- Chapter 36~
  Transport in Plants

Structural Features Used for Resource Acquistion

- Roots and stems to do transport of resources
  - Diffusion, active transport, and bulk flow

- Work in vascular plants to transport water, minerals, and products of photosynthesis

Review

- What are the characteristics of the 2 main types of transport?
- What is diffusion and facilitated diffusion?
- What is endocytosis and exocytosis?

Acquiring Resources

- Algal ancestors absorbed water, minerals, and CO_2 directly from water
- Early land plants evolved photosynthetic shoots with waxy cuticles and few stomata
- Larger shoots and broad leaves of taller plants require more anchorage and water
- Evolution favored plants with vascular tissue
  - Adaptations for acquiring resources is a compromise between enhancing photosynthesis and minimizing water loss

Review

- What is the equation for photosynthesis?
- What are the steps of the light reaction?
- What are the steps of the Calvin cycle?
- What is the difference between cyclic and non-cyclic electron flow?

Plant Adaptations

- Phyllotaxy = arrangement of leaves on a stem to maximize light capture
- Leaf orientation – horizontal or vertical orientation to capture light
  - Intense light can injure leaves and disrupt photosynthesis
- Stem branching – finite amount of energy for shoot growth
- Stem thickness – taller plants require thicker stems

Plant Adaptations

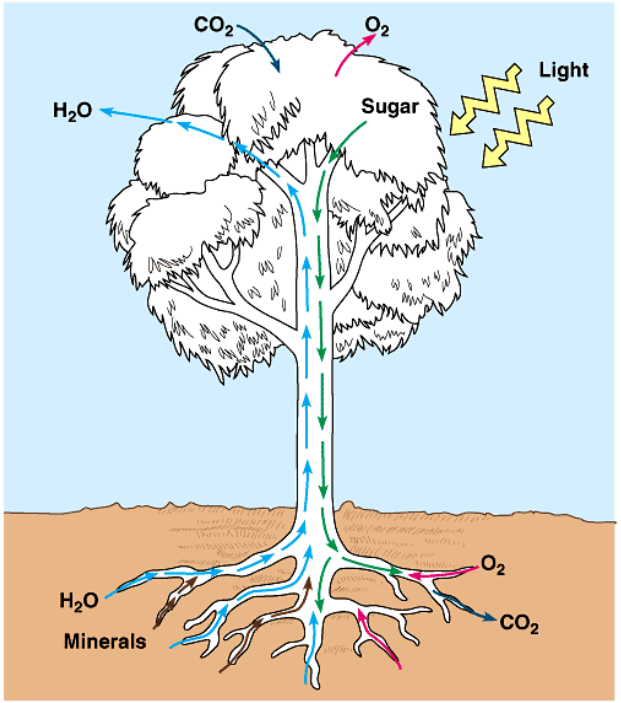
- Gymnosperms and Eudicots anchored by taproots
  - Most monocots are shorter because their fibrous roots don't anchor them as well as the taproot
- Mycorrhizae = mutualistic relationship between roots of legumes and fungi

Transport Overview

- Uptake and loss of water and solutes by individual cells (root cells)
- Short-distance transport from cell to cell (sugar loading from leaves to phloem)
- Long-distance transport of sap within xylem and phloem in whole plant

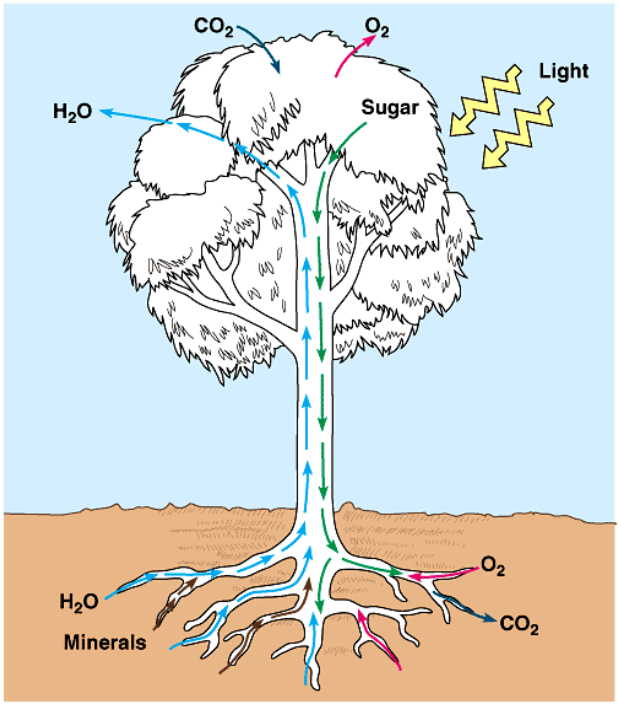
Whole Plant Transport

- Roots absorb water and dissolved minerals from soil
- Roots exchange gases with air spaces of soil (supports cellular respiration in roots)
- Water and minerals are transported upward from roots to shoots as xylem sap



