胞), guard cells





43.4 What Are the Structures and Functions of Leaves?

- Many plants produce specialized leaves
  - –Temperature
  - –the availability of water
  - –light

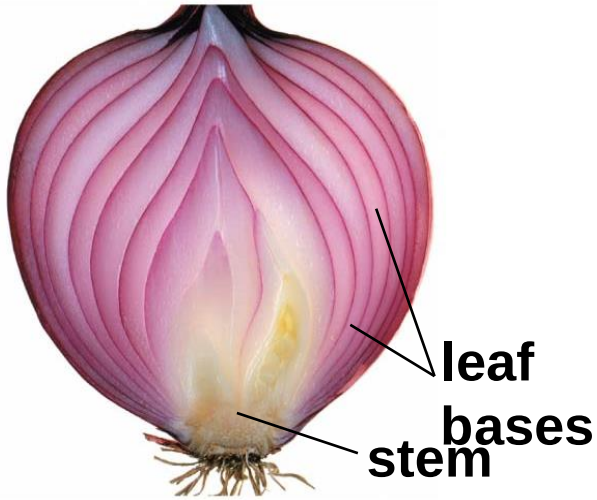
  have exerted strong selection pressure on leaves

(a) Elephant ear leaves

(b) Cactus spines

(c) Succulent leaves

肉质植物



(d) Leaves of an onion

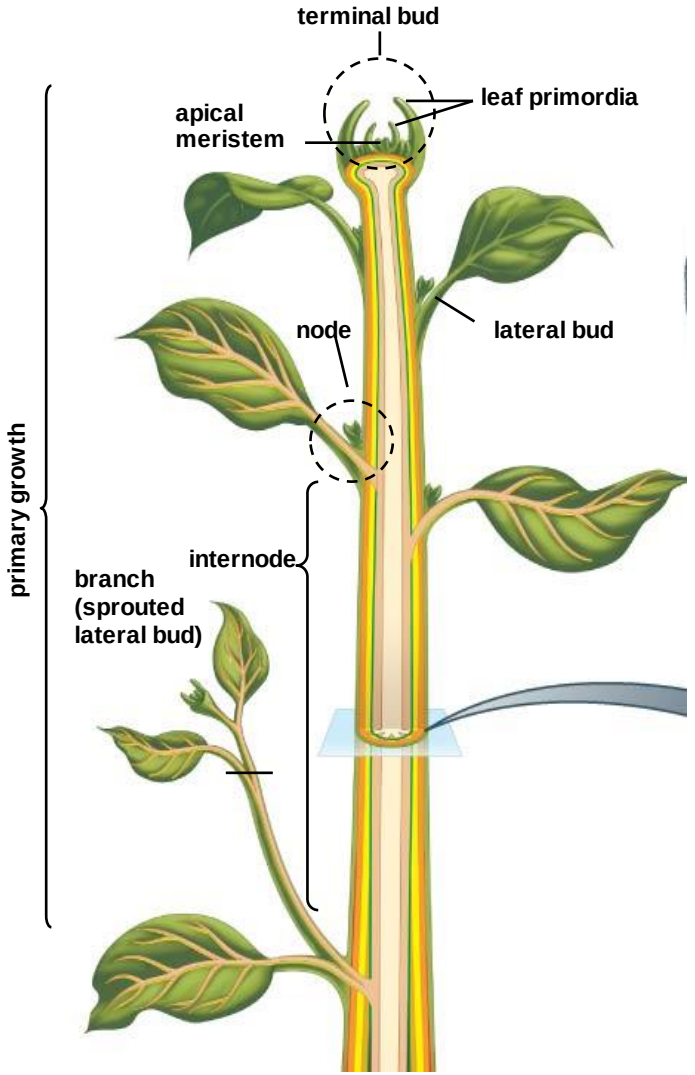
43.4 What Are the Structures and Functions of Leaves?

Venus flytraps

Tendrils： 卷须

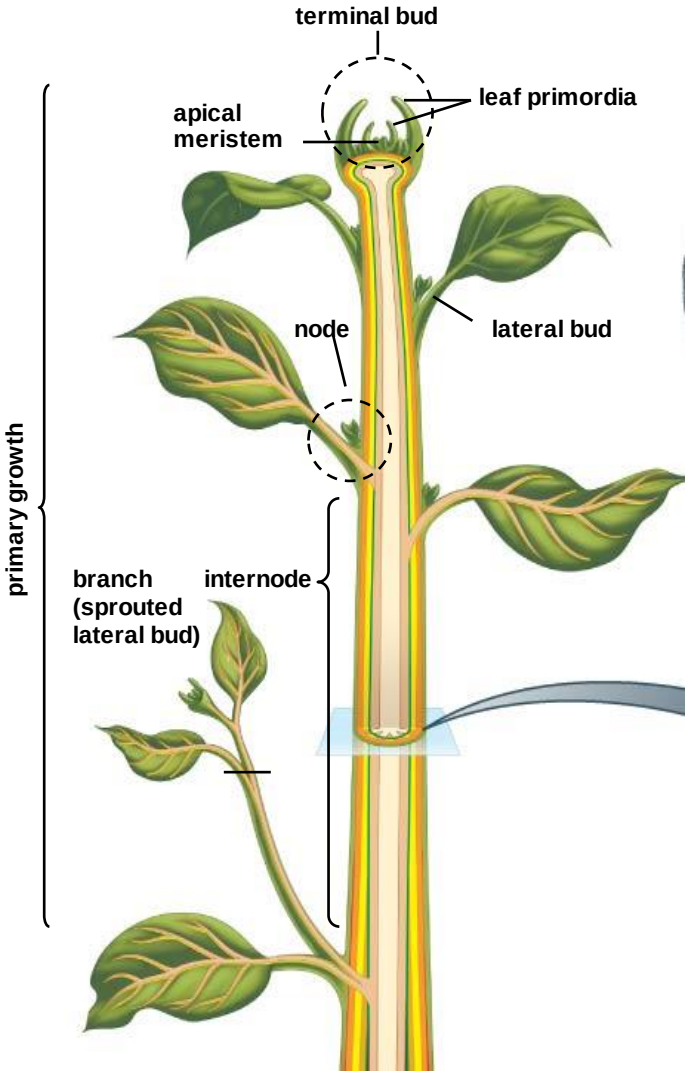
43.5 What Are the Structures and Functions of Stems?

- The functions of stems
  - support its leaves, lifting them up to the sunlight
  - Transport
- The structure of stems
  - Terminal bud, lateral bud, flower bud
  - Node/internode



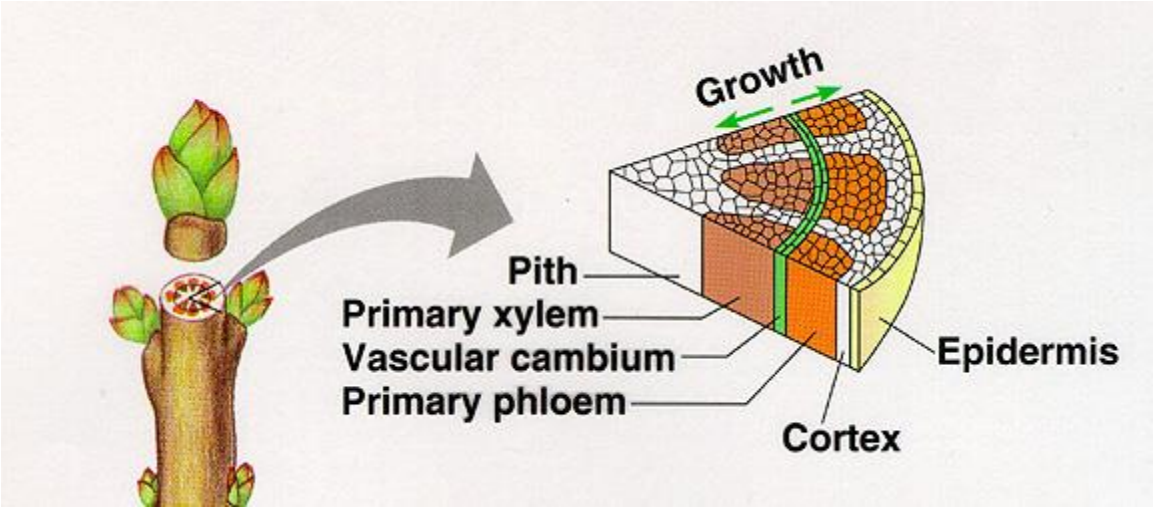
43.5 What Are the Structures and Functions of Stems?

- Primary growth produces the structures of a young stem
  - **terminal bud (顶芽)**
    - apical meristem cells
    - **leaf primordia (叶原基)**, or developing leaves
    - During primary growth, most of the daughter cells of the apical meristem differentiate into the **specialized cell types of leaves, buds, and the structures of the lengthening stem**



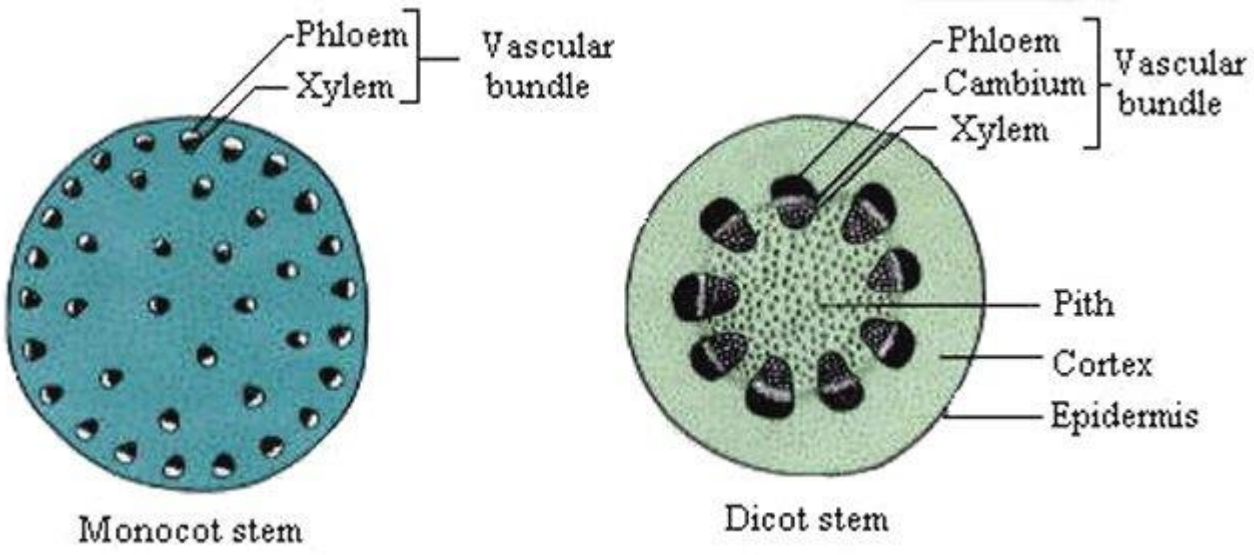
43.5 What Are the Structures and Functions of Stems?

