LSM1301
GENERAL BIOLOGY

Plant form and function

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Learning objectives

- To describe the distinguishing **features of four major plant groups**, the **alternation of generations** and **adaptations** for terrestrial life
- To describe the **different types of tissues**, external and internal structures and functions of organs in angiosperms
- To describe the process of **photosynthesis**, primary and secondary growth
- To describe the **process of reproduction** in angiosperms, including the structures and functions of flowers and fruits

Learning activities

- Pre-lecture
  - Watch videos on vascular plants (11min) and diversity (5min)
  - Take down notes and refer to lecture slides.

- Post-lecture
  - Take ungraded quiz to revise lecture material

    (LumiNUS > Quiz > “Plant form and function”

Outline

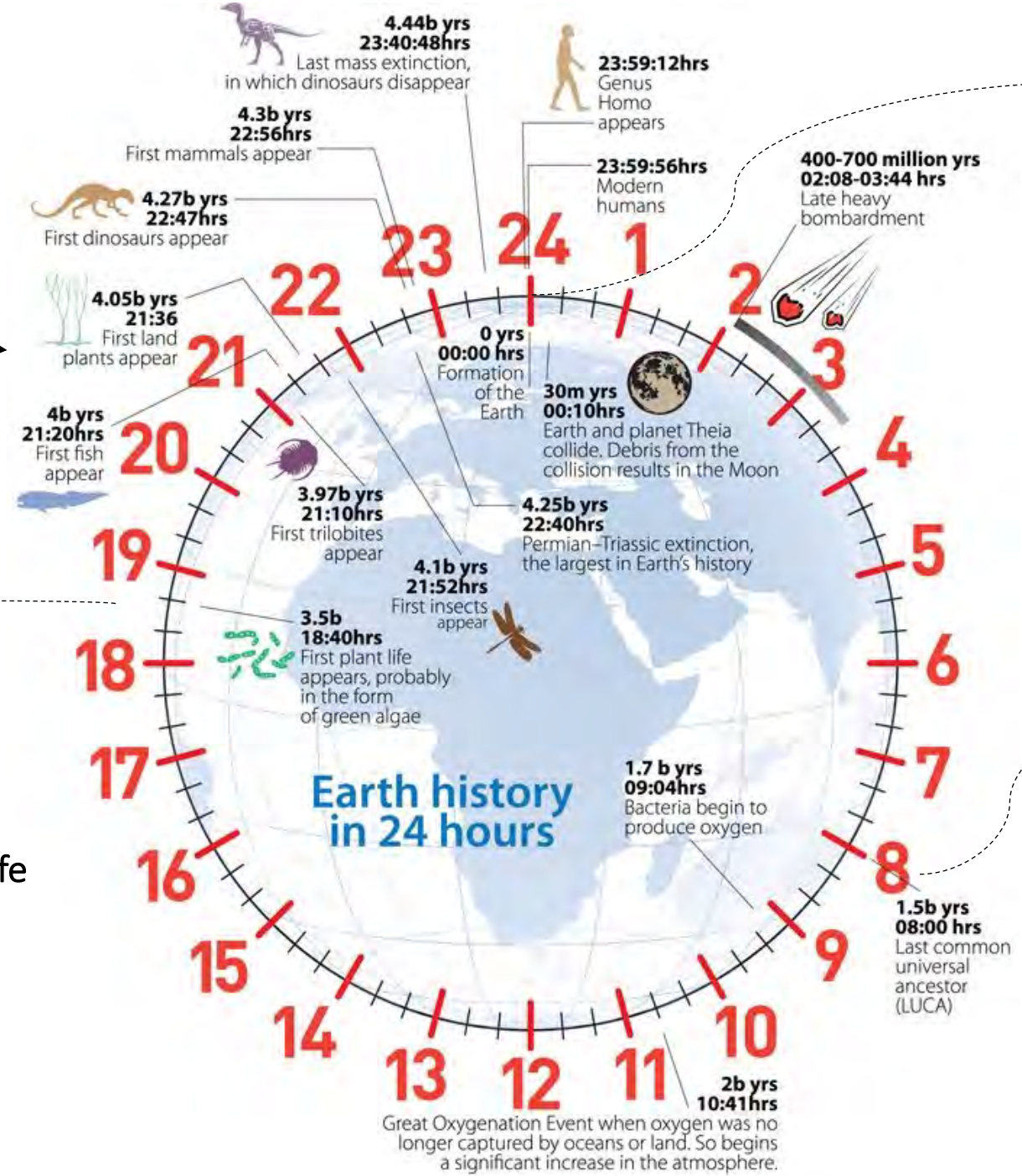
- Introduction to major plant groups and plant evolution
- Flowering plant anatomy
  - Tissues
  - Organs (leaves, stems, roots)
  - Modified organs
- Flowering plant functions
  - Photosynthesis
  - Growth (primary and secondary)
  - Reproduction (flowers and fruits)

Terrestrial plant forms

First photosynthetic life
i.e. green algae

Formation of the earth

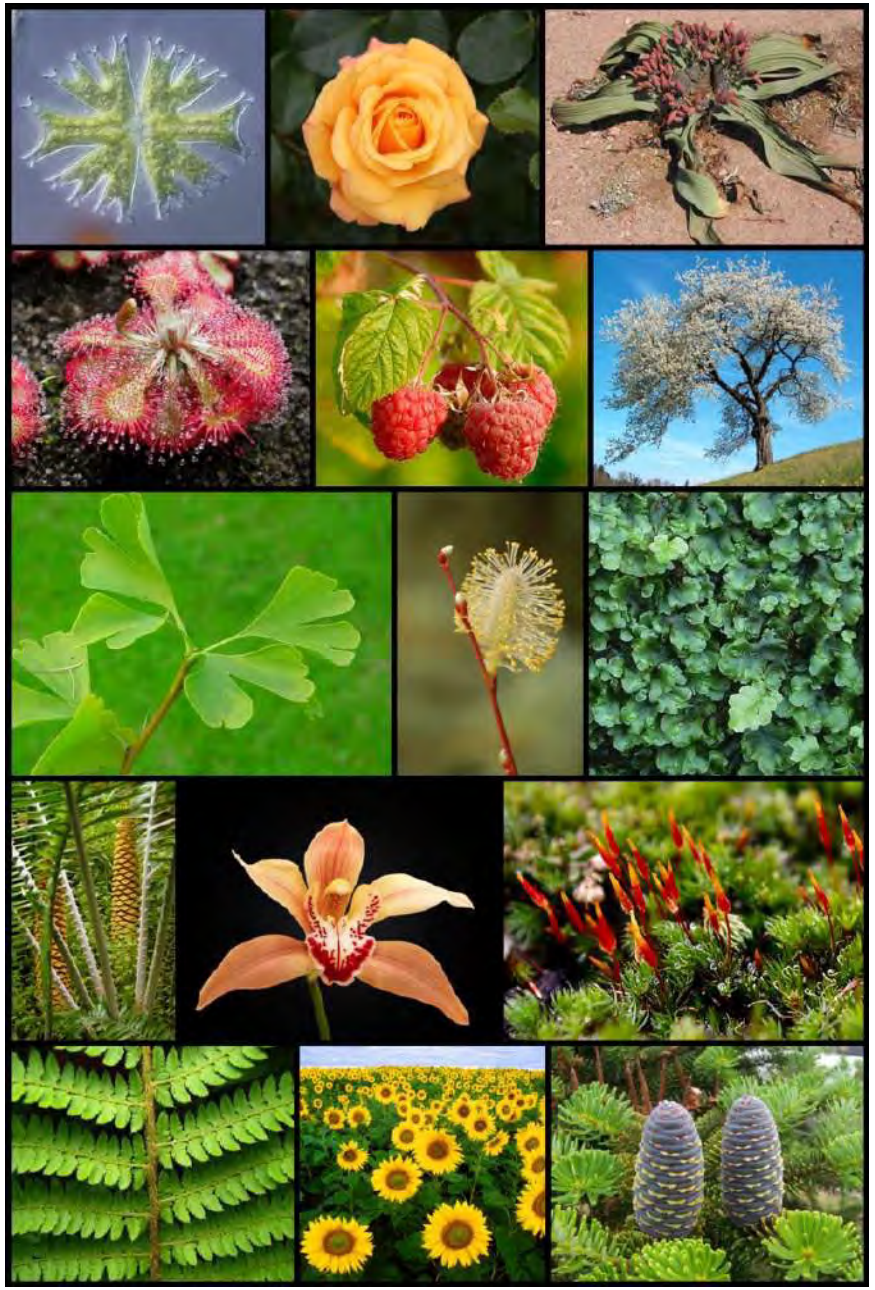
Last common universal ancestor



Introduction to plants

Key features of plants

- Eukaryotic, multicellular
- Cell walls have cellulose
- Photosynthetic autotrophs
- Alternating haploid and diploid generations



Plant evolution

Common ancestor of land plants is thought to be similar to extant freshwater green algae

Plant evolution shows how they have adapted to terrestrial existence

Life on dry land:

- Advantages: higher levels of light; CO_2 for photosynthesis; soil rich in minerals
- Disadvantages: threat of drying out; challenges to reproduction

Charophytes are green algae most closely related to plants

Given the right conditions, some plants can survive a long time

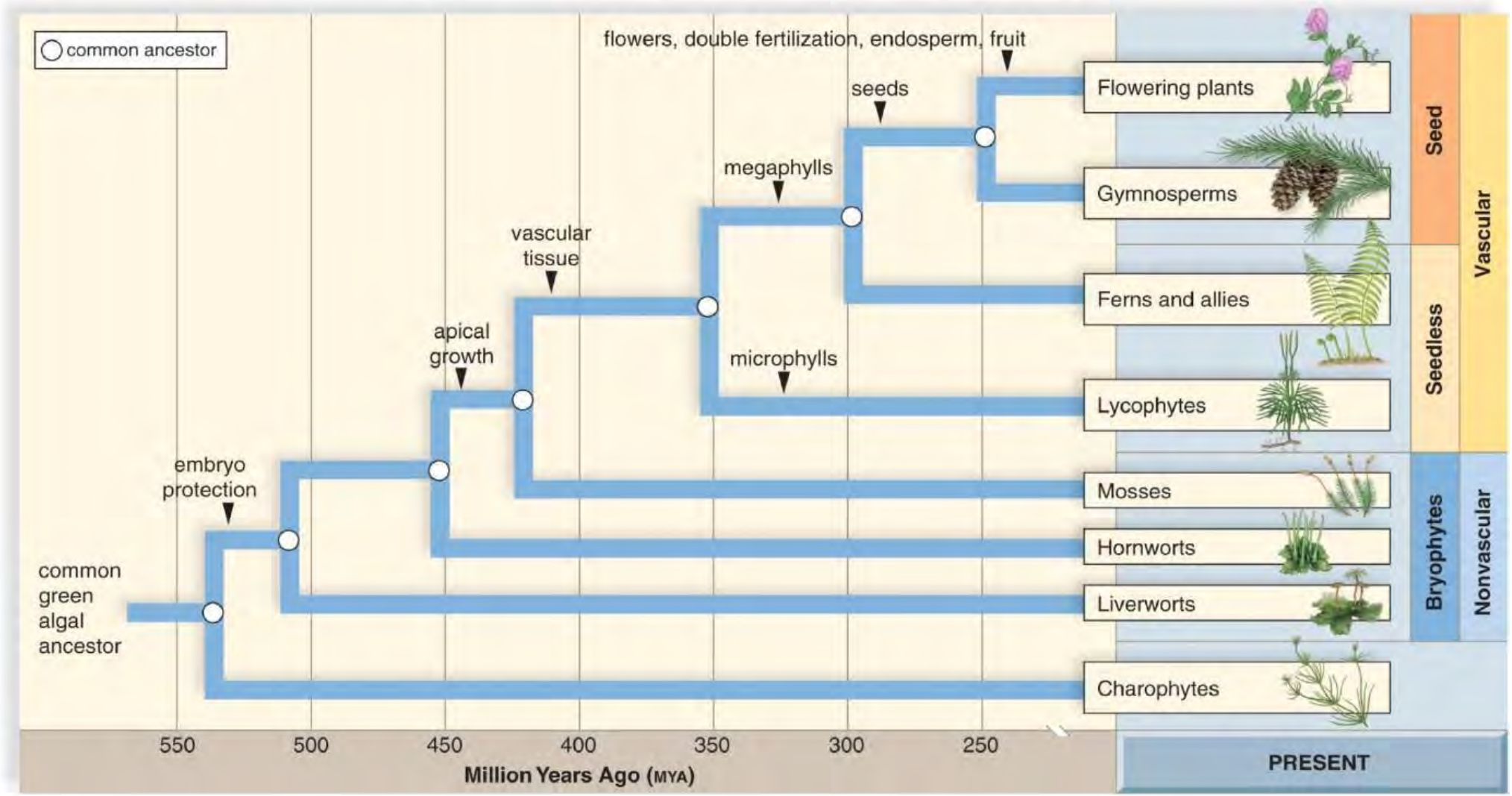
Bristlecone pine trees that are highly resilient to harsh weather and bad soils are among the longest-lived life forms
~ 5000 years old

Trembling giant, clonal colony of quaking aspen. Identical genetic markers indicate it is a single living organism with one massive underground root system **~ 80,000 years old**

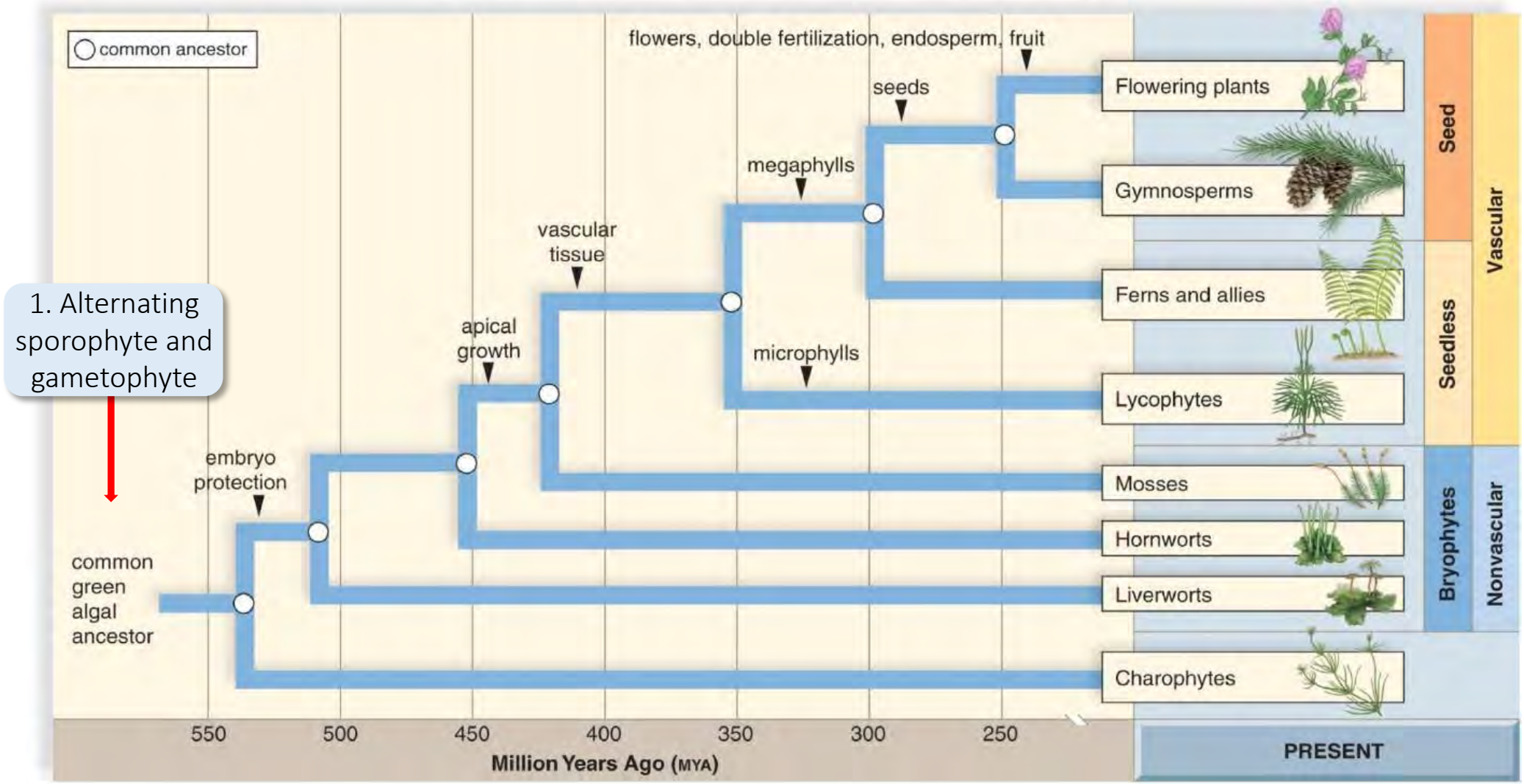
Major plant groups

Bryophytes • Mosses • Liverworts • Hornworts		➢ *Non-vascular* tissue ➢ Small sized, need moist environment ➢ Reproduce by spores
Seedless Vascular Plants • Ferns • Fern allies		➢ Have *vascular* tissue ➢ True leaves, stems and roots ➢ Reproduce by spores
Gymnosperms • Conifers • Gingkos	 	➢ Complex *vascular* system ➢ Cones are reproductive structure ➢ Have a ‘naked’ seed
Angiosperms • Monocots • Eudicots	 	➢ Complex *vascular* system ➢ Flowers are reproductive structure ➢ Seeds are enclosed in fruits

