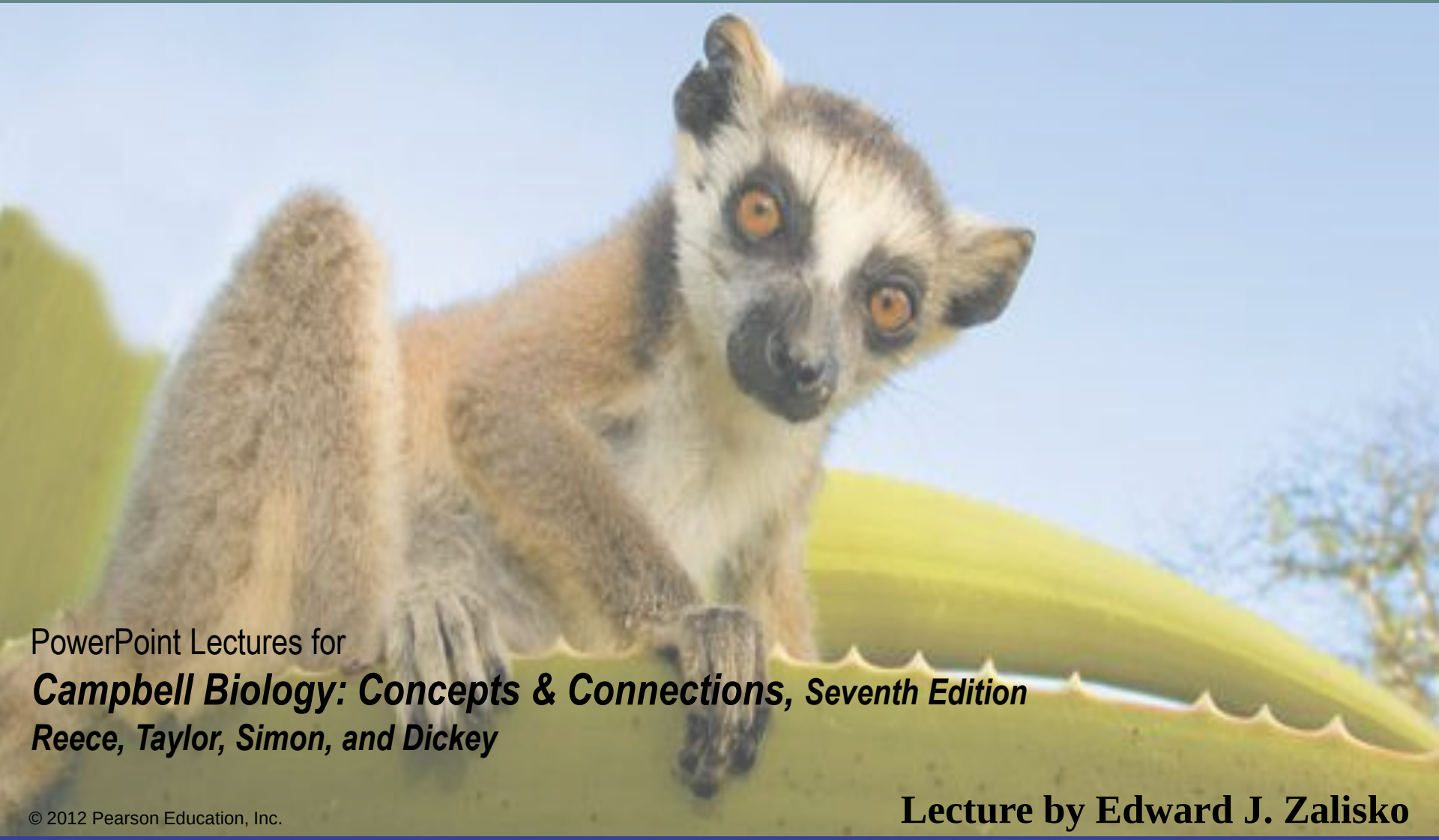
Chapter 31

Plant Structure, Growth, and Reproduction



PowerPoint Lectures for

***Campbell Biology: Concepts & Connections*, Seventh Edition**

Reece, Taylor, Simon, and Dickey

Lecture by Edward J. Zalisko

Introduction

- Some plants, such as coast redwoods, are among the largest and oldest organisms on Earth.
- Coast redwoods are gymnosperms, a kind of plant that bears seeds on cones.
- Angiosperms, or flowering plants, bear seeds in fruits.
- Most plants are angiosperms, which will be the focus of this unit on plant structure.

Figure 31.0_1

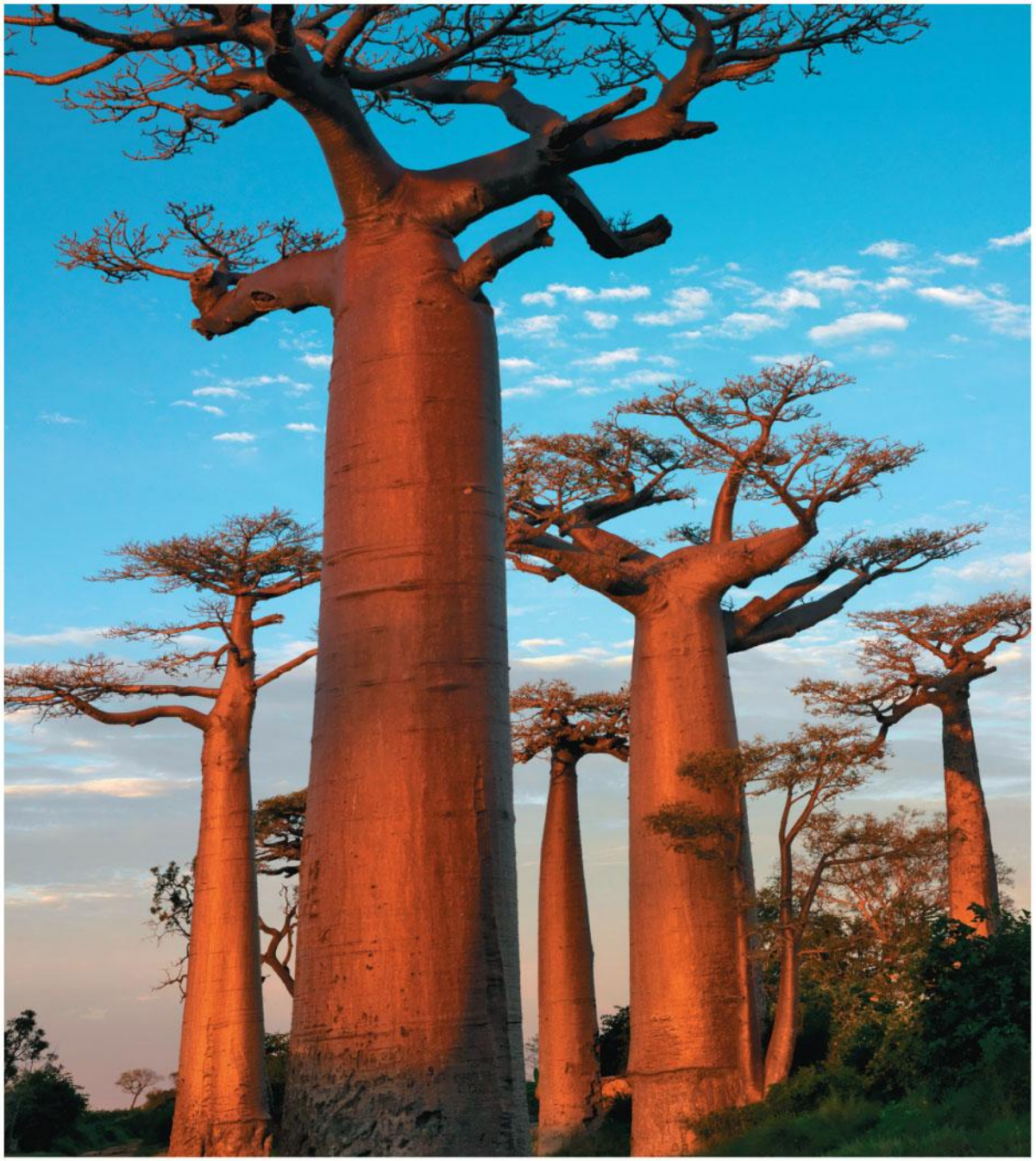
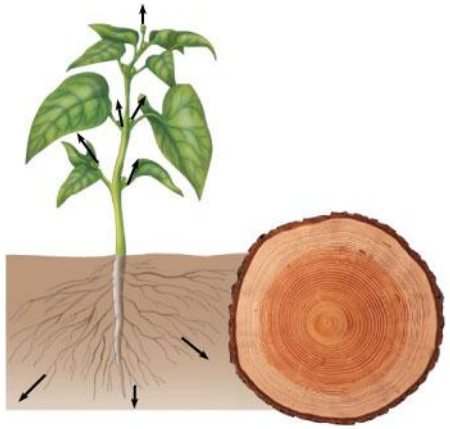


Figure 31.0_2

Chapter 31: Big Ideas

Plant Structure and Function



Plant Growth

Reproduction of Flowering Plants

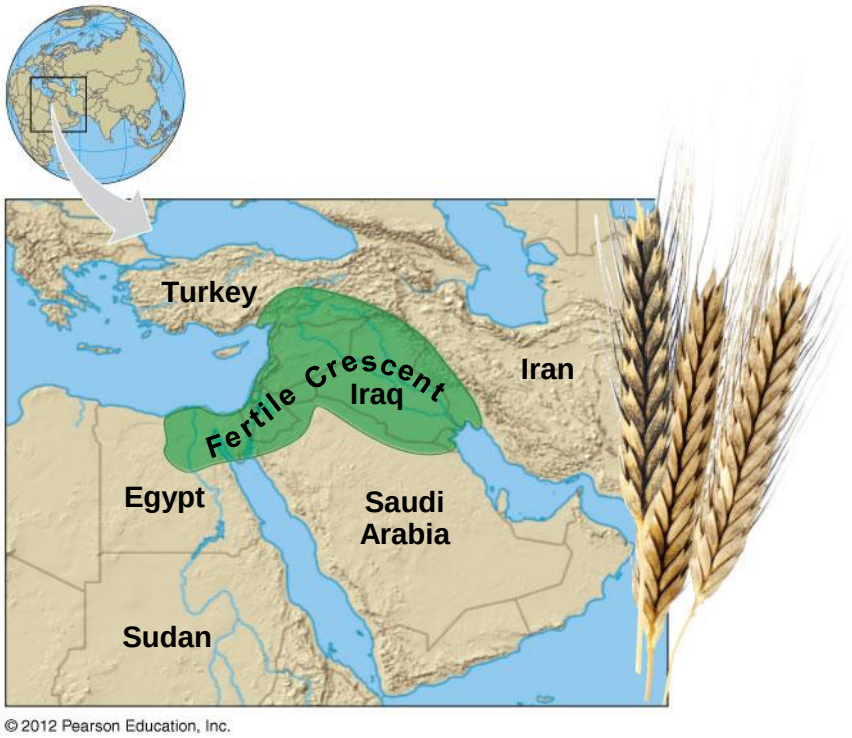
Figure 31.0_3

PLANT STRUCTURE AND FUNCTION

31.1 CONNECTION: People have manipulated plants since prehistoric times

- Humans have engaged in agriculture for about 10,000 years.
- Genetic manipulation of crop plants such as wheat began with cross-pollination of plants with desirable traits.
- Today many crop plants are genetically modified using DNA technology.

Figure 31.1



31.2 The two major groups of angiosperms are the monocots and the eudicots

- Monocots and eudicots differ in
  - number of **cotyledons** (seed leaves),
  - pattern of leaf venation,
  - arrangement of stem vascular tissue,
  - number of flower parts, and
  - root structure.

31.2 The two major groups of angiosperms are the monocots and the eudicots

- **Monocots**, such as wheat and corn, have
  - one cotyledon,
  - parallel leaf venation,
  - scattered vascular bundles,
  - flower parts in threes or multiples of three, and
  - fibrous roots.

31.2 The two major groups of angiosperms are the monocots and the eudicots

- **Eudicots**, which are most plants are, have
  - two cotyledons,
  - branched leaf venation,
  - a ring of vascular bundles,
  - flower parts in fours or fives (or multiples), and
  - a taproot system.

Figure 31.2

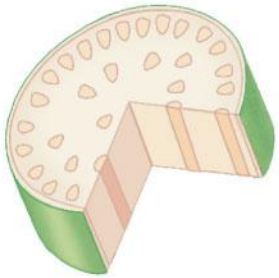
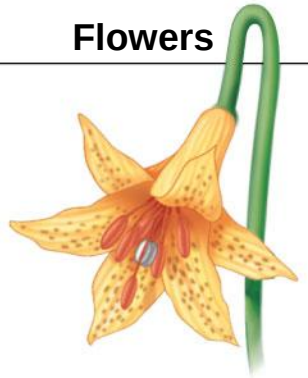
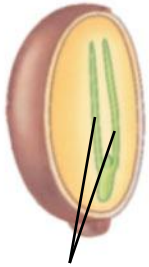
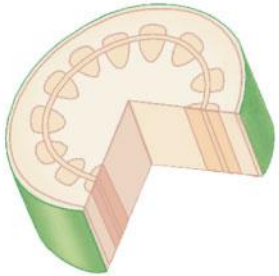
	Seed leaves	Leaf veins	Stems	Flowers	Roots
MONOCOTS	 One cotyledon	 Veins usually parallel	 Vascular bundles in complex arrangement	 Floral parts usually in multiples of three	 Fibrous root system
EUDICOTS	 Two cotyledons	 Veins usually branched	 Vascular bundles arranged in ring	 Floral parts usually in multiples of four or five	 Taproot usually present

Figure 31.2_1

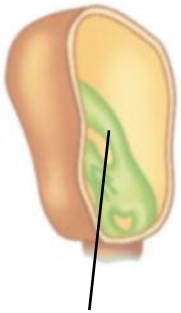
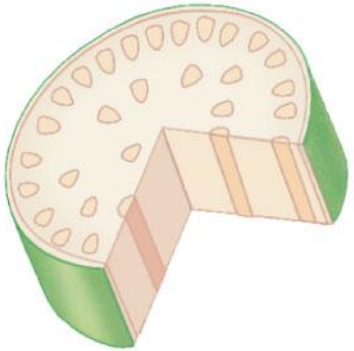
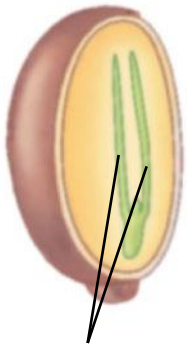
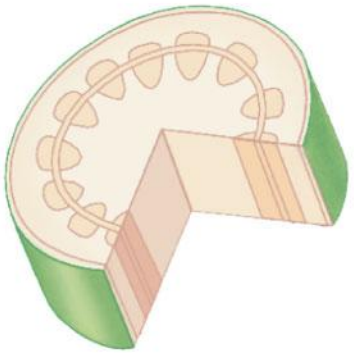
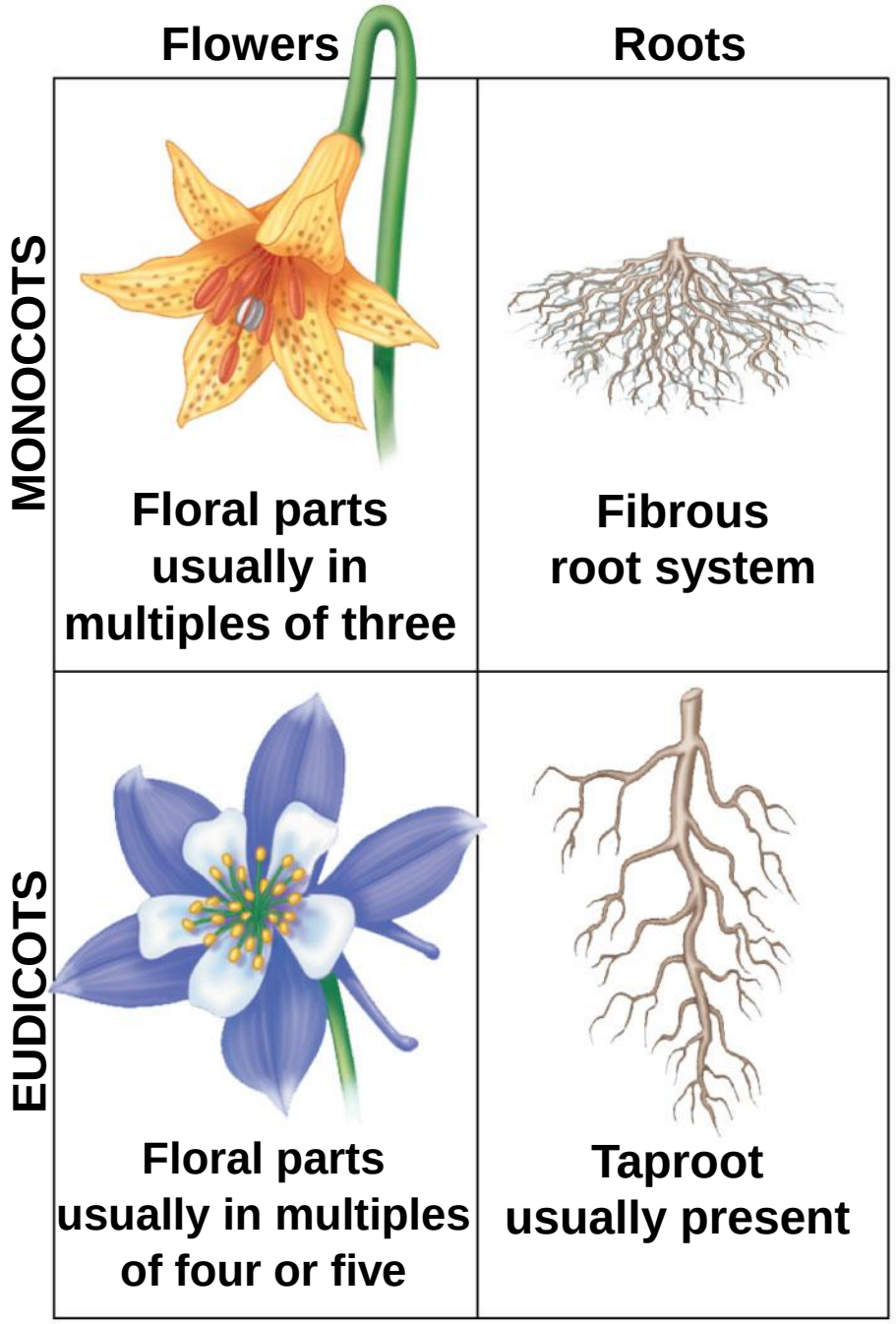
	Seed leaves	Leaf veins	Stems
MONOCOTS	 One cotyledon	 Veins usually parallel	 Vascular bundles in complex arrangement
EUDICOTS	 Two cotyledons	 Veins usually branched	 Vascular bundles arranged in ring

Figure 31.2_2



31.3 A typical plant body contains three basic organs: roots, stems, and leaves

- Plant **organs** consist of several types of tissues that together carry out particular functions.
- Plants use a **root system** to
  - anchor the plant in the soil,
  - absorb and transport water and minerals, and
  - store food.
  - **Root hairs**
    - are tiny tubular projections off of roots that
    - greatly increase the surface area for absorption.

31.3 A typical plant body contains three basic organs: roots, stems, and leaves

- Plants use a **shoot system** to absorb the sun's energy and carbon dioxide from the air.
- A shoot system consists of
  - **stems**,
  - **leaves**, and
  - adaptations for reproduction.
- A stem has
  - **nodes**, the points at which leaves are attached, and
  - **internodes**, the portions of the stem between nodes.

31.3 A typical plant body contains three basic organs: roots, stems, and leaves

- Plants typically have two kinds of buds.
  - **Terminal buds** are at the apex of stems, with developing leaves and a compact series of nodes and internodes.
  - **Axillary buds** are found in the angles formed by the leaf and the stem.
- In many plants, the terminal bud produces hormones that inhibit growth of the axillary buds in a phenomenon called **apical dominance**.

31.3 A typical plant body contains three basic organs: roots, stems, and leaves

- Plant root and shoot systems are interdependent.
  - Plant roots depend on shoots for carbohydrates produced via photosynthesis.
  - Plant shoots depend on roots for water and minerals.

Figure 31.3

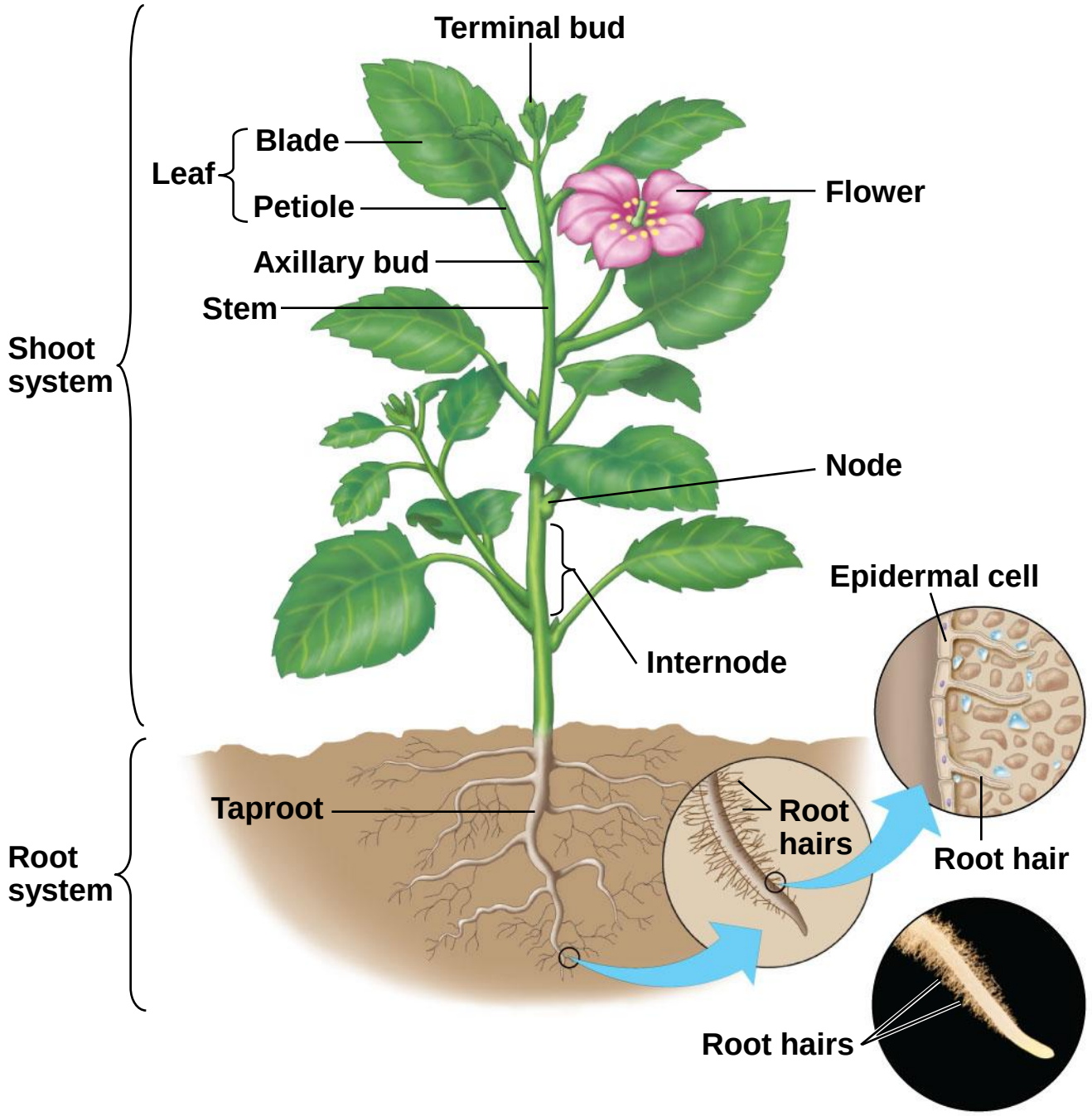
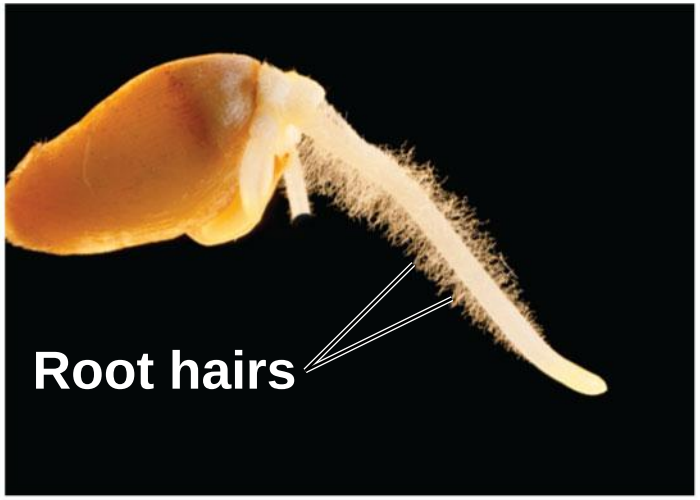


Figure 31.3_1



31.4 Many plants have modified roots, stems, and leaves

- Modifications of plant parts are adaptations for various functions, including
  - food or water storage,
  - asexual reproduction,
  - protection,
  - climbing, and
  - photosynthesis.

Figure 31.4A

31.4 Many plants have modified roots, stems, and leaves

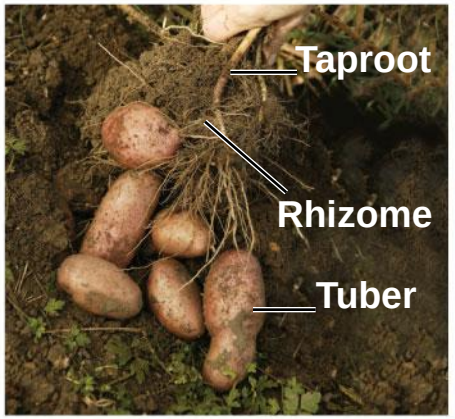
- Stems may be modified as
  - stolons, for asexual reproduction,
  - **tubers**, for storage and asexual reproduction,
  - **rhizomes**, for storage and asexual reproduction, or
  - cactus stems, for water storage and photosynthesis.

Figure 31.4B

Strawberry plant

Stolon (runner)

Iris plant



Potato plant

Figure 31.4B_1

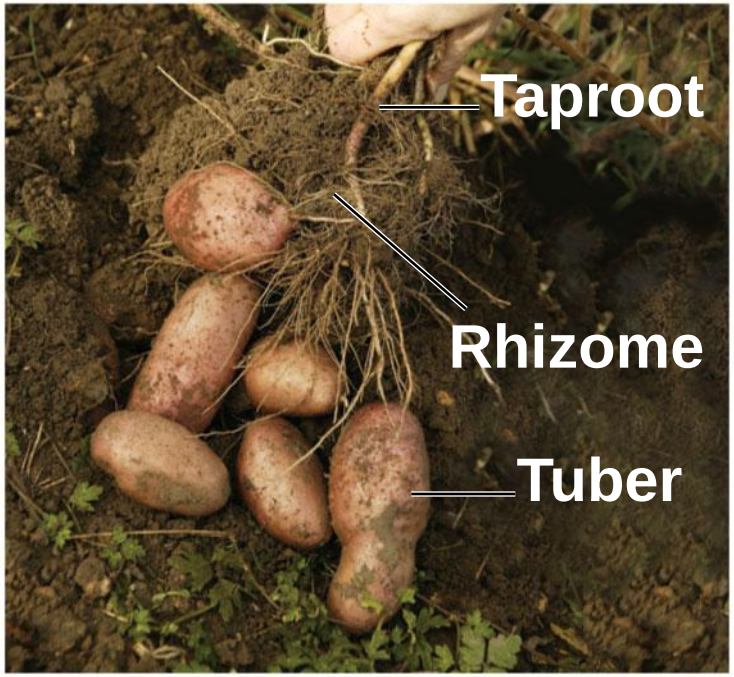
Strawberry plant

Stolon (runner)

Figure 31.4B_2

Iris plant

Figure 31.4B_3



Potato plant

31.4 Many plants have modified roots, stems, and leaves

- Leaves may be modified for
  - climbing, such as a pea plant **tendril**, or
  - protection, such as a cactus spine.