- The apical meristem of a shoot also produces the internal structures of the stem, typically grouped into four tissues: **epidermis, cortex (皮层), pith (木髓) , and vascular tissues**
- The epidermis of the stem reduces water loss while allowing carbon dioxide to enter
- The cortex and pith support the stem, store food, and may photosynthesize



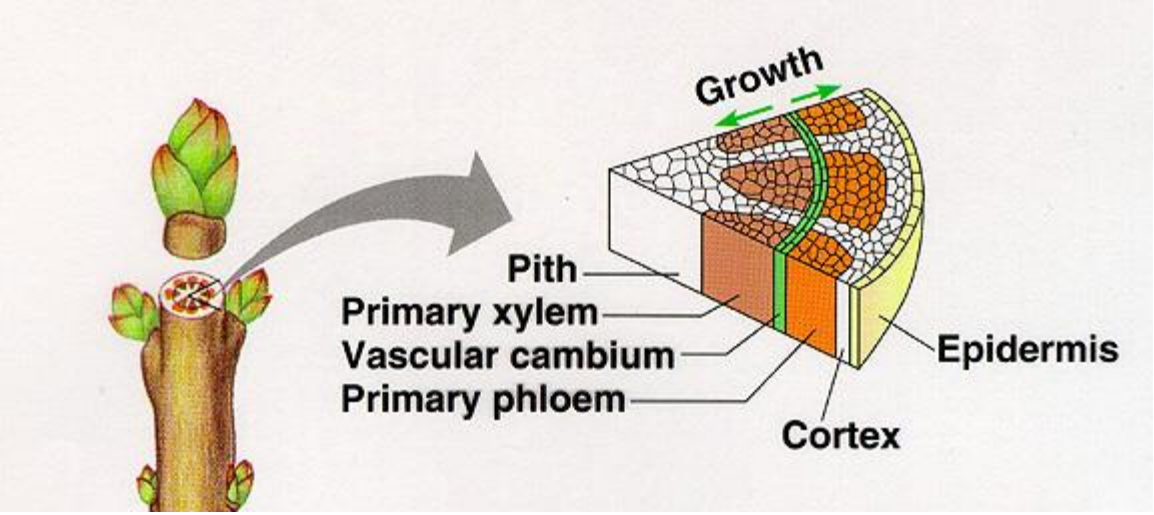
43.5 What Are the Structures and Functions of Stems?

- Vascular tissues in the stem transport water, dissolved nutrients, and hormones
  - Most young dicot stems contain bundles of vascular tissue



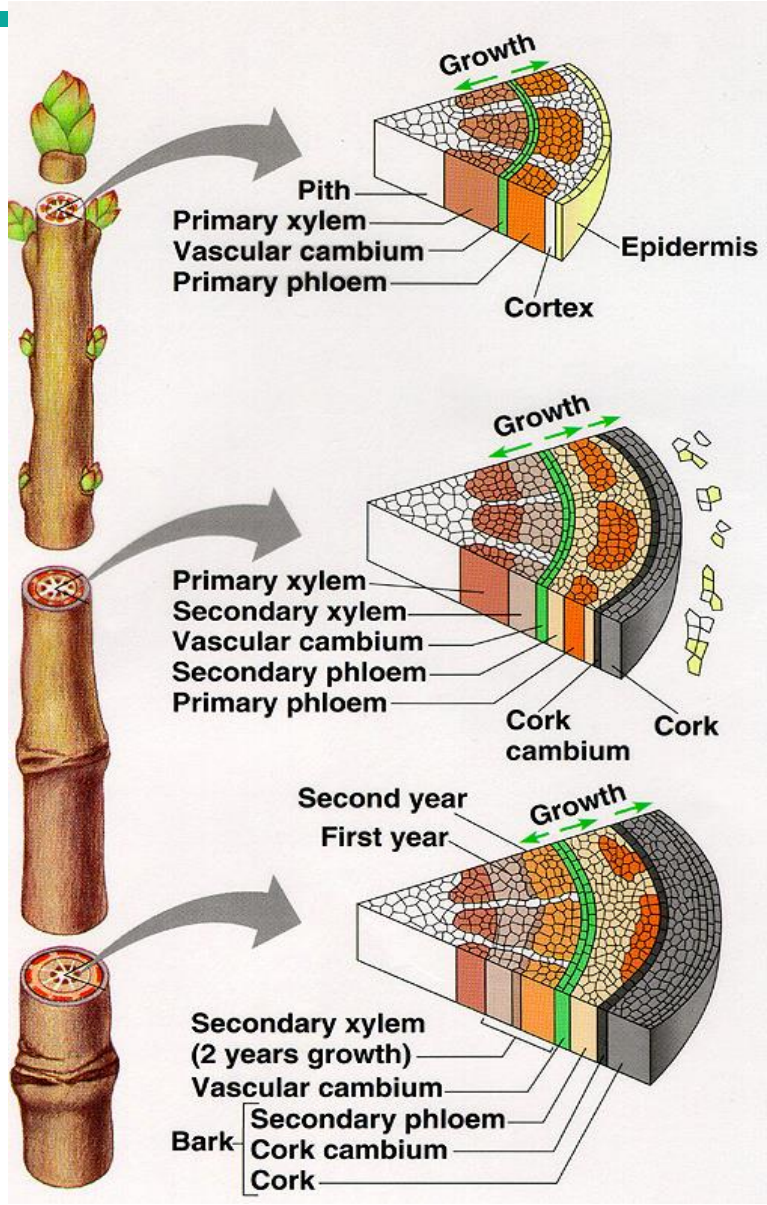
43.5 What Are the Structures and Functions of Stems?

- **primary xylem (** 初生木质部**) and primary phloem (**初生韧皮部**)**
  - These structures are called primary xylem and primary phloem because they are **produced from apical meristem** during primary growth



43.5 What Are the Structures and Functions of Stems?

- **Secondary growth** produces thicker, stronger stems
  - result from cell division in the **lateral meristems** of the **vascular cambium and cork cambium**
  - produces secondary xylem and secondary phloem



43.5 What Are the Structures and Functions of Stems?

- Young secondary xylem, called **sapwood (** 边材； 白木质**)**, transports water and minerals

- Older secondary xylem, the **heartwood (**心材**)**, fills the central portion of older stems
  - Heartwood no longer carries water and minerals
  - annual rings (年轮)

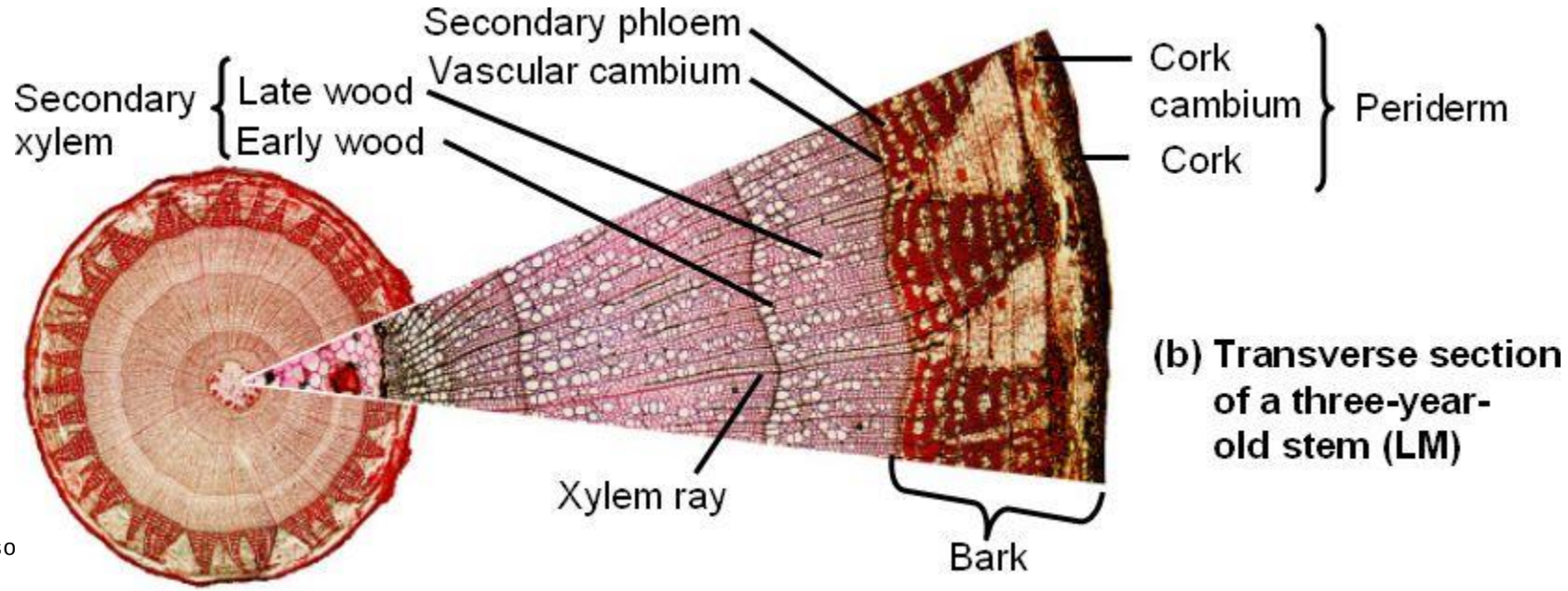
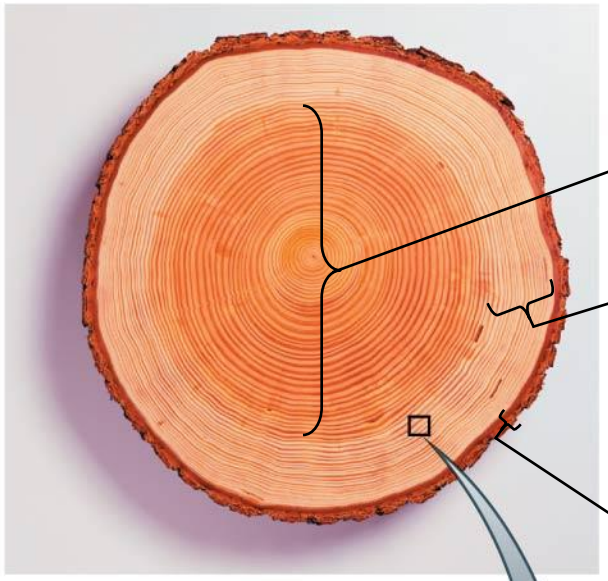
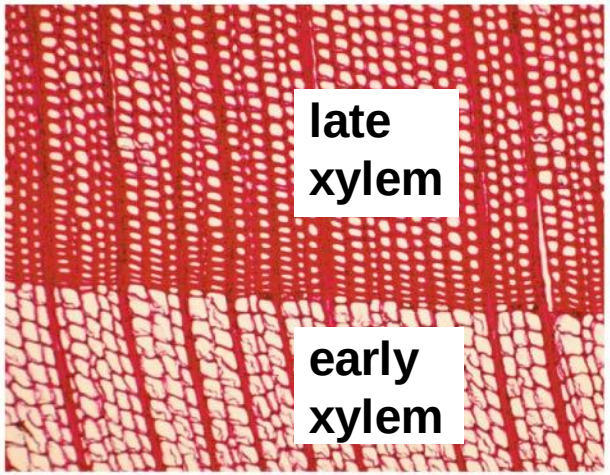


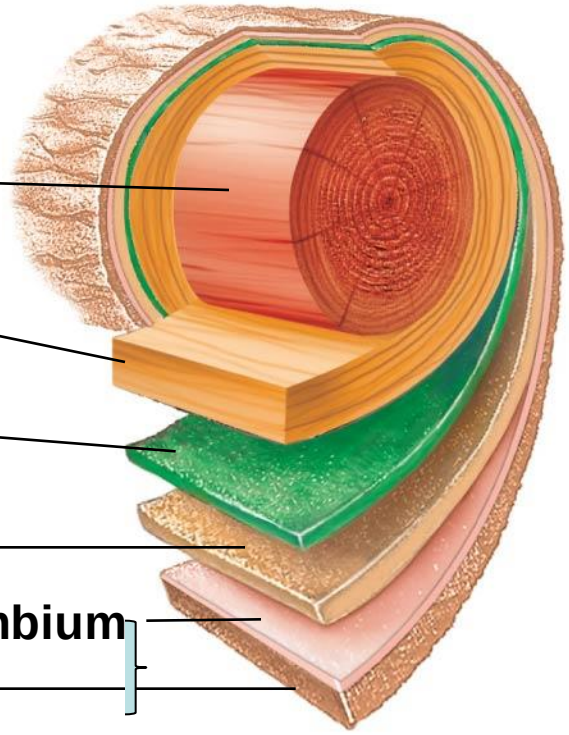
Figure 43-10 Annual rings



(a) Cross-section of a tree trunk



(b) An annual ring



Periderm (周皮)

Some cells in the epidermis, cortex, or phloem become capable of cell division and form a layer of lateral meristem cells, the **cork cambium (栓皮形成层)**