Key events in plant evolution



Key events in plant evolution

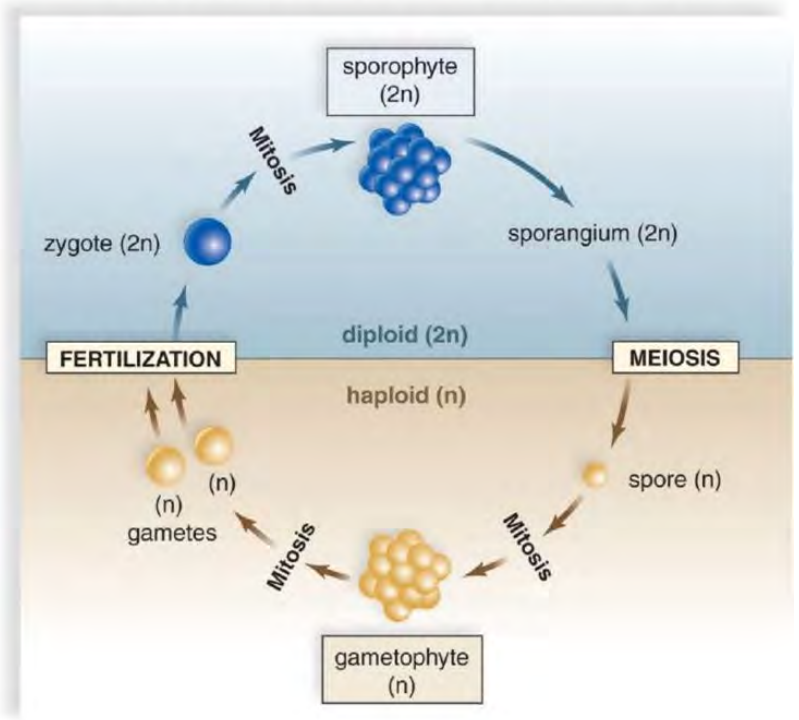


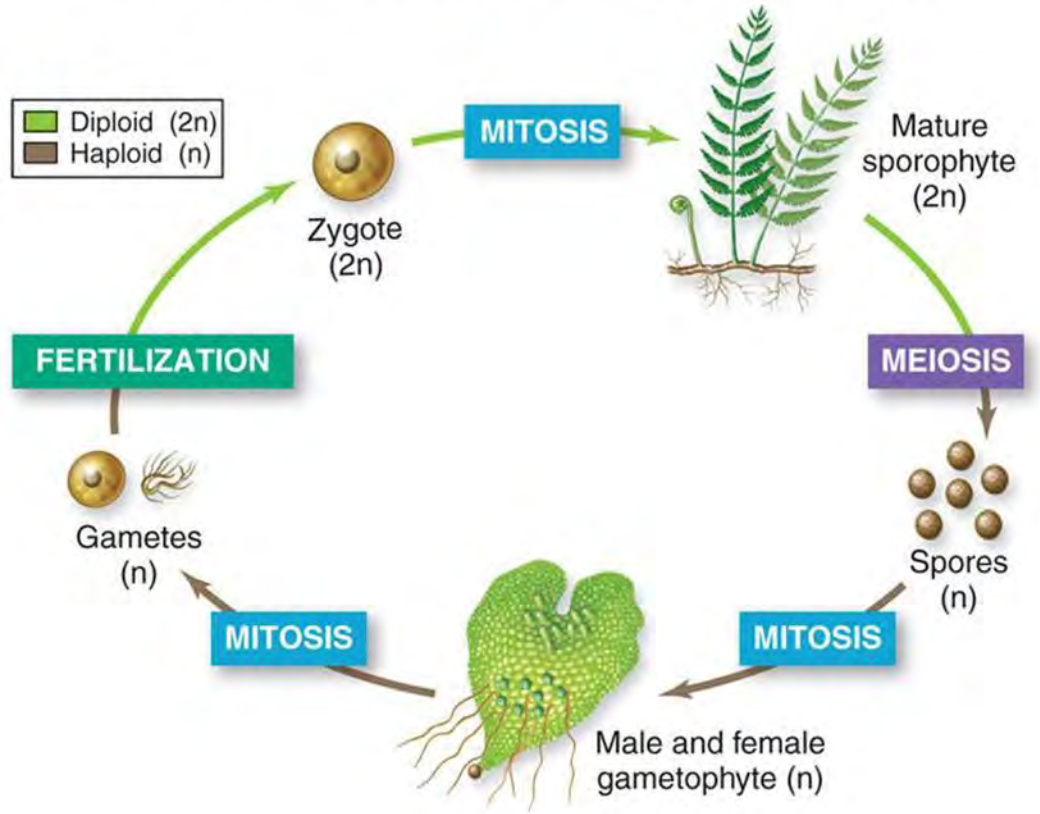
1. Alternating sporophyte and gametophyte

Plant evolution

Sporophyte: Diploid; 2 copies of chromosomes (2n)
Gametophyte: Haploid; single set of chromosomes (n)

The plant life cycle is an **alternation of generations** with *multicellular* diploid (**sporophyte**) and haploid (**gametophyte**) stages





Bryophytes (Non-vascular plants)

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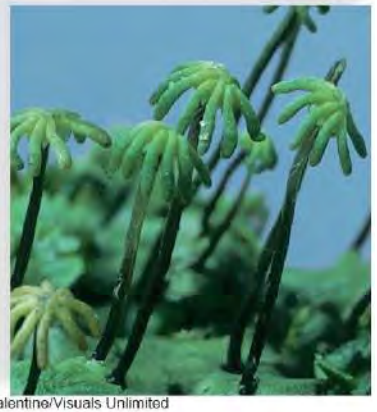

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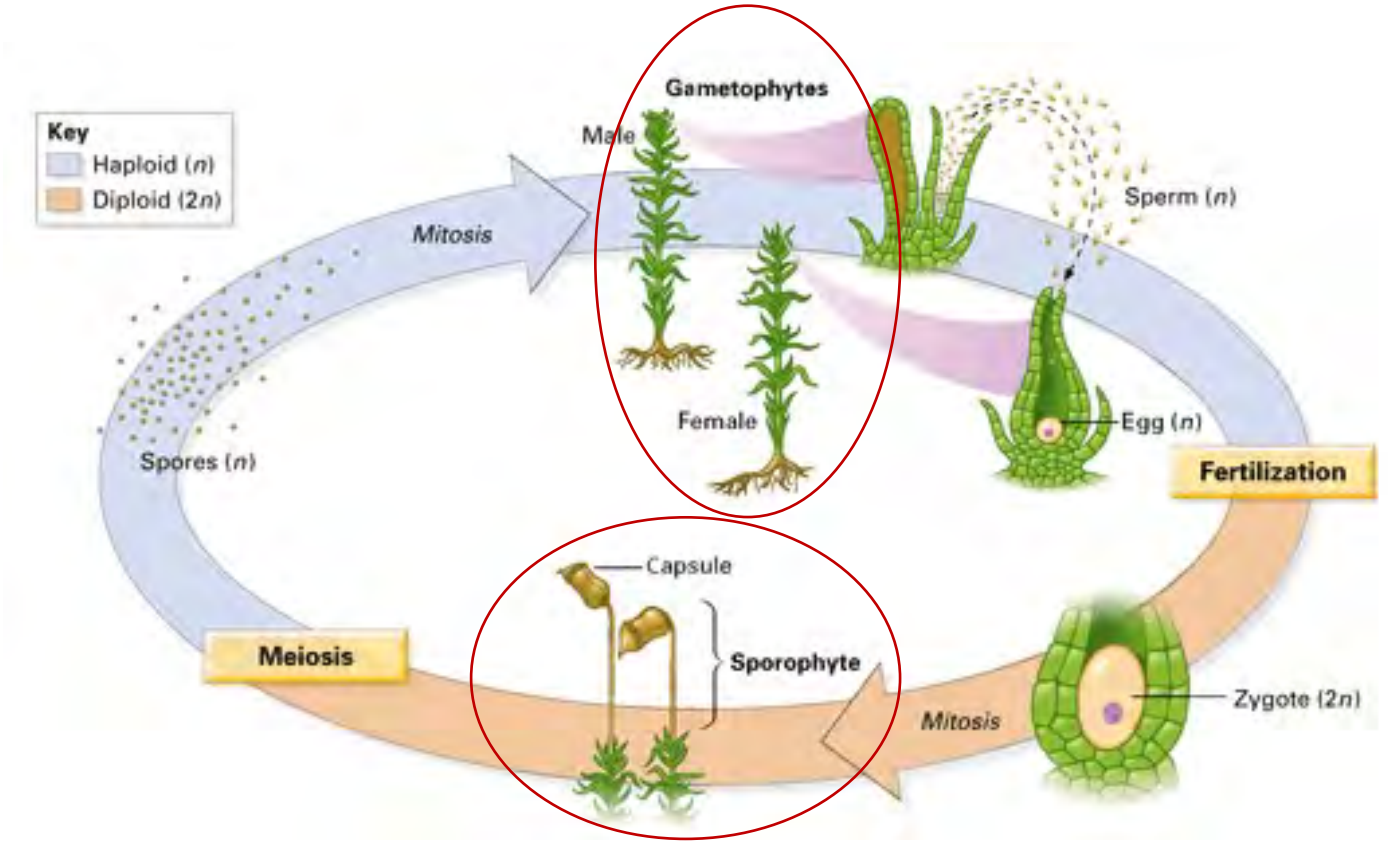
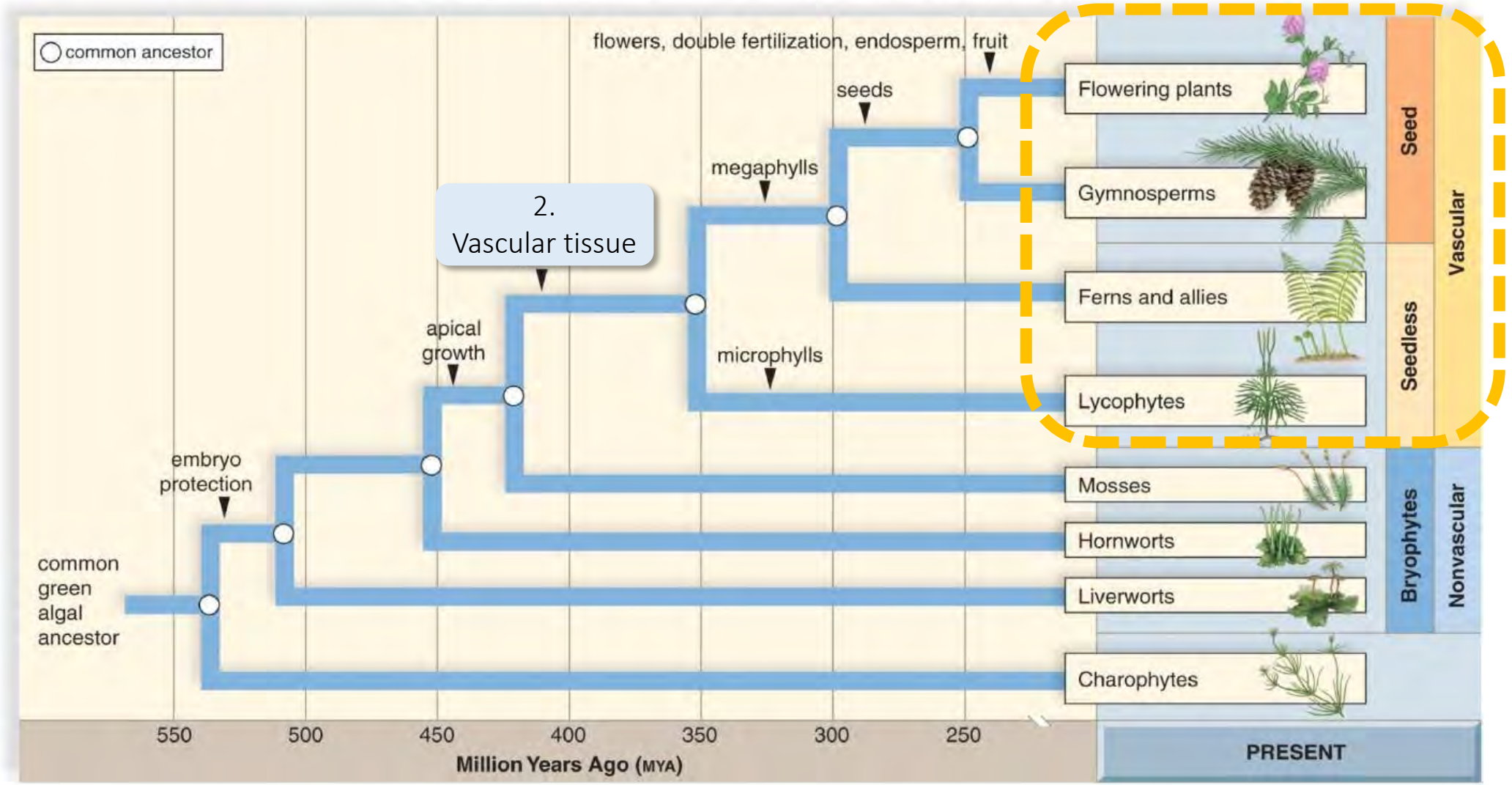


Key events in plant evolution



Seedless Vascular Plants

a. b. c. d.

