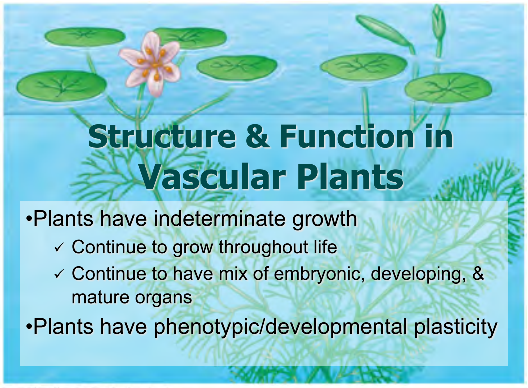


Structure & Function in Vascular Plants

- Plants have indeterminate growth
  - ✓ Continue to grow throughout life
  - ✓ Continue to have mix of embryonic, developing, & mature organs
- Plants have phenotypic/developmental plasticity

Fig. 35.24 Developmental plasticity in fanwort (*Cabomba caroliniana*)

Plants Cells

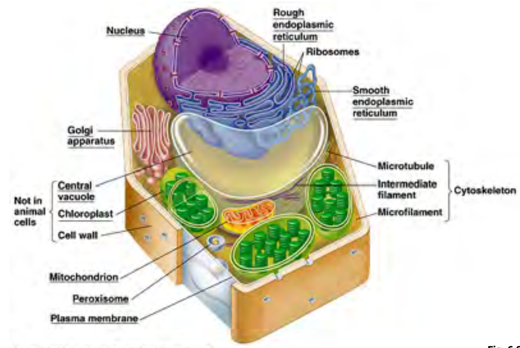
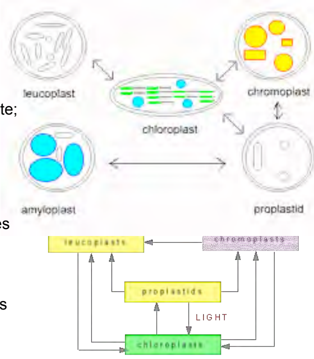


Fig. 6.8b

Plastids

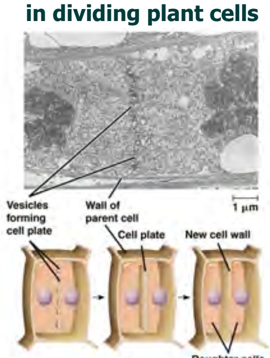
- **Proplastid**: reduced from chloroplasts in megasporocyte; passed to ova; produce functional plastids in embryo
- **Chloroplast**: chlorophyll, accessory pigments, starch synthesis
- **Leucoplast**: chloroplast loses pigments in dark
- **Chromoplast**: accessory pigments only
- **Amyloplast**: starch synthesis only



Localized Photosynthesis & Starch synthesis

- The leaf was covered with a negative and exposed to light for several hours. Starch was produced in the exposed areas that can be detected with potassium iodate (dark areas of the photo).
  - (D. A: WALKER, 1983)

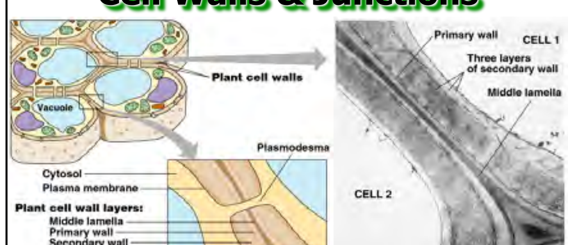
Cytokinesis & primary wall formation in dividing plant cells



(b) Cell plate formation in a plant cell (TEM)

Fig. 12.10b

Cell Walls & Junctions



- **Plasmodesmata** form gap (communicating) junctions between cells

- **Primary wall** – deposited during cell division
  - Short-chain cross-linked **cellulose microfibrils** in gel-like matrix
  - Strong, but flexible & porous
- **Middle lamella** – pectin gel (inter-cell glue)
- **Secondary wall** (not in all tissues)
  - Long-chain **cellulose microfibrils**
    - Arranged in parallel cross-linked pattern
  - Sometimes reinforced with aromatic polymers (e.g., **lignin**)
    - Irreversibly stronger & waterproof