Whole Plant Transport

- Transpiration, the loss of water from leaves, creates a force that pulls xylem sap upwards
- Leaves exchange CO_2 and O_2 through stomata
- Sugar is produced by photosynthesis in leaves
- Sugar is transported as phloem sap to roots and other parts of plant



Cellular Transport

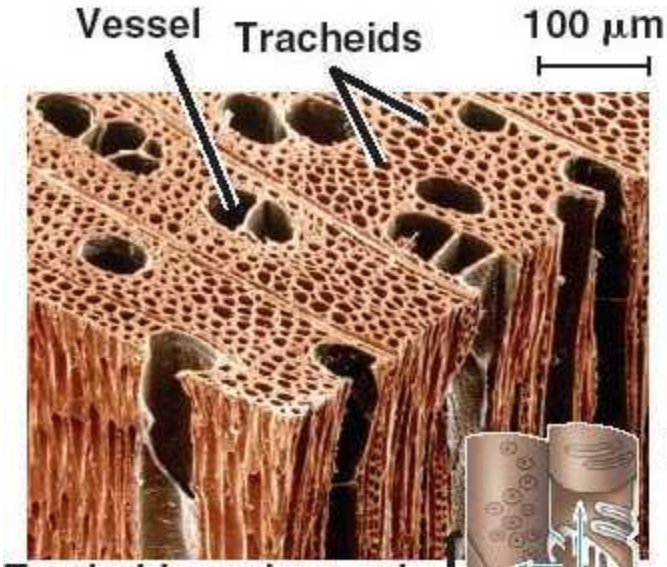
- Passive and active transport move materials into and out of cells
  - K^+ channels, proton pumps for solute transport (cotransport), osmosis

- Water potential = physical pressure from cell wall and solute concentration
  - Pressure potential + solute potential (osmotic potential)
  - Solute potential = iCRT
  - Water moves from high to low water potential

- Flaccid (limp, isotonic)
- Plasmolysis (cell loses water in a hypertonic environment; plasma membrane pulls away)
- Turgor pressure (influx of water due to osmosis; hypotonic environment)
  - Cell contents presses plasma membrane against the cell wall

Bulk Flow

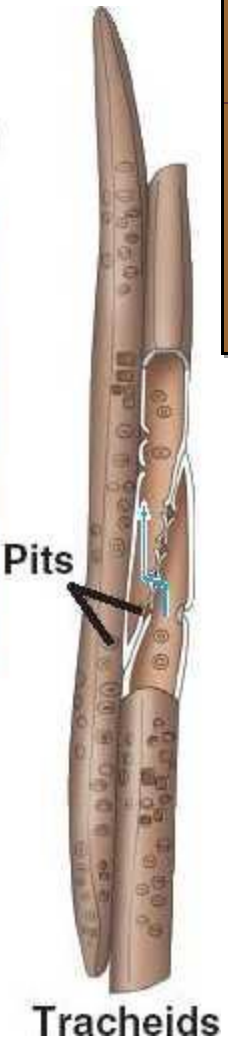
- Diffusion and active transport are too slow over long distances
- Structure of xylem and phloem maximize the transport of materials by reducing resistance to flow
  - Xylem: tracheids and vessel elements are dead at maturity and lack cytoplasm
  - Phloem: sieve-tube elements lack organelles and sieve plates have many perforations to allow for movement