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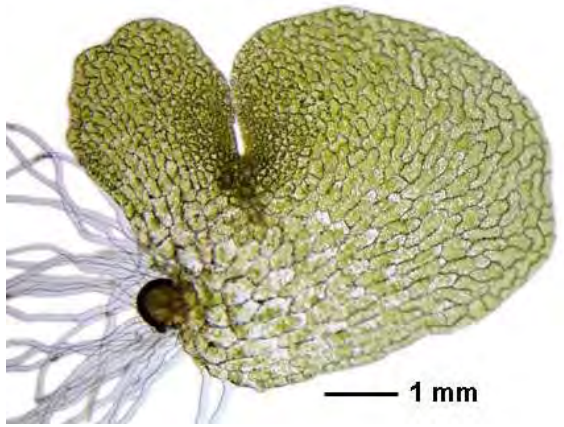
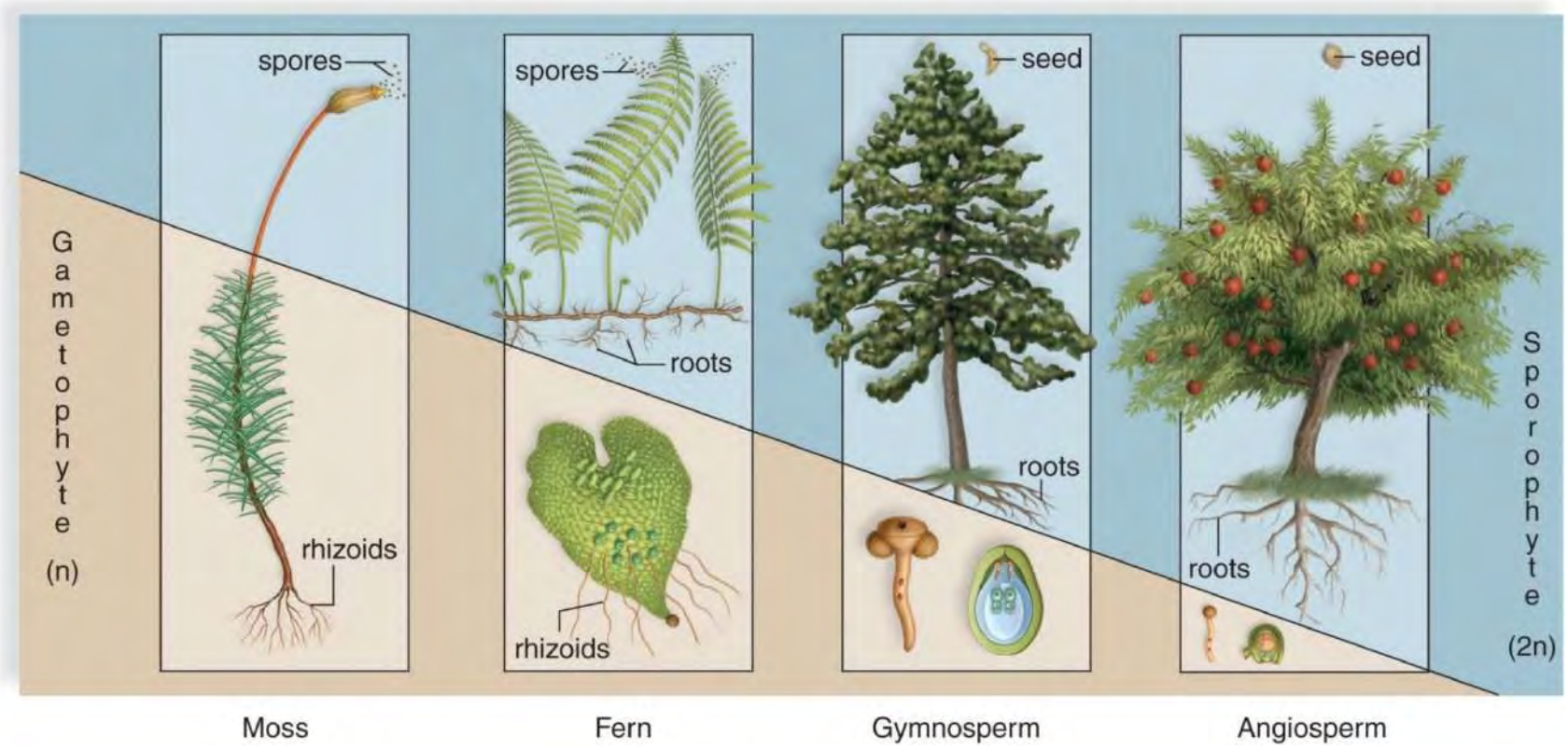


Plant evolution

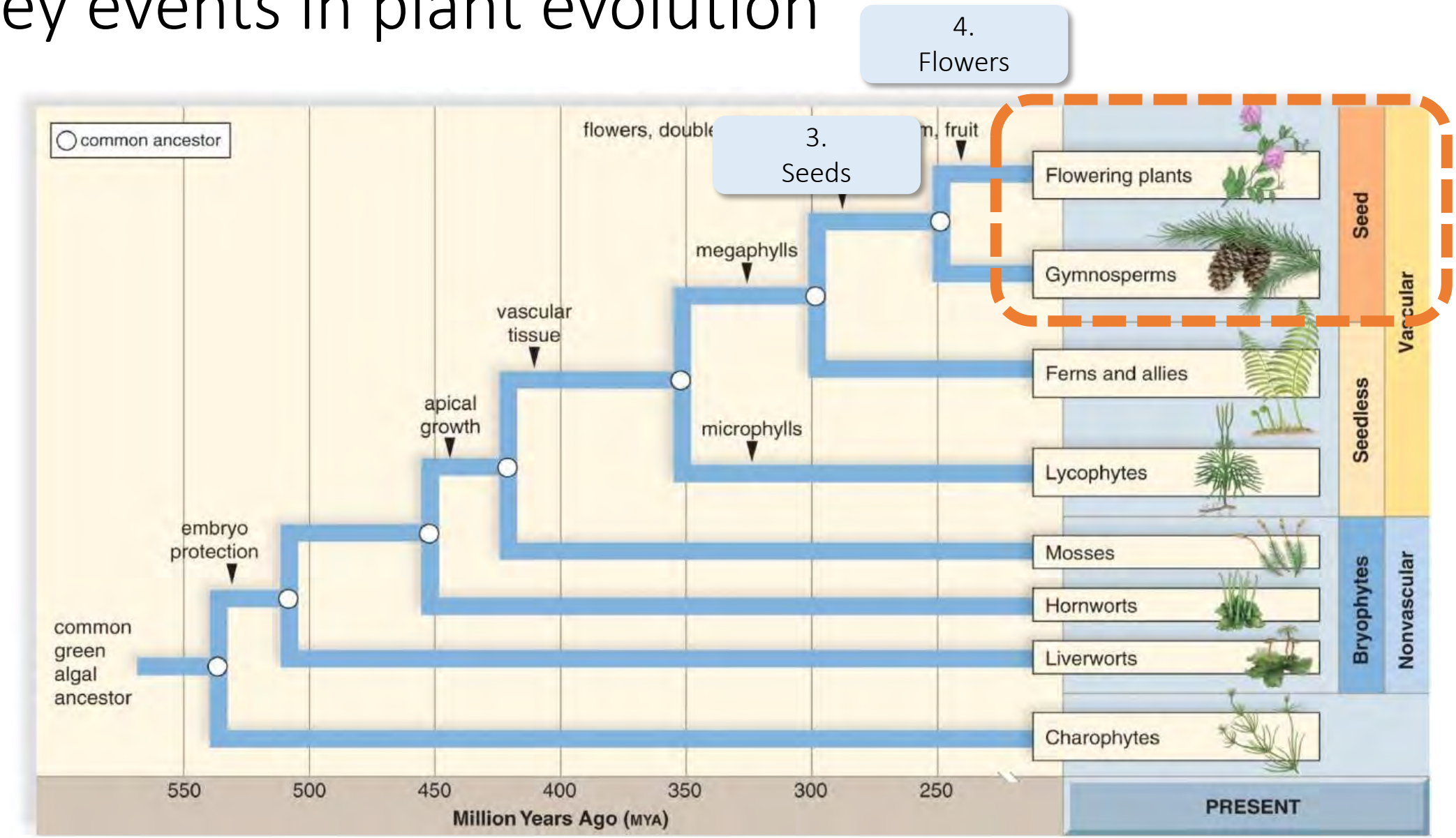
More about meiosis & mitosis (haploid, diploid etc.) later in course

Shift to **sporophyte dominance** in plant evolution

- Gametophyte becoming microscopic and dependent on sporophyte



Key events in plant evolution



Evolution of seeds

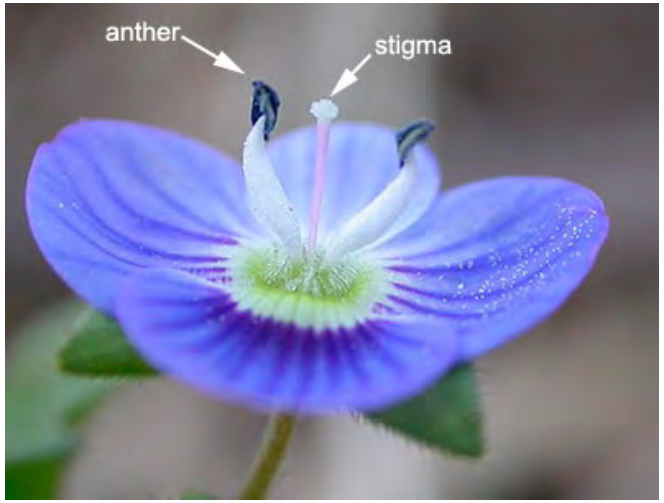
Embryos packaged with a supply of nutrients inside a protective coat

Origin ~ 360 mya

Gymnosperms

Largely wind pollination

Evolution of flowers



Largely animal pollination (insects/birds)

Angiosperms

b.

d.

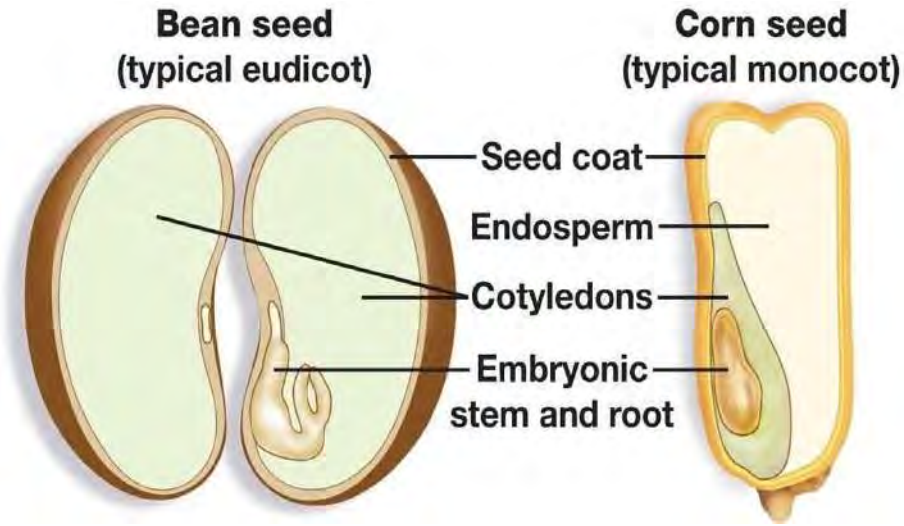
Two groups of flowering plants:

Eudicotyledons

- Two embryonic seed leaves
  - E.g. beans, roses, cabbage

Monocotyledons

- One embryonic seed leaf
  - E.g. orchids, grasses, palms



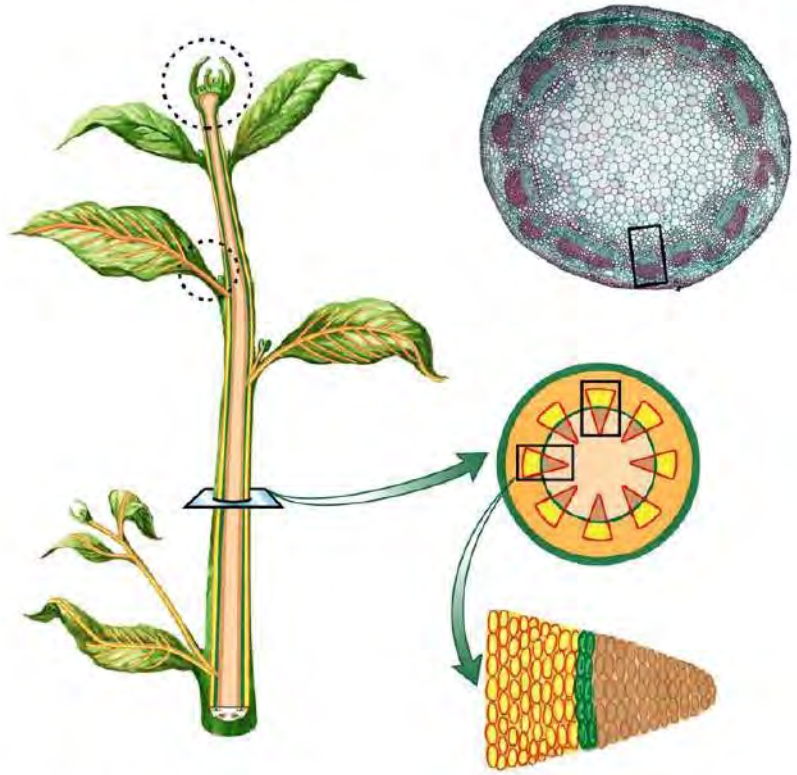
Flowering plant anatomy

Internal anatomy

- Cells specialized according to function
- Organized into tissues

External anatomy

- Plant organs
- Shoot and root system



Plant tissues

Ground tissue

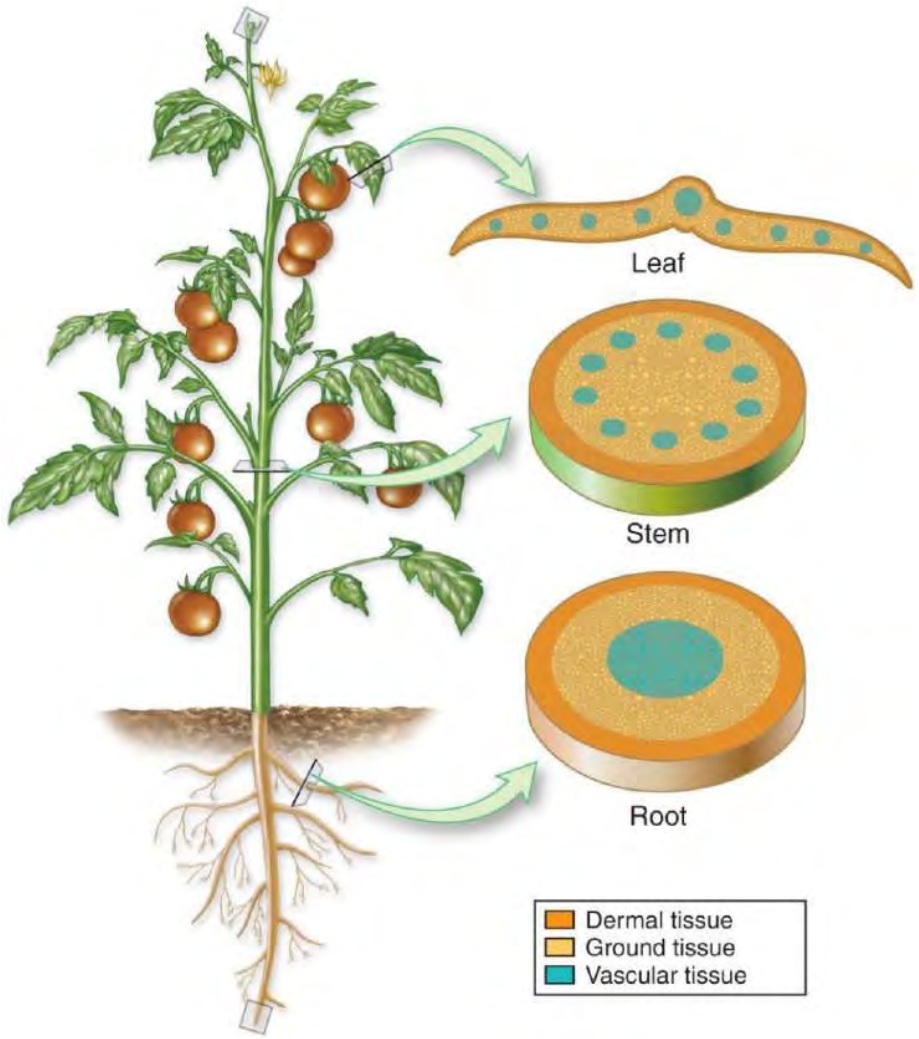
- Makes up most of the plant body
- Functions: respiration, photosynthesis, storage, support

Dermal tissue

- Outer covering of the plant (primary growth)
- Functions: protection and gas exchange

Vascular tissues

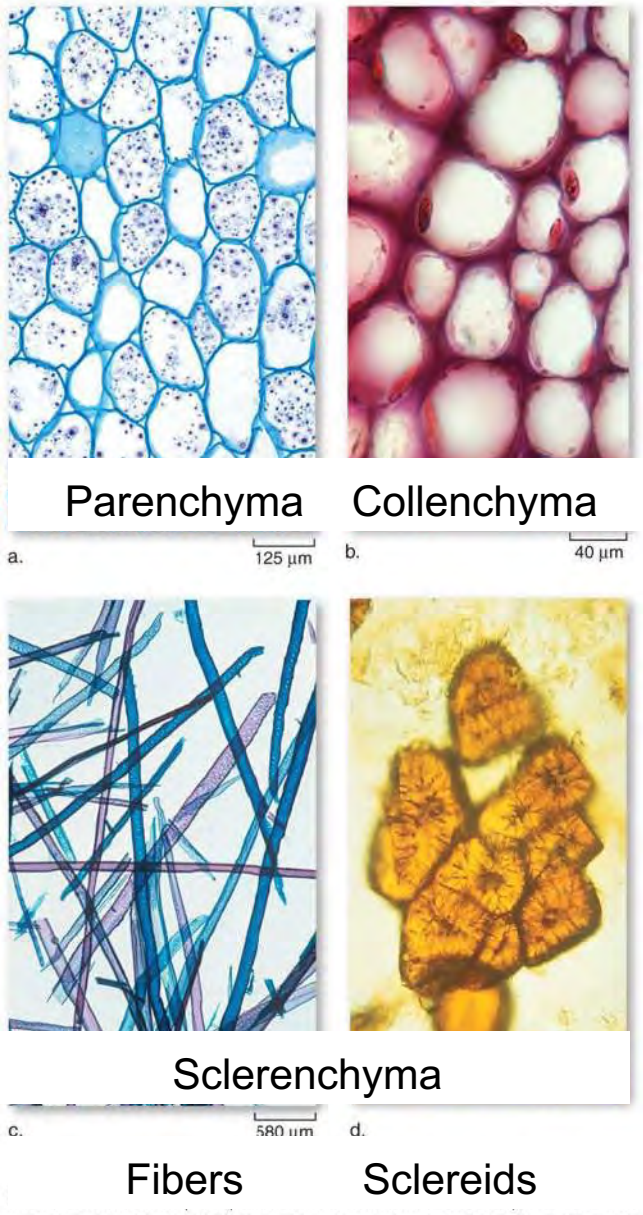
- Xylem and phloem
- Function: transport of materials