Figs. 6.27 & 6.29

Multicellular Growth & Development

1. Proliferation – mitotic cell divisions
2. Hypertrophy – enlarging or elongating cells
3. Differentiation – tissue formation
4. Morphogenesis – pattern formation

1. Proliferation – plane & symmetry of cell division

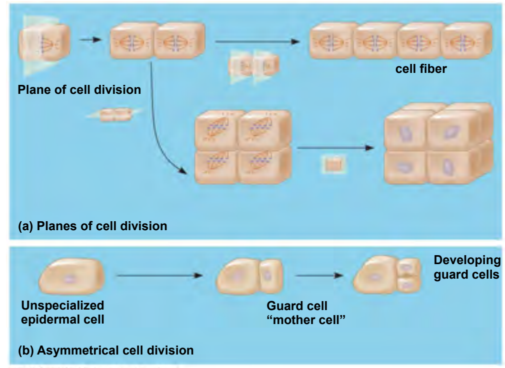
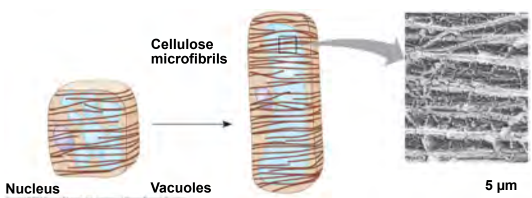


Fig. 35.28

2. Hypertrophy – cell elongation



1. Cell wall enzymes activated → weaken cross-links between microfibrils
2. Central vacuole takes on water by osmosis → cell expands
3. Cell can only expand perpendicular to microfibrils → directional elongation
4. New microfibrils constructed between old ones and new cross-links form

Fig. 35.30

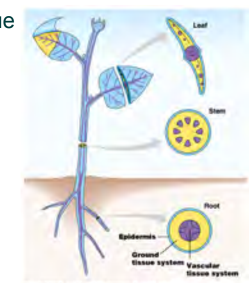
3. Differentiation – Major plant tissue types

A. Meristematic tissue
   i. Apical meristems
   ii. Lateral meristems

B. Dermal tissue
   i. Epidermis
   ii. Periderm

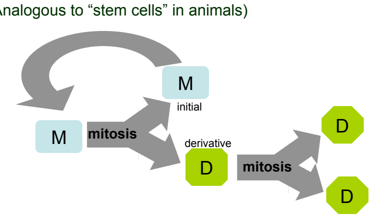
C. Ground tissue
   i. Parenchyma
   ii. Collenchyma
   iii. Sclerenchyma

D. Vascular tissue
   i. Xylem – tracheids & vessel elements
   ii. Phloem – sieve-tube elements & companion cells



A. Meristematic tissue

- Meristematic tissue: contains undifferentiated cells that continue to divide throughout their lives to produce all of the other plant tissues.
- (Analogous to "stem cells" in animals)



Meristem cells divides:
1. One daughter cell (**initial**) remains undifferentiated to replace original meristem cell.
2. Second daughter cell (**derivative**) divides to produce specialized cells.

A. Meristematic tissue

- **Apical meristem**: growth of end of roots, shoots, & axillary buds.
  - Makes primary meristem tissues:
    - Protoderm → epidermis
    - Ground meristem → ground tissue
    - Procambium → primary xylem & phloem
- **Lateral meristem**: in woody plants, adds girth
  - Contains secondary meristem derived from primary
    - Vascular cambium
    - Cork cambium