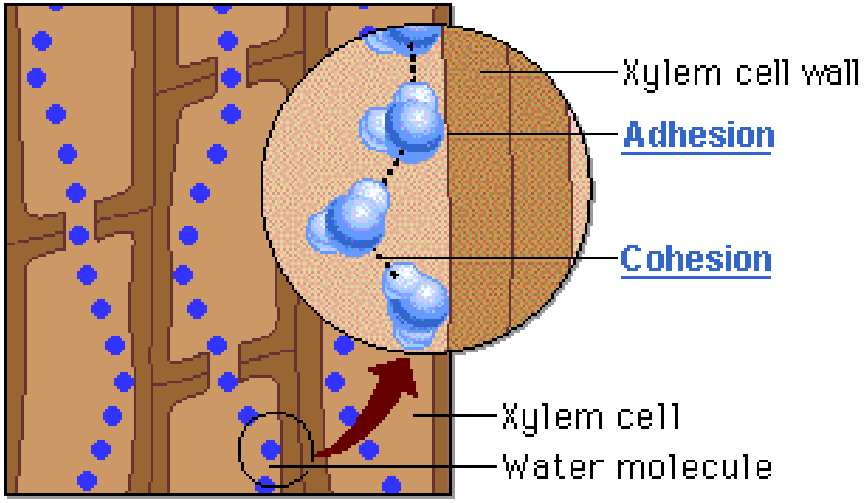
Tracheids and vessels

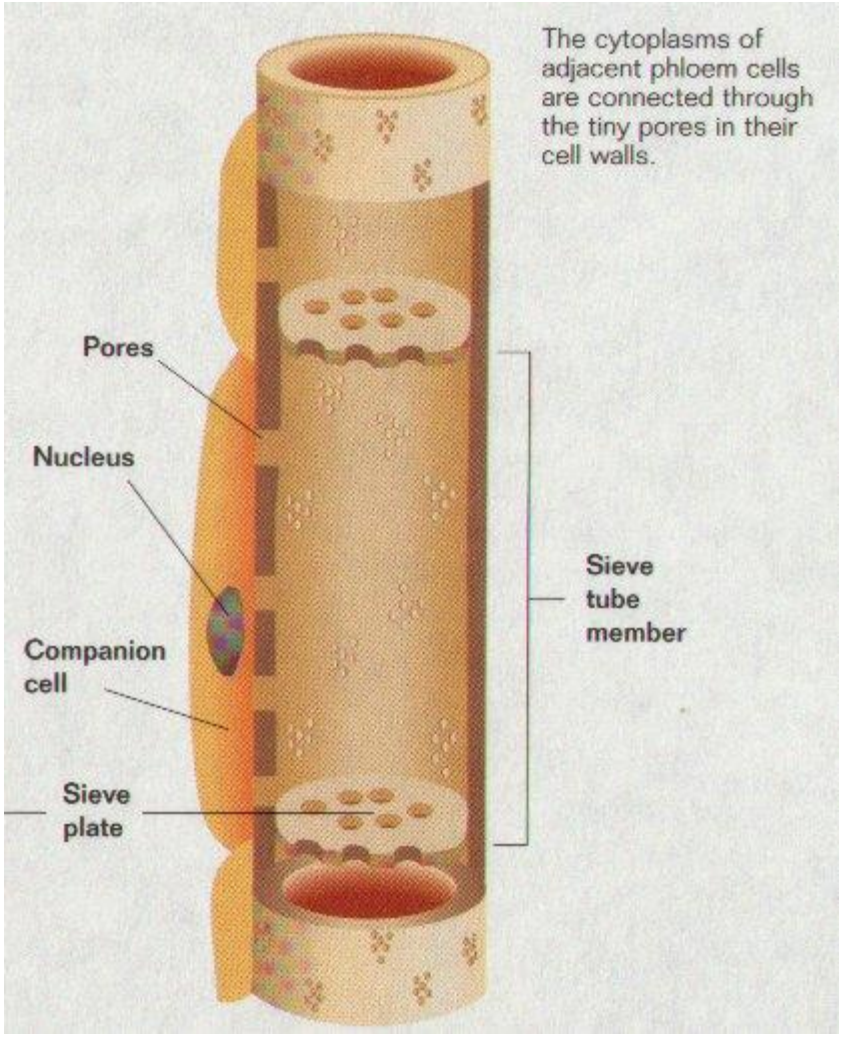
Vessel element

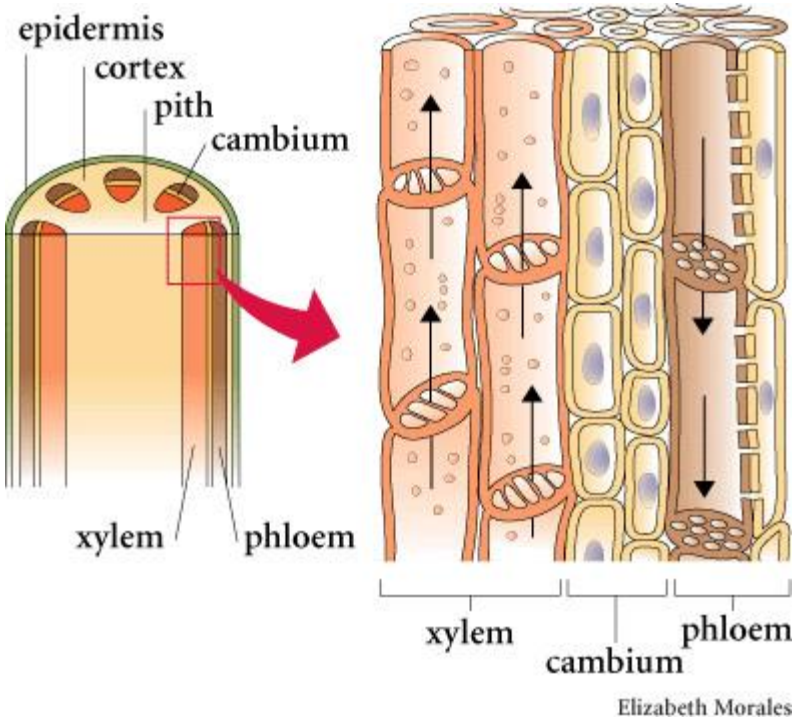
Vessel elements with partially perforated end walls



Tracheids




The cytoplasms of adjacent phloem cells are connected through the tiny pores in their cell walls.
Pores
Nucleus
Companion cell
Sieve plate
Sieve tube member

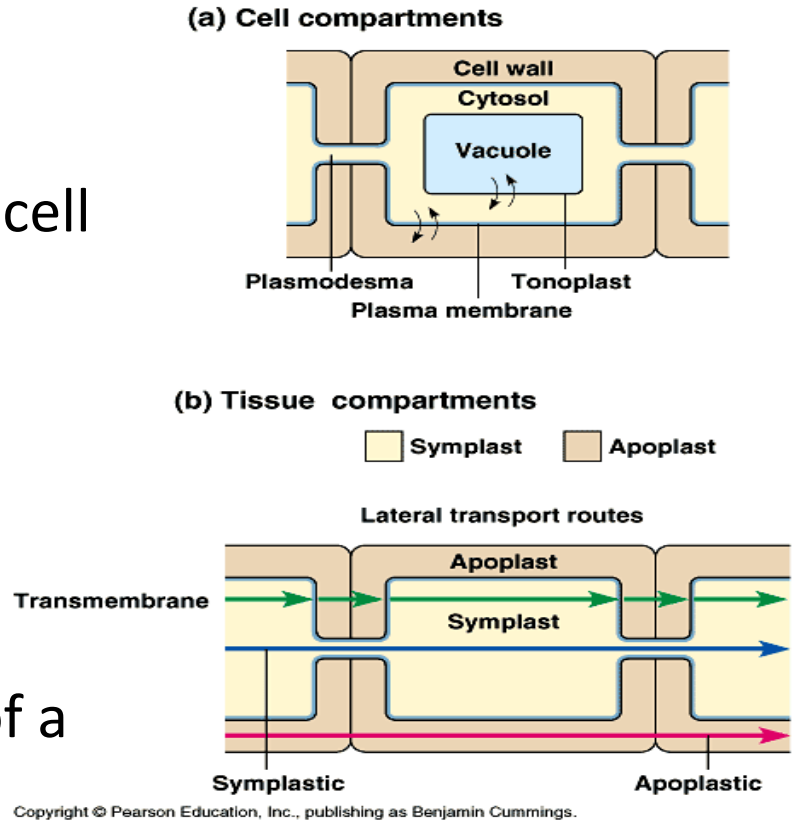

epidermis
cortex
pith
cambium
xylem
phloem
xylem
cambium
phloem
Elizabeth Morales

Transport within tissues/organs

- Aquaporins: transport proteins for water
- Tonoplast: vacuole membrane

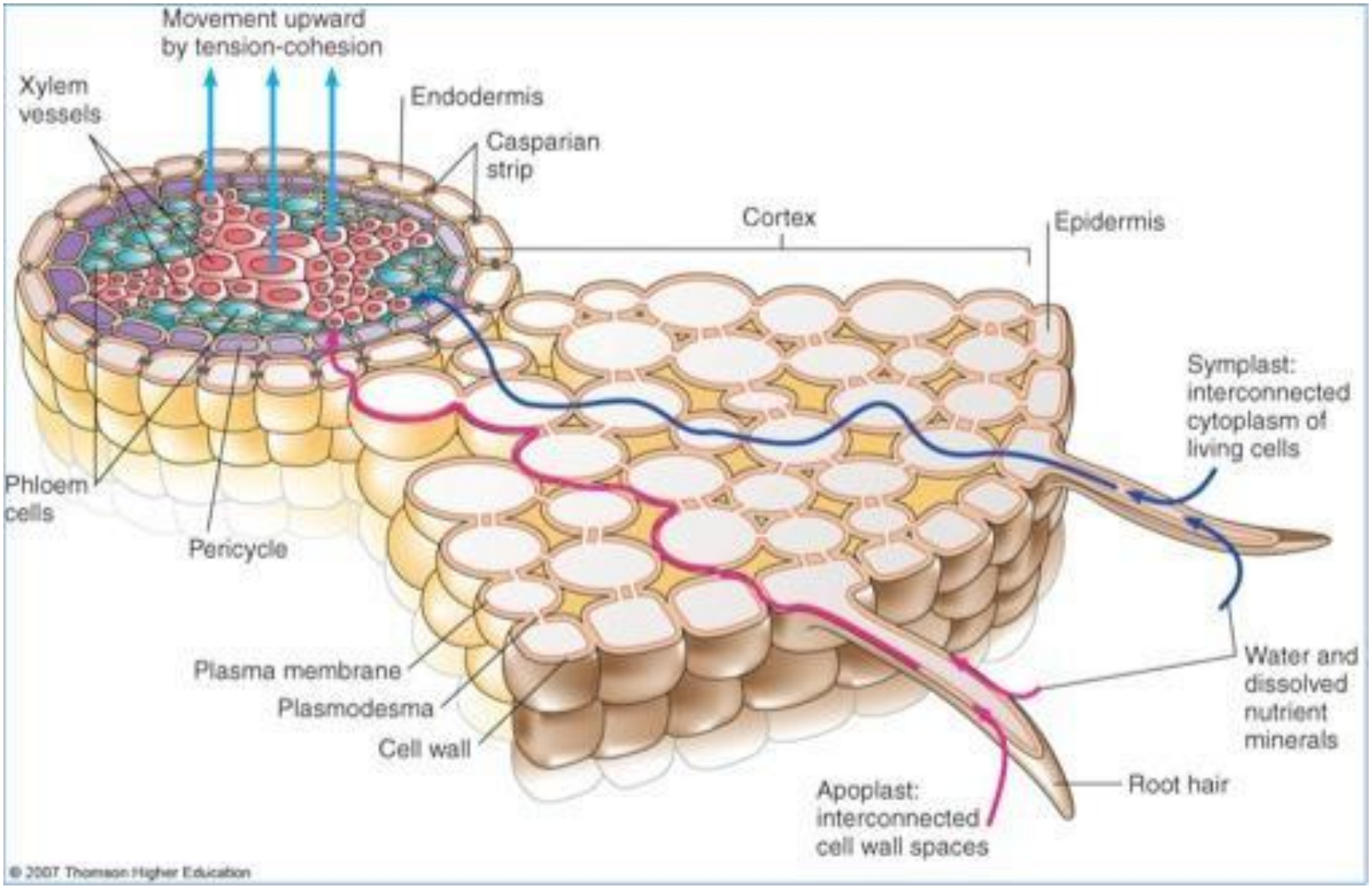
- Apoplast route (lateral): continuum of cell walls and movement by diffusion
  - Mineral ions readily diffuse through the polysaccharides of the cell wall
- Symplast route (lateral): cytoplasmic continuum
  - Plasmodesmata: cytosolic connection
- Bulk flow (long distance): movement of a fluid by pressure (xylem and phloem)

- Apoplastic, Symplastic, and Transmembrane routes for transport



Root absorption of water and minerals

- Mycorrhizae = symbiotic structures consisting of plant roots and fungi
  - Aids in absorption into deep parts of plant
- Water and minerals absorb into root hairs through the apoplast and symplast
- When water and minerals reach the inner wall of endodermal cells called the Casparian strip
  - Nutrients have to flow through a symplast to get to the vascular tissue


Movement upward
by tension-cohesion
Xylem
vessels
Endodermis
Casparian
strip
Cortex
Epidermis
Symplast:
interconnected
cytoplasm of
living cells
Phloem
cells
Pericycle
Plasma membrane
Plasmodesma
Cell wall
Water and
dissolved
nutrient
minerals
Root hair
Apoplast:
interconnected
cell wall spaces
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