Figure 31.4C

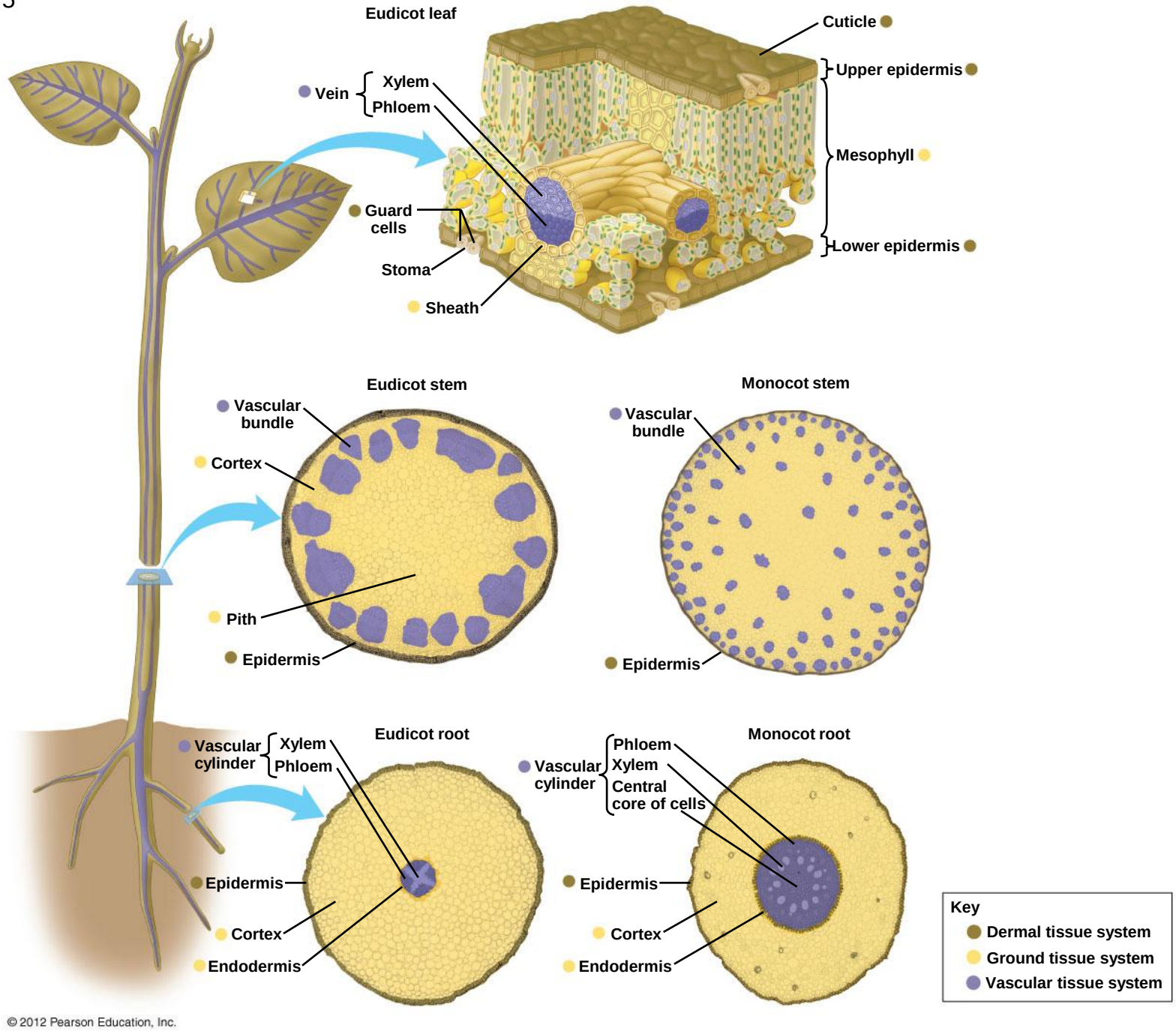
Figure 31.4C_1

Figure 31.4C_2

31.5 Three tissue systems make up the plant body

- The organs of plants contain **tissues**, which are a group of cells that together perform a specialized function. For example
  - **xylem** tissue contains water-conducting cells that convey water and dissolved minerals upward from roots and
  - **phloem** tissue contains cells that transport sugars and other organic nutrients from leaves or storage tissues to other parts of the plant.

Figure 31.5



31.5 Three tissue systems make up the plant body

- Each plant organ (root, stem, or leaf) has three types of tissues.
  1. **Dermal tissue** provides a protective outer covering.
  2. **Vascular tissue** provides support and long-distance transport.
  3. **Ground tissue** composes the bulk of the plant body and is involved in
     - food production,
     - storage, and
     - support.

31.5 Three tissue systems make up the plant body

- **Dermal tissues** form
  - a layer of tightly packed cells called the **epidermis**,
  - the first line of defense against damage and infection, and
  - a waxy layer called the **cuticle**, which reduces water loss.

31.5 Three tissue systems make up the plant body

- **Vascular tissue**
  - is composed of xylem and phloem and
  - arranged in
    - a **vascular cylinder** in a root or
    - **vascular bundles** in stems.

Figure 31.5_2

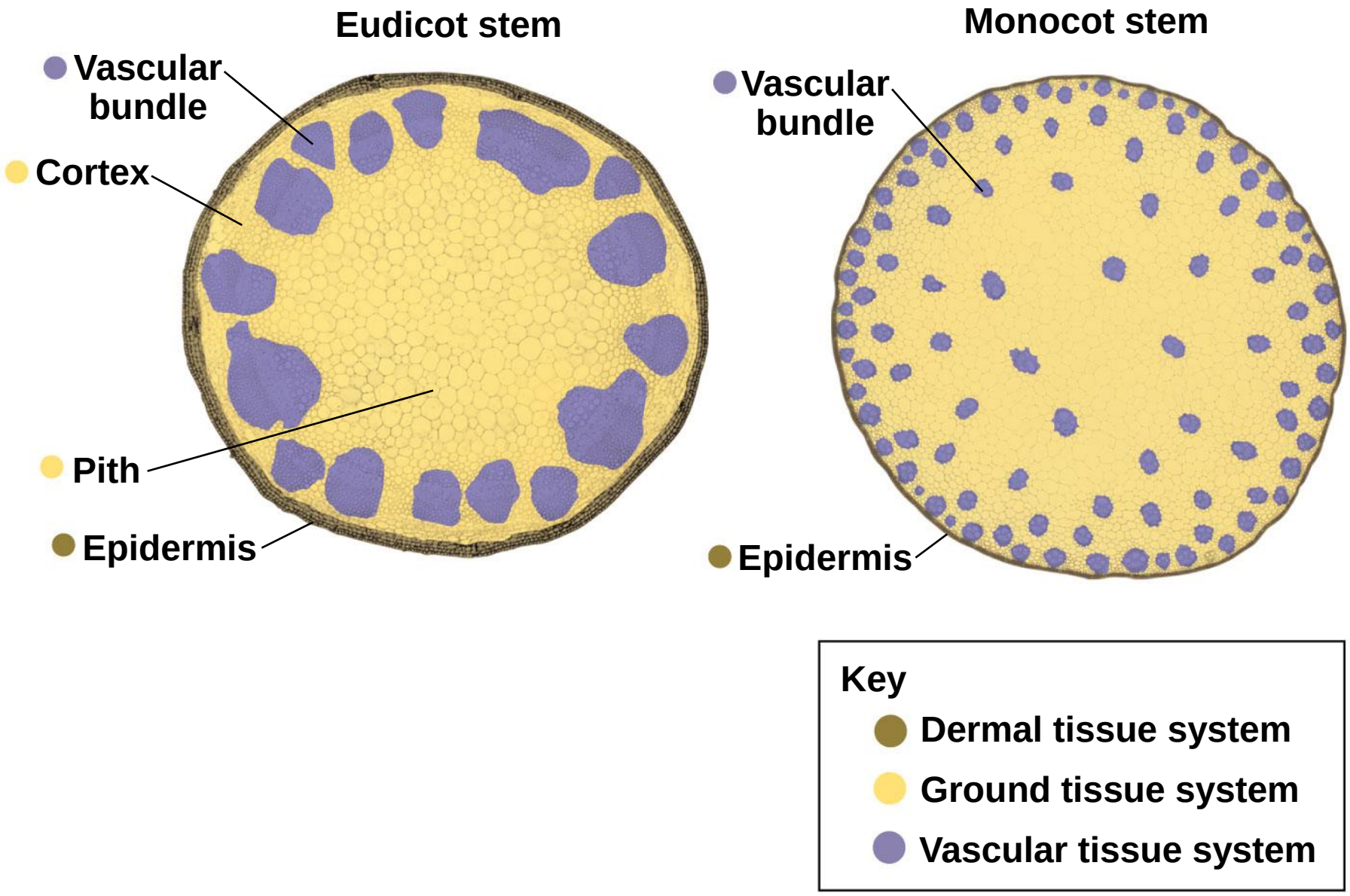
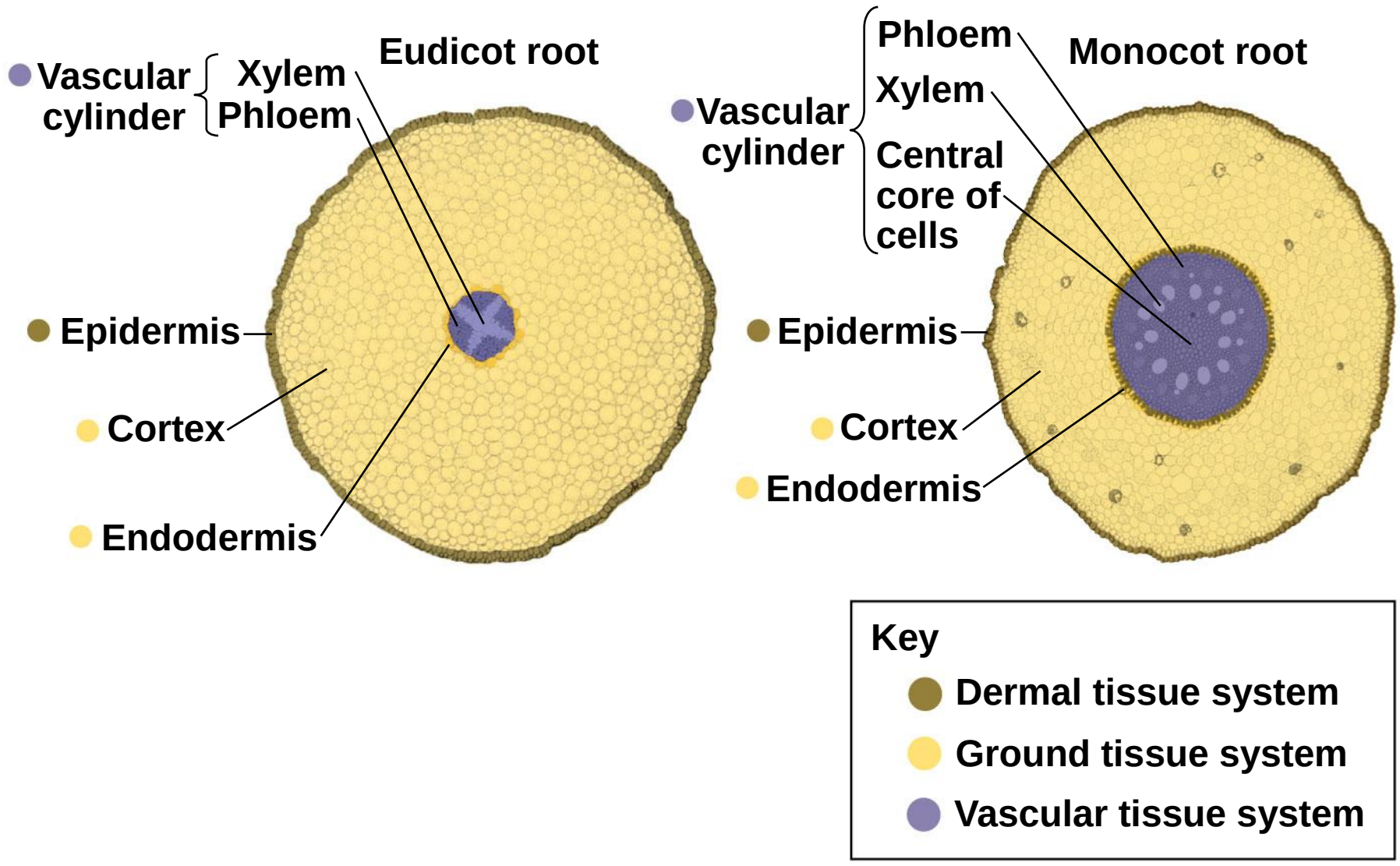


Figure 31.5_3



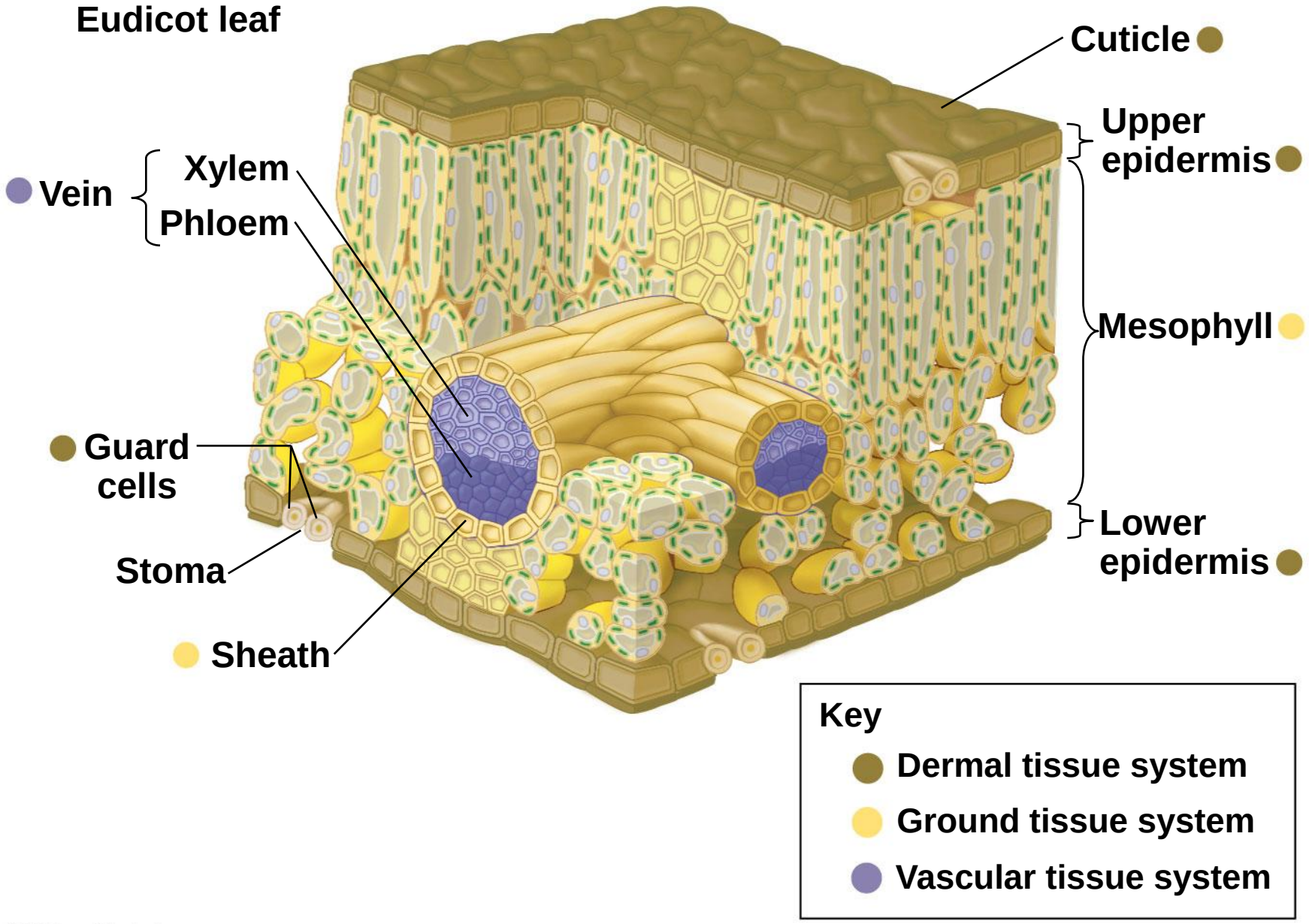
31.5 Three tissue systems make up the plant body

- **Ground tissues** lie between dermal and vascular tissue.
  - Eudicot stem ground tissue is divided into **pith** and **cortex**.
  - Leaf ground tissue is called **mesophyll**.

31.5 Three tissue systems make up the plant body

- In a leaf, the epidermis is interrupted by tiny pores called **stomata**, which allow exchange of CO_2 and O_2 between
  - the surrounding air and
  - the photosynthetic cells inside the leaf.
  - Each stoma is flanked by two **guard cells** that regulate the opening and closing of the stoma.

Figure 31.5_1



31.6 Plant cells are diverse in structure and function

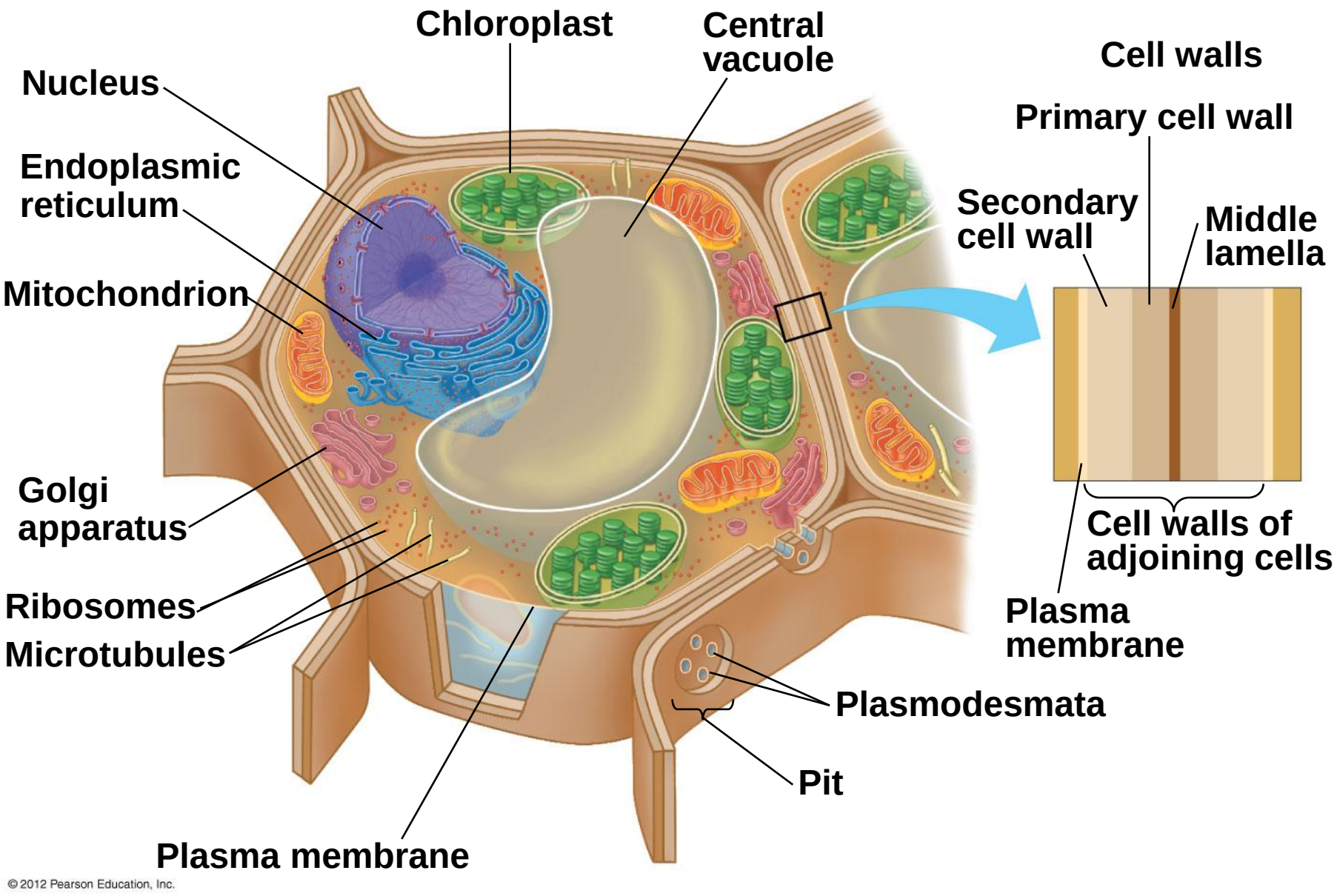
- Plant cells have three structures that distinguish them from animal cells:

1. chloroplasts, the site of photosynthesis,
2. a central vacuole containing fluid that helps maintain cell turgor (firmness), and
3. a protective cell wall composed of cellulose.

31.6 Plant cells are diverse in structure and function

- Plant cell walls
  - Some plant cell walls have two layers.
    1. A primary cell wall forms the outermost layer.
    2. A secondary cell wall forms a tough layer inside the primary wall.
  - A sticky layer called the middle lamella lies between adjacent plant cells.
  - Openings in cell walls called plasmodesmata allow cells to communicate and exchange materials easily.

Figure 31.6A



31.6 Plant cells are diverse in structure and function

- Plant cell structure is related to function.
- There are five major types of plant cells with different functions:
  1. parenchyma cells,
  2. collenchyma cells,
  3. sclerenchyma cells,
  4. water-conducting cells, and
  5. food-conducting cells

31.6 Plant cells are diverse in structure and function

- **Parenchyma cells**
  - are the most abundant type of cell in most plants,
  - usually have only a thin and flexible primary cell wall,
  - perform most of the metabolic functions of a plant, and
  - can divide and differentiate into other types of plant cells under certain conditions.

Figure 31.6B

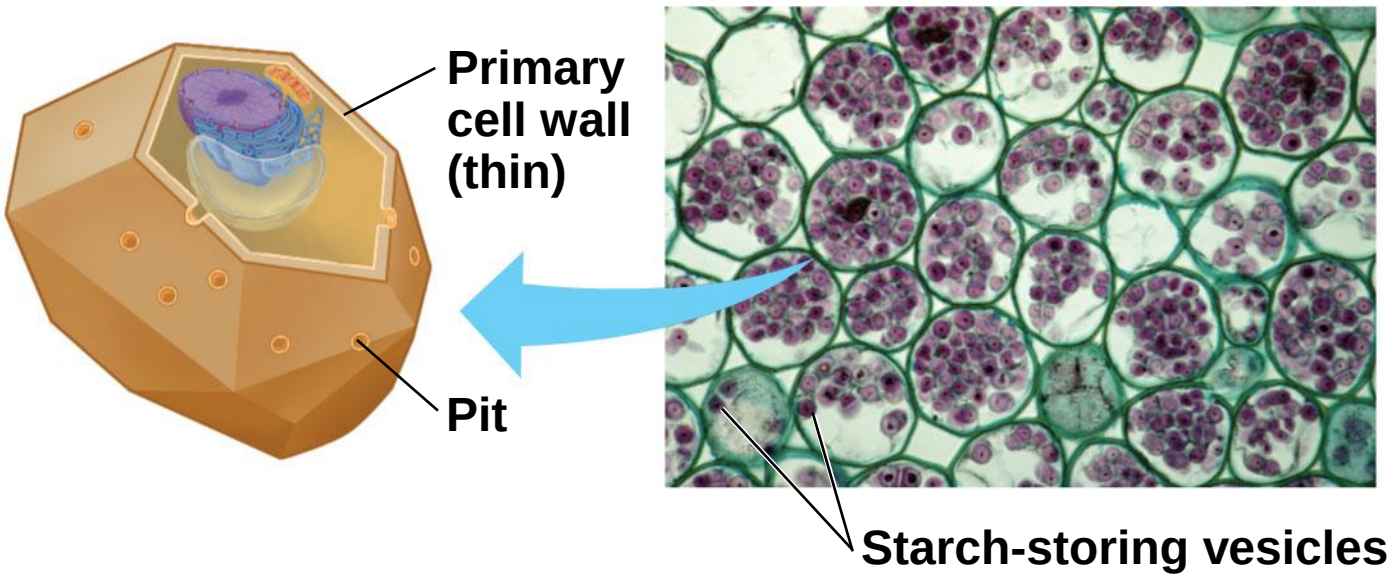
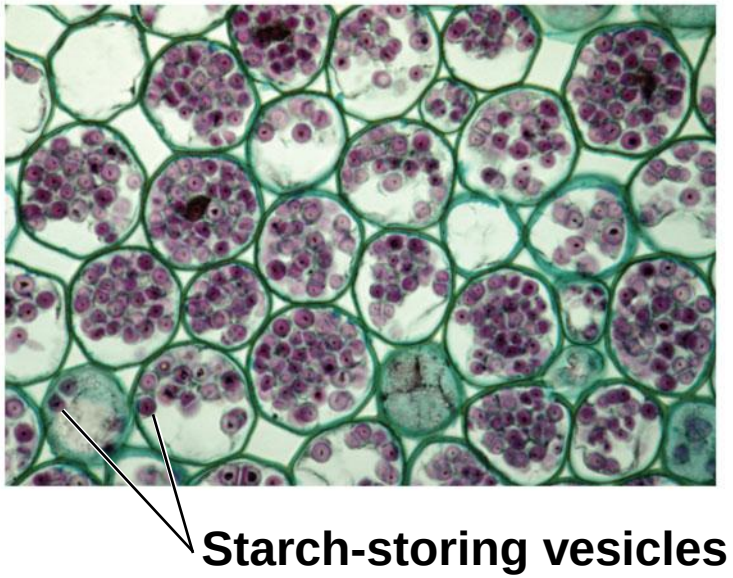


Figure 31.6B_1



31.6 Plant cells are diverse in structure and function

- **Collenchyma cells**
  - lack a secondary cell wall,
  - have an unevenly thickened primary cell wall, and
  - provide flexible support in actively growing parts of the plant.

