AP Biology

Daily Agenda Slides

Plants

Unit 11

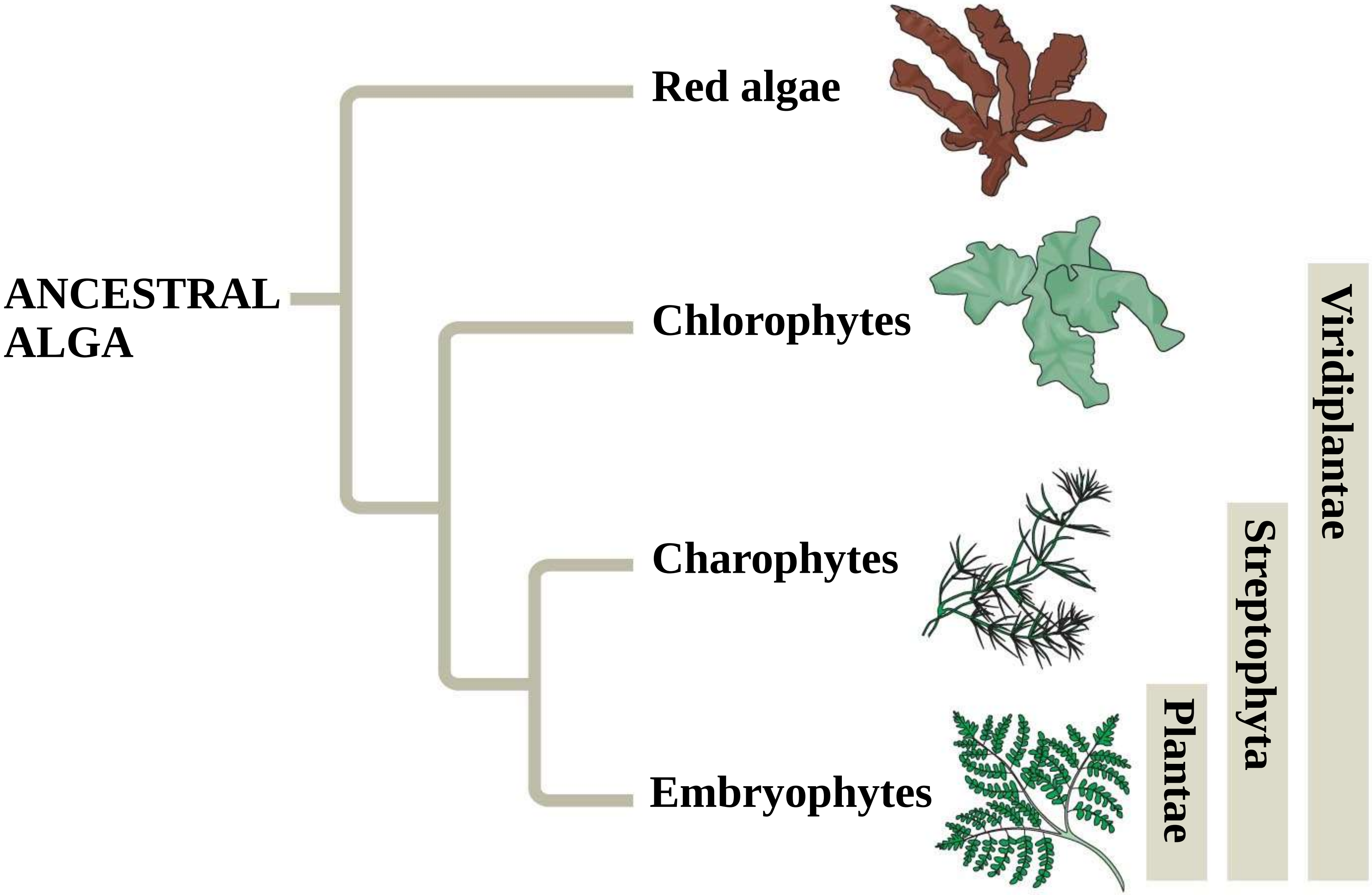
Day 1

- Intro to plants
- KWL plants
- Plant scavenger hunt

Day 2

- QOD – What features evolved to help plants live out of water
- Plant evolution power point (includes types)
- Plant leaf and photosynthesis google doc assignment
- Germinate seeds for root structure analysis

Fig. 29-4


Red algae
ANCESTRAL
ALGA
Chlorophytes
Charophytes
Embryophytes
Viridiplantae
Streptophyta
Plantae

Morphological and Molecular Evidence

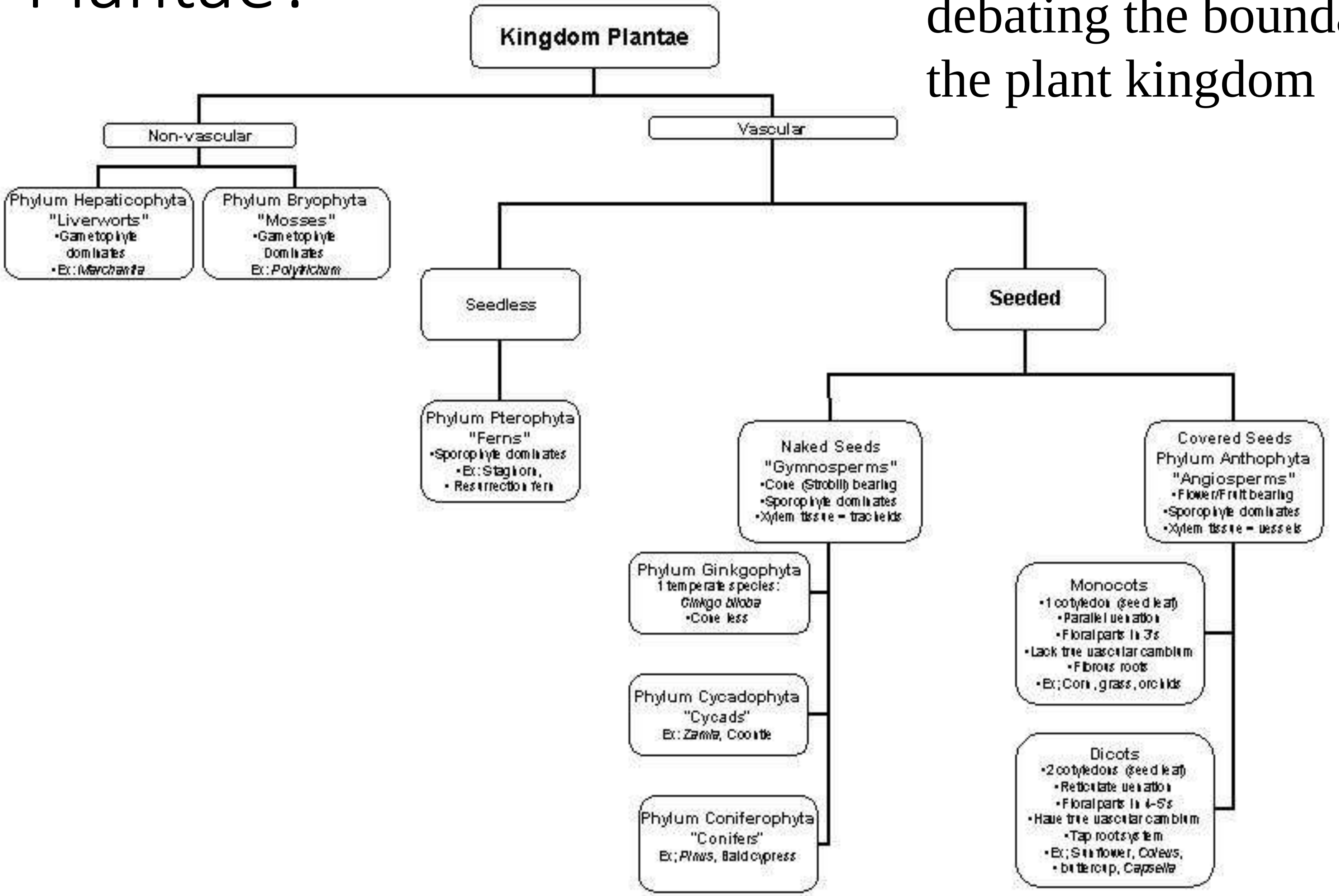
- Many characteristics of land plants also appear in a variety of algal clades, mainly algae
- However, land plants share key traits only with charophytes

Plant Origins

- Green algae called charophytes are the closest relatives of land plants
- **Similarities:**
  - **Cell walls made of cellulose**
  - **Photosynthesis**
  - **Chlorophyll a and b**
  - **Similar sperm structure**
  - **Closely related genetically**

Kingdom Plantae?

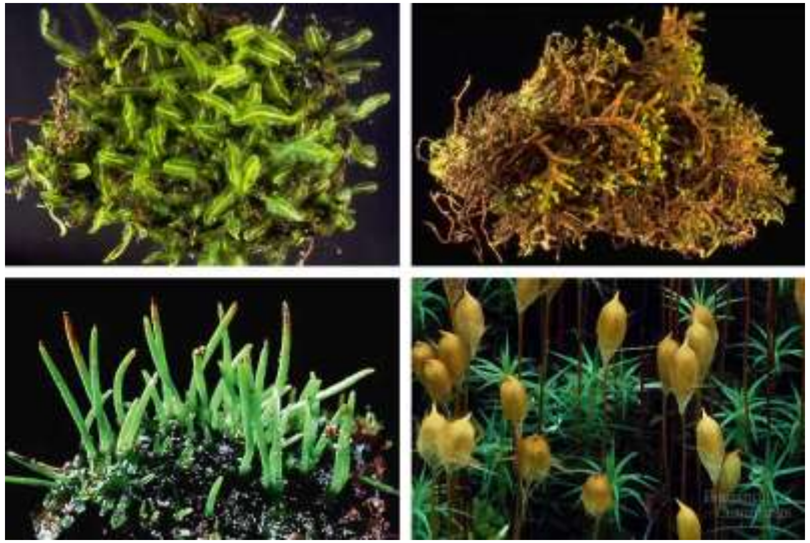
Systematists are currently debating the boundaries of the plant kingdom



Nonvascular plants have life cycles dominated by gametophytes

- Bryophytes are represented today by three phyla of small herbaceous (nonwoody) plants:
  - **Liverworts**, phylum Hepatophyta
  - **Hornworts**, phylum Anthocerophyta
  - **Mosses**, phylum Bryophyta

Bryophytes



- 1st to exhibit the embryonic condition
  - male = antheridium
  - female = archegonium
- Flagellated (water) sperm
- No vascular tissue (imbibe water)
- No lignin (short, herbaceous)
- Haploid gametophyte is the dominant generation

Origins and Traits of Vascular Plants

- Fossils of the forerunners of vascular plants date back about 420 million years
- These early tiny plants had independent, branching sporophytes
- Living vascular plants are characterized by:
    - Life cycles with dominant sporophytes
    - Vascular tissues called xylem and phloem
    - Well-developed roots and leaves

Pteridophytes: seedless vascular plants

- Ferns, horsetails
- True roots and leaves
- Roots have lignified vascular tissue
- Sporophyte-dominant life cycle
- Homosporous plants: a single type of spore….
- Sporophyte---->
  - Single type of spore
  - Bisexual gametophyte
  - Eggs; sperm (flagellated; damp locations)
- Carboniferous period plants

Gymnosperms

- Cone-bearing plants
- Ginkgo, cycads, and conifers
- All are “evergreens”
- Needle-shaped leaves
- Lack enclosed chambers (ovaries) for seeds
- Ovules and seeds develop on specialized leaves called sporophylls
- Vascular tissue refinement: *tracheids*~ water conducting and supportive element of xylem

Angiosperms

- Most diverse and geographically widespread of all plants
- "Flowering plants"(Phy: *Anthophyta*)
- Monocots: 1 embryonic seed leaf (lilies, palms, grasses, grain crops)
- Dicots: 2 embryonic seed leaves (roses, peas, sunflowers, oaks, maples)
- Vascular tissue refinement: vessel elements/fiber cells

(a) Flowering Plants


(b) *Amborella*


(c) Water lily

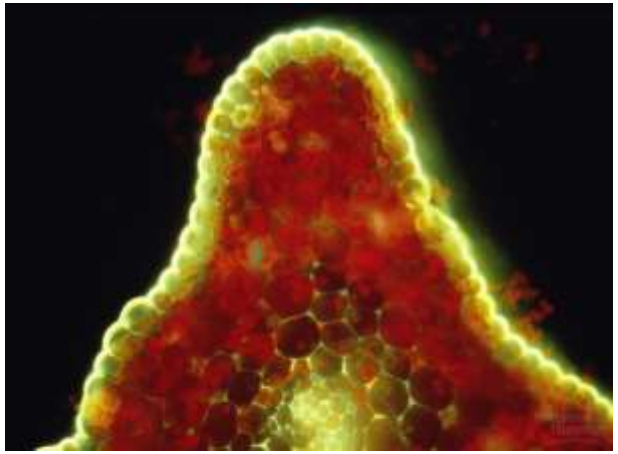

(d) Star anise

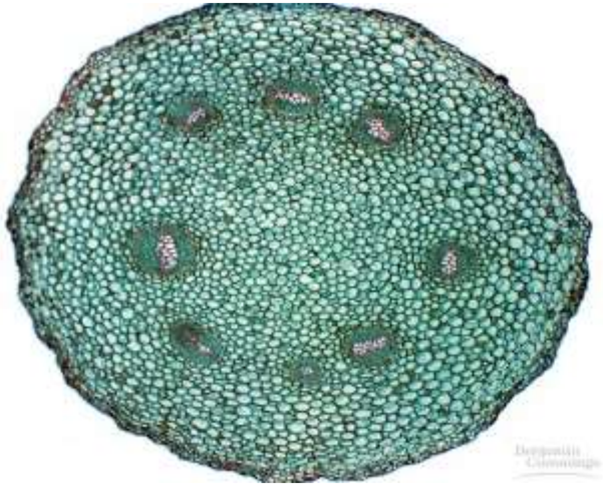

(e) Orchid (monocot)


(f) California poppy (eudicot)

Terrestrial adaptations

- Cuticle
- Stomata
- Vascular tissue - xylem and phloem
- Secondary compounds (protection from herbivore)





Plant Growth

QOD

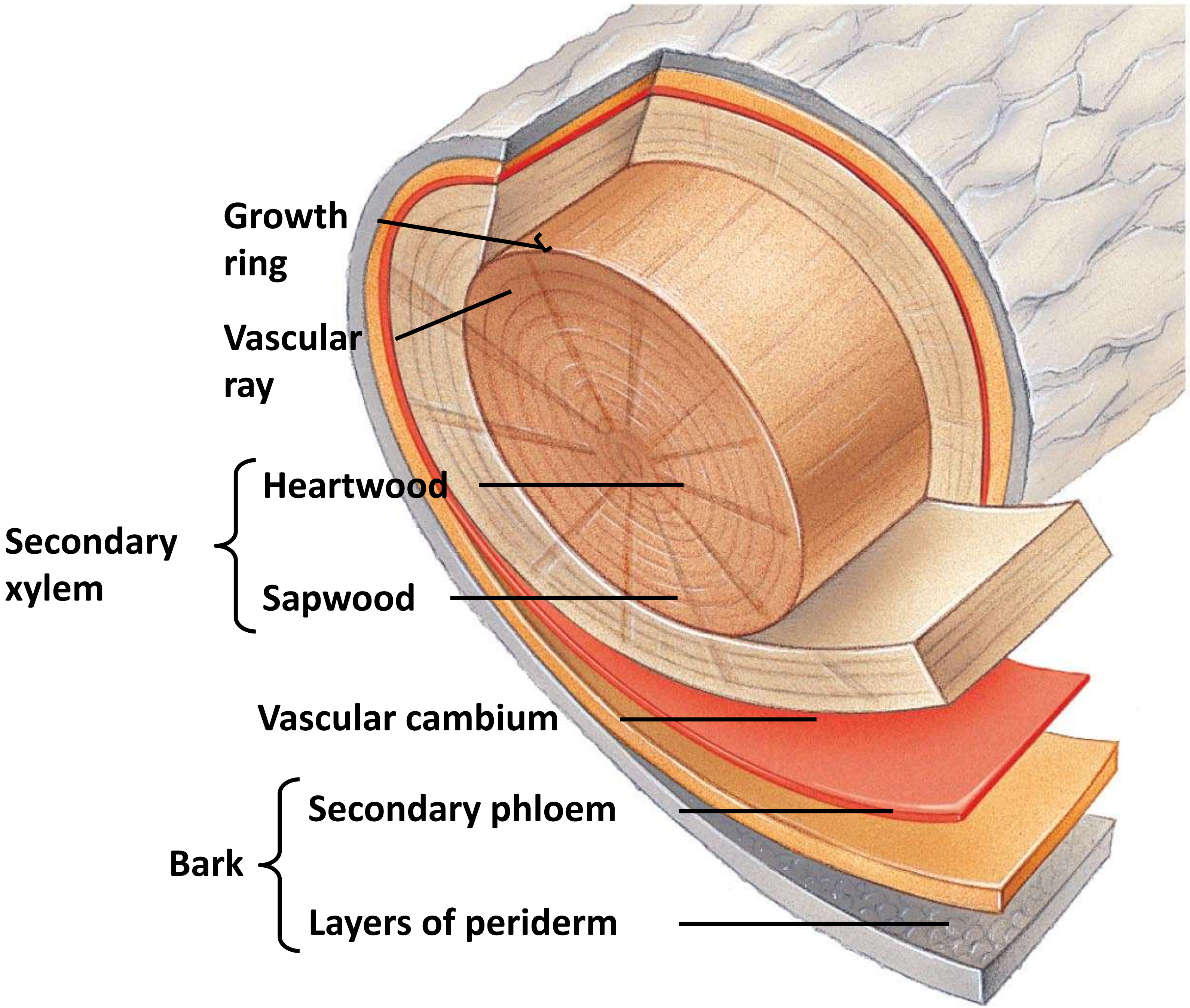
- Leaves, stems and roots can all be modified to serve special functions. For each plant organ listed above, give three examples of a specialized form and the function it carries out.

MODIFIED ROOTS

MODIFIED LEAVES

MODIFIED STEMS

- The growth occurs in the *cambium* (the thin, continuous sheath of cells between bark and wood):
- Outside the cambium. The outer cells become part of the *phloem*. Some of the phloem dies each year and becomes part of the outer bark.
- Inside the cambium. The inner cells become part of the *xylem*. These cells contribute most of a tree's growth in diameter. These cells show the most annual variation:
  - When a tree grows quickly, the xylem cells are large with thin walls. This early wood or springwood is the lighter-colored part of a tree ring.
  - In late summer, growth slows; the walls of the xylem cells are thicker. This late wood or summerwood is the darker-colored part of a tree ring.
- [*Xylem*, which is a useful word for Scrabble games, is pronounced "ZI-lem." The word is derived from *xylon*, a Greek word for wood.]
- *Dendrochronology* is the analysis of tree ring growth patterns, and can be used to study past climate change


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

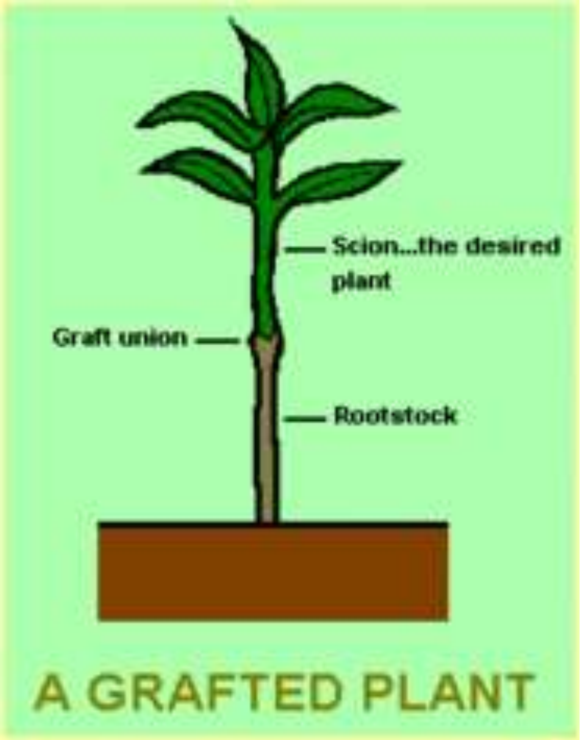
Seed Germination Lab

- Choose a seed
- Think about what it needs to germinate
- Prepare the seed to germinate
- Do research to see what type of seed you have
- Record Day 1 notes in your lab notebook
- Turn in your lab notebook

Germination of Seeds

Day 12

- QOD 4 : Plants are able to reproduce both sexually and asexually. Sexual reproduction is much more complicated and takes more energy. What features of sexual reproduction justify the extra energy required.



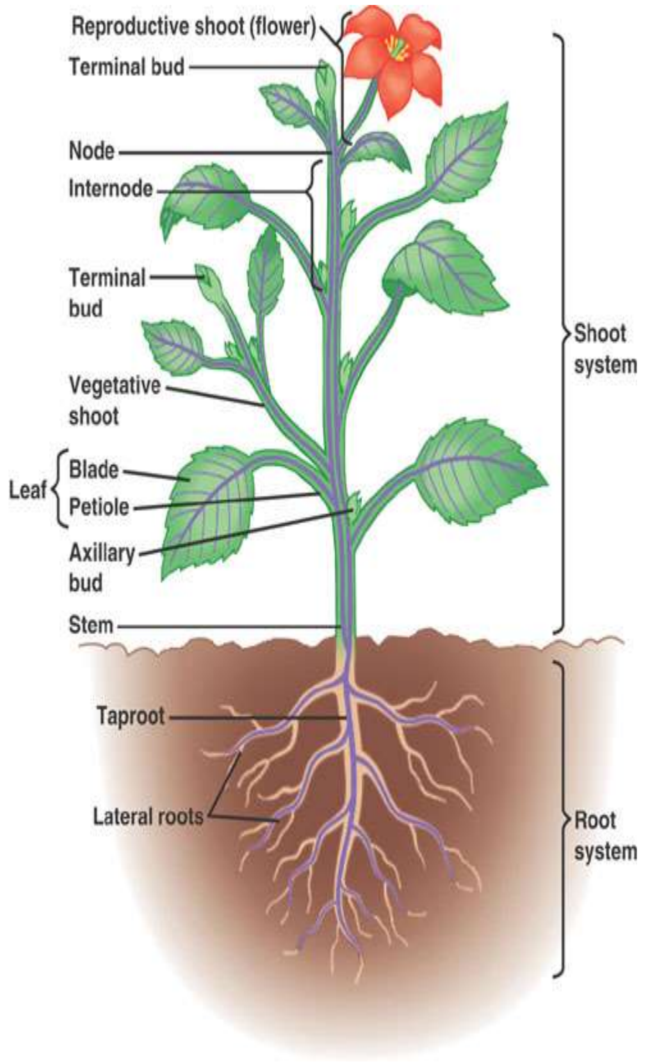
- Chapter #35~ *Plant Structure and Growth*

What part of a plant is represented by each of these:

- Carrot
- Celery
- Red Pepper
- Tomato
- Lettuce
- Garbanzo Bean

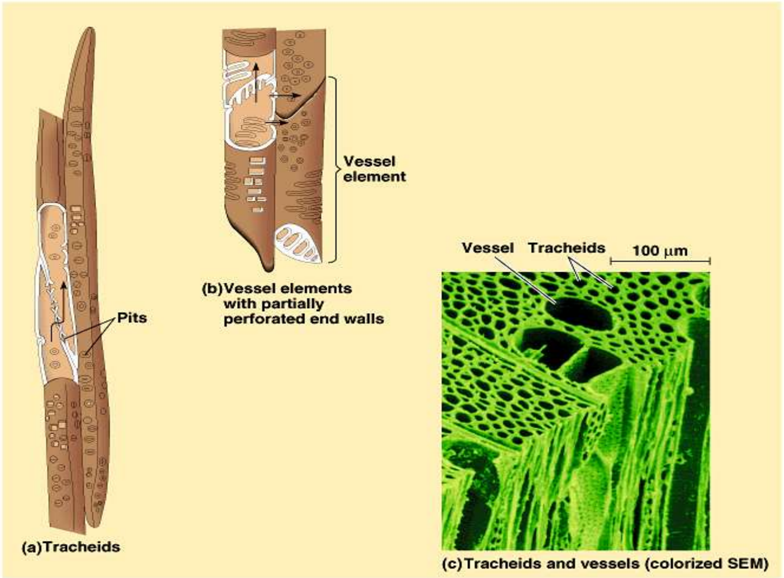
Angiosperm structure

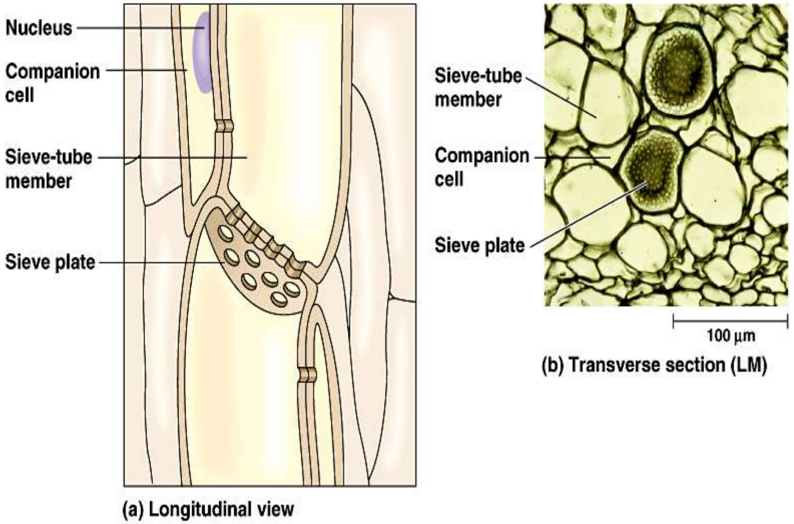
- **<u>Three basic organs</u>**:
- <u>Roots</u> (root system)
  - fibrous: mat of thin roots
  - taproot: one large, vertical root
- <u>Stems</u> (shoot system)
  - nodes: leave attachment
  - internodes: stem segments
  - axillary bud: dormant, vegetative potential
  - terminal bud: apex of young shoot
  - apical dominance: inhibits axillary buds
- <u>Leaves</u> (shoot system)
  - blade
  - petiole



Plant Organ Systems

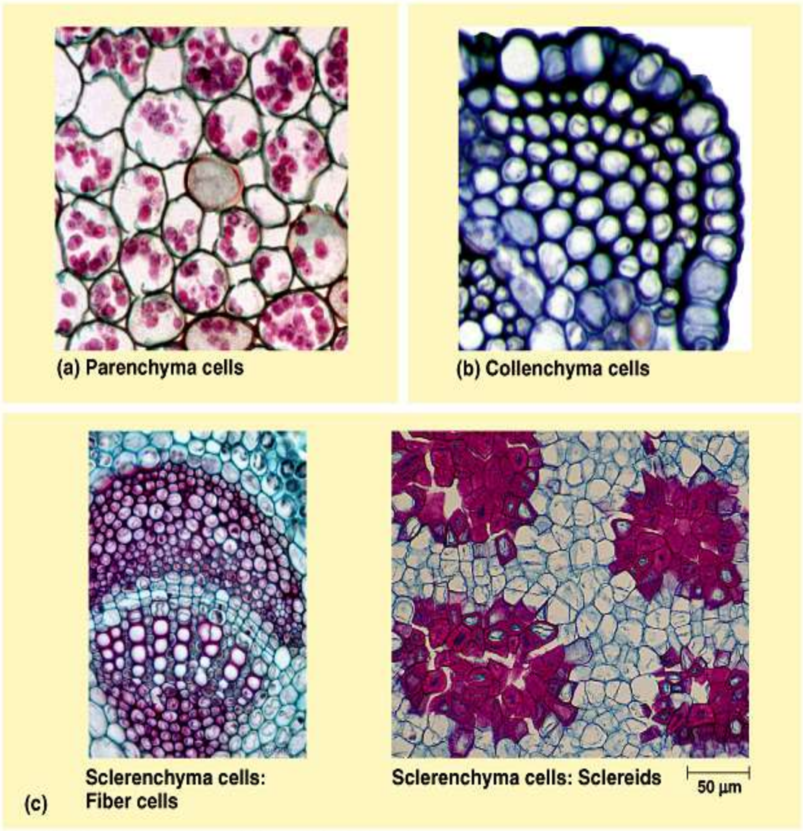
- <u>Dermal</u>
- epidermis: single layer of cells for protection
- Periderm: bark
- cuticle
- <u>Vascular</u> (material transport)
- xylem: water and dissolved minerals roots to shoots
- tracheids & vessel elements: xylem elongated cells dead at maturity
- phloem: food from leaves to roots and fruits
- sieve-tube members: phloem tubes alive at maturity capped by sieve plates; companion cells (nonconducting) connected by plasmodesmata
- <u>Ground</u> (photosynthesis, storage, support): pith and cortex





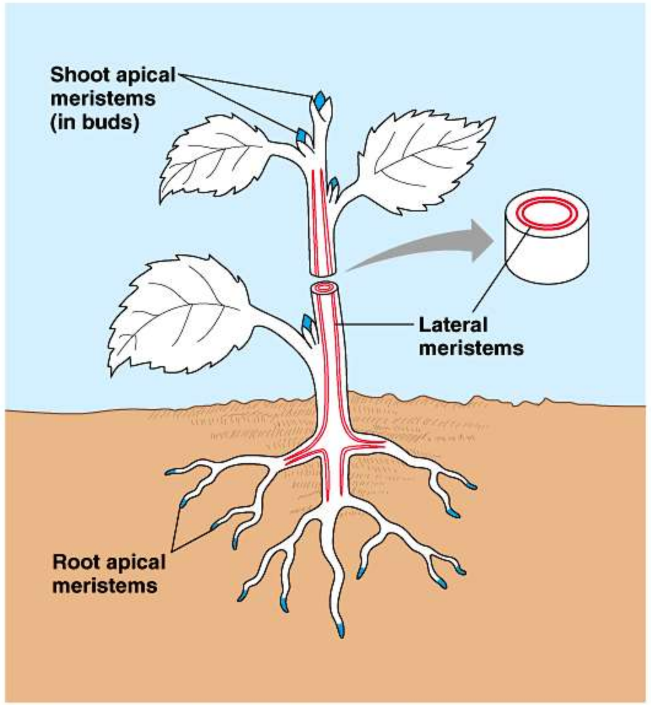
Plant Tissue Cell Types

- Parenchyma primary walls thin and flexible; no secondary walls; large central vacuole; most metabolic functions of plant (chloroplasts)
- Collenchyma unevenly thick primary walls used for plant support (no secondary walls ; no lignin)
- Sclerenchyma support element strengthened by secondary cell walls with lignin (may be dead; xylem cells); fibers and sclereids for support



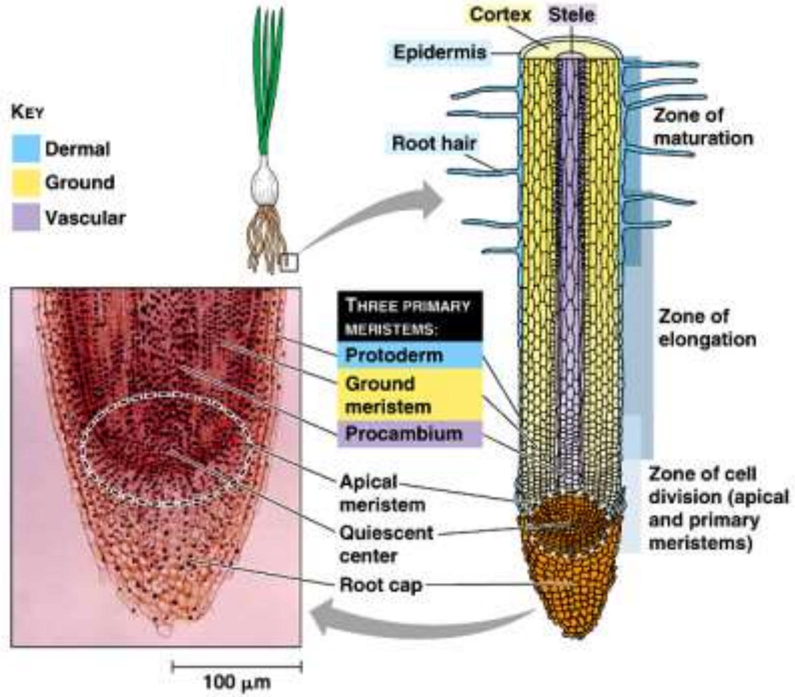
Plant Growth

- **Life Cycles**
- *annuals*: 1 year (wildflowers; food crops)
- *biennials*: 2 years (beets; carrots)
- *perennials*: many years (trees; shrubs)
  - Deciduous
  - Evergreen
- **Meristems**
- *apical*: tips of roots and buds; primary growth
- *lateral*: cylinders of dividing cells along length of roots and stems; secondary growth (wood)



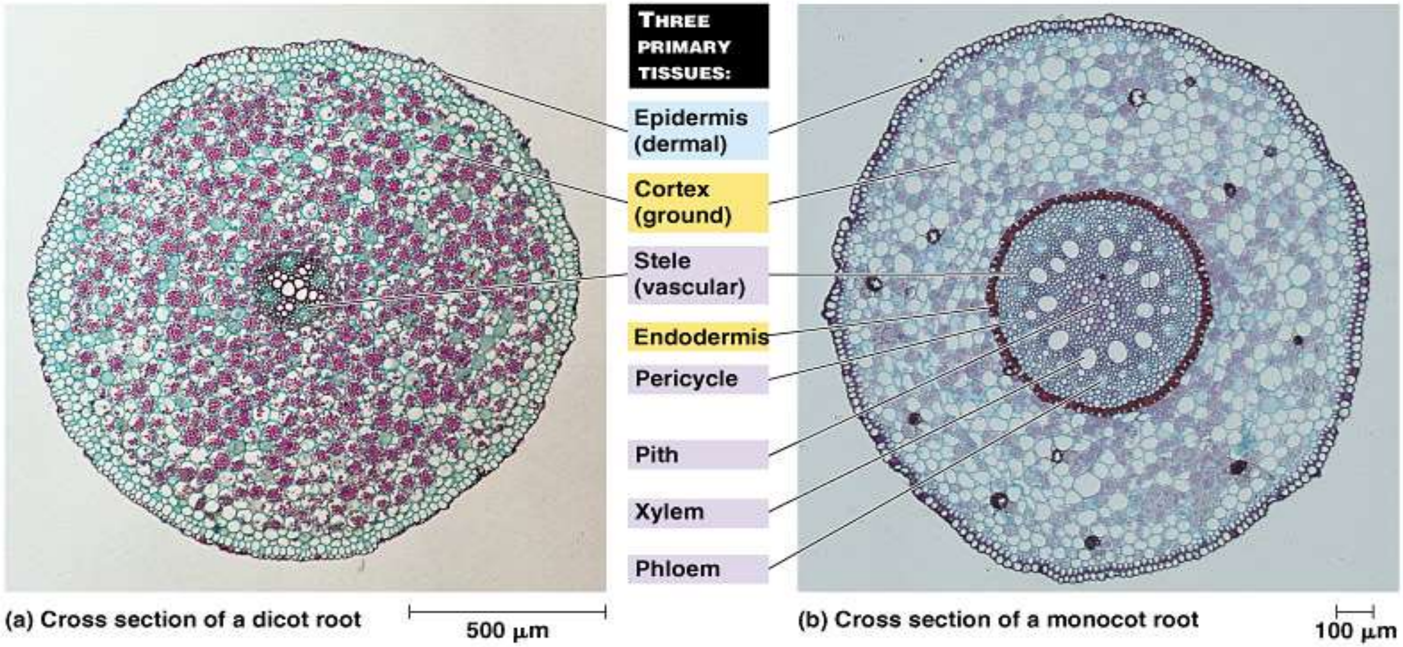
Primary growth

- **Roots**
- *root cap*~ protection of meristem
- *zone of cell division*~ primary (apical) meristem
- *zone of elongation*~ cells elongate; pushes root tip
- *zone of maturation*~ differentiation of cells (formation of 3 tissue systems)



Primary Tissues of Roots

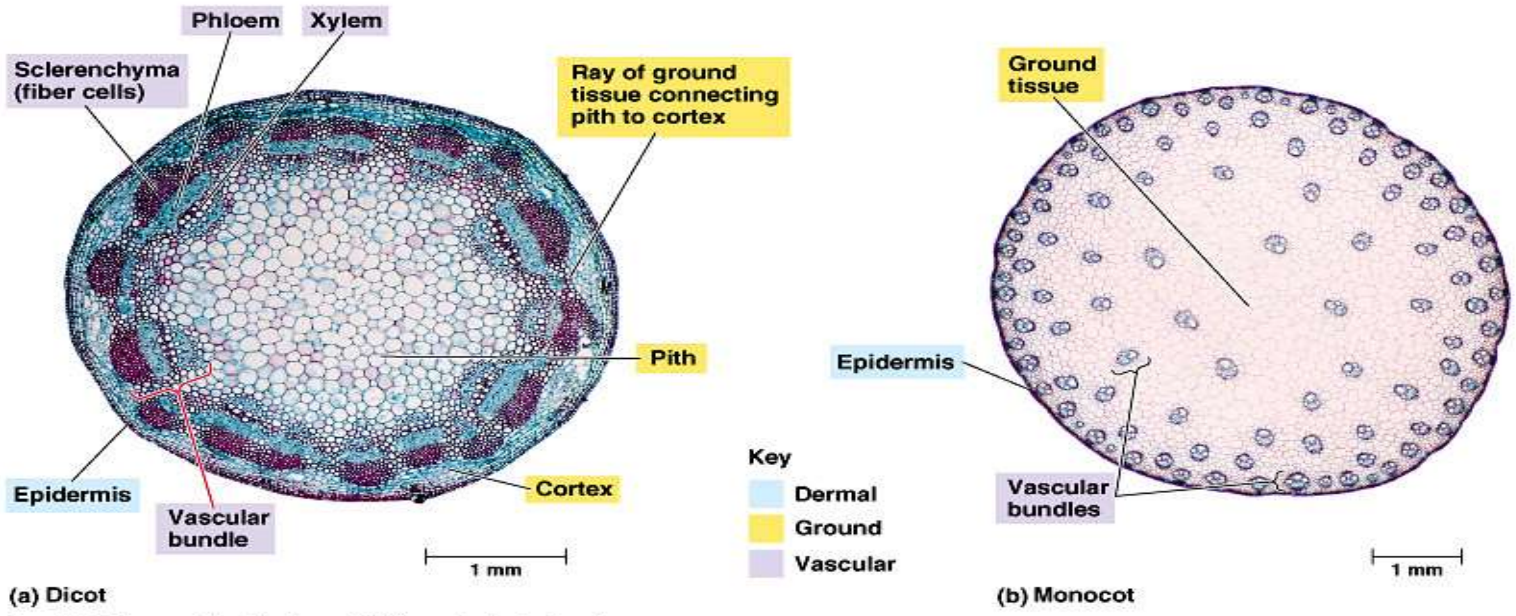
- *Stele*~ the vascular bundle where both xylem and phloem develop
- *Pith*~ central core of stele in monocot; parenchyma cells
- *Cortex*~ region of the root between the stele and epidermis (innermost layer: *endodermis*)
- *Lateral roots*~ arise from *pericycle* (outermost layer of stele); just inside endodermis, cells that may become meristematic