Plant tissues

Ground tissue

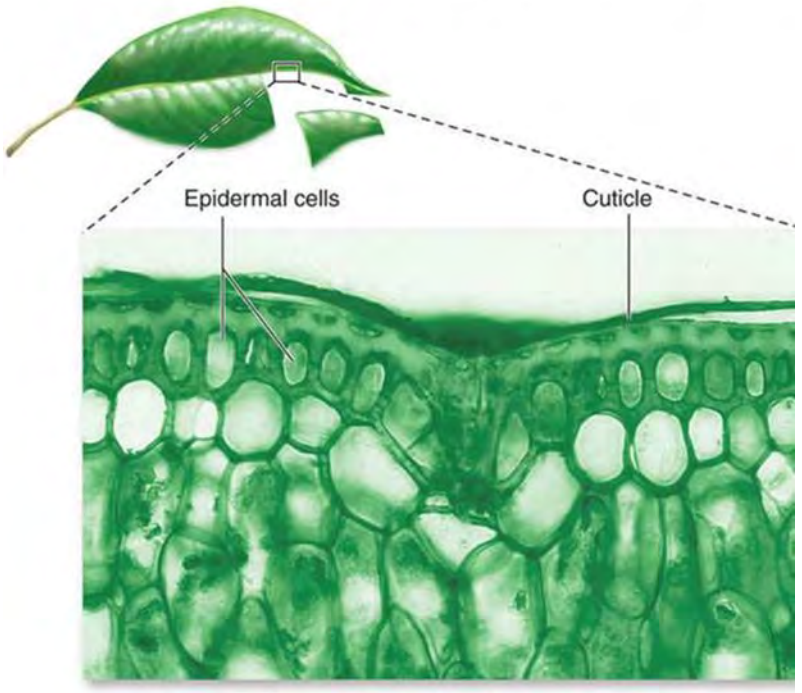
- Parenchyma
  - Most abundant type
  - Cell wall of equal thickness
- Collenchyma
  - Uneven cell walls
  - Can stretch as the plant grows
- Sclerenchyma
  - Dead at maturity
  - Cell walls usually contain lignin (strong polymer)
  - Provides rigid support



Plant tissues

Dermal tissue

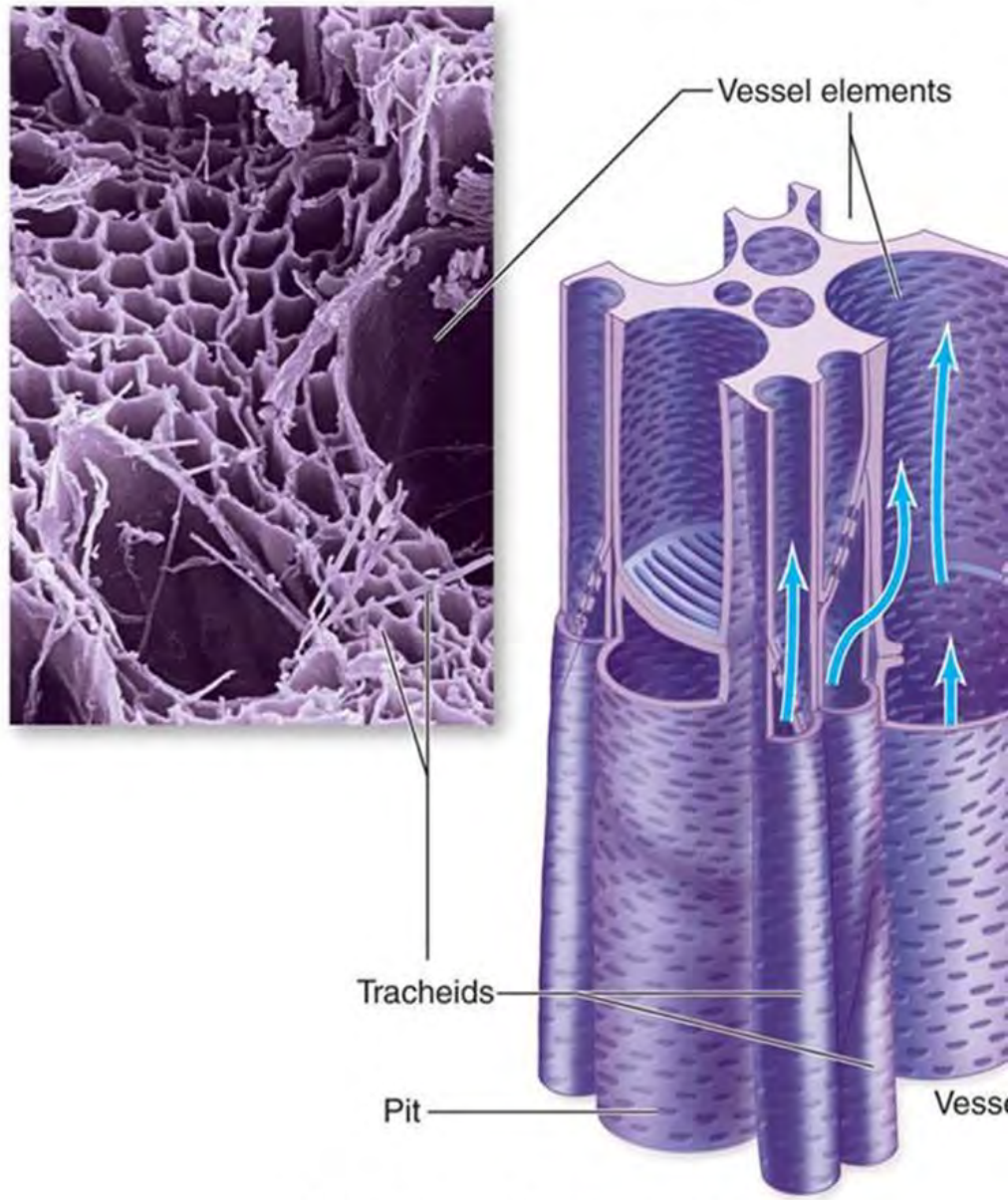
- Epidermal cells are flat, transparent, tightly packed
- Cuticle is a waxy waterproof coating which prevents water loss in herbaceous parts, impermeable to CO_2 and O_2
- Specialized cells
  - Guard cells and trichomes in leaves
  - Root hairs in roots



Plant tissues

Vascular tissue - i

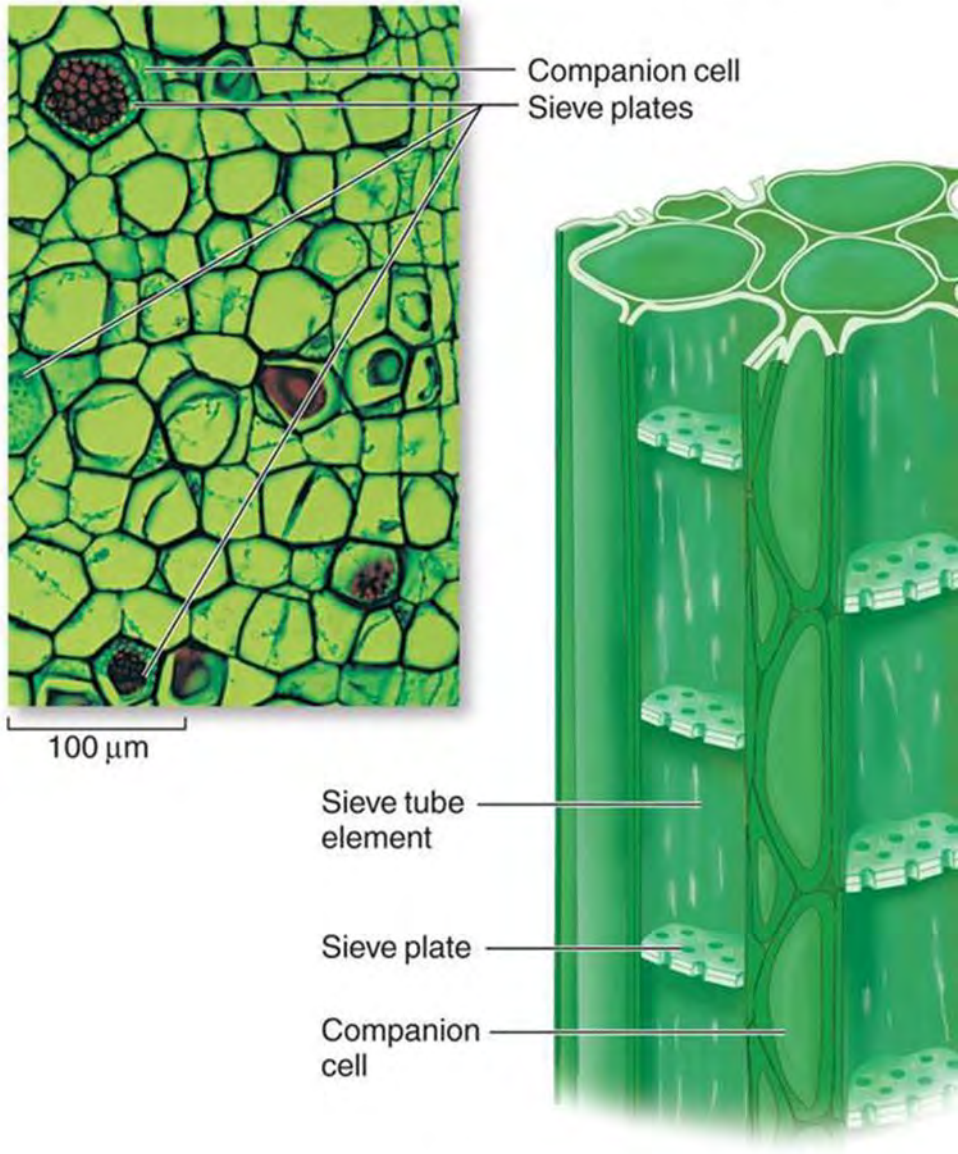
- Xylem
  - Conduct water and dissolved minerals
  - Sclerenchyma cells with perforations and pits to allow easy passage of materials
- Specialized conducting cells
  - Tracheids = thin and tapered
  - Vessel element = large diameter



Plant tissues

Vascular tissue - ii

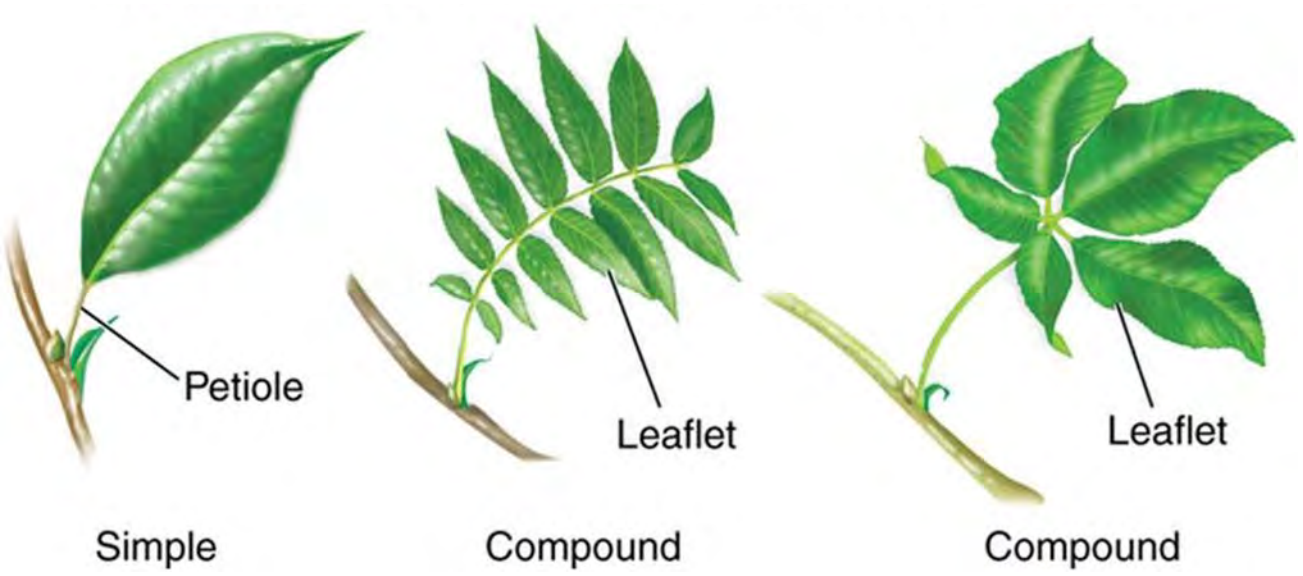
- Phloem
  - For transporting dissolved organic compounds (sugars and starch)
- Specialized conducting cells
  - Sieve tube element = stacked end to end, conduct materials through sieve plates
  - Companion cells = transfer materials into and out of the sieve tube elements



Plant organs

Leaf external morphology

- Function for **photosynthesis**
  - Blade = flattened portion
  - Petiole = stalk-like structure that attaches to stem



Single, undivided blade

Each blade consists of multiple leaflets

Plant organs

Leaf internal morphology

- Epidermis – dermal tissue covering the outside
- Mesophyll – parenchyma cells with abundant chloroplasts
- Vascular tissue – xylem and phloem seen as ‘veins’

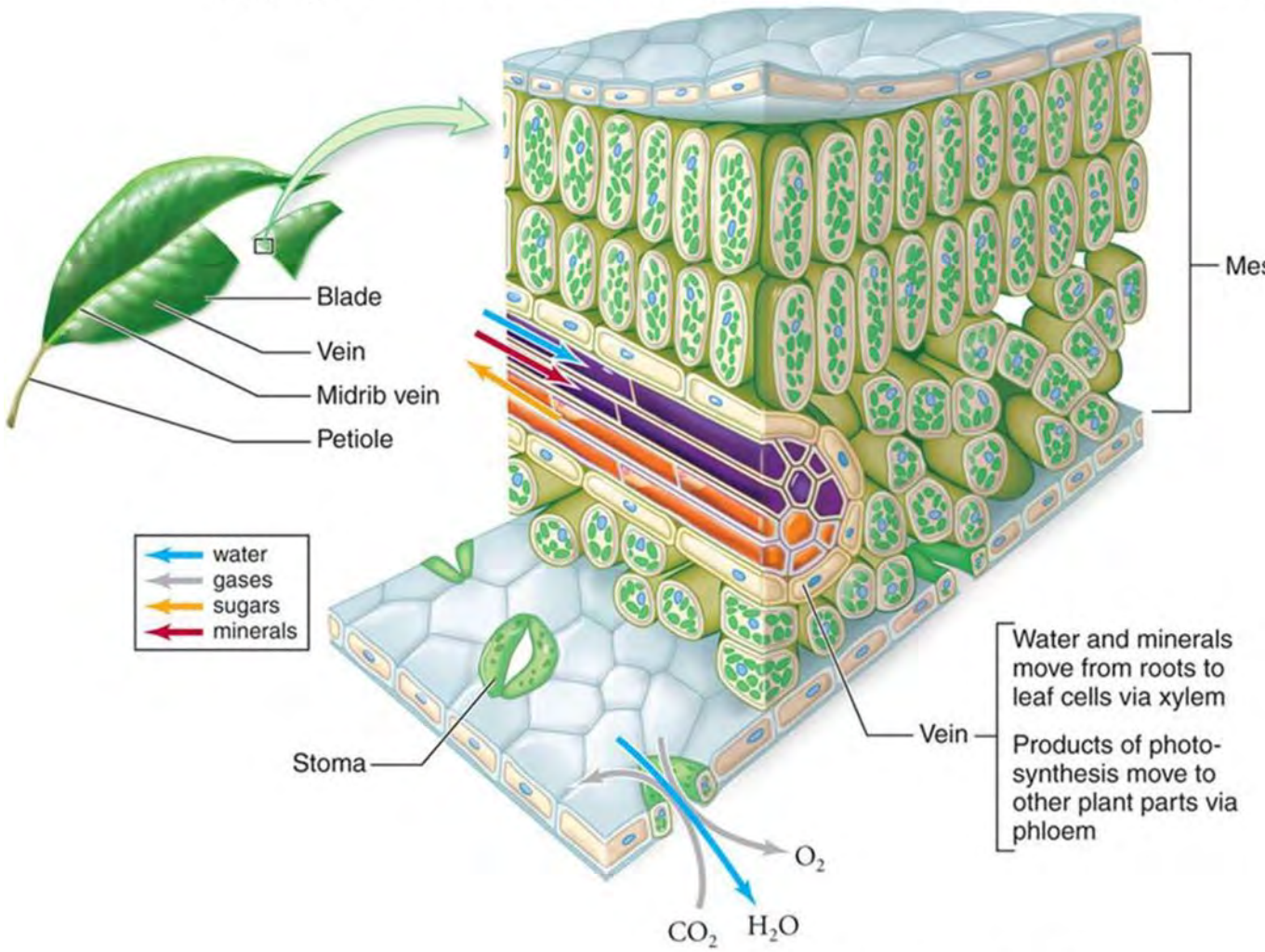
a.