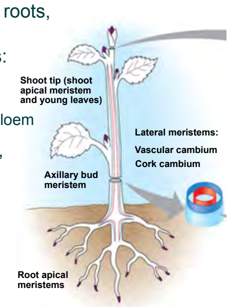
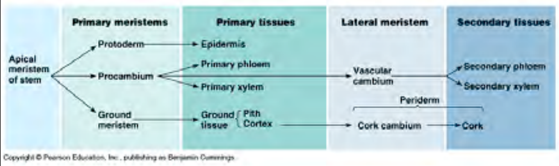
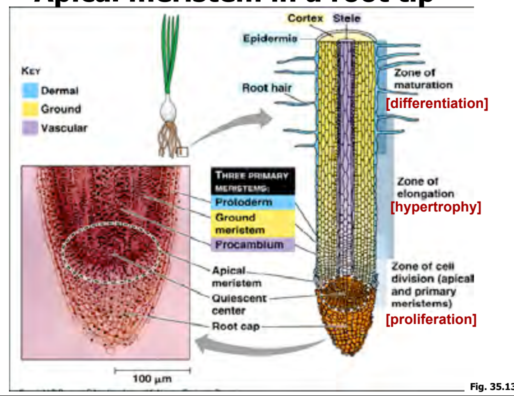


Fig. 35.11

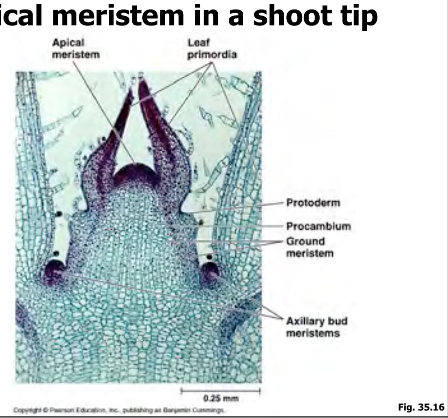
A. Meristematic tissue



Apical meristem in a root tip



Apical meristem in a shoot tip



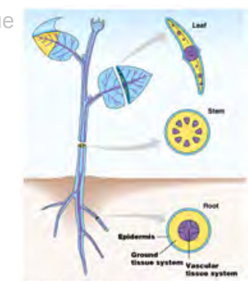
3. Differentiation – Major plant tissue types

A. Meristematic tissue
   i. Apical meristems
   ii. Lateral meristems

B. Dermal tissue
   i. Epidermis
   ii. Periderm

C. Ground tissue
   i. Parenchyma
   ii. Collenchyma
   iii. Sclerenchyma

D. Vascular tissue
   i. Xylem – tracheids & vessel elements
   ii. Phloem – sieve-tube elements & companion cells



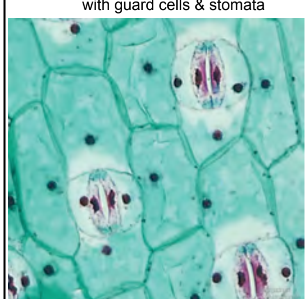
B. Dermal tissue

- Covers the outer surface of the plant
- Resists desiccation, infection, and herbivory

i. **Epidermis** (from protoderm) – surface of primary plant body
- Secretes waxy cuticle
- Produces specialized cells:
  - Guard cells around stomata for gas exchange
  - Trichomes: bristles to resist desiccation & herbivory (cotton)
  - Root hairs to increase surface area for absorption

B. Dermal tissue — Epidermis

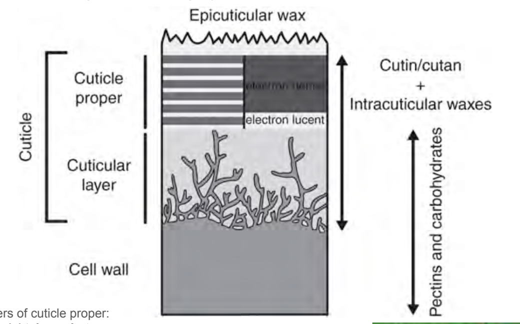
- Leaf epidermis with guard cells & stomata



