Chapter 35

Plant Structure, Growth, and Development

PowerPoint Lectures for
***Biology*, Seventh Edition**
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Lectures by Chris Romero

- Overview: No two Plants Are Alike
- To some people
  - The fanwort is an intrusive weed, but to others it is an attractive aquarium plant
- This plant exhibits plasticity
  - The ability to alter itself in response to its environment

Figure 35.1

What are some adaptations of these plants?

- In addition to plasticity
  - Entire plant species have by natural selection accumulated characteristics of morphology that vary little among plants 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 are in turn composed of cells

The Three Basic Plant Organs: Roots, Stems, and Leaves

- The basic morphology of vascular plants
  - Reflects their evolutionary history as terrestrial organisms that draw nutrients from two very different environments: below-ground and above-ground

- Three basic organs evolved: roots, stems, and leaves
- They are organized into a root system and a shoot system

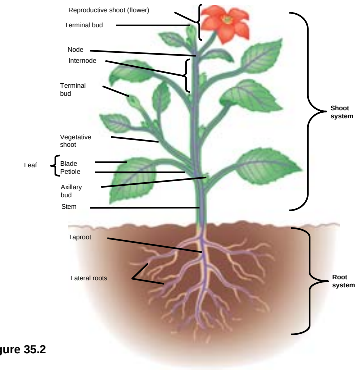


Figure 35.2

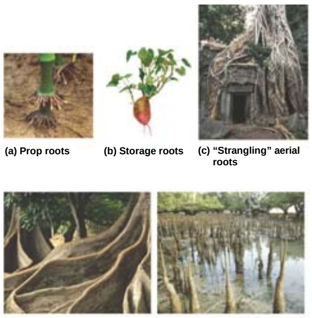
Roots

- A root
  - Is an organ that anchors the vascular plant
  - Absorbs minerals and water
  - Often stores organic nutrients