(a) Cross section of a dicot root (b) Cross section of a monocot root

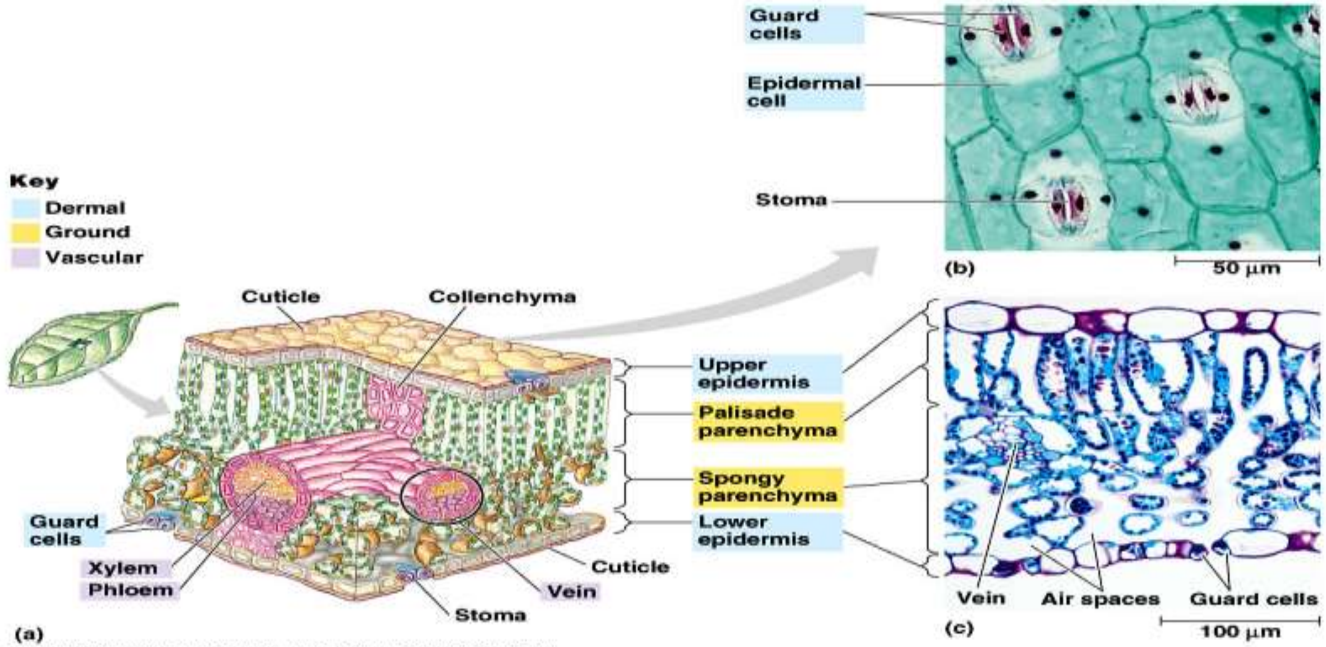
Primary Tissues of Stems

- Vascular bundles (xylem and phloem)
- Surrounded by ground tissue (xylem faces pith and phloem faces cortex)
- Mostly parenchyma; some collenchyma and sclerenchyma for support



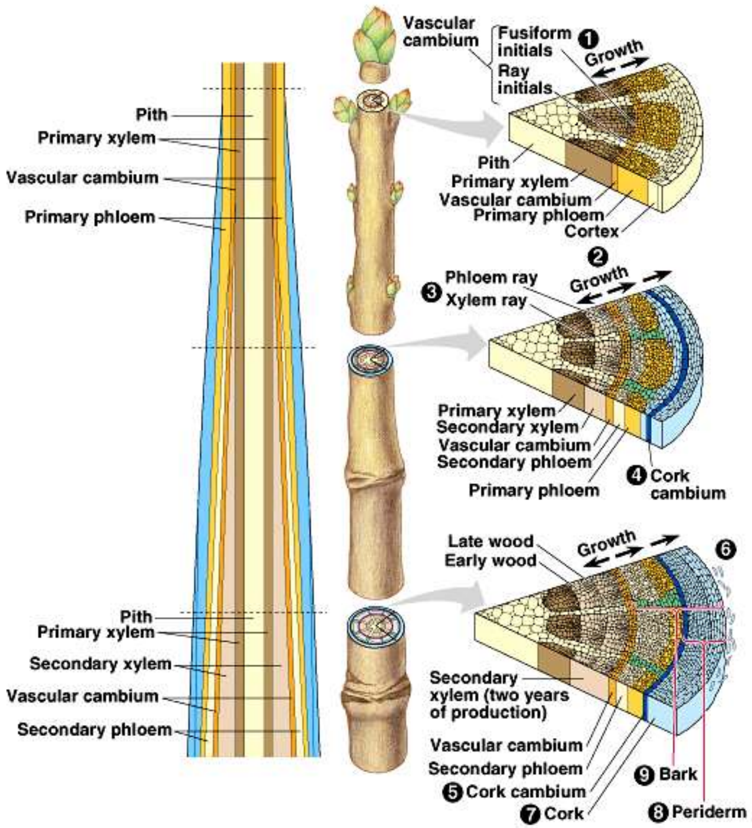
Primary Tissues of Leaves

- Epidermis/cuticle (protection; desiccation)
- *Stomata* (tiny pores for gas exchange and transpiration)/*guard cells*
- *Mesophyll*: ground tissue between upper and lower epidermis (parenchyma with chloroplasts); palisade (most photosynthesis) and spongy (gas circulation)

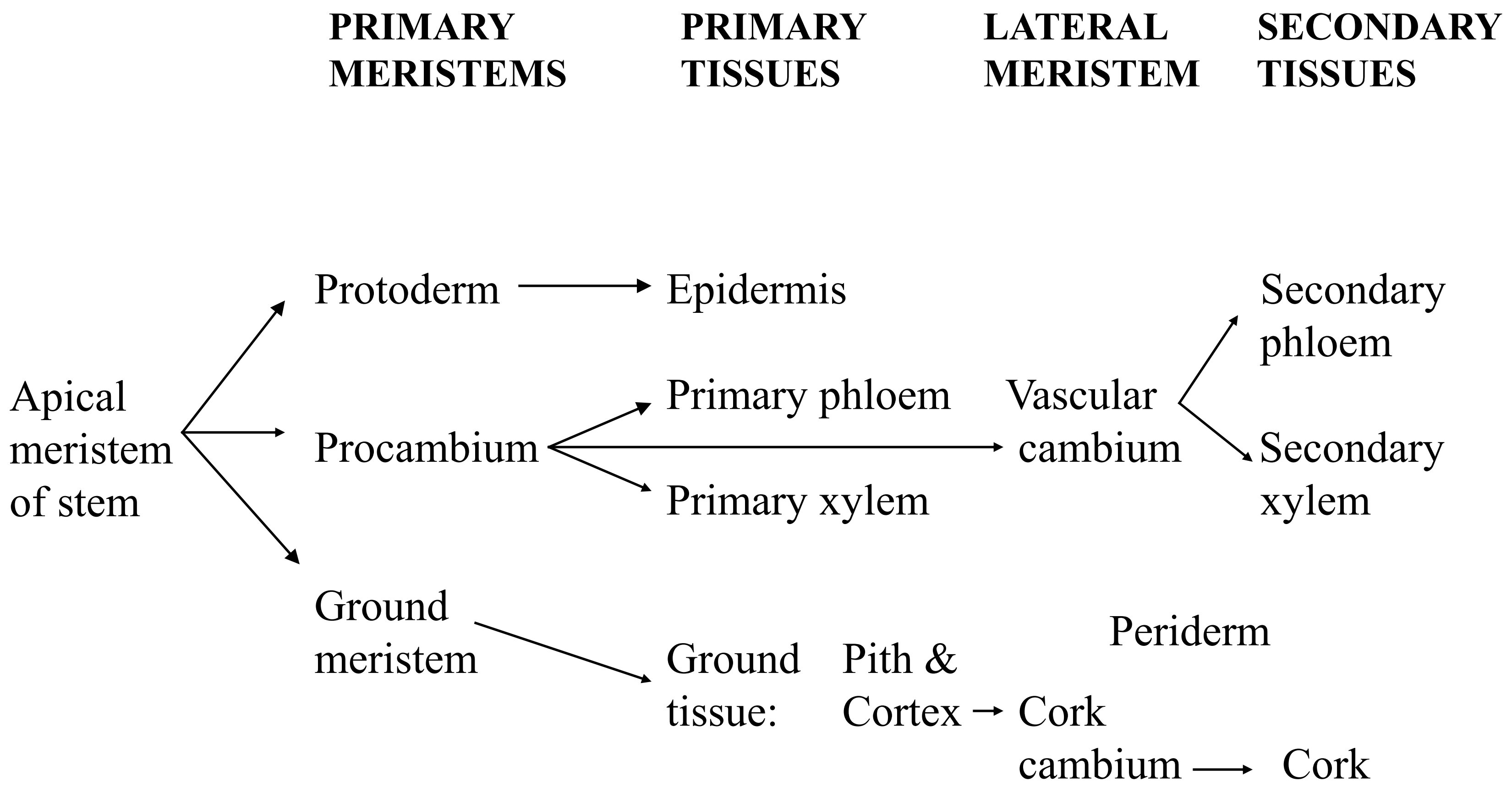


Secondary Growth

- <u>Two lateral meristems</u>
- *vascular cambium* ~
  produces secondary xylem
  (wood) and secondary
  phloem (diameter increase;
  annual growth rings)
- *cork cambium* ~
  produces thick covering
  that replaces the epidermis;
  produces cork cells; cork plus cork cambium make up the *periderm*; *lenticels* (split regions of periderm) allow for gas exchange; *bark*~ all tissues external to vascular cambium (phloem plus periderm)



Summary of primary & secondary growth in a woody a stem



Today's Lab: Structure and Function in Plants

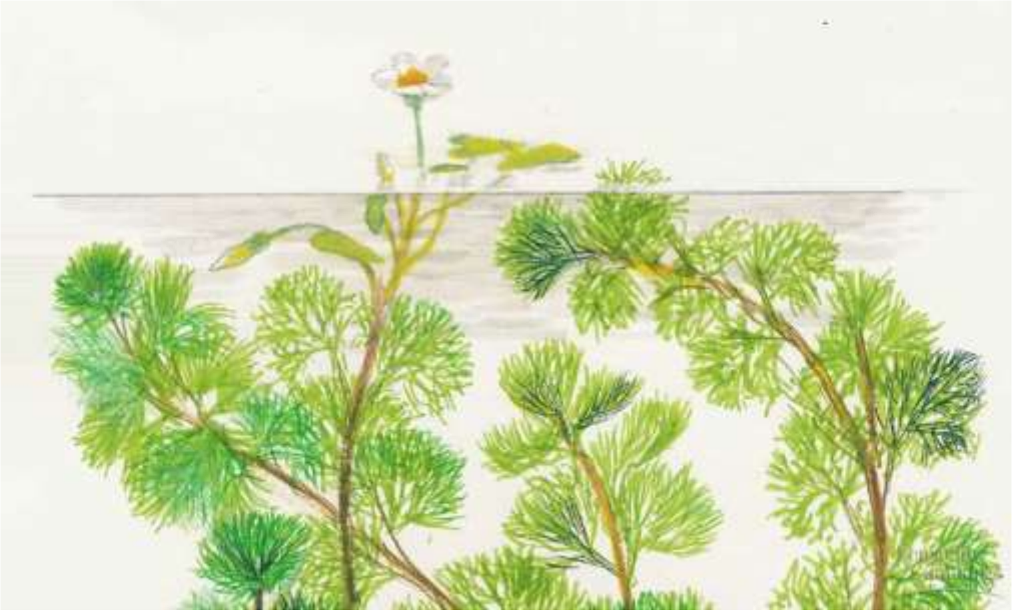
You will be observing the three main organs of plants

- root
- shoot
- leaf

For each organ, you will need to make a sketch of each of the following levels of organization:

- organ
- tissue
- cell

Each sketch will show labeled structures and include a description of the function of each part



Plant Structure and Growth

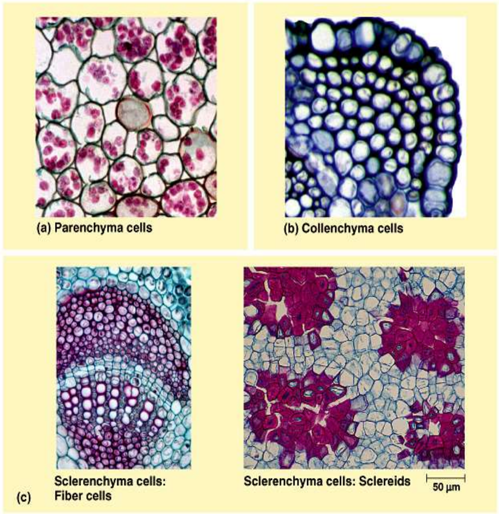
Plant Tissue Foldable

- Three cell types
  - Parenchyma
  - Collenchyma
  - Sclerenchyma

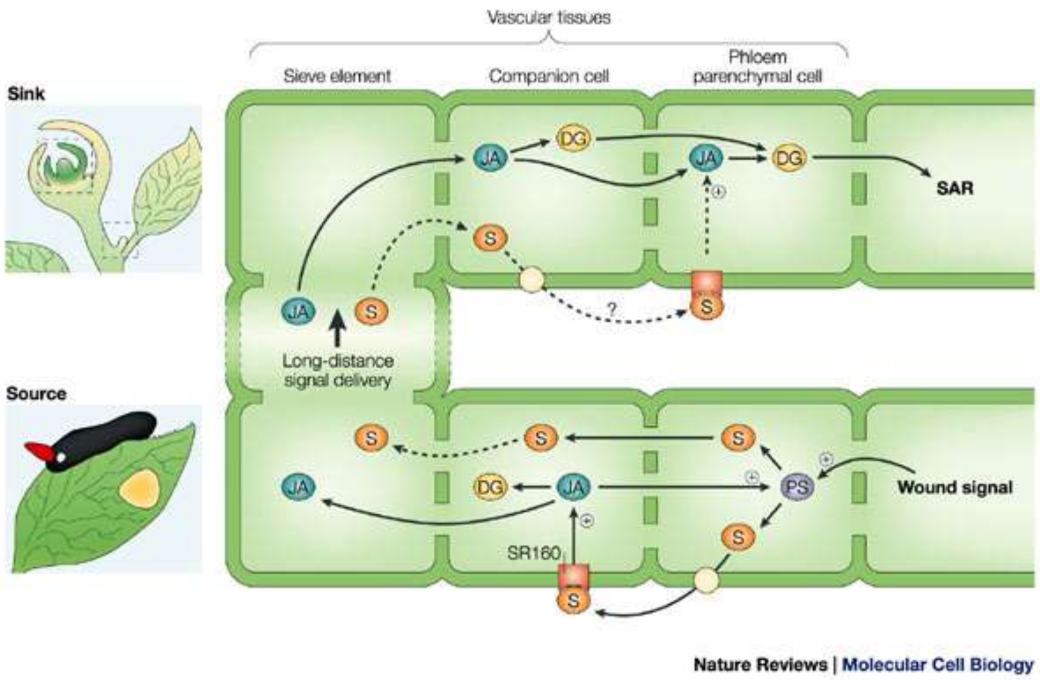
- Fold paper in half (hot dog)
- Divide it into thirds
- Front Cover
  - Picture with labels
- Inside top
  - Examples of where cell type is found
- Inside bottom
  - Description of structure
  - Description of function

Plant Tissue Cell Types

- Parenchyma
  primary walls thin and flexible; no secondary walls; large central vacuole; most metabolic functions of plant (chloroplasts)
- Collenchyma
  unevenly thick primary walls used for plant support (no secondary walls ; no lignin)
- Sclerenchyma
  support element strengthened by secondary cell walls with lignin (may be dead; xylem cells); fibers and sclereids for support



Cell Junctions



- Gap Junction
- Desmosome
- Tight junction
- Adheren
- Plasmodesmata

Plant Tissues

- Dermal (epidermis): single layer of cells for protection
- cuticle
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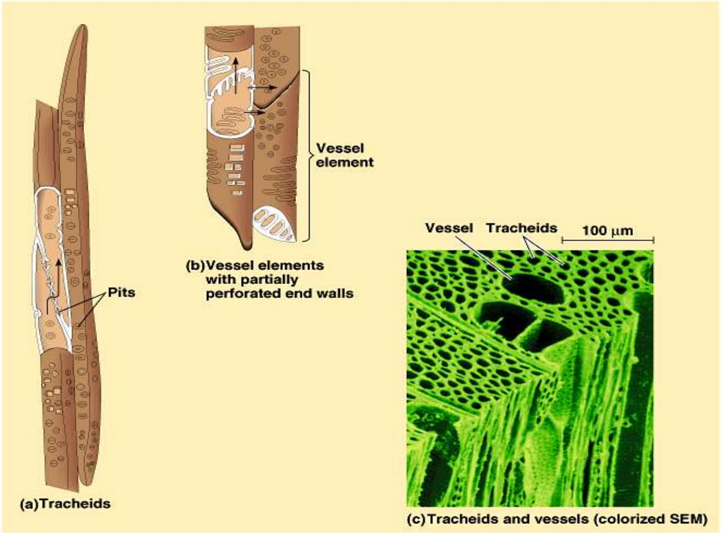

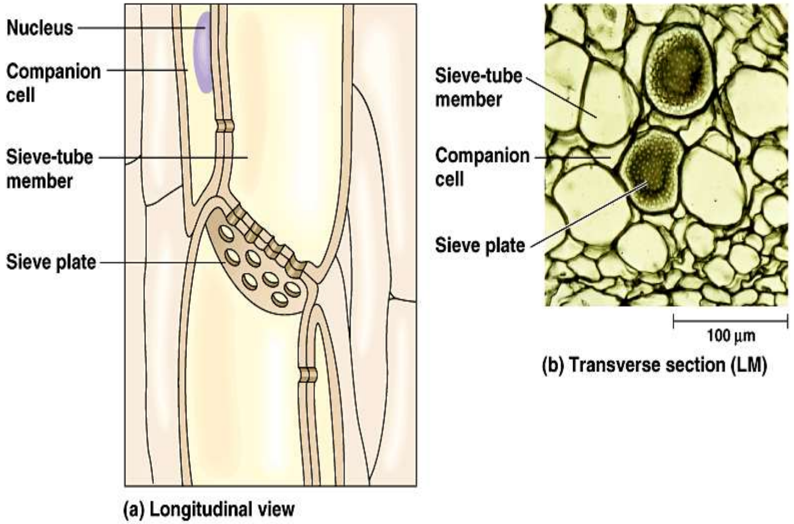

Angiosperm structure

- **Three basic organs**:
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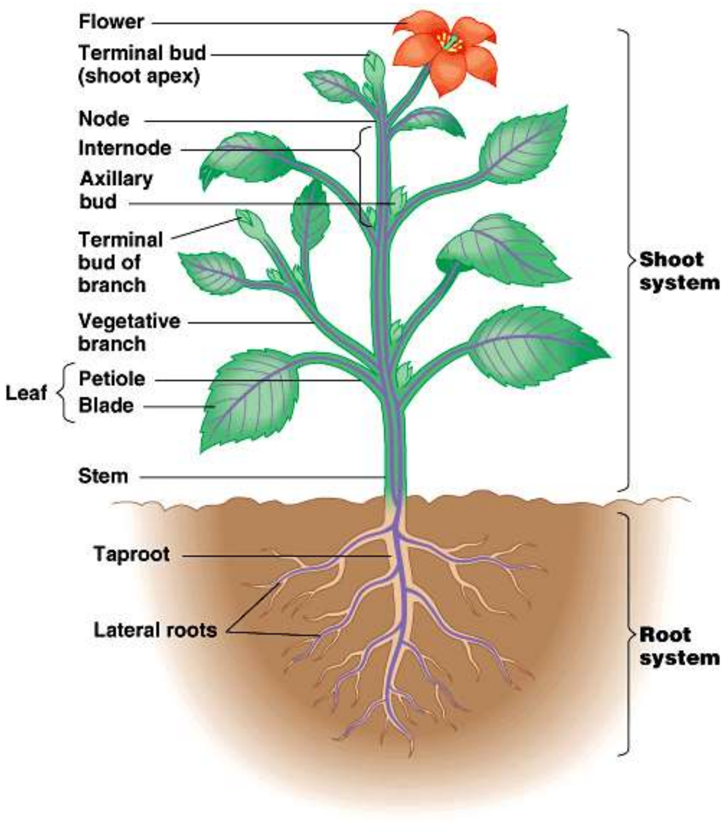
- Leaves (shoot system)
  - blade



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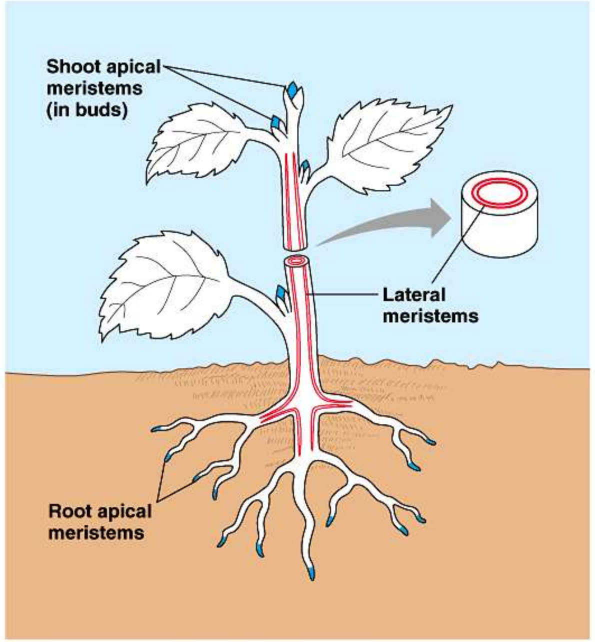

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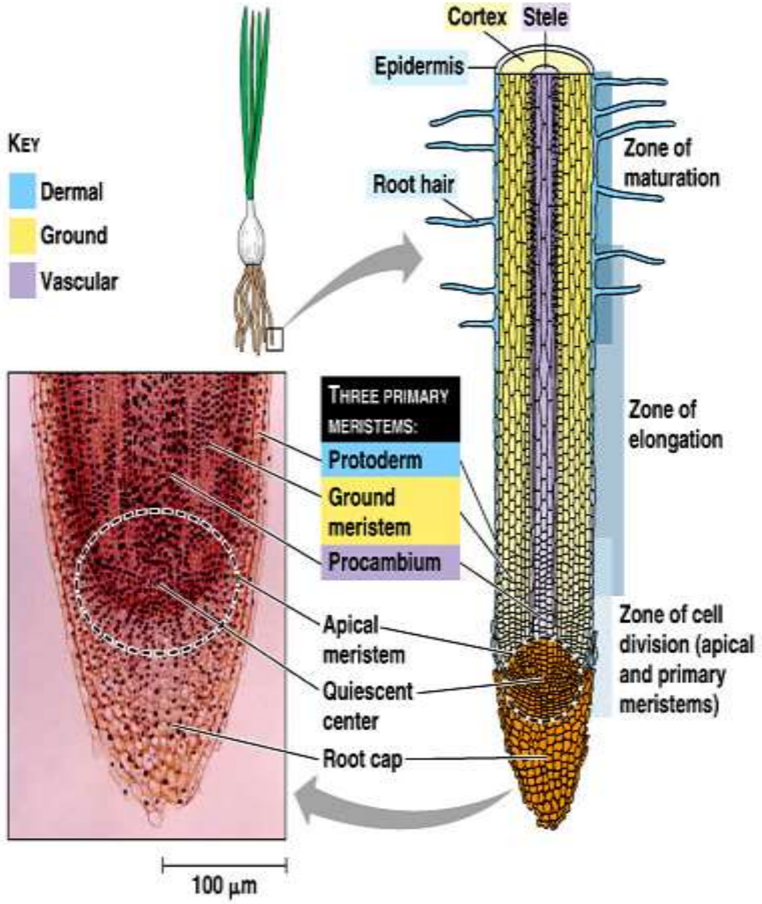

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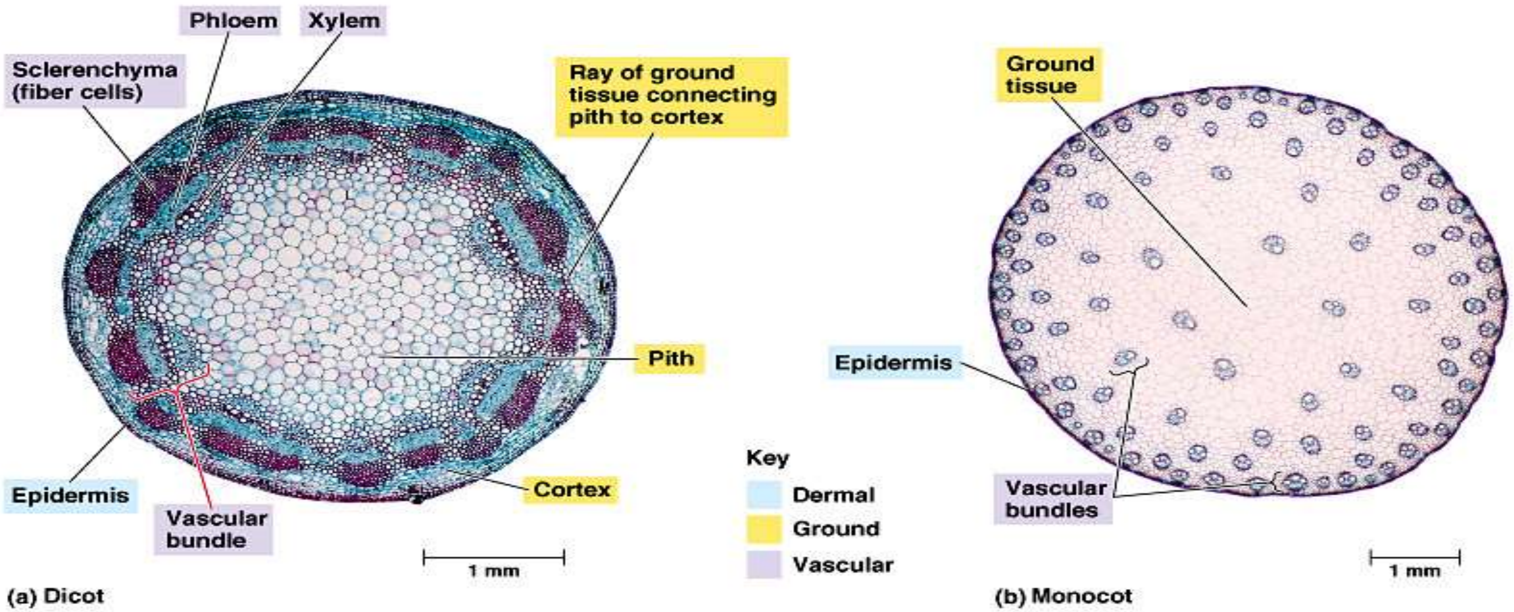

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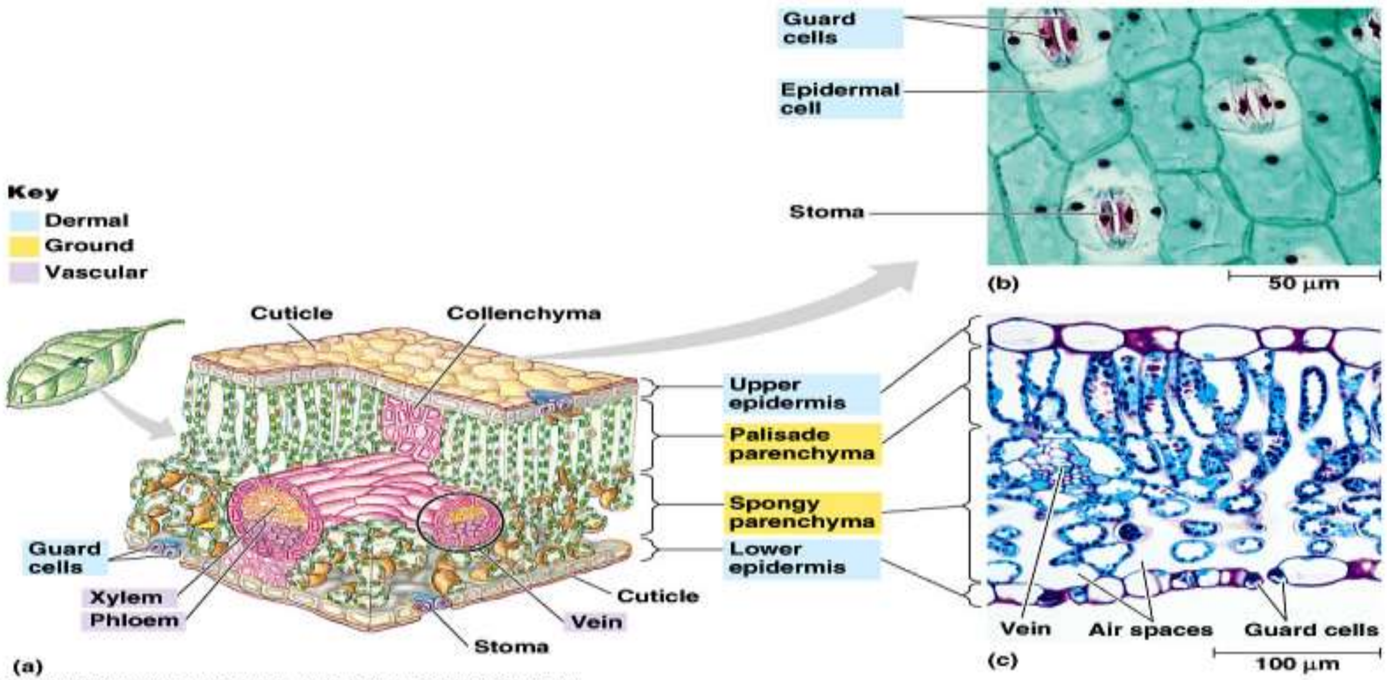

Secondary Growth

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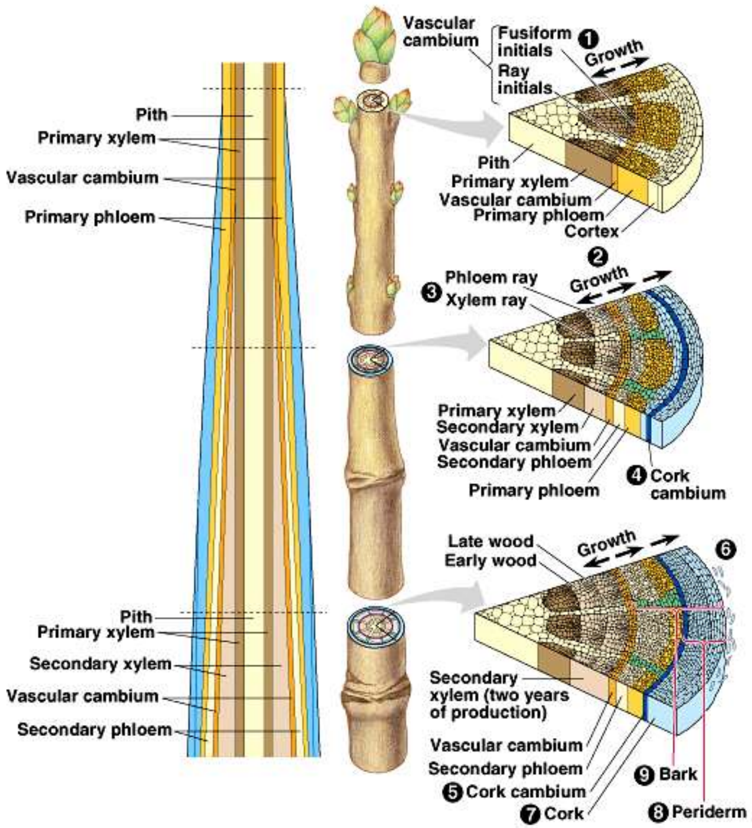
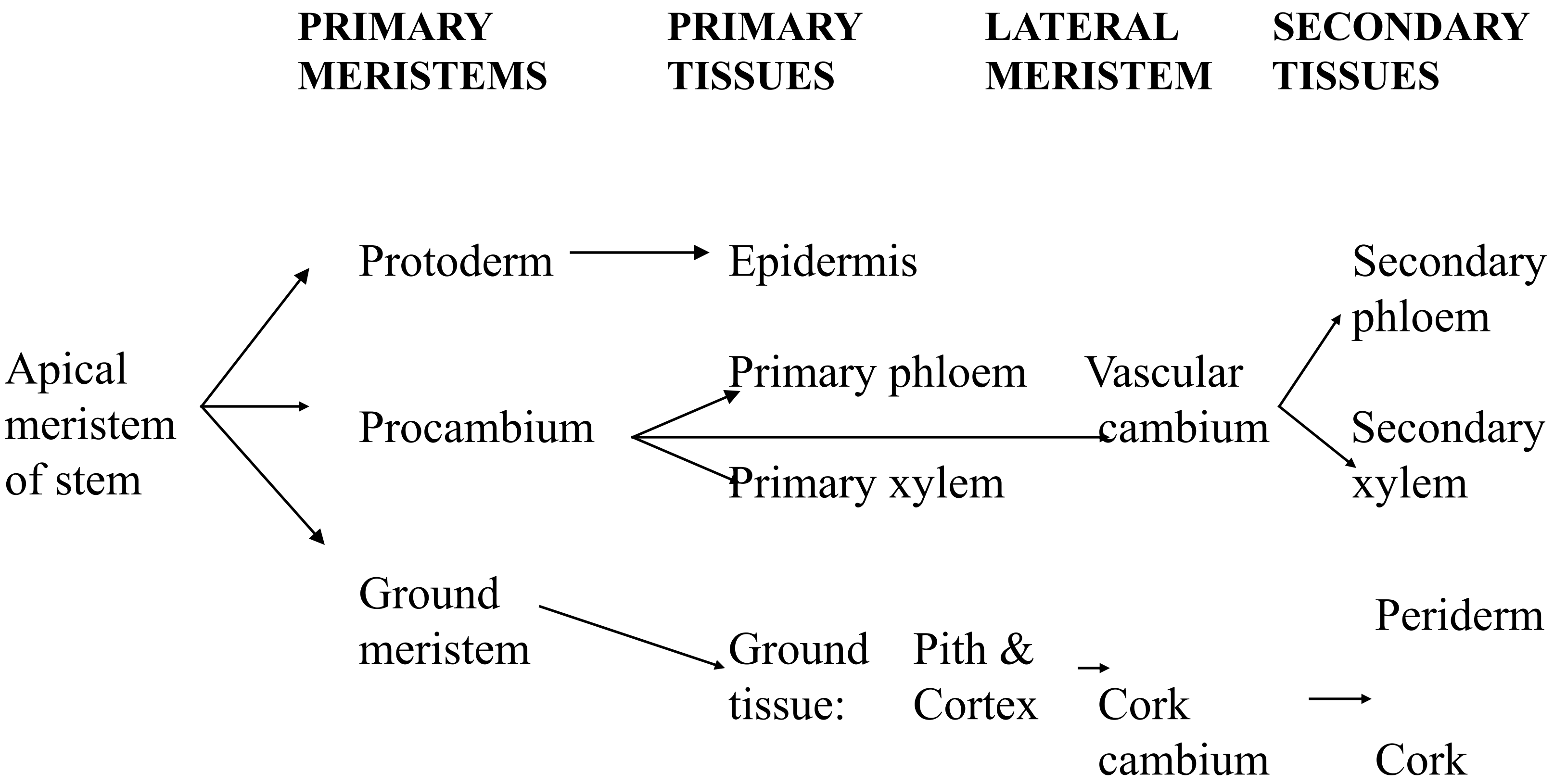


<u>Summary of primary & secondary growth in a woody a stem</u>



Plant Growth

QOD

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MODIFIED ROOTS

MODIFIED LEAVES

MODIFIED STEMS

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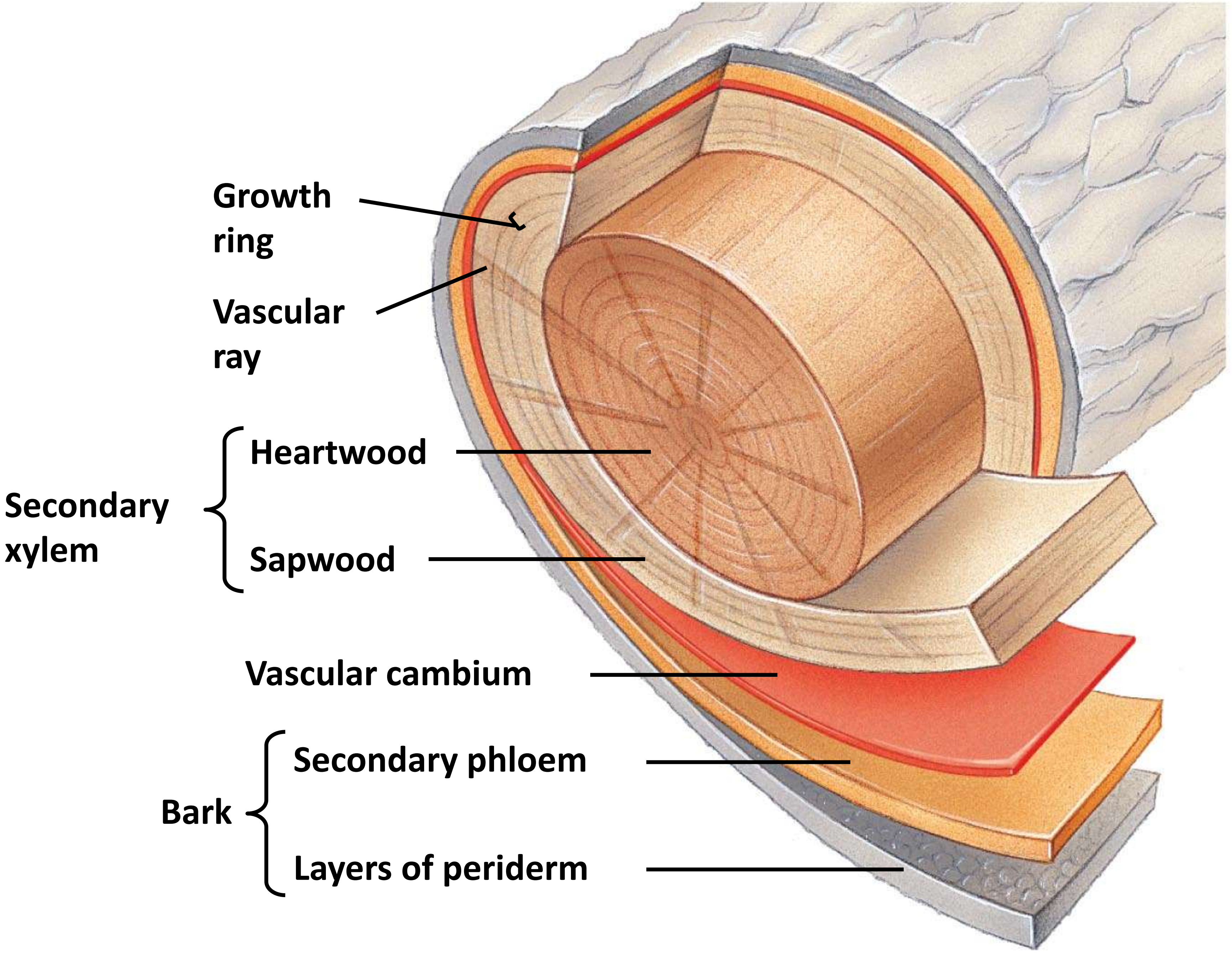
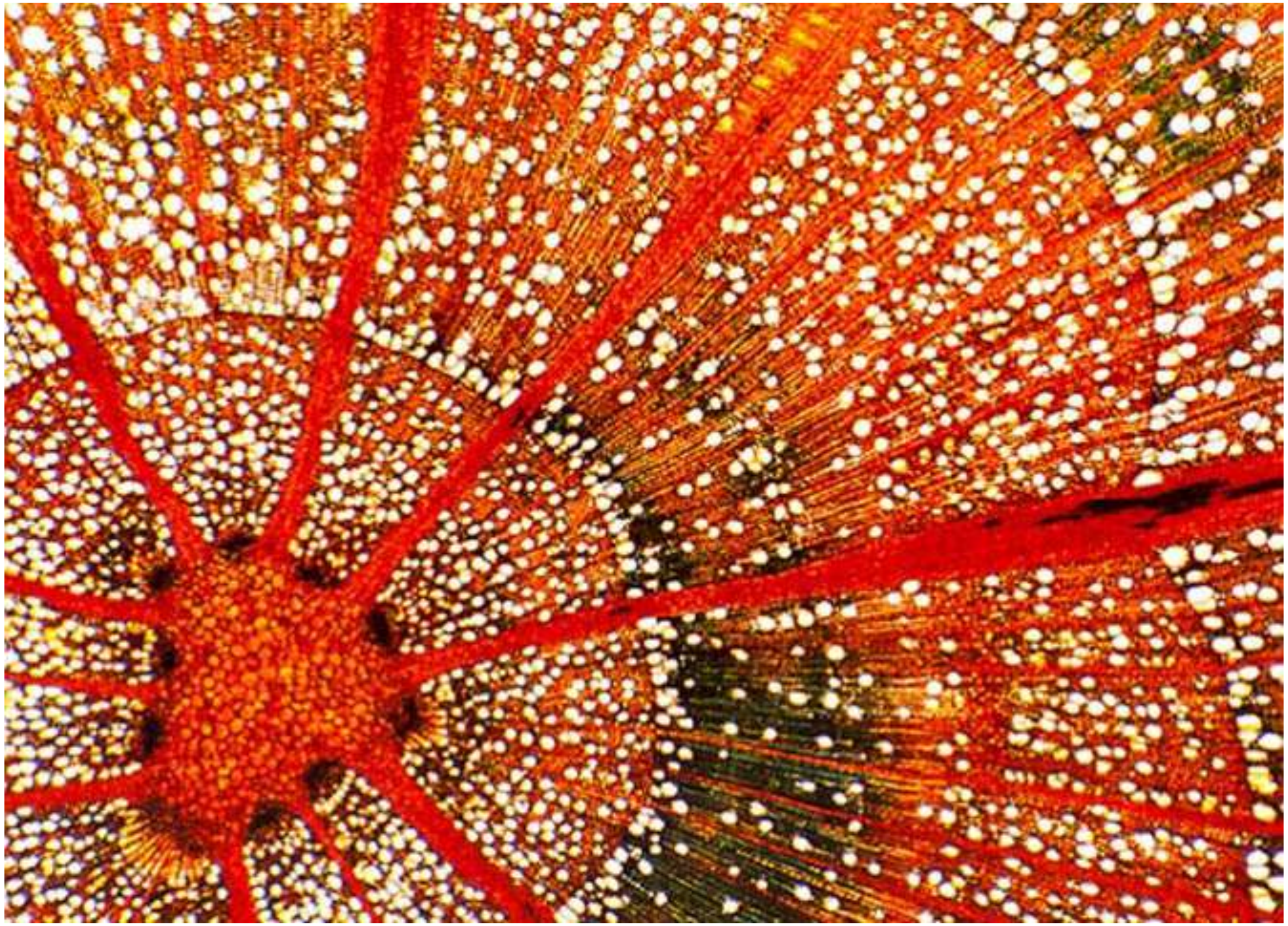
Fig. 35-22