Figure 31.6C

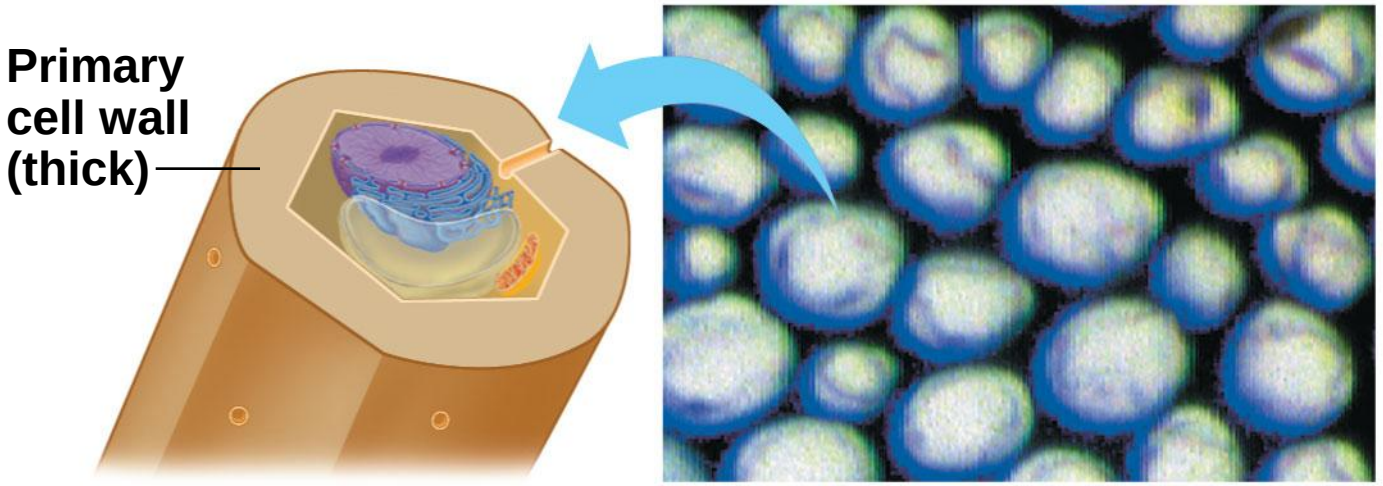
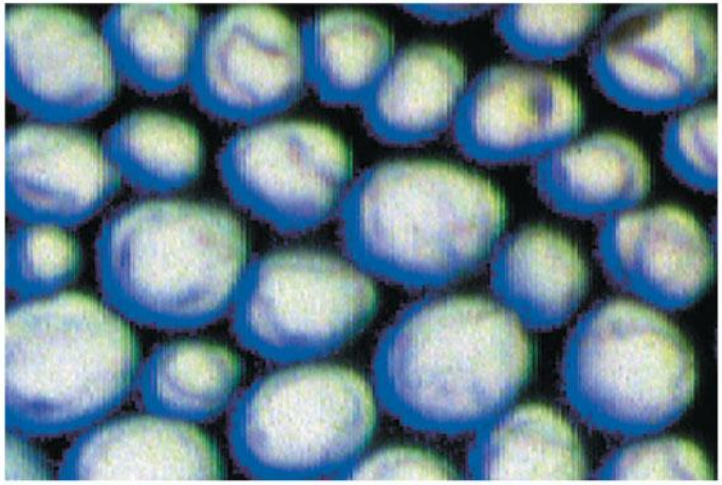


Figure 31.6C_1



31.6 Plant cells are diverse in structure and function

- **Sclerenchyma cells**
  - have a thick secondary cell wall usually strengthened with lignin, the main chemical component of wood, and
  - cannot elongate at maturity and are therefore found only in regions of the plant that have stopped growing in length.
  - When mature, most sclerenchyma cells are dead, their cell walls forming a rigid “skeleton” that supports the plant.

31.6 Plant cells are diverse in structure and function

- Two types of sclerenchyma cells are

1. **fibers**, long and slender cells usually arranged in bundles, and

2. **sclereids**, shorter than fibers, have thick, irregular and very hard secondary cell walls that impart the hardness present in nut shells and pear tissue.

Figure 31.6D

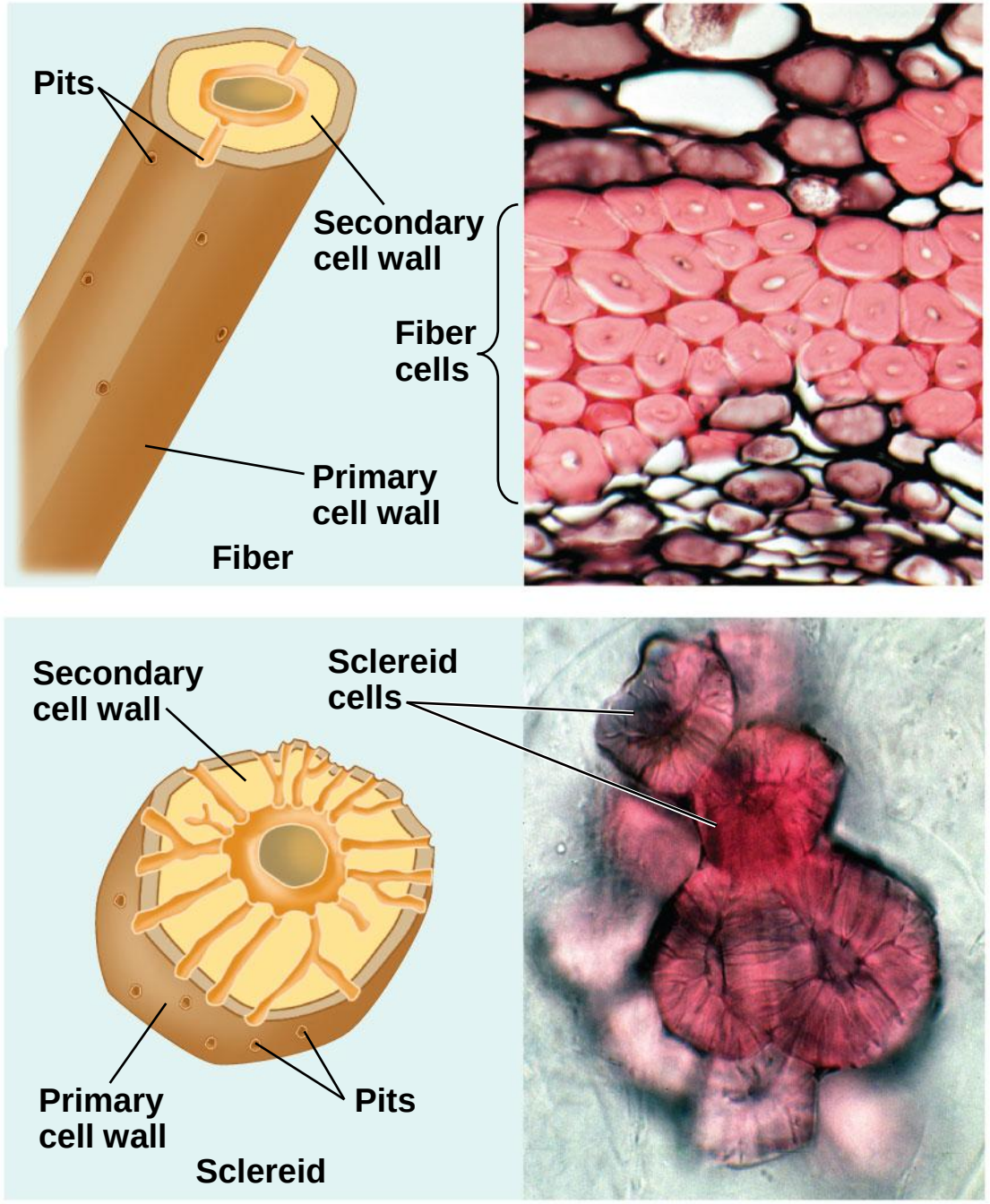


Figure 31.6D_1

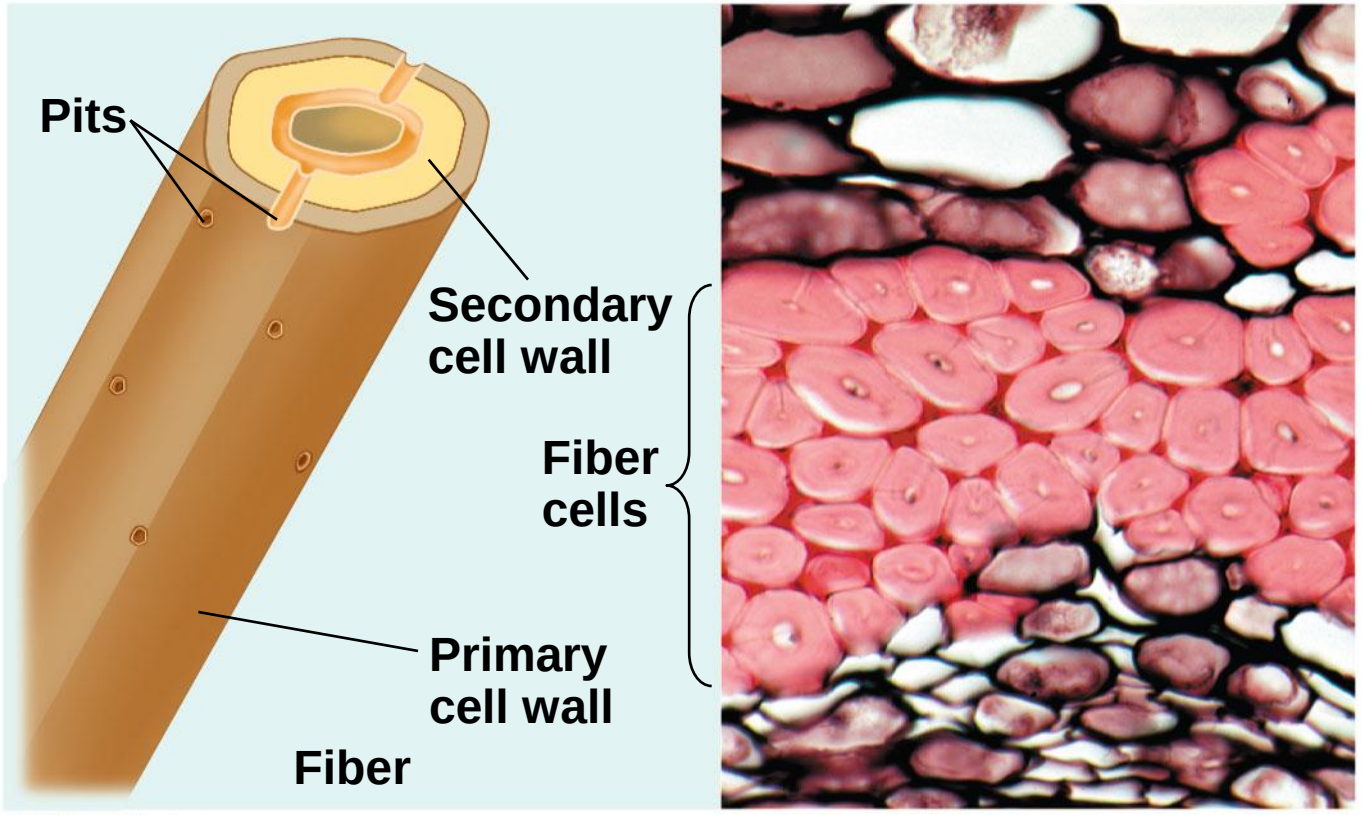


Figure 31.6D_2

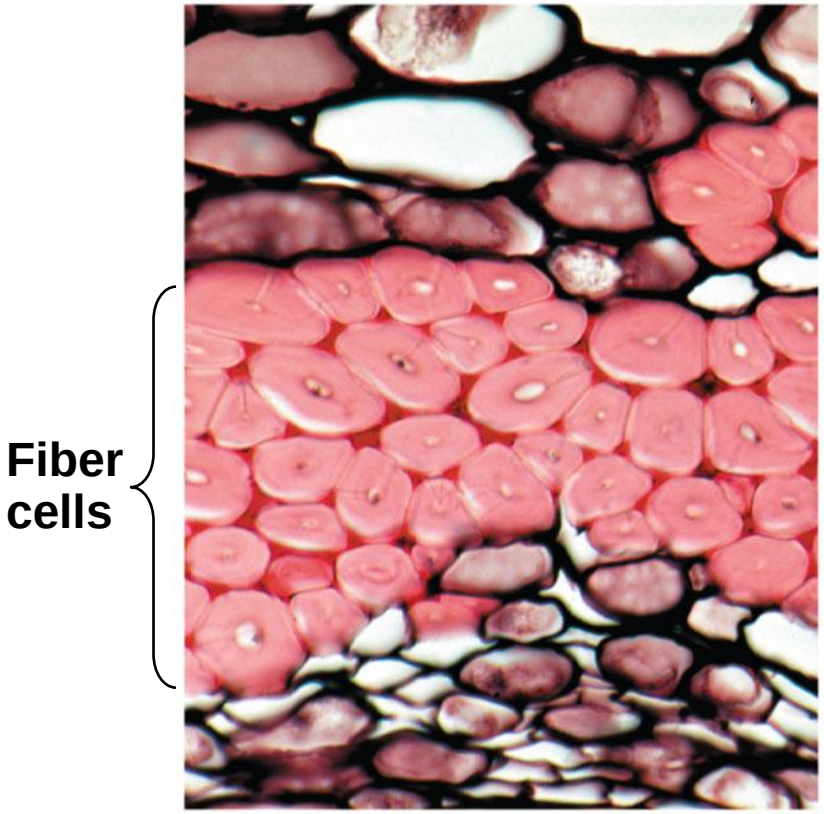


Figure 31.6D_3

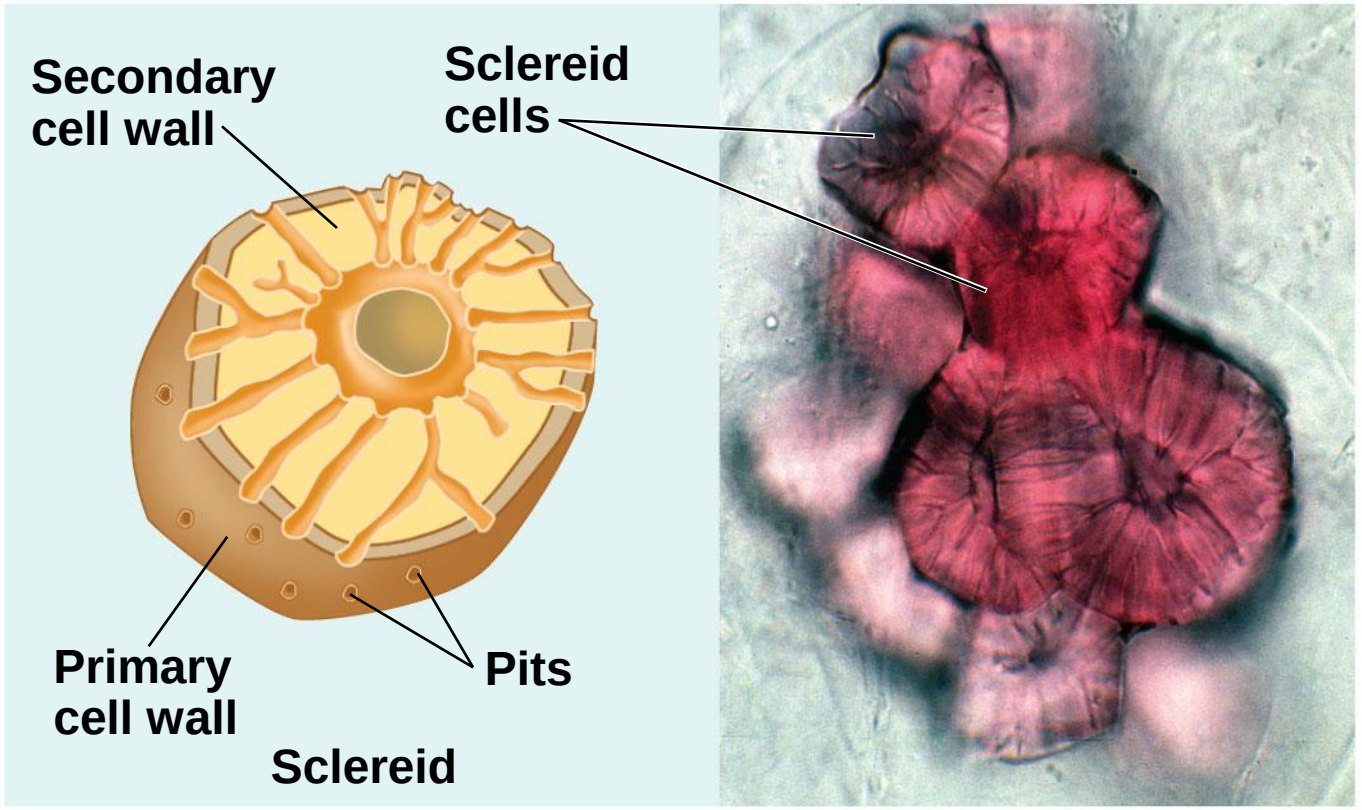
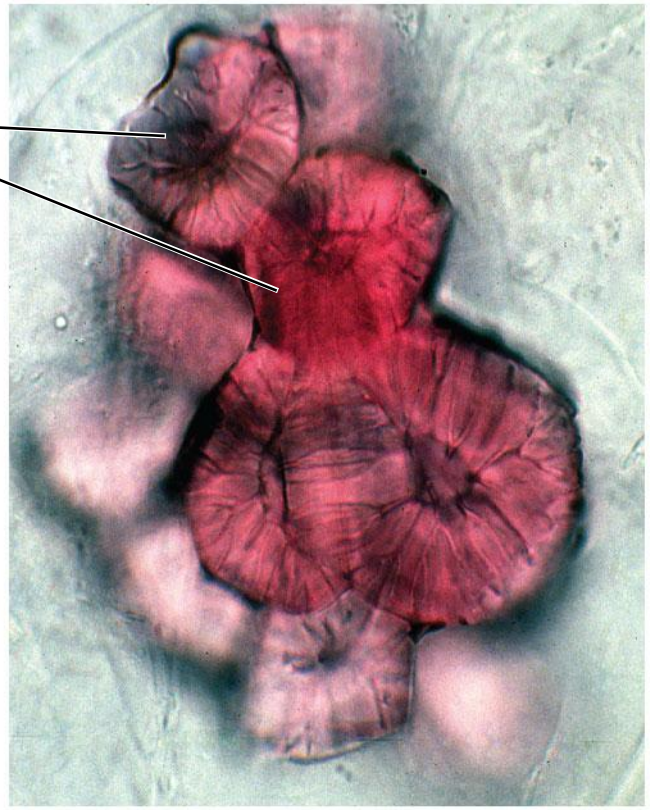


Figure 31.6D_4



31.6 Plant cells are diverse in structure and function

- Xylem tissue of angiosperms includes two types of water-conducting cells, **tracheids** and **vessel elements**. Both cell types
  - have rigid, lignin-containing secondary cell walls,
  - are dead at maturity, and
  - form chains with overlapping ends that create tubes within vascular tissue.

Figure 31.6E

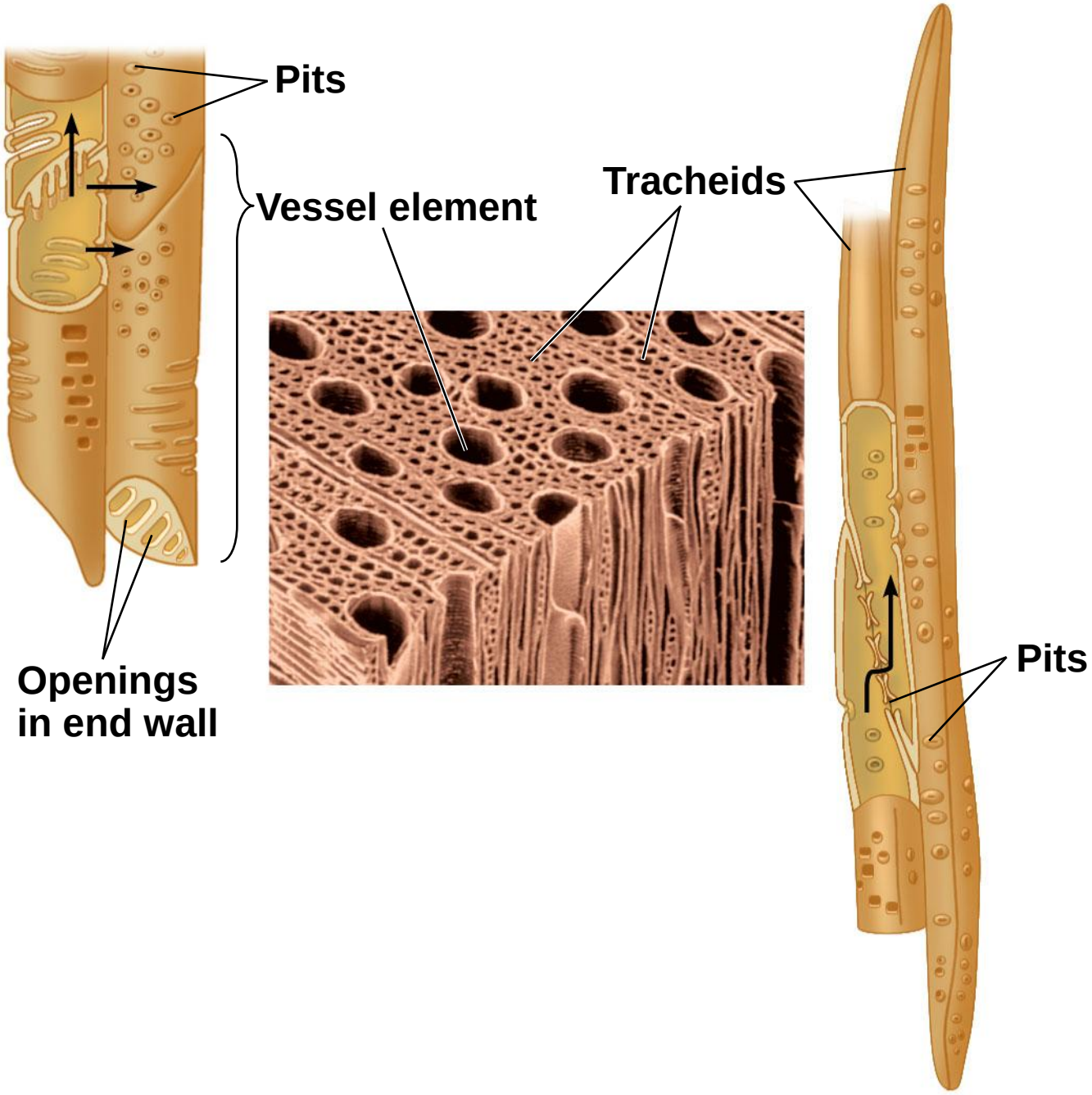
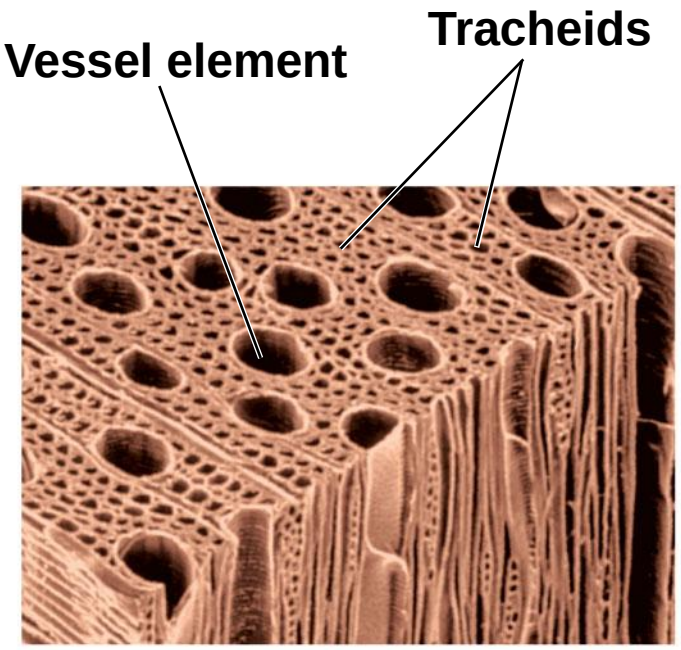


Figure 31.6E_1



31.6 Plant cells are diverse in structure and function

- Food-conducting cells known as **sieve-tube elements** (or members)
  - remain alive at maturity but lack most organelles and
  - have end walls, called **sieve plates**, with pores that allow fluid to flow from cell to cell along the sieve tube.
- Alongside each sieve-tube element is at least one **companion cell**, which is connected to surrounding sieve-tube elements by numerous plasmodesmata. Companion cells produce and transport proteins to sieve-tube elements.