Figure 43-11 Cork

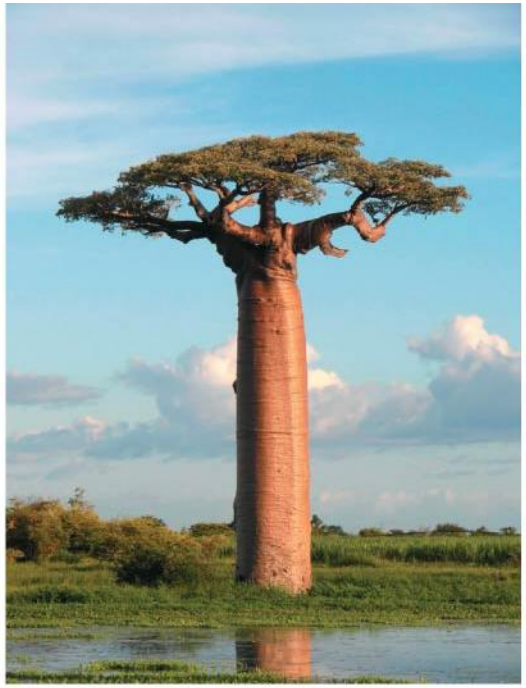
(a) Cork protects this giant sequoia tree

(b) Harvesting cork from a cork oak

Corks (软木塞) used to plug wine bottles are made from the outermost layer of cork from cork oaks

Removing a strip of **bark** all the way around a tree, called **girdling** （束腰；环状剥皮）**--Kills the tree**

Many plants produce specialized stems or branches



(a) Baobab tree 猴面包树

(b) Strawberry plants

(c) Grape vine

(d) Honey locust tree

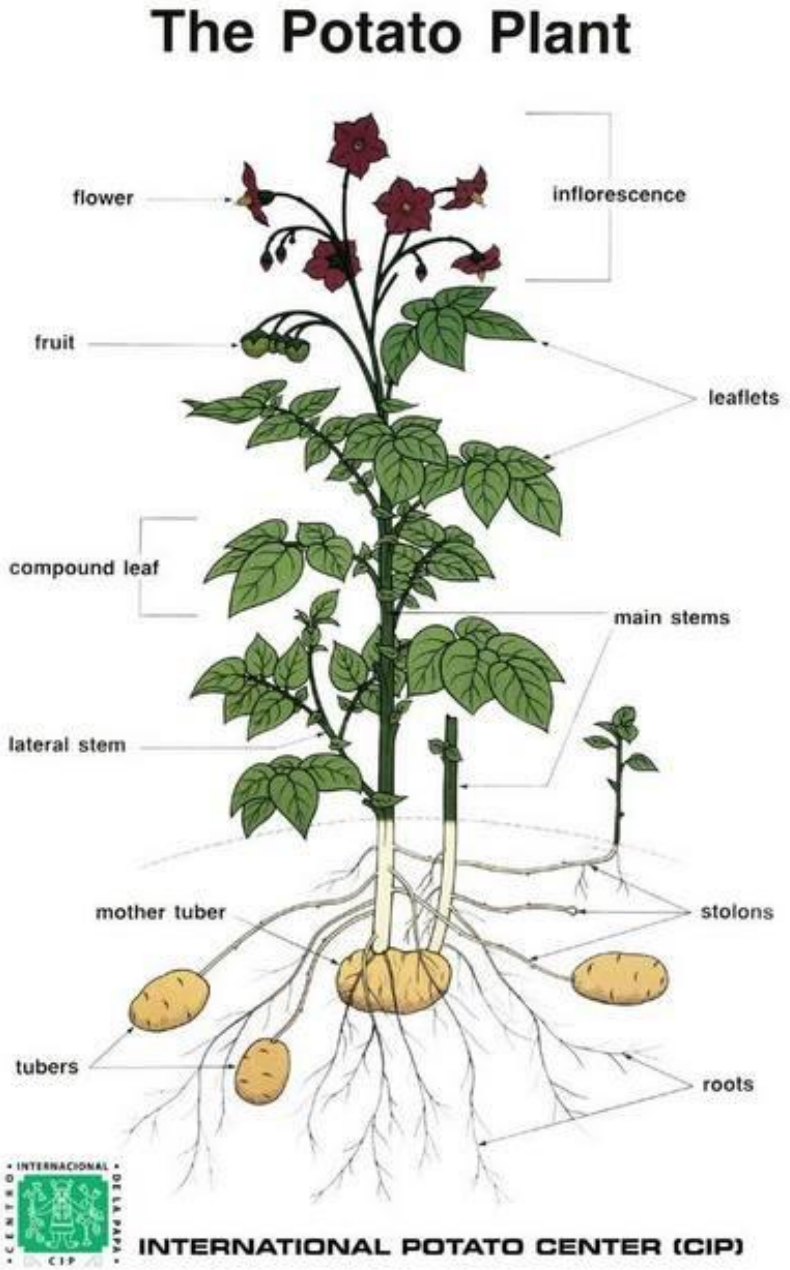
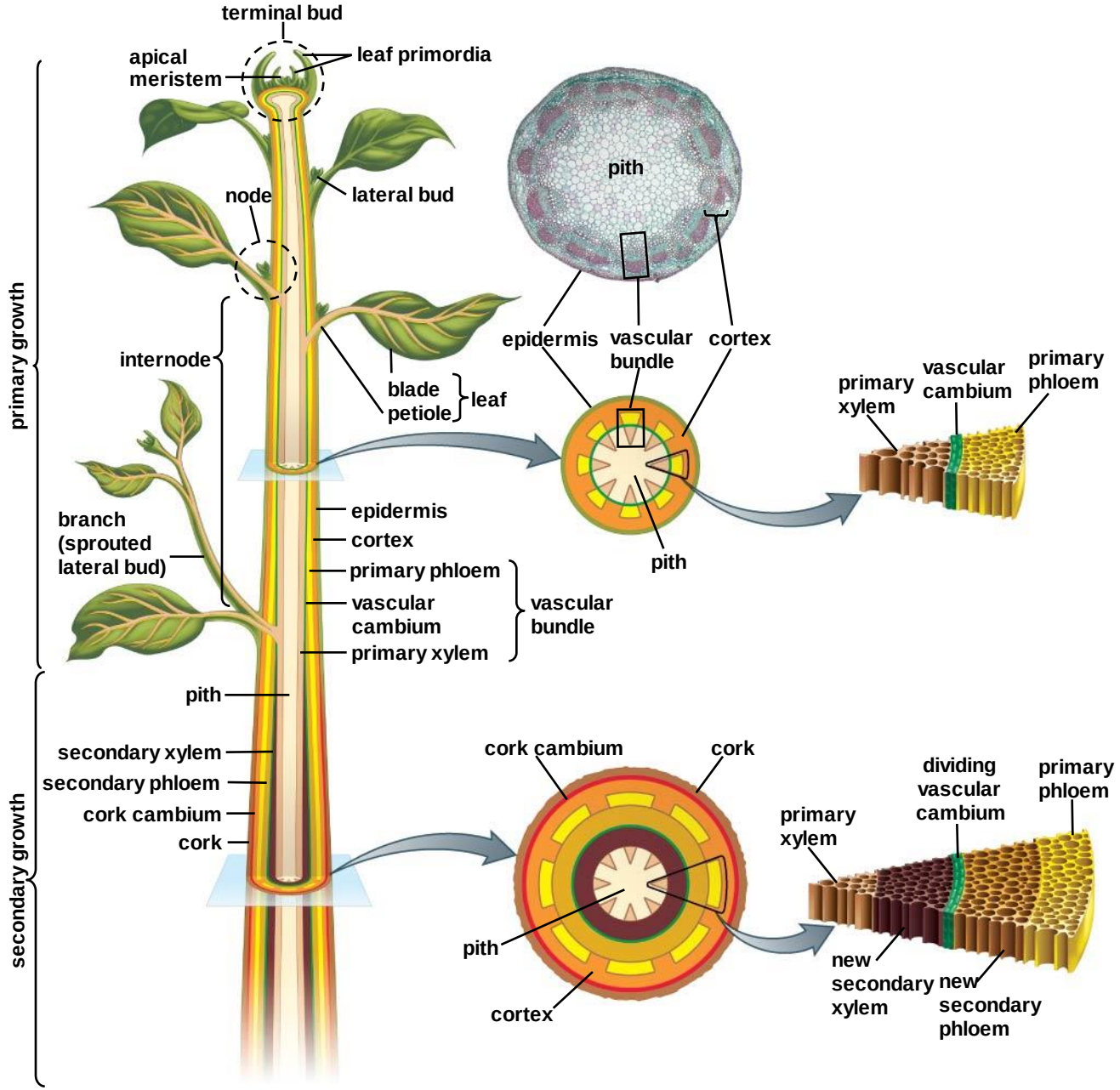
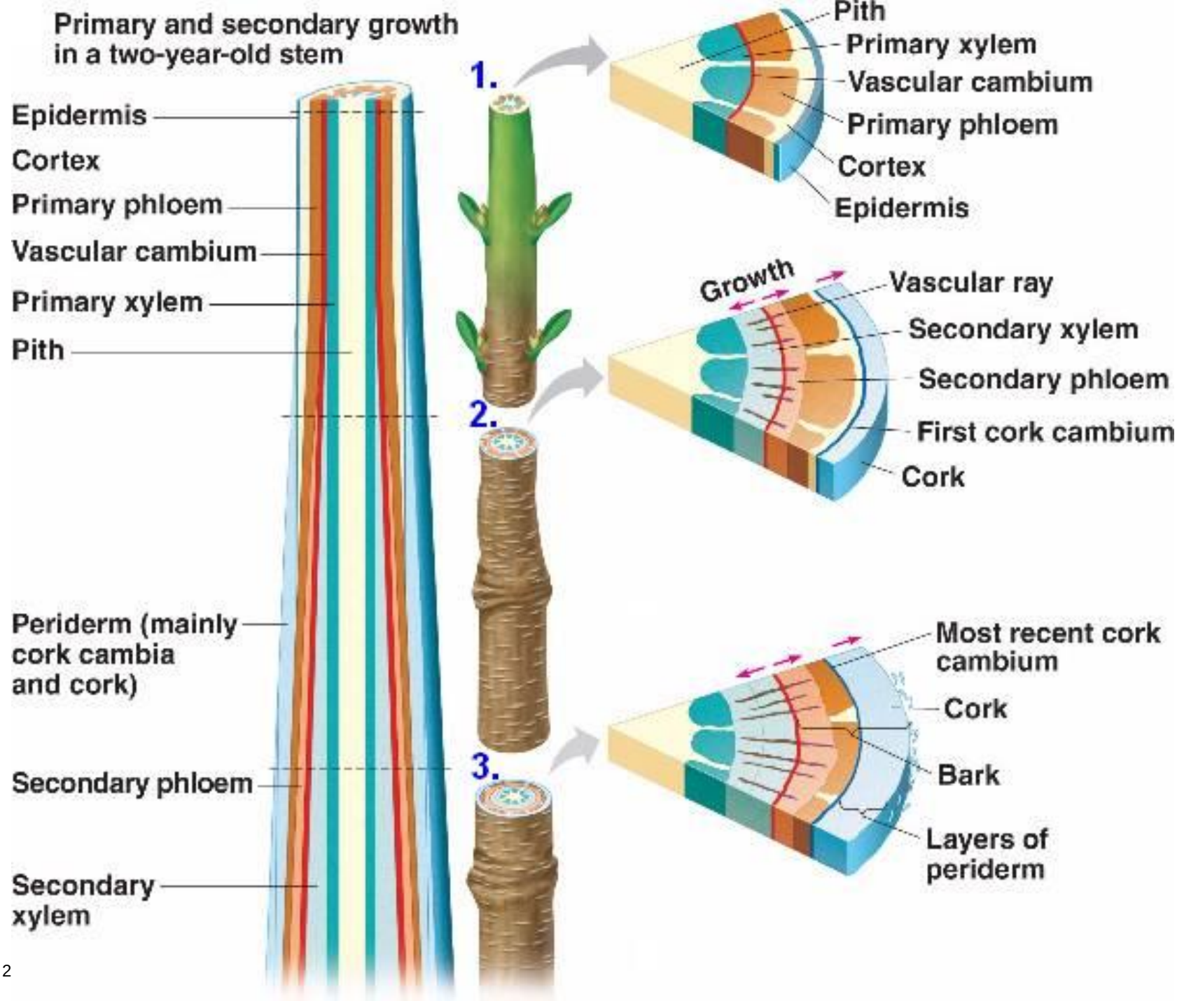