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

Transport in Plants

Cross Section of Beech Tree



QOD

List as many strategies as you can that a plant might use to limit water loss

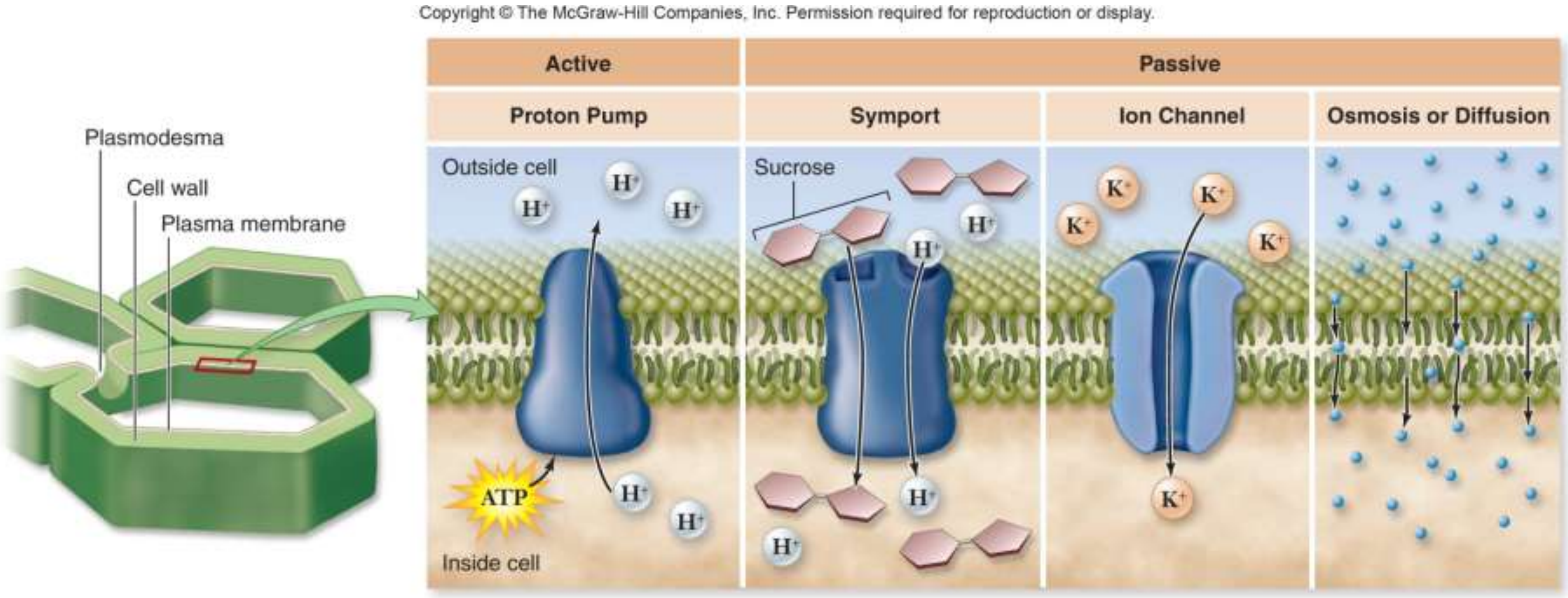
Transport Overview

1- uptake and loss of water and solutes by individual cells (root cells)

2- short-distance transport from cell to cell (sugar loading from leaves to phloem)

3- long-distance transport of sap within xylem and phloem in whole plant

Fig. 38.1



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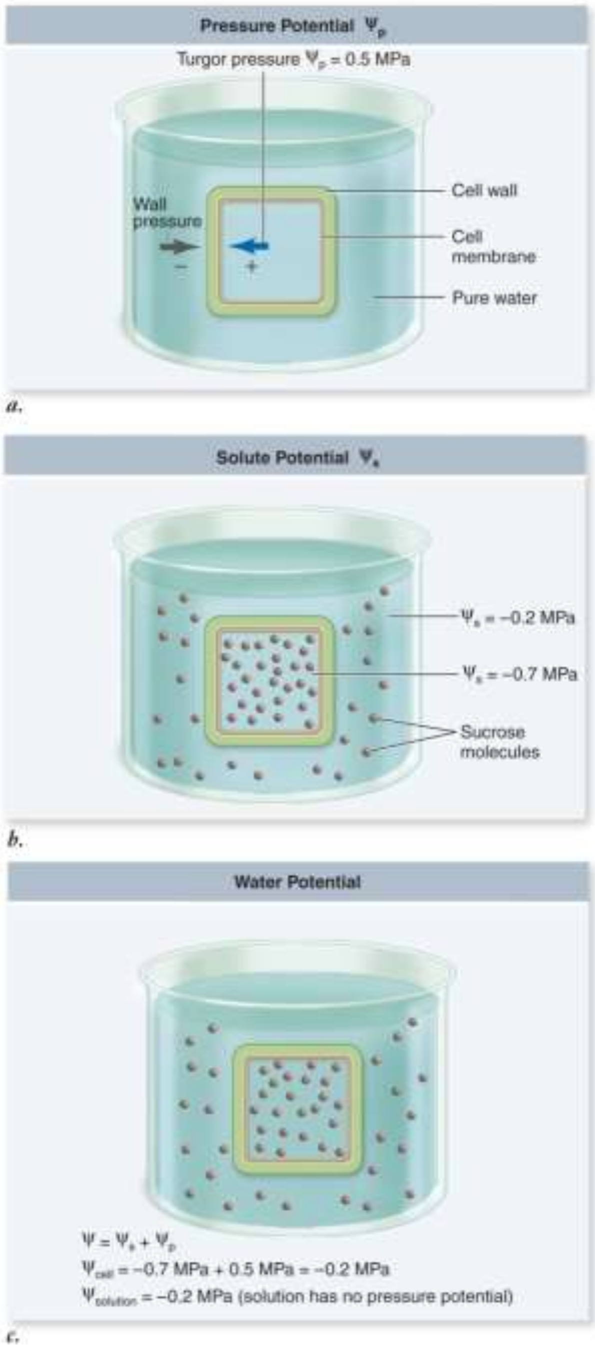
Active
Passive
Proton Pump
Symport
Ion Channel
Osmosis or Diffusion
Plasmodesma
Cell wall
Plasma membrane
Outside cell
Inside cell
ATP
Sucrose
H^+
K^+

Fig. 38.3


Pressure Potential Ψp
Turgor pressure Ψp = 0.5 MPa
Wall pressure
−
+
Cell wall
Cell membrane
Pure water
a.
Solute Potential Ψs
Ψs = −0.2 MPa
Ψs = −0.7 MPa
Sucrose molecules
b.
Water Potential
Ψ = Ψs + Ψp
Ψcell = −0.7 MPa + 0.5 MPa = −0.2 MPa
Ψsolution = −0.2 MPa (solution has no pressure potential)
c.

Whole Plant Transport

1- Roots absorb water and dissolved minerals from soil

2- Water and minerals are transported upward from roots to shoots as xylem sap

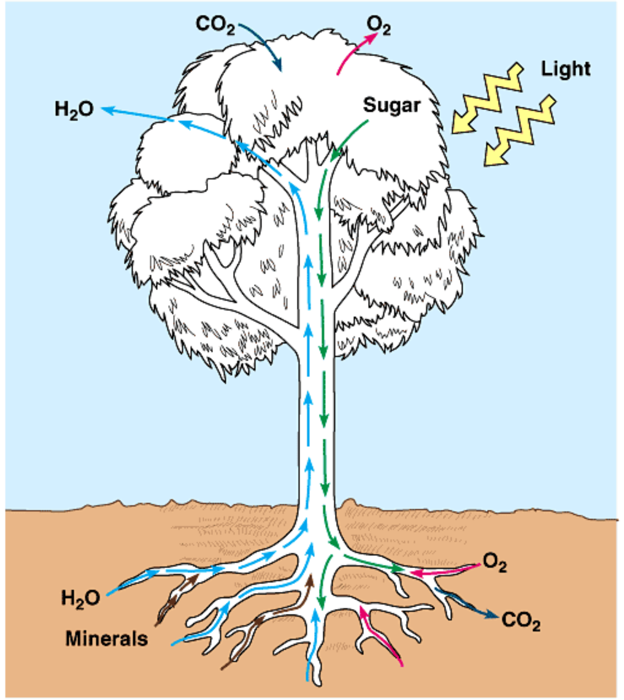
3- Transpiration, the loss of water from leaves, creates a force that pulls xylem sap upwards

4- Leaves exchange CO2 and O2 through stomata

5- Sugar is produced by photosynthesis in leaves

6- Sugar is transported as phloem sap to roots and other parts of plant

7- Roots exchange gases with air spaces of soil (supports cellular respiration in roots)



Cellular Transport

- Water transport
- Osmosis; hyper-; hypo-; iso-
- Cell wall creates physical pressure: water potential solutes decrease; pressure increase
- Water moves from high to low water potential
- Flaccid (limp, iostonic);
- Plasmolysis (cell loses water in a hypertonic environment; plasma membrane pulls away);
- Turgor pressure (influx of water due to osmosis; hypotonic environment)

Transport within tissues/organs

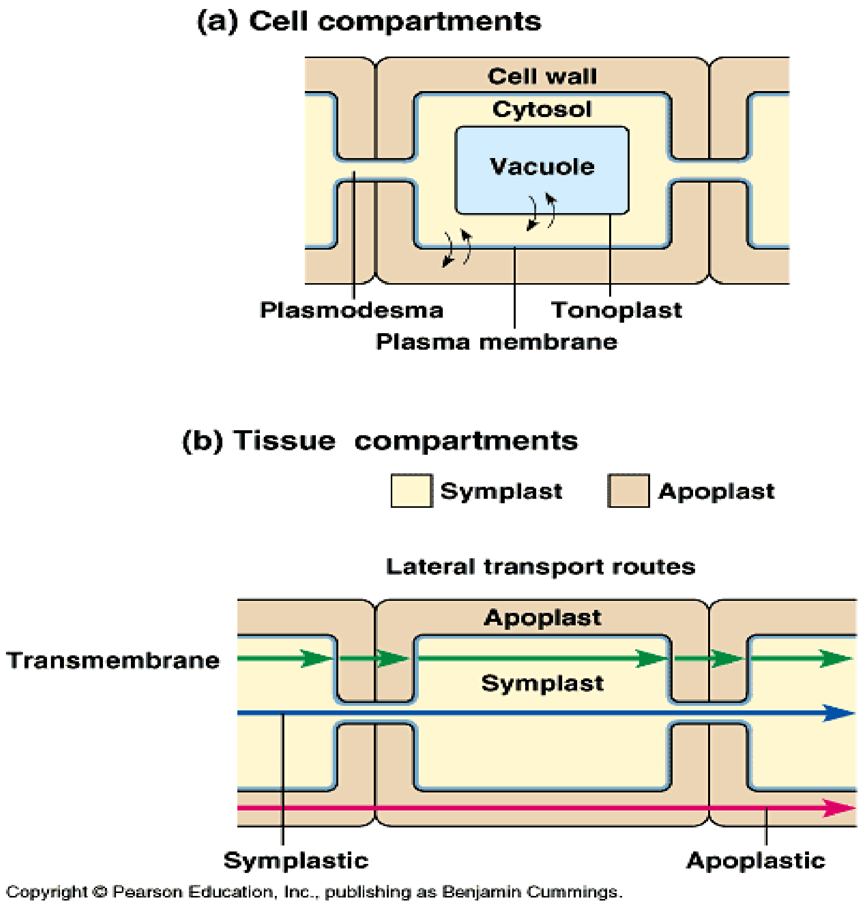
Tonoplast
vacuole membrane

Plasmodesmata (components)
cytosolic connection

Symplast route (lateral)
cytoplasmic continuum

Apoplast route (lateral)
continuum of cell walls

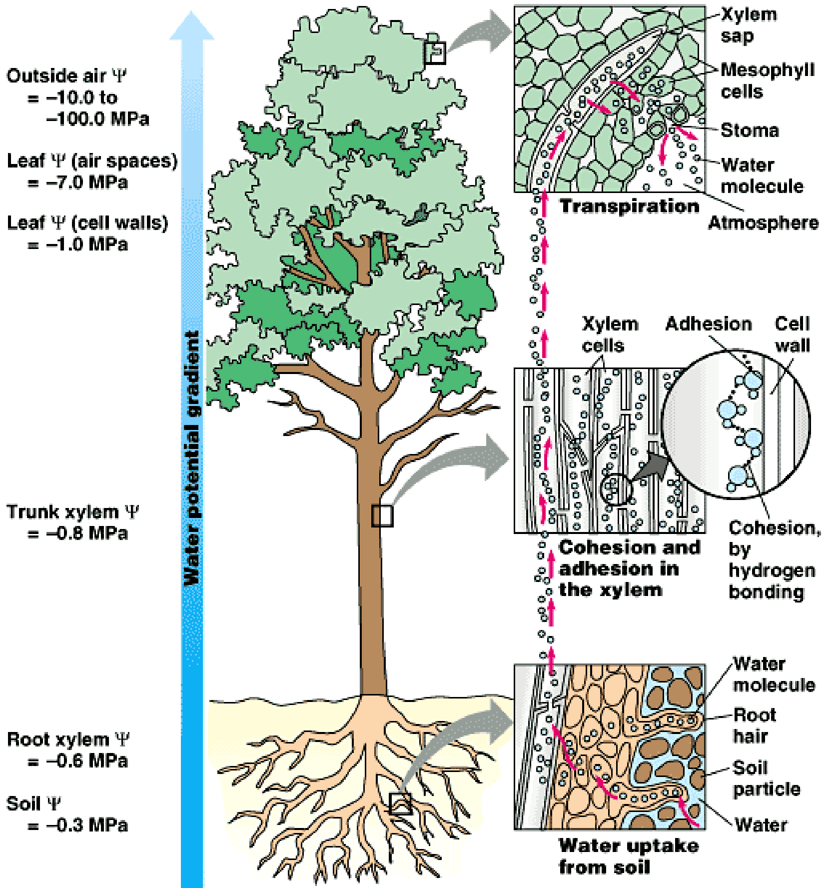
Bulk flow (long distance)
movement of a fluid by pressure (xylem)



Transport of Xylem Sap

<u>Transpiration</u>: loss of water vapor from leaves *pulls* water from roots (transpirational pull); cohesion and adhesion of water

<u>Root pressure</u>: at night (low transpiration), roots cells continue to pump minerals into xylem; this generates pressure, *pushing* sap upwards; guttation

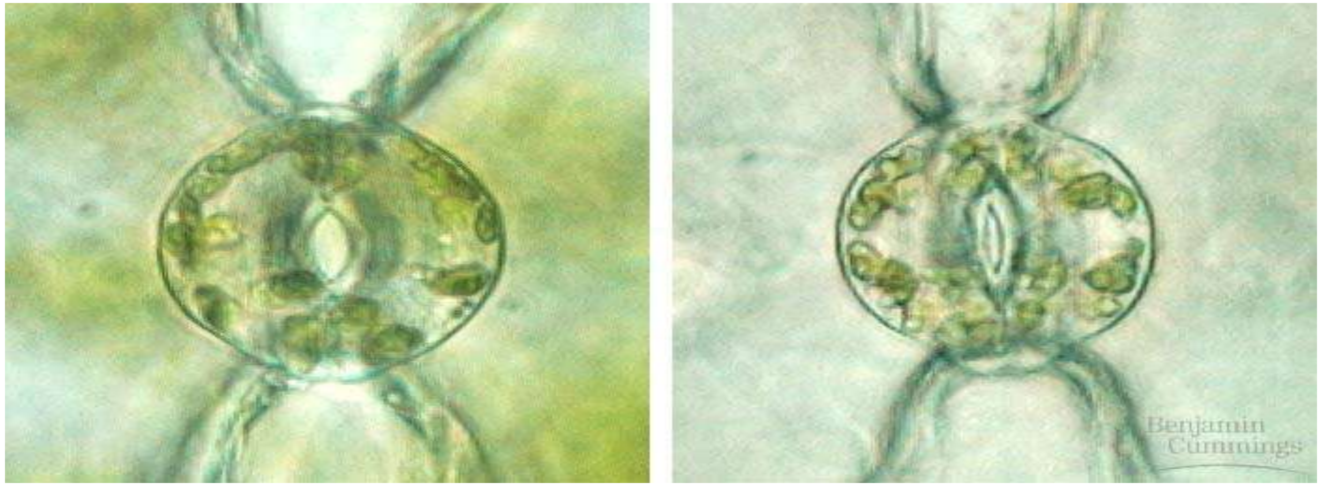


Transpirational Control

Photosynthesis-Transpiration compromise….

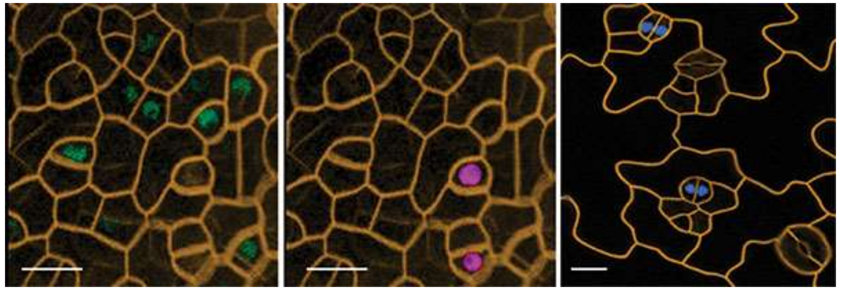
Guard cells control the size of the stomata

Xerophytes (plants adapted to arid environments)~ thick cuticle; small spines for leaves



Stomatal Development

- Images from a time series in stomata formation. Cells at different developmental stages are marked by nuclei labeled green (SPCH, stem-cell like), pink (MUTE, committed), or blue (FAMA, differentiating). The first two panels show the same group of cells at an early time point; in the third panel, taken a day later, cells are maturing. Scale bar in each is 5 microns. Images courtesy of Bergmann lab.



Source: http://www.hhmi.org/bulletin/spring-2015/open-and-shut-case?utm_source=HHMI+Bulletin&utm_campaign=6805c8788e-HHMI_Bulletin_Spring_2015&utm_medium=email&utm_term=0_c8d2a543bc-6805c8788e-69869733

Translocation of Phloem Sap

Translocation: food/phloem transport

Sugar source: sugar production organ (mature leaves)

Sugar sink: sugar storage organ (growing roots, tips, stems, fruit)

1- loading of sugar into sieve tube at source reduces water potential inside; this causes tube to take up water from surroundings by osmosis

2- this absorption of water generates pressure that forces sap to flow alon tube

3- pressure gradient in tube is reinforced by unloading of sugar and consequent loss of water from tube at the sink

4- xylem then recycles water from sink to source

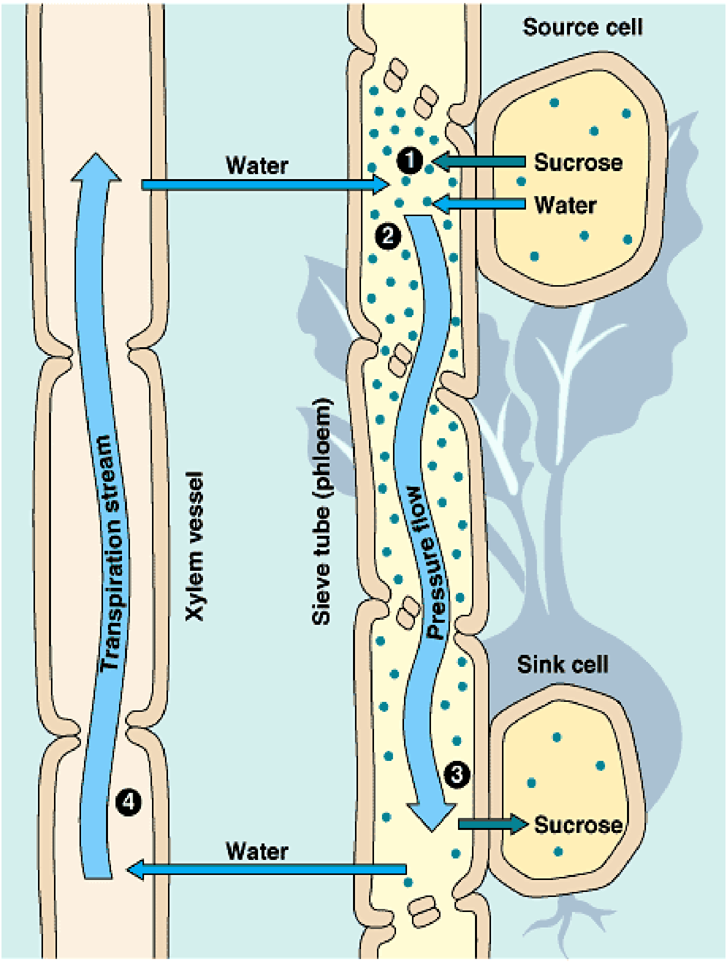
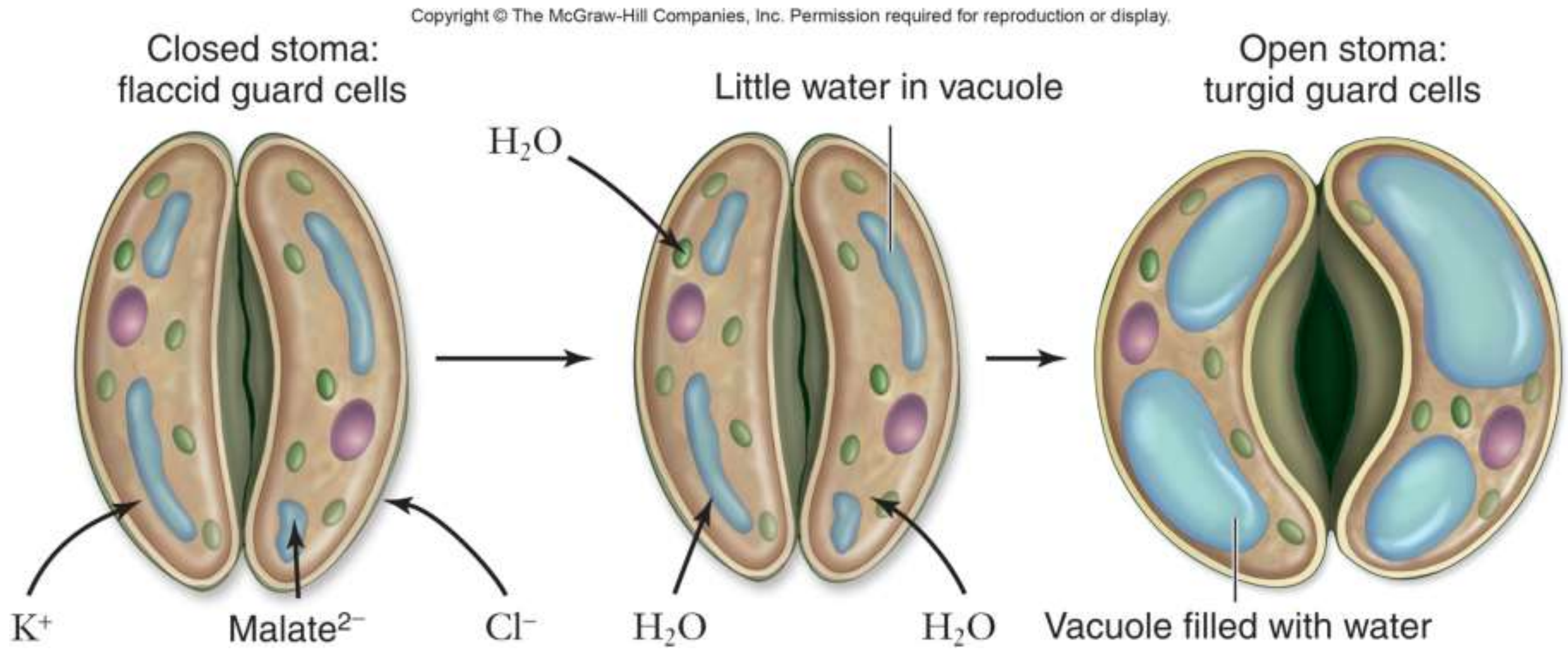
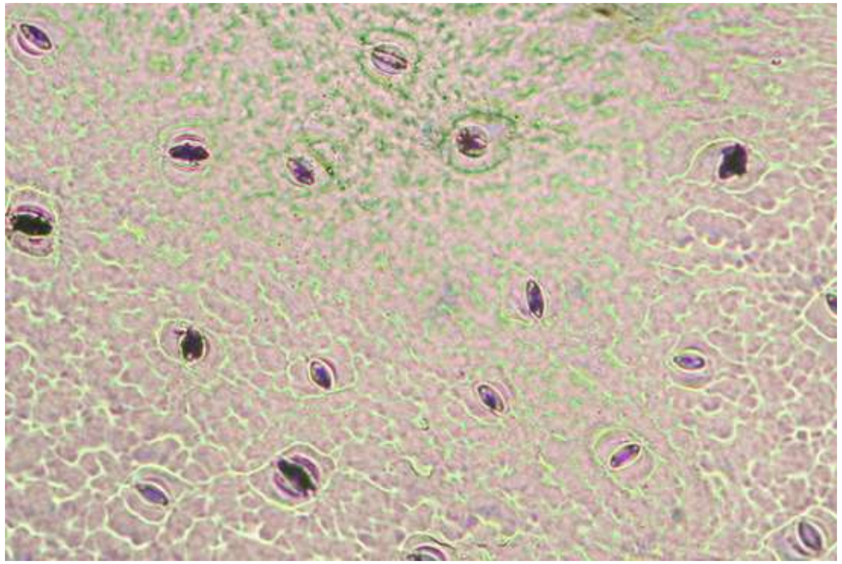
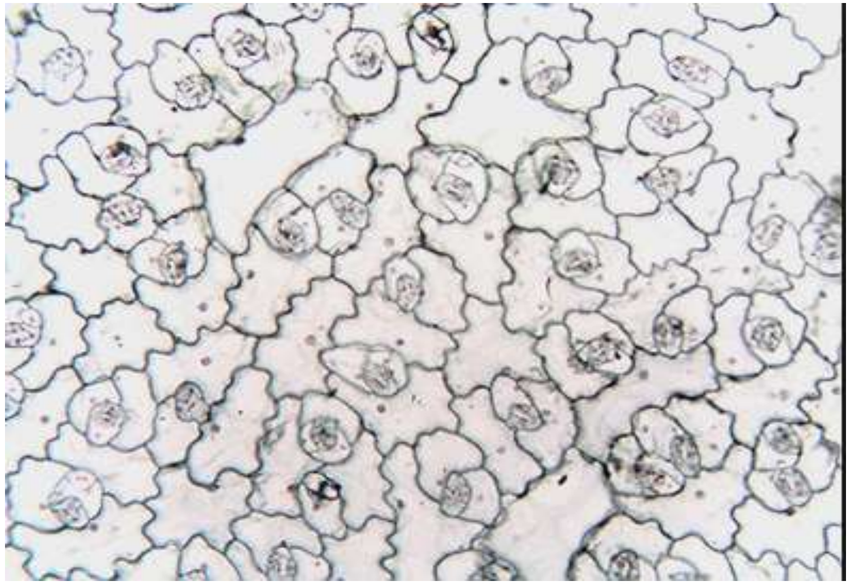
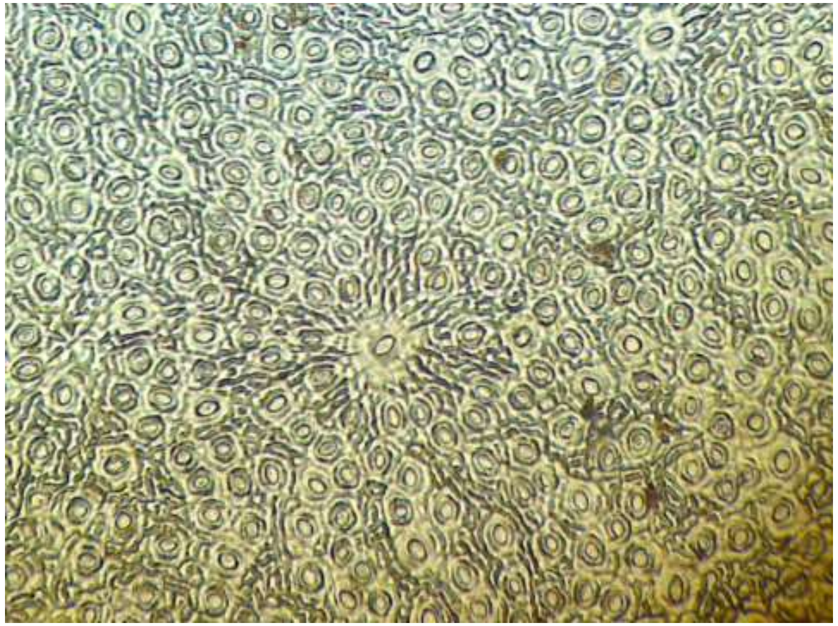


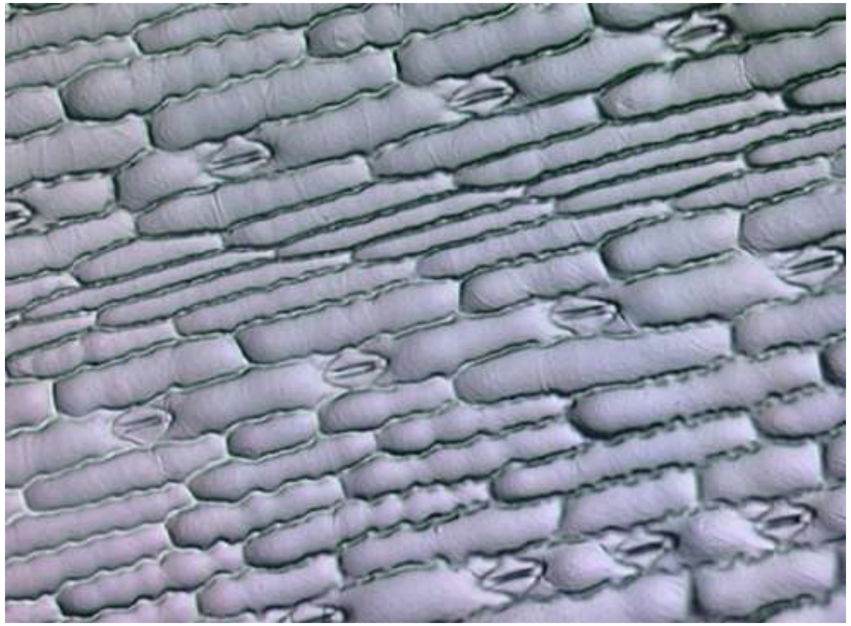
Fig. 38.12


Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.
Closed stoma: flaccid guard cells
Little water in vacuole
Open stoma: turgid guard cells
H_2O
K^+
$Malate^{2-}$
Cl^-
H_2O
H_2O
Vacuole filled with water







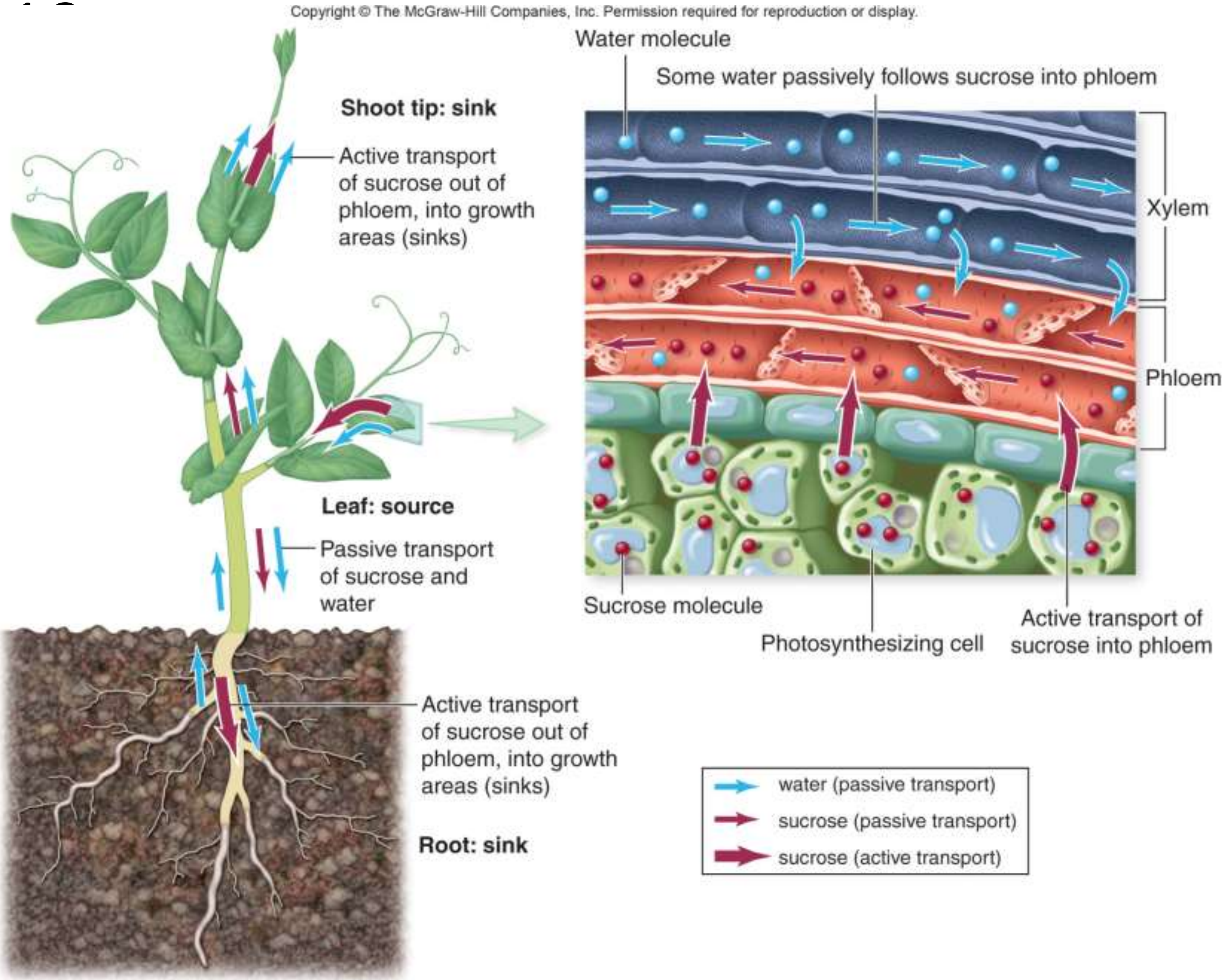


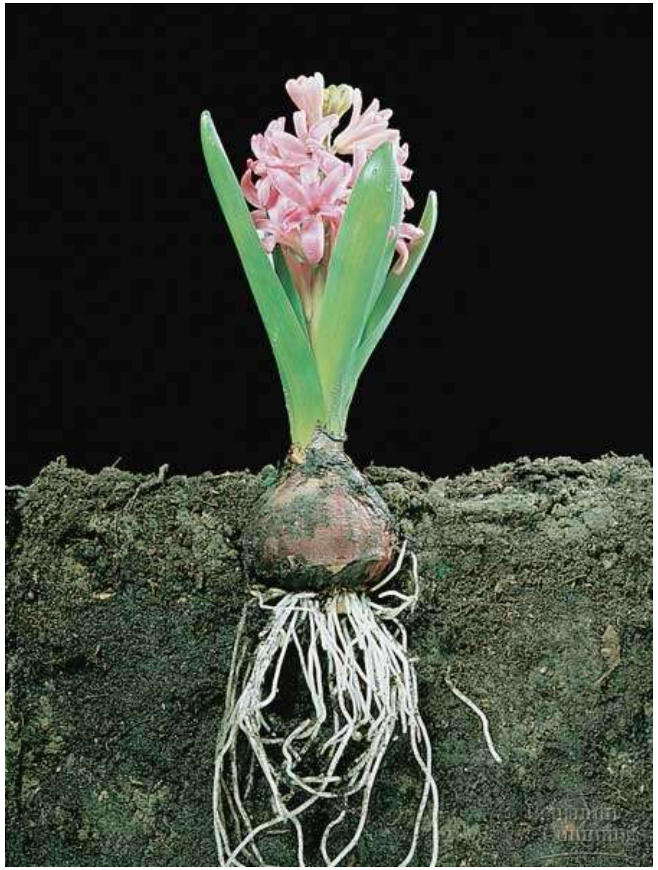
Practice Problem

If a plant cell's ΨP = 2 bars and its ΨS = -4.5 bars, what is the resulting Ψ?

. The that plant cell is placed in a beaker of sugar water with ΨS = -4.0 bars. In which direction will the net flow of water be?