Figure 31.6F

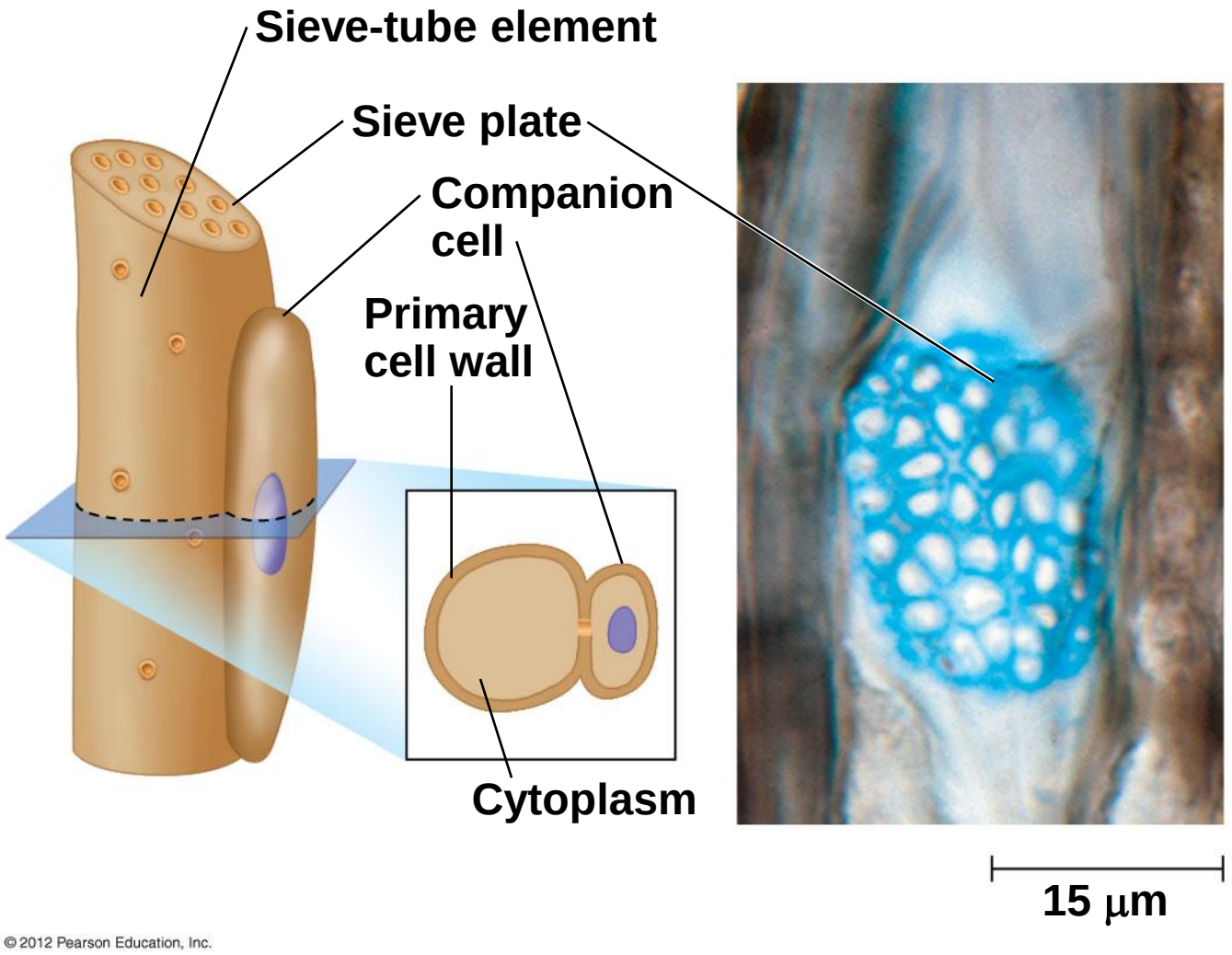
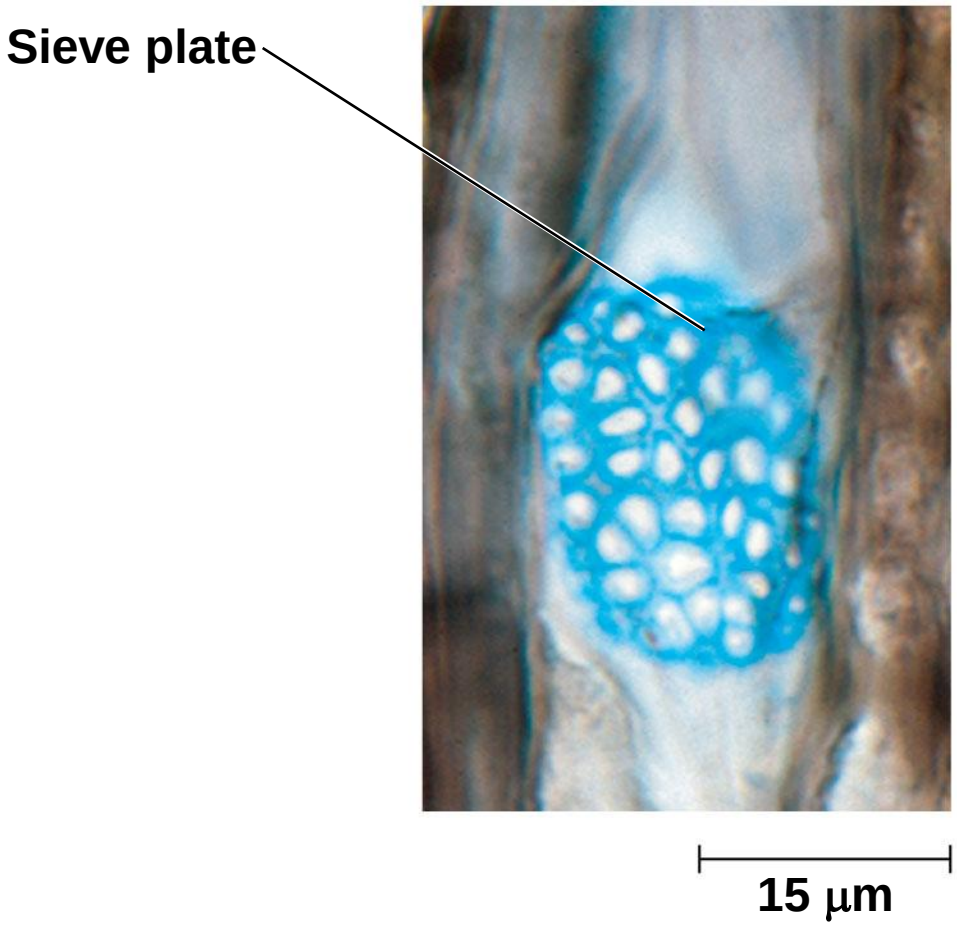


Figure 31.6F_1



PLANT GROWTH

31.7 Primary growth lengthens roots and shoots

- Animal growth is **determinate**, stopping after a certain size is reached.
- Plant growth is **indeterminate**, continuing throughout a plant's life.
- Plants are categorized based on how long they live.
  - **Annuals** complete their life cycle in one year.
  - **Biennials** complete their life cycle in two years.
  - **Perennials** live for many years.

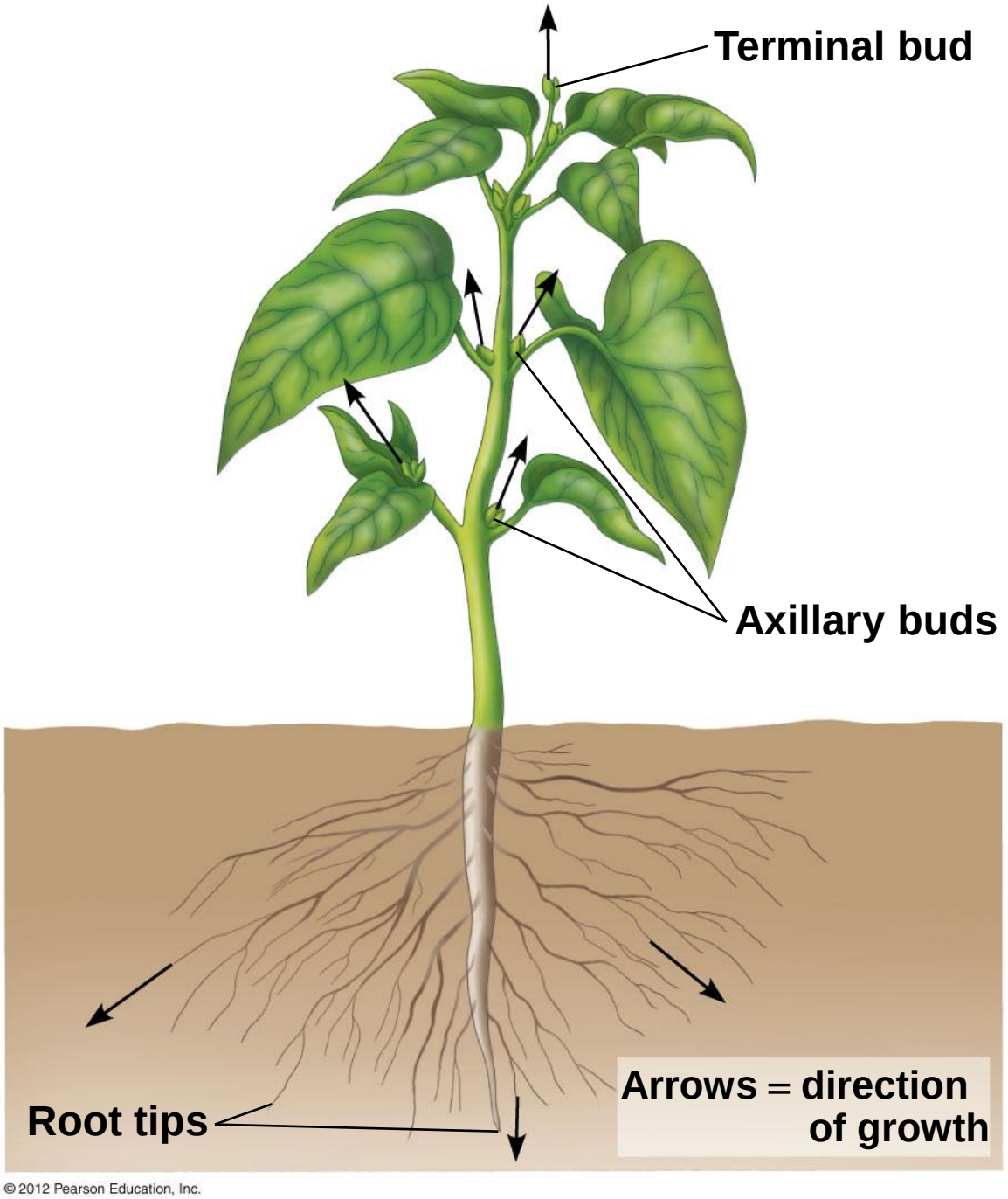
31.7 Primary growth lengthens roots and shoots

- Plant growth occurs in specialized tissues called **meristems**, consisting of undifferentiated cells that divide when conditions permit.
- **Apical meristems** are found at the tips of roots and shoots.
- **Primary growth**
  - occurs at apical meristems,
  - allows roots to push downward through the soil, and
  - allows shoots to grow upward toward the sun.

PLAY

Video: Root Growth in a Radish Seed (time lapse)

Figure 31.7A



31.7 Primary growth lengthens roots and shoots

- The apical meristems of root tips are covered by a **root cap**.
- Root growth occurs behind the root cap in three zones.
  1. Zone of cell division includes the apical meristem and cells derived from it.
  2. Zone of cell elongation, where cells lengthen by as much as 10 times.
  3. Zone of differentiation, where cells differentiate into dermal, vascular, and ground tissues, including the formation of **primary xylem** and **primary phloem**.

Figure 31.7B

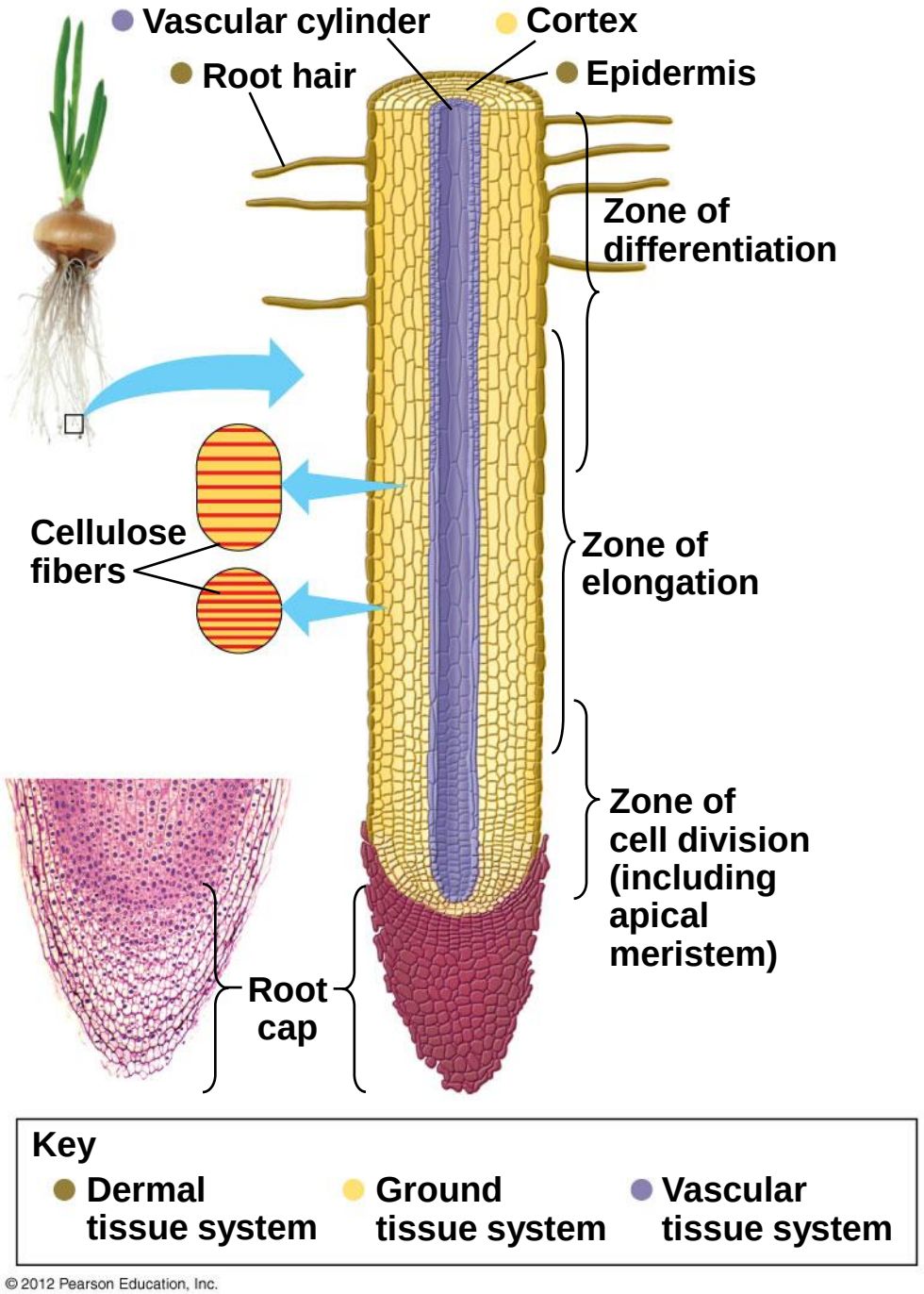
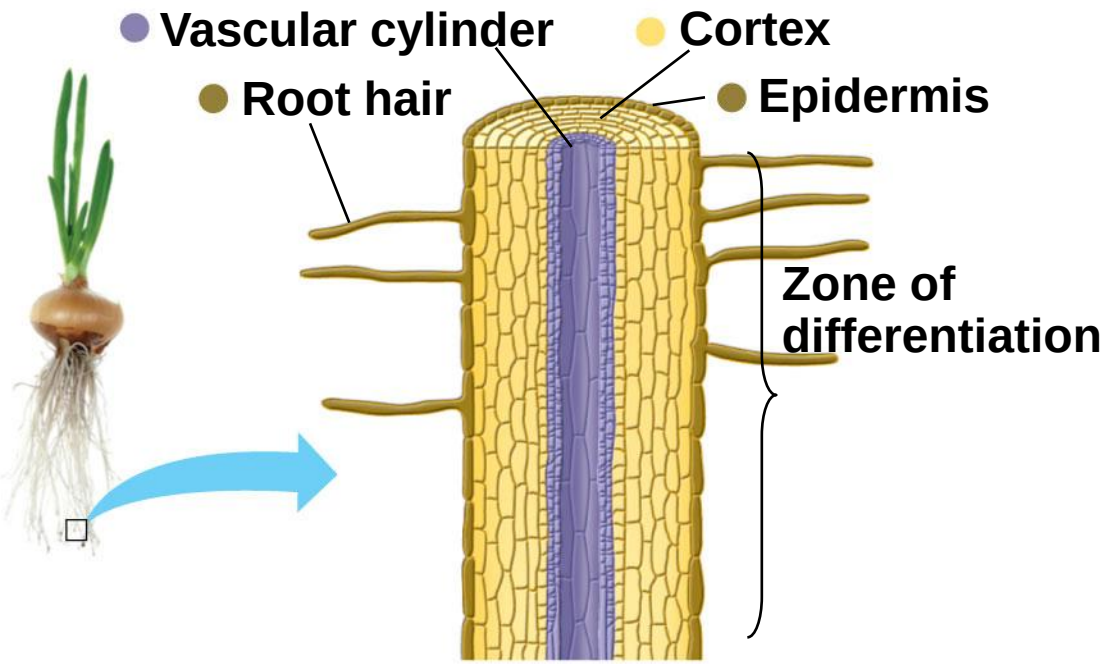


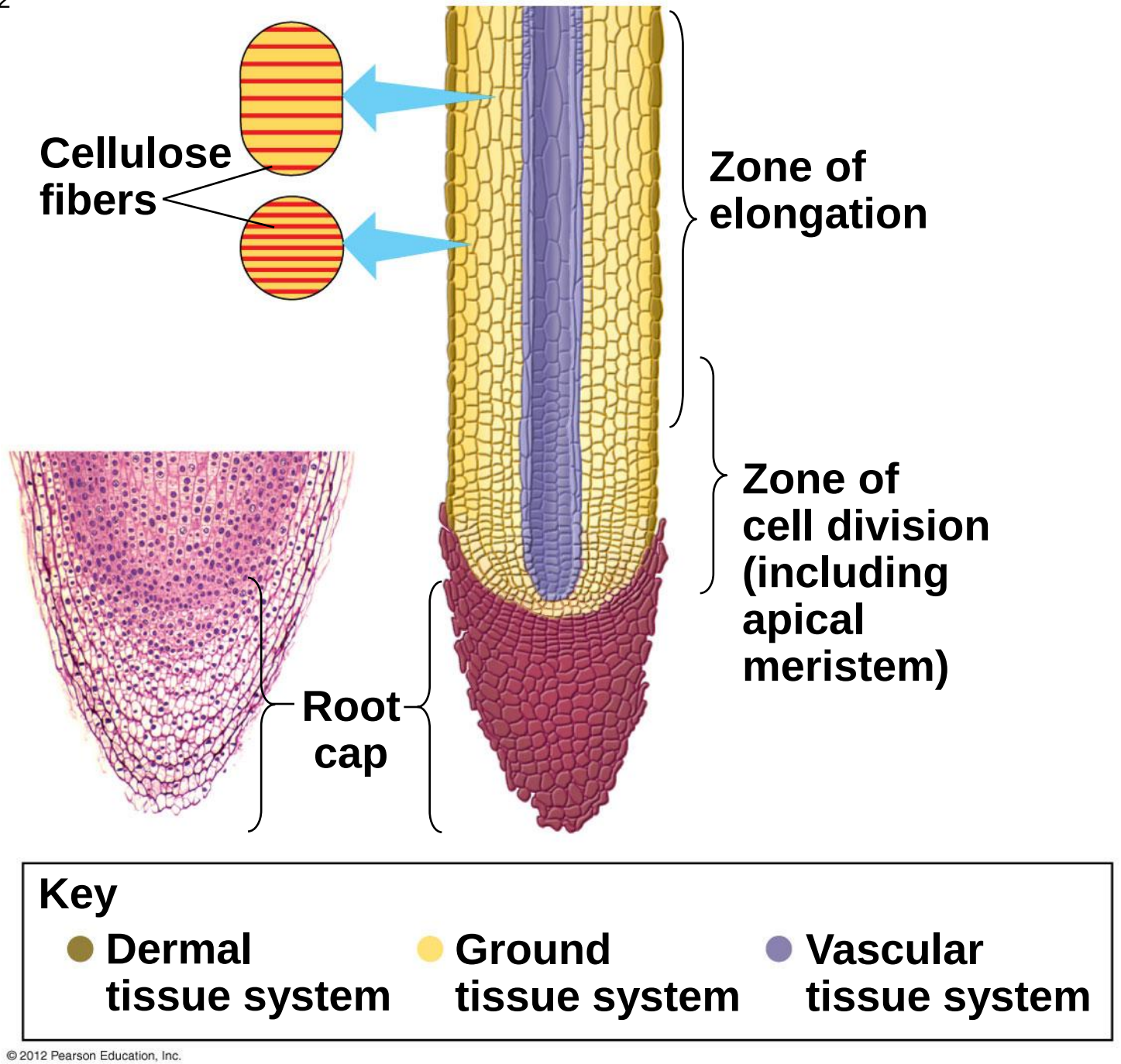
Figure 31.7B_1



Key

- Dermal tissue system
- Ground tissue system
- Vascular tissue system

Figure 31.7B_2



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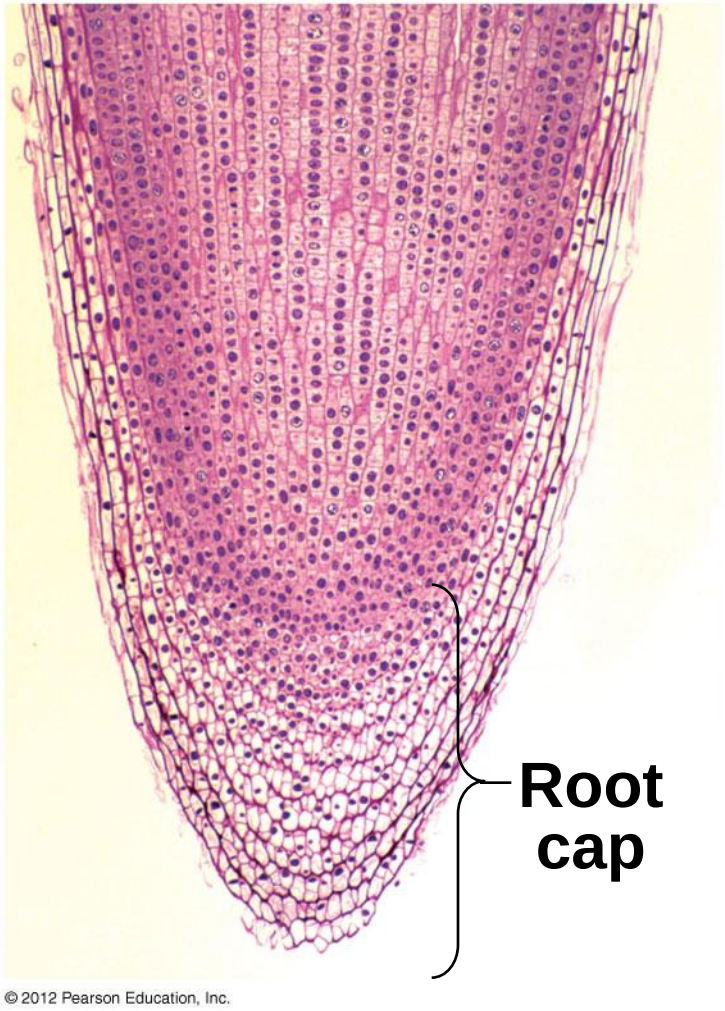
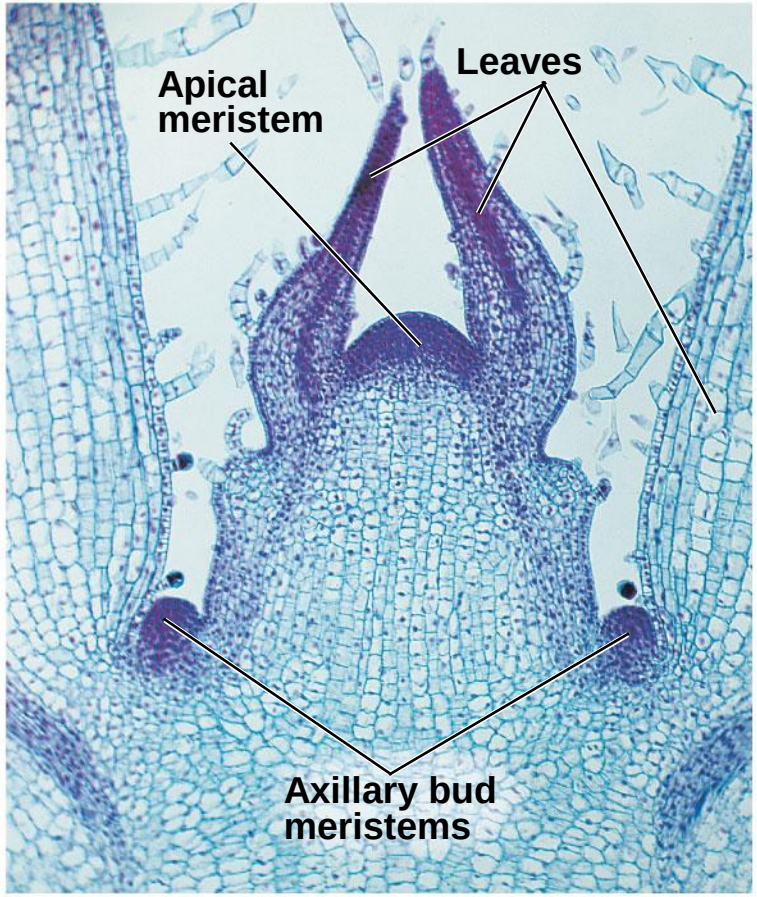
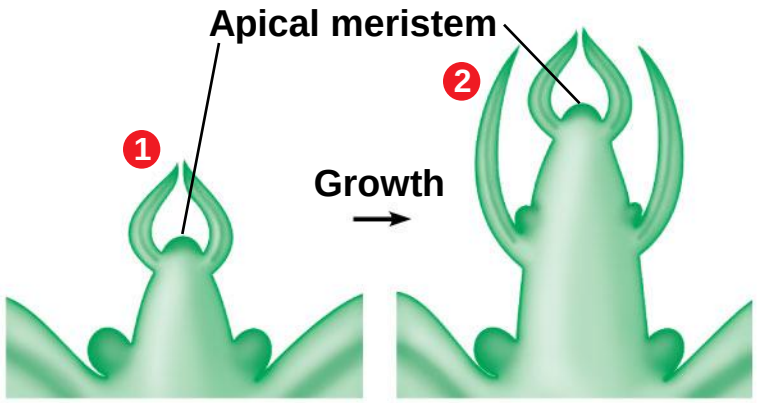


Figure 31.7C





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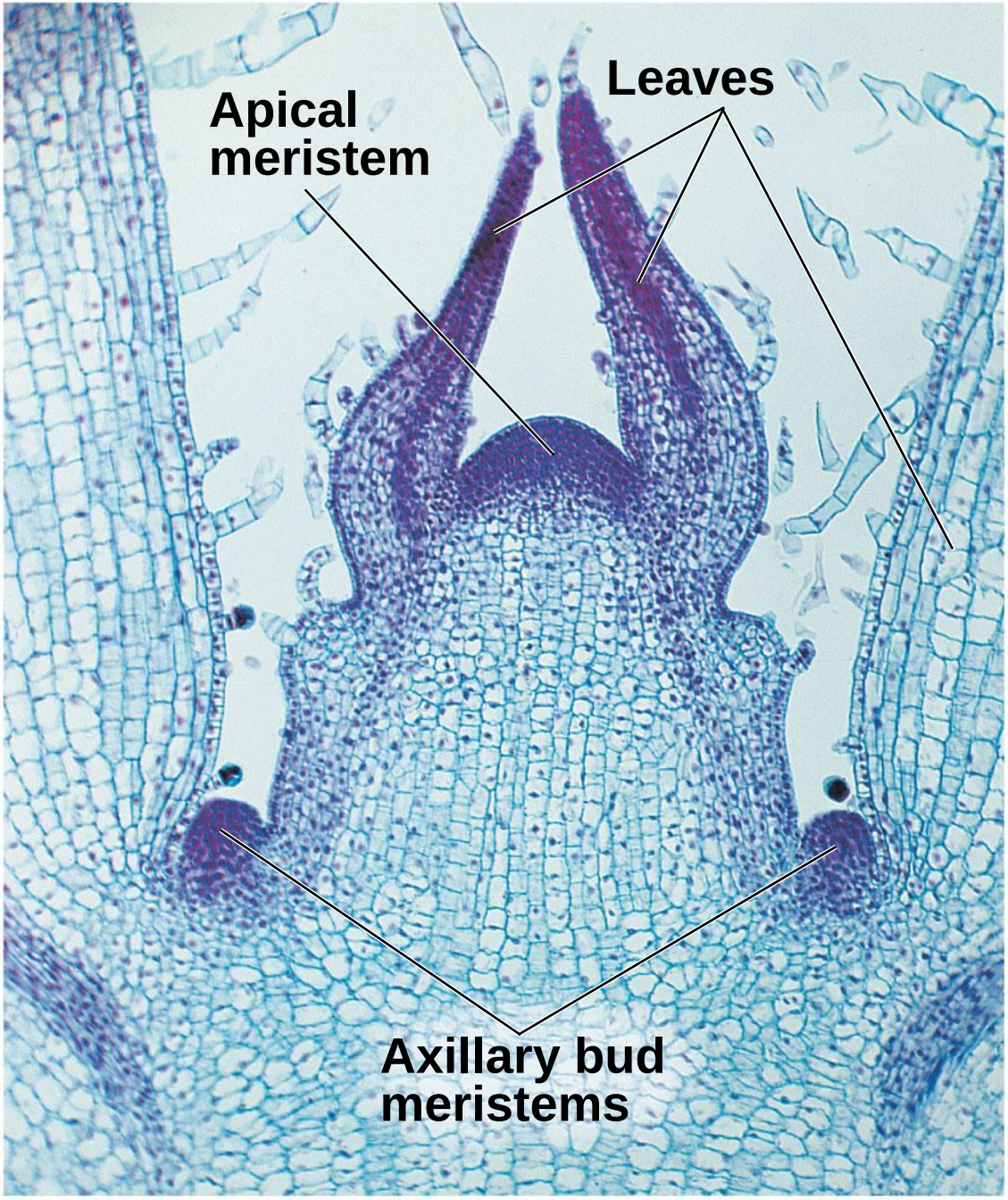