Figure 43-9 Primary and secondary growth in a dicot shoot




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
1.
2.
3.
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

43.6 What Are the Structures and Functions of Roots?

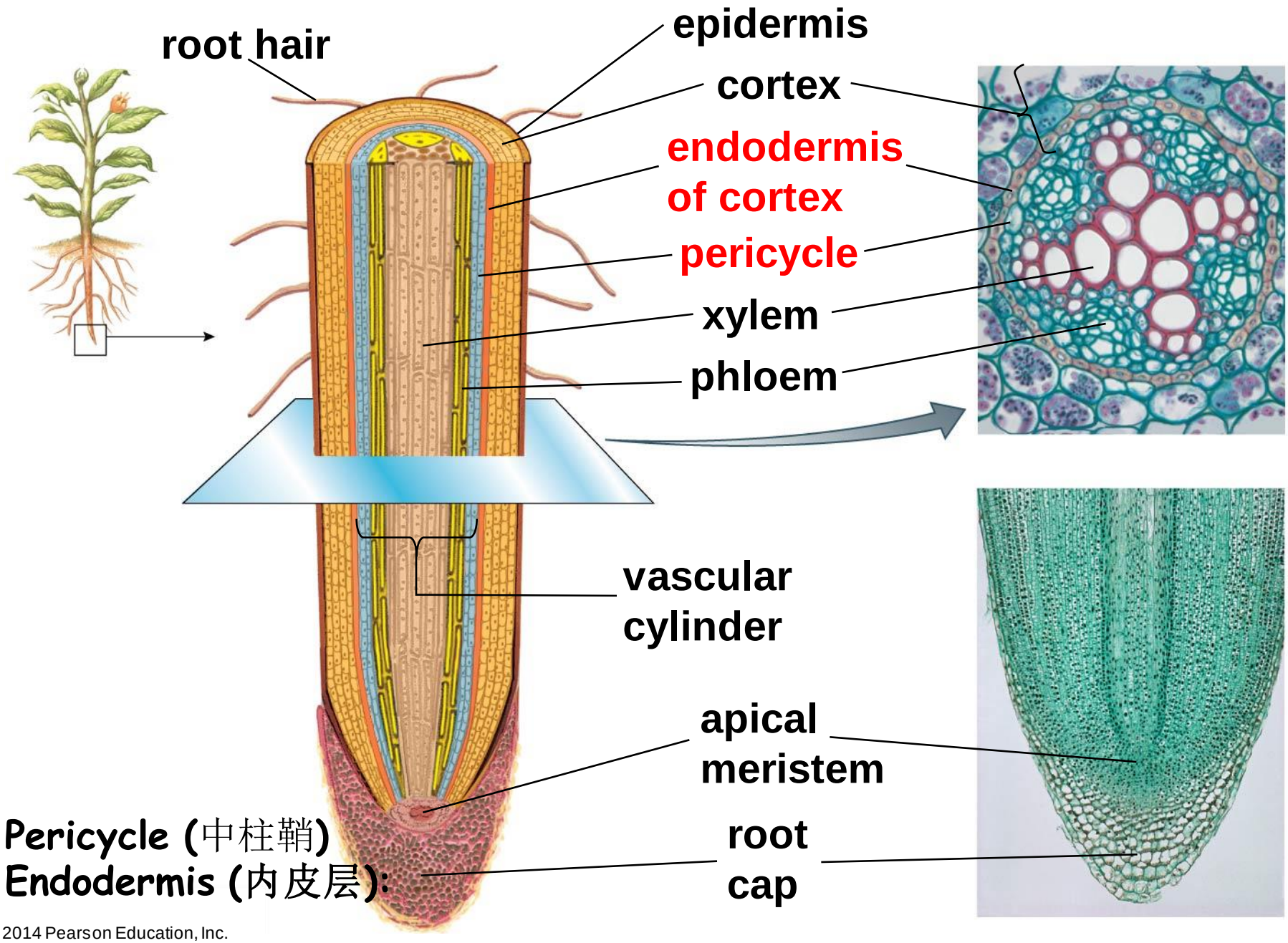
(a) A taproot system

(b) A fibrous root system

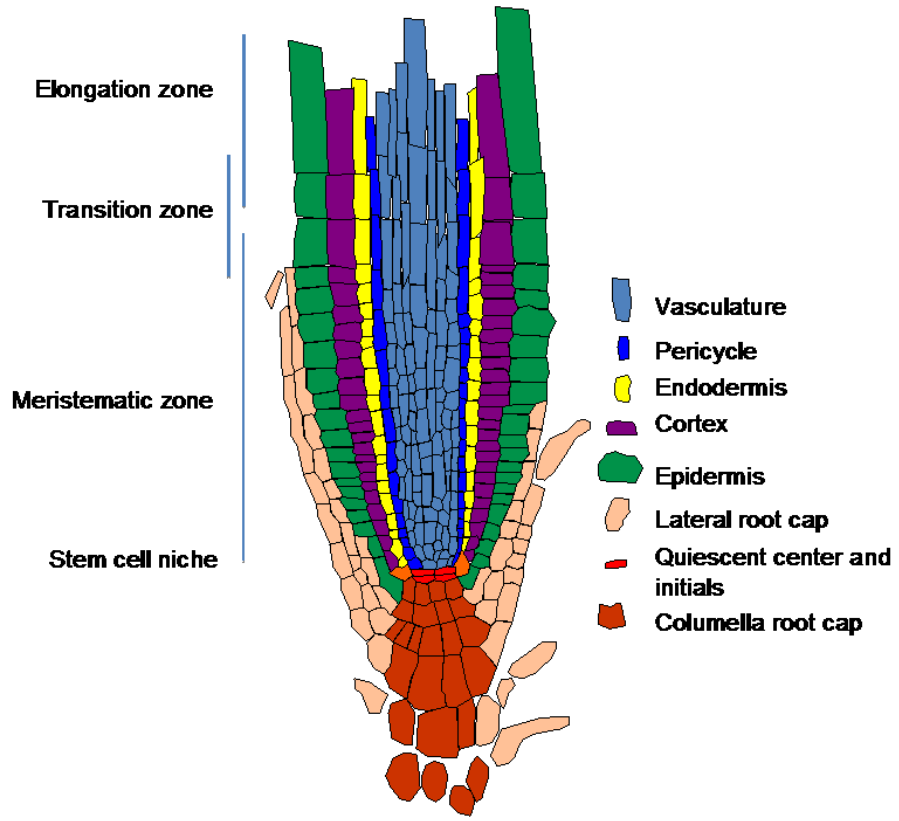
43.6 What Are the Structures and Functions of Roots?

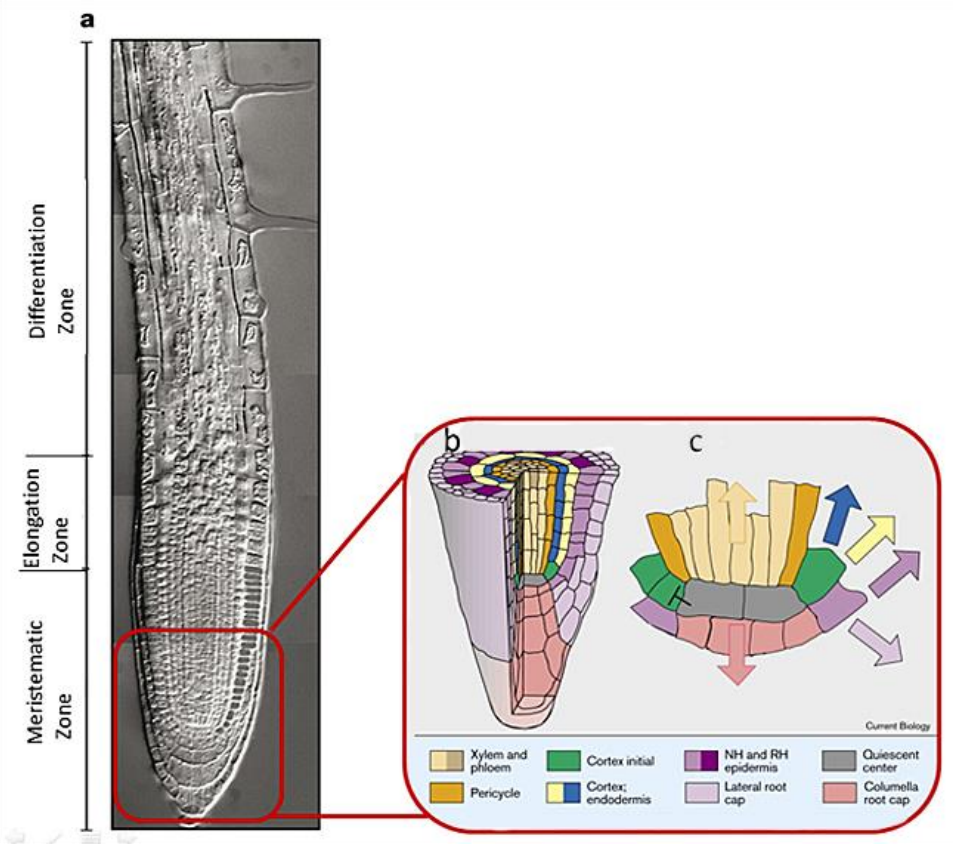
- In **young roots** of both taproot and fibrous root systems, divisions of the **apical meristem** and differentiation of the resulting daughter cells give rise to four distinct regions
- **root cap** (根冠): protects the apical meristem, have thick cell walls and **secrete a slimy lubricant , must be continuously replaced**
- epidermis, cortex, and vascular cylinder

Figure 43-14 Primary growth in roots



Arabidopsis Root development



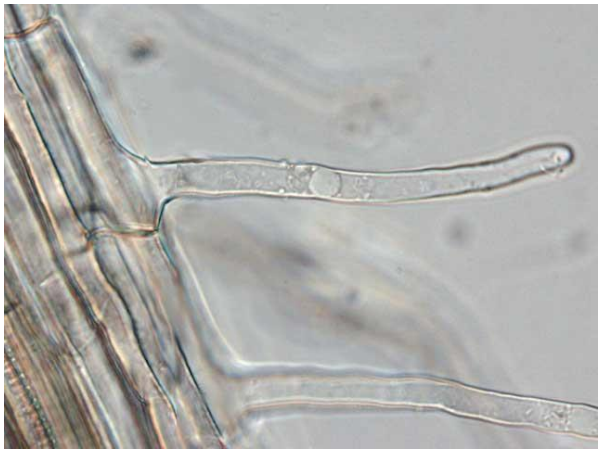


Credit : Yvon Jaillais
http://www.ens-lyon.fr/RDP/SiCE/Resources.html

http://mob.wmmrc.nl/auxin/modelling/polarization-pin-proteins-roots-and-auxin-morphogen

43.6 What Are the Structures and Functions of Roots?

- The epidermis of the root is **permeable to water and minerals**
  - Young roots absorb water and minerals from the soil
  - root epidermis lacks a cuticle
  - many epidermal cells grow **root hairs** into the surrounding soil



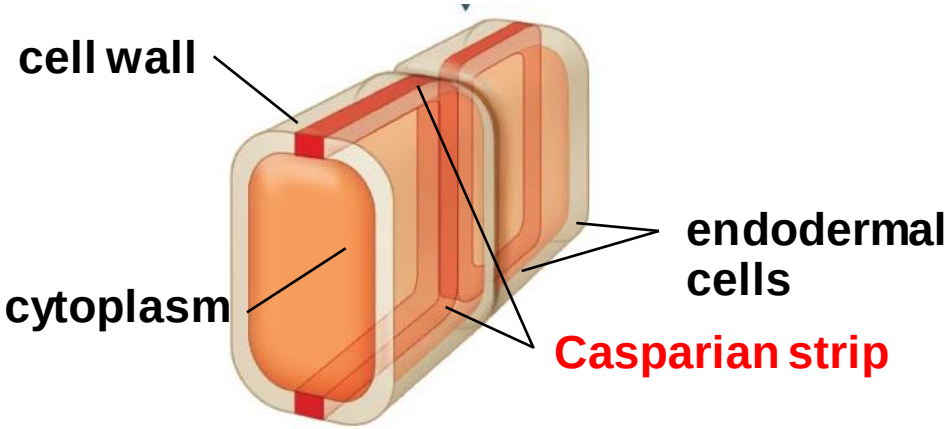
43.6 What Are the Structures and Functions of Roots?