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

Figure 35.3

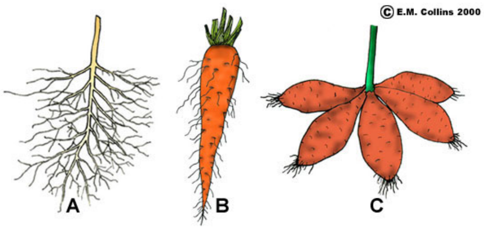
- Many plants have modified roots



(a) Prop roots (b) Storage roots (c) “Strangling” aerial roots

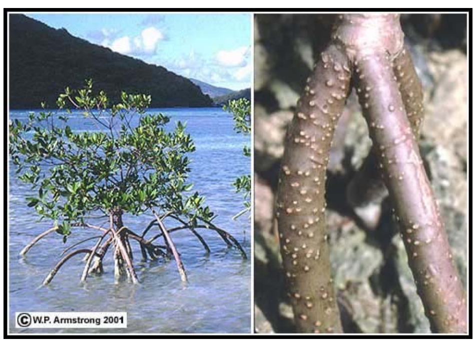
(d) Buttress roots (e) Pneumatophores

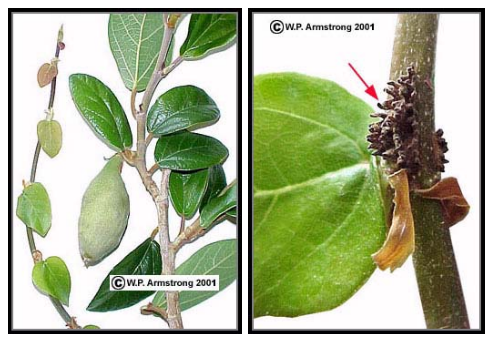
Figure 35.4a–e

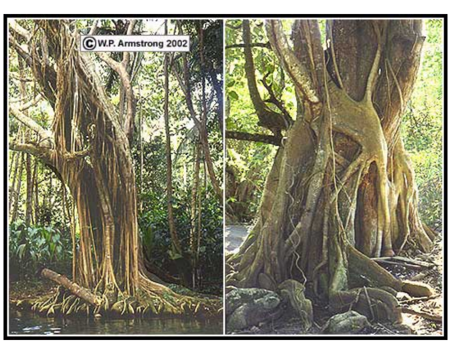


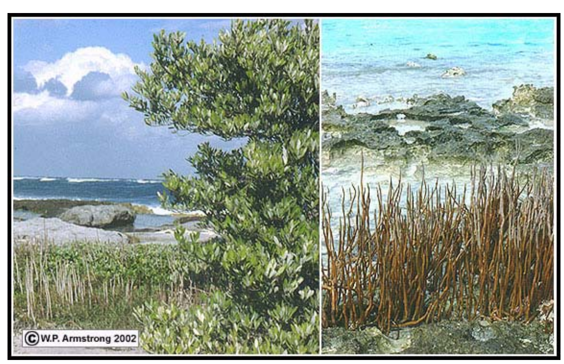
Adventitious roots grow on organs other than roots

Red Mangrove







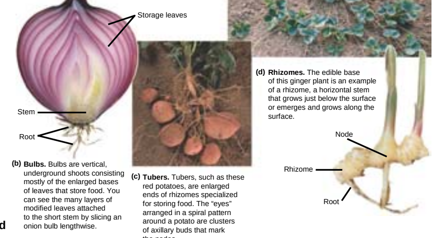


Stems

- A stem is an organ consisting of
  - An alternating system of nodes, the points at which leaves are attached
  - Internodes, the stem segments between nodes

- An axillary bud
  - Is a structure that has the potential to form a lateral shoot, or branch
- A terminal bud
  - Is located near the shoot tip and causes elongation of a young shoot

- Many plants have modified stems



(a) Stolons. Shown here on a strawberry plant, stolons are horizontal stems that grow along the surface. These "runners" enable a plant to reproduce asexually, as plantlets form at nodes along each runner.

(b) Bulbs. Bulbs are vertical, underground shoots consisting mostly of the enlarged bases of leaves that store food. You can see the many layers of modified leaves attached to the short stem by slicing an onion bulb lengthwise.

(c) Tubers. Tubers, such as these red potatoes, are enlarged ends of rhizomes specialized for storing food. The "eyes" arranged in a spiral pattern around a potato are clusters of axillary buds that mark the nodes.

(d) Rhizomes. The edible base of this ginger plant is an example of a rhizome, a horizontal stem that grows just below the surface or emerges and grows along the surface.

Figure 35.5a–d

Leaves

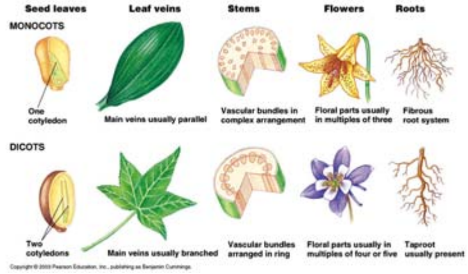
- The leaf
  - Is the main photosynthetic organ of most vascular plants

- Leaves generally consist of
  - A flattened blade and a stalk
  - The petiole, which joins the leaf to a node of the stem

- Monocots and dicots
  - Differ in the arrangement of veins, the vascular tissue of leaves
- Most monocots
  - Have parallel veins
- Most dicots
  - Have branching veins

Monocots and Dicots

are the two major divisions of Angiosperms



- In classifying angiosperms
  - Taxonomists may use leaf morphology as a criterion

(a) Simple leaf. A simple leaf is a single, undivided blade. Some simple leaves are deeply lobed, as in an oak leaf.

(b) Compound leaf. In a compound leaf, the blade consists of multiple leaflets. Notice that a leaflet has no axillary bud at its base.

(c) Doubly compound leaf. In a doubly compound leaf, each leaflet is divided into smaller leaflets.

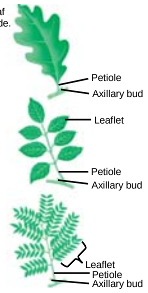
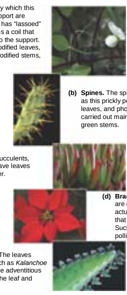


Figure 35.6a–c

Leaf modifications

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



(a) Tendrils. The tendrils by which this pea plant clings to a support are modified leaves. After it has "lassoed" a support, a tendril forms a coil that brings the plant closer to the support. Tendrils are typically modified leaves, but some tendrils are modified stems, as in grapevines.