Eudicot

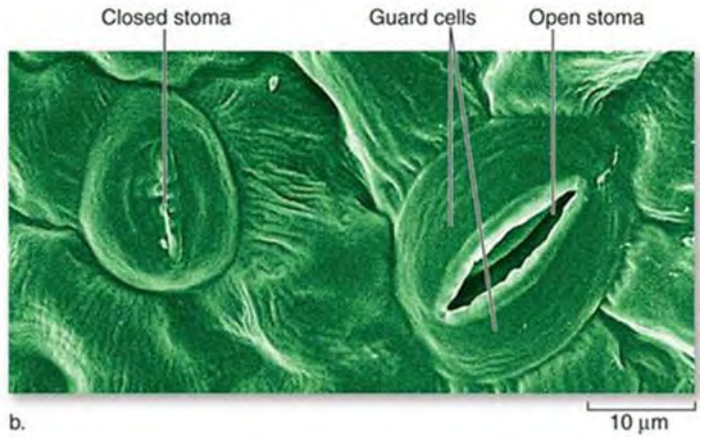
b.

Monocot

Cross section of a eudicot leaf



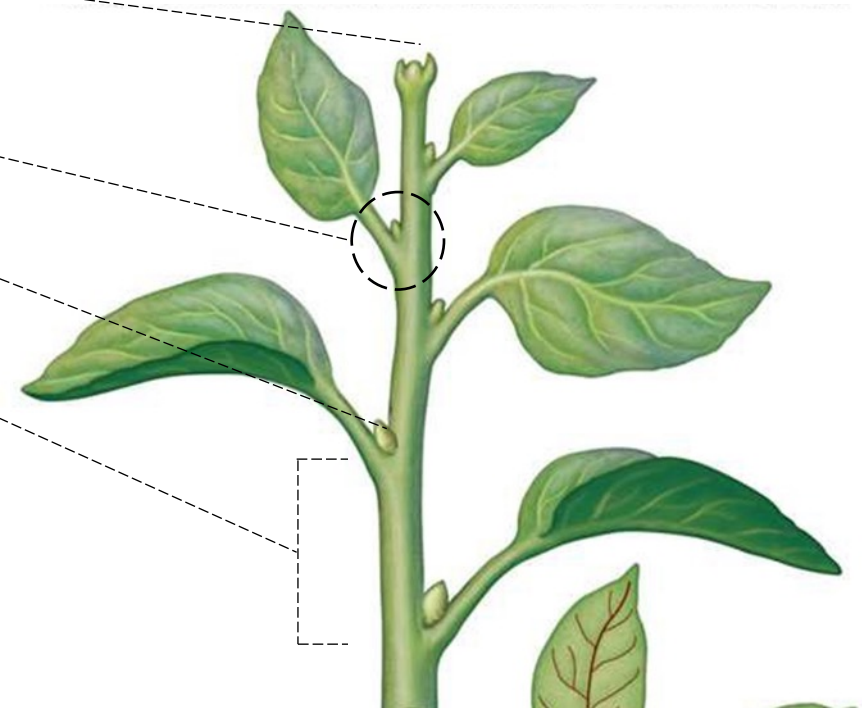
More on stoma & guard cells later…



Plant organs

Stem external morphology

- Functions for **support**, **elongation** and **growth**
  - Terminal bud – growth via the apical meristem at the stem tips
  - Node – point at which leaves attach
  - Axillary bud – other buds found at the nodes
  - Internode – stem area between nodes



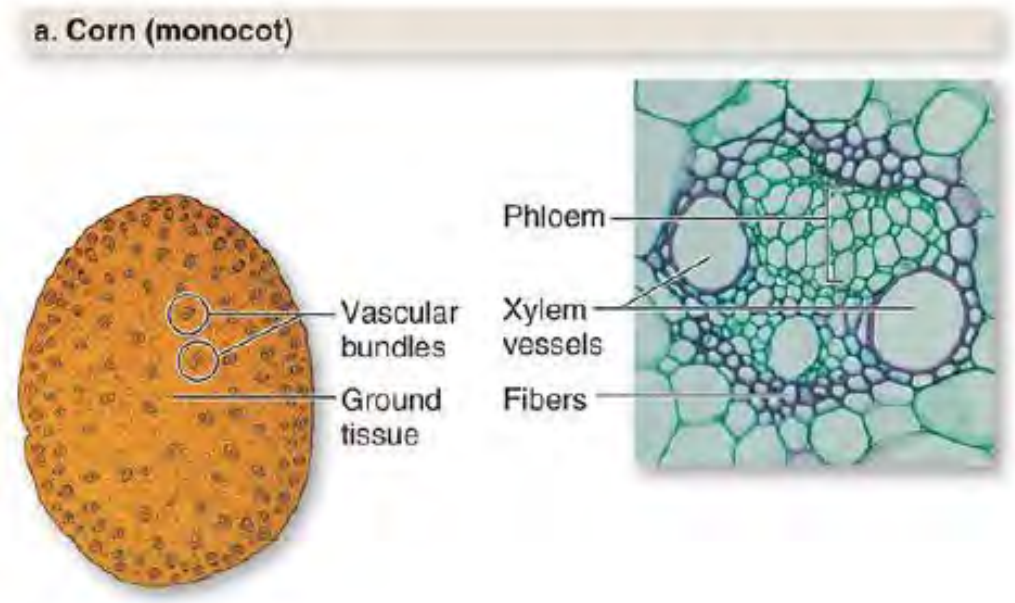
Plant organs

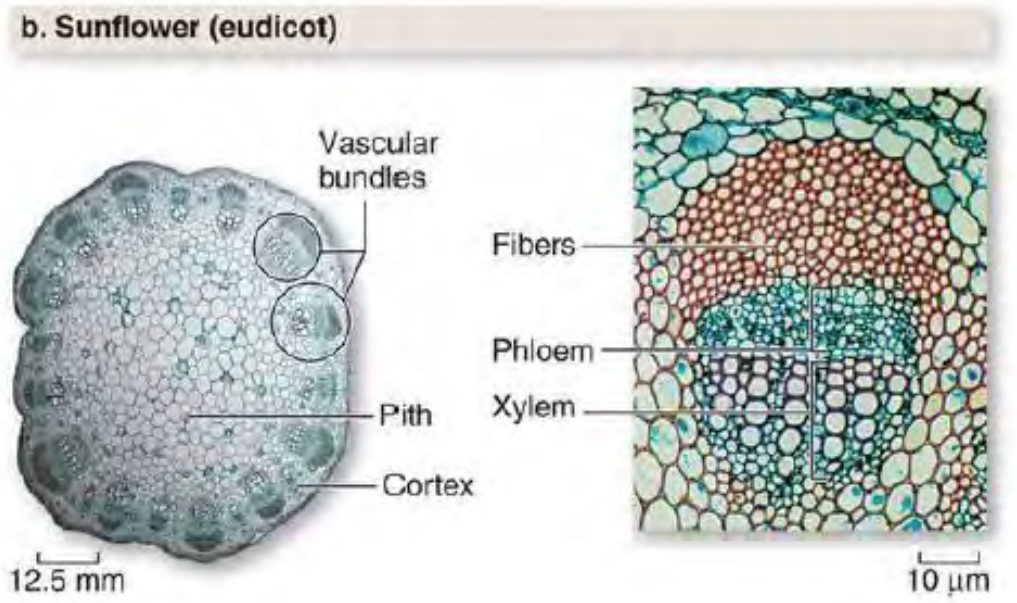
Stem internal morphology

- Young stem
  - Epidermis
  - Primary xylem and primary phloem arranged in vascular bundles
  - Ground tissue
- Old eudicot stem
  - Secondary ‘woody’ tissues produced by secondary **meristems**

Plant organs

Monocots and eudicots have different arrangements of vascular tissue and ground tissue in their **stems**





Plant organs

Root external morphology

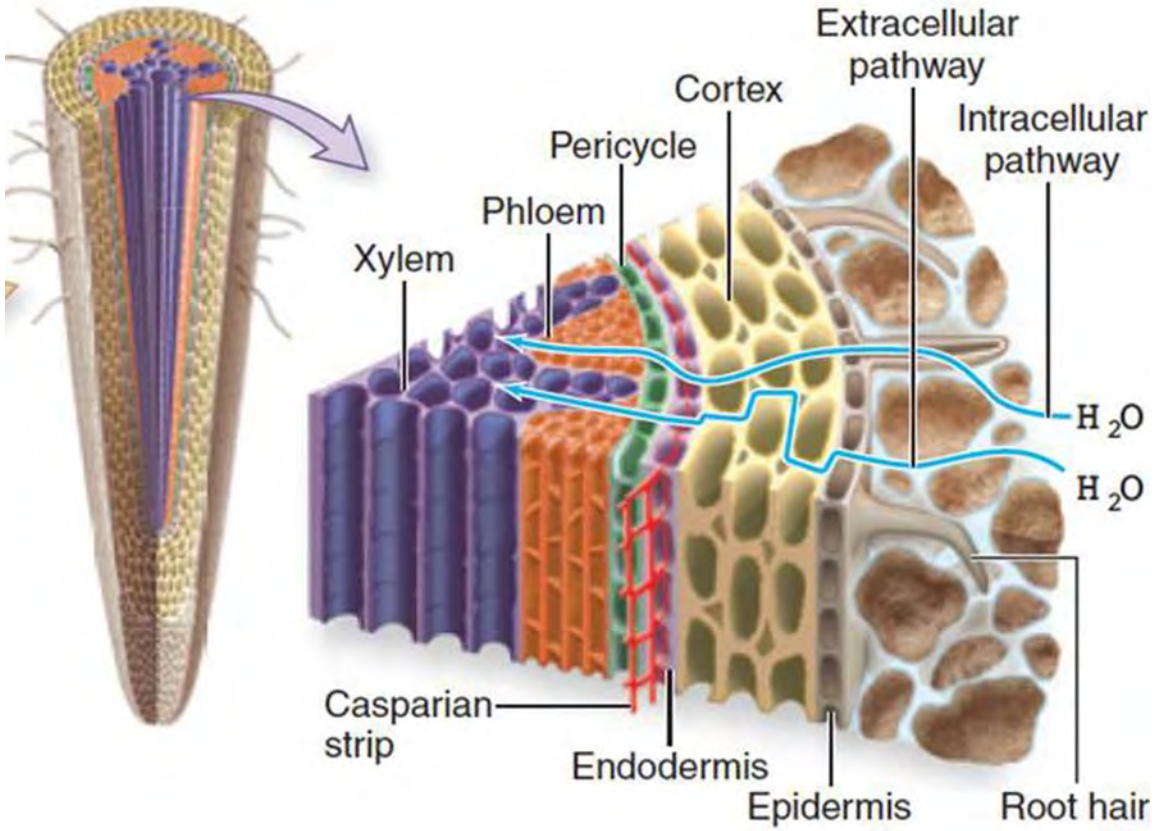
- For **anchoring** and **absorption** of water and nutrients
  - Taproot system – with large main central root and have fewer branches than fibrous roots
  - Fibrous root system – slender, shallow and arise from base of the stem

Eudicot Monocot

Plant organs

Root internal morphology

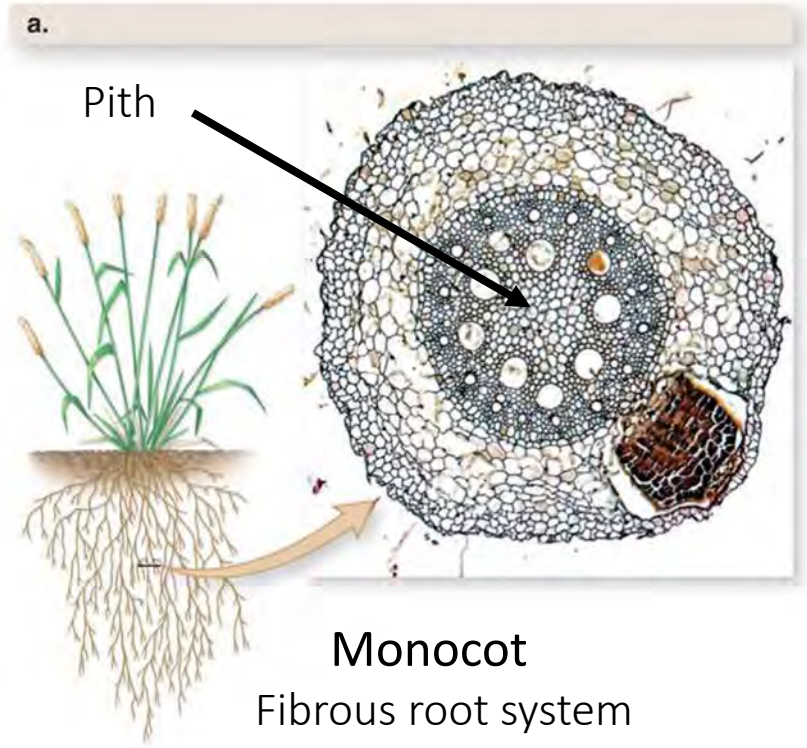
- **Central vascular cylinder** and surrounding ground tissue
- **Root hairs** – extensions of epidermal cells near the tip to increase absorption
- **Endodermis** – special cells which encircle the vascular tissue ensures all absorbed material passes through cells



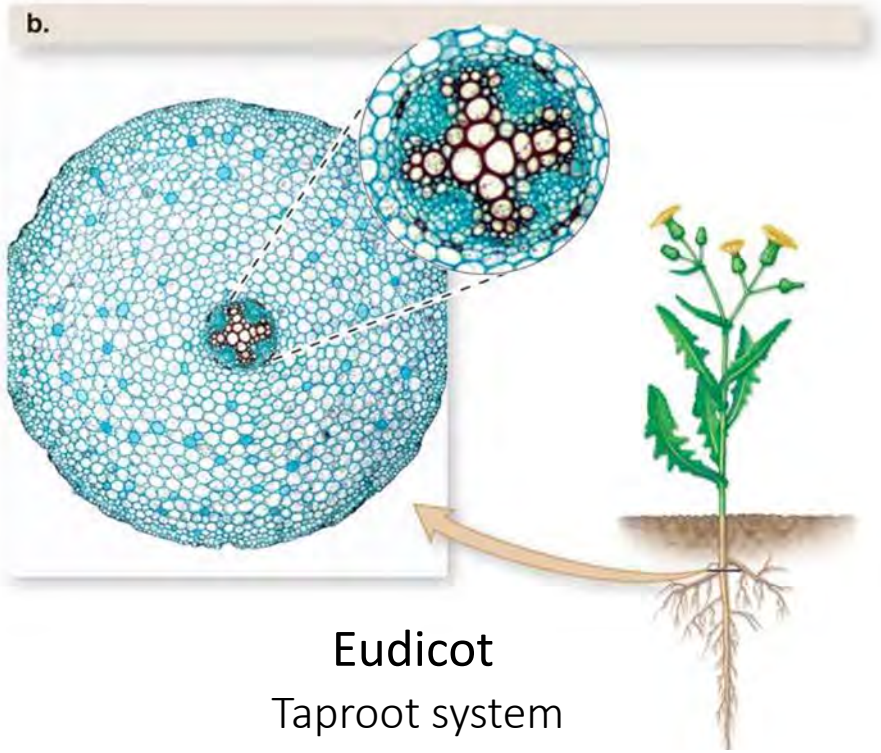
Root hairs increase surface area for absorption