- The cortex **stores food and controls the absorption of water and minerals** into the root
  - Cortex occupies most of the inside of a young root, between the epidermis and the vascular cylinder

1. Cortex consists of _____ cell?
2. Why would plants store food in roots?

43.6 What Are the Structures and Functions of Roots?

- **Endodermis (内皮层):** the innermost layer of cortex
- The cell wall of each endodermal cell contains a band of waterproof material called the **Casparian strip (凯氏带)**



43.6 What Are the Structures and Functions of Roots?

- The vascular cylinder (维管束) contains **conducting tissues and forms branch roots**
  - The **vascular cylinder** contains
    - the conducting tissues of xylem and phloem
    - **Pericycle (中柱鞘)**
    - **The pericycle is also the source of branching in roots**

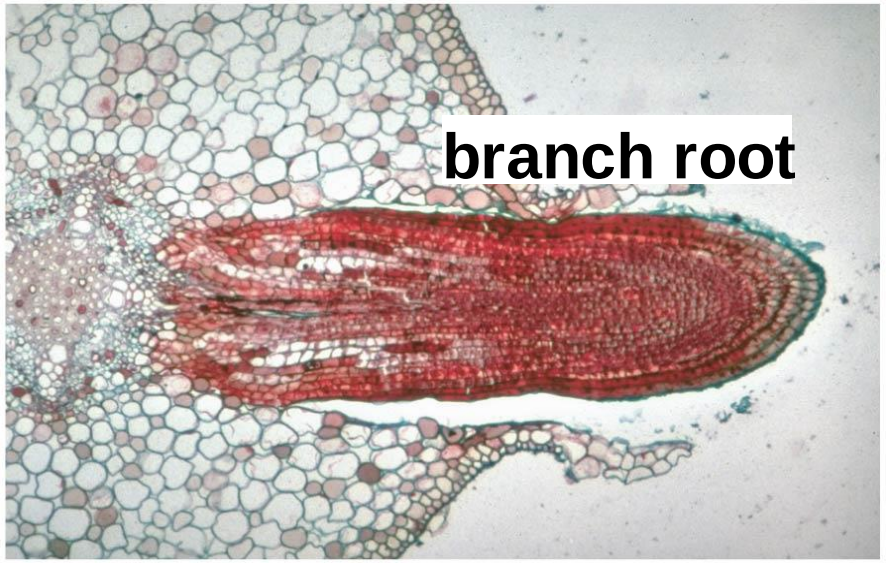
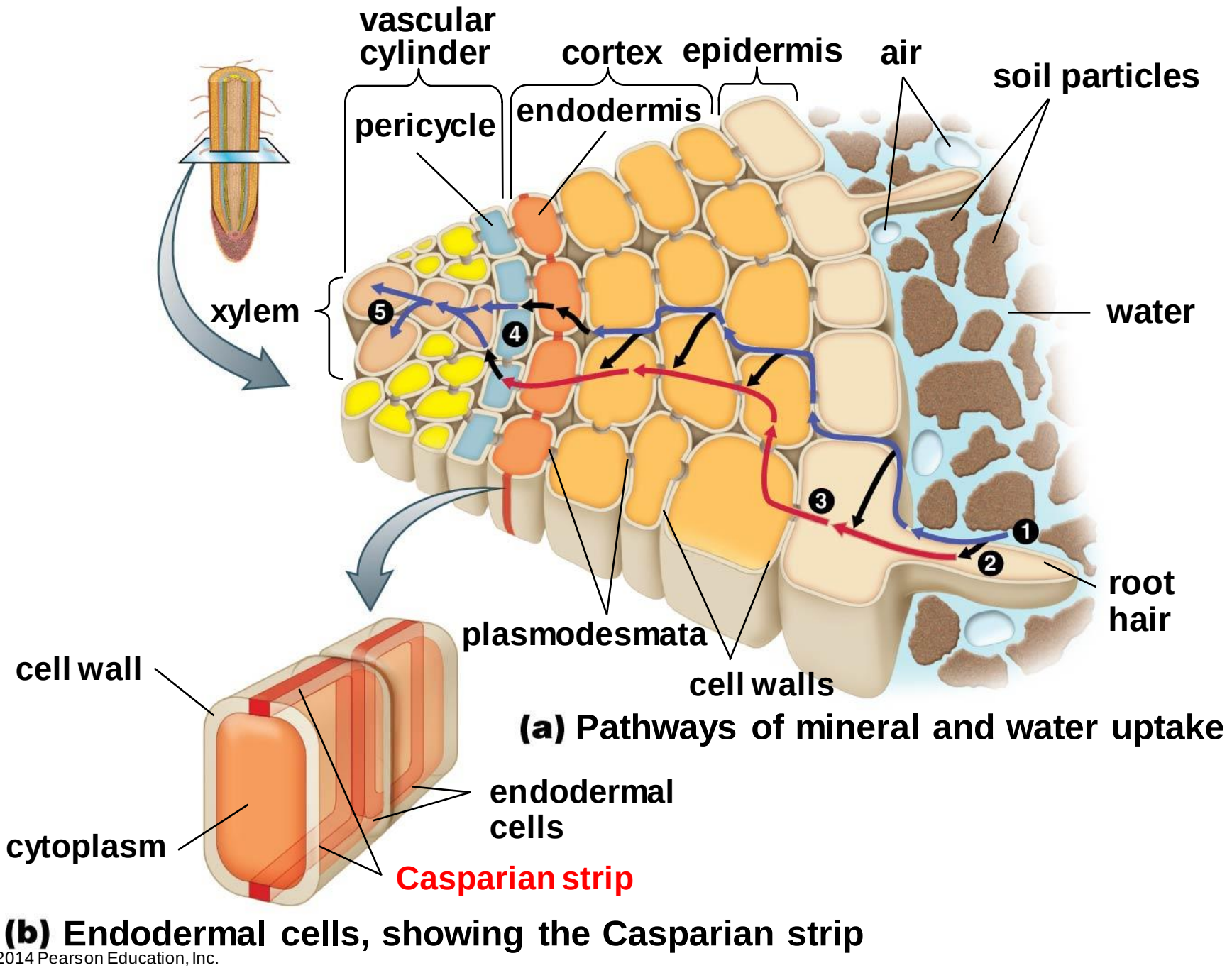


Figure 43-18 Mineral and water uptake by roots



43.6 What Are the Structures and Functions of Roots?

- Roots may undergo secondary growth
  - The roots of **woody plants**, including conifers and deciduous trees and shrubs, become thicker and stronger through secondary growth
  - Although there are some differences between secondary growth in stems and roots, the essentials are similar
    - **Vascular cambium** produces secondary xylem and phloem in the interior of the root
    - The **cork cambium** produces a thick protective layer of cork cells on the outside

43.7 How Do Plants Acquire Nutrients?

- **Nutrients** are substances obtained from the environment that are required for the growth and survival of an organism
  - Plants need **only inorganic nutrients** because, unlike animals, plants can synthesize all of their own organic molecules
    - **Macronutrients (大量元素)**, are required in large quantities: collectively, these make up more than 99% of the dry weight of the plant body
    - **Micronutrients (微量元素),** are needed only in trace amounts

Table 43-2 Essential Nutrients Required by Plants

TABLE 43-2 Essential Nutrients Required by Plants

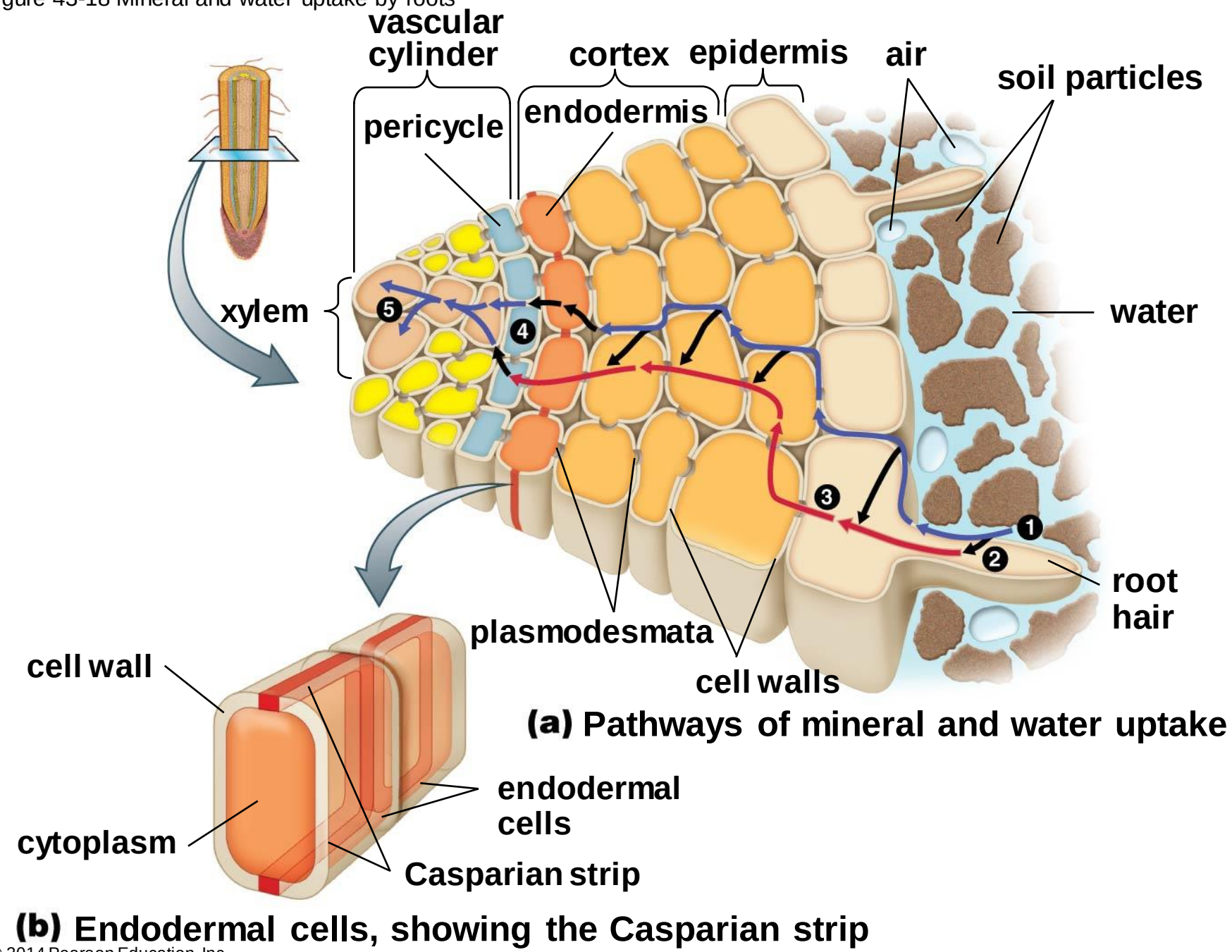
Element*	Major Source	Function
Macronutrients		
Carbon	CO_2 in air	Component of all organic molecules
Oxygen	O_2 in air and dissolved in soil water	Component of all organic molecules
Hydrogen	Water in soil	Component of all organic molecules
Nitrogen	Dissolved in soil water (as nitrate and ammonia)	Component of proteins, nucleotides, and chlorophyll
Potassium	Dissolved in soil water	Helps control osmotic pressure, and regulates stomata opening and closing
Calcium	Dissolved in soil water	Component of cell walls; is involved in enzyme activation and the control of responses to environmental stimuli
Phosphorus	Dissolved in soil water (as phosphate)	Component of ATP, nucleic acids, and phospholipids
Magnesium	Dissolved in soil water	Component of chlorophyll; activates many enzymes
Sulfur	Dissolved in soil water (as sulfate)	Component of some amino acids and proteins; component of coenzyme A
Micronutrients		
Iron	Dissolved in soil water	Component of some enzymes; activates some enzymes; is required for chlorophyll synthesis
Chlorine	Dissolved in soil water	Helps maintain ionic balance across membranes; participates in splitting water during photosynthesis
Copper	Dissolved in soil water	Component of some enzymes; activates some enzymes
Manganese	Dissolved in soil water	Activates some enzymes; participates in splitting water during photosynthesis
Zinc	Dissolved in soil water	Component of some enzymes; activates some enzymes
Boron	Dissolved in soil water	Found in cell walls
Molybdenum	Dissolved in soil water	Component of some enzymes involved in nitrogen utilization

*Listed in approximate order of abundance in the plant body.