(b) Spines. The spines of cacti, such as this prickly pear, are actually leaves, and photosynthesis is carried out mainly by the fleshy green stems.

(c) Storage leaves. Most succulents, such as this ice plant, have leaves modified for storing water.

(d) Bracts. Red parts of the poinsettia are often mistaken for petals but are actually modified leaves called bracts that surround a group of flowers. Such brightly colored leaves attract pollinators.

(e) Reproductive leaves. The leaves of some succulents, such as *Kalanchoe daigremontiana*, produce adventitious plantlets, which fall off the leaf and take root in the soil.

Figure 35.6a–e

The Three Tissue Systems: Dermal, Vascular, and Ground

- Each plant organ
  - Has dermal, vascular, and ground tissues

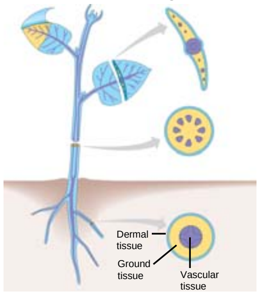


Figure 35.8

- The dermal tissue system
  - Consists of the epidermis and periderm

- The vascular tissue system
  - Carries out long-distance transport of materials between roots and shoots
  - Consists of two tissues, 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

- Ground tissue
  - Includes various cells specialized for functions such as 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 of the major types of plant cells include
  - Parenchyma
  - Collenchyma
  - Sclerenchyma
  - Water-conducting cells of the xylem
  - Sugar-conducting cells of the phloem

- Parenchyma, collenchyma, and sclerenchyma cells

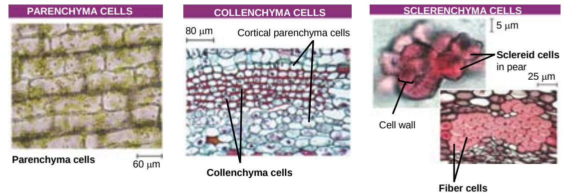


Figure 35.9

- Water-conducting cells of the xylem and sugar-conducting cells of the phloem

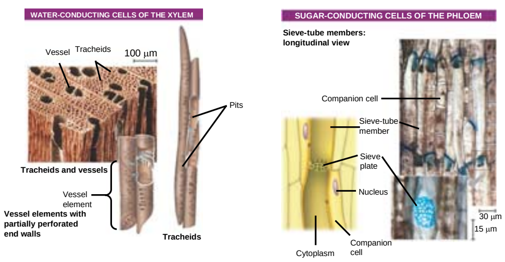


Figure. 35.9

- Concept 35.2: Meristems generate cells for new organs
- Apical meristems
  - Are located at the tips of roots and in the buds of shoots
  - Elongate shoots and roots through primary growth

- Lateral meristems
  - Add thickness to woody plants through secondary growth

- An overview of primary and secondary growth

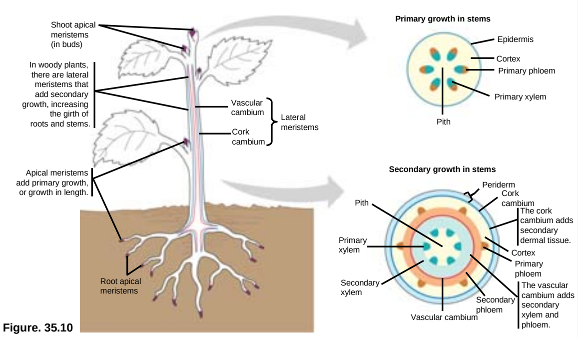


Figure. 35.10

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

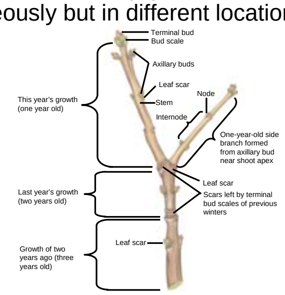


Figure 35.11

- 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 delicate apical meristem as the root pushes through soil during primary growth

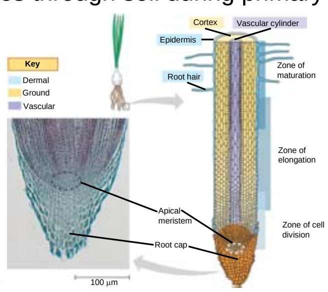


Figure 35.12

- The primary growth of roots
  - Produces the epidermis, ground tissue, and vascular tissue