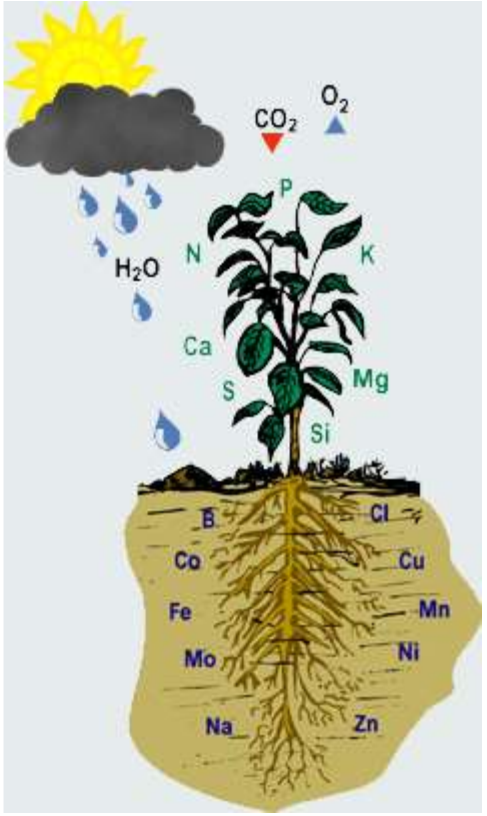
Fig. 38.13


Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.
Shoot tip: sink
Active transport of sucrose out of phloem, into growth areas (sinks)
Leaf: source
Passive transport of sucrose and water
Active transport of sucrose out of phloem, into growth areas (sinks)
Root: sink
Water molecule
Some water passively follows sucrose into phloem
Xylem
Phloem
Sucrose molecule
Photosynthesizing cell
Active transport of sucrose into phloem
water (passive transport)
sucrose (passive transport)
sucrose (active transport)



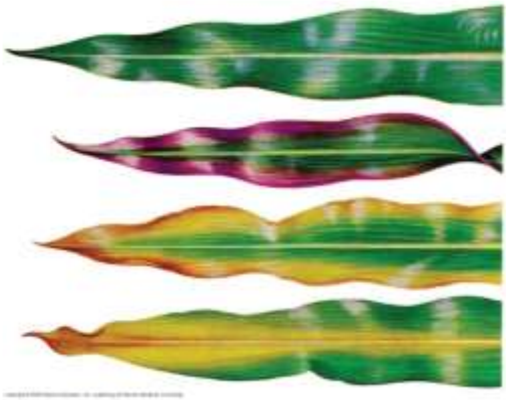
- Chapter 37 ~
  Plant Nutrition

QOD



- What is the origin of most of a plants mass?

Nutrients



- Essential: required for the plant life cycle
- Macro- (large amounts) carbon, oxygen, hydrogen, nitrogen, sulfur, phosphorus, potassium, calcium, magnesium
- Micro- (small amounts; cofactors of enzyme action) chlorine, iron, boron, manganese, zinc, copper, molybdenum, nickel
- Deficiency • chlorosis (lack of magnesium; chlorophyll production)

Table 37.1 Essential Elements in Plants

Element	Form Available to Plants	% Mass in Dry Tissue	Major Functions
Macronutrients			
Carbon	CO_2	45%	Major component of plant's organic compounds
Oxygen	CO_2	45%	Major component of plant's organic compounds
Hydrogen	H_2O	6%	Major component of plant's organic compounds
Nitrogen	NO_3^-, NH_4^+	1.5%	Component of nucleic acids, proteins, hormones, chlorophyll, coenzymes
Potassium	K^+	1.0%	Cofactor that functions in protein synthesis; major solute functioning in water balance; operation of stomata
Calcium	Ca^{2+}	0.5%	Important in formation and stability of cell walls and in maintenance of membrane structure and permeability; activates some enzymes; regulates many responses of cells to stimuli
Magnesium	Mg^{2+}	0.2%	Component of chlorophyll; activates many enzymes
Phosphorus	$H_2PO_4^-$, HPO_4^{2-}	0.2%	Component of nucleic acids, phospholipids, ATP, several coenzymes
Sulfur	SO_4^{2-}	0.1%	Component of proteins, coenzymes
Micronutrients			
Chlorine	Cl^-	0.01%	Required for water-splitting step of photosynthesis; functions in water balance
Iron	Fe^{3+}, Fe^{2+}	0.01%	Component of cytochromes; activates some enzymes
Manganese	Mn^{2+}	0.005%	Active in formation of amino acids; activates some enzymes; required for water-splitting step of photosynthesis
Boron	$H_2BO_3^-$	0.002%	Cofactor in chlorophyll synthesis; may be involved in carbohydrate transport and nucleic acid synthesis; role in cell wall function
Zinc	Zn^{2+}	0.002%	Active in formation of chlorophyll; activates some enzymes
Copper	Cu^+, Cu^{2+}	0.001%	Component of many redox and lignin-biosynthetic enzymes
Nickel	Ni^{2+}	0.001%	Cofactor for an enzyme functioning in nitrogen metabolism
Molybdenum	MoO_4^{2-}	0.0001%	Essential for symbiotic relationship with nitrogen-fixing bacteria; cofactor in nitrate reduction

- Macro:
- COHNKCaMgPS

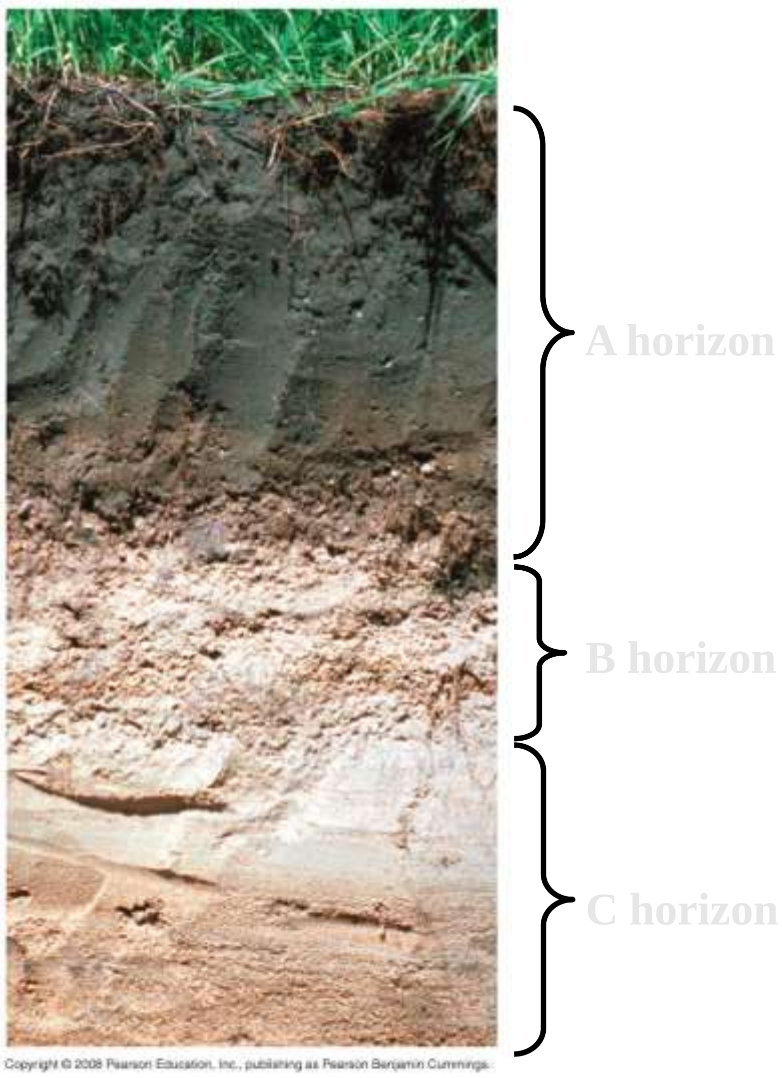
- **Micro: ClFeMnBZnCuNiMo**

Smart Plants

- "Smart" plants inform the grower of a nutrient deficiency before damage has occurred
- A blue tinge indicates when these plants need phosphate-containing fertilizer

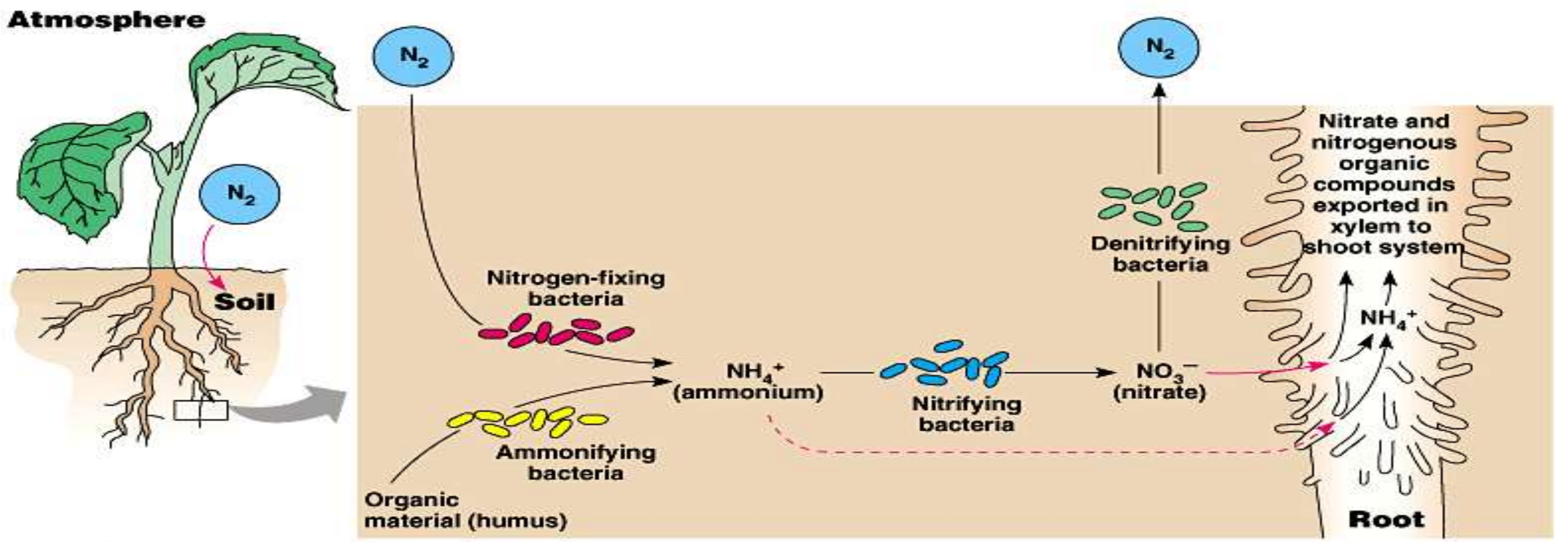
Soil

- Determines plant growth & variety (also climate)
- Composition/*horizons*:
- <u>•topsoil</u> (rock particles, living organisms, humus- partially decayed organic material)
- <u>•loams</u> (equal amounts of sand, silt, and clay)



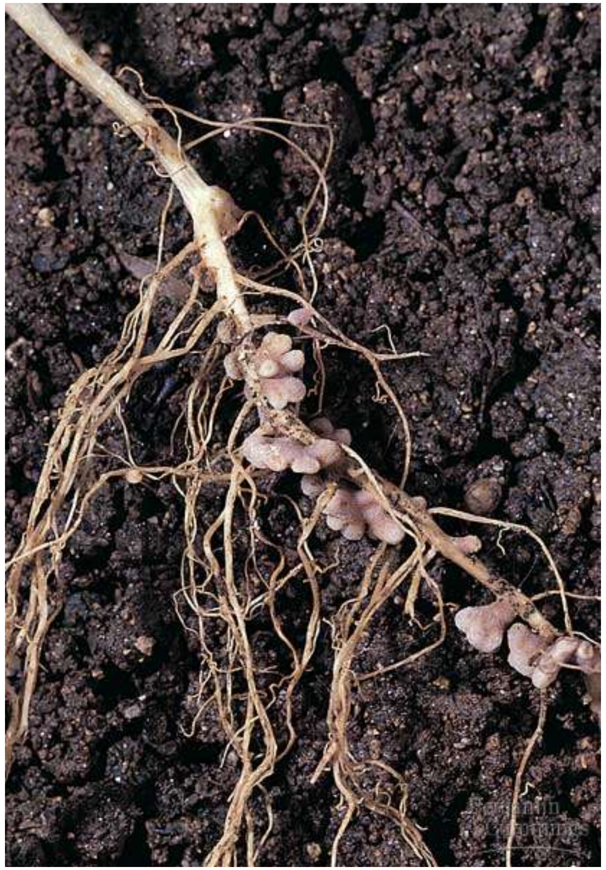
Nitrogen Fixation

- Atmosphere, 80% N_2
- Conversion to: ammonium (NH_4^+) or nitrate (NO_3^-)
- <u>Bacteria types</u>: Ammonifying (humus decomposition); nitrogen-fixing (atmospheric N_2); nitrifying (convert NH_4^+ to NO_3^-); denitrifying (convert NO_3^- to N_2)
- Nitrogen fixation; crop rotation



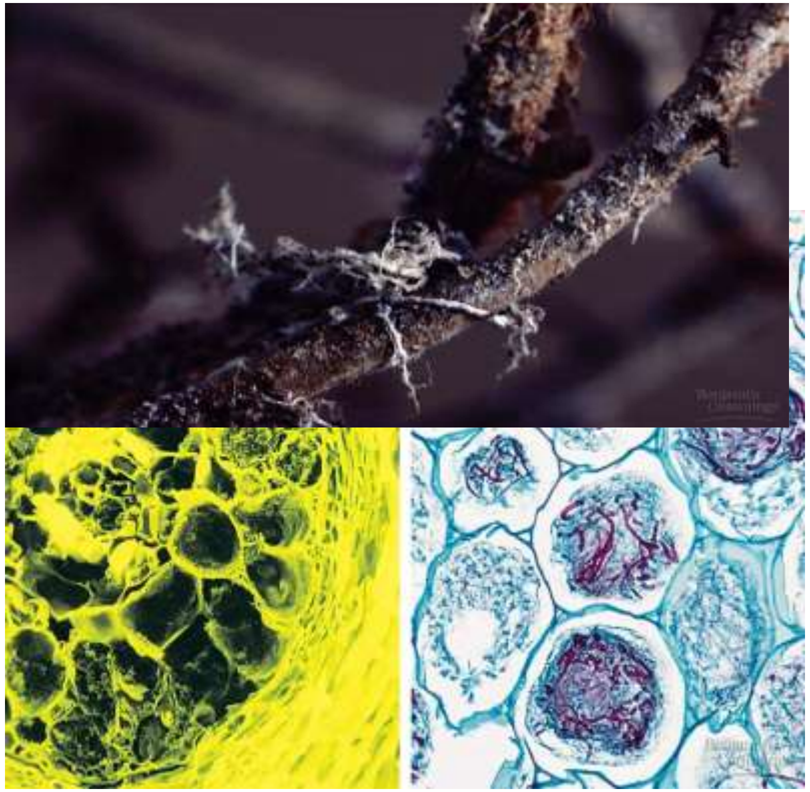
Plant symbiosis, I

- *Rhizobium* bacteria (found in root nodules in the legume family)
- Mutualistic: legume receives fixed N_2; bacteria receives carbohydrates & organic materials



Plant symbiosis, II

- *Mycorrhizae* (fungi); modified roots
- Mutualistic: fungus receives sugar; plant receives increased root surface area and increased phosphate uptake
- Two types:
  ectomycorrhizae • ensheaths the root
  endomycorrhizae (90% of plants) •through cell wall but not cell membrane



Plant parasitism & predation

- Mistletoe (parasite)
- Epiphytes
- Carnivorous plants

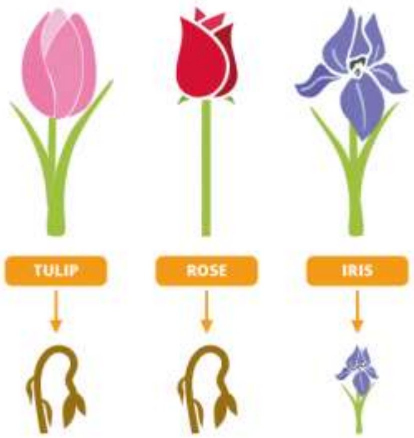
QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

- Chapter 41
- *Plant Responses to Internal and External Signals*

ARE DAFFODILS FLOWER KILLERS?

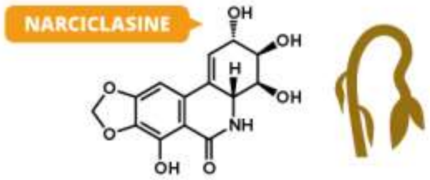
Daffodils bloom beautifully – but can cause other flowers to quickly wither and die if they are placed in a vase together. This graphic looks at the chemical explanation.

AFFECTED FLOWERS

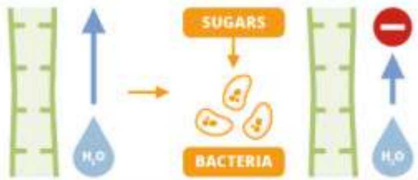


The mucilage from daffodil stems can kill other flowers in the same vase. Studies have shown this effect with tulips and roses. In another study the opposite effect was seen with iris flowers, with the presence of daffodils prolonging blooming time.

CHEMICAL CAUSE

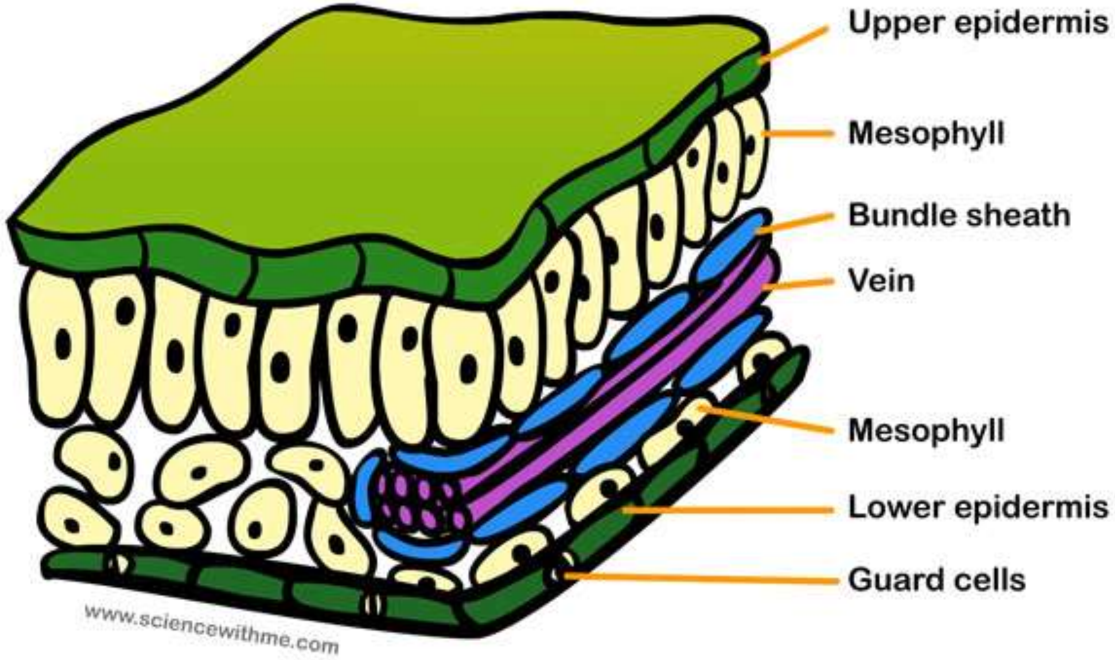


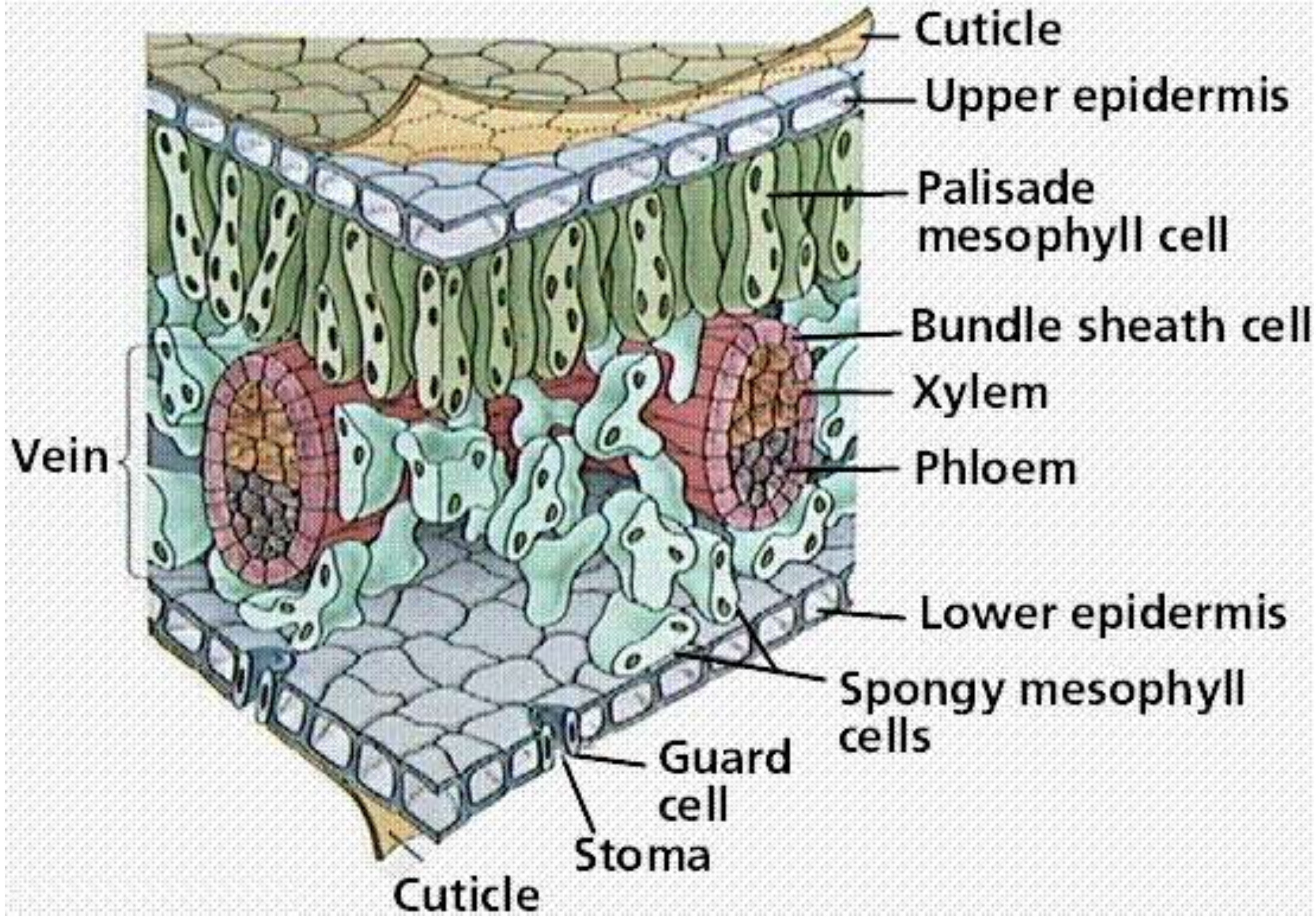
Alkaloids in daffodil mucilage are toxic to flowers including tulips. Narciclasine is a key culprit, though it can prolong the life of iris blooms.



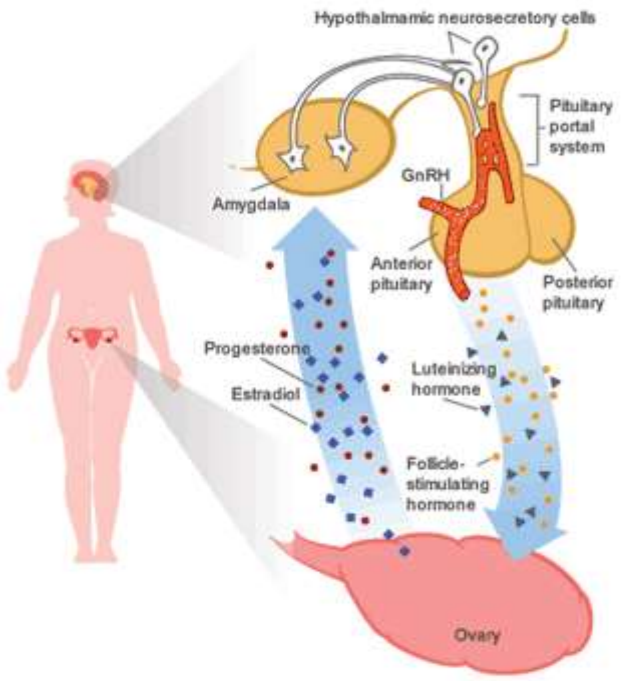
In roses, sugars and polysaccharides in daffodil mucilage increase bacterial growth, blocking water uptake.

CROSS SECTION OF A LEAF




Cuticle
Upper epidermis
Palisade mesophyll cell
Bundle sheath cell
Xylem
Phloem
Vein
Lower epidermis
Spongy mesophyll cells
Guard cell
Stoma
Cuticle

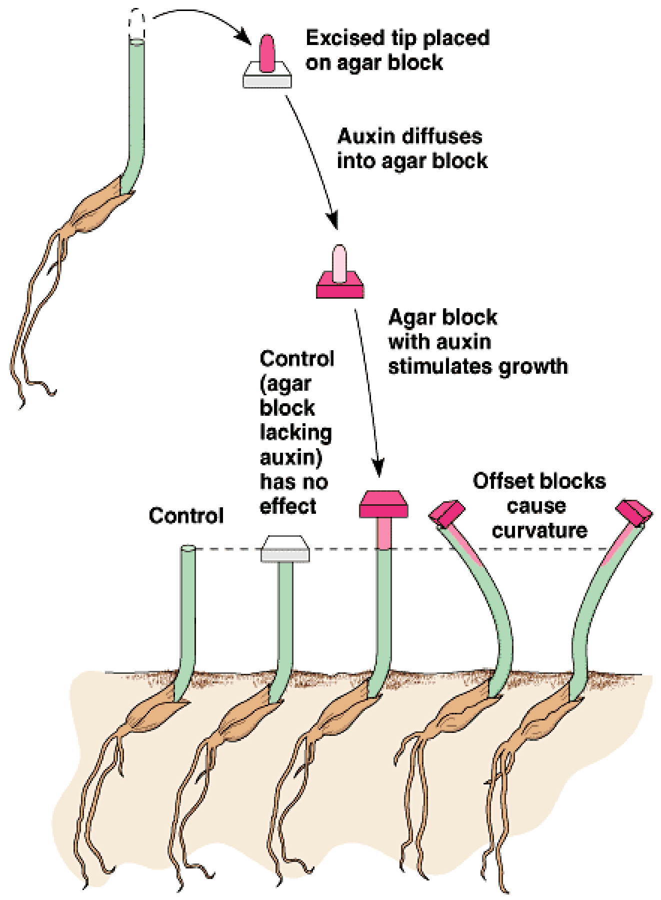
QOD



- Explain what a hormone is, what it does, and list three examples in plant or humans

Plant hormones

- Hormone: chemical signals that coordinate parts of an organism; produced in one part of the body and then transported to other parts of the body; low concentrations
- Tropism: movement toward or away from a stimulus
- Went experiments (phototropism)
- Hormone: auxin
- Others: gravitropism, thigmotropism



Hormone Summary Chart

Hormone	Picture/ Example	Location	Function

1. Auxin
2. Cytokinin
3. Gibberellin
4. Abscisic Acid
5. Ethylene
6. Brassinoste roids

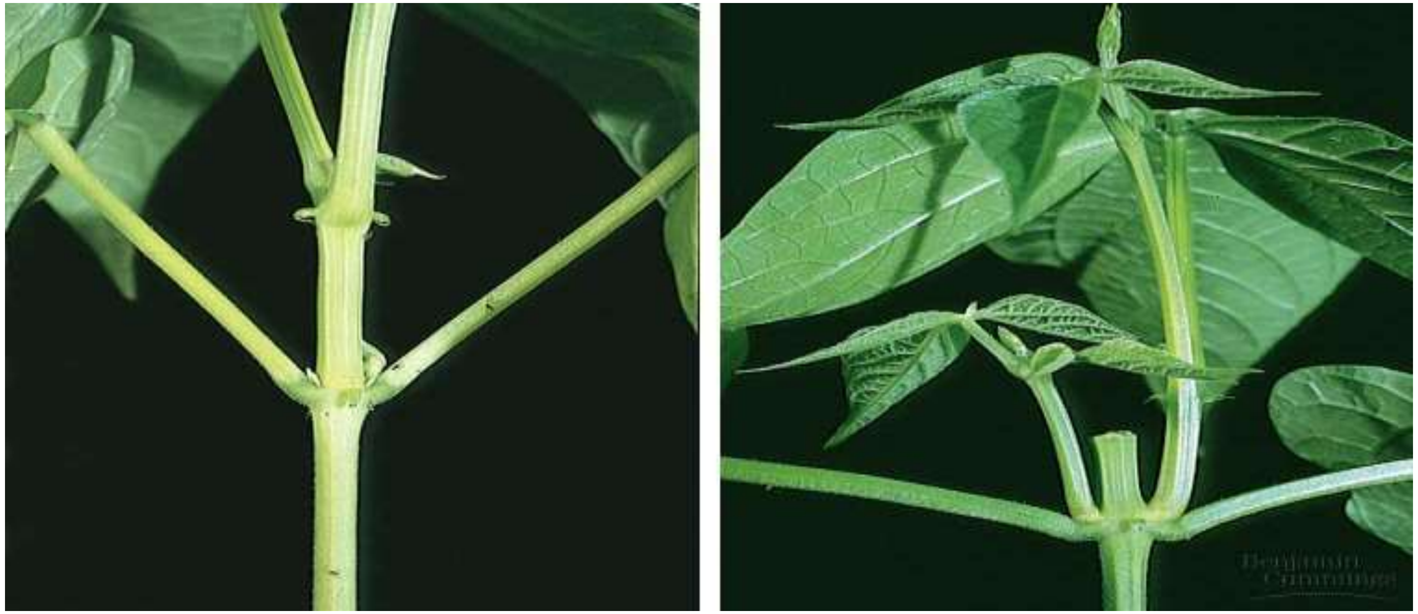
Auxin

- IAA (indoleacetic acid)
- Location: seed embryo; meristems of apical buds and young leaves
- Function: stem elongation; root growth, differentiation, branching; fruit development; apical dominance; tropisms

QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

Cytokinins

- Zeatin
- <u>Location:</u> roots (and actively growing tissues)
- <u>Function:</u> root growth and differentiation; cell division and growth; germination; delay senescence (aging); apical dominance (w/ auxin)



Gibberellins

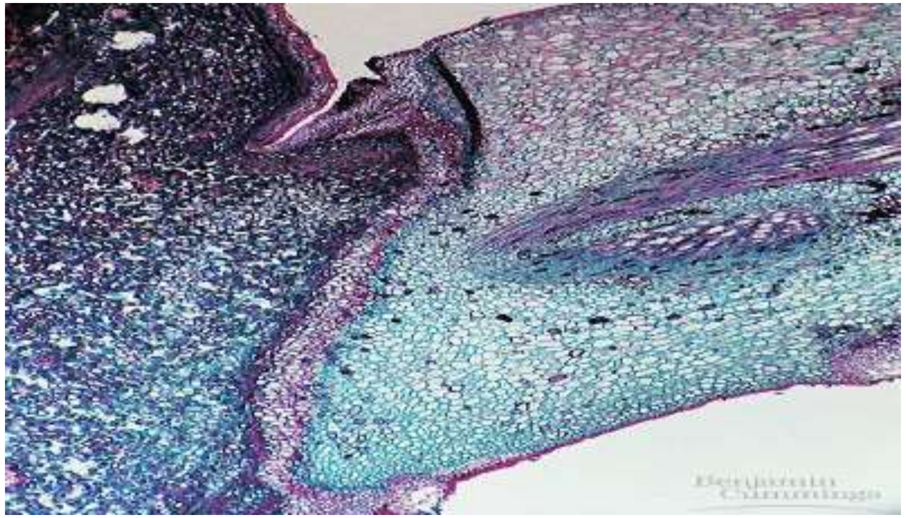
- GA_3
- <u>Location:</u> meristems of apical buds and roots, young leaves, embryo
- <u>Function:</u> germination of seed and bud; stem elongation; leaf growth; flowering (bolting); fruit development; root growth and differentiation

Abscisic acid

- ABA
- <u>Location:</u> leaves, stems, roots, green fruit
- <u>Function:</u> inhibits growth; closes stomata during stress; counteracts breaking of dormancy

Ethylene

- Gaseous hormone
- <u>Location:</u> ripening fruit tissue; stem nodes; aging leaves and flowers
- <u>Function:</u> fruit ripening; oppositional to auxin (leaf abscission); promotes/inhibits: growth/development of roots, leaves, and flowers; senescence



QOD

- Plants are able to respond to their environment in many ways. Choose three specific plant responses and briefly describe how they occur and what selective advantage they offer to the plant.

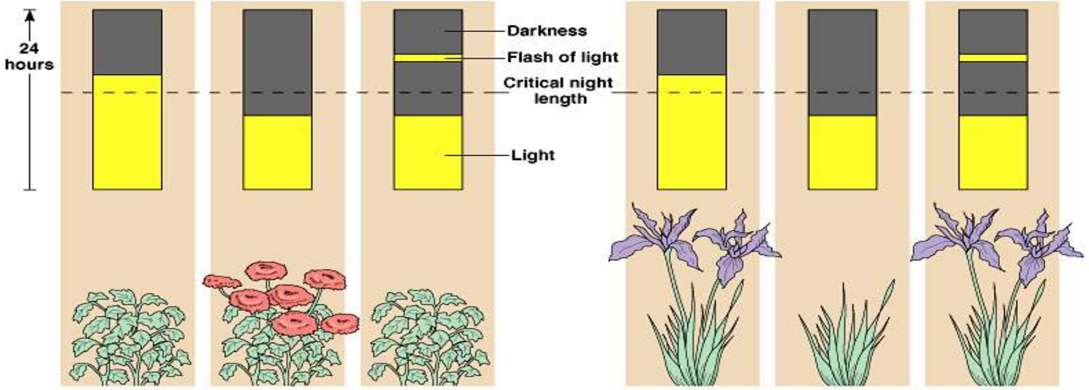
Daily and Seasonal Responses

- *Circadian rhythm* (24 hour periodicity)
- Short-day plant: light period shorter than a critical length to flower (flower in late summer, fall, or winter;
- Long-day plant: light period longer than a critical length to flower - flower in late spring or early summer;
- Day-neutral plant: unaffected by photoperiod
- *Critical night length* controls flowering
- *Photoperiodism* (phytochromes)

(poinsettias, chrysanthemums)

(spinach, radish, lettuce, iris)

(tomatoes, rice, dandelions)

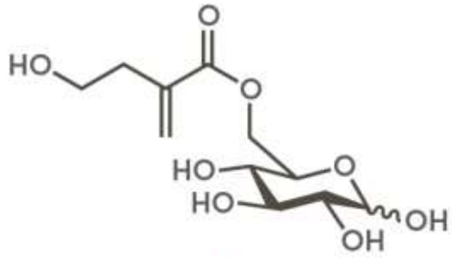


(a) Short-day (long-night) plant (b) Long-day (short-night) plant

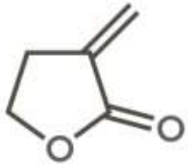
THE CHEMISTRY OF TULIPS AND TULIP FINGERS

WHAT ARE 'TULIP FINGERS?

'Tulip fingers' is used to describe the allergic contact dermatitis that can afflict those who frequently handle tulip bulbs. It can also affect those who cut or pick the flowers. It can appear as redness, eczema, or pustules on their fingers and hands.



6-TULIPOSIDE A



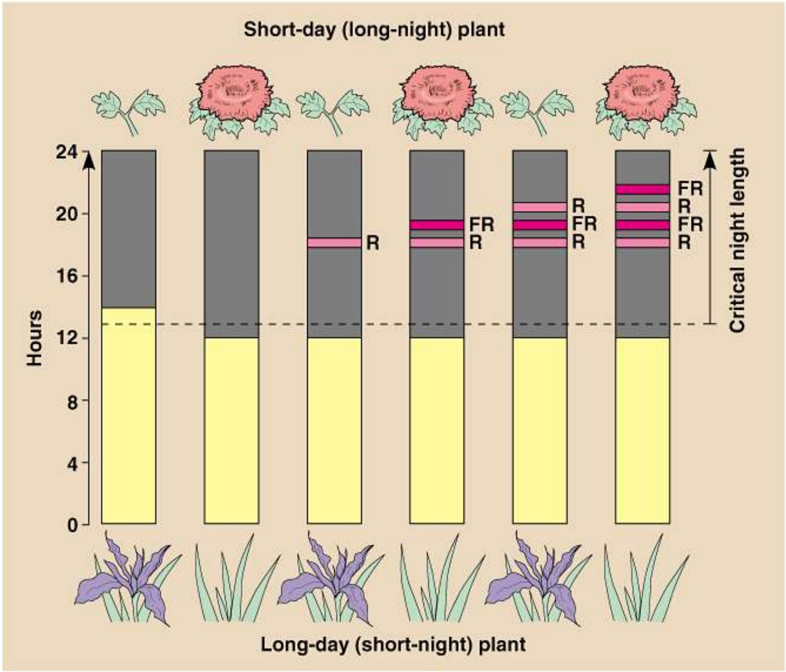
TULIPALIN A

TULIPOSIDES & TULIPALINS

6-tuliposide A is one of several tuliposides found in tulips that can trigger allergic skin reactions. Another dermatitis-inducing compound is 6-tuliposide A's breakdown product, tulipalin A. In the plant tulipalins function as a defence against soil fungi.

Phytochromes

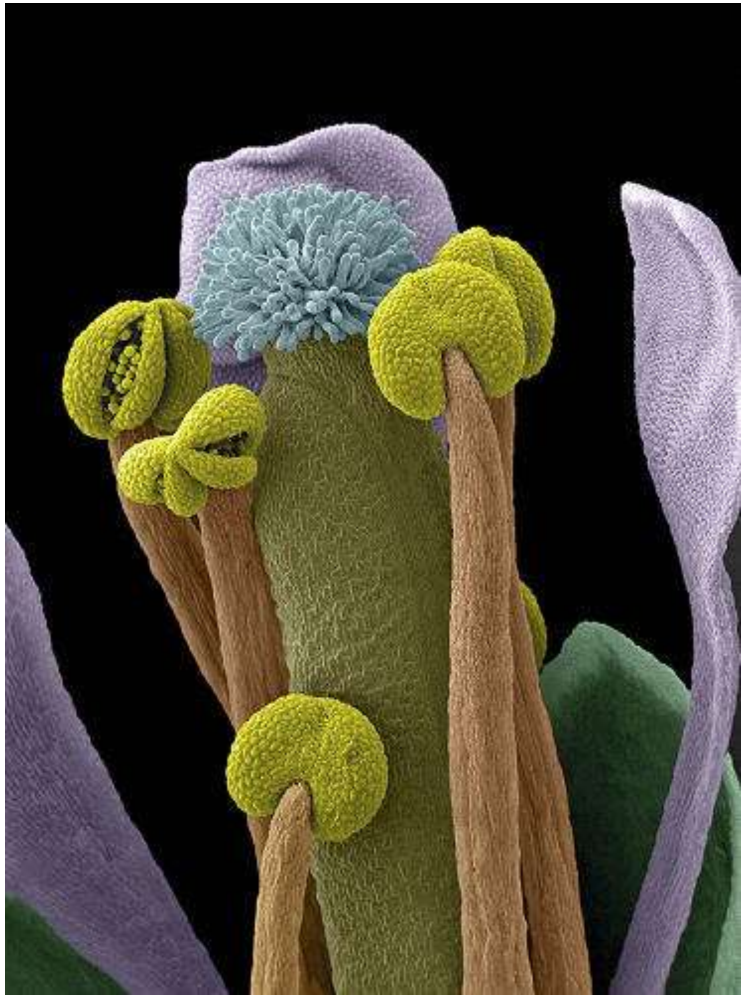
- Plant pigment that measures length of darkness in a photoperiod (red light)
- P_r (red absorbing) 660nm
- P_{fr} (far-red absorbing) 730nm



Can Plants Think?