43.7 How Do Plants Acquire Nutrients?

- Roots transport minerals from the soil into the **xylem** of the vascular cylinder
  - **Only minerals dissolved in the soil water** can be taken up by roots
  - A young root is made up of
    - **Living cells**, **extracellular space**, the tracheids and vessel elements of **xylem**
  - **The Casparian strip divides the extracellular space of a root into two compartments**

Figure 43-18 Mineral and water uptake by roots



43.7 How Do Plants Acquire Nutrients?

- The Casparian strip **prevents the loss of minerals from the vascular cylinder**
  - The soil water soaked into the cortex of a root has a low concentration of minerals
  - Minerals are **actively** transported into cells
  - The vascular cylinder acquires a much higher concentration of minerals
  - Roots take up water from the soil by osmosis (滲透)

    Water moves **passively** across plasma membranes by **osmosis**, diffusing from areas of high free water concentration

43.7 How Do Plants Acquire Nutrients?

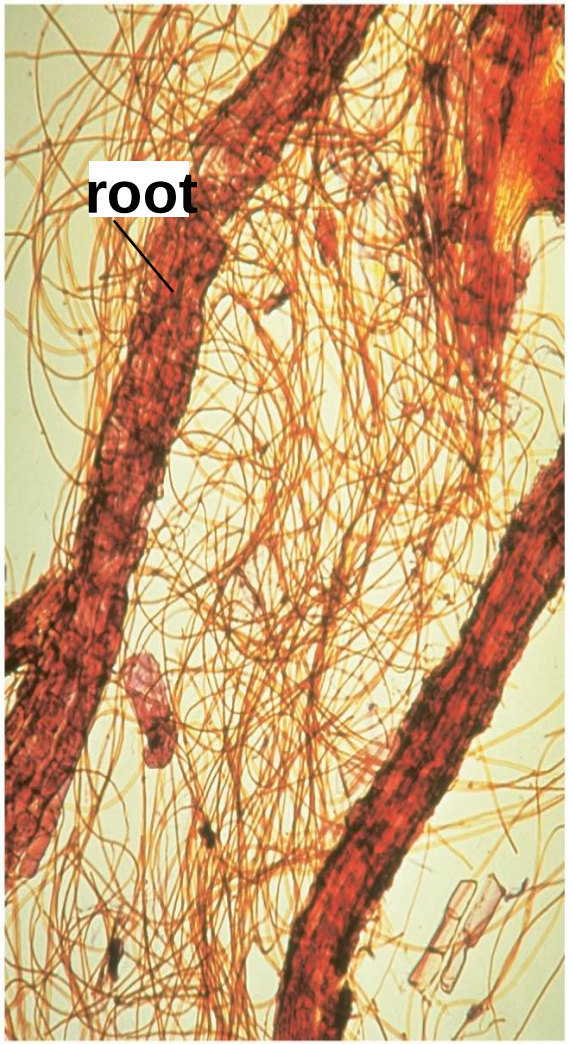
- In some plants, this is so powerful that it creates **root pressure(根压)**
- Water entering the vascular cylinder actually pushes the solution of minerals up the root into the shoot
- In most plants under most conditions osmosis following mineral uptake is **not** the major force that causes water to enter into roots

43.7 How Do Plants Acquire Nutrients?

- **Symbiotic relationships** help plants acquire nutrients
  - However, most plants have evolved **mutually beneficial** relationships with fungi that help them acquire these minerals
  - **Mycorrhizae (菌根), root-fungi**
  - **Root nodule (根瘤), root-nitrogen fixing bacteria**

43.7 How Do Plants Acquire Nutrients?

1. Fungal **mycorrhizae** (fungus root, 菌根) help most plants acquire **minerals**
   - greatly **increases the volume** of soil from which minerals can be absorbed
   - the fungus can **extract some minerals**, particularly **phosphate**



mycorrhizae

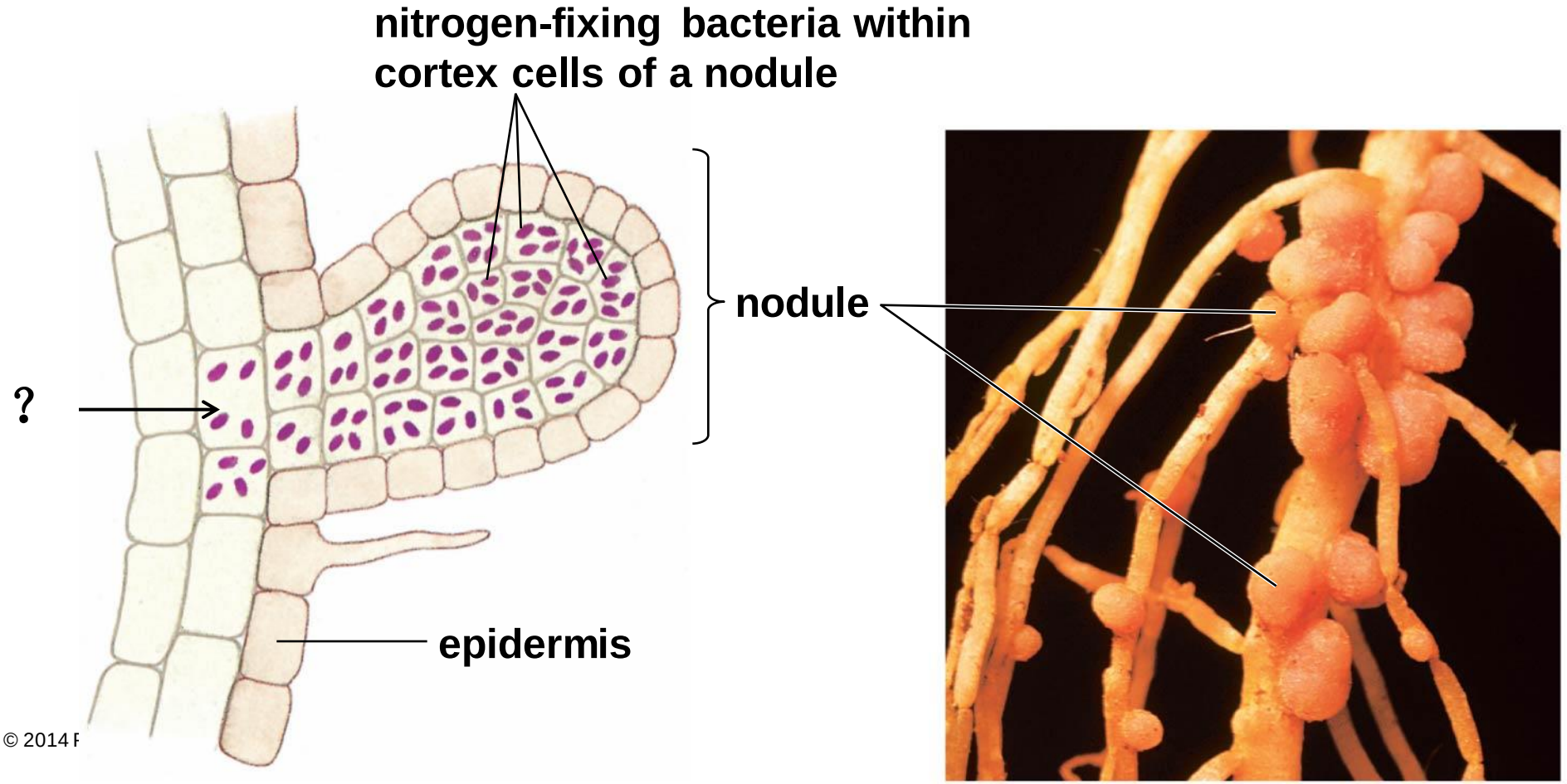
43.7 How Do Plants Acquire Nutrients?

2. Nitrogen-fixing bacteria help legumes (豆科) acquire nitrogen

- **nitrogen** is almost always in short supply in the soil, plants can use nitrogen only in the form of **ammonium (NH_4^+) or nitrate (NO_3^-) ions**
- Some **nitrogen-fixing bacteria** in the soil combine atmospheric N_2 hydrogen to make NH_3, a process called **nitrogen fixation**
  - Nitrogen fixation requires a lot of energy
- mutually beneficial relationship

43.7 How Do Plants Acquire Nutrients?

- The bacteria live off the root's food reserves, they obtain so much food that they produce more NH_4^+ than they need



Summary IV

- How Do Plants Acquire Nutrients?
  - Active transport of minerals dissolved in water
    - Casparian strips
  - Passive transport of water through osmosis
  - Symbiotic relationship with fungi and nitrogen-fixing bacteria

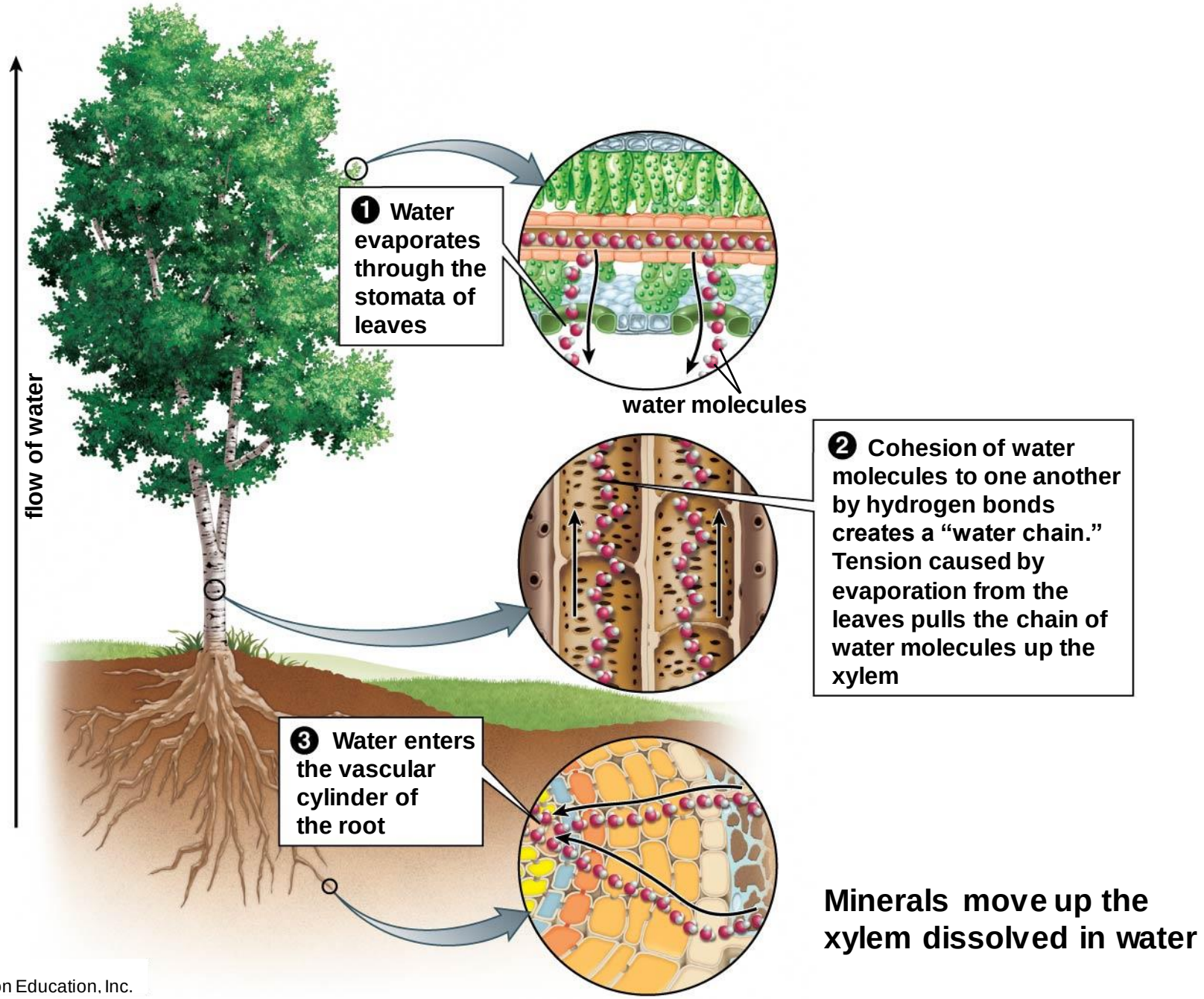
43.8 How Do Plants Move Water and Minerals from Roots to Leaves?