- Organization of primary tissues in young roots

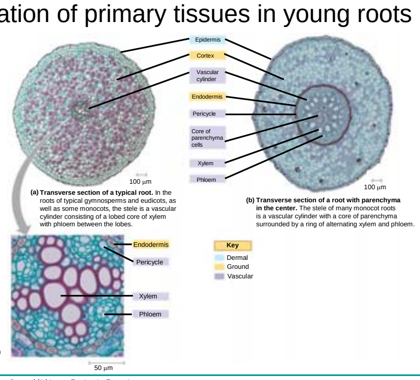


Figure 35.13a, b

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

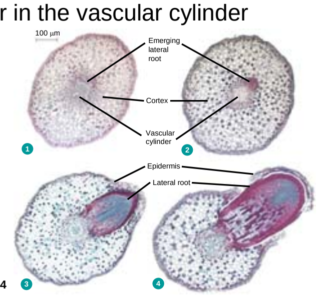


Figure 35.14

Primary Growth of Shoots

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

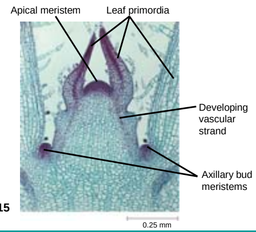


Figure. 35.15

Tissue Organization of Stems

- In gymnosperms and most eudicots
  - The vascular tissue consists of vascular bundles arranged in a ring

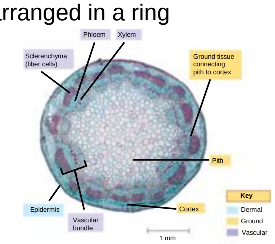


Figure 35.16a **(a) A eudicot stem.** A eudicot stem (sunflower), with vascular bundles forming a ring. Ground tissue toward the inside is called pith, and ground tissue toward the outside is called cortex. (LM of transverse section)

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

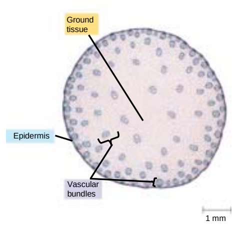


Figure 35.16b **(b) A monocot stem.** A monocot stem (maize) with vascular bundles scattered throughout the ground tissue. In such an arrangement, ground tissue is not partitioned into pith and cortex. (LM of transverse section)

Tissue Organization of Leaves

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

- Leaf anatomy

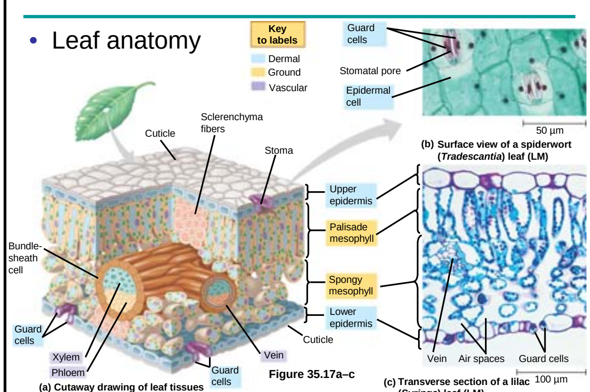


Figure 35.17a–c

- 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

The Vascular Cambium and Secondary Vascular Tissue

- The vascular cambium
  - Is a cylinder of meristematic cells one cell thick
  - Develops from parenchyma cells

- Primary and secondary growth of a stem

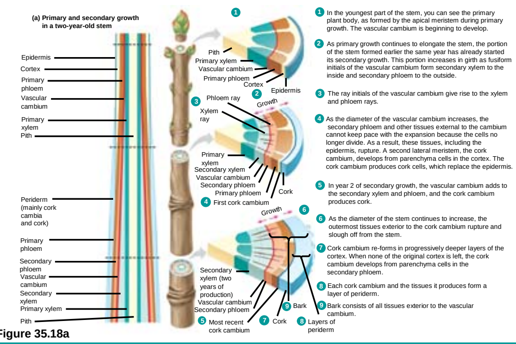
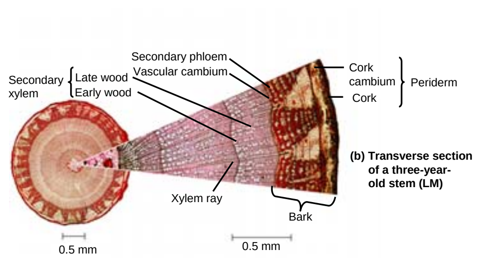