- https://www.youtube.com/watch?v=u2GWd2j3qJ8

Plant Reproduction



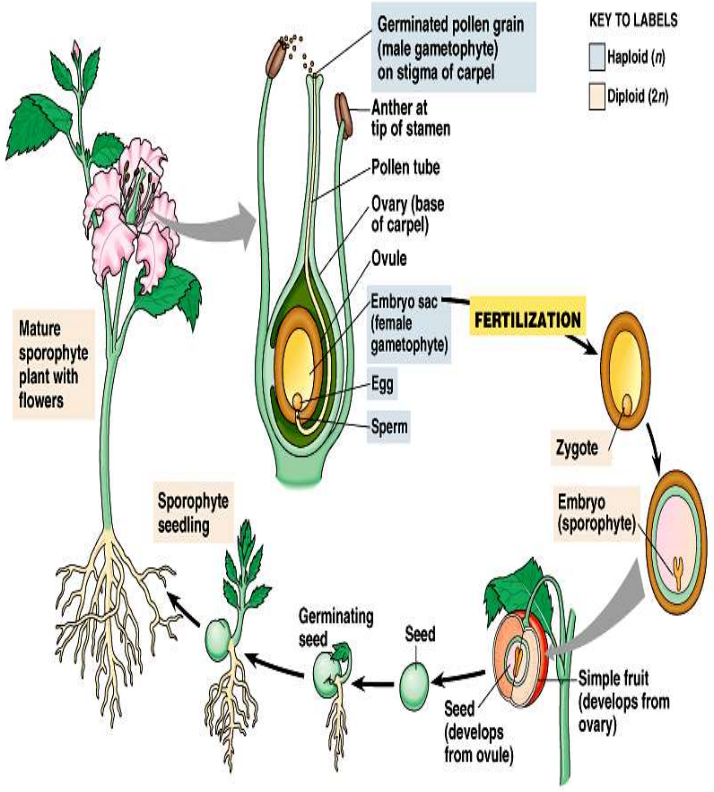
- *Plant Reproduction and Development*

QOD

- List three modified seeds and briefly describe the advantage of each modification.

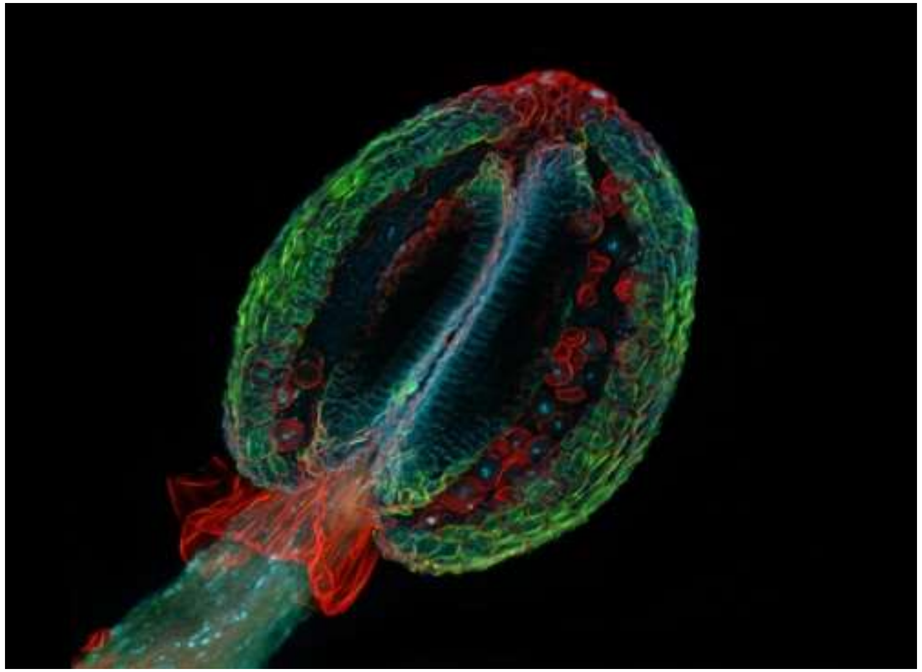
Sexual Reproduction

- Alternation of generations: haploid (n) and diploid (2n) generations take turns producing each other
- Sporophyte (2n): produces haploid spores by meiosis; these spores divide by mitosis giving rise to male and female haploid plants called….
- Gametophytes (n): develop and produce gametes



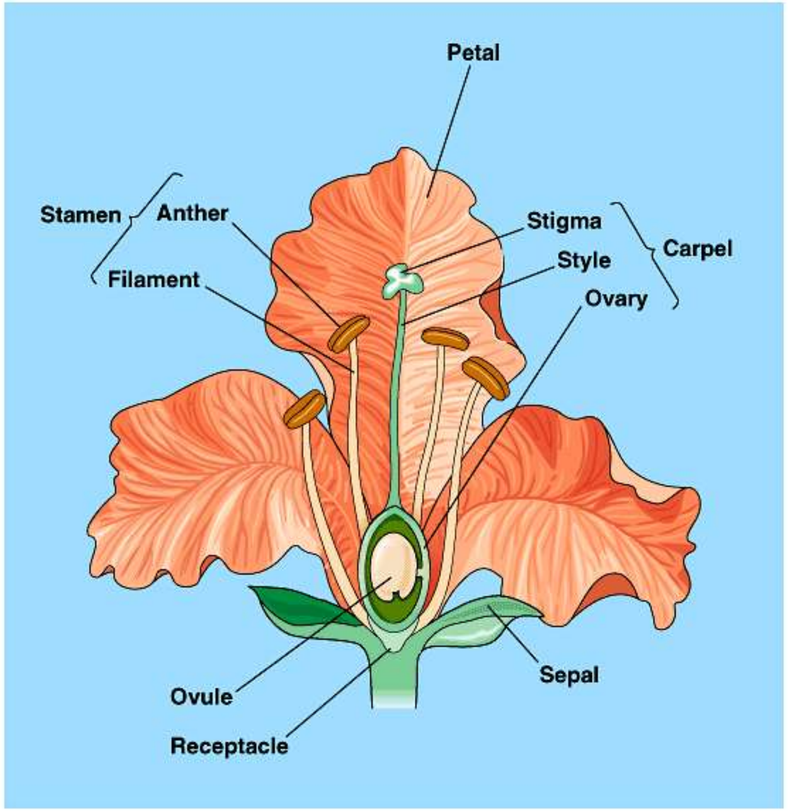
Male Reproductive Structure

- Filament supports the anther where pollen is produced



Floral variations

- Floral organs: sepals, petals, stamens (male), carpels (female)
- complete: all 4 floral organs
- incomplete: lacking 1 or more floral organs
- perfect: both stamens and carpels on 1 flower
- imperfect: lacking either a stamen or carpel
- monoecious: staminate and carpellate flowers on 1 plant)
- dioecious: staminate and carpellate flowers on separate plants



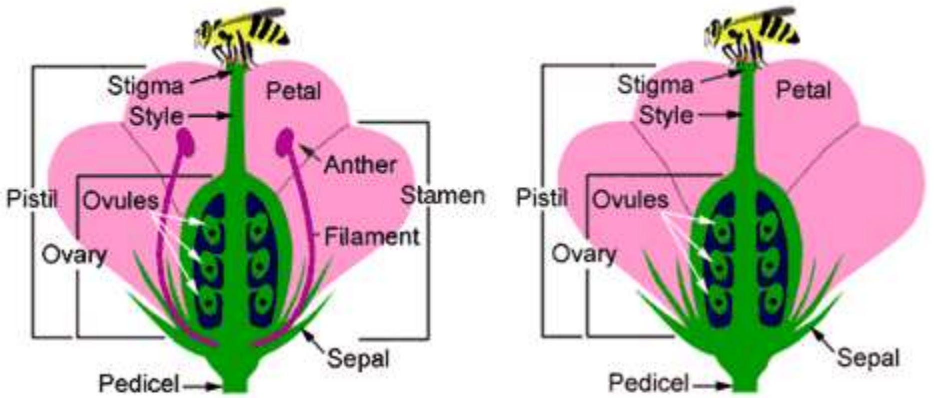
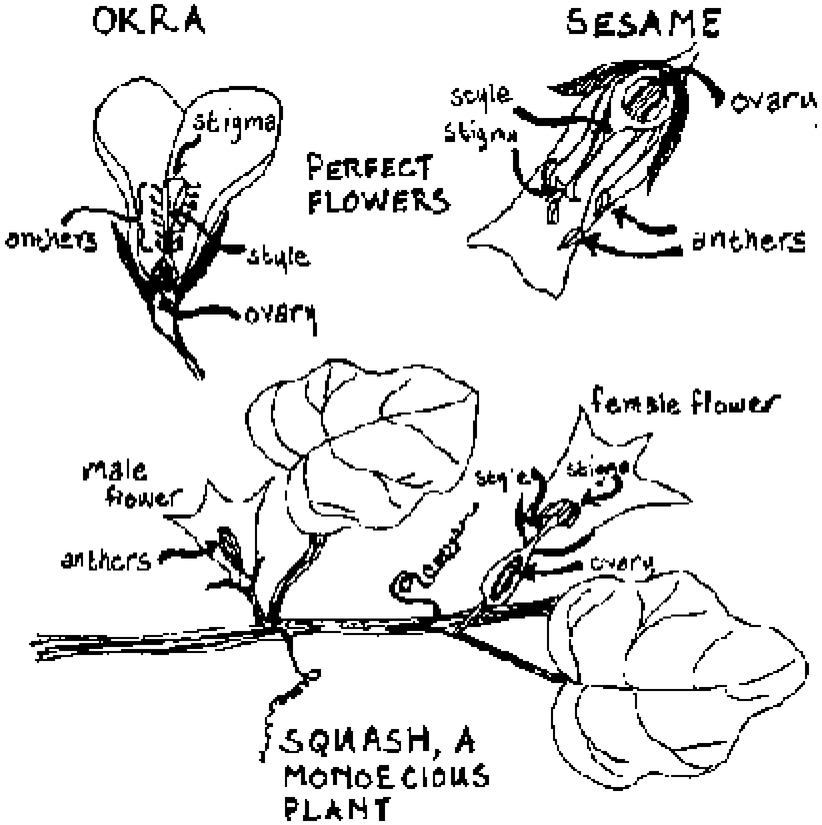
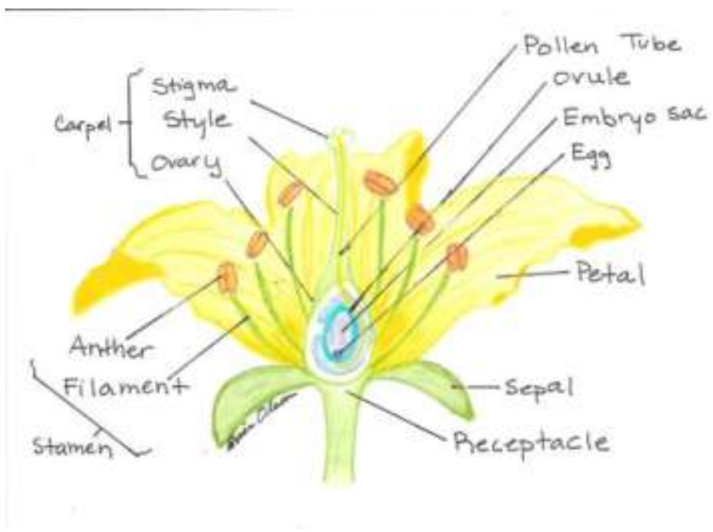


Figure 20. Complete flower structure

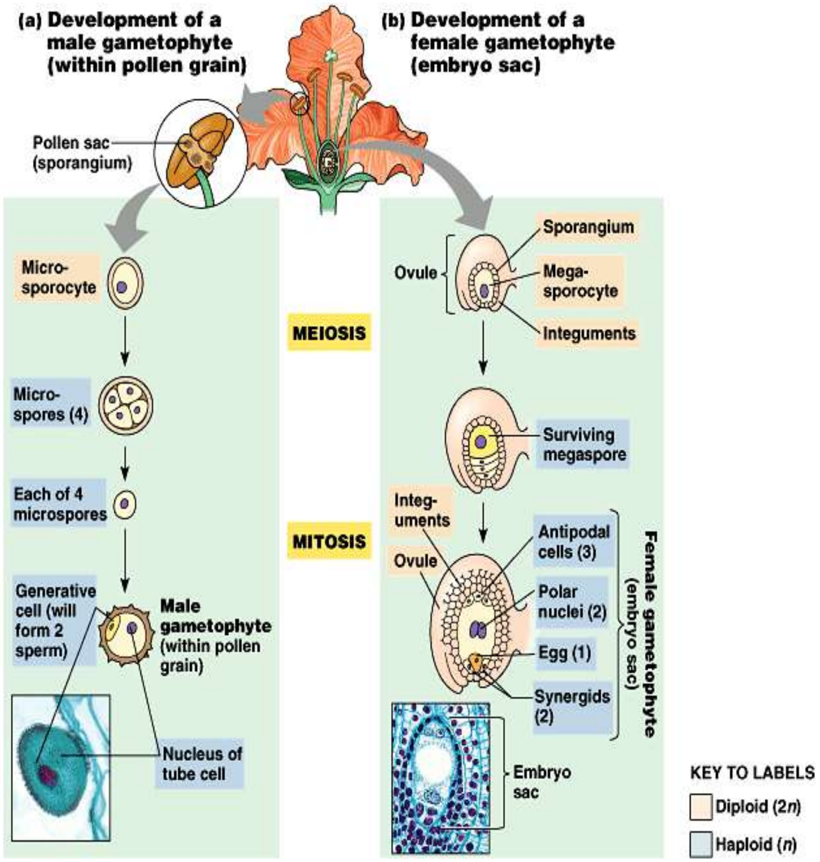
Imperfect (pistillate) flower structure





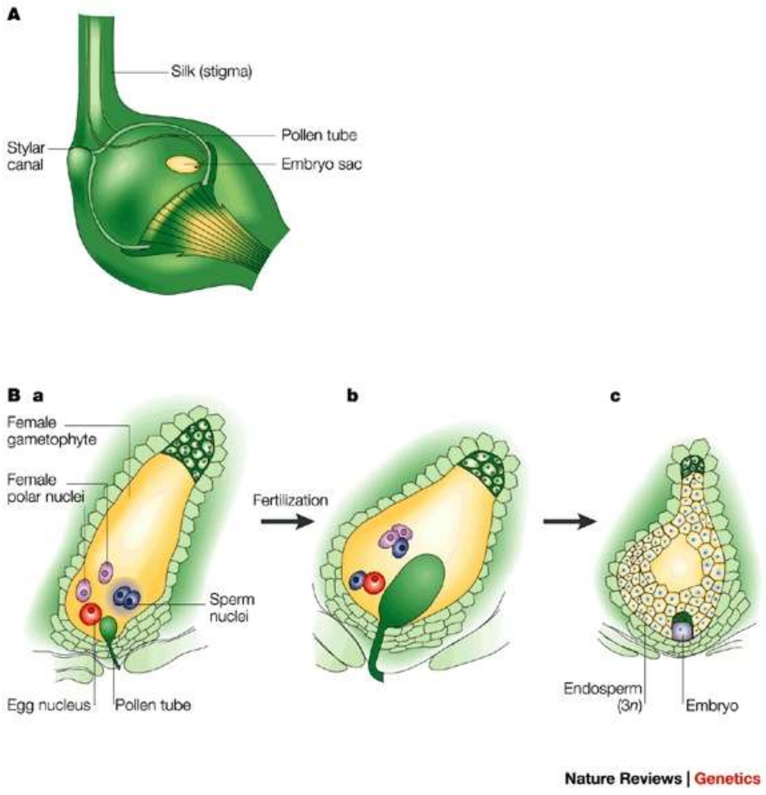
Gametophyte development

- Male gametophyte: *microsporocyte* (in pollen sacs of anther) divides by meiosis into 4-1N microspores; mitosis produces a generative cell (sperm) and a tube cell (pollen tube)= a pollen grain
- Female gametophyte: *megasporocyte* (in ovule) divides by meiosis to 4 cells, only 1 survives to a 1-N megaspore; 3 mitotic divisions forms the embryo sac; includes: 1 egg cell (female gamete) and 2 polar nuclei (synergids)



Double Fertilization

- pollen lands on stigma, pollen tube forms
- 2 male sperm travel to embryo sac
- One sperm fertilizes egg nucleus to make zygote
- Other sperm fuses with double polar nuclei to make endosperm

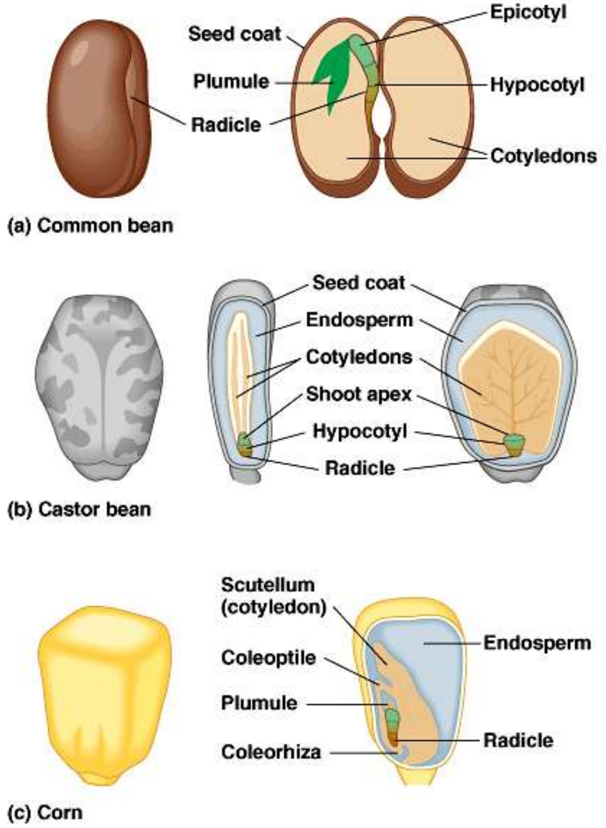


Video of Double Fertilization

- https://www.youtube.com/watch?v=bUjVHUf4d1I

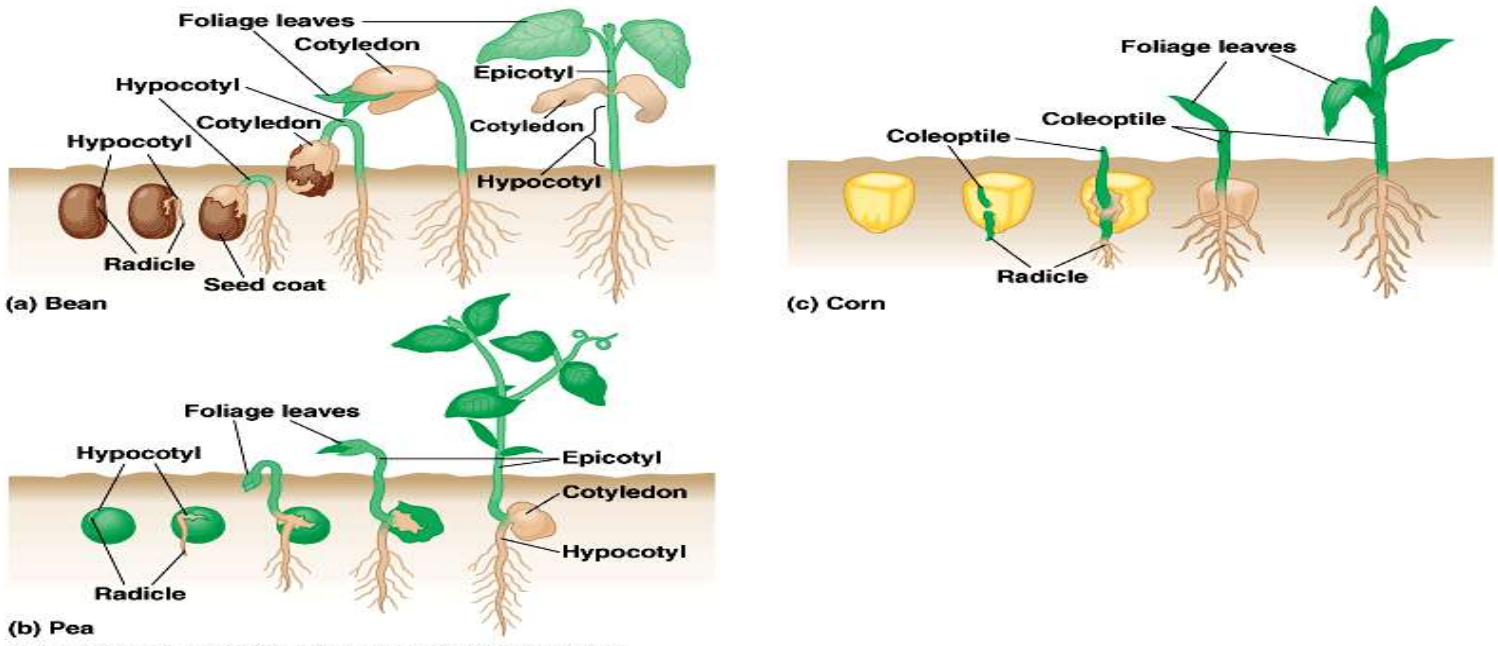
The seed

- From fertilized ovule…..
- The mature seed:
- •seed coat (protection)
- •cotyledons (seed leaves)
- •hypocotyl (lower embryonic axis)
- •radicle (embryonic root)
- •epicotyl (upper embryonic axis)
- •plummule (shoot tip)
- •coleoptile (sheath for embryonic shoot)



Seed germination

- Seed dormancy (low metabolic rate and growth suspension)
- Imbibition (uptake of water)
- Radicle 1st, then shoot tip (hypocotyl); stimulated by light
- Germination



The fruit

- From ovary….
- Fruit protects seeds and aids in their dispersal
- Pericarp (thickened wall of fruit from ovary wall)
- Fruit types:
- •<u>simple</u> (1 ovary/1 flower)~ cherry, soybean
- •<u>aggregate</u> (1 flower with many carpels/ovaries)~ blackberry
- •<u>multiple</u> (inflorescence; group of flowers/ovaries) ~ pineapple

Seedless Vascular to Seeds

Day 2

QOD

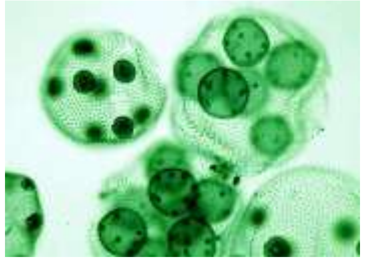
- Match each picture to an evolutionary stage of plants

- Charophyceans
- Bryophytes
- Seedless vascular plants
- Gymnosperms
- Angiosperms

A

B

C



D

E

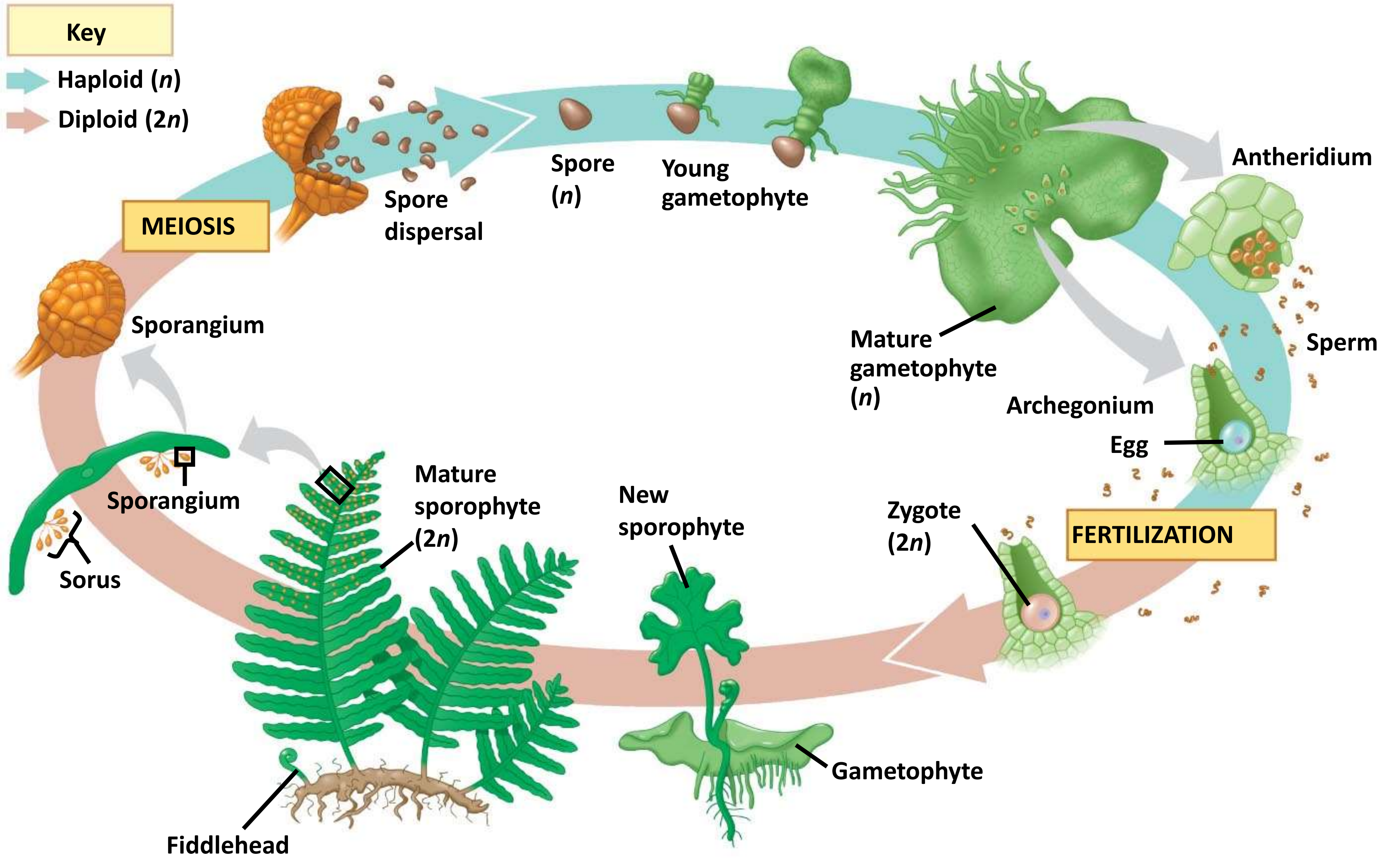
Concept 29.3: Ferns and other seedless vascular plants were the first plants to grow tall

- Bryophytes and bryophyte-like plants were the prevalent vegetation during the first 100 million years of plant evolution
- Vascular plants began to diversify during the Devonian and Carboniferous periods
- Vascular tissue allowed these plants to grow tall
- Seedless vascular plants have flagellated sperm and are usually restricted to moist environments

Classification of Seedless Vascular Plants

- There are two phyla of seedless vascular plants:
  - Phylum Lycophyta includes club mosses, spike mosses, and quillworts
  - Phylum Pterophyta includes ferns, horsetails, and whisk ferns and their relatives

Fig. 29-13-3



Key
Haploid (n)
Diploid (2n)
MEIOSIS
Spore dispersal
Spore (n)
Young gametophyte
Antheridium
Sperm
Mature gametophyte (n)
Archegonium
Egg
FERTILIZATION
Zygote (2n)
New sporophyte
Gametophyte
Mature sporophyte (2n)
Sporangium
Sporangium
Sorus
Fiddlehead

Transport in Xylem and Phloem

- Vascular plants have two types of vascular tissue: xylem and phloem
- **Xylem** conducts most of the water and minerals and includes dead cells called **tracheids**
- **Phloem** consists of living cells and distributes sugars, amino acids, and other organic products
- Water-conducting cells are strengthened by **lignin** and provide structural support
- Increased height was an evolutionary advantage

Evolution of Roots

- **Roots** are organs that anchor vascular plants
- They enable vascular plants to absorb water and nutrients from the soil
- Roots may have evolved from subterranean stems

Evolution of Leaves

•**Leaves** are organs that increase the surface area of vascular plants, thereby capturing more solar energy that is used for photosynthesis

Homosporous spore production

Sporangium on sporophyll → Single type of spore → Typically a bisexual gametophyte → Eggs / Sperm

Heterosporous spore production

Megasporangium on megasporophyll → Megaspore → Female gametophyte → Eggs

Microsporangium on microsporophyll → Microspore → Male gametophyte → Sperm

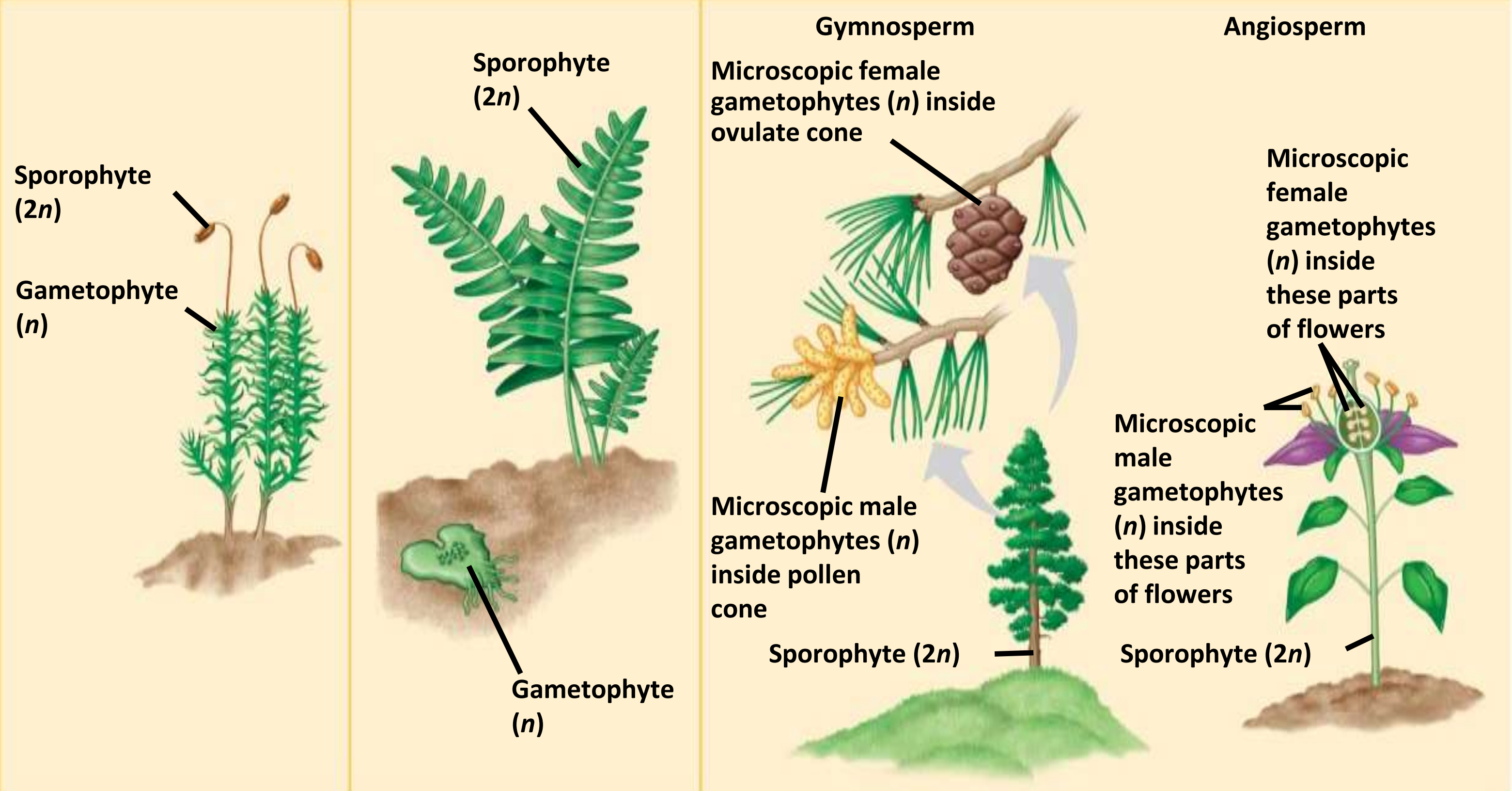
Overview: Transforming the World

- Seeds changed the course of plant evolution, enabling their bearers to become the dominant producers in most terrestrial ecosystems
- A **seed** consists of an embryo and nutrients surrounded by a protective coat
- In addition to seeds, the following are common to all seed plants
  - Reduced gametophytes
  - Heterospory
  - Ovules
  - Pollen

Fig. 30-2

	PLANT GROUP		
	Mosses and other nonvascular plants	Ferns and other seedless vascular plants	Seed plants (gymnosperms and angiosperms)
Gametophyte	Dominant	Reduced, independent (photosynthetic and free-living)	Reduced (usually microscopic), dependent on surrounding sporophyte tissue for nutrition
Sporophyte	Reduced, dependent on gametophyte for nutrition	Dominant	Dominant

Example

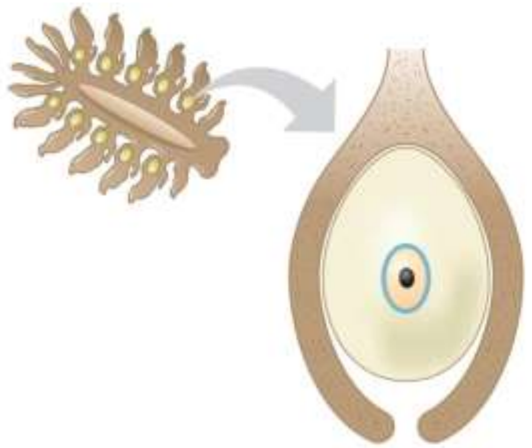


Heterospory: The Rule Among Seed Plants

- The ancestors of seed plants were likely homosporous, while seed plants are heterosporous
- Megasporangia produce megaspores that give rise to female gametophytes
- Microsporangia produce microspores that give rise to male gametophytes

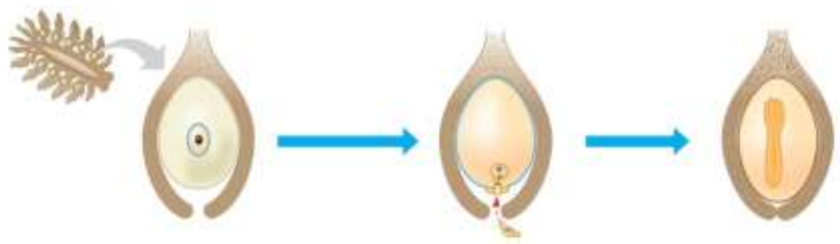
Ovules and Production of Eggs

- An **ovule** consists of a megasporangium, megaspore, and one or more protective **integuments**
- Gymnosperm megaspores have one integument
- Angiosperm megaspores usually have two integuments



Pollen and Production of Sperm

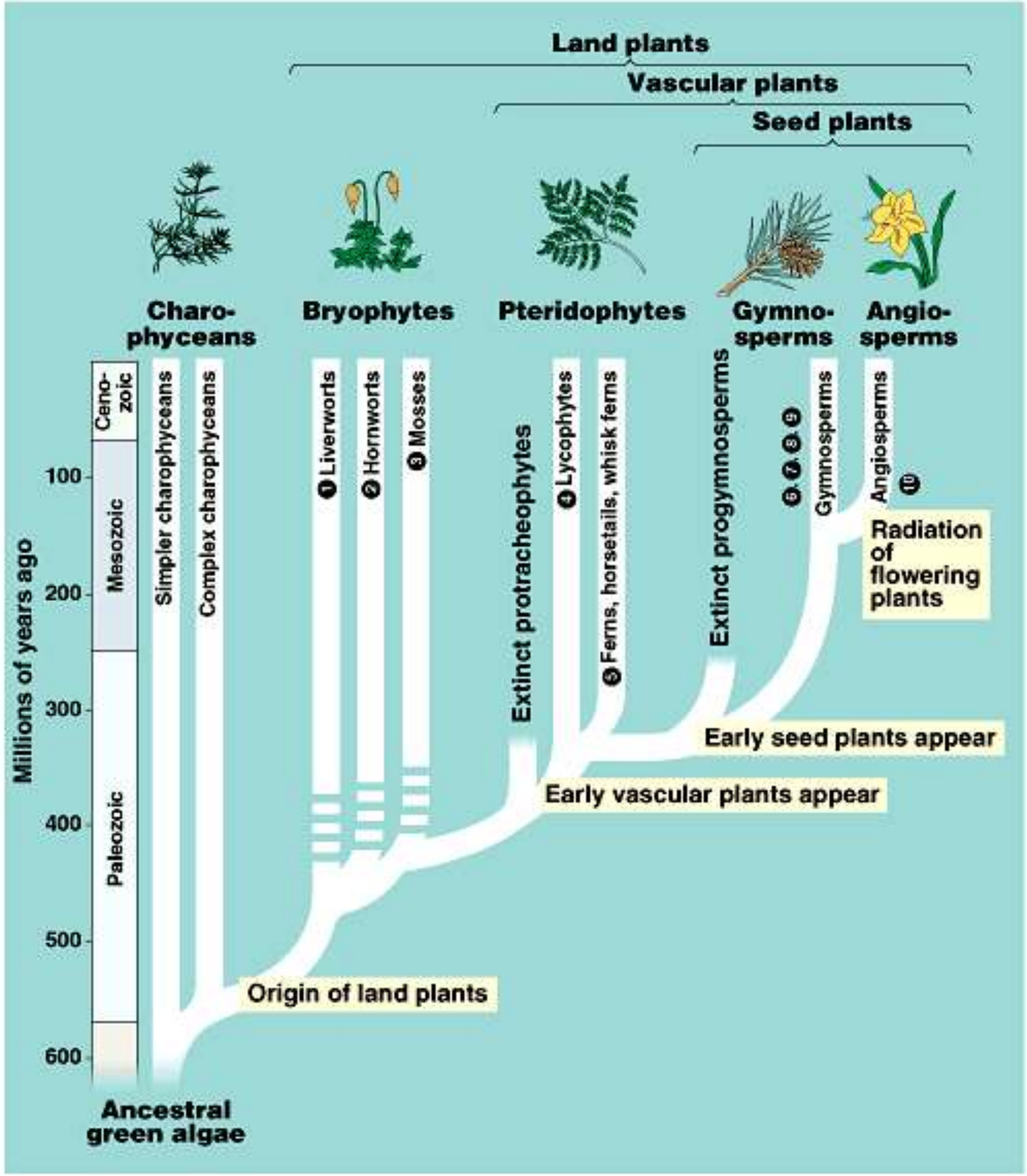
- Microspores develop into **pollen grains,** which contain the male gametophytes
- **Pollination** is the transfer of pollen to the part of a seed plant containing the ovules
- Pollen eliminates the need for a film of water and can be dispersed great distances by air or animals
- If a pollen grain germinates, it gives rise to a pollen tube that discharges two sperm into the female gametophyte within the ovule



Concept 30.2: Gymnosperms bear "naked" seeds, typically on cones

- The gymnosperms have "naked" seeds not enclosed by ovaries and consist of four phyla:
  - Cycadophyta (cycads)
  - Gingkophyta (one living species: *Ginkgo biloba*)
  - Gnetophyta (three genera: *Gnetum, Ephedra, Welwitschia*)
  - Coniferophyta (conifers, such as pine, fir, and redwood)

- *Plant Diversity I: The Colonization of Land*


Land plants
Vascular plants
Seed plants
Charo-phyceans
Bryophytes
Pteridophytes
Gymno-sperms
Angio-sperms
Cenozoic
Mesozoic
Paleozoic
Millions of years ago
100
200
300
400
500
600
Simpler charophyceans
Complex charophyceans
1 Liverworts
2 Hornworts
3 Mosses
Extinct protracheophytes
4 Lycophytes
5 Ferns, horsetails, whisk ferns
Extinct progymnosperms
6 7 8 9 Gymnosperms
Angiosperms 10
Radiation of flowering plants
Early seed plants appear
Early vascular plants appear
Origin of land plants
Ancestral green algae

QOD

- Put each of these plants in order from earliest to evolve to most recent:

  - Angiosperms
  - Bryophytes
  - Charophyceans
  - Gymnosperms
  - Seedless vascular plants

- Then give an example of each

Concept 29.1: Land plants evolved from green algae

- Green algae called charophytes are the closest relatives of land plants

Morphological and Molecular Evidence

- Many characteristics of land plants also appear in a variety of algal clades, mainly algae
- However, land plants share key traits only with charophytes

Kingdom Plantae?