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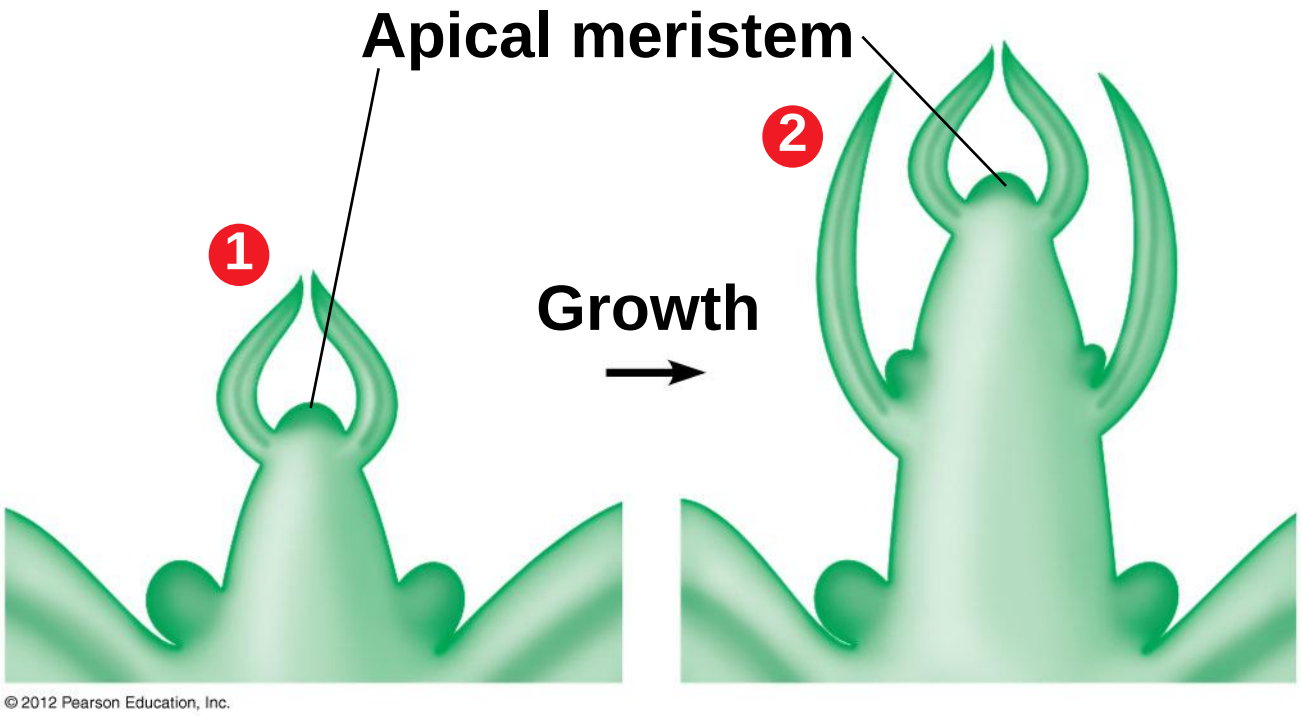


31.8 Secondary growth increases the diameter of woody plants

- **Secondary growth**
  - is an increase in thickness of stems and roots and
  - occurs at lateral meristems.
- **Lateral meristems** are areas of active cell division that exist in two cylinders that extend along the length of roots and shoots.
  1. **Vascular cambium** is a lateral meristem that lies between primary xylem and primary phloem.
  2. **Cork cambium** is a lateral meristem that lies at the outer edge of the stem cortex.

31.8 Secondary growth increases the diameter of woody plants

- Vascular cambium produces cells in two directions.
  1. **Secondary xylem** produces **wood** toward the interior of the stem.
  2. **Secondary phloem** produces the inner bark toward the exterior of the stem.
- **Cork cambium** produces
  - cells in one direction,
  - the outer **bark**, which is composed of cork cells.

Figure 31.8A

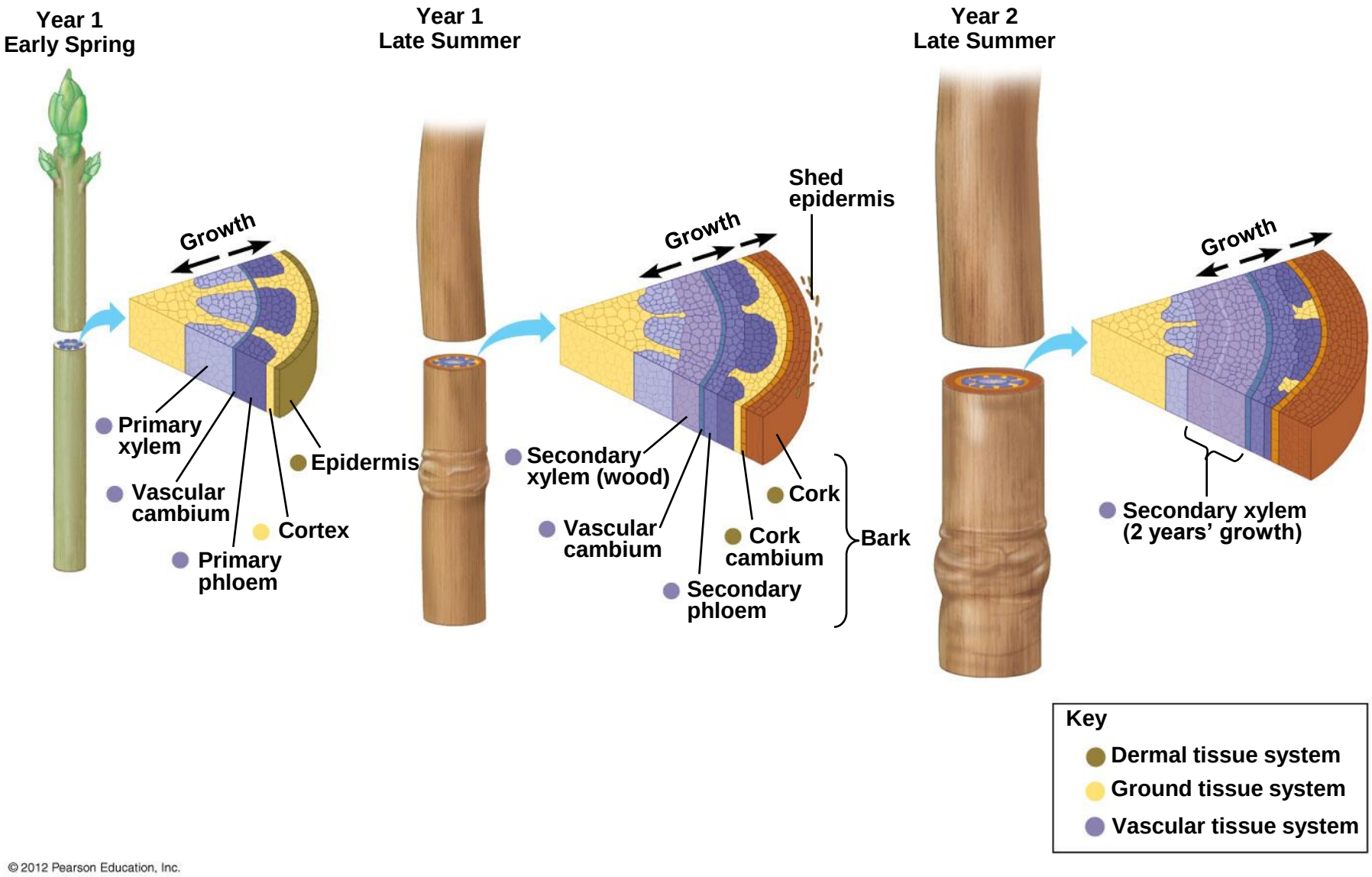
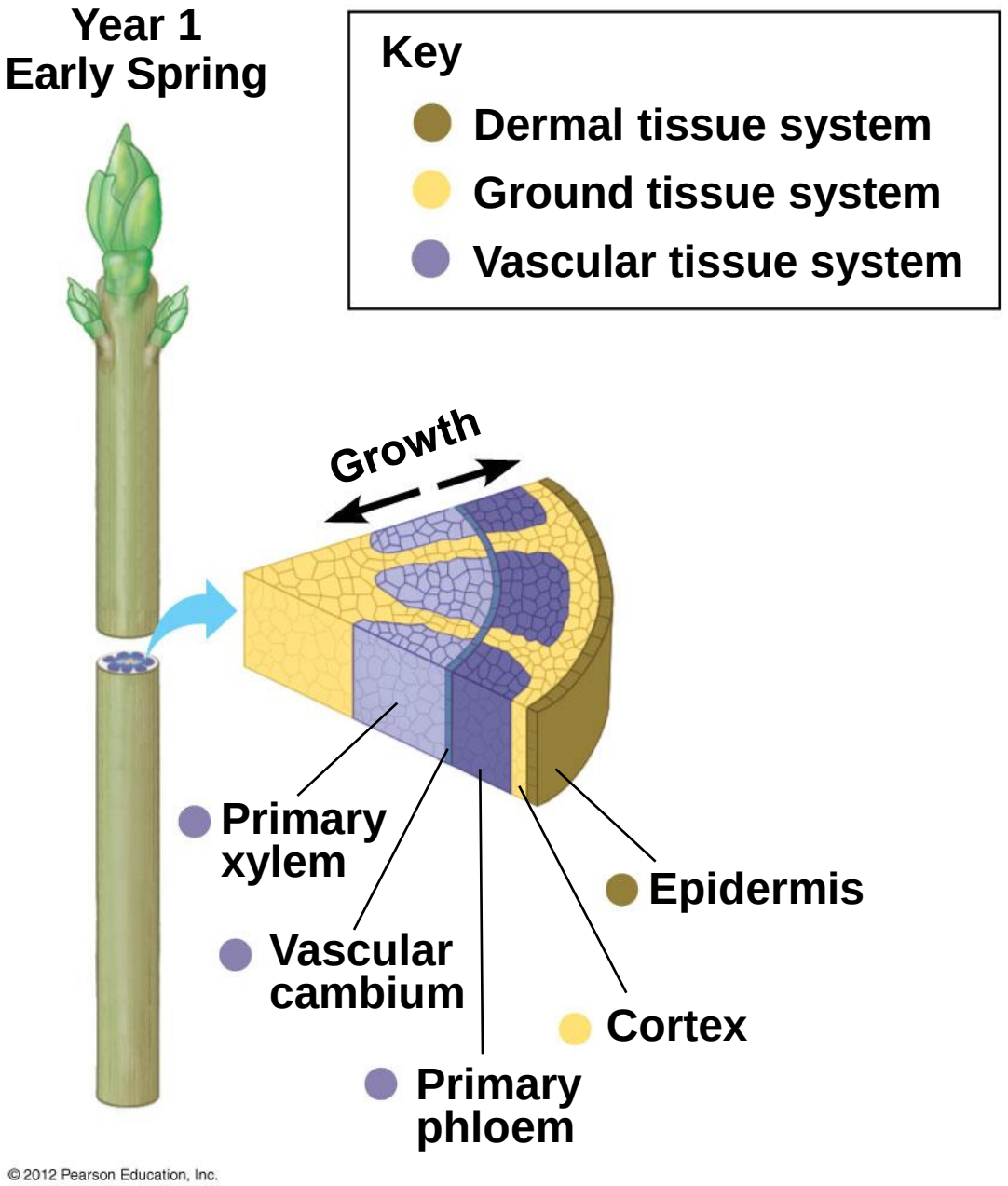


Figure 31.8A_1



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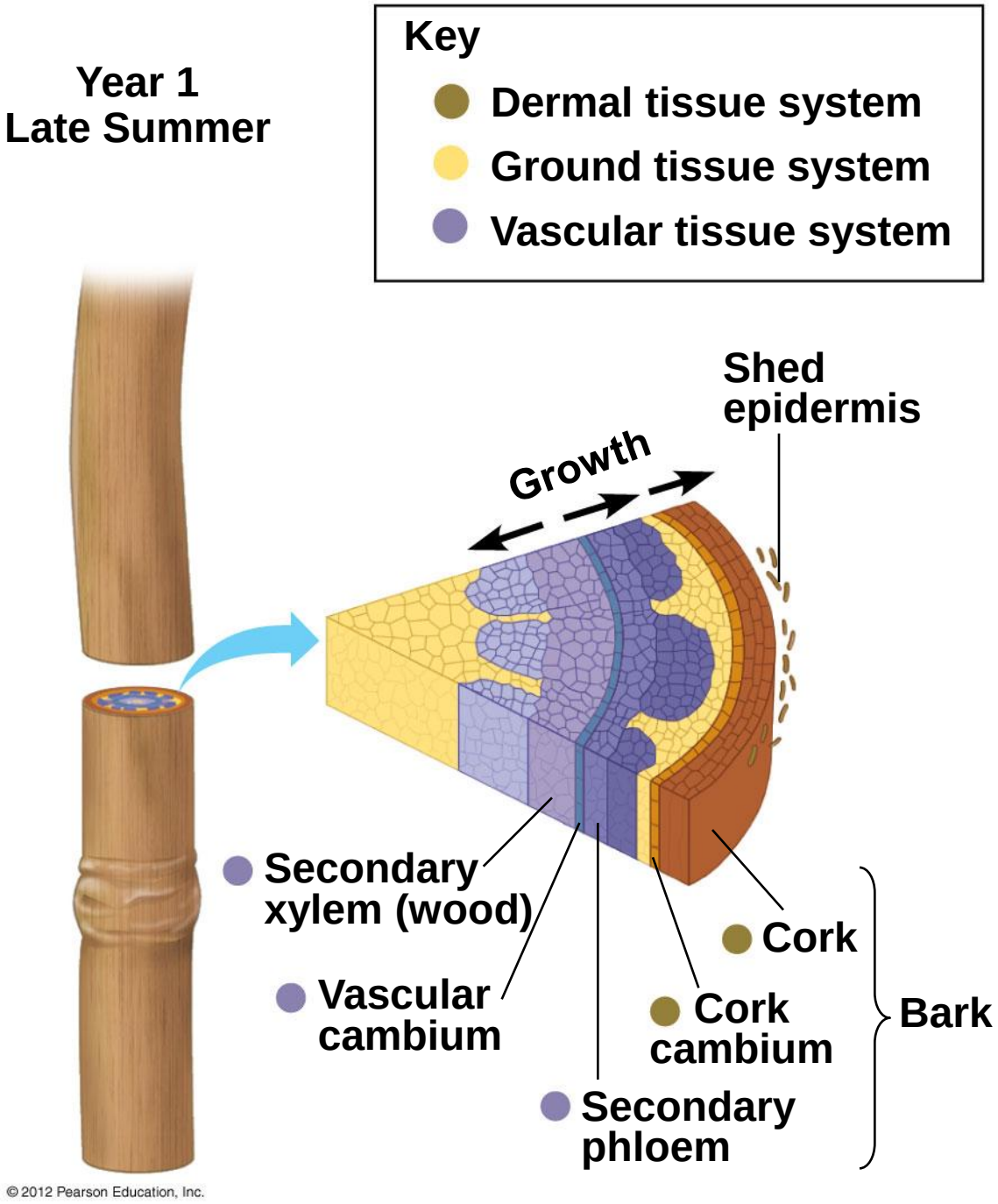

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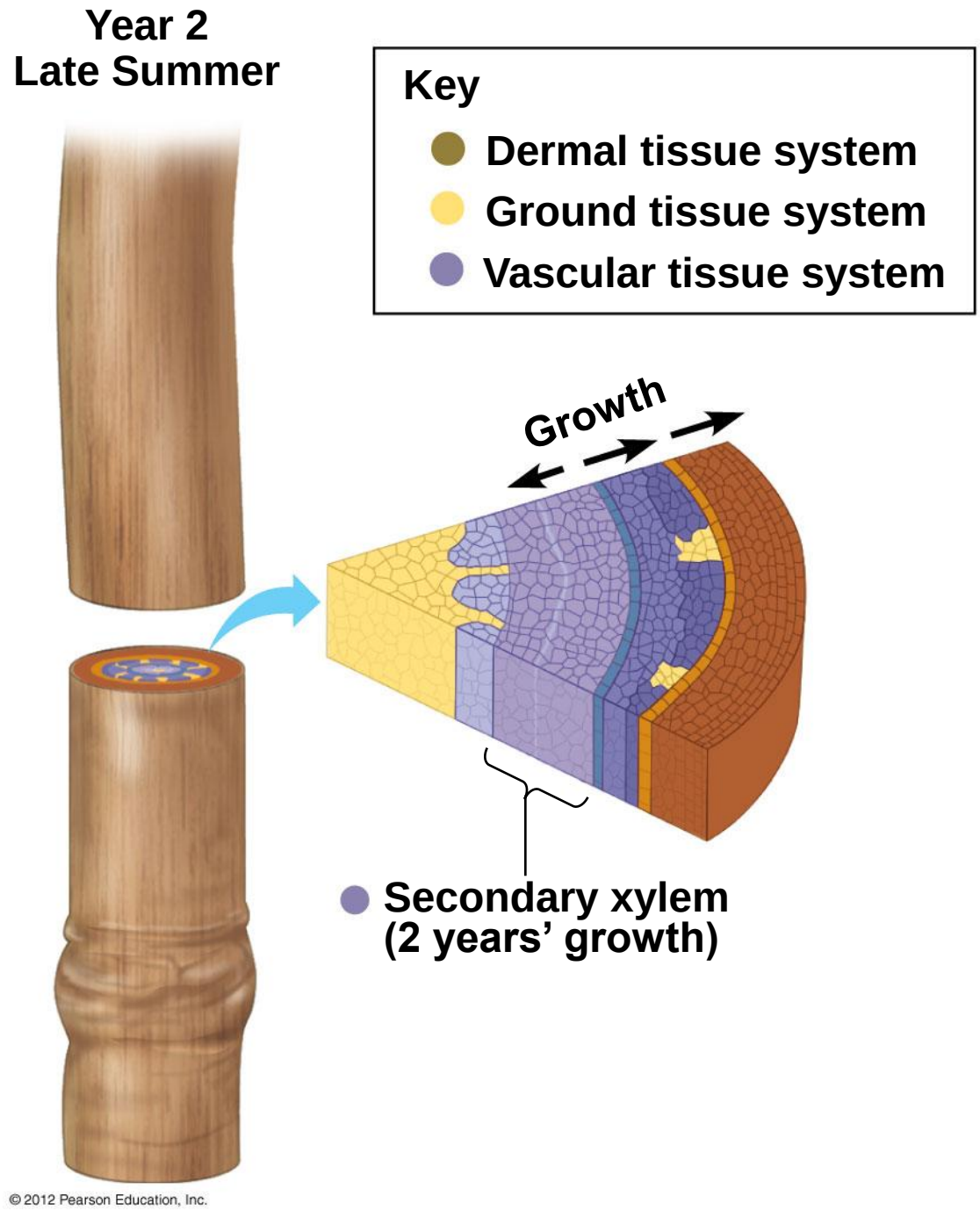


31.8 Secondary growth increases the diameter of woody plants

- Wood annual rings show layers of secondary xylem.
  - In temperate regions, periods of dormancy stop growth of secondary xylem.
  - Rings occur in areas when new growth starts each year.
- The bark (secondary phloem and cork) is sloughed off over time.

31.8 Secondary growth increases the diameter of woody plants

- **Wood rays**
  - consist of parenchyma cells that radiate from the stem's center and
  - function in
    - lateral transport of water and nutrients,
    - storage of starch, and
    - wound repair.

31.8 Secondary growth increases the diameter of woody plants

- Most transport occurs near the vascular cambium.
  - **Sapwood** near the vascular cambium conducts xylem sap.
  - **Heartwood** consists of older layers of secondary xylem that no longer transports water and instead stores resins and wastes.
  - Secondary phloem near the vascular cambium transports sugars.

Figure 31.8B

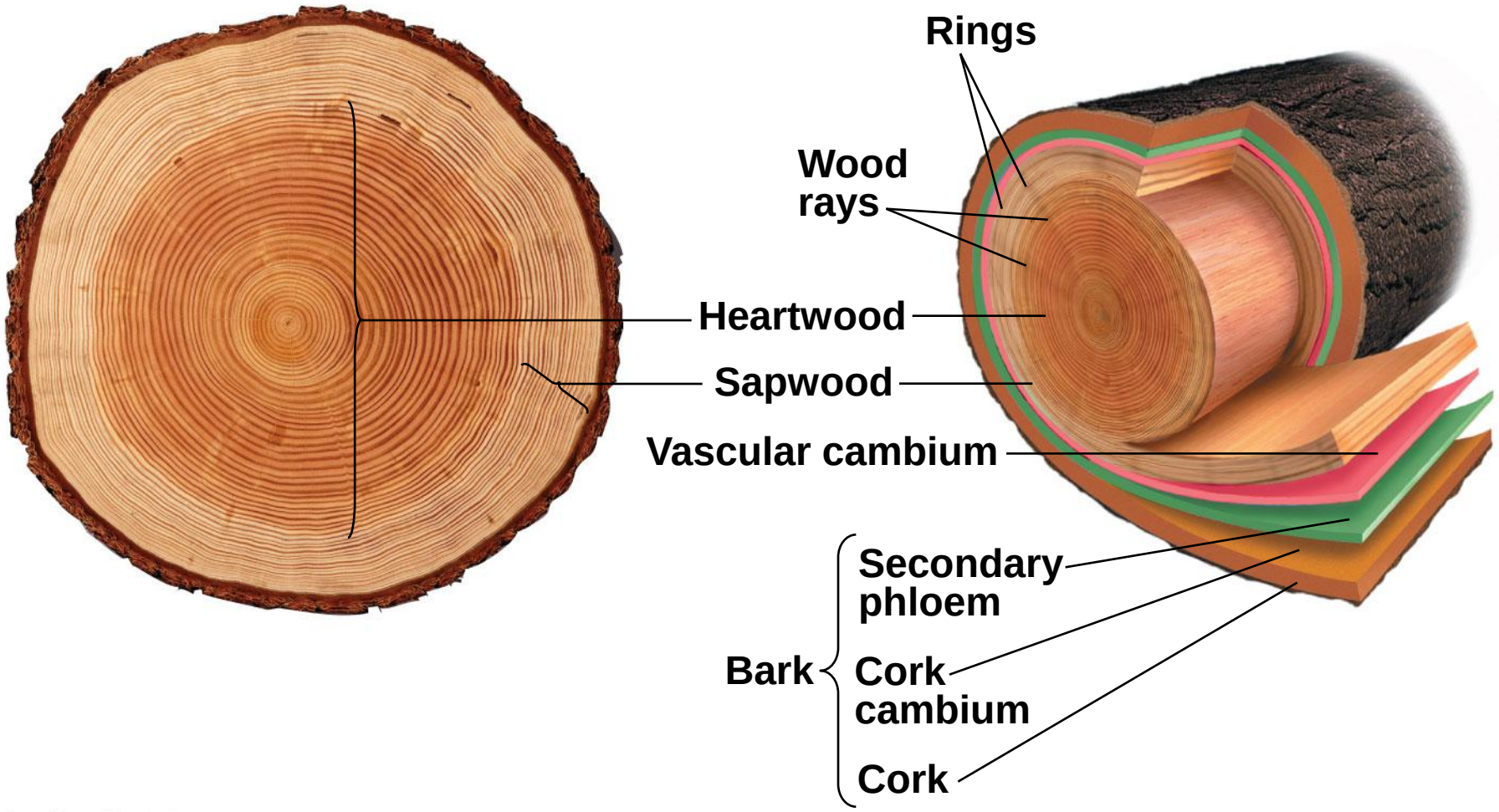
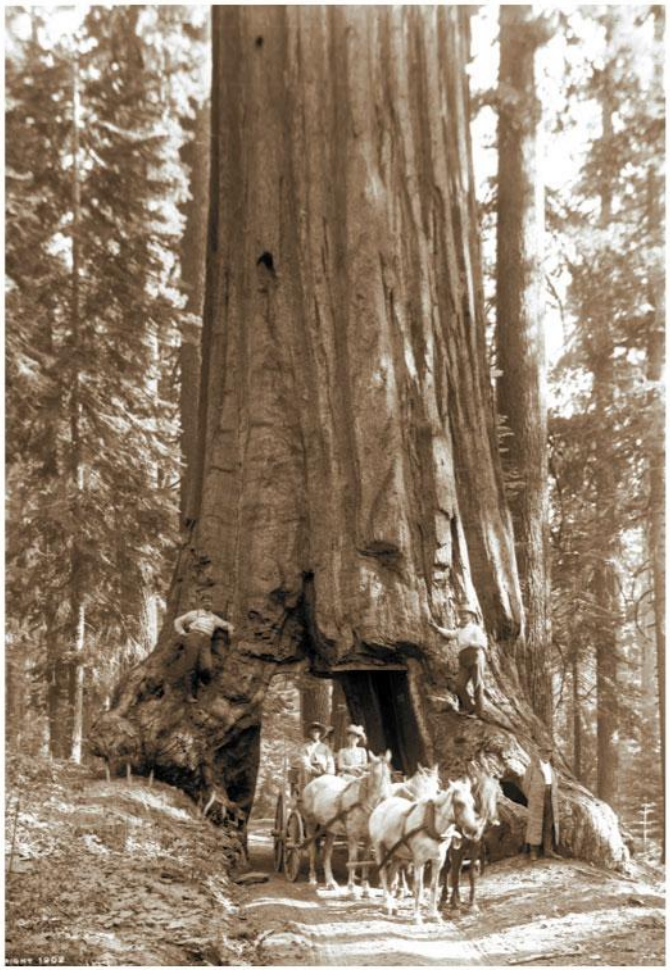


Figure 31.8C



REPRODUCTION OF FLOWERING PLANTS

31.9 The flower is the organ of sexual reproduction in angiosperms

- Flowers typically contain four types of highly modified leaves called floral organs.
  1. **Sepals** enclose and protect a flower bud.
  2. **Petals** are showy and attract pollinators.
  3. **Stamens** are male reproductive structures.
  4. **Carpels** are female reproductive structures.