- In most plants, at least **90%** of the water absorbed by the roots evaporates through the stomata of leaves
  - This evaporation, called **transpiration (蒸腾作用)**, drives the movement of water upward through the plant body
- The cohesion–tension (内聚力 -张力) mechanism explains water movement in xylem

43.8 How Do Plants Move Water and Minerals from Roots to Leaves?

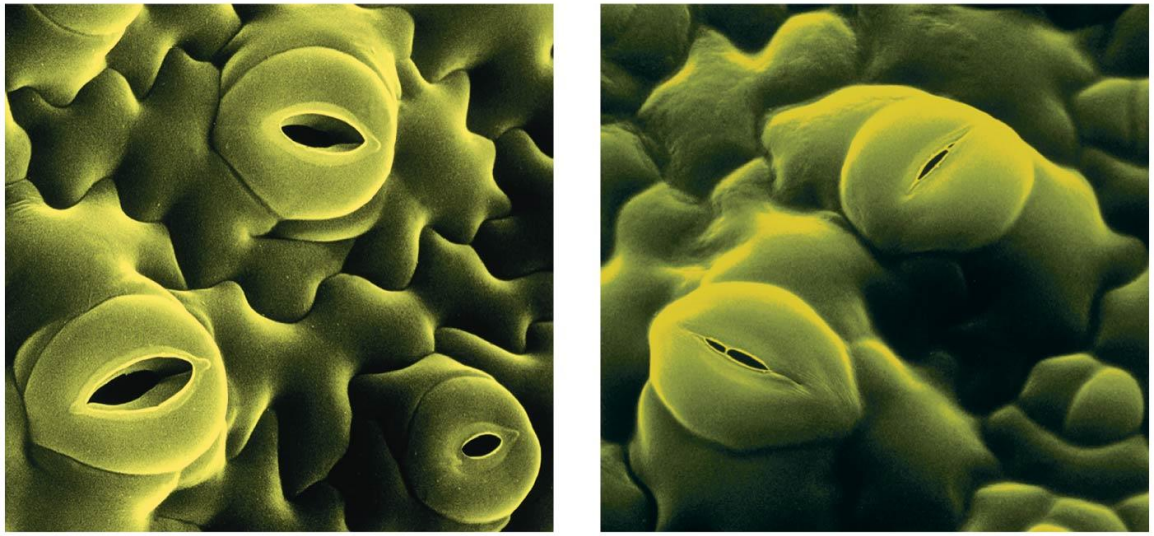
- **Cohesion**—Attraction binds water molecules
  - Hydrogen bonds between water produce cohesion
- **Tension**—the ability of a substance to resist being pulled apart
  - The chain of water is pulled up the xylem by tension produced by evaporating water from the leaves, transpiration
- The **tension** in the xylem is **strong** enough to lift water up more than 500 feet (over 150 meters), much taller than any living tree
- Tension pulling water up the xylem **continues** all the way down to the roots where water in the intercellular space of the vascular cylinder is pulled through

Figure 43-22 The cohesion–tension theory of water flow from root to leaf in xylem



43.8 How Do Plants Move Water and Minerals from Roots to Leaves?

- Stomata control the rate of transpiration
  - Transpiration -> open stomata-> **water loss**
  - Closing the stomata-> prevents CO_2 from entering the leaf
  - Balance between acquiring CO_2 <-> losing H_2O

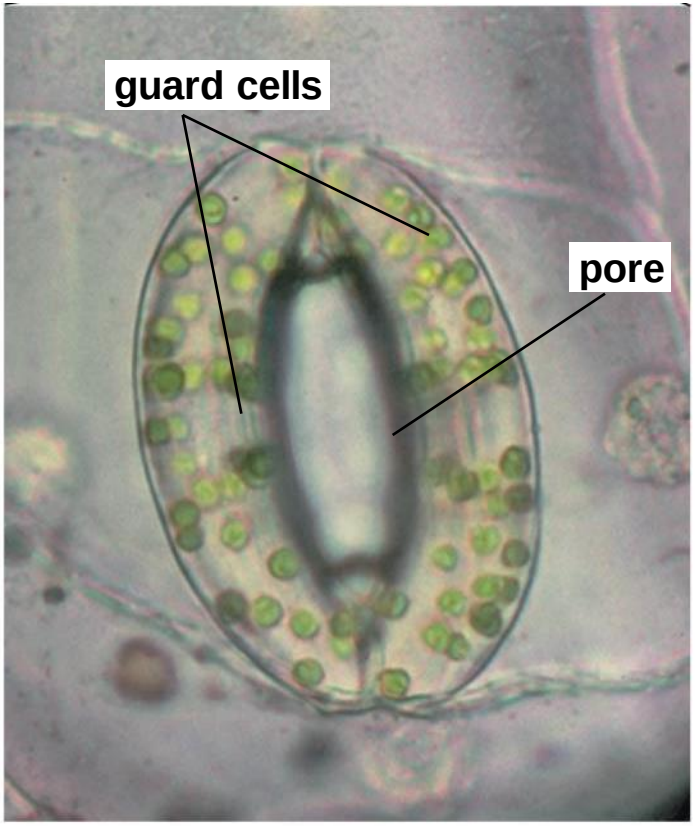


(a) Stomata open (b) Stomata closed

43.8 How Do Plants Move Water and Minerals from Roots to Leaves?

Guard cells regulate opening and closing of stomata

- A stoma consists of a central pore, surrounded by two guard cells
- Plants open and close their stomata
  - **Mechanically**, how the size of the opening is changed
  - **Physiologically**, how guard cells respond to stimuli, such as sunlight or dehydration, and adjust the size of the opening



(a) Light micrograph of a stoma

43.8 How Do Plants Move Water and Minerals from Roots to Leaves?

- Guard cells adjust the size of the opening of a stoma by **changing their volume and shape**, which they accomplish by **taking up or losing water**
  - Guard cells have both an unusual shape and a specific arrangement of cellulose (纤维素)
  - Cellulose fibers in the guard cell walls encircle the cells, prevent the cells from getting fatter, and so they **must get longer** instead

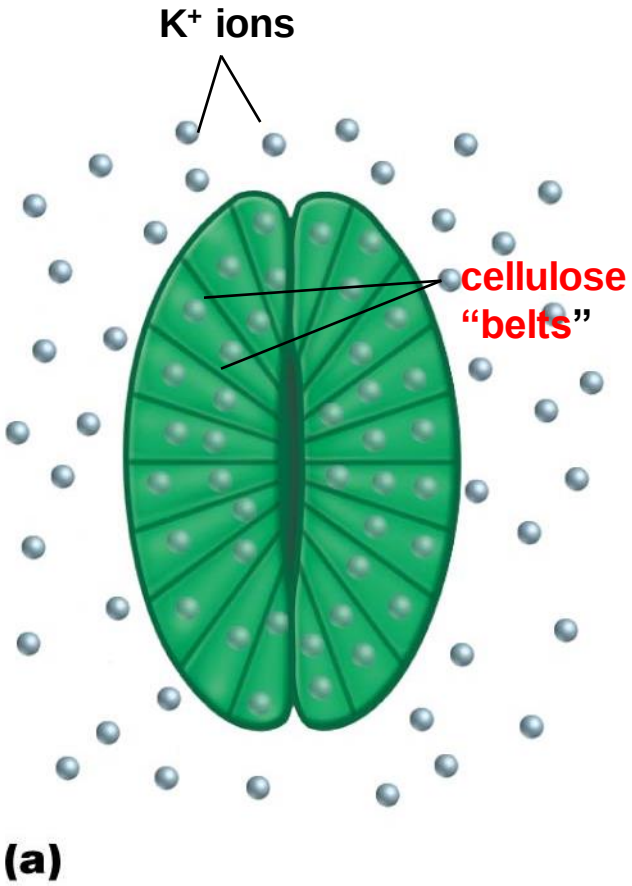
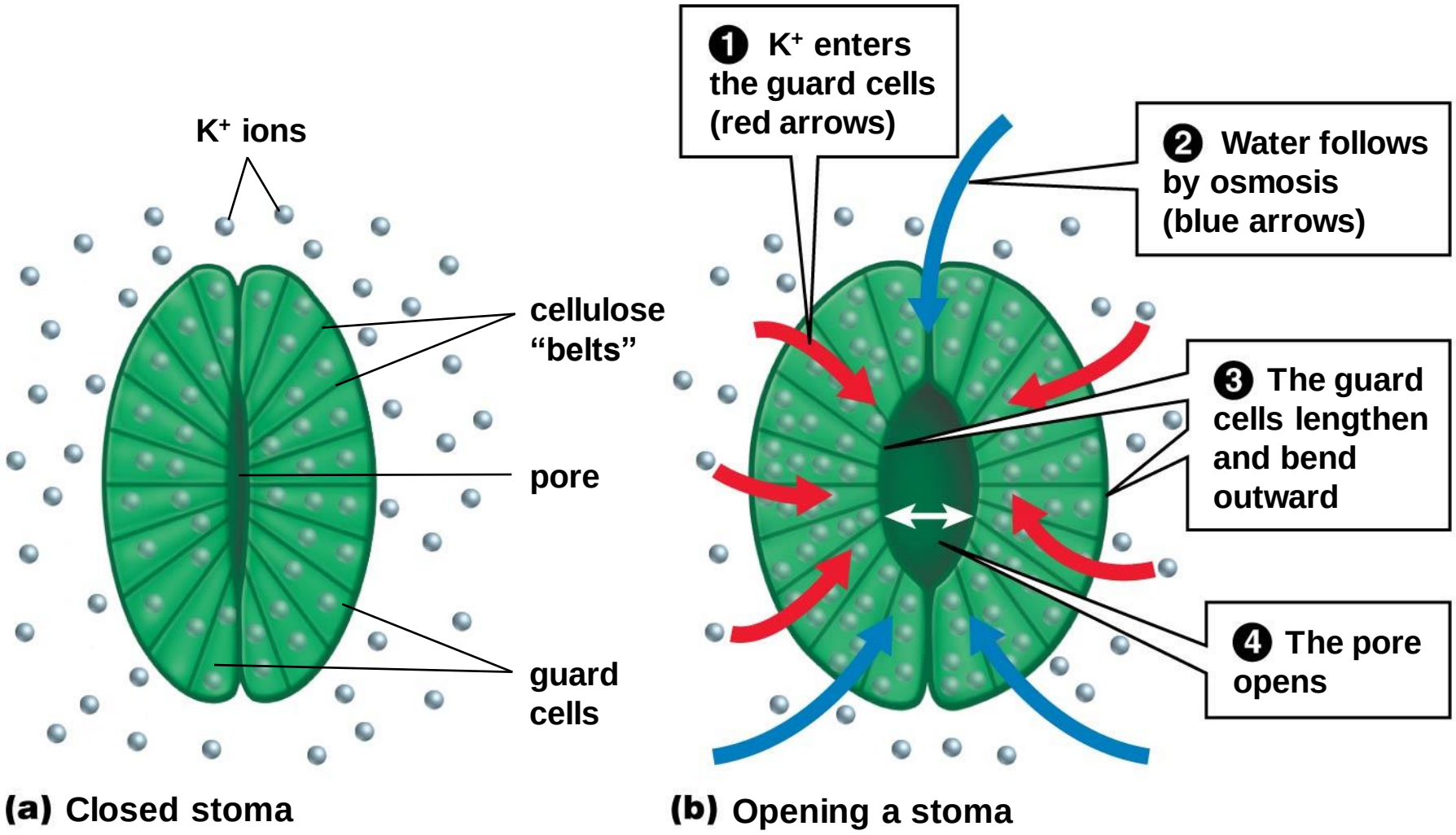
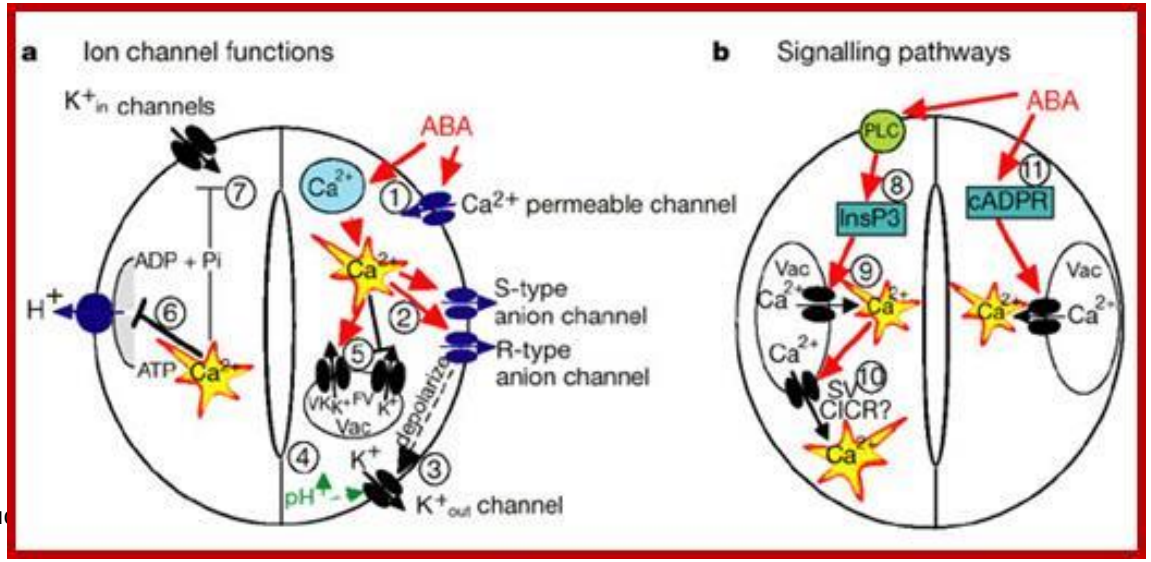