Roots

Monocots and eudicots have different arrangements of vascular tissue and ground tissue in their **roots**



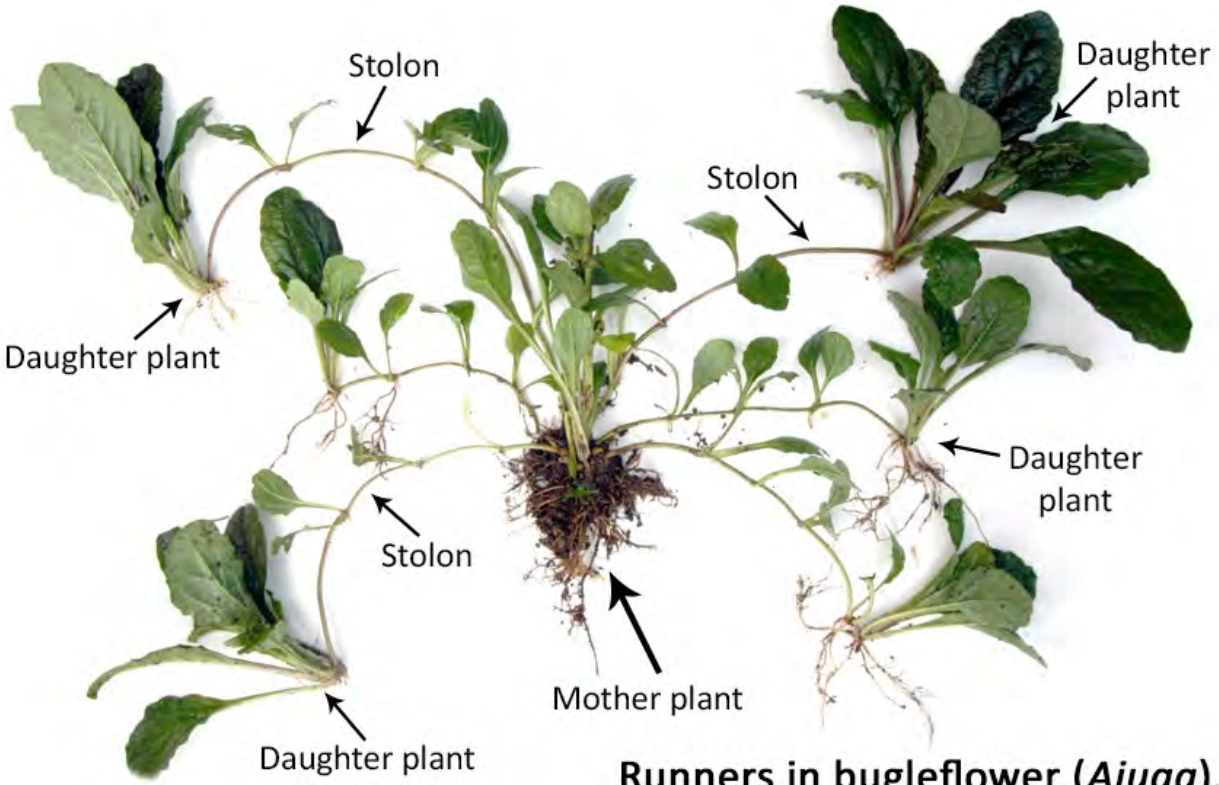
Monocot
Fibrous root system



Eudicot
Taproot system

Modified plant organs

- Stems
  - Stolons – horizontal aboveground stems, asexually forming new plants at node



Runners in bugleflower (*Ajuga*).

Modified plant organs

- Stems
  - Stolons – horizontal aboveground stems, asexually forming new plants at node
  - Rhizomes – horizontal underground stems
  - Tubers – swollen underground stems for storage
  - Thorns – modified branches for protection
  - Phylloclade – green stem that can photosynthesize

Narrow-lidded pitcher plant
Nepenthes ampullaria Jack (1835)

Raffles pitcher plant
Nepenthes rafflesiana Jack 1819

Slender pitcher plant
Nepenthes gracilis Korth (1839)

Modified plant organs

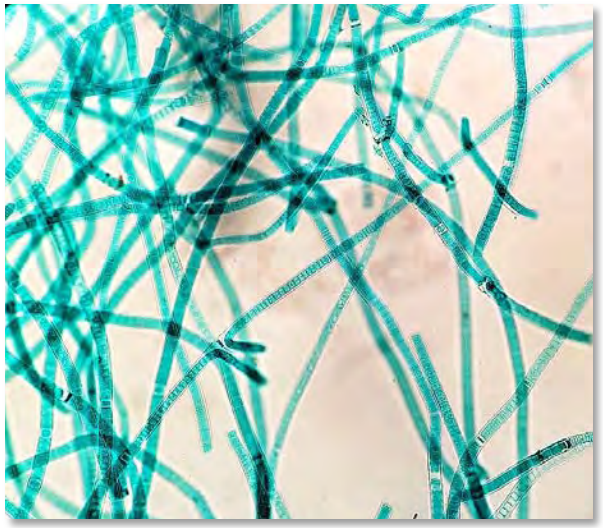
- Roots
  - Prop – structural support
  - Aerial – water absorption from air
  - Storage – swollen main roots or branches
  - Respiratory – oxygen absorption
  - Buttress – shallow, nutrient poor soils

Modified plant organs

Commonly used plant ingredients: stems, leaves, roots?

Photosynthesis

- Plants use solar energy to build glucose from carbon dioxide
- Use water in the process and release oxygen
- Store energy in the chemical bonds of glucose



Cyanobacteria

$6H_2O + 6CO_2$

Water **Carbon Dioxide**

$6O_2 + C_6H_{12}O_6$

Oxygen **Glucose**

Photosynthesis

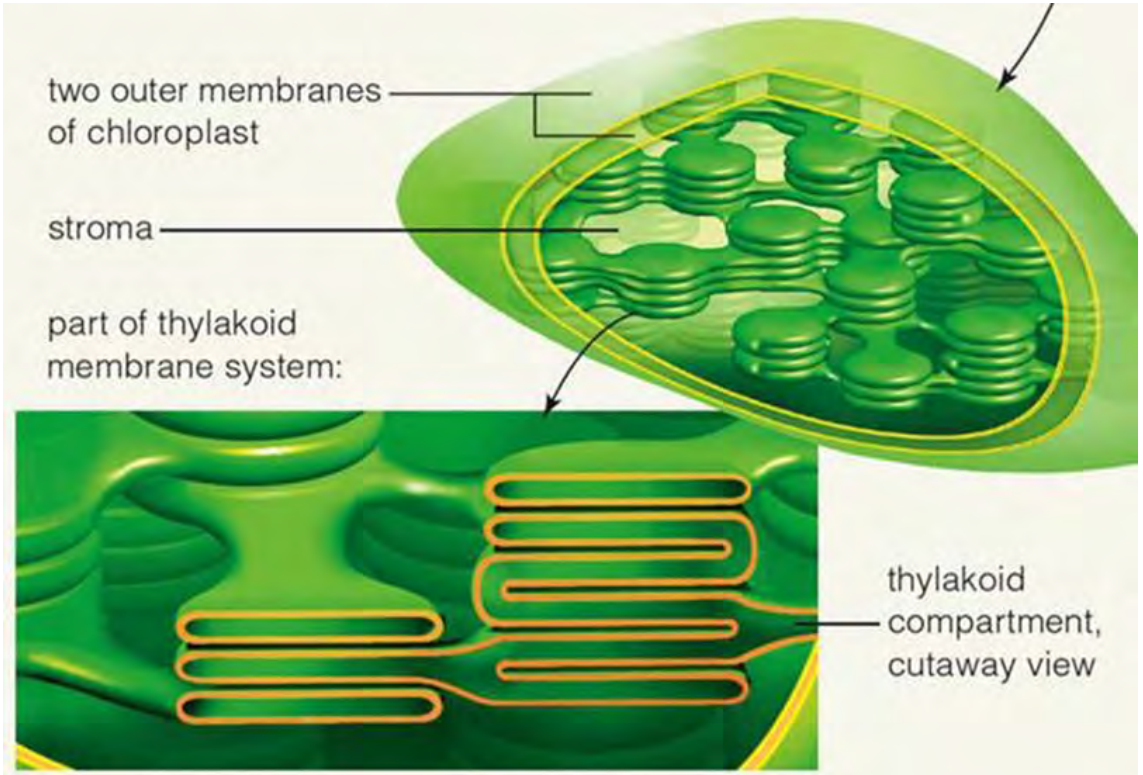
Chloroplasts via **endosymbiosis**

Occurs in primarily in leaf cell chloroplasts

- Chloroplast structure:

Two outer membranes

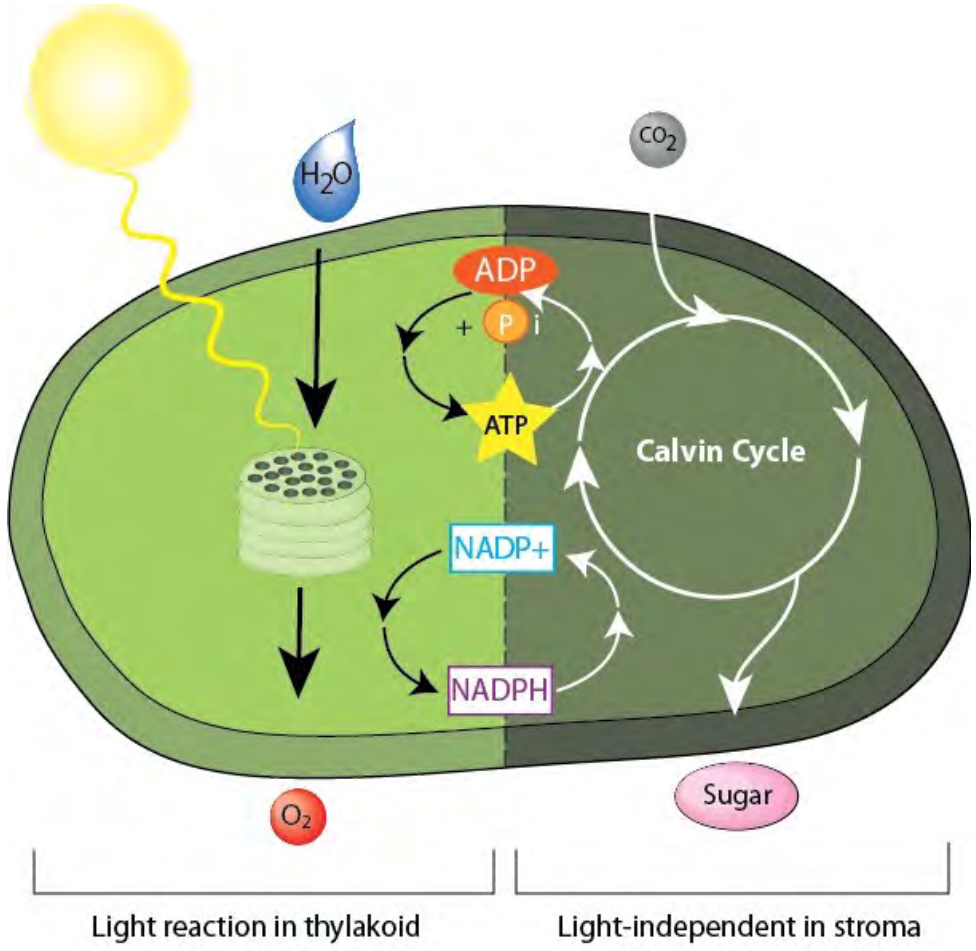
- Stroma – internal space containing enzymes, ribosomes, DNA, and thylakoids
- Thylakoid – stacked membranous structures with photosynthetic pigments enclosing thylakoid space



B Chloroplast structure. No matter how highly folded, its thylakoid memb system forms a single, continuous compartment in the stroma.

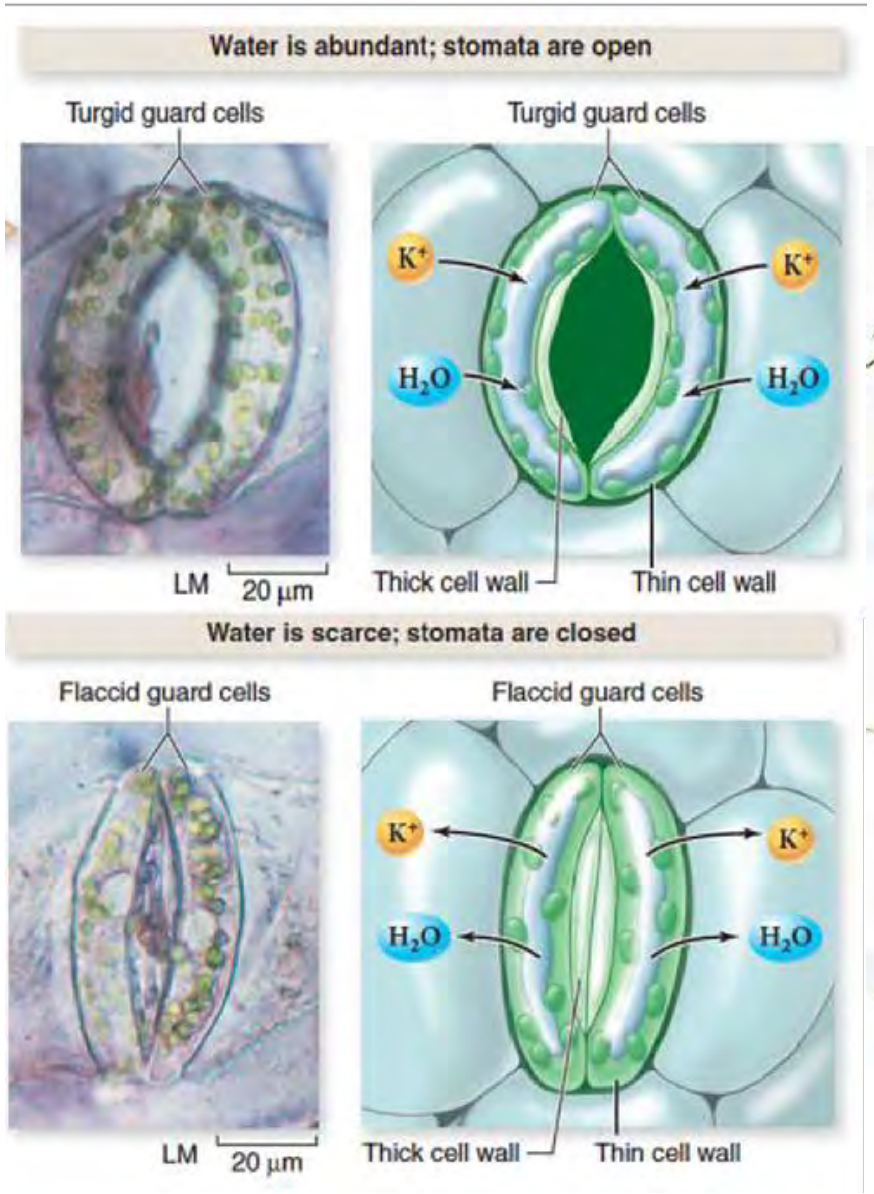
Two stages of photosynthesis

- **Light-dependent** reactions
  - Occur in thylakoid membranes
  - Convert solar energy to chemical energy through the electron transport chain
  - Energy from captured photons used to make ATP (stores energy) and NADPH (carries electrons)
- **Light-independent** reactions
  - Occur in stroma
  - ATP and NADPH used to reduce CO_2 to glucose
  - Also known as carbon fixation or Calvin cycle