Systematists are currently debating the boundaries of the plant kingdom

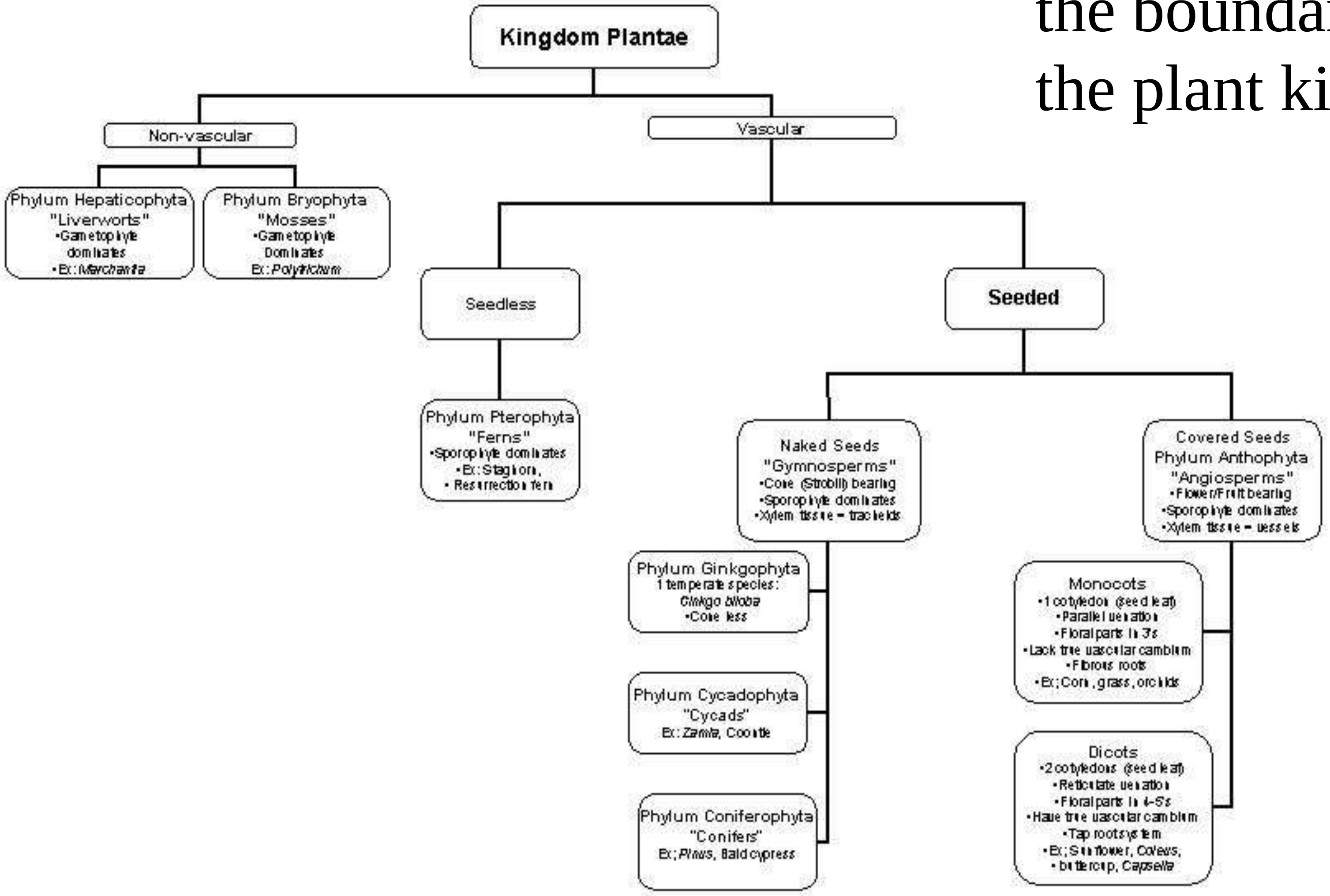
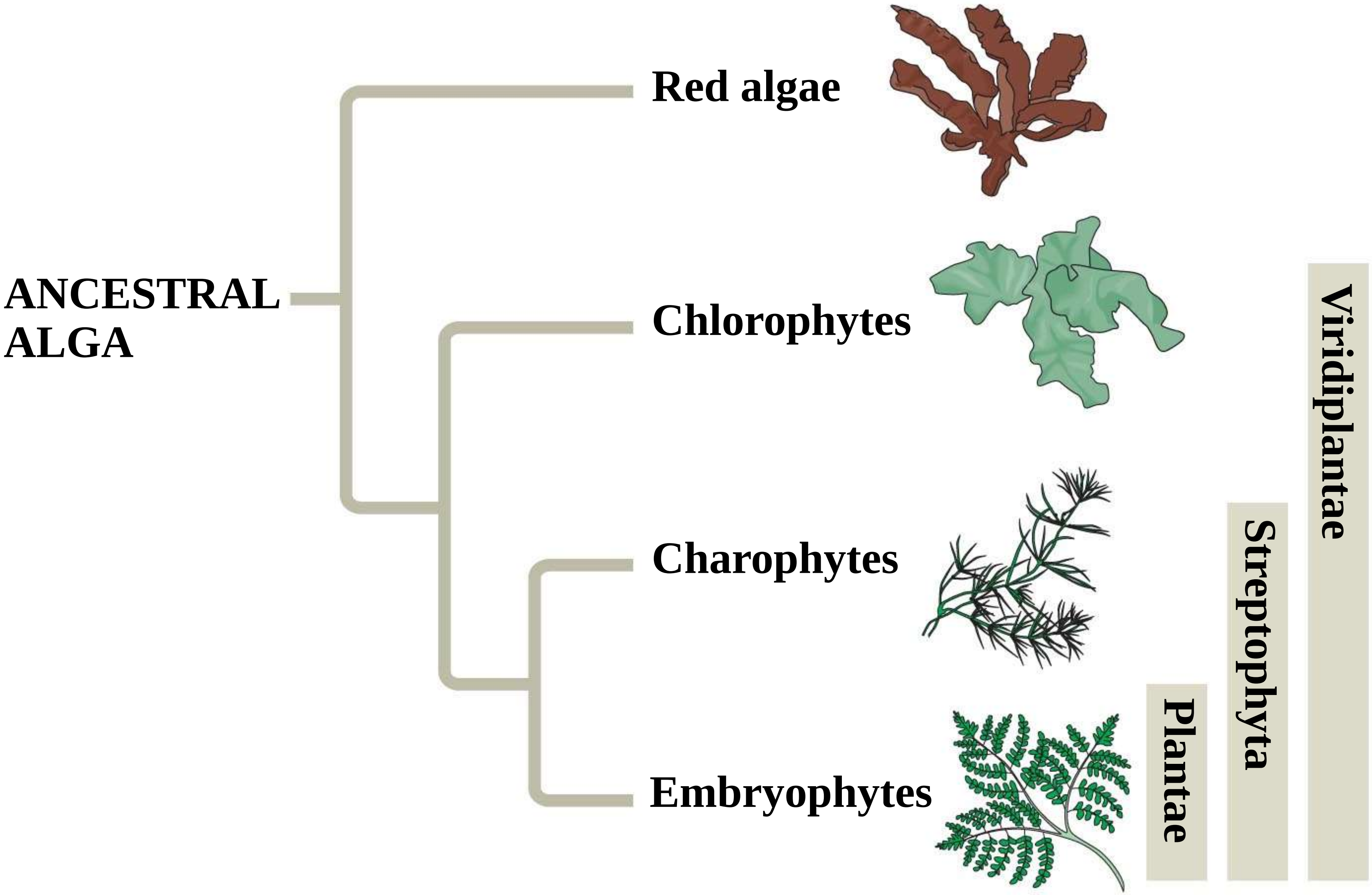


Fig. 29-4


Red algae
ANCESTRAL ALGA
Chlorophytes
Charophytes
Embryophytes
Viridiplantae
Streptophyta
Plantae

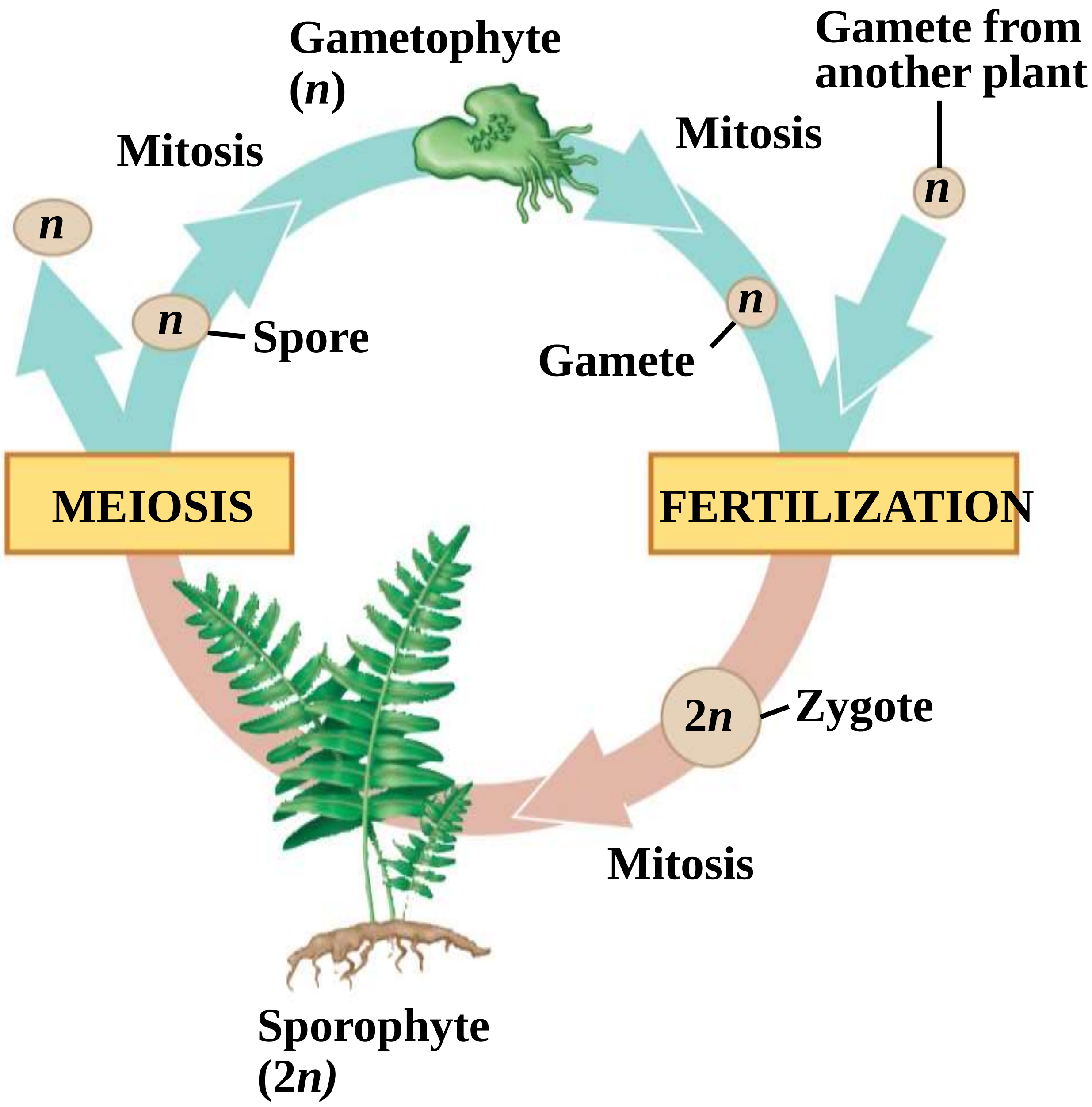
Derived Traits of Plants

- Four key traits appear in nearly all land plants but are absent in the charophytes:
  - Alternation of generations (with multicellular, dependent embryos)
  - Walled spores produced in sporangia
  - Multicellular gametangia
  - Apical meristems

Alternation of Generations and Multicellular, Dependent Embryos

- Plants alternate between two multicellular stages, a reproductive cycle called **alternation of generations**
- The **gametophyte** is haploid and produces haploid gametes by mitosis
- Fusion of the gametes gives rise to the diploid **sporophyte**, which produces haploid **spores** by meiosis

Fig. 29-5a



Alternation of generations

Table 29-1

Table 29.1 Ten Phyla of Extant Plants

	Common Name	Estimated Number of Species
Nonvascular Plants (Bryophytes)		
Phylum Hepatophyta	Liverworts	9,000
Phylum Anthocerophyta	Hornworts	100
Phylum Bryophyta	Mosses	15,000
Vascular Plants		
Seedless Vascular Plants		
Phylum Lycophyta	Lycophytes	1,200
Phylum Pterophyta	Pterophytes	12,000
Seed Plants		
Gymnosperms		
Phylum Ginkgophyta	Ginkgo	1
Phylum Cycadophyta	Cycads	130
Phylum Gnetophyta	Gnetophytes	75
Phylum Coniferophyta	Conifers	600
Angiosperms		
Phylum Anthophyta	Flowering plants	250,000

Fig. 29-7

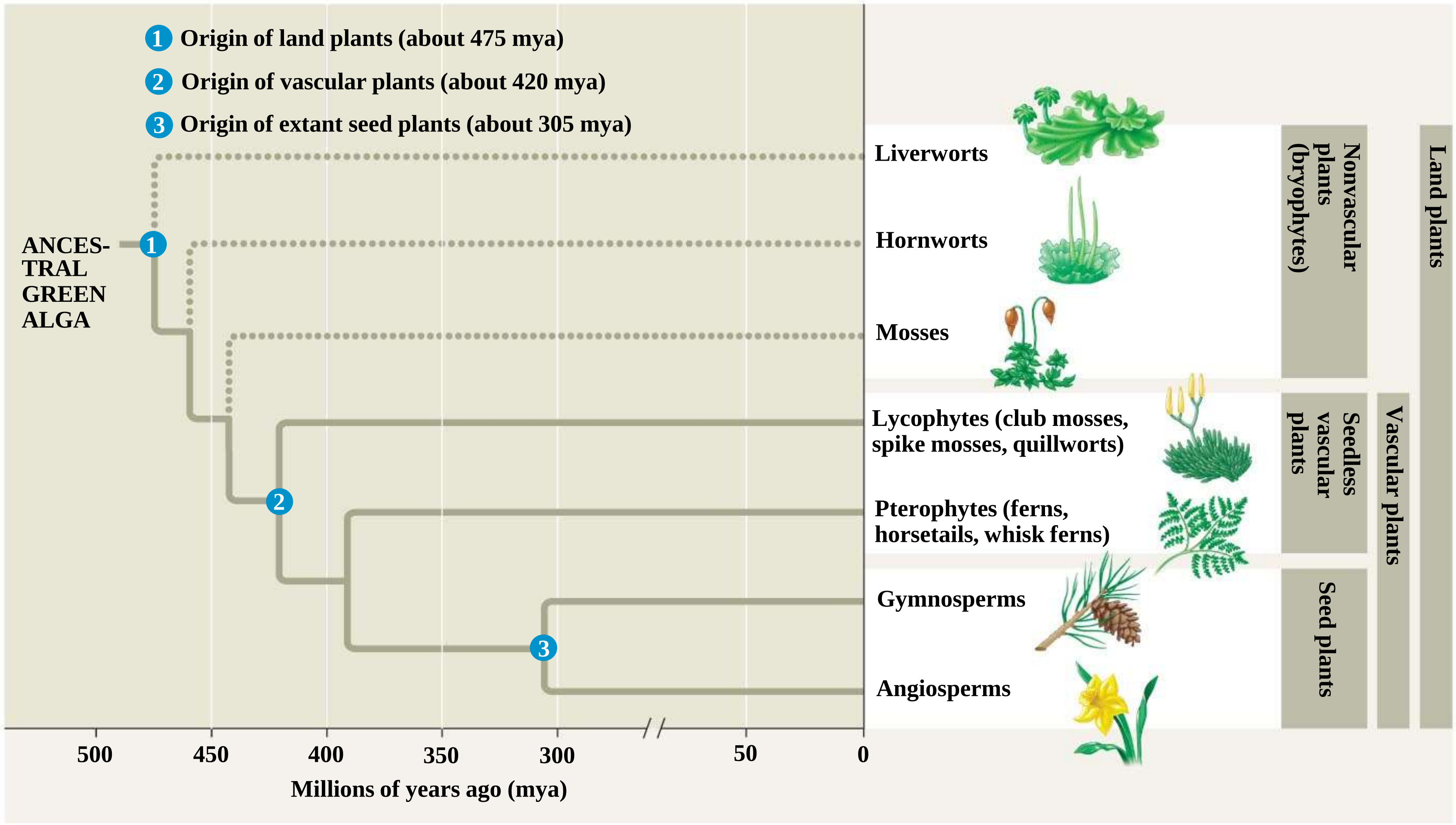
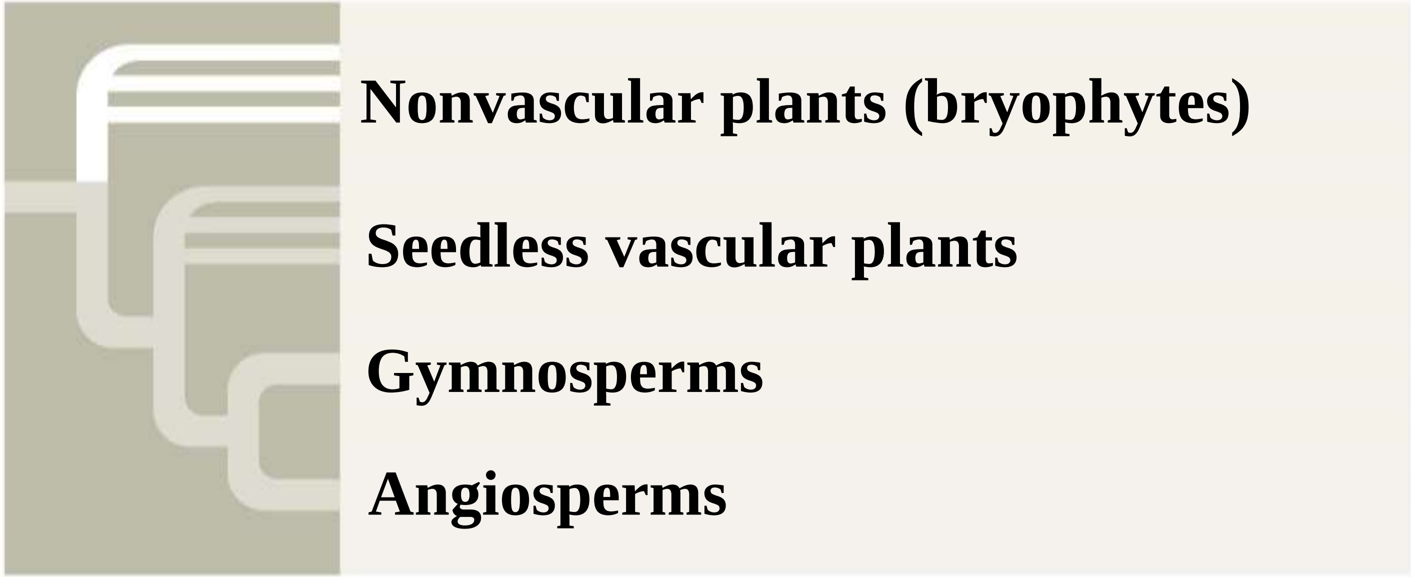

1 Origin of land plants (about 475 mya)
2 Origin of vascular plants (about 420 mya)
3 Origin of extant seed plants (about 305 mya)
ANCES-
TRAL
GREEN
ALGA
Liverworts
Hornworts
Mosses
Lycophytes (club mosses, spike mosses, quillworts)
Pterophytes (ferns, horsetails, whisk ferns)
Gymnosperms
Angiosperms
Nonvascular plants (bryophytes)
Seedless vascular plants
Seed plants
Vascular plants
Land plants
500
450
400
350
300
50
0
Millions of years ago (mya)

Fig. 29-UN1


Nonvascular plants (bryophytes)
Seedless vascular plants
Gymnosperms
Angiosperms

Concept 29.2: Mosses and other nonvascular plants have life cycles dominated by gametophytes

- Bryophytes are represented today by three phyla of small herbaceous (nonwoody) plants:
  - **Liverworts**, phylum Hepatophyta
  - **Hornworts**, phylum Anthocerophyta
  - **Mosses**, phylum Bryophyta
- Mosses are most closely related to vascular plants

Bryophyte Sporophytes

- Bryophyte sporophytes grow out of archegonia, and are the smallest and simplest sporophytes of all extant plant groups
- A sporophyte consists of a **foot**, a **seta** (stalk), and a sporangium, also called a **capsule**, which discharges spores through a **peristome**
- Hornwort and moss sporophytes have **stomata** for gas exchange

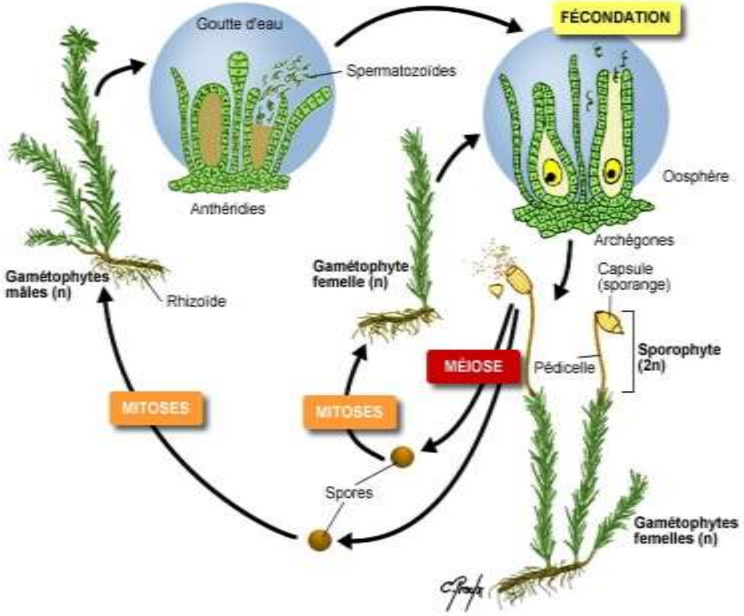


Fig. 29-9b

***Plagiochila deltoidea*, a “leafy” liverwort**

Fig. 29-9d

Polytrichum commune, hairy-cap moss

Capsule

Seta

Sporophyte (a sturdy plant that takes months to grow)

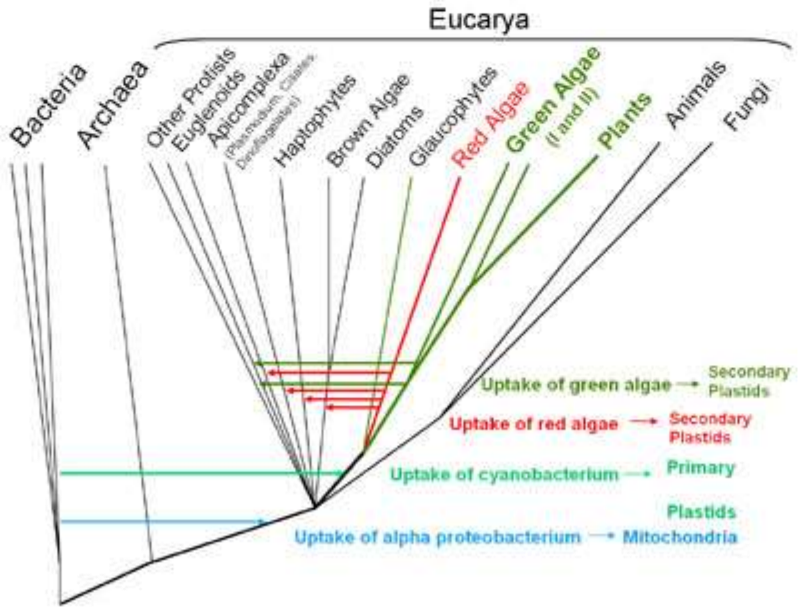
Gametophyte

Origins and Traits of Vascular Plants

- Fossils of the forerunners of vascular plants date back about 420 million years
- These early tiny plants had independent, branching sporophytes
- Living vascular plants are characterized by:
  - Life cycles with dominant sporophytes
  - Vascular tissues called xylem and phloem
  - Well-developed roots and leaves

Plant Evolution

- *bryophytes* (mosses), *pteridophytes* (ferns), *gymnosperms* (pines and conifers); *angiosperms* (flowering plants)
- Plants: multicellular, eukaryotic, photosynthetic autotrophs
- Terrestrial colonization:
- Vascular tissue
- The seed
- The flower

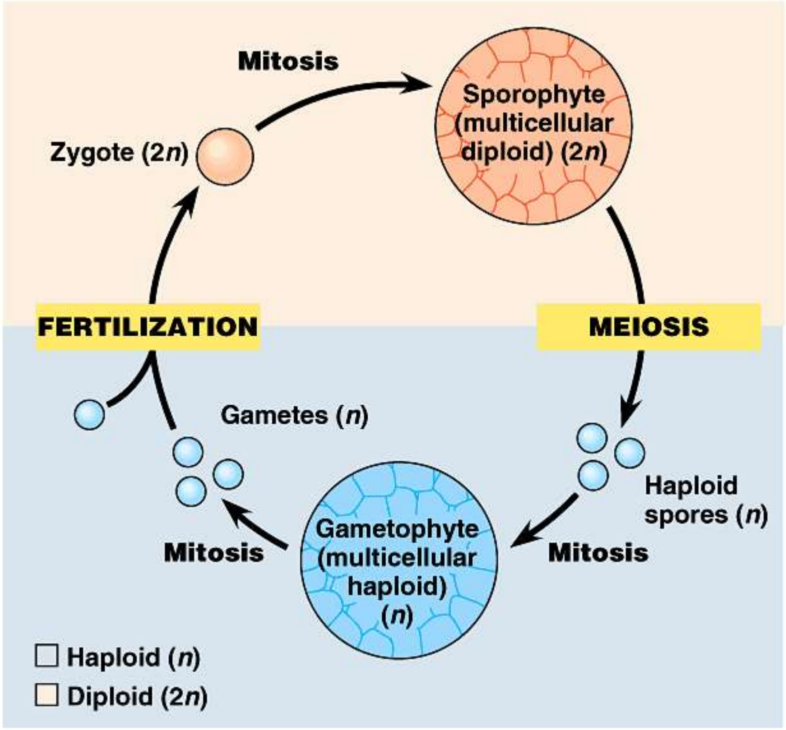


Plant origins

- ***Charophytes*: green algae (closest plant ancestor)**
- **<u>Similarities:</u>**
  - **Cell walls made of cellulose**
  - **Photosynthesis**
  - **Chlorophyll a and b**
  - **Similar sperm structure**
  - **Closely related genetically**

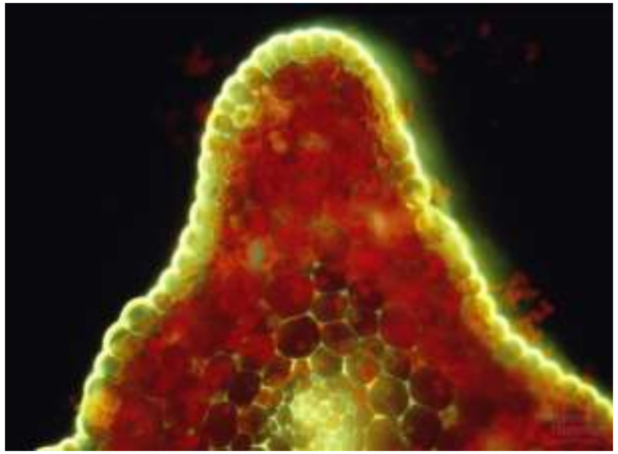
Characteristics that separate plants from algae ancestors

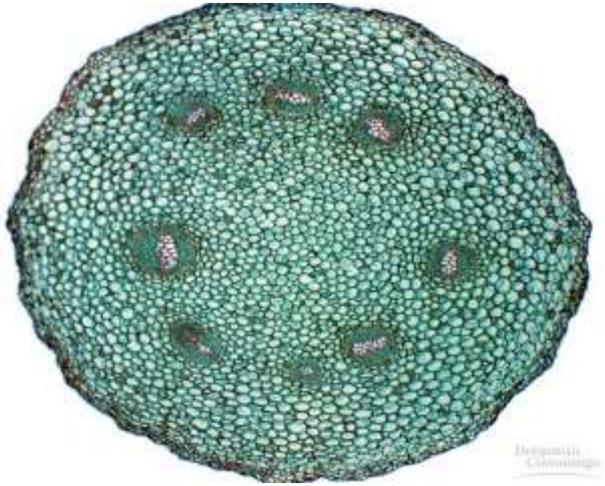
- Apical meristems: localized regions of cell division
- Multicellular, dependent embryos (embryophytes)
- Alternation of generations
- Walled spores produced in sporangia
- Multicellular gametophytes
- Organs – roots, stems leaves



Other terrestrial adaptations

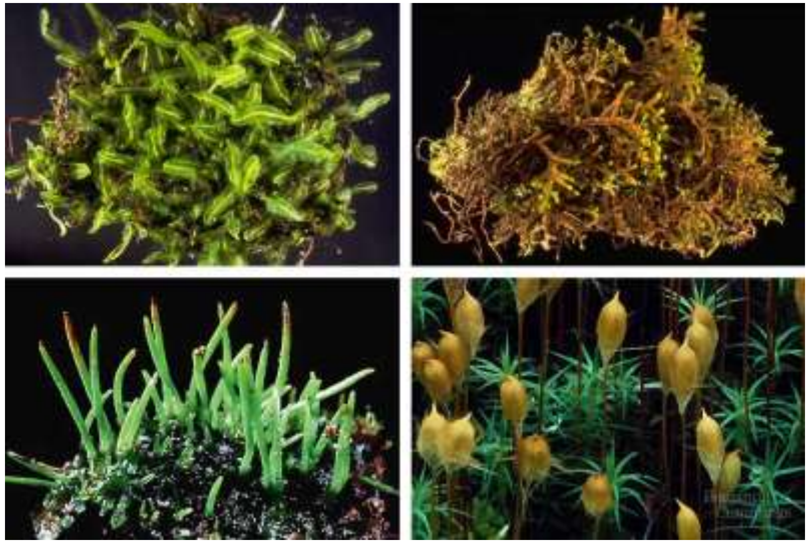
- Cuticle
- Stomata
- Vascular tissue - xylem and phloem
- Secondary compounds (protection from herbivore)





Bryophytes

- Mosses, liverworts, and hornworts
- 1st to exhibit the embryonic condition (male = antheridium; female = archegonium)
- Flagellated (water) sperm
- No vascular tissue (imbibe water)
- No lignin (short stature)
- Haploid gametophyte is the dominant generation



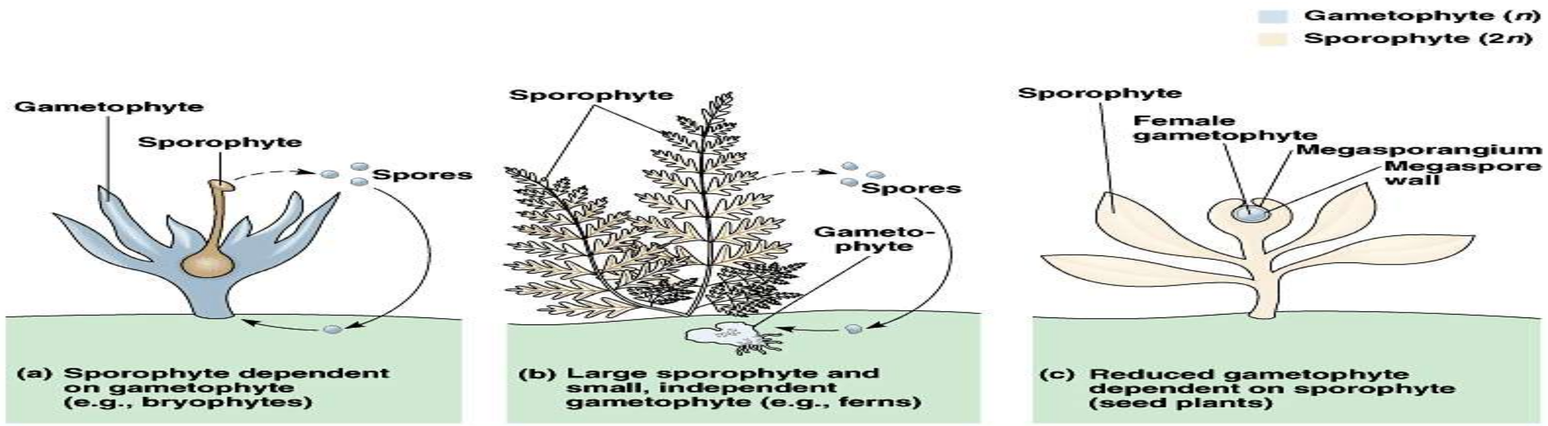
Pteridophytes: seedless vascular plants

- Ferns, club ‘moss’, horsetails
- True roots and leaves
- Roots have lignified vascular tissue
- Sporophyte-dominant life cycle
- Homosporous plants: a single type of spore….
- Sporophyte---->Single type of spore ---->Bisexual gametophyte ---->Eggs; sperm (flagellated; damp locations)
- Carboniferous period plants

- *Plant Diversity II: The Evolution of Seed Plants*

Seed Plant Reproductive Adaptations

- **<u>Reduction of the gametophyte</u>**: shift from haploid to diploid condition; female gametophyte and embryo remain in sporangia (protection against drought and ionizing radiation on land?)
- **<u>Advent of the seed</u>** multicellular sporophyte embryo with food supply and protective coat; heterosporous (two types of spores): megaspores--->female gametophyte--->eggs; microspores---> male gametophyte--->sperm
- **<u>Evolution of pollen</u>**: develop from microspores which mature into the male gametophytes; resistant and airborne for a terrestrial environment; eliminated water (sporopollenin coats)



Gymnosperms

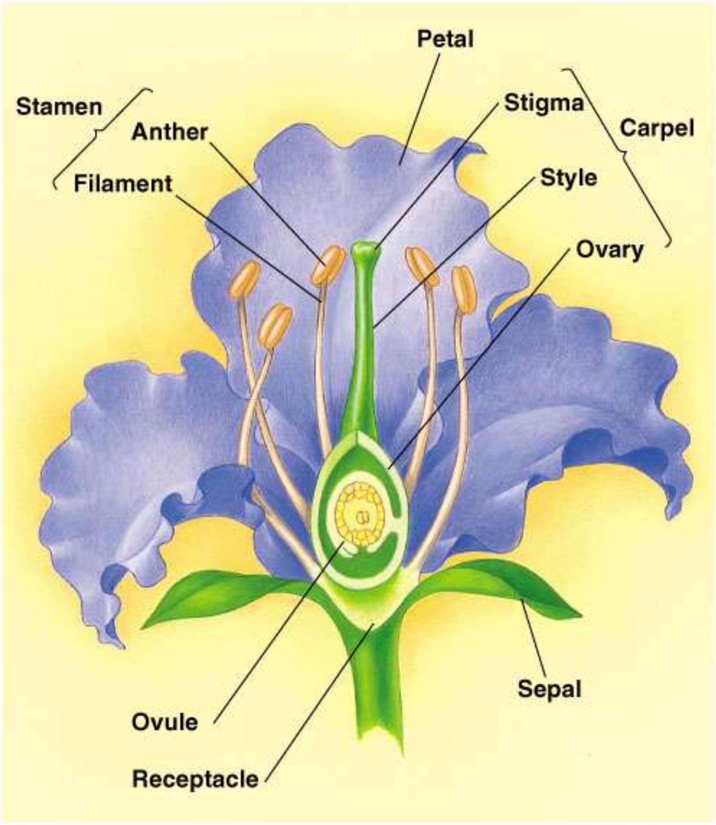
- Cone-bearing plants
- Lack enclosed chambers (ovaries) for seeds
- Ovules and seeds develop on specialized leaves called sporophylls
- Ginkgo, cycads, and conifers
- All are “evergreens”
- Needle-shaped leaves
- Vascular tissue refinement: *tracheids*~ water conducting and supportive element of xylem

Angiosperms

- Most diverse and geographically widespread of all plants
- "Flowering plants"(Phy: *Anthophyta*)
- Monocots: 1 embryonic seed leaf (lilies, palms, grasses, grain crops)
- Dicots: 2 embryonic seed leaves (roses, peas, sunflowers, oaks, maples)
- Vascular tissue refinement: vessel elements/fiber cells

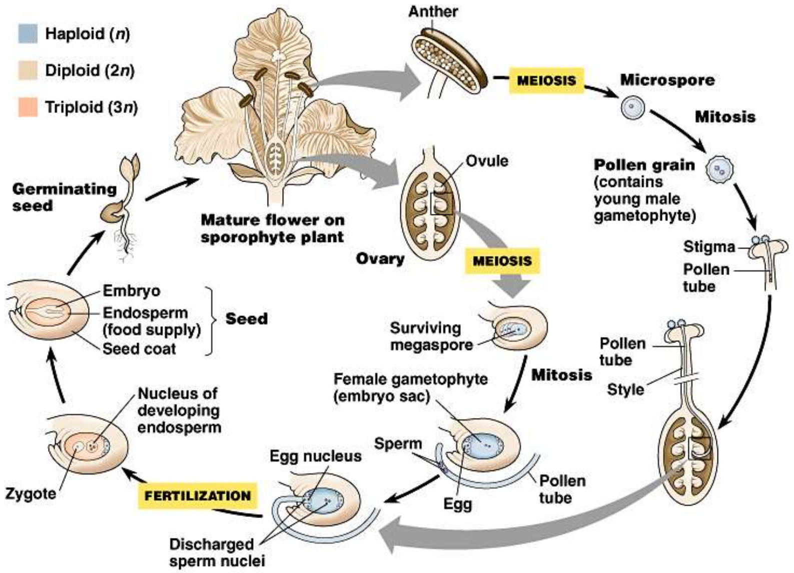
The flower: the defining structure of angiosperms

- <u>Reproductive structure</u>: pollen transfer; specialized shoot with modified leaves
- <u>Sepals</u>: enclose flower before it opens
- <u>Petals</u>: attract pollinators
- <u>Stamens</u>: male; anther (produces pollen), filament
- <u>Carpels</u>: female; stigma, style, ovary, ovules



Angiosperm life cycle

- Fruit (mature ovary); seeds from ovules
- Pollen grains: 2 haploid cells (immature male gametophytes)
- Ovules (female gametophyte~ embryo sac)
- <u>Double fertilization</u>: 1 sperm w/ egg = diploid zygote; other sperm w/ 2 nuclei in center of sac = triploid endosperm



QOD

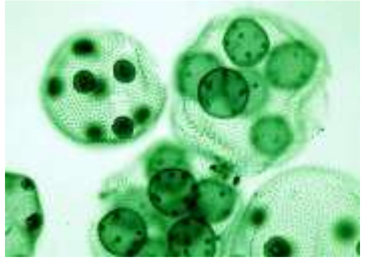
- Match each picture to an evolutionary stage of plants