- Root hairs

Epidermis — Cuticle

Diagram illustrating layers and composition of the cuticle

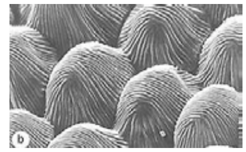


Layers of cuticle proper:
- right: **bryophyte**
- left: **tracheophyte**

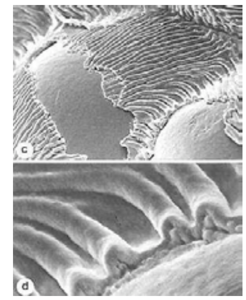
Budke J M et al. Ann Bot 2011;aob.mcr079

ANNALS OF BOTANY

Epidermis — Cuticle



- Upper surface of a chamomile flower
- These cuticle folds have several functions:
  - they enhance the intense velvet effect of the flower color
  - increase the water-repellent quality of the flower surface
  - strengthen the stability of the petals
  - could be recognized by landing pollinator insects as additional information concerning the 'right' landing strip.

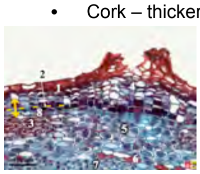


B. Dermal tissue

- Covers the outer surface of the plant
- Resists desiccation, infection, and herbivory

i. **Epidermis** (from protoderm) – surface of primary plant body

ii. **Periderm** (from cork cambium) – replaces epidermis on surface of secondary growth (woody) areas
   - Cork – thicker, tougher & more water-proof
     - secondary walls permeated with waxy ***suberin***



Onset of cork formation from cork cambium: **1 cork** (= phellem); **2 cork cambium** (= phellogen); 3 collenchyma; 4 lenticel; 5 parenchyma; 6 sclerenchyma; 7 phloem; **8 cork cortex** (= phelloderm) (http://www.vcbio.science.ru.nl/en/virtuallessons/cambiumcork/)

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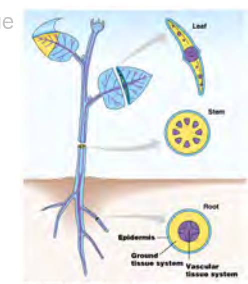
   i. Xylem – tracheids & vessel elements
   ii. Phloem – sieve-tube elements & companion cells

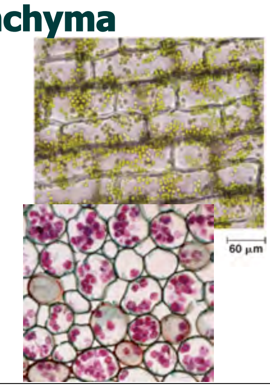


C. Ground Tissue — Parenchyma

- Most common/least specialized cell type in plants
  - Including most photosynthetic cells (leaf mesophyll)
  - And most non-photosynthetic storage tissues
- Capable of dividing and live a long time
  - Can differentiate into other tissue types
    - Wound healing, asexual propagation, etc.
- Thin primary cell walls and reduced/absent secondary walls
- Large central vacuoles

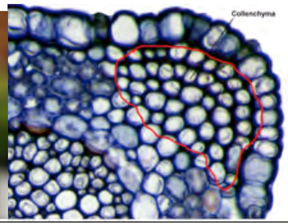
C. Ground Tissue — Parenchyma

- Leaf parenchyma (mesophyll) with chloroplasts (**chlorenchyma**)
- Root parenchyma (cortex) with amyloplasts. [starch grains stain red]



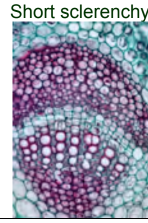
C. Ground Tissue — Collenchyma

- Thicker primary cell walls than parenchyma. No secondary walls
- Usually stacked to form long strands or cylinders, often just below epidermis
- Used for flexible support, esp. in young stems & petioles
- Mature cells remain viable and elongate with growing stem