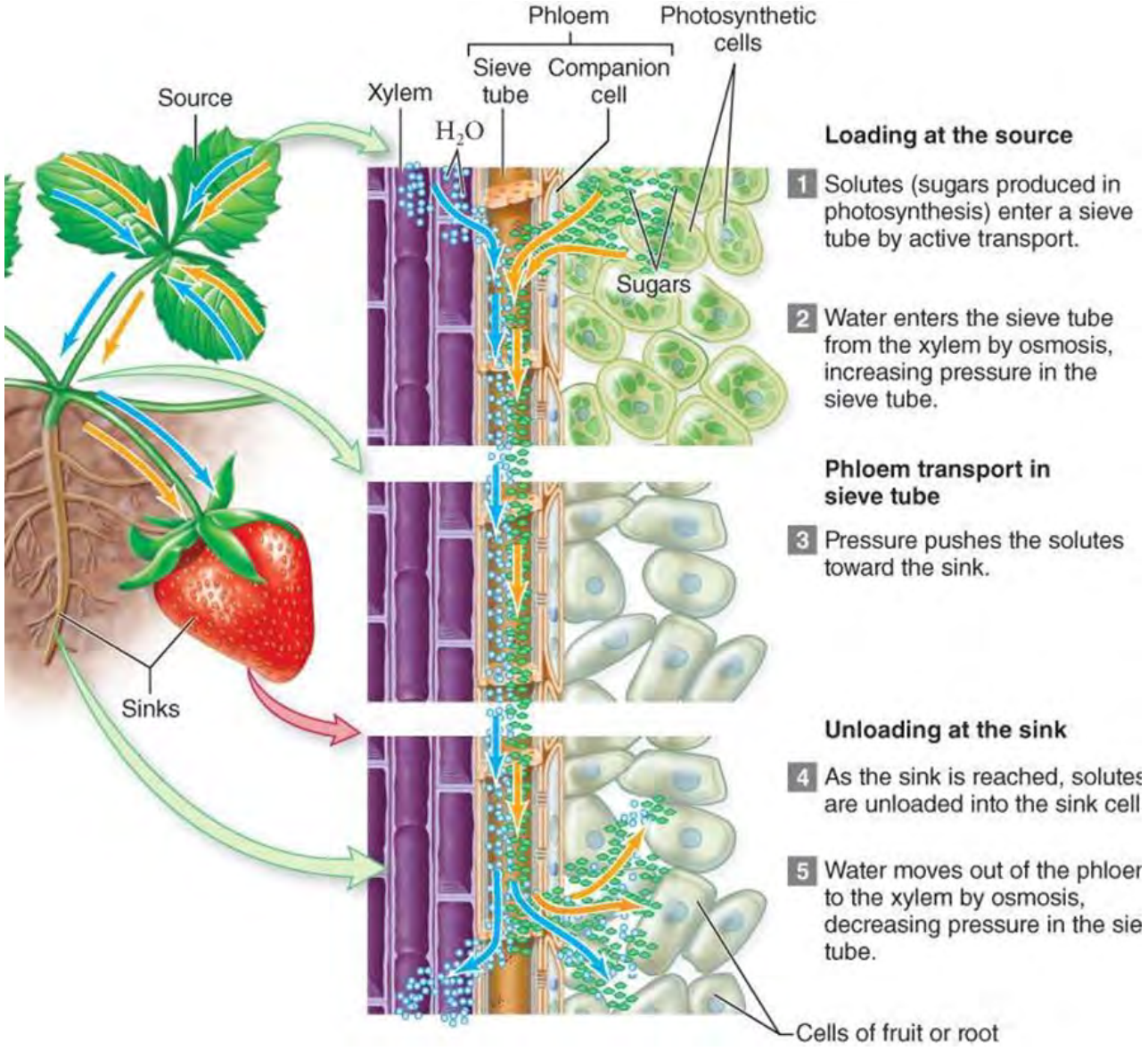
Photosynthesis

- **Guard cells** play an important role by regulating stomata opening for gas exchange balancing between carbon dioxide intake and water loss
- When water evaporates from the leaves, in a process called transpiration, cohesion pulls adjacent water molecules closer to the stomata
- Stomata close when the plant needs to conserve water



Photosynthesis

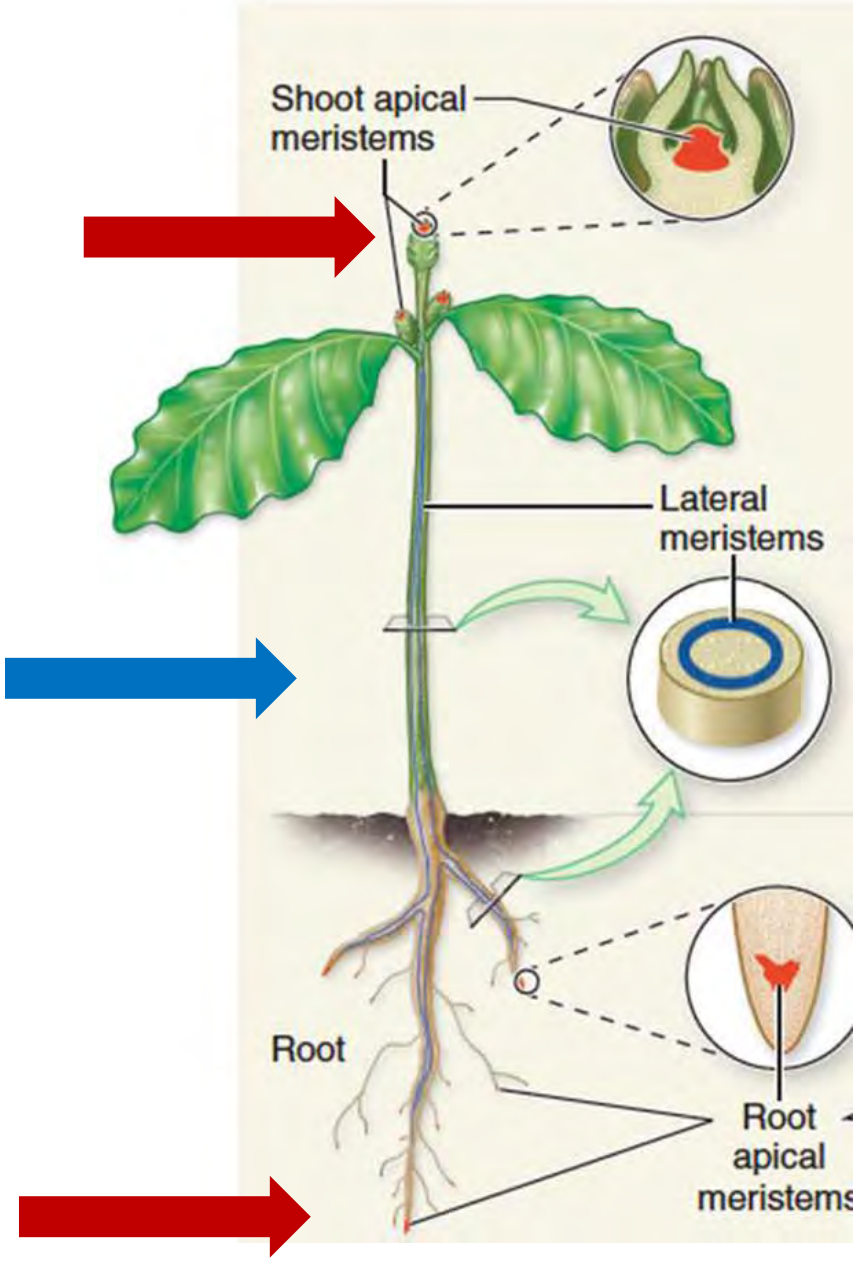
- Products of photosynthesis (sugars) are actively transported from photosynthetic cells to phloem
- Water movement from xylem causes pressure changes in phloem tissue
- Sugars are unloaded into non-photosynthetic cells in different parts of the plant



Plant growth

Plant growth occurs at the meristems, regions of active cell division (mitosis)

- **Primary** growth
  - Occurs at apical meristems
  - Lengthens the tips of the shoots and roots
- **Secondary** growth
  - Occurs at lateral meristems
  - Increases the diameter of plants

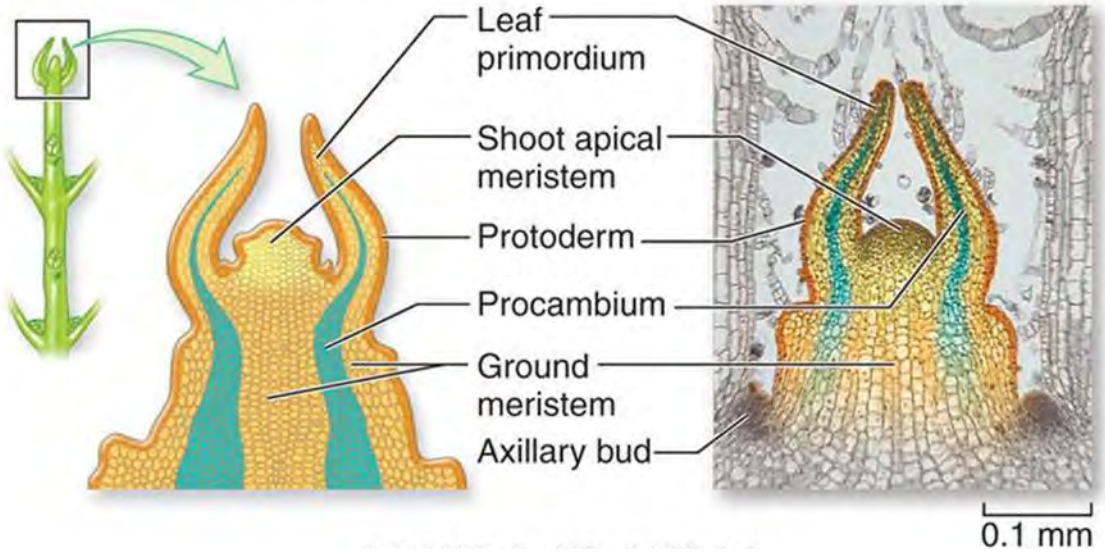


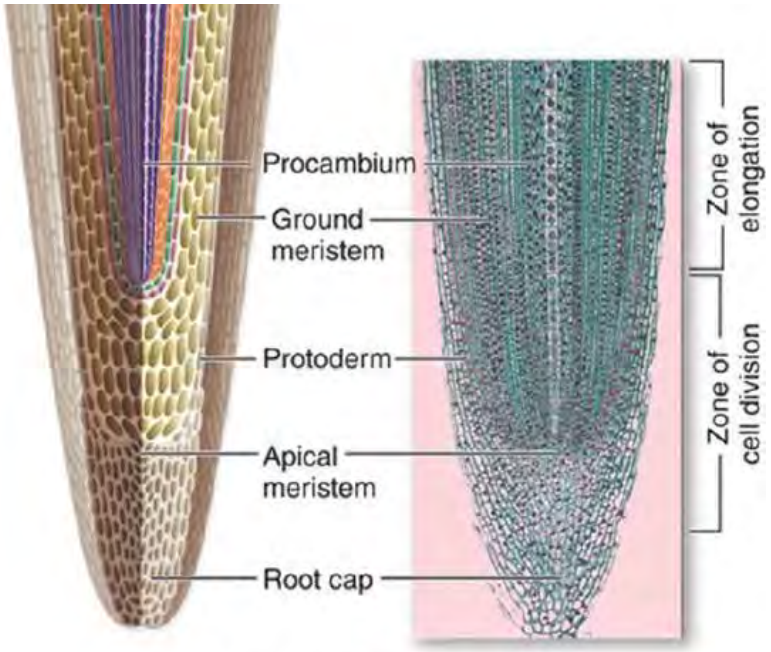
Plant growth

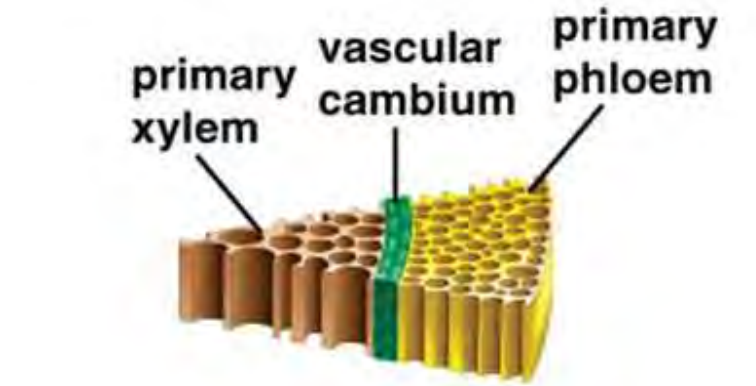
Apical dominance is an evolutionary adaptation to increase exposure to light and water

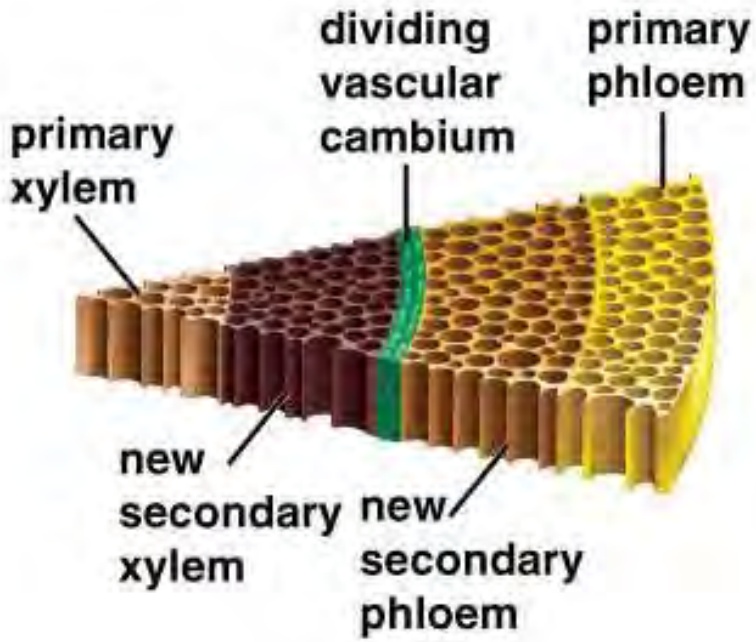
Apical meristems

- Found at the tips of stems and roots
- New cells differentiate into the primary tissues – epidermis, primary xylem and phloem, ground tissue





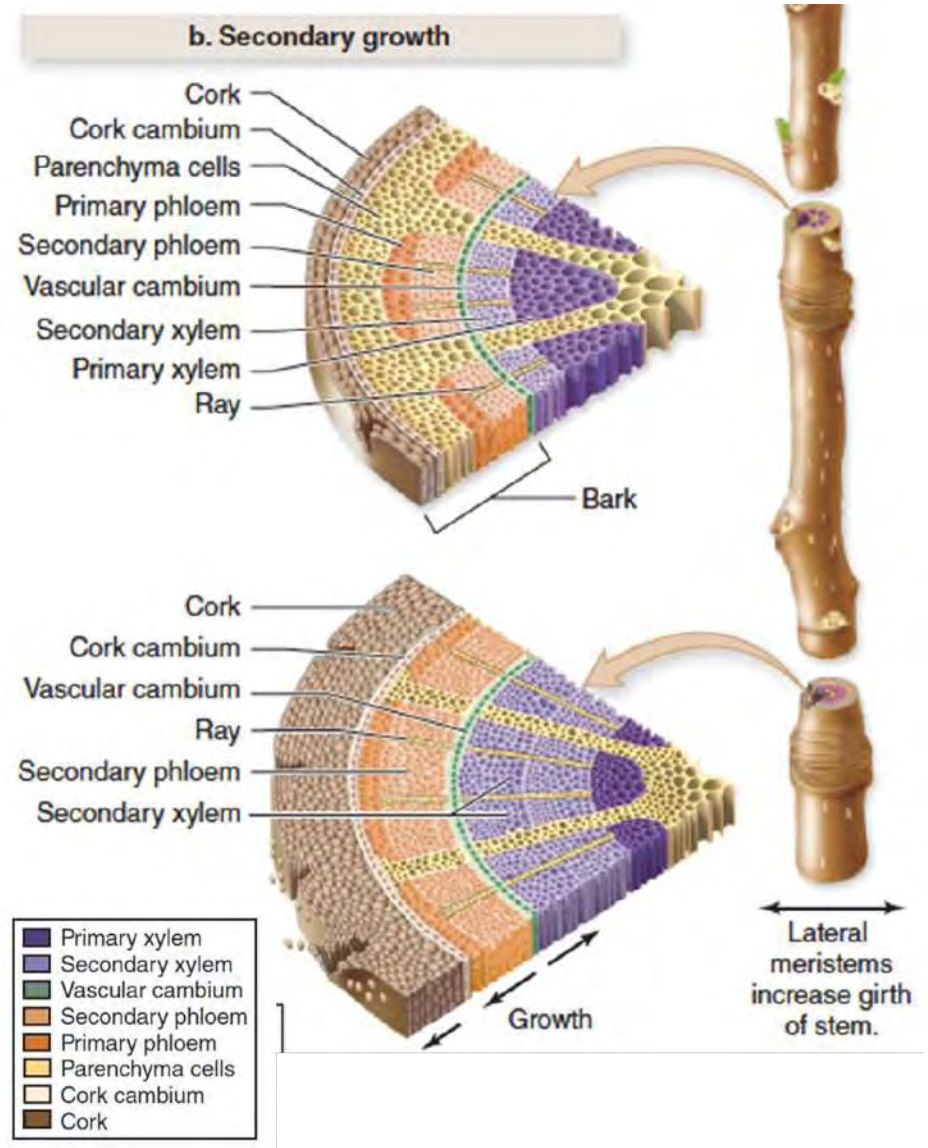

primary xylem
vascular cambium
primary phloem


primary xylem
dividing vascular cambium
primary phloem
new secondary xylem
new secondary phloem