1. Charophyceans
2. Bryophytes
3. Seedless vascular plants
4. Gymnosperms
5. Angiosperms

A

B

C



D

E

Ferns and other seedless vascular plants were the first plants to grow tall

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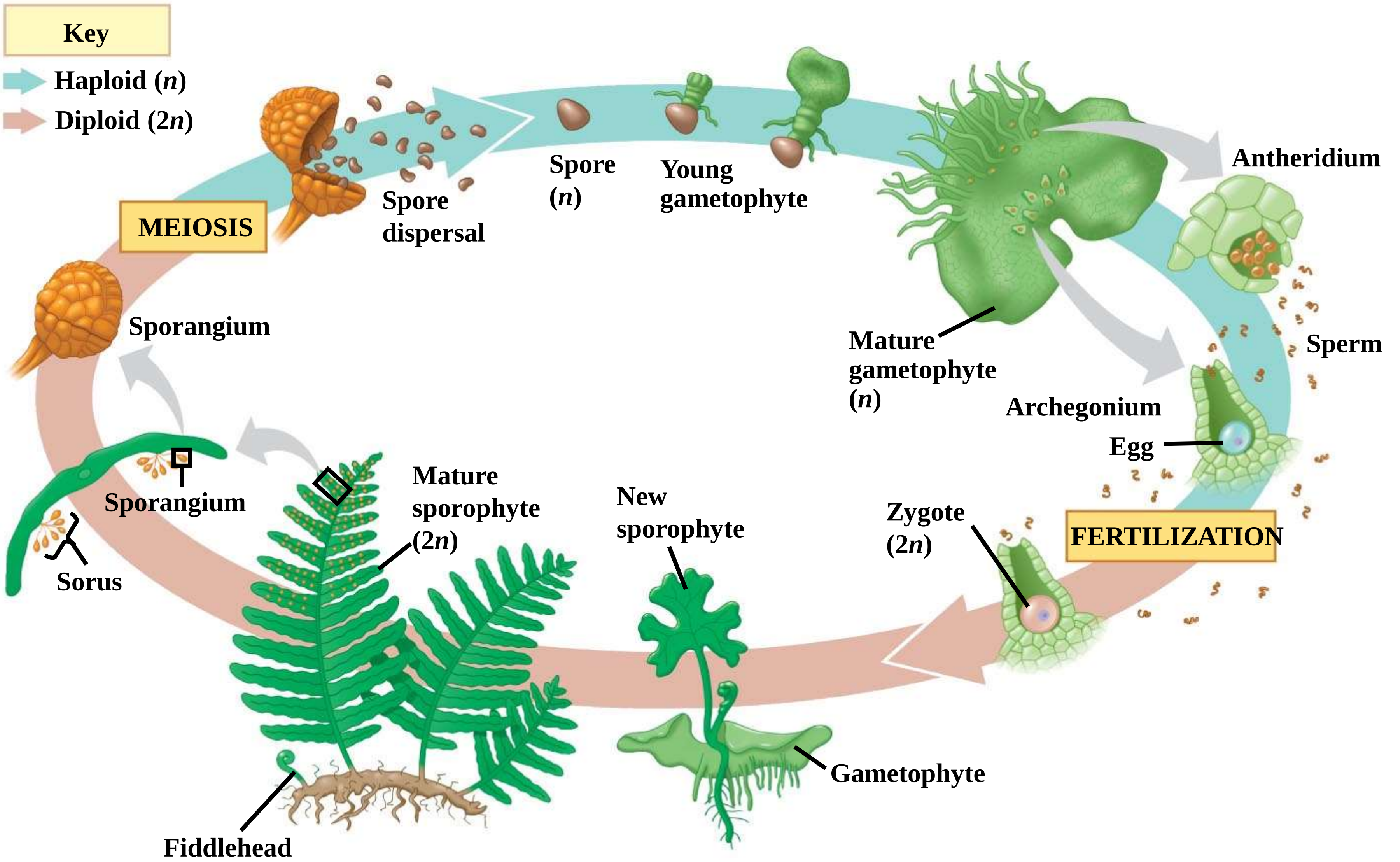
Fig. 29-13-3


Key
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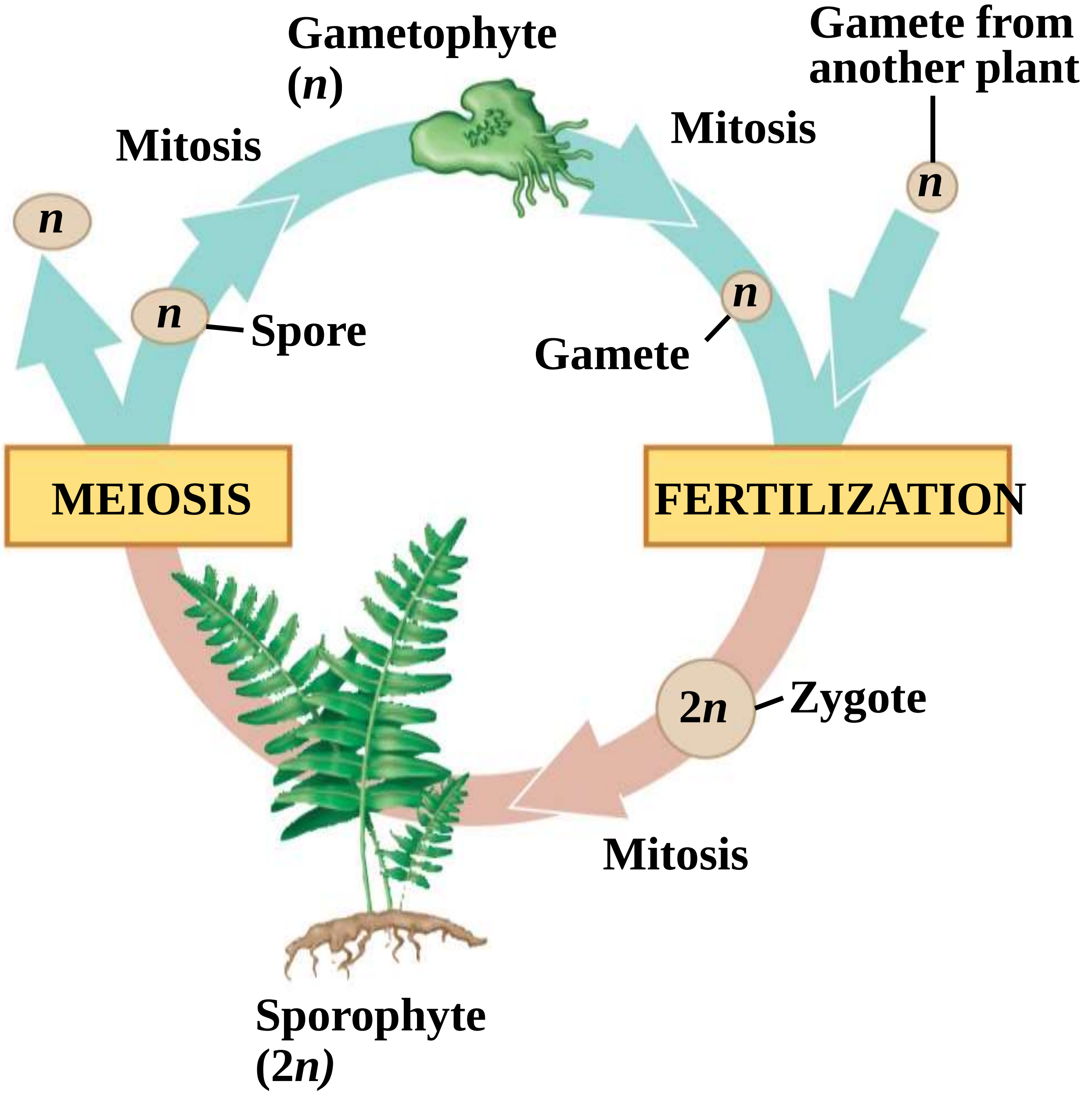
Sperm
Archegonium
Egg
Sporangium
Sporangium
Sorus
Mature sporophyte (2n)
New sporophyte
Zygote (2n)
FERTILIZATION
Gametophyte
Fiddlehead

Fig. 29-5a



Alternation of generations

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Evolution of Roots

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- They enable vascular plants to absorb water and nutrients from the soil
- Roots may have evolved from subterranean stems

Evolution of Leaves

•**Leaves** are organs that increase the surface area of vascular plants, thereby capturing more solar energy that is used for photosynthesis

Fig. 29-UN3

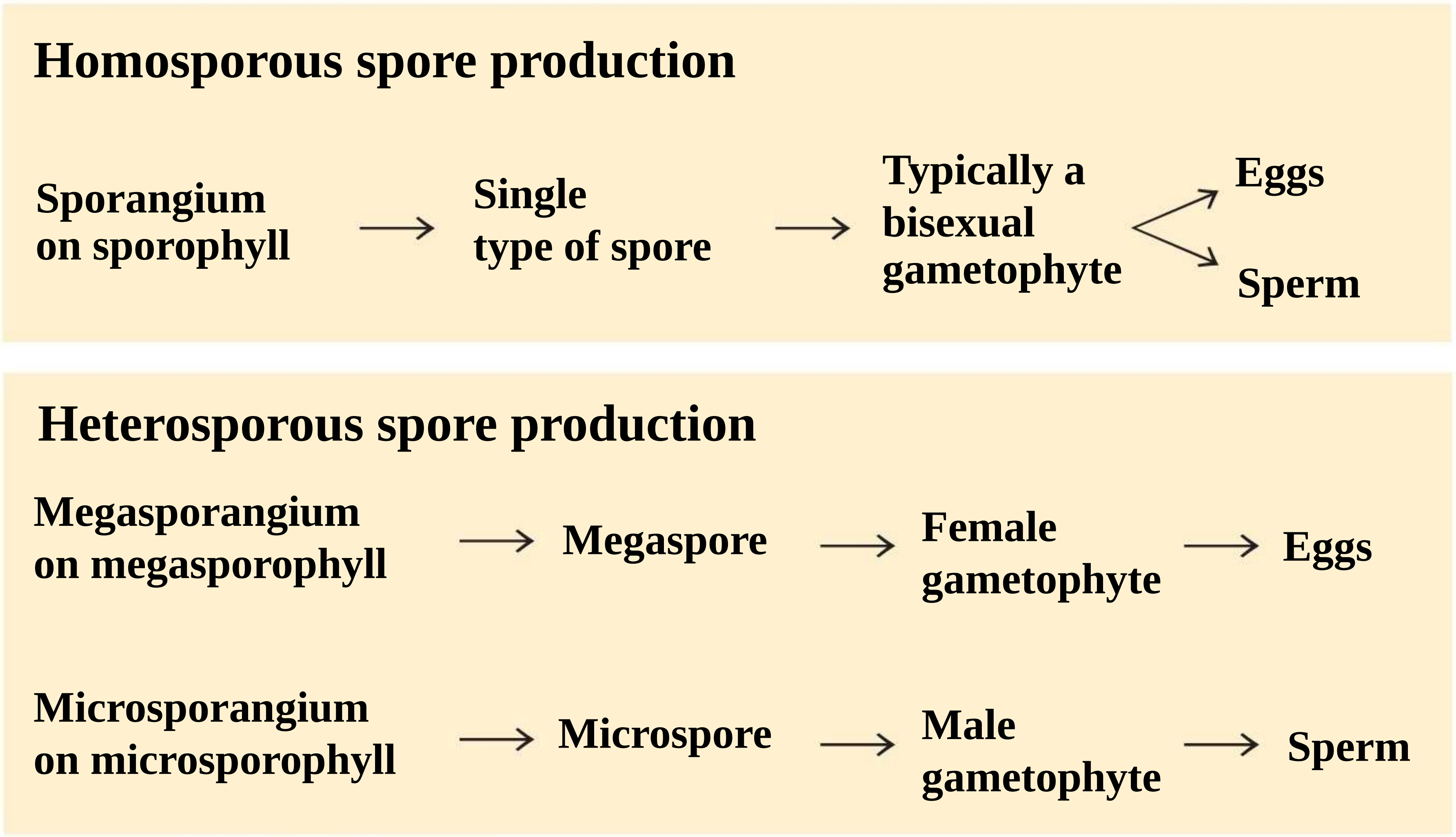
Homosporous spore production
Sporangium on sporophyll
Single type of spore
Typically a bisexual gametophyte
Eggs
Sperm
Heterosporous spore production
Megasporangium on megasporophyll
Megaspore
Female gametophyte
Eggs
Microsporangium on microsporophyll
Microspore
Male gametophyte
Sperm

Fig. 30-2

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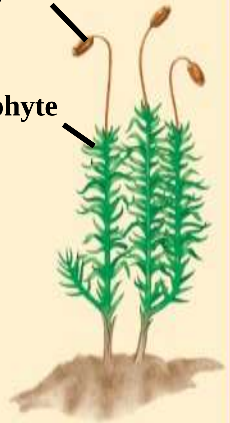
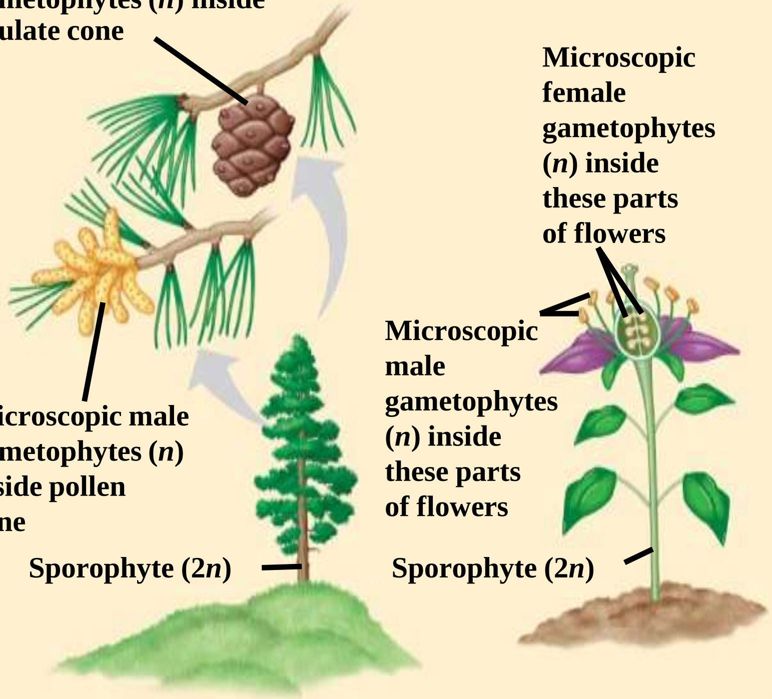
Sporophyte	Reduced, dependent on gametophyte for nutrition	Dominant	Dominant
Example			

Heterospory: The Rule Among Seed Plants

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- Microsporangia produce microspores that give rise to male gametophytes

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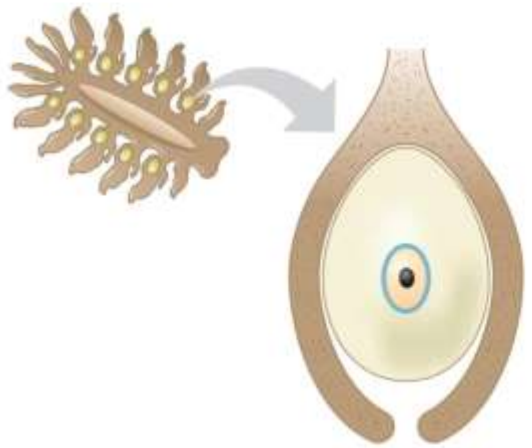
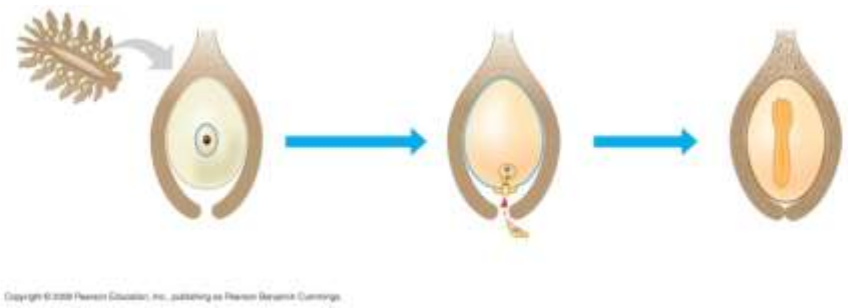
- An **ovule** consists of a megasporangium, megaspore, and one or more protective **integuments**
- Gymnosperm megaspores have one integument
- Angiosperm megaspores usually have two integuments



Pollen and Production of Sperm

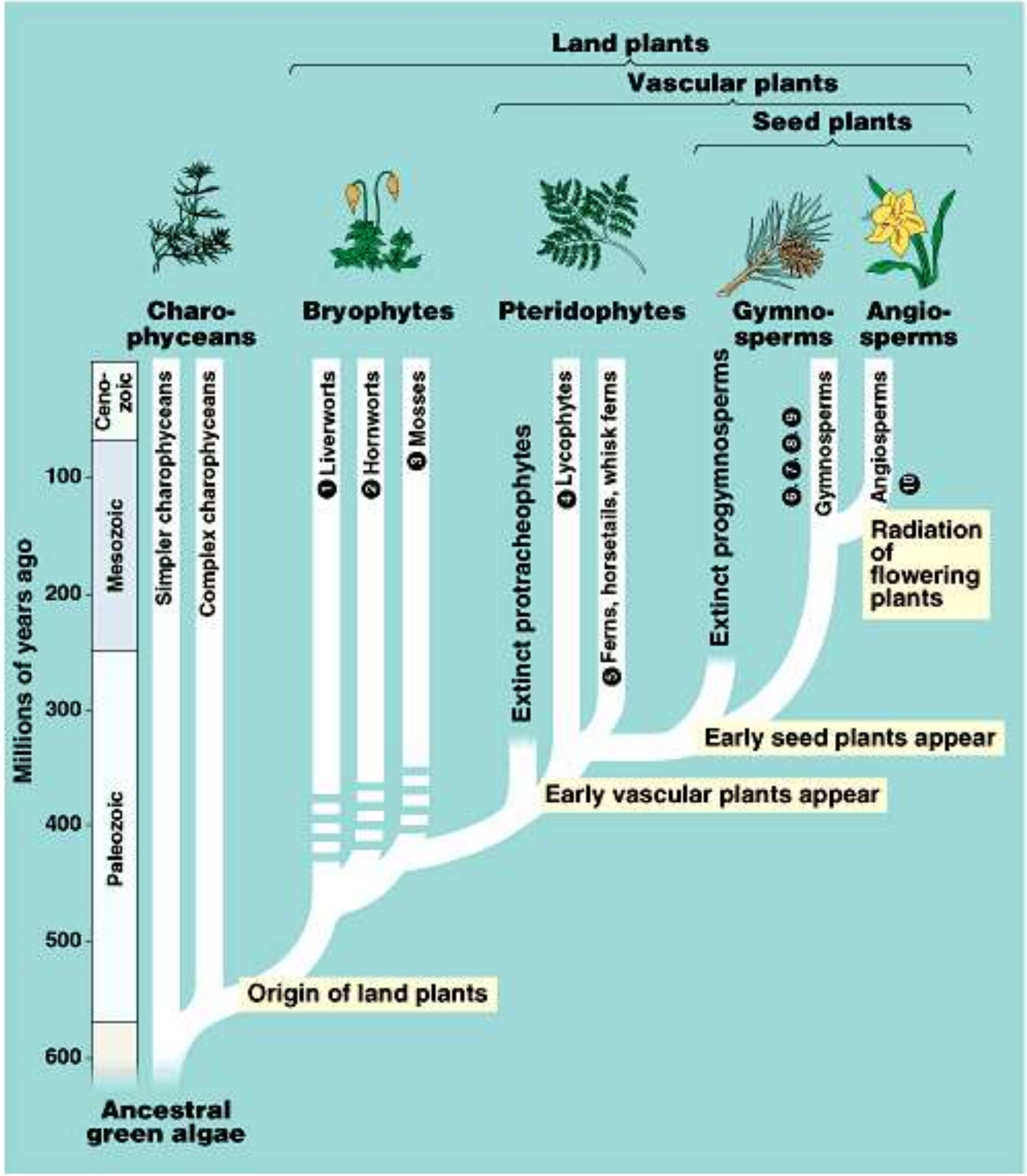
- Microspores develop into **pollen grains,** which contain the male gametophytes
- **Pollination** is the transfer of pollen to the part of a seed plant containing the ovules
- Pollen eliminates the need for a film of water and can be dispersed great distances by air or animals
- If a pollen grain germinates, it gives rise to a pollen tube that discharges two sperm into the female gametophyte within the ovule



Concept 30.2: Gymnosperms bear "naked" seeds, typically on cones

- The gymnosperms have "naked" seeds not enclosed by ovaries and consist of four phyla:
  - Cycadophyta (cycads)
  - Gingkophyta (one living species: *Ginkgo biloba*)
  - Gnetophyta (three genera: *Gnetum, Ephedra, Welwitschia*)
  - Coniferophyta (conifers, such as pine, fir, and redwood)

- *Plant Diversity I: The Colonization of Land*



Land plants
Vascular plants
Seed plants
Charo-phyceans
Bryophytes
Pteridophytes
Gymno-sperms
Angio-sperms
Cenozoic
Mesozoic
Paleozoic
Millions of years ago
100
200
300
400
500
600
Simpler charophyceans
Complex charophyceans
1 Liverworts
2 Hornworts
3 Mosses
Extinct protracheophytes
4 Lycophytes
5 Ferns, horsetails, whisk ferns
Extinct progymnosperms
6 7 8 9 Gymnosperms
Angiosperms 10
Radiation of flowering plants
Early seed plants appear
Early vascular plants appear
Origin of land plants
Ancestral green algae

QOD

- Put each of these plants in order from earliest to evolve to most recent:
  - Angiosperms
  - Bryophytes
  - Charophyceans
  - Gymnosperms
  - Seedless vascular plants
- Then give an example of each

Concept 29.1: Land plants evolved from green algae

- Green algae called charophytes are the closest relatives of land plants

Morphological and Molecular Evidence

- Many characteristics of land plants also appear in a variety of algal clades, mainly algae
- However, land plants share key traits only with charophytes

Kingdom Plantae?

Systematists are currently debating the boundaries of the plant kingdom

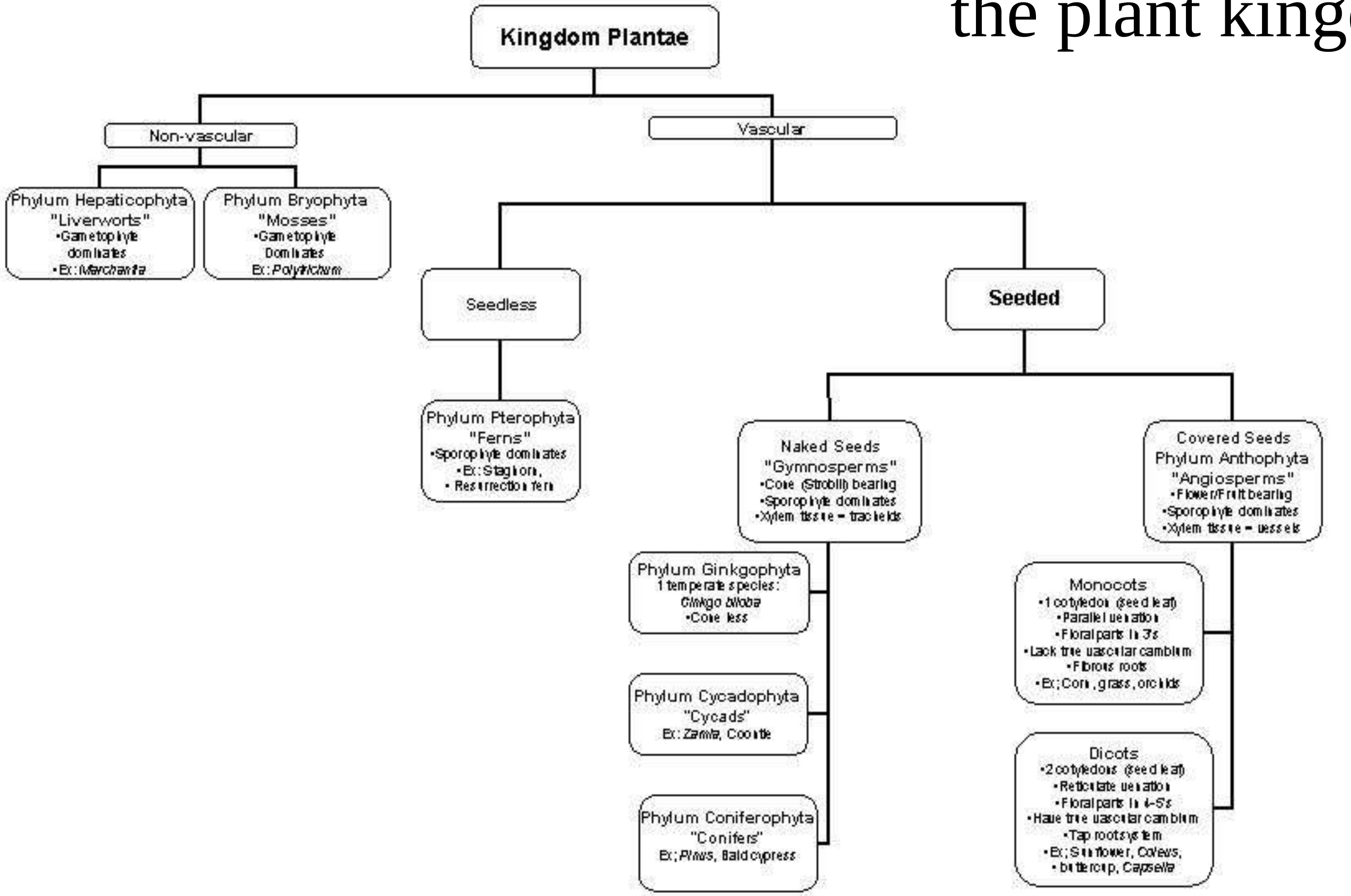
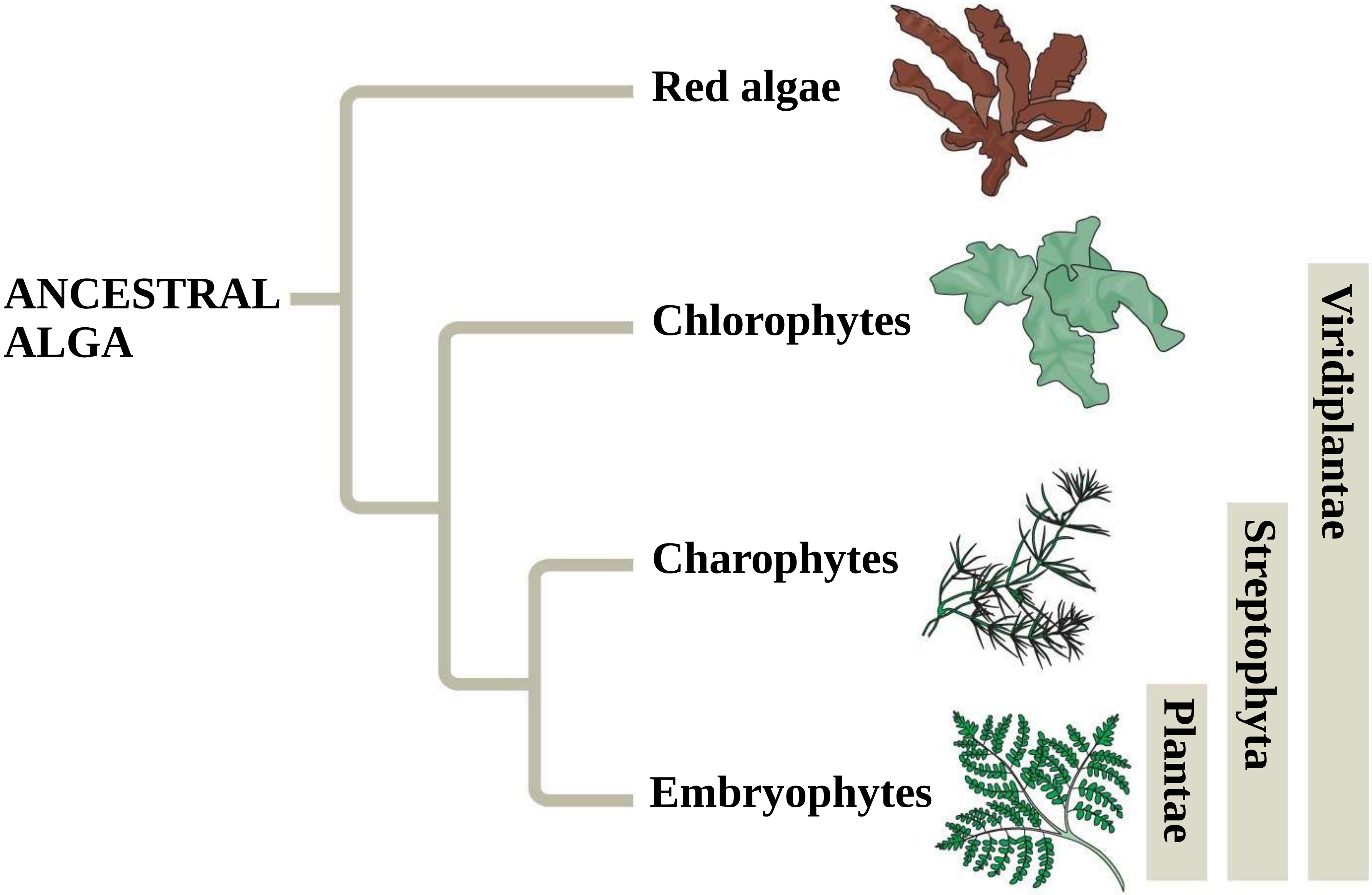


Fig. 29-4



Red algae
ANCESTRAL ALGA
Chlorophytes
Charophytes
Embryophytes
Viridiplantae
Streptophyta
Plantae

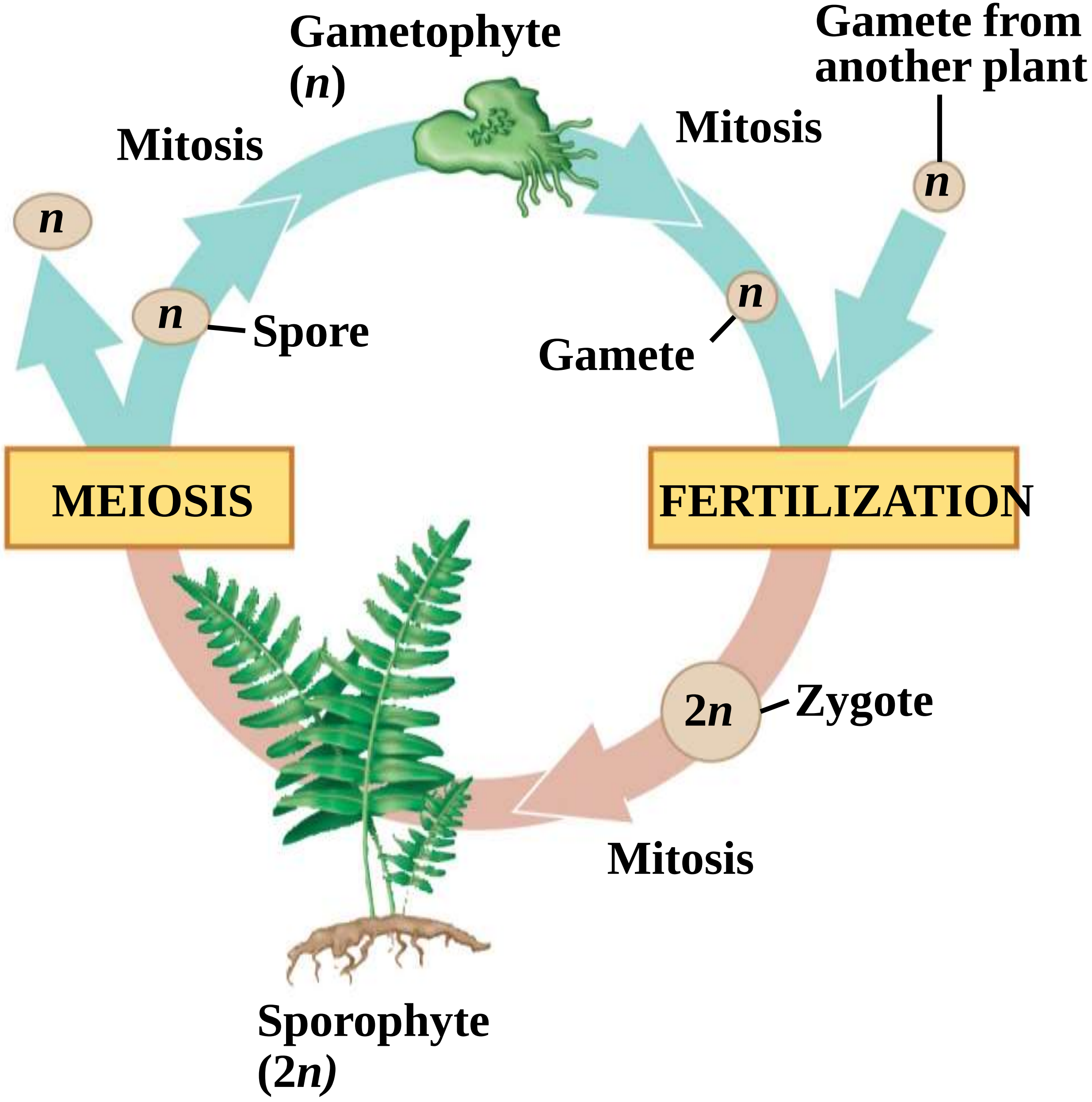
Derived Traits of Plants

- Four key traits appear in nearly all land plants but are absent in the charophytes:
  - Alternation of generations (with multicellular, dependent embryos)
  - Walled spores produced in sporangia
  - Multicellular gametangia
  - Apical meristems

Alternation of Generations and Multicellular, Dependent Embryos

- Plants alternate between two multicellular stages, a reproductive cycle called **alternation of generations**
- The **gametophyte** is haploid and produces haploid gametes by mitosis
- Fusion of the gametes gives rise to the diploid **sporophyte**, which produces haploid **spores** by meiosis

Fig. 29-5a



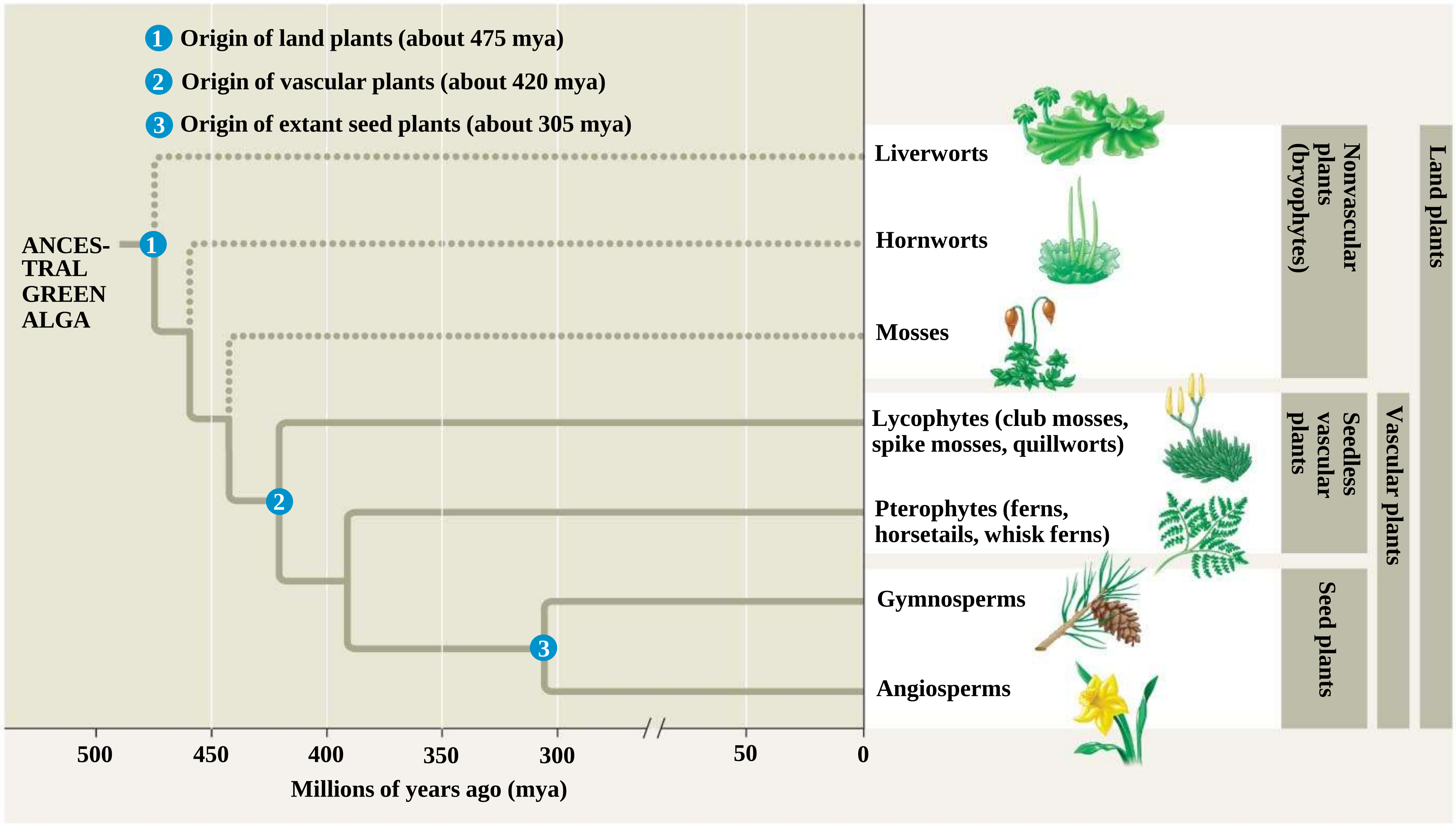
Alternation of generations

Table 29-1

Table 29.1 Ten Phyla of Extant Plants

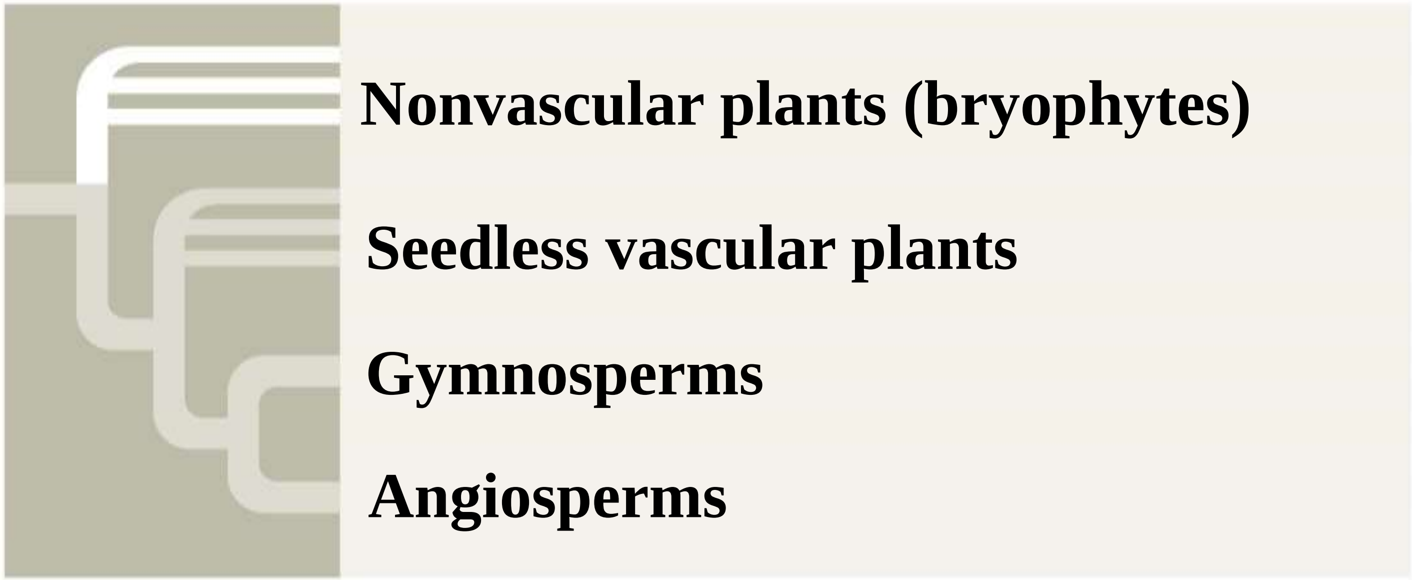
	Common Name	Estimated Number of Species
Nonvascular Plants (Bryophytes)		
Phylum Hepatophyta	Liverworts	9,000
Phylum Anthocerophyta	Hornworts	100
Phylum Bryophyta	Mosses	15,000
Vascular Plants		
Seedless Vascular Plants		
Phylum Lycophyta	Lycophytes	1,200
Phylum Pterophyta	Pterophytes	12,000
Seed Plants		
Gymnosperms		
Phylum Ginkgophyta	Ginkgo	1
Phylum Cycadophyta	Cycads	130
Phylum Gnetophyta	Gnetophytes	75
Phylum Coniferophyta	Conifers	600
Angiosperms		
Phylum Anthophyta	Flowering plants	250,000