C. Ground Tissue — Sclerenchyma

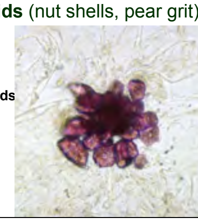
- Thick, lignified secondary walls
- Harder & more rigid than collenchyma, but cannot elongate
- Cells die when wall is done. Left for structural support
  - May persist for decades!
- Elongated sclerenchyma forms **fibers** (hemp, flax)
- Short sclerenchyma forms **sclerids** (nut shells, pear grit)



Cross-section of **fibers**

sclerids

(lignin stains red)



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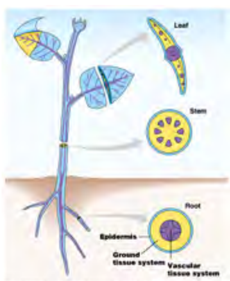
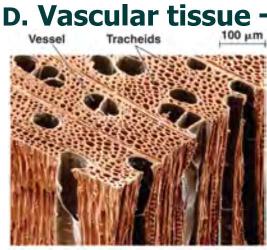


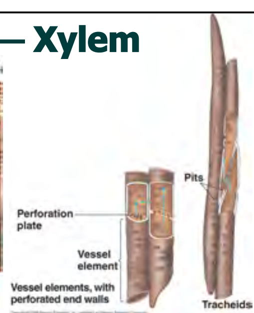
D. Vascular tissue — Xylem

Xylem: elongated cells with thick lignified cell walls.
- Cells die, walls remain.
- Pits in secondary cell wall; porous primary wall filters water as it flows across
  - Supportive tissue
  - Produce vessels to conduct water, minerals and ions from the root tips to the leaf tips
- **Tracheids**: longer, narrower, with overlapping tapered ends
- **Vessel elements**: shorter & fatter, aligned end-to-end → "micropipes" (**vessels**) — ***in angiosperms only***

D. Vascular tissue — Xylem



Tracheids and vessels (colorized SEM)



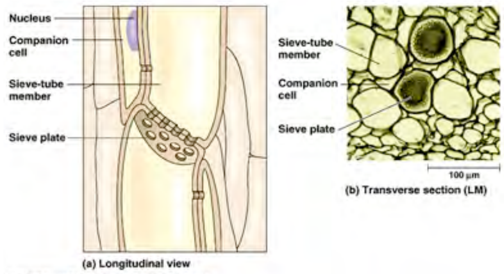
Vessel elements, with perforated end walls

- **Tracheids**: longer, narrower, with overlapping tapered ends
- **Vessel elements**: shorter & fatter, aligned end-to-end → "micropipes" (**vessels**) — ***in angiosperms only***
- Usually associated with sclerenchyma fibers for tensile strength, and rays of parenchyma tissue for lateral water transport

D. Vascular tissue — Phloem

Phloem vessels to transport organic fuel, mostly sucrose, from source tissues to sink organ
- **Sieve-tube elements**: moderately elongated cells with very thin primary cell walls / no secondary walls.
  - Aligned end-to-end with sieve plate in walls between adjacent cells.
  - Cells persist alive, but without nuclei or vacuoles
  - Phloem sap flows from cell to cell through sieve pores and plasma membranes
- **Companion cells**: aligned parallel to sieve-tube element cells (descended from same mother cell)
  - Cytoplasms connect through plasmadesmata
  - Synthesize proteins to support sieve-tube element cell
  - In source tissues, secrete sugars into phloem
- In gymnosperms & pterophytes, **sieve cells** are similar to sieve-tube elements, but retain nuclei. No companion cells

D. Vascular tissue — Phloem



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- Usually associated with sclerenchyma fibers for tensile strength, and rays of parenchyma tissue for lateral water/sugar transport

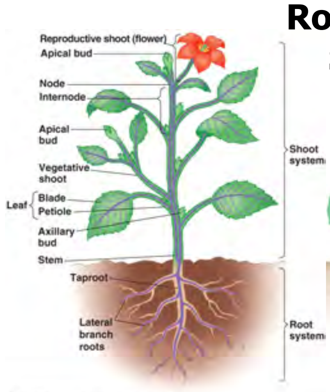
- In gymnosperms & pterophytes, **sieve cells** are similar to sieve-tube elements, but retain nuclei. No companion cells