Plant growth

Secondary tissues

- Wood - core of secondary xylem
- Bark - secondary phloem and tissues produced by cork cambium



Plant reproduction

Most angiosperms reproduce sexually (some undergo asexual reproduction)

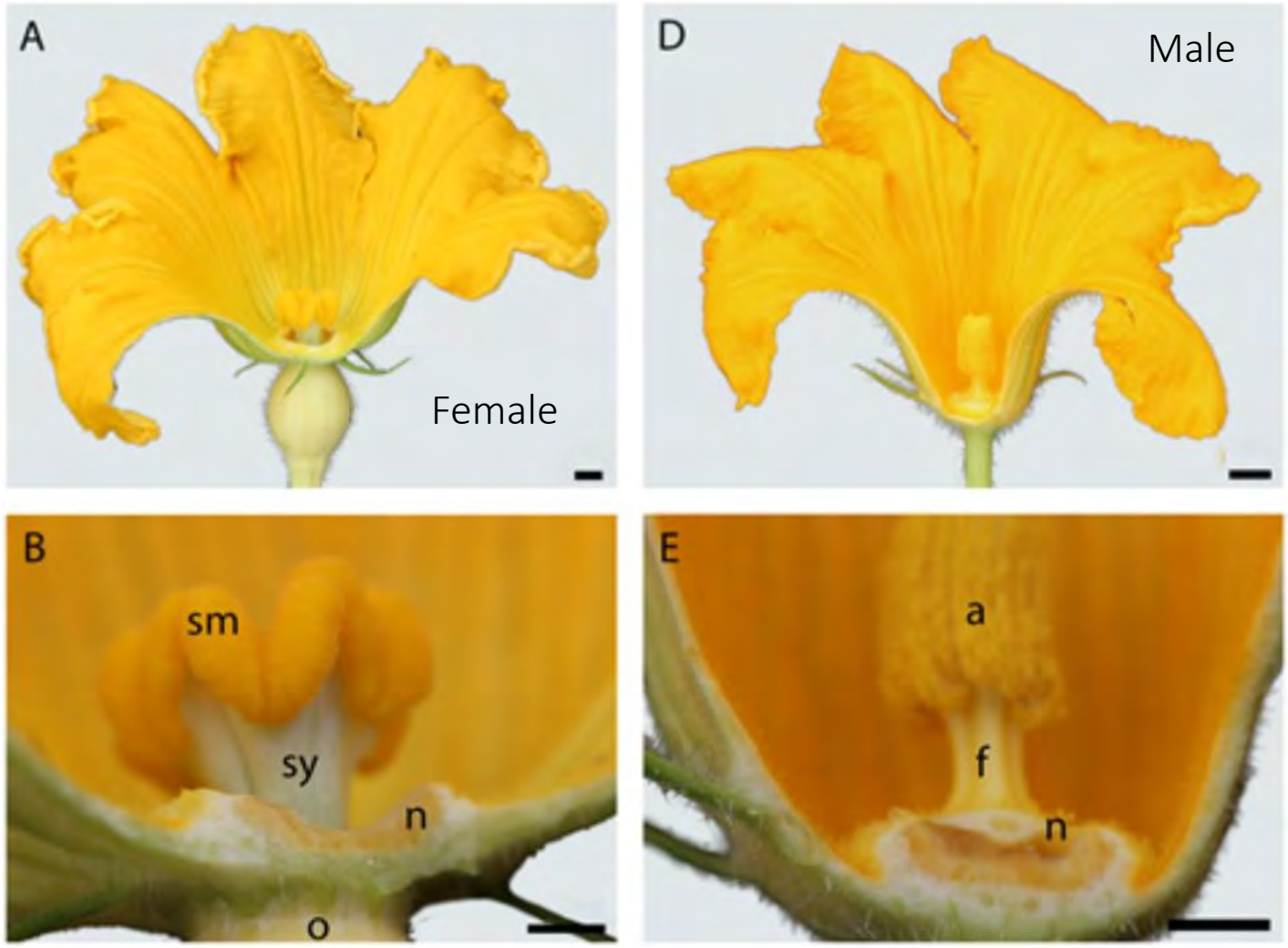
- Flowers are the sex organs of angiosperms, where pollen and egg cells are produced
  - Important adaptation to life on land
  - Pollen enables fertilization in the absence of free water
  - Ovaries develop into fruits that aid in seed dispersal

Plant reproduction

Dioecious plant species have flowers of separate sexes i.e. stamens only or carpels only

Parts of flower

- Sepals – enclose and protect inner parts when immature
- Petals – usually for attracting pollinators
- Stamens – male reproductive parts (anther + filament)
- Carpels – female reproductive parts (stigma + style + ovary)



Plant reproduction

Parts of flower

- Sepals – enclose and protect inner parts when immature
- Petals – usually for attracting pollinators
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- Carpels – female reproductive parts (stigma + style + ovary)

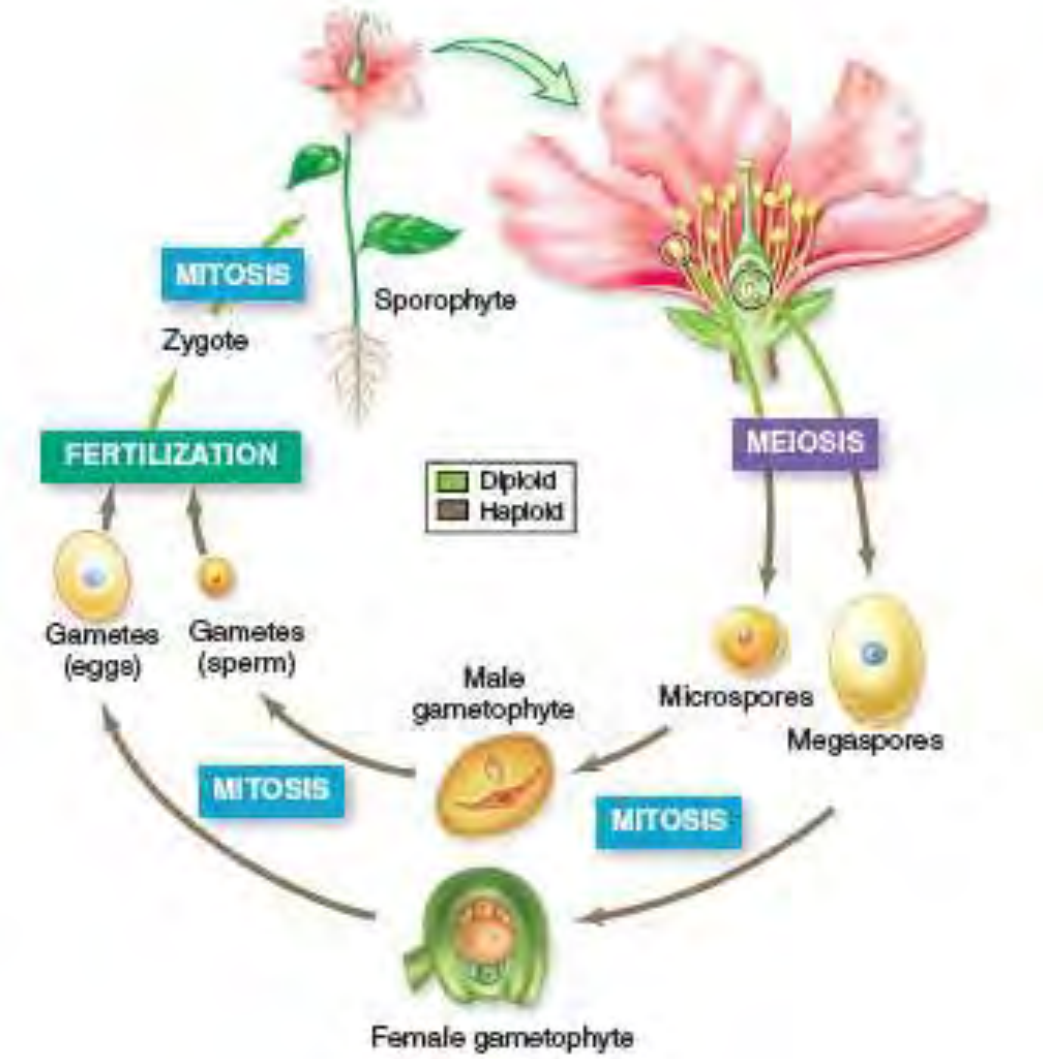
Flower parts in multiples of three

Flower parts in multiples of four or five

Plant reproduction

Alternation of generations in angiosperms

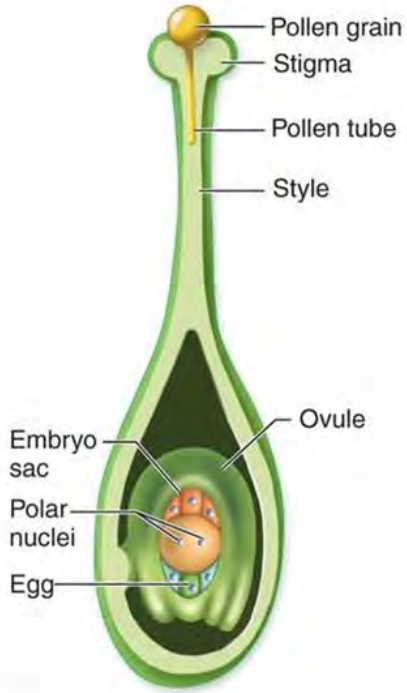
- Anthers produce microspores, which divide into male gametophytes (pollen grains)
- Ovules produce megaspores, which divide into female gametophytes (embryo sacs)



Plant reproduction

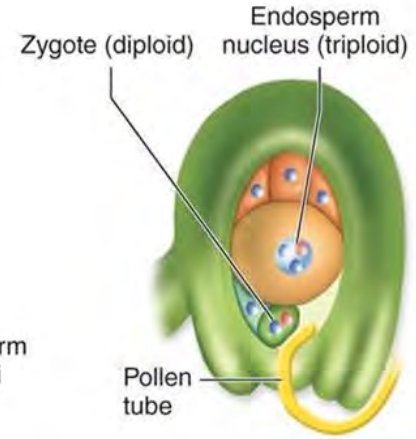
Pollination occurs when a pollen grain lands on a receptive stigma

- Pollen germinates and pollen tube extends down the style
- One nucleus in the pollen divides to produce sperm
- **Double fertilization** produces the zygote and endosperm



1 Pollen grain lands on stigma and germinates; pollen tube grows into style.

2 Two sperm nuclei travel through pollen tube to ovary.



3 One sperm nucleus fuses with egg nucleus to form diploid zygote. The other sp nucleus fuses with two pola nuclei to form triploid endo

Plant reproduction

After fertilization, the flower develops into a fruit in response to hormones from the seeds

- Fruits protect developing seeds
  - Diploid zygote → plant embryo
  - Triploid endosperm → stored food
  - Ovary wall or other floral parts → fruit flesh or skin

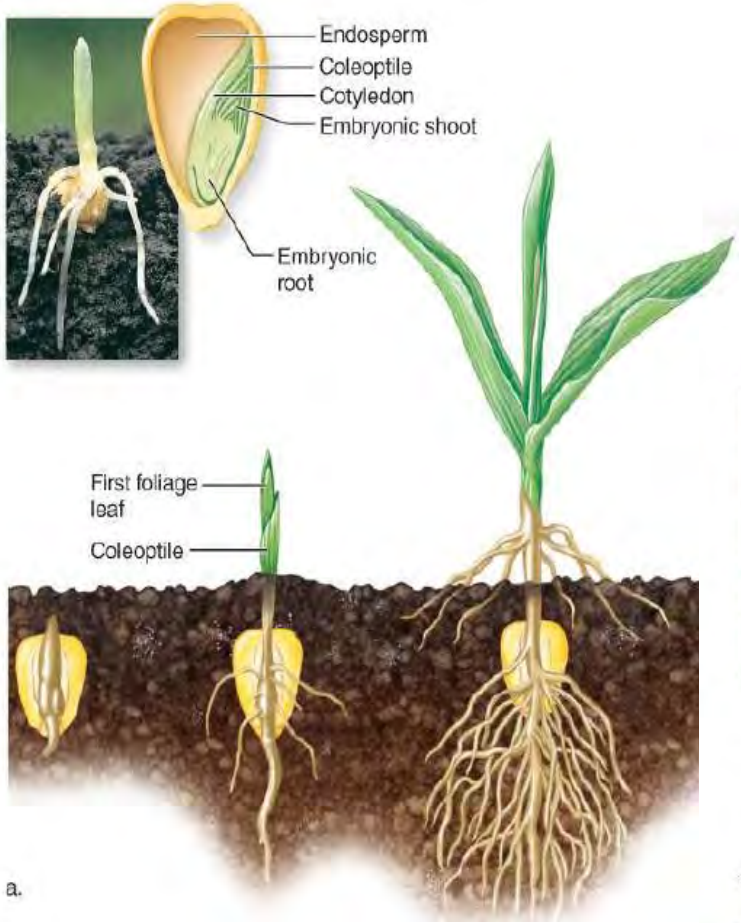
Plant reproduction

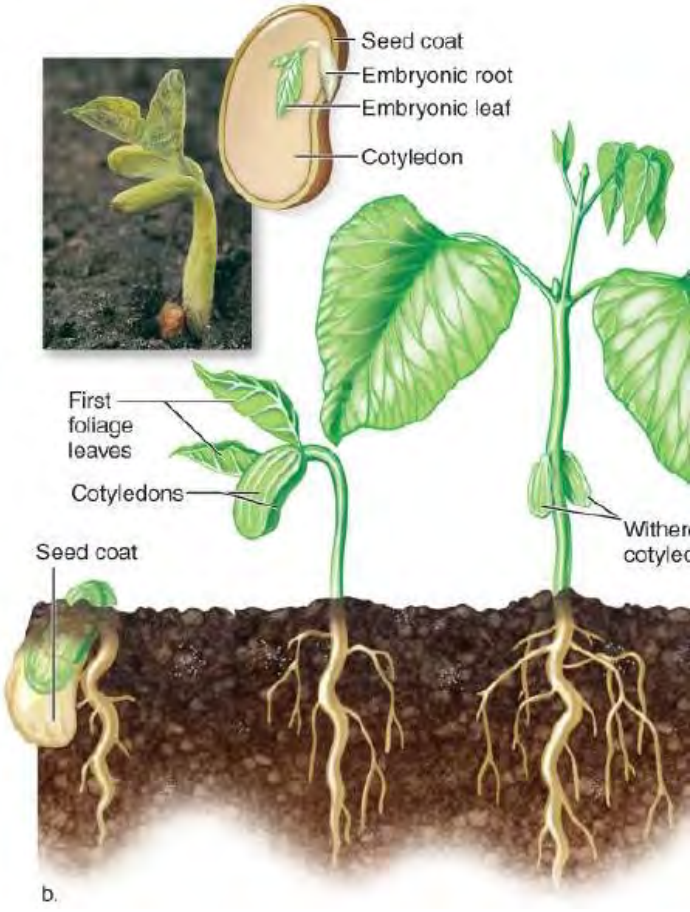
- Fruits also function to help seeds disperse
  - Wind
  - Water
  - Animals
- Seeds carried away from parent plants decrease the chance of competition among parents and siblings

(a) Dandelion fruits (b) Maple fruits

Plant reproduction

- Seeds are composed of
  - Dormant plant embryo
  - Endosperm – stored food
  - Seed coat





- Germination occurs when a seed is dispersed to a location with the right conditions for growth
  - Monocots (a) and eudicots (b) have slightly different development patterns

Summary

- Multicellular autotrophs that have a modular form of growth (nodes and internodes)
- Three main plant tissues (dermal, vascular, ground) found in different plant organs
- Plant reproduction varies across lineages (both asexual as well as sexual reproduction)
- Take home questions:
  - How does gas exchange happen in plants?
  - What are the main differences between monocots and eudicots?
  - Why do some plants bloom throughout the year whilst others are short-lived?