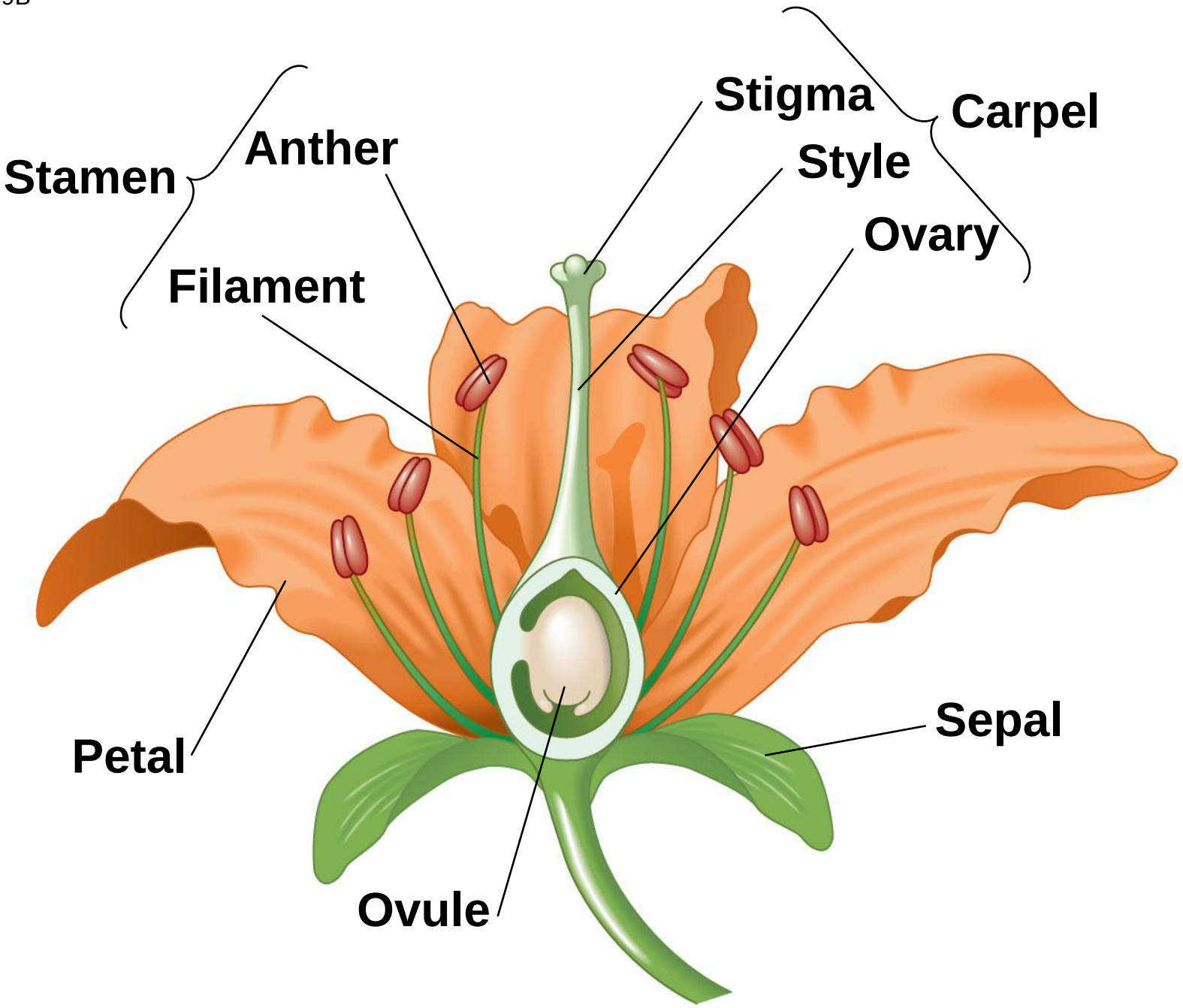
31.9 The flower is the organ of sexual reproduction in angiosperms

- A **stamen** has two parts.
  1. An **anther** produces pollen, which house cells that develop into sperm.
  2. A stalk (filament) elevates the anther.
- A **carpel** has three parts.
  1. The **stigma** is the landing platform for pollen.
  2. The **ovary** houses one or more **ovules**, in which each ovule contains a developing egg and supporting cells.
  3. A slender neck (style) leads to an ovary.

Video: Flower Blooming (time lapse)

Figure 31.9A

Figure 31.9B



31.9 The flower is the organ of sexual reproduction in angiosperms

- The term **pistil** is sometimes used to refer to a single carpel or a group of fused carpels.
- In the life cycle of a generalized angiosperm,
  - fertilization occurs in an ovule,
  - the ovary develops into a fruit,
  - the ovule develops into the seed containing the embryo,
  - the seed **germinates** in a suitable habitat, and
  - the embryo develops into a seedling and then mature plant.

PLAY

Video: Flowering Plant Life (time lapse)

Figure 31.9C_s1

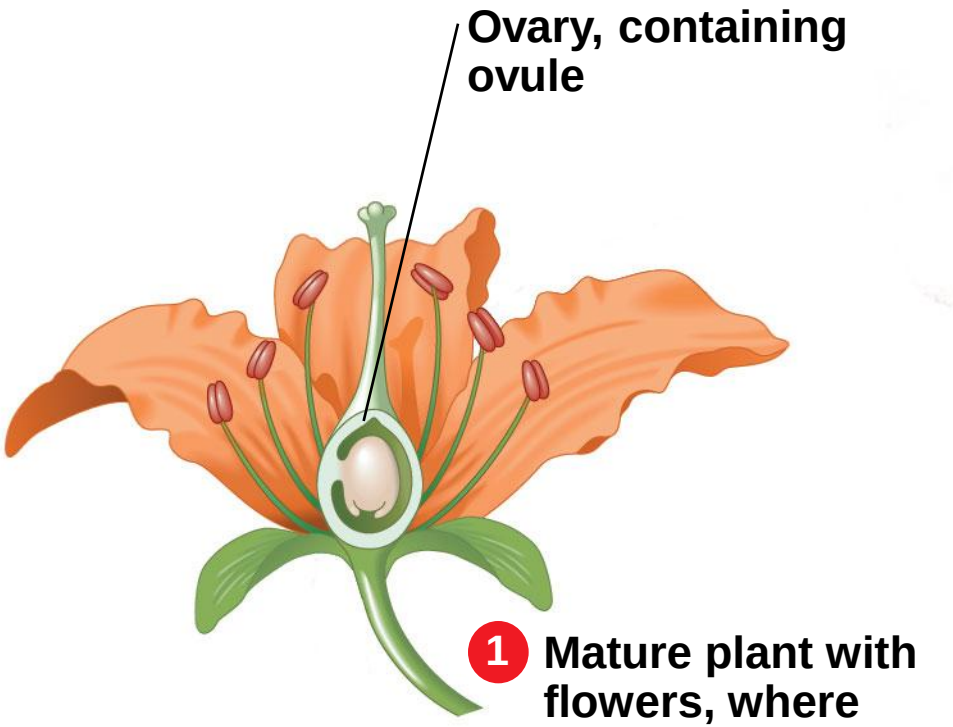


Figure 31.9C_s2

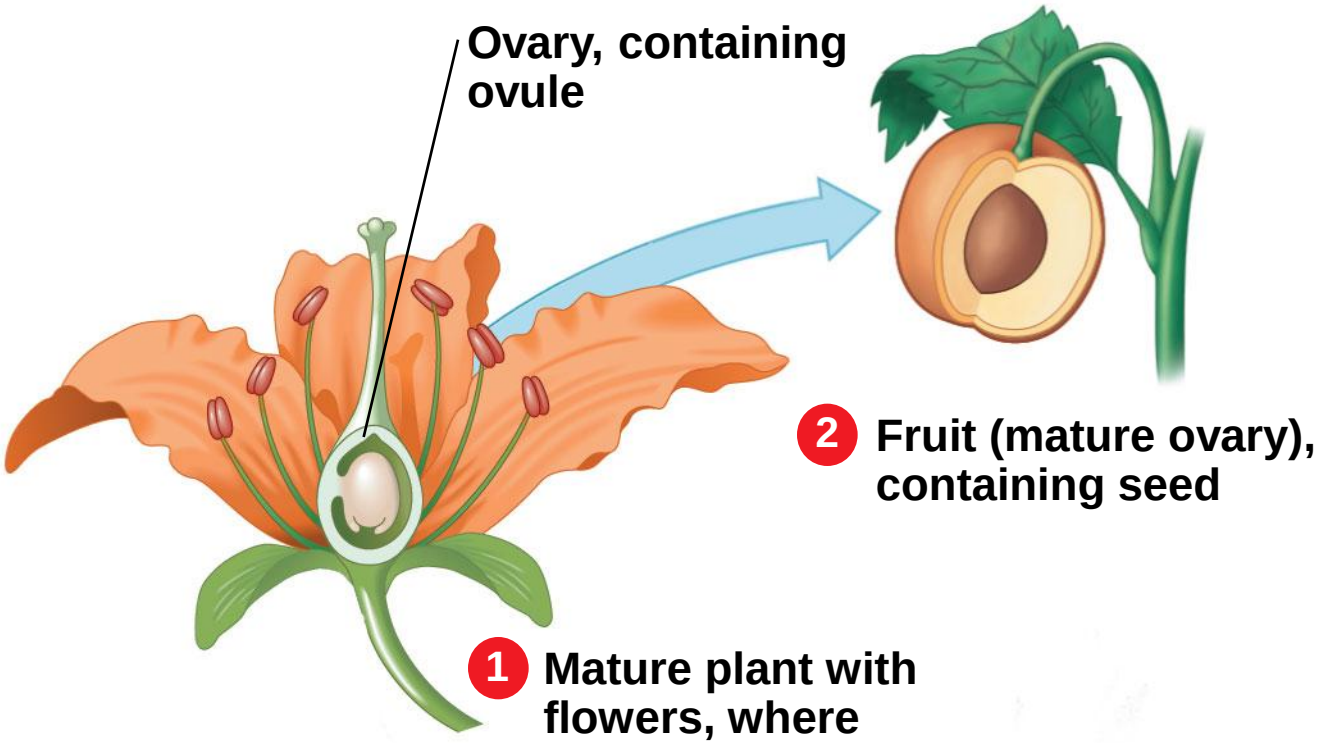


Figure 31.9C_s3

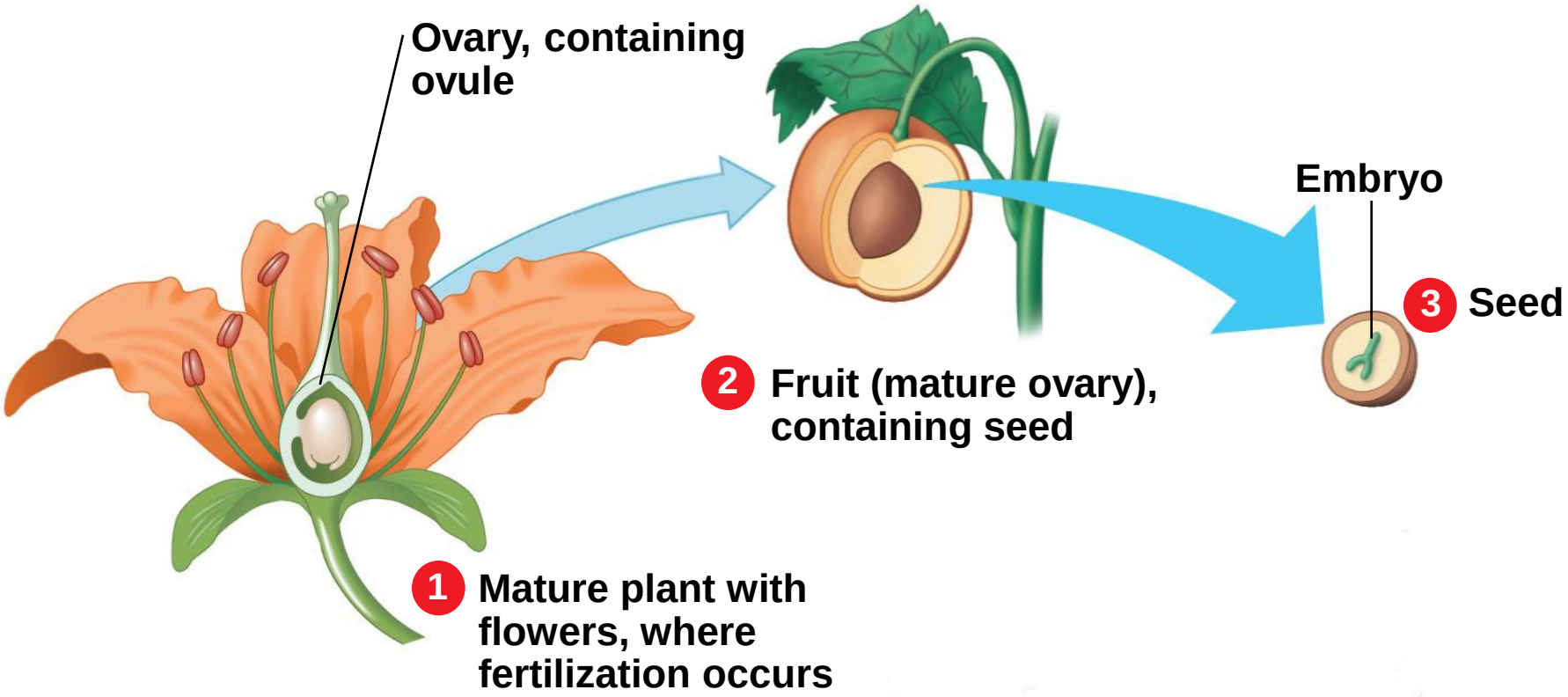


Figure 31.9C_s4

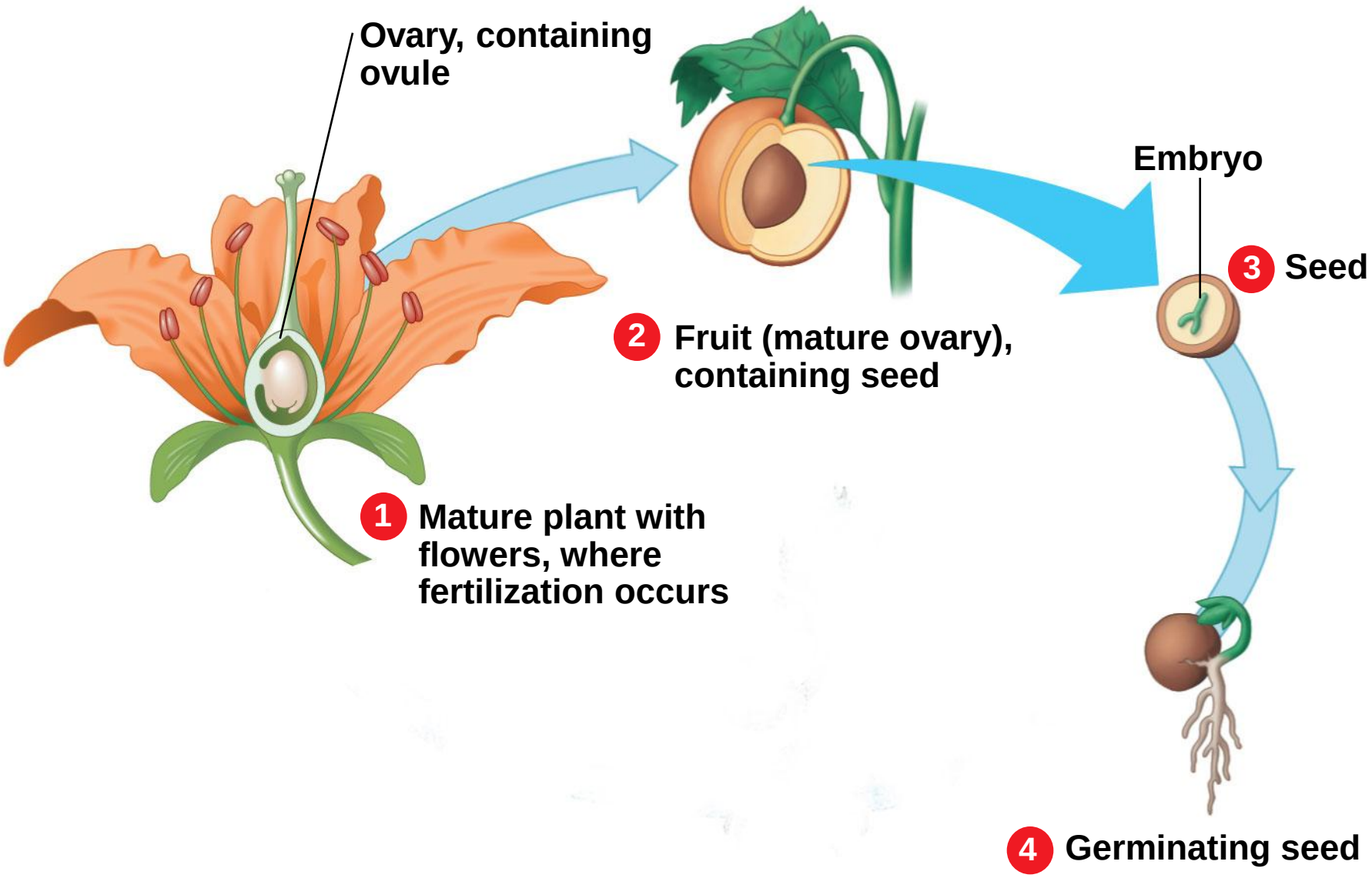
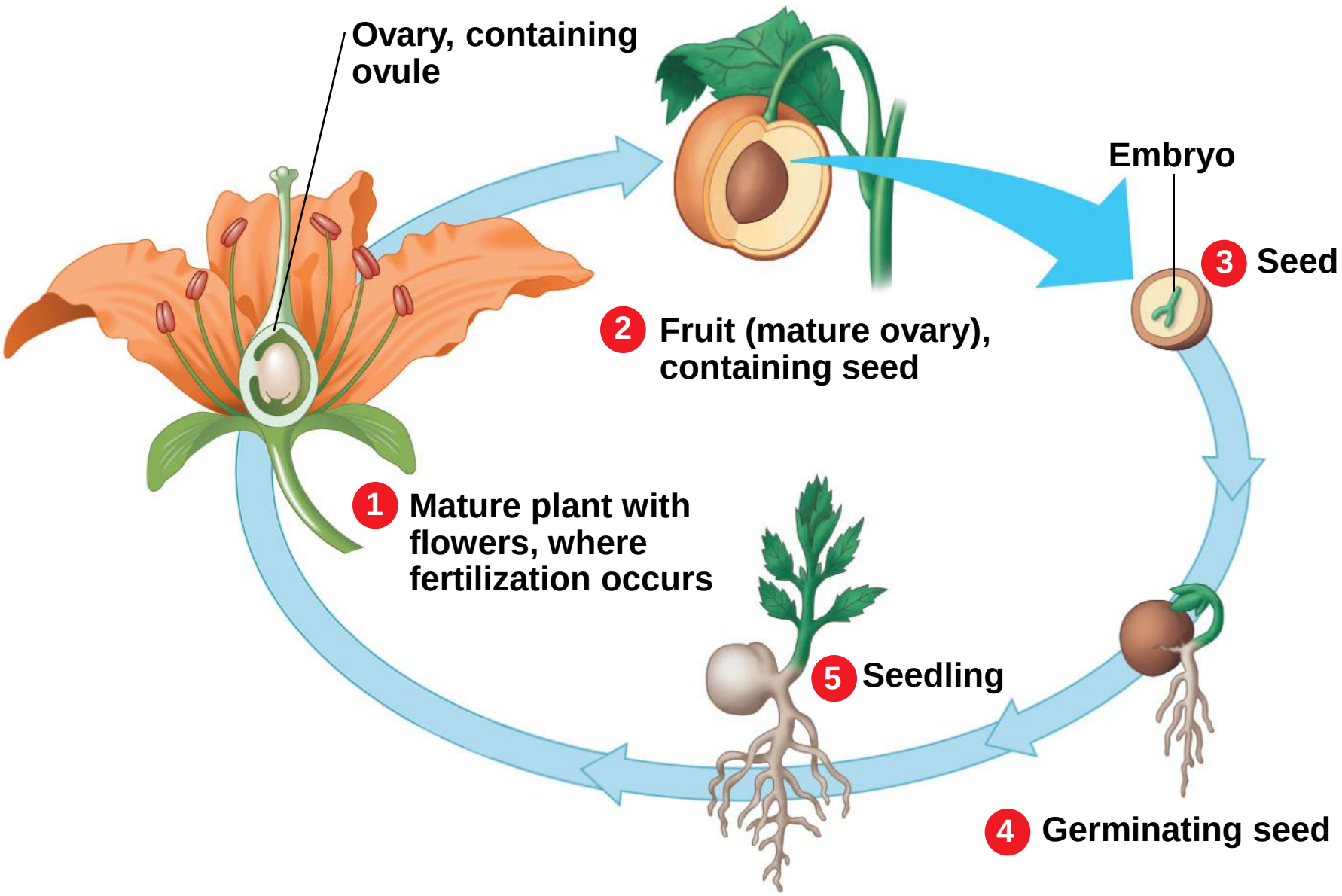


Figure 31.9C_s5



31.10 The development of pollen and ovules culminates in fertilization

- Plant life cycles involve alternating diploid (2*n*) and haploid (*n*) generations.
  - The diploid generation is called the **sporophyte**.
    - Specialized diploid cells in anthers and ovules undergo meiosis to produce haploid spores.
    - The haploid spores undergo mitosis and produce the haploid generation.
  - The haploid generation is called the **gametophyte**, which produces gametes via mitosis.
  - At fertilization, gametes from male and female gametophytes unite to produce a diploid zygote.

31.10 The development of pollen and ovules culminates in fertilization

- Pollen grains are the male gametophytes.
  - A cell in the anther undergoes meiosis to produce four haploid spores.
  - Each spore then divides via mitosis to produce two cells:
    1. the tube cell and
    2. generative cell.
  - A tough wall forms around the cells to produce a pollen grain.
  - Pollen grains are released from the anther.

31.10 The development of pollen and ovules culminates in fertilization

- The female gametophyte is an **embryo sac**.
  - A cell in the ovule undergoes meiosis to produce four haploid spores.
  - Three of the spores degenerate.
  - The surviving spore undergoes a series of mitotic divisions to produce the embryo sac.
  - One cell within the embryo sac is a haploid egg ready to be fertilized.
  - One central cell within the embryo sac has two nuclei and will produce **endosperm**.

31.10 The development of pollen and ovules culminates in fertilization

- **Pollination** is the transfer of pollen from anther to stigma.
- Pollen may be carried by wind, water, and animals.
- As a pollen grain germinates,
  - the tube cell gives rise to the pollen tube, which grows downward into the ovary, and
  - the generative cell divides by mitosis, producing two sperm.

31.10 The development of pollen and ovules culminates in fertilization

- At fertilization,
  - one sperm fertilizes the haploid egg to produce a diploid zygote, and
  - another sperm fuses with the diploid central cell nucleus to produce a triploid (3*n*) cell that will give rise to the **endosperm**, which nourishes the developing embryo.
- This formation of a diploid zygote and a triploid nucleus is called **double fertilization**.