Multicellular Growth & Development

1. Proliferation – mitotic cell divisions
2. Hypertrophy – enlarging or elongating cells
3. Differentiation – tissue formation
4. Morphogenesis – pattern formation

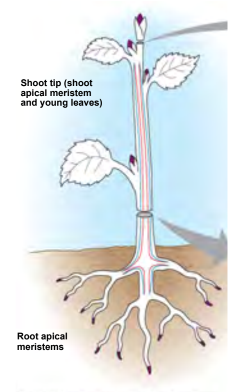
Embryo (seed)
- ⇒ Roots
- ⇒ Shoots
  - ⇒ Stems
  - ⇒ Leaves
    - ⇒ Reproductive organs

Root & Shoot Systems



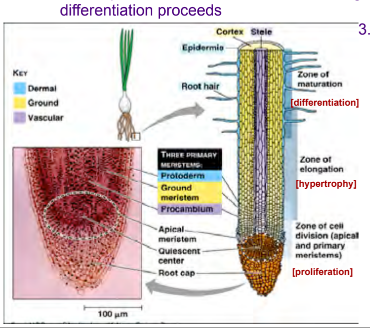
Primary Growth

Roots & shoots lengthen
- by proliferation of apical meristems,
- followed by hypertrophy, and
- early differentiation into primary meristem tissues



Primary Growth in a Root Tip

1. Apical meristem secretes growth-regulating factors → Inhibits differentiation
2. Once apical meristem has moved far enough away, differentiation proceeds
3. Some regions of pericycle, once released from root tip inhibition, become new apical meristems for growth of lateral branches



Primary Growth in a Root Tip

- Development of lateral roots originates in pericycle (outermost layer of vascular bundle) to form vascular core (stele) of the lateral root.

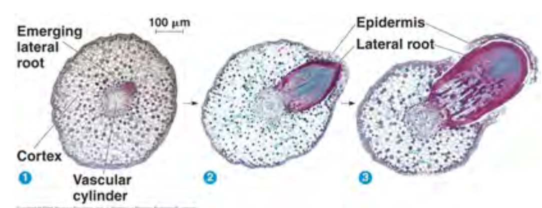
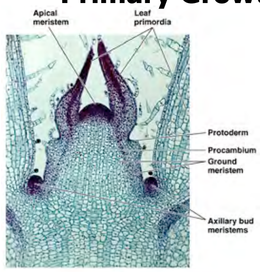


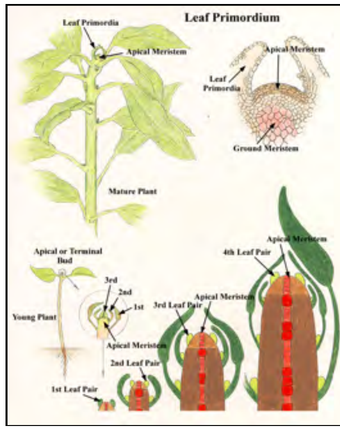
Fig. 35.15

Primary Growth in a Shoot Tip



1. Apical meristem projects laterally to form **leaf primordia**
2. Hypertrophy of region between primordia creates internode lengths between leaves
3. Once apical meristem extends far enough away, primary meristems in stem and leaves differentiate
4. Islands of meristem left behind at upper axis of leaf primordia → **axillary buds**

Primary Growth in the Shoot



1. Apical meristem projects laterally to form **leaf primordia** at **nodes**
2. Leaf primordia develop into leaves at nodes
3. Hypertrophy of **internode** region between primordia creates internode lengths between leaves
4. Islands of meristem left behind at upper axis of leaf primordia → **axillary buds**
5. Axillary bud may become apical meristem of lateral stem **branch**