Figure 43-24 How guard cells open a stoma



43.8 How Do Plants Move Water and Minerals from Roots to Leaves?

- Three important stimuli control K^+ movement into and out of guard cells
  - **Light** ->causes K^+ to (**enter/exit?)** the cells
  - **Carbon dioxide**—> Ca $^{2+}$ -> ion channels
  - **Water loss**—> **abscisic acid** (ABA) -> ion channels



Summary V

- How Do Plants Move Water and Minerals from Roots to Leaves?
  - Absorbed by root system
  - Moved up through xylem
  - Ultimate driving force: transpiration through stomata
    - Controlled by environmental signals

43.9 How Do Plants Transport Sugars?

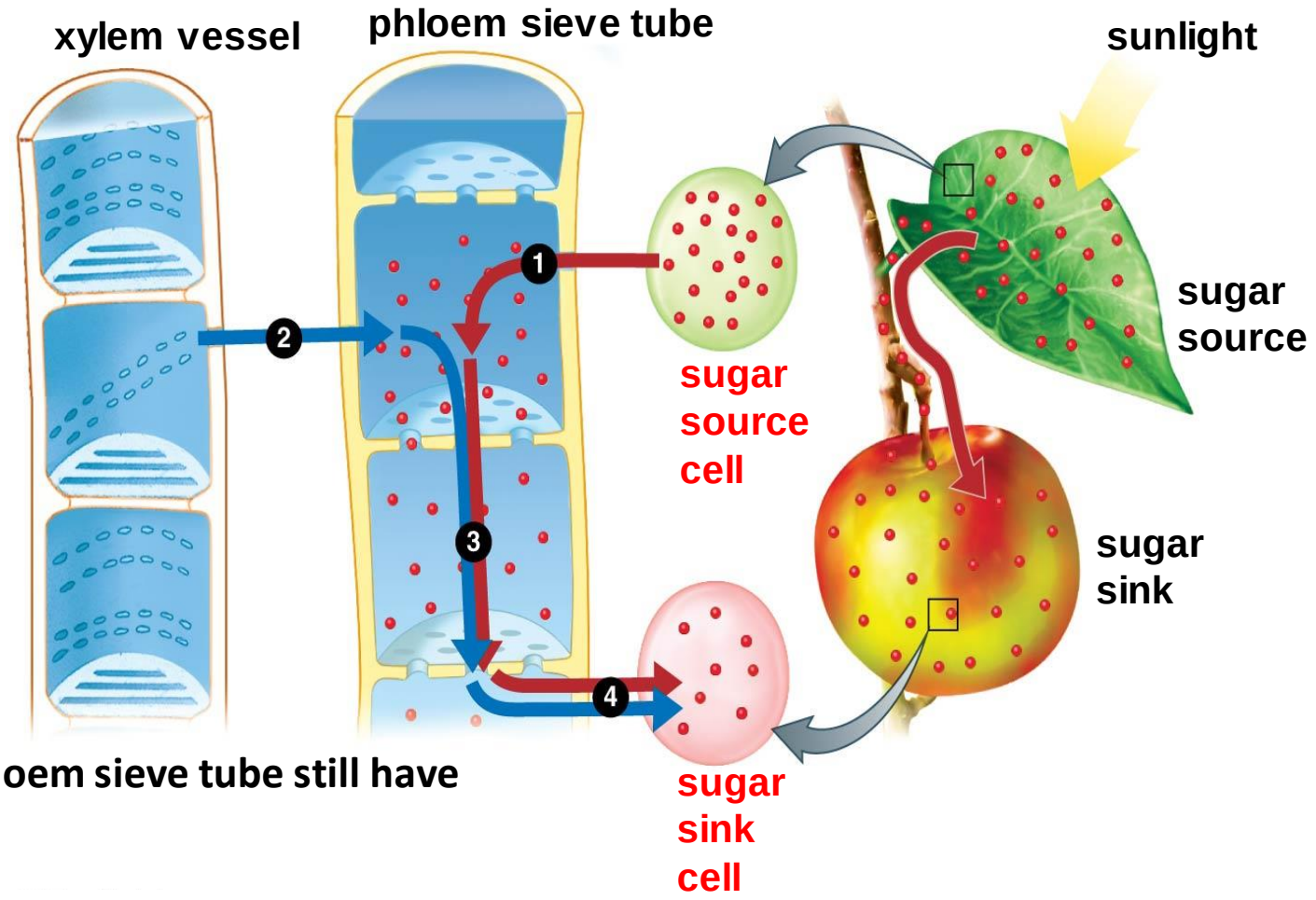
- **Sugars** synthesized in _____must be moved to _____?
  - **Sugar transport is a function of phloem**

(a) An aphid sucks sap

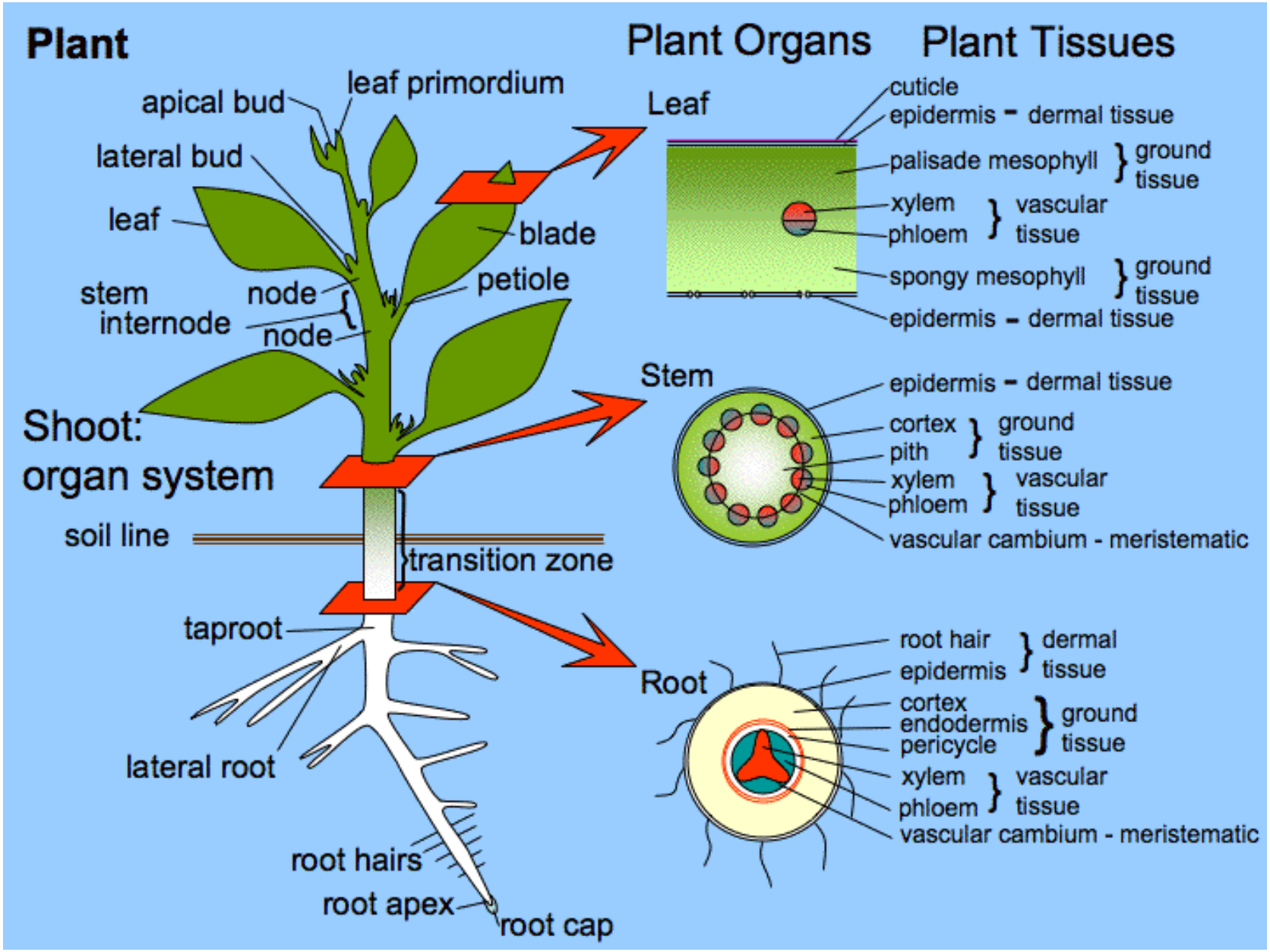
(b) A stylet penetrates into phloem

43.9 How Do Plants Transport Sugars?

- The **pressure-flow** mechanism explains sugar movement in phloem



Why cells in the phloem sieve tube still have cell membrane?



The End !