Fig. 29-7



1 Origin of land plants (about 475 mya)
2 Origin of vascular plants (about 420 mya)
3 Origin of extant seed plants (about 305 mya)
ANCES-
TRAL
GREEN
ALGA
Liverworts
Hornworts
Mosses
Lycophytes (club mosses, spike mosses, quillworts)
Pterophytes (ferns, horsetails, whisk ferns)
Gymnosperms
Angiosperms
Nonvascular plants (bryophytes)
Seedless vascular plants
Seed plants
Vascular plants
Land plants
500
450
400
350
300
50
0
Millions of years ago (mya)

Fig. 29-UN1

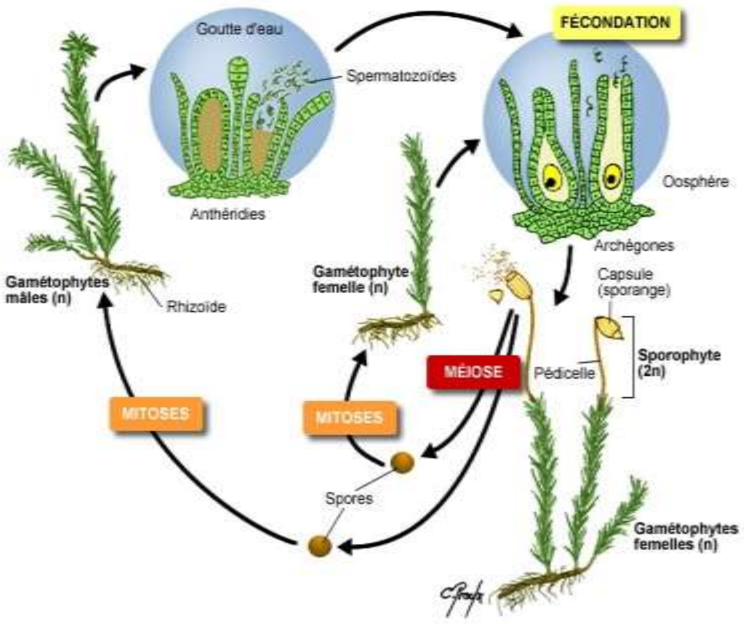

Nonvascular plants (bryophytes)
Seedless vascular plants
Gymnosperms
Angiosperms

Concept 29.2: Mosses and other nonvascular plants have life cycles dominated by gametophytes

- Bryophytes are represented today by three phyla of small herbaceous (nonwoody) plants:
  - **Liverworts**, phylum Hepatophyta
  - **Hornworts**, phylum Anthocerophyta
  - **Mosses**, phylum Bryophyta
- Mosses are most closely related to vascular plants

Bryophyte Sporophytes

- Bryophyte sporophytes grow out of archegonia, and are the smallest and simplest sporophytes of all extant plant groups
- A sporophyte consists of a **foot**, a **seta** (stalk), and a sporangium, also called a **capsule**, which discharges spores through a **peristome**
- Hornwort and moss sporophytes have **stomata** for gas exchange



***Plagiochila deltoidea*, a “leafy” liverwort**

Fig. 29-9d

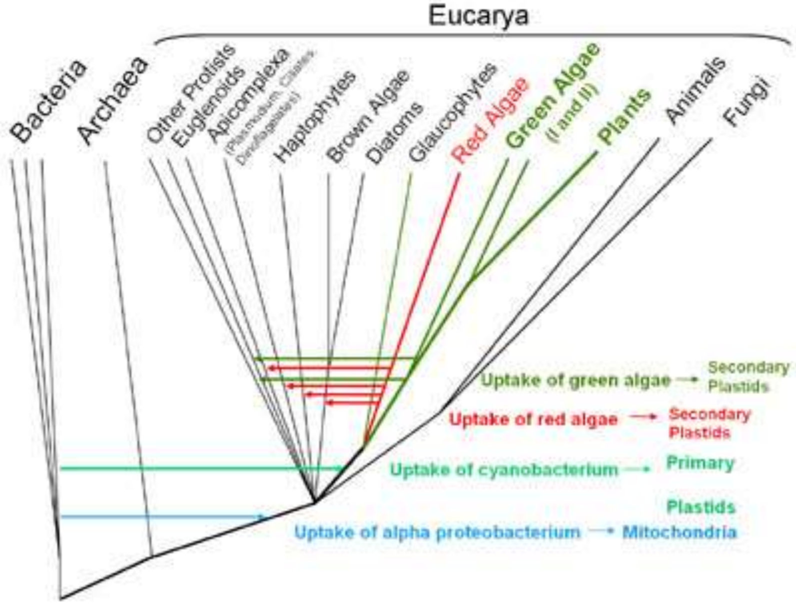
***Polytrichum commune*,**
hairy-cap moss

Origins and Traits of Vascular Plants

- Fossils of the forerunners of vascular plants date back about 420 million years
- These early tiny plants had independent, branching sporophytes
- Living vascular plants are characterized by:
    - Life cycles with dominant sporophytes
    - Vascular tissues called xylem and phloem
    - Well-developed roots and leaves

Plant Evolution

- *bryophytes* (mosses), *pteridophytes* (ferns), *gymnosperms* (pines and conifers); *angiosperms* (flowering plants)
- Plants: multicellular, eukaryotic, photosynthetic autotrophs
- Terrestrial colonization:
- Vascular tissue
- The seed
- The flower

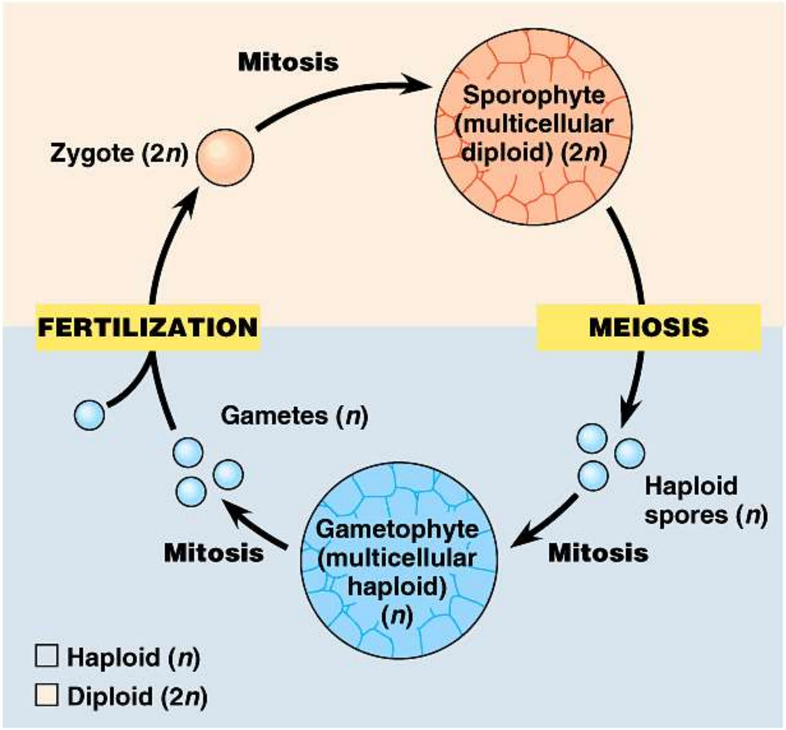


Plant origins

- ***Charophytes*: green algae (closest plant ancestor)**
- **<u>Similarities:</u>**
  - **Cell walls made of cellulose**
  - **Photosynthesis**
  - **Chlorophyll a and b**
  - **Similar sperm structure**
  - **Closely related genetically**

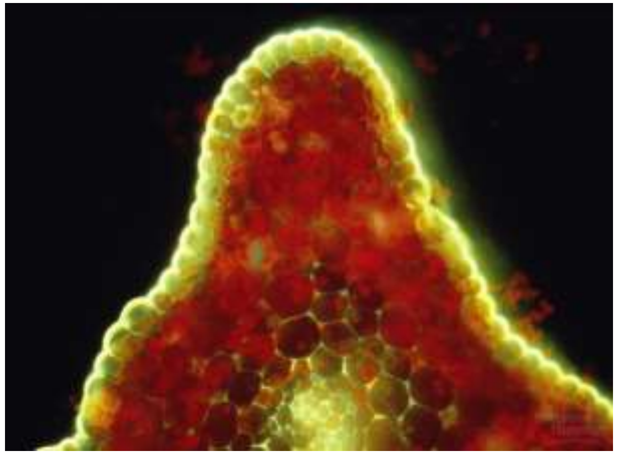
Characteristics that separate plants from algae ancestors

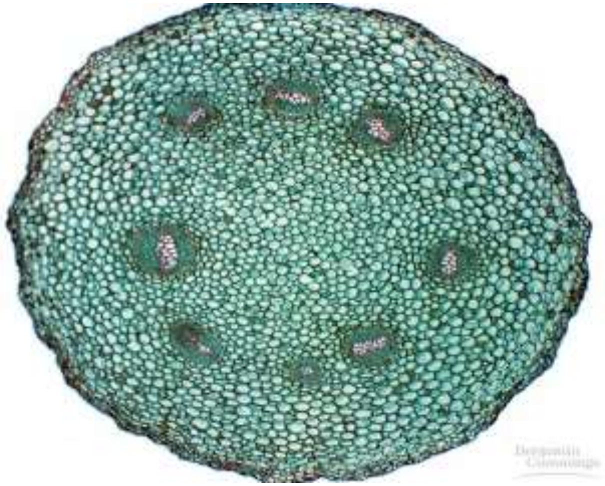
- Apical meristems: localized regions of cell division
- Multicellular, dependent embryos (embryophytes)
- Alternation of generations
- Walled spores produced in sporangia
- Multicellular gametophytes
- Organs – roots, stems leaves



Other terrestrial adaptations

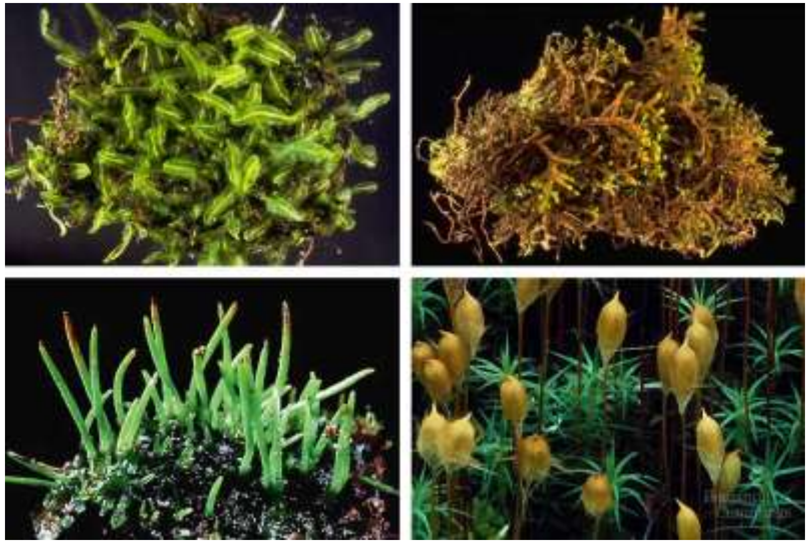
- Cuticle
- Stomata
- Vascular tissue - xylem and phloem
- Secondary compounds (protection from herbivore)





Bryophytes

- Mosses, liverworts, and hornworts
- 1st to exhibit the embryonic condition (male = antheridium; female = archegonium)
- Flagellated (water) sperm
- No vascular tissue (imbibe water)
- No lignin (short stature)
- Haploid gametophyte is the dominant generation

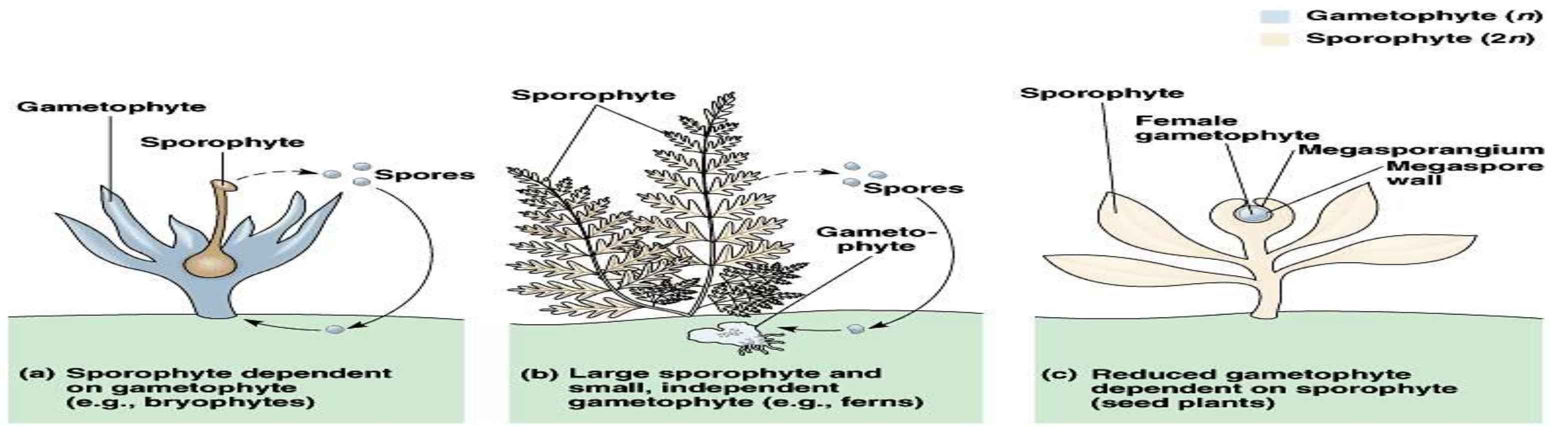


Pteridophytes: seedless vascular plants

- Ferns, club ‘moss’, horsetails
- True roots and leaves
- Roots have lignified vascular tissue
- Sporophyte-dominant life cycle
- Homosporous plants: a single type of spore….
- Sporophyte---->Single type of spore ---->Bisexual gametophyte ---->Eggs; sperm (flagellated; damp locations)
- Carboniferous period plants

Seed Plant Reproductive Adaptations

- **<u>Reduction of the gametophyte</u>**: shift from haploid to diploid condition; female gametophyte and embryo remain in sporangia (protection against drought and ionizing radiation on land?)
- **<u>Advent of the seed</u>** multicellular sporophyte embryo with food supply and protective coat; heterosporous (two types of spores): megaspores--->female gametophyte--->eggs; microspores---> male gametophyte--->sperm
- **<u>Evolution of pollen</u>**: develop from microspores which mature into the male gametophytes; resistant and airborne for a terrestrial environment; eliminated water (sporopollenin coats)



Gymnosperms

- Cone-bearing plants
- Lack enclosed chambers (ovaries) for seeds
- Ovules and seeds develop on specialized leaves called sporophylls
- Ginkgo, cycads, and conifers
- All are “evergreens”
- Needle-shaped leaves
- Vascular tissue refinement: *tracheids*~ water conducting and supportive element of xylem

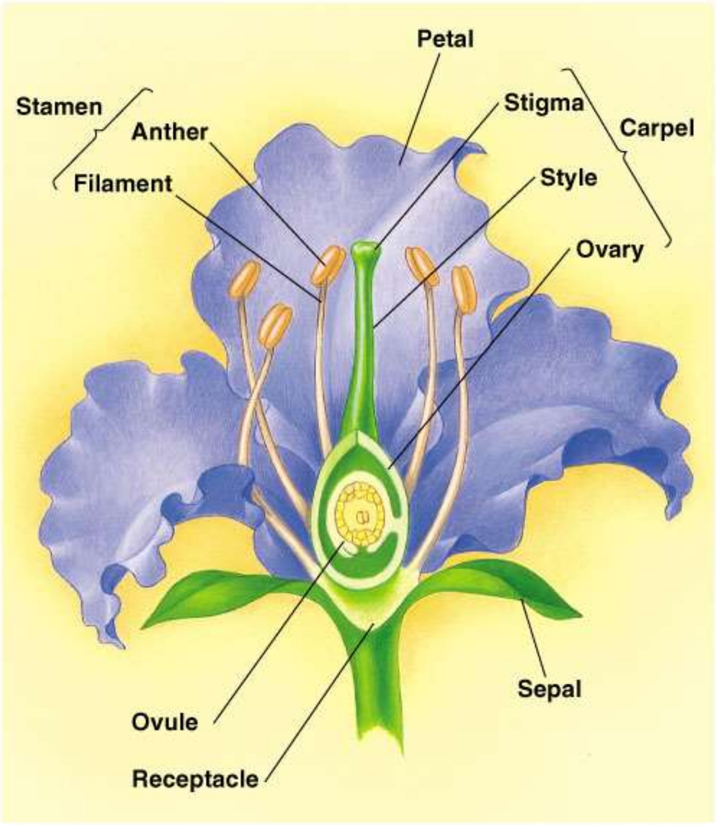
Angiosperms

- Most diverse and geographically widespread of all plants
- "Flowering plants"(Phy: *Anthophyta*)
- Monocots: 1 embryonic seed leaf (lilies, palms, grasses, grain crops)
- Dicots: 2 embryonic seed leaves (roses, peas, sunflowers, oaks, maples)
- Vascular tissue refinement: vessel elements/fiber cells

(a) Flowering Plants (b) *Amborella* (c) Water lily (d) Star anise (e) Orchid (monocot) (f) California poppy (eudicot)

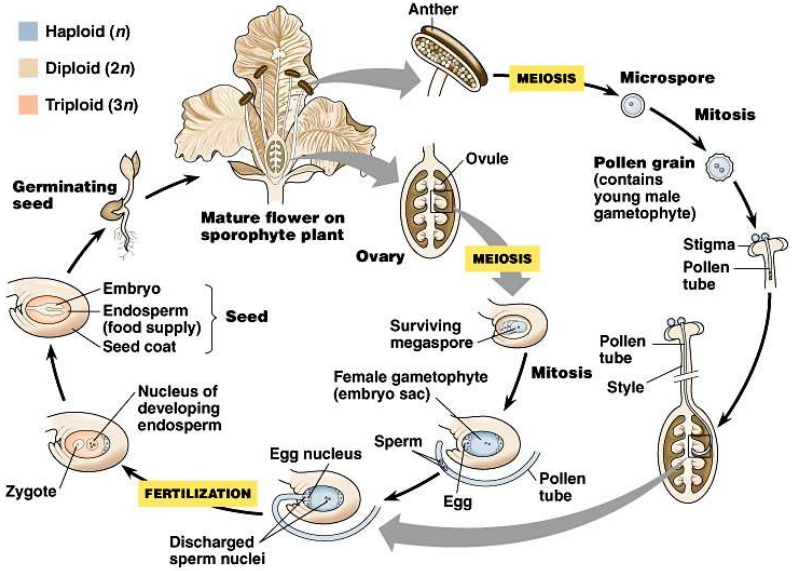
The flower: the defining structure of angiosperms

- Reproductive structure: pollen transfer; specialized shoot with modified leaves
- Sepals: enclose flower before it opens
- Petals: attract pollinators
- Stamens: male; anther (produces pollen), filament
- Carpels: female; stigma, style, ovary, ovules



Angiosperm life cycle

- Fruit (mature ovary); seeds from ovules
- Pollen grains: 2 haploid cells (immature male gametophytes)
- Ovules (female gametophyte~ embryo sac)
- <u>Double fertilization</u>: 1 sperm w/ egg = diploid zygote; other sperm w/ 2 nuclei in center of sac = triploid endosperm



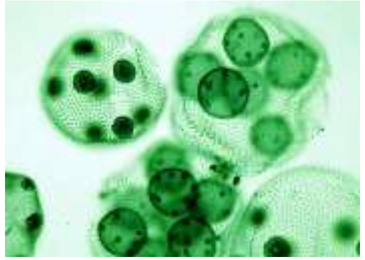
QOD

- Match each picture to an evolutionary stage of plants

1. Charophyceans
2. Bryophytes
3. Seedless vascular plants
4. Gymnosperms
5. Angiosperms

A


B


C


D


E

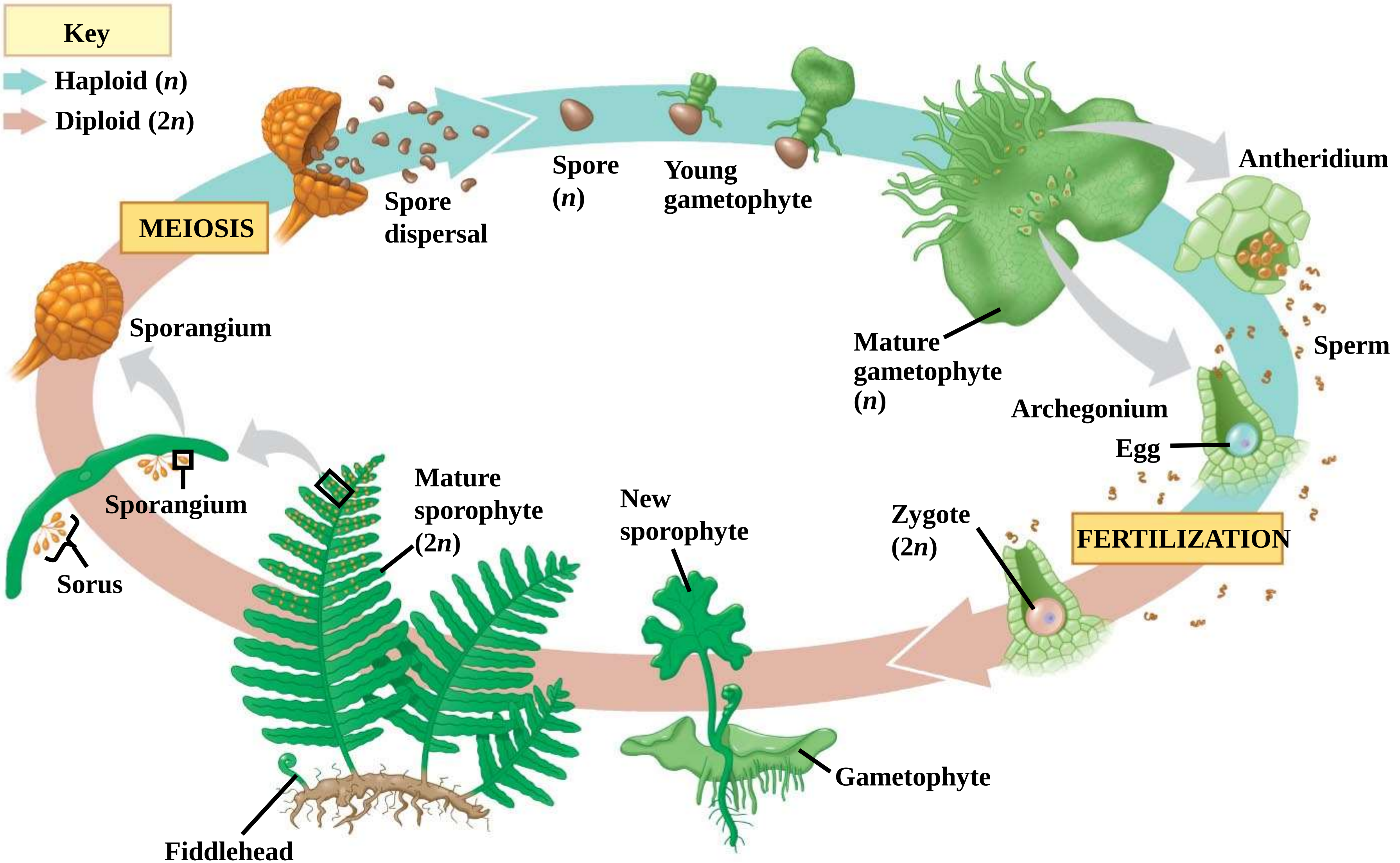

Ferns and other seedless vascular plants were the first plants to grow tall

- Bryophytes and bryophyte-like plants were the prevalent vegetation during the first 100 million years of plant evolution
- Vascular plants began to diversify during the Devonian and Carboniferous periods
- Vascular tissue allowed these plants to grow tall
- Seedless vascular plants have flagellated sperm and are usually restricted to moist environments

Classification of Seedless Vascular Plants

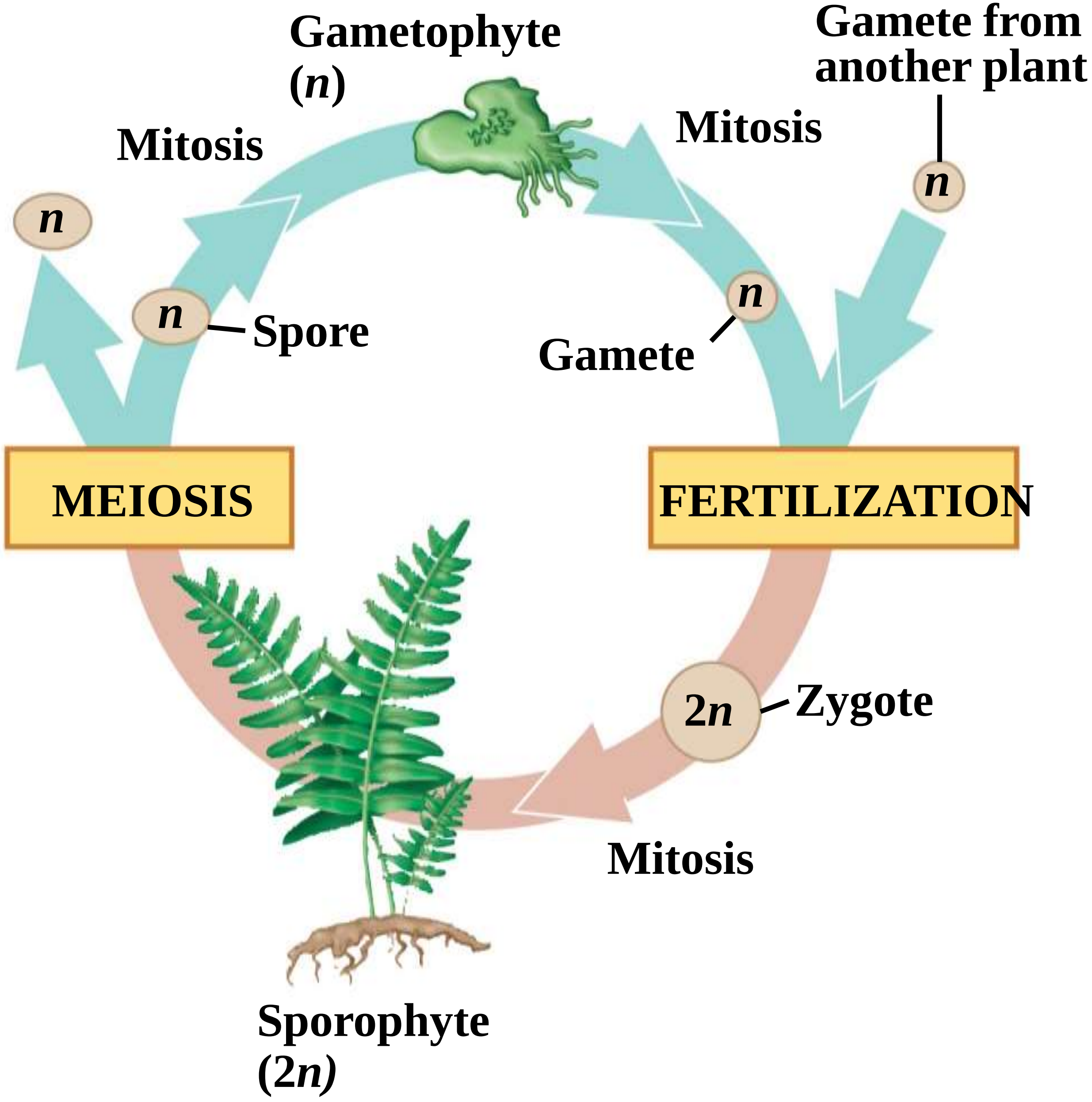
- There are two phyla of seedless vascular plants:
  - Phylum Lycophyta includes club mosses, spike mosses, and quillworts
  - Phylum Pterophyta includes ferns, horsetails, and whisk ferns and their relatives

Fig. 29-13-3



Key
Haploid (n)
Diploid (2n)
MEIOSIS
Spore dispersal
Spore (n)
Young gametophyte
Antheridium
Mature gametophyte (n)
Sperm
Archegonium
Egg
FERTILIZATION
Zygote (2n)
New sporophyte
Gametophyte
Mature sporophyte (2n)
Sporangium
Sporangium
Sorus
Fiddlehead

Fig. 29-5a



Alternation of generations

Transport in Xylem and Phloem

- Vascular plants have two types of vascular tissue: xylem and phloem
- **Xylem** conducts most of the water and minerals and includes dead cells called **tracheids**
- **Phloem** consists of living cells and distributes sugars, amino acids, and other organic products
- Water-conducting cells are strengthened by **lignin** and provide structural support
- Increased height was an evolutionary advantage

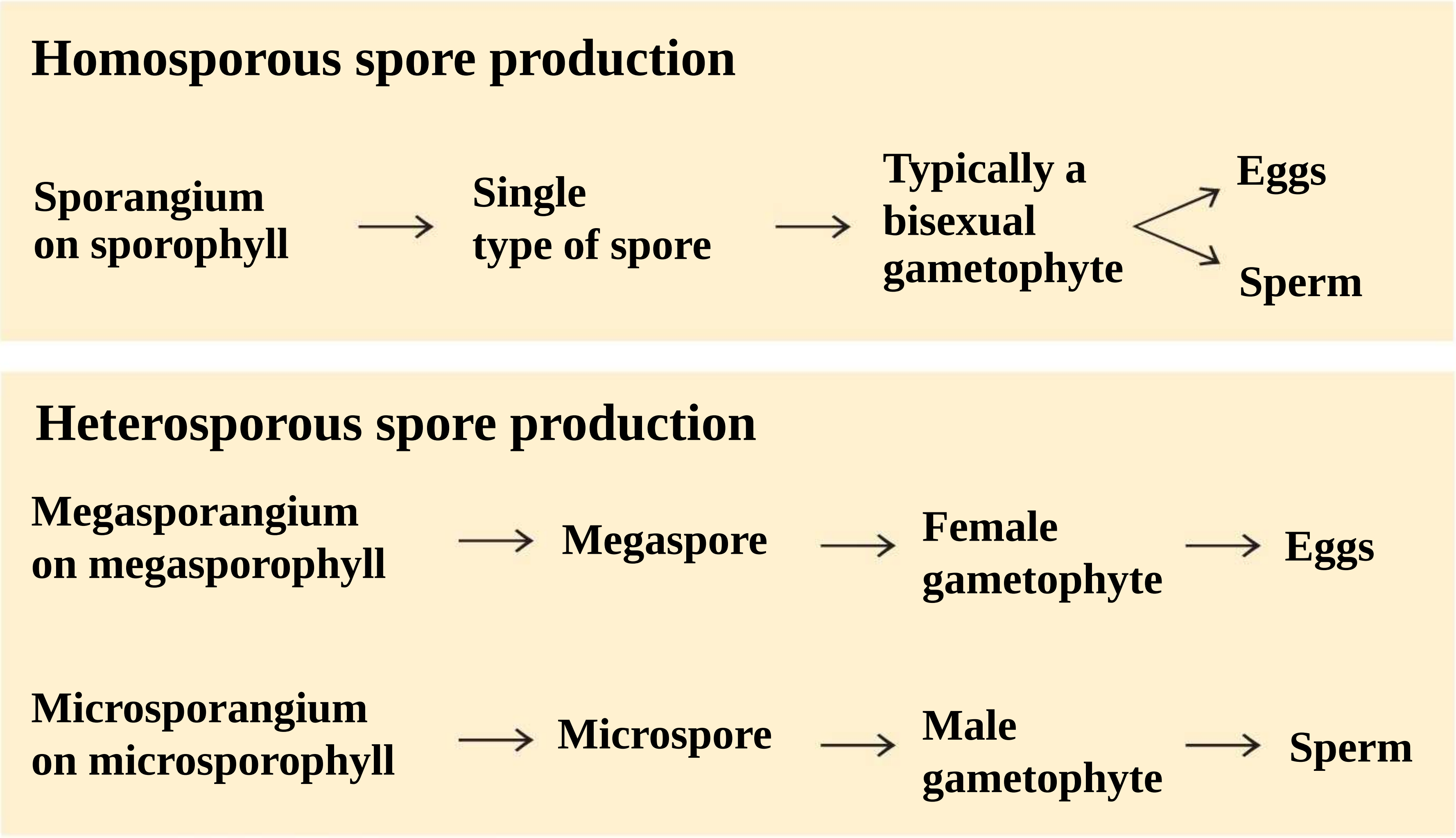
Evolution of Roots

- **Roots** are organs that anchor vascular plants
- They enable vascular plants to absorb water and nutrients from the soil
- Roots may have evolved from subterranean stems

Evolution of Leaves

- **Leaves** are organs that increase the surface area of vascular plants, thereby capturing more solar energy that is used for photosynthesis

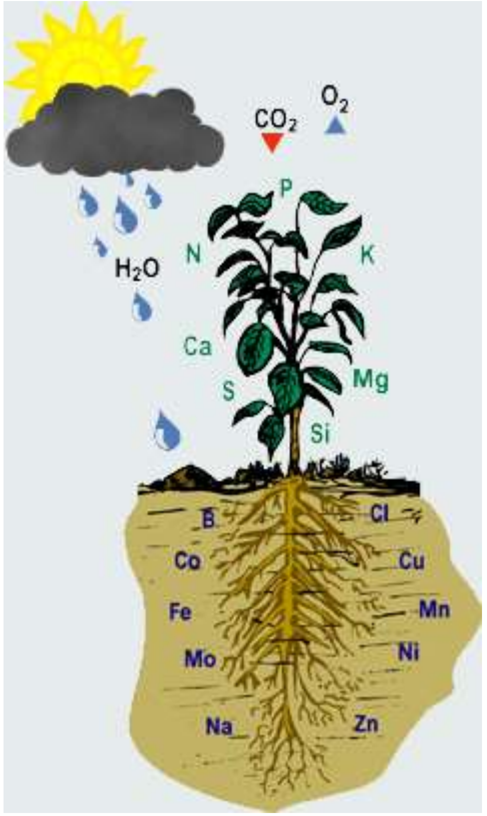
Fig. 29-UN3


Homosporous spore production
Sporangium on sporophyll
Single type of spore
Typically a bisexual gametophyte
Eggs
Sperm
Heterosporous spore production
Megasporangium on megasporophyll
Megaspore
Female gametophyte
Eggs
Microsporangium on microsporophyll
Microspore
Male gametophyte
Sperm

Concept 30.2: Gymnosperms bear “naked” seeds, typically on cones

- The gymnosperms have “naked” seeds not enclosed by ovaries and consist of four phyla:
  - Cycadophyta (cycads)
  - Gingkophyta (one living species: *Ginkgo biloba*)
  - Gnetophyta (three genera: *Gnetum, Ephedra, Welwitschia*)
  - Coniferophyta (conifers, such as pine, fir, and redwood)

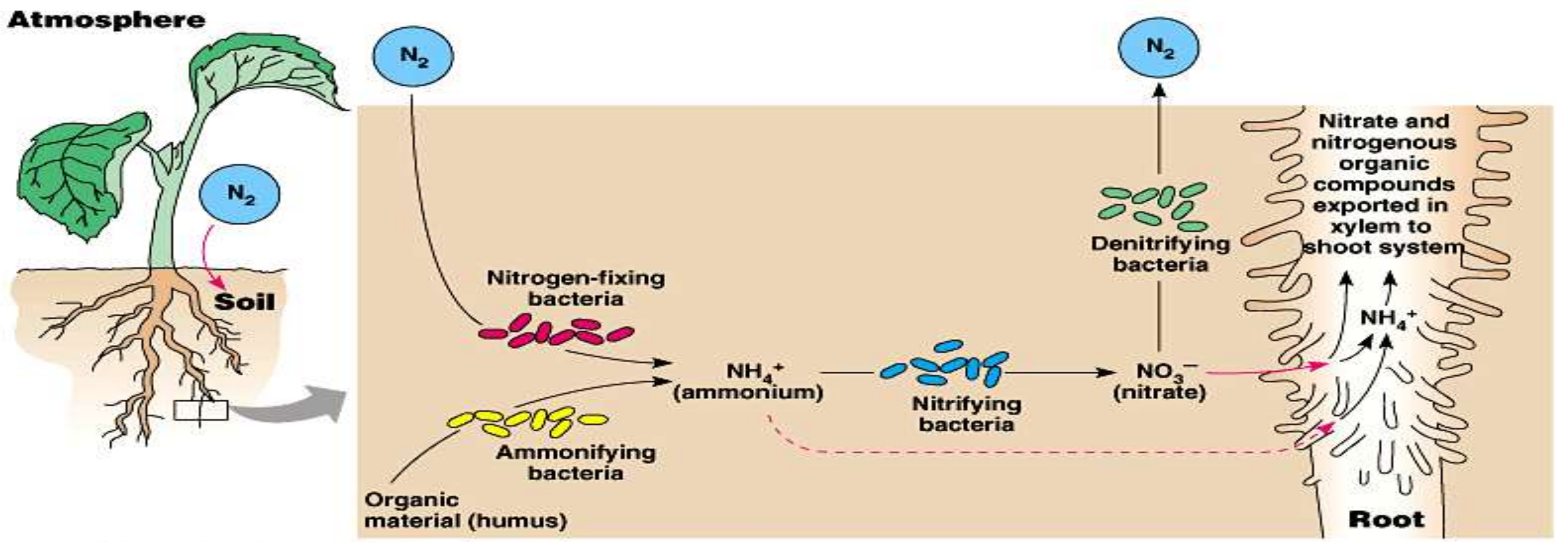
QOD



- What is the origin of most of a plants mass?

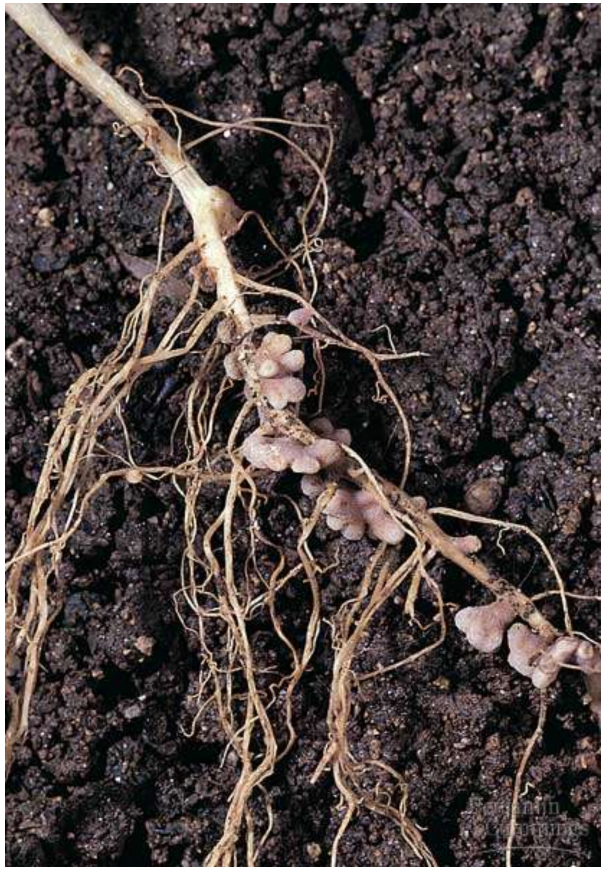
Nitrogen Fixation

- Atmosphere, 80% N_2
- Conversion to: ammonium (NH_4^+) or nitrate (NO_3^-)
- <u>Bacteria types</u>: Ammonifying (humus decomposition); nitrogen-fixing (atmospheric N_2); nitrifying (convert NH_4^+ to NO_3^-); denitrifying (convert NO_3^- to N_2)
- Nitrogen fixation; crop rotation



Plant symbiosis, I

- *Rhizobium* bacteria (found in root nodules in the legume family)
- Mutualistic: legume receives fixed N_2; bacteria receives carbohydrates & organic materials



Plant symbiosis, II

- *Mycorrhizae* (fungi); modified roots
- Mutualistic: fungus receives sugar; plant receives increased root surface area and increased phosphate uptake
- Two types:
  <u>ectomycorrhizae</u> • ensheaths the root
  <u>endomycorrhizae</u> (90% of plants) •through cell wall but not cell membrane