PLAY Video: Bat Pollinating Agave Plant

PLAY Video: Bee Pollinating

PLAY Animation: Plant Fertilization

Figure 31.10

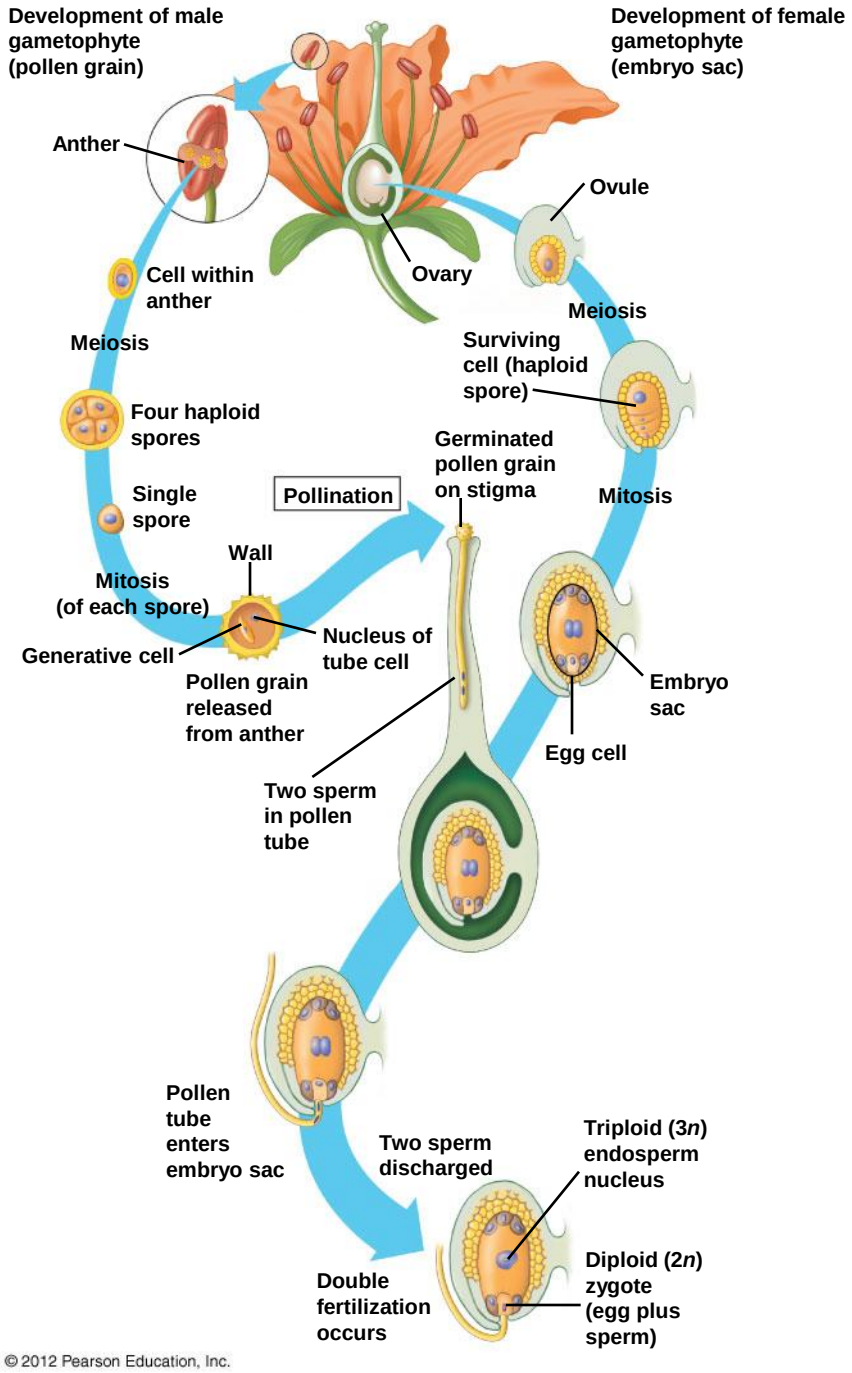


Figure 31.10_1

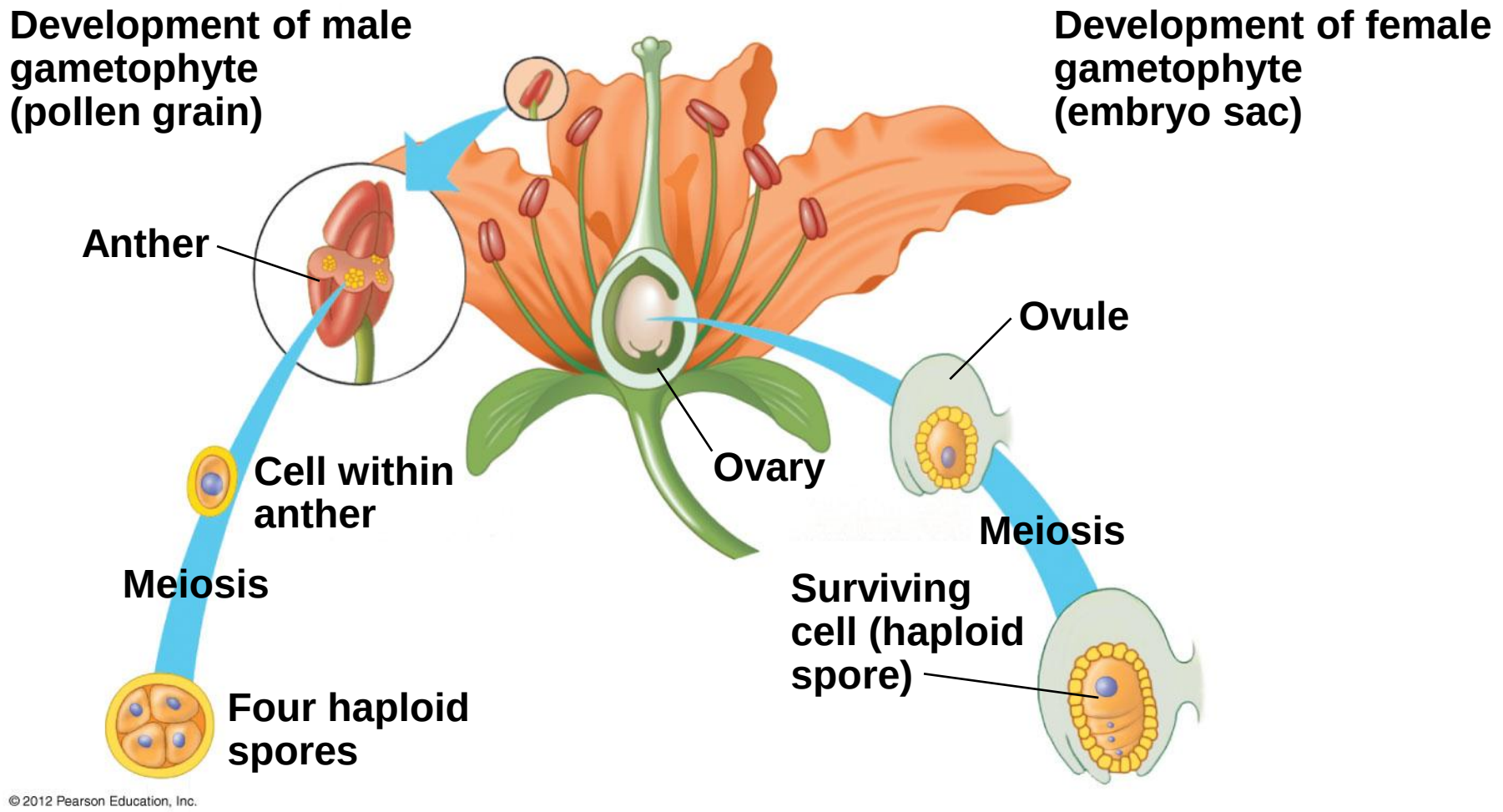


Figure 31.10_2

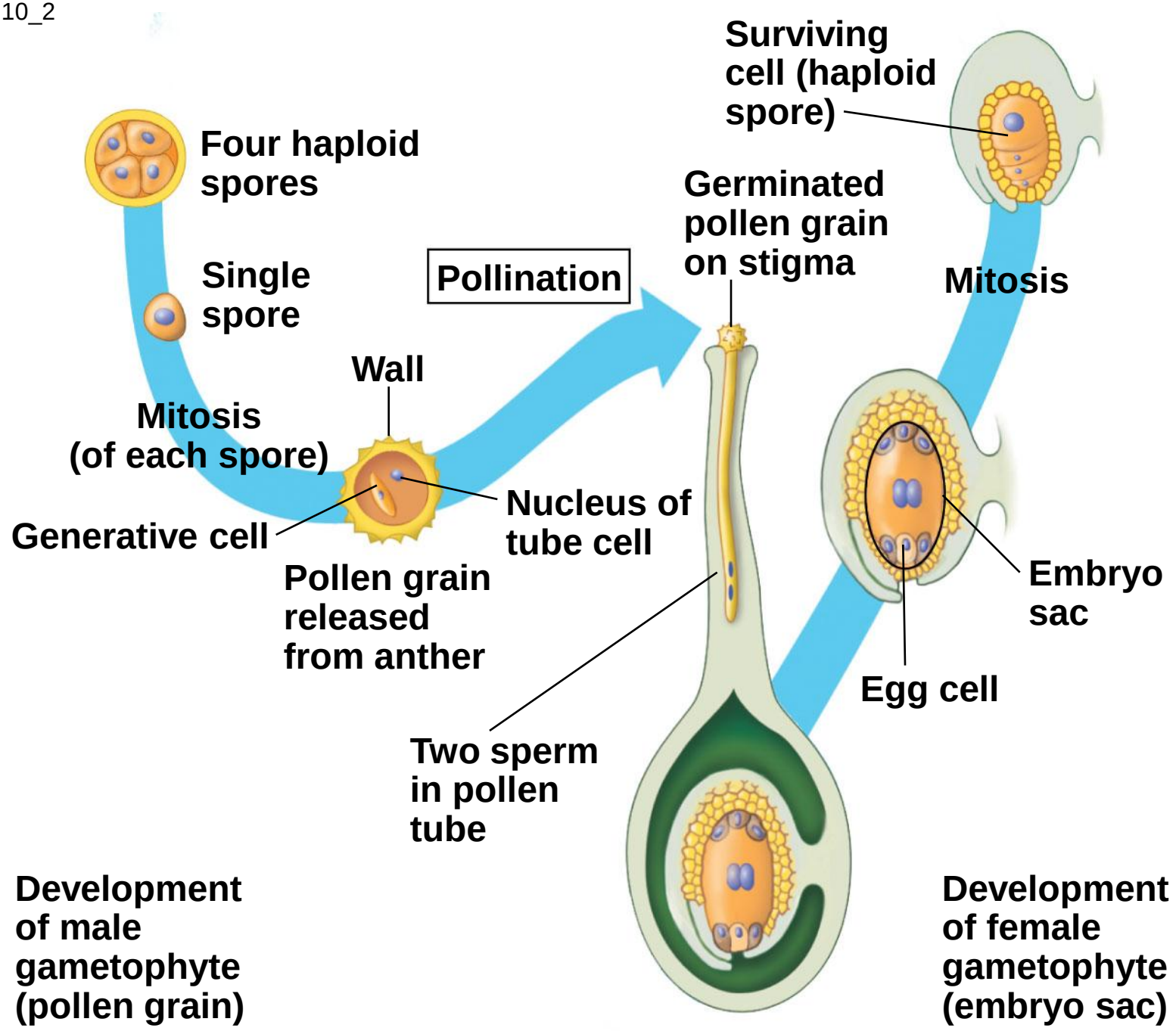
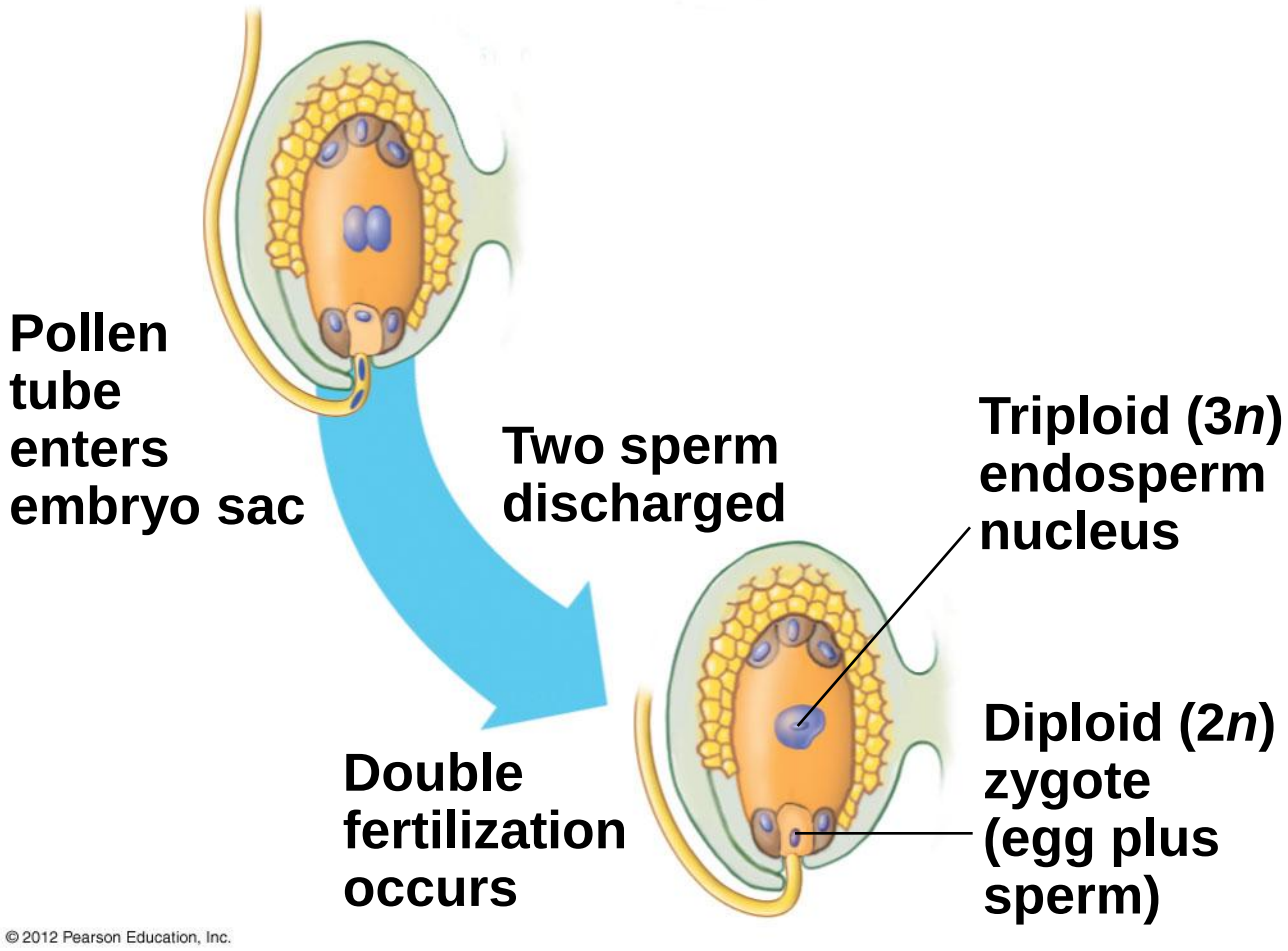


Figure 31.10_3



31.11 The ovule develops into a seed

- After fertilization, the ovule, containing the triploid central cell and the diploid zygote, begins developing into a seed.
- The seed stockpiles proteins, oils, and starches.
- The zygote first divides by mitosis to produce two cells.
  - One cell becomes the embryo.
  - The other cell divides to form a thread of cells that pushes the embryo into the endosperm.

31.11 The ovule develops into a seed

- The result of embryonic development in the ovule is a mature seed, including
  - an endosperm,
  - one or two cotyledons,
  - a root,
  - a shoot, and
  - a tough **seed coat**.

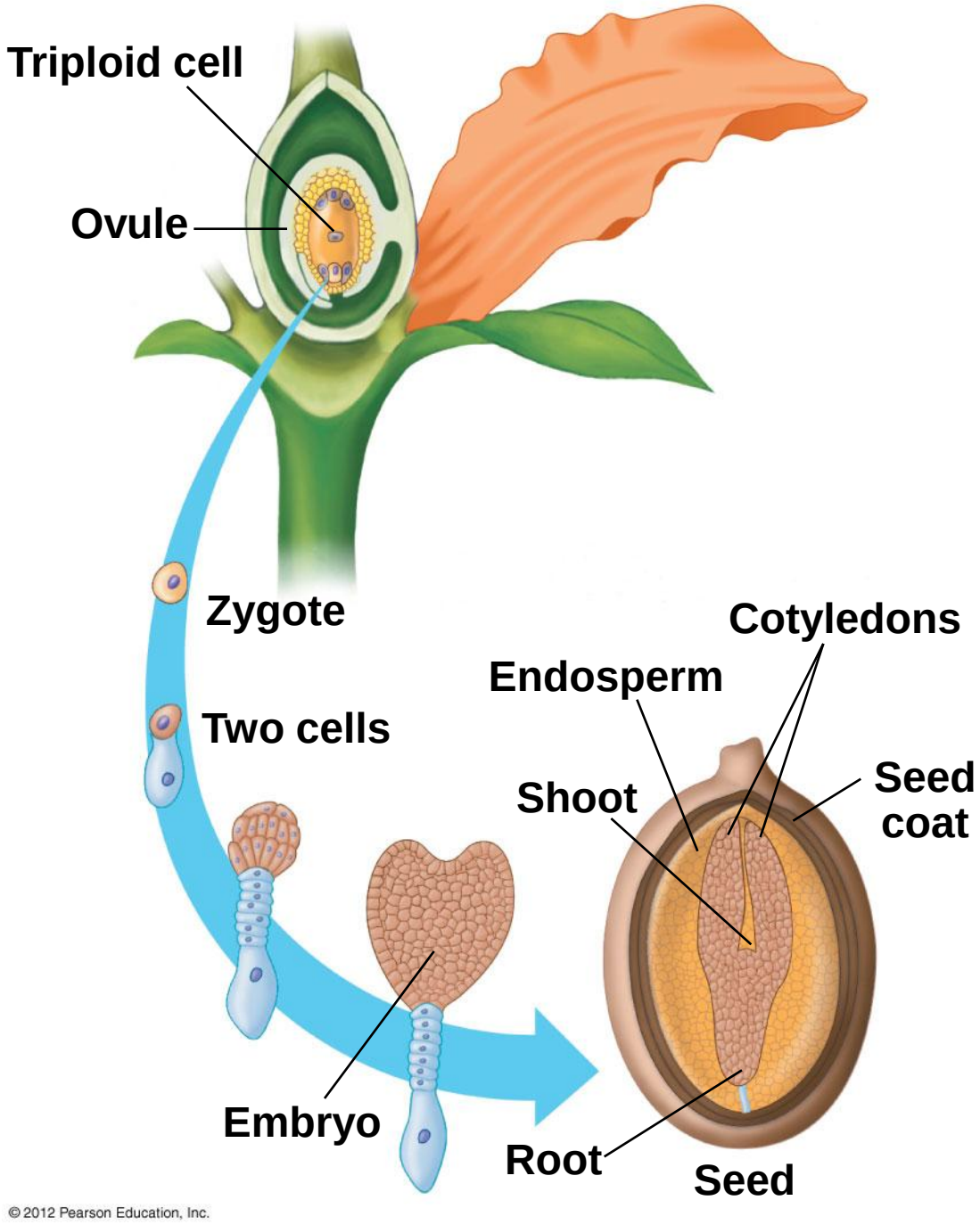
PLAY

Animation: Seed Development

31.11 The ovule develops into a seed

- **Seed dormancy**
  - is a period when embryonic growth and development are suspended and
  - allows for germination when conditions are favorable.

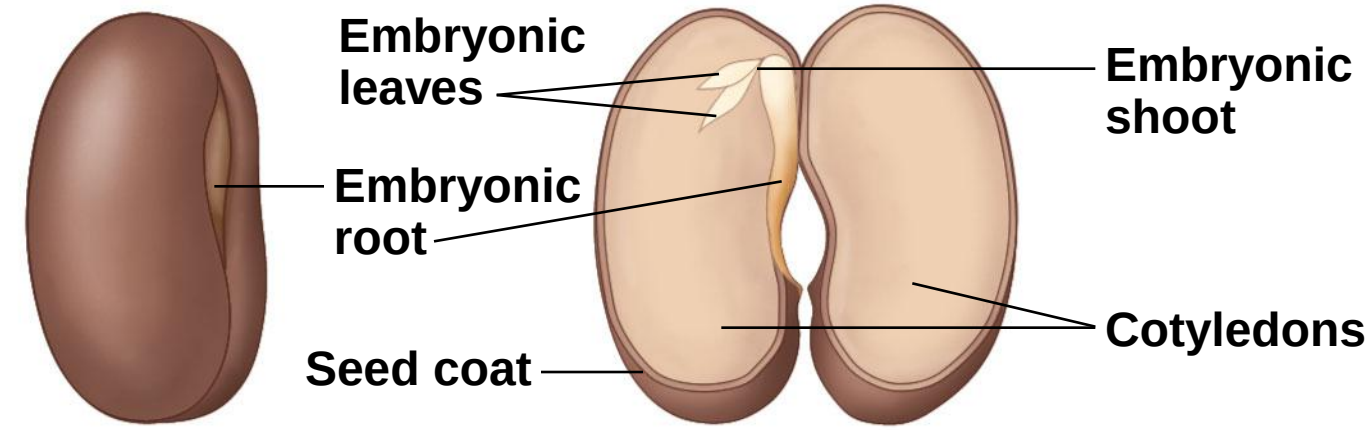
Figure 31.11A



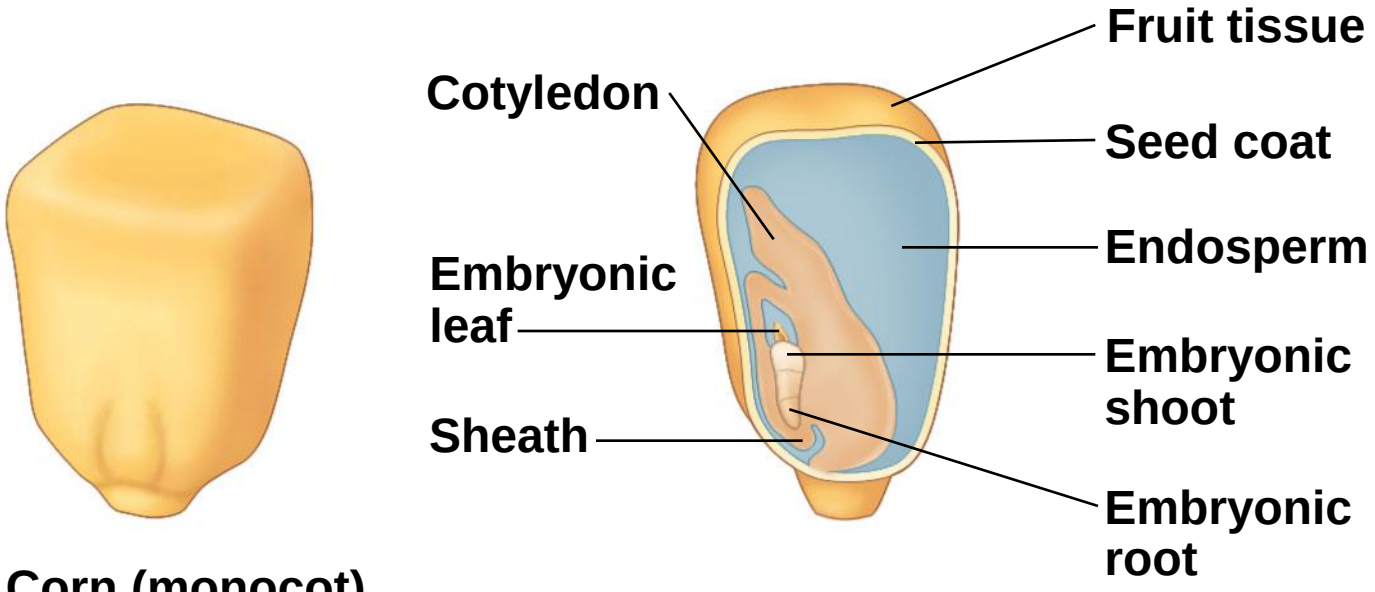
31.11 The ovule develops into a seed

- Eudicot seeds have
  - two cotyledons,
  - apical meristems that lack protective sheaths, and
  - no endosperm because the fleshy cotyledons absorbed the endosperm nutrients as the seed formed.
- Monocot seeds have
  - a single cotyledon,
  - an embryonic root and shoot with protective sheaths, and
  - endosperm.

Figure 31.11B



Common bean (eudicot)



Corn (monocot)

31.12 The ovary develops into a fruit

- Hormonal changes induced by fertilization trigger the ovary to develop into a **fruit.**
- Fruits
  - house and protect seeds and
  - aid in their dispersal.

PLAY

Animation: Fruit Development

31.12 The ovary develops into a fruit

- After pollination, a pea plant flower
  - drops its petals,
  - the ovary starts to grow, expanding tremendously, and its wall thickens, and
  - a pod forms, holding the peas, or seeds.

Figure 31.12A

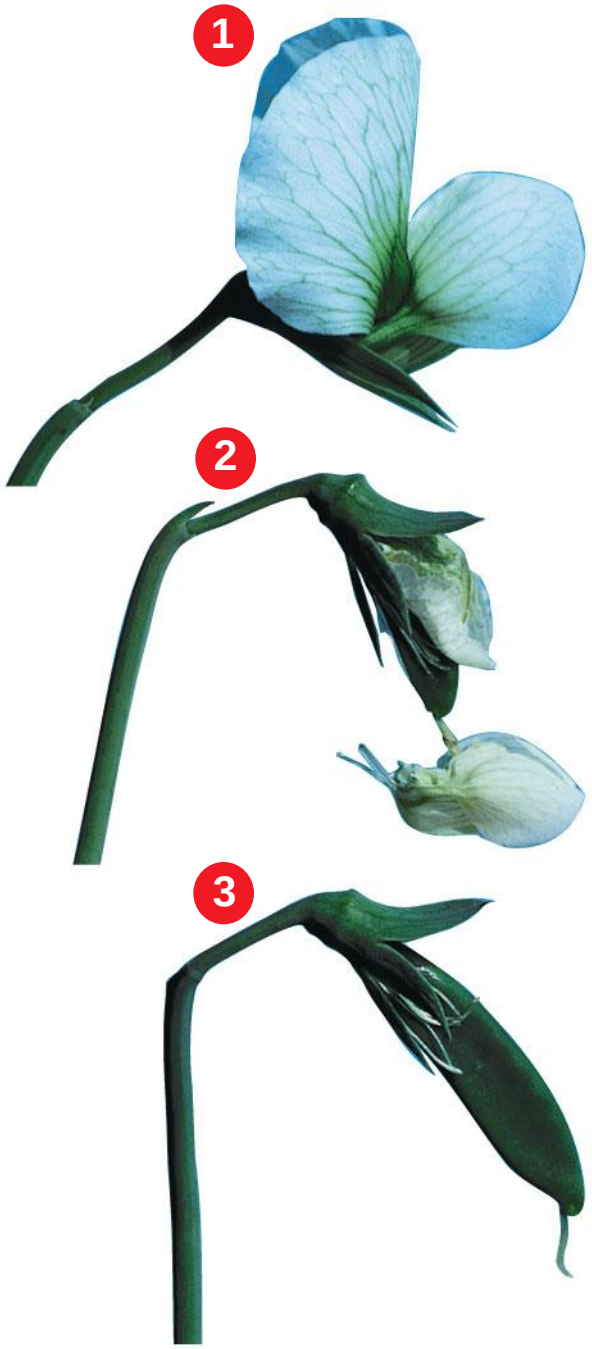


Figure 31.12A_1

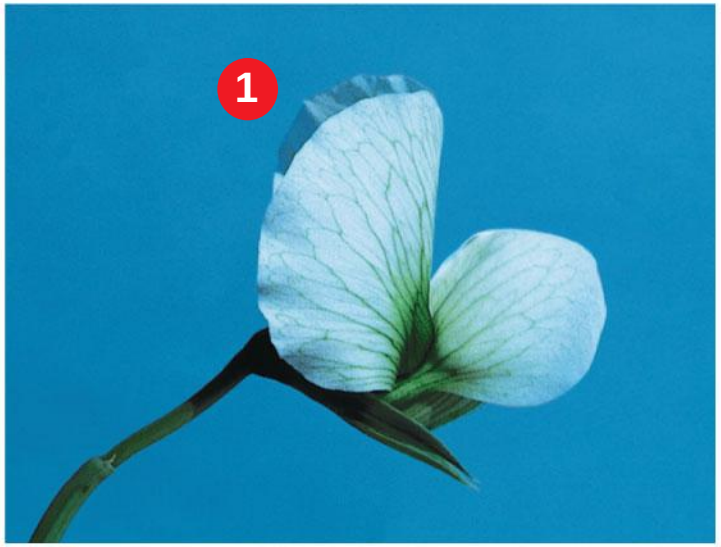


Figure 31.12A_2

Figure 31.12A_3

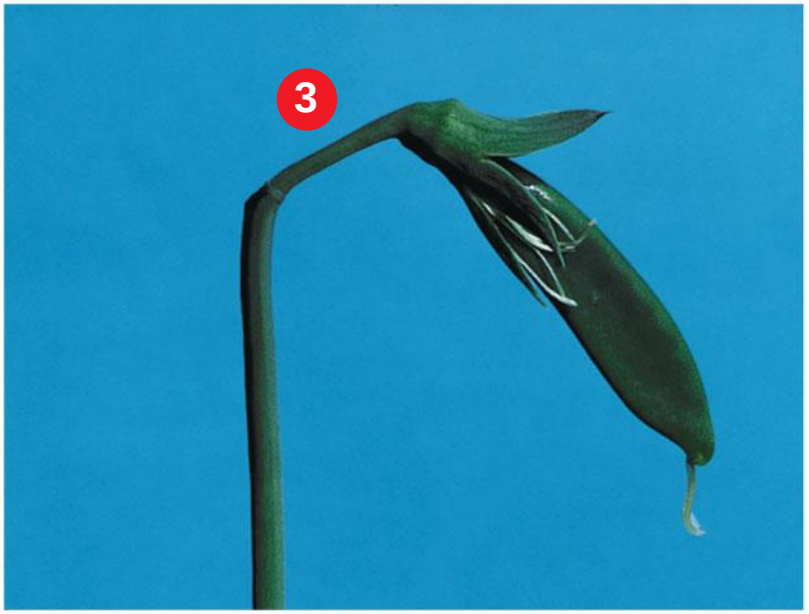
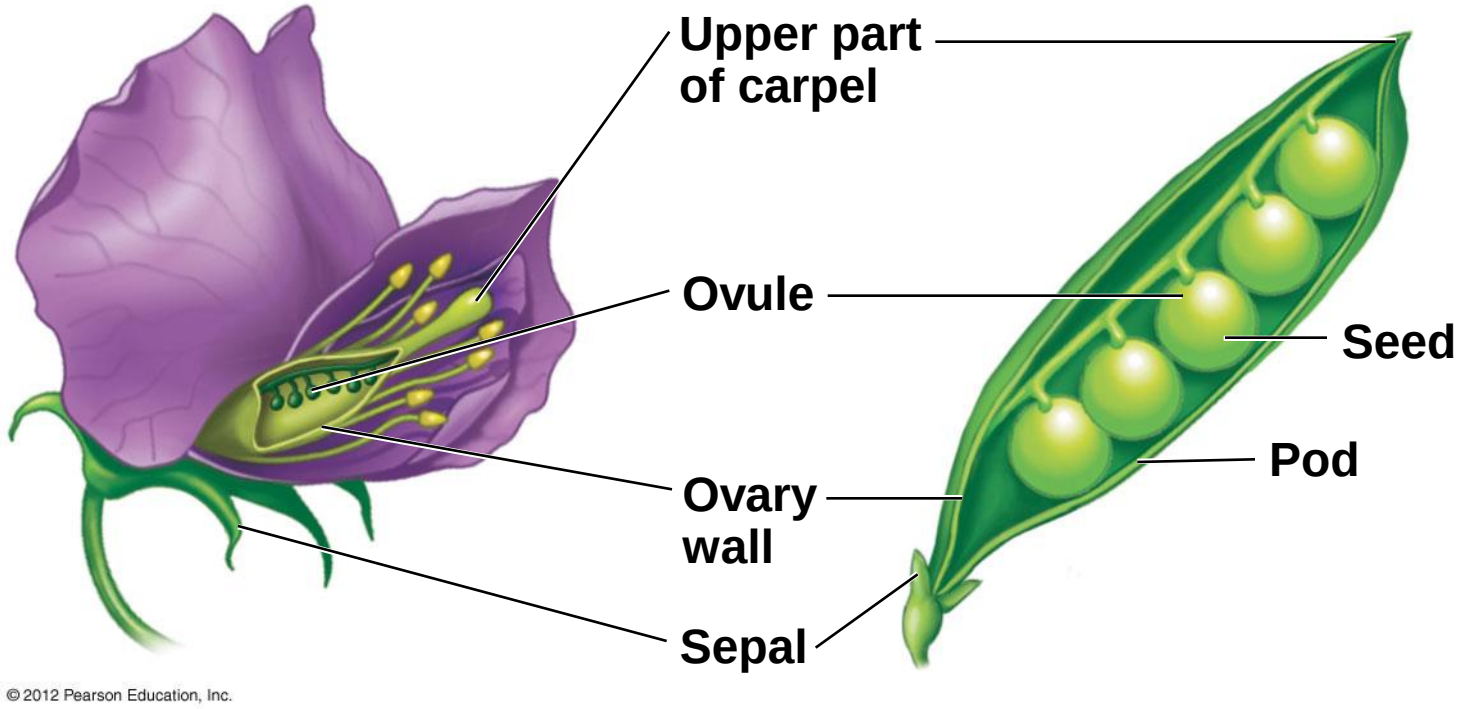


Figure 31.12B



31.12 The ovary develops into a fruit

- Mature fruits may be fleshy or dry.
  - Fleshy fruits include oranges, tomatoes, and grapes.
  - Dry fruits include beans, nuts, and grains.