Primary Growth in a Shoot Tip

Fig. 36.3

- **axillary buds** at successive nodes arranged in spiral pattern
- **Phyllotaxy** ("leaf order"): the arrangement of the leaves on the stem of a plant — unique for that species
  - Determines the amount of self-shading of lower leaves by upper leaves

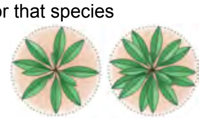


Fig. 36.4

Primary Growth in a Shoot Tip

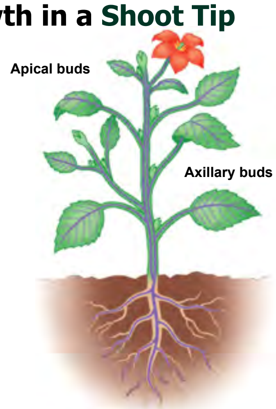
1. In non-growing season (winter), apical meristem goes dormant (**apical bud**) protected by hardened leaf primorida (**bud scales**)
2. When growing season resumes (spring), scales fall of leaving **bud scar** and apical bud extends again

Fig. 35.12

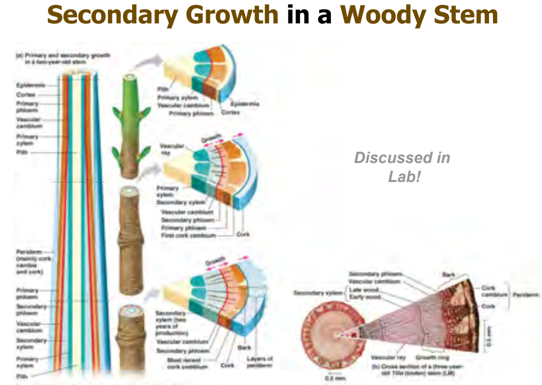
Primary Growth in a Shoot Tip

Apical dominance:

1. Proximity of apical bud causes axillary buds to remain dormant.
2. Once shoot tip growth moves apical bud away, axillary buds may be stimulated to become new apical bud to form shoot or branch
3. Removal of apical bud (grazing/pruning) likewise removes apical dominance and results in lateral shoot formation



Secondary Growth in a Woody Stem



Discussed in Lab!

Fig. 35.19

Developmental Phase Changes of Meristem
and
Determinate Development of Leaves

Fig. 35.33


Fig. 35.24

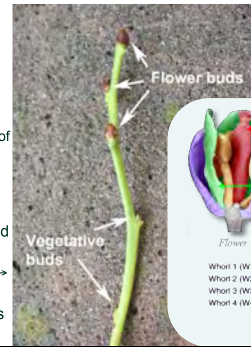
Developmental Phase Changes of Meristem
and
Development of Flowers

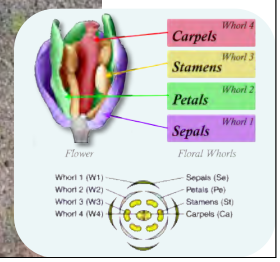
Specific developmental & environmental cues →

Axillary buds develop as **floral buds** →

flower instead of branch

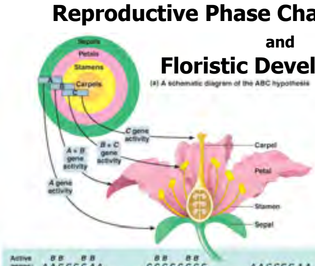
- Nodes of floral axis develop as **whorled floral primordia** instead of leaf primordia
- First internode → petiole
- Distal internodes very short





Reproductive Phase Changes of Meristem
and
Floristic Development

- Meristem identity genes: leaf primordia → floral primordia
- Organ identity genes: which floral primordia node becomes which floral component
  - The ABC hypothesis



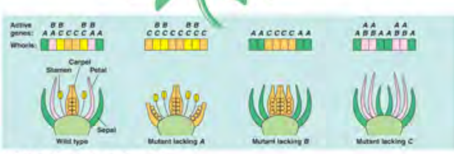


Fig. 35.28