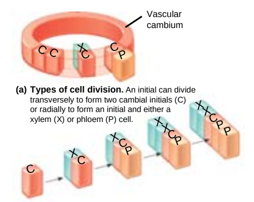
Figure 35.18a



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

Figure 35.18b

- Viewed in transverse section, the vascular cambium
  - Appears as a ring, with interspersed regions of dividing cells called fusiform initials and ray initials



(a) Types of cell division. An initial can divide transversely to form two cambial initials (C) or radially to form an initial and either a xylem (X) or phloem (P) cell.

(b) Accumulation of secondary growth. Although shown here as alternately adding xylem and phloem, a cambial initial usually produces much more xylem.

Figure 35.19a, b

- 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

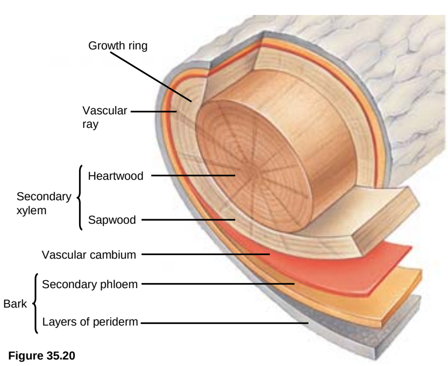


Figure 35.20

Cork Cambia and the Production of Periderm

- The cork cambium
  - Gives rise to the secondary plant body's protective covering, or periderm

- Periderm
  - Consists of the cork cambium plus the layers of cork cells it produces
- Bark
  - Consists of all the tissues external to the vascular cambium, including secondary phloem and periderm

- Concept 35.5: Growth, morphogenesis, and differentiation produce the plant body
- The three developmental processes of growth, morphogenesis, and cellular differentiation
  - Act in concert to transform the fertilized egg into a plant

Molecular Biology: Revolutionizing the Study of Plants

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

- *Arabidopsis*
  - Is the first plant to have its entire genome sequenced

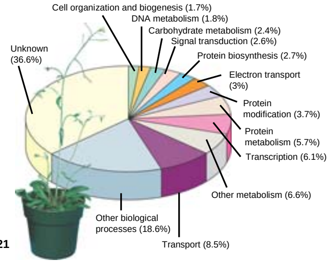


Figure 35.21

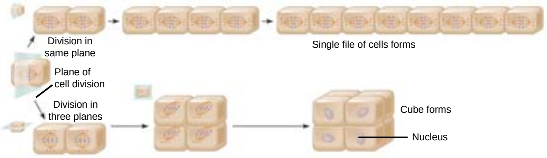
Growth: Cell Division and Cell Expansion

- 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

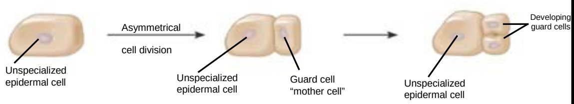
- If the planes of division of cells are parallel to the plane of the first division
  - A single file of cells will be produced



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

Figure 35.22a

- If the planes of division vary randomly
  - Asymmetrical cell division occurs



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

Figure 35.22b

- The plane in which a cell divides
  - Is determined during late interphase
- Microtubules in the cytoplasm
  - Become concentrated into a ring called the preprophase band

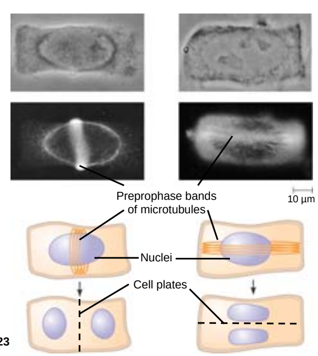


Figure 35.23

Orientation of Cell Expansion

- Plant cells
  - Rarely expand equally in all directions

- The orientation of the cytoskeleton
  - Affects the direction of cell elongation by controlling the orientation of cellulose microfibrils within the cell wall

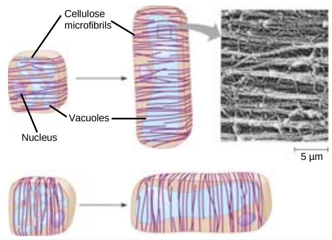


Figure 35.24

Microtubules and Plant Growth

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

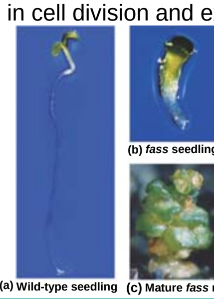


Figure 35.25a–c (a) Wild-type seedling (b) *fass* seedling (c) Mature *fass* mutant

Morphogenesis and Pattern Formation

- Pattern formation
  - Is the development of specific structures in specific locations
  - Is determined by positional information in the form of signals that indicate to each cell its location

- Polarity
  - Is one type of positional information
- In the *gnom* mutant of *Arabidopsis*
  - The establishment of polarity is defective

Figure 35.26

- Morphogenesis in plants, as in other multicellular organisms
  - Is often under the control of homeotic genes

Figure 35.27

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
  - Is affected by homeotic genes

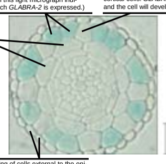


Figure 35.28

Location and a Cell's Developmental Fate

- A cell's position in a developing organ
  - Determines its pathway of differentiation

Shifts in Development: Phase Changes

- Plants pass through developmental phases, called phase changes
  - Developing from a juvenile phase to an adult vegetative phase to an adult reproductive phase

- The most obvious morphological changes
  - Typically occur in leaf size and shape

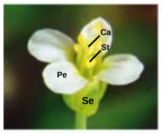
Figure 35.29

Genetic Control of Flowering

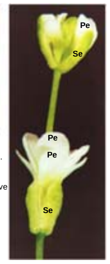
- Flower formation
  - Involves a phase change from vegetative growth to reproductive growth
  - Is triggered by a combination of environmental cues and internal signals

- The transition from vegetative growth to flowering
  - Is associated with the switching-on of floral meristem identity genes

- Plant biologists have identified several organ identity genes
  - That regulate the development of floral pattern



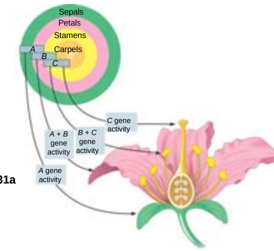
(a) Normal *Arabidopsis* flower. *Arabidopsis* normally has four whorls of flower parts: sepals (Se), petals (Pe), stamens (St), and carpels (Ca).



(b) Abnormal *Arabidopsis* flower. Reseachers have identified several mutations of organ identity genes that cause abnormal flowers to develop. This flower has an extra set of petals in place of stamens and an internal flower where normal plants have carpels.

Figure 35.30a, b

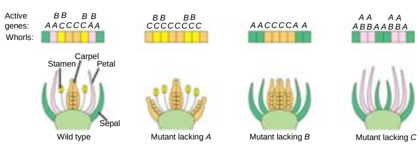
- The ABC model of flower formation
  - Identifies how floral organ identity genes direct the formation of the four types of floral organs



(a) A schematic diagram of the ABC hypothesis. Studies of plant mutations reveal that three classes of organ identity genes are responsible for the spatial pattern of floral parts. These genes are designated *A*, *B*, and *C* in this schematic diagram of a floral meristem in transverse view. These genes regulate expression of other genes responsible for development of sepals, petals, stamens, and carpels. Sepals develop from the meristematic region where only *A* genes are active. Petals develop where both *A* and *B* genes are expressed. Stamens arise where *B* and *C* genes are active. Carpels arise where only *C* genes are expressed.

Figure 35.31a

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



(b) Side view of organ identity mutant flowers. Combining the model shown in part (a) with the rule that if *A* gene or *C* gene activity is missing, the other activity spreads through all four whorls, we can explain the phenotypes of mutants lacking a functional *A*, *B*, or *C* organ identity gene.

Figure 35.31b