Figure 31.12C

31.13 Seed germination continues the life cycle

- At germination, a seed
  - takes up water and
  - resumes growth and development.
- In eudicot seedlings
  - the embryonic root of a bean emerges first and grows downward, and
  - shoots emerge from the soil with the apical meristem “hooked” downward to protect it.
- In monocot seedlings, the shoots are covered by a protective sheath and emerge straight from the soil.

Figure 31.13A

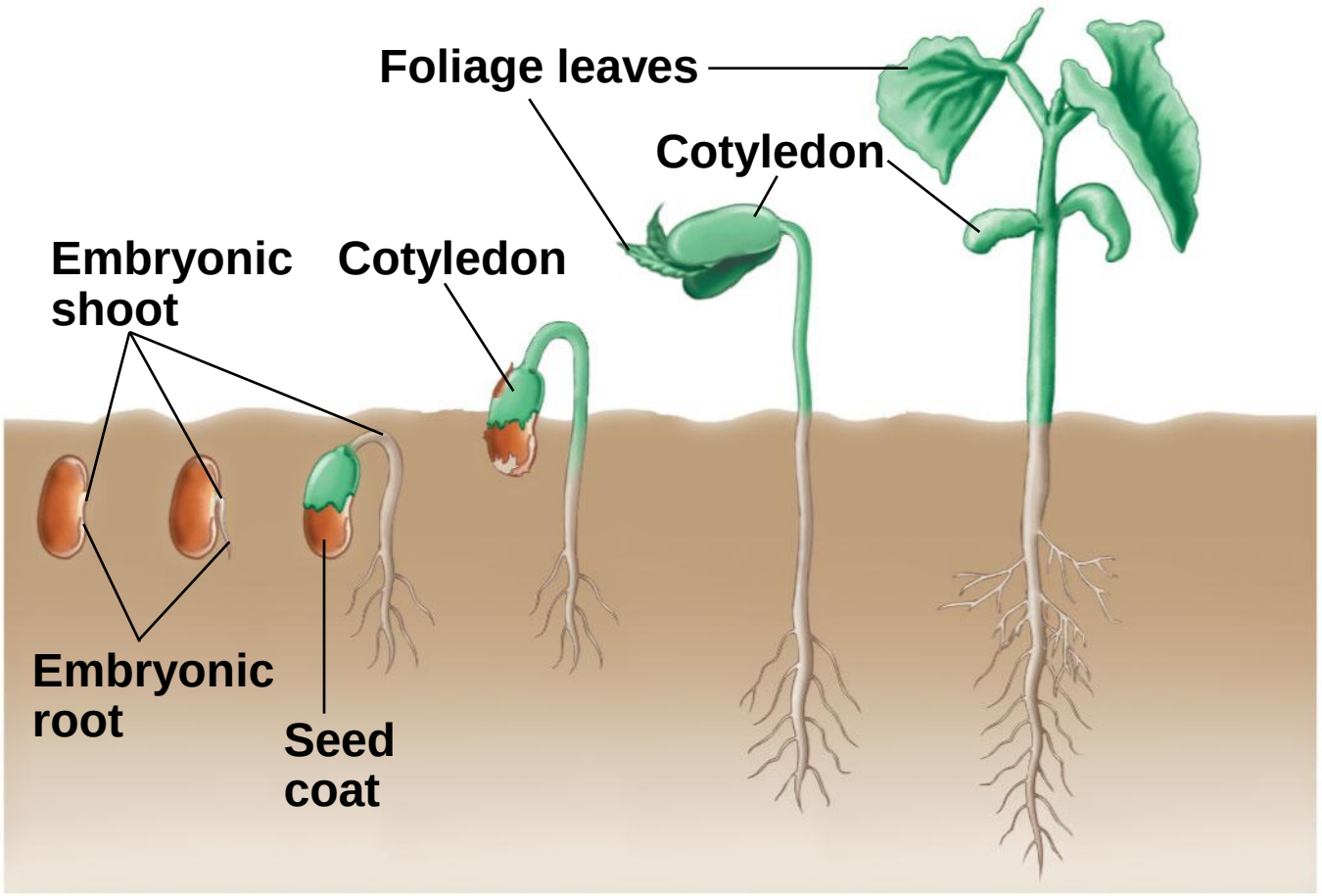
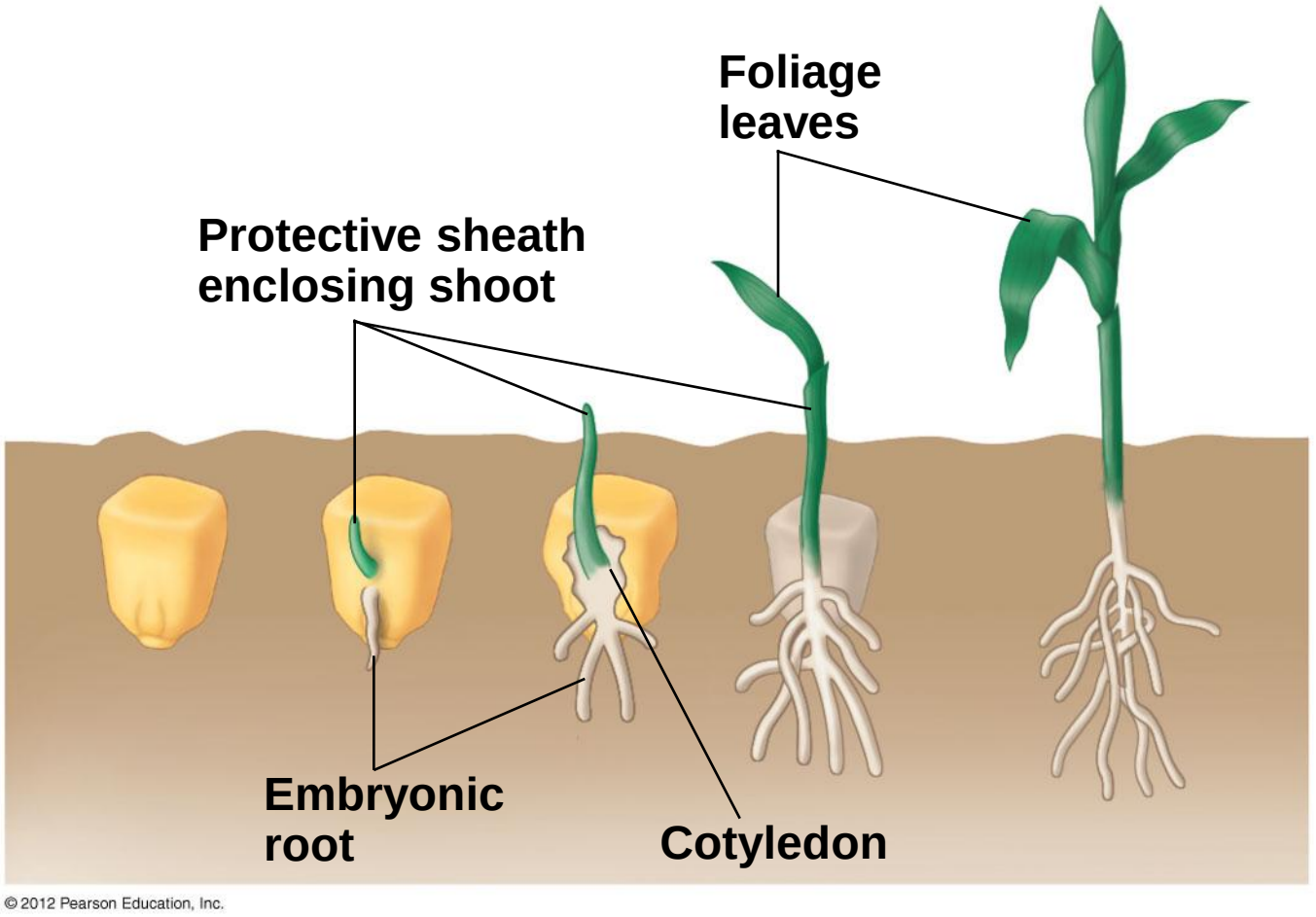


Figure 31.13B



31.14 Asexual reproduction produces plant clones

- Most plants are capable of asexual reproduction, producing genetically identical offspring (**clones**).
- Asexual reproduction can be advantageous in very stable environments.
- Clones naturally result from
  - **fragmentation**, the separation of a parent plant into parts that develop into whole plants, such as occurs in a garlic bulb,
  - root sprouts, and
  - runners.

Figure 31.14A

Figure 31.14B

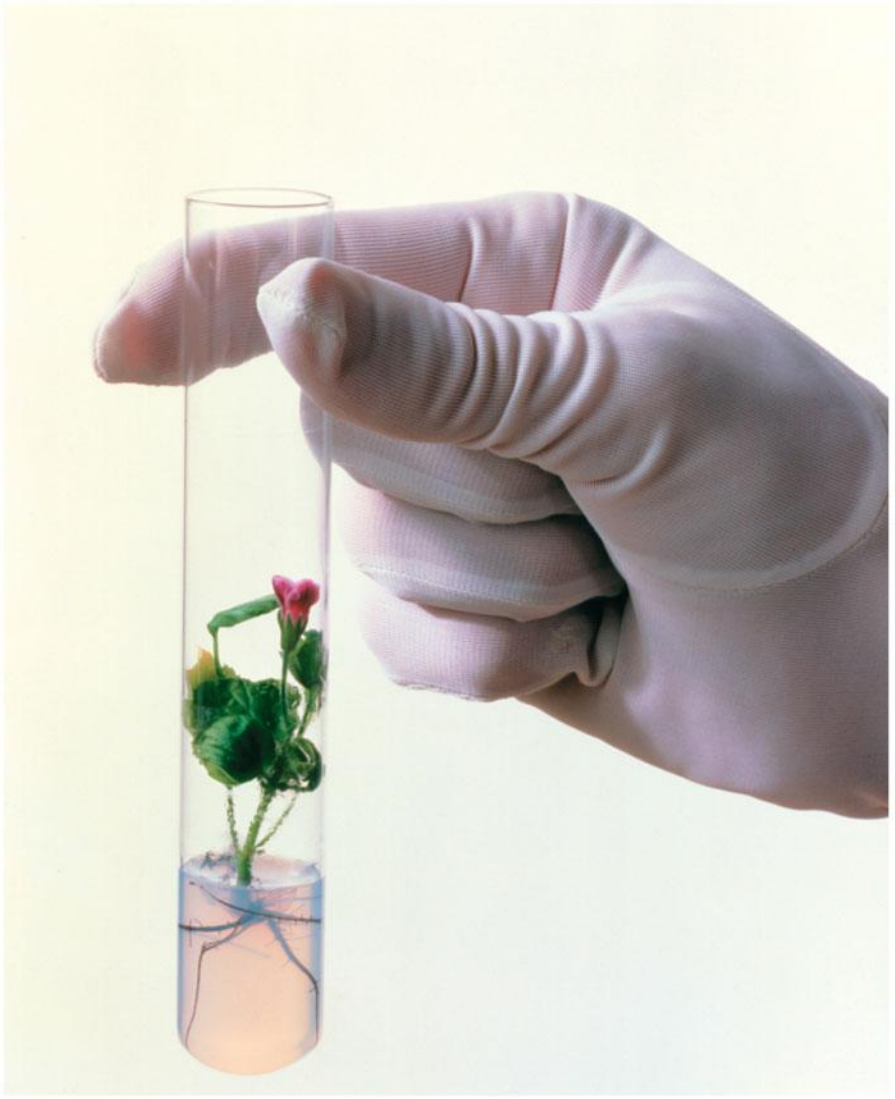
Figure 31.14C

Figure 31.14D

31.14 Asexual reproduction produces plant clones

- Plants are often propagated by taking cuttings, which can produce roots.
- Plants can be cultured on specialized media in tubes.

Figure 31.14E



31.15 EVOLUTION CONNECTION: Evolutionary adaptations help some trees to live very long lives

- Some plants can survive a very long time.
  - Some coast redwoods can be 2,000–3,000 years old.
  - The oldest organism on Earth is thought to be a 4,600-year-old bristlecone pine (*Pinus longaeva*) named Methuselah.
- A long life increases evolutionary fitness by increasing the number of reproductive opportunities.

31.15 EVOLUTION CONNECTION: Evolutionary adaptations help some trees to live very long lives

- Several adaptations allow some plants to live much longer than animals.
  - Meristem tissues allow for continued growth and repair throughout life.
  - A decentralized vascular (circulatory) system allows part of a tree to survive damage and regrow.
  - Plants produce defensive compounds that help protect them.
  - Plants have a well-adapted hormonal control system that coordinates all of these behaviors.

Figure 31.15

You should now be able to

1. Explain how the cultivation of wheat has changed over the past 10,000 years.
2. Compare the structure of monocots and eudicots.
3. Compare the structures and functions of roots, stems, and leaves.
4. Distinguish between a taproot, stolon, rhizome, tuber, bulb, petiole, and tendril, and indicate common examples of each from a vegetable garden.

You should now be able to

5. Define a tissue system. Describe the three main types of tissue systems found in young eudicot roots, stems, and leaves.
6. Describe the three unique structures found in most plant cells.
7. Describe the structures and functions of the five major types of plant cells.
8. Distinguish between (a) indeterminate and determinate growth and (b) annuals, biennials, and perennials.

You should now be able to

9. Describe and compare primary and secondary growth.
10. Describe the parts of a flower and their functions.
11. Describe the processes and events that lead to double fertilization.
12. Explain how a seed forms. Compare the structures of eudicot and monocot seeds and explain the significance of seed dormancy.

You should now be able to

13. Describe the structure and functions of fruit.
14. Describe and compare germination in bean and corn plants.
15. Describe four examples of cloning in plants.
16. Compare the advantages and disadvantages of asexual versus sexual reproduction.
17. Describe plant adaptations that permit very long lives.

Figure 31.UN01

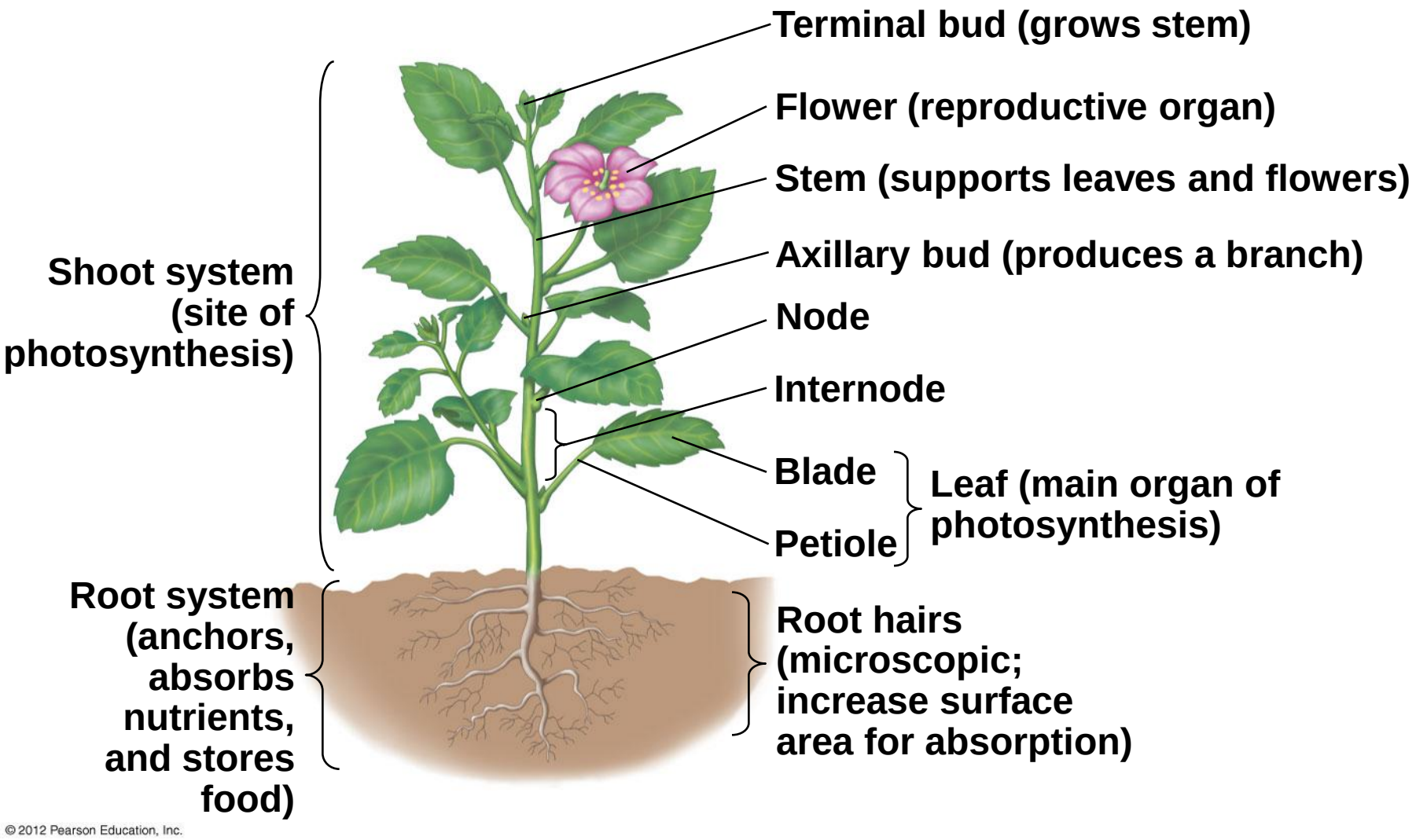


Figure 31.UN02

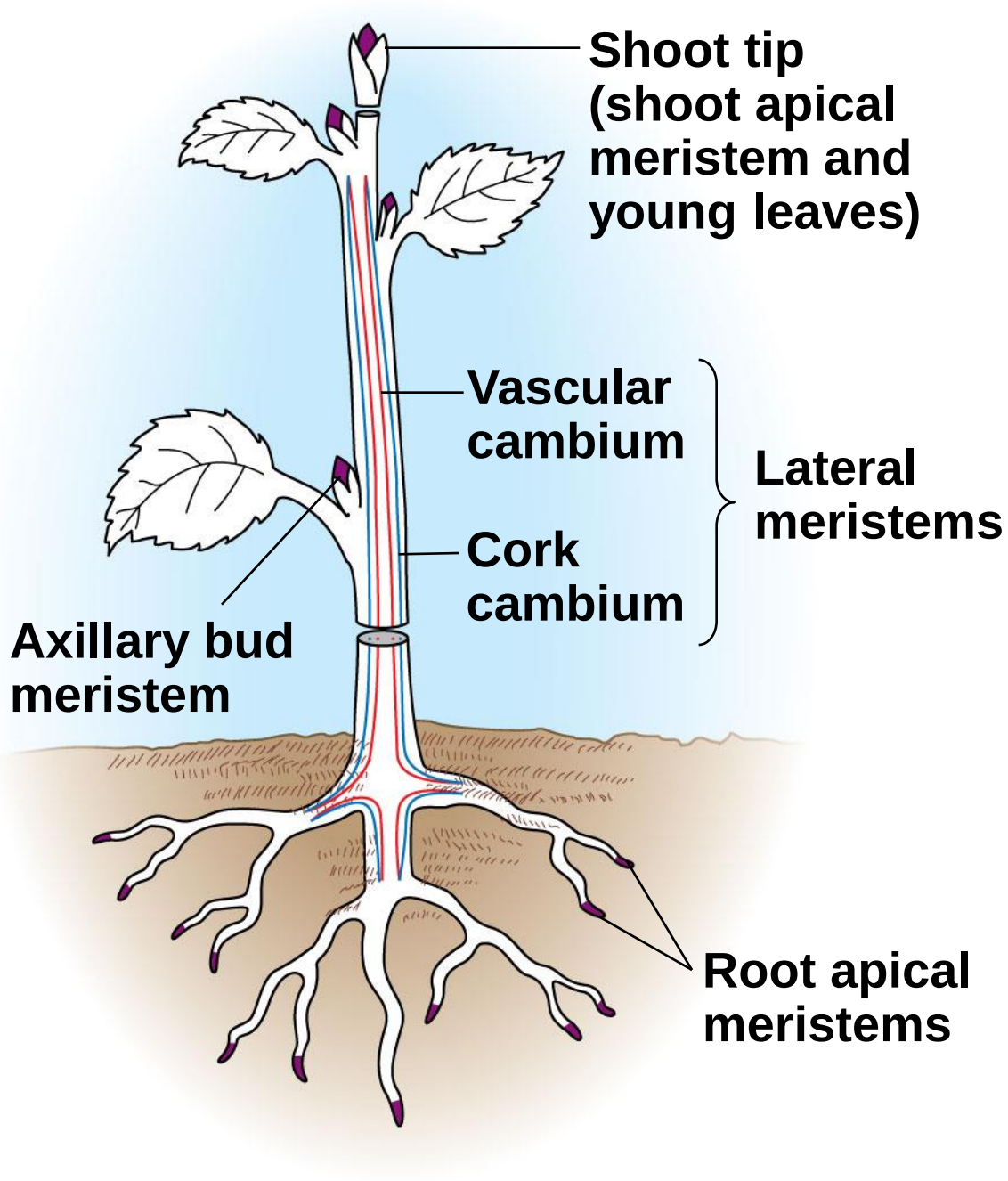


Figure 31.UN03

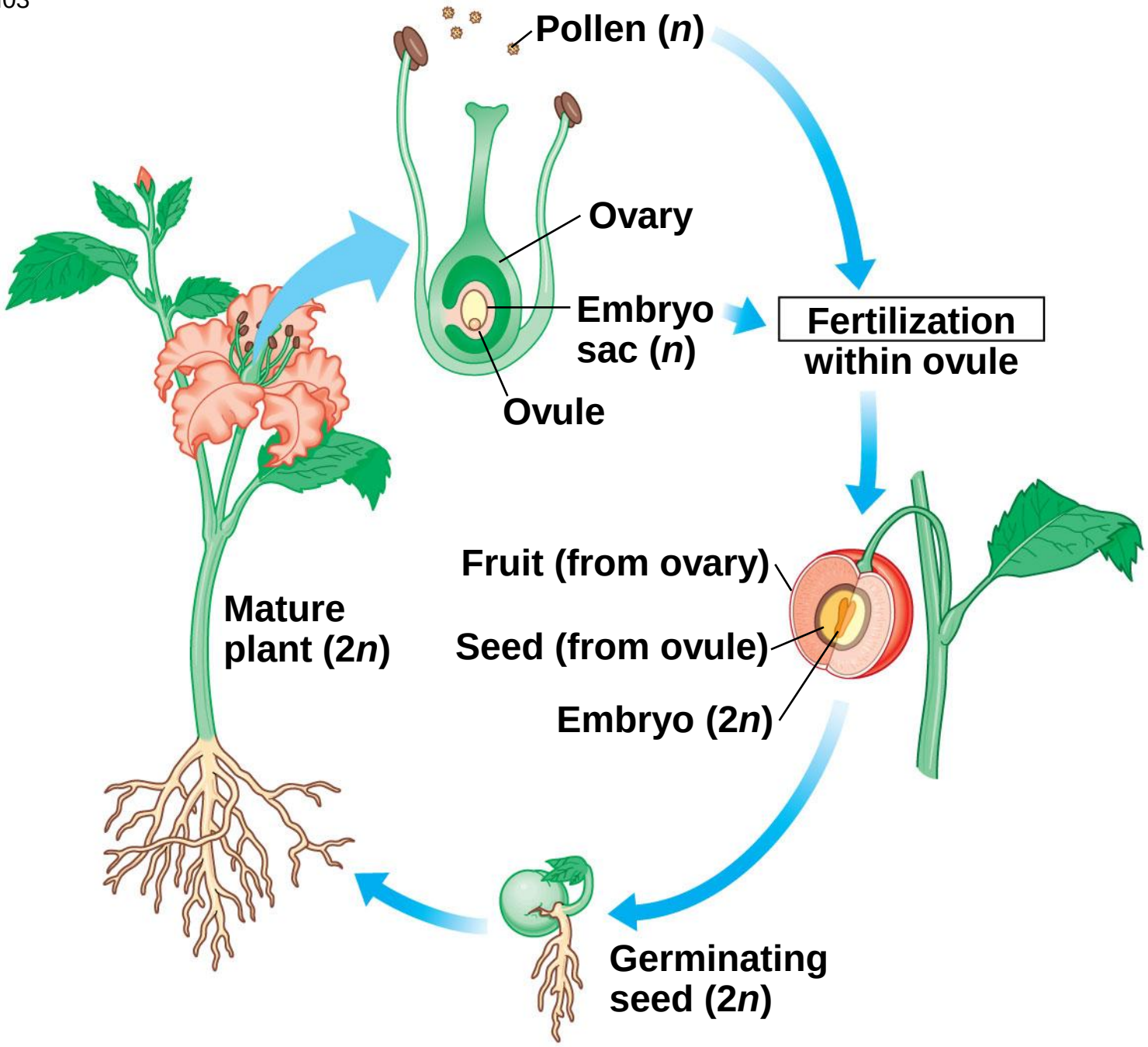


Figure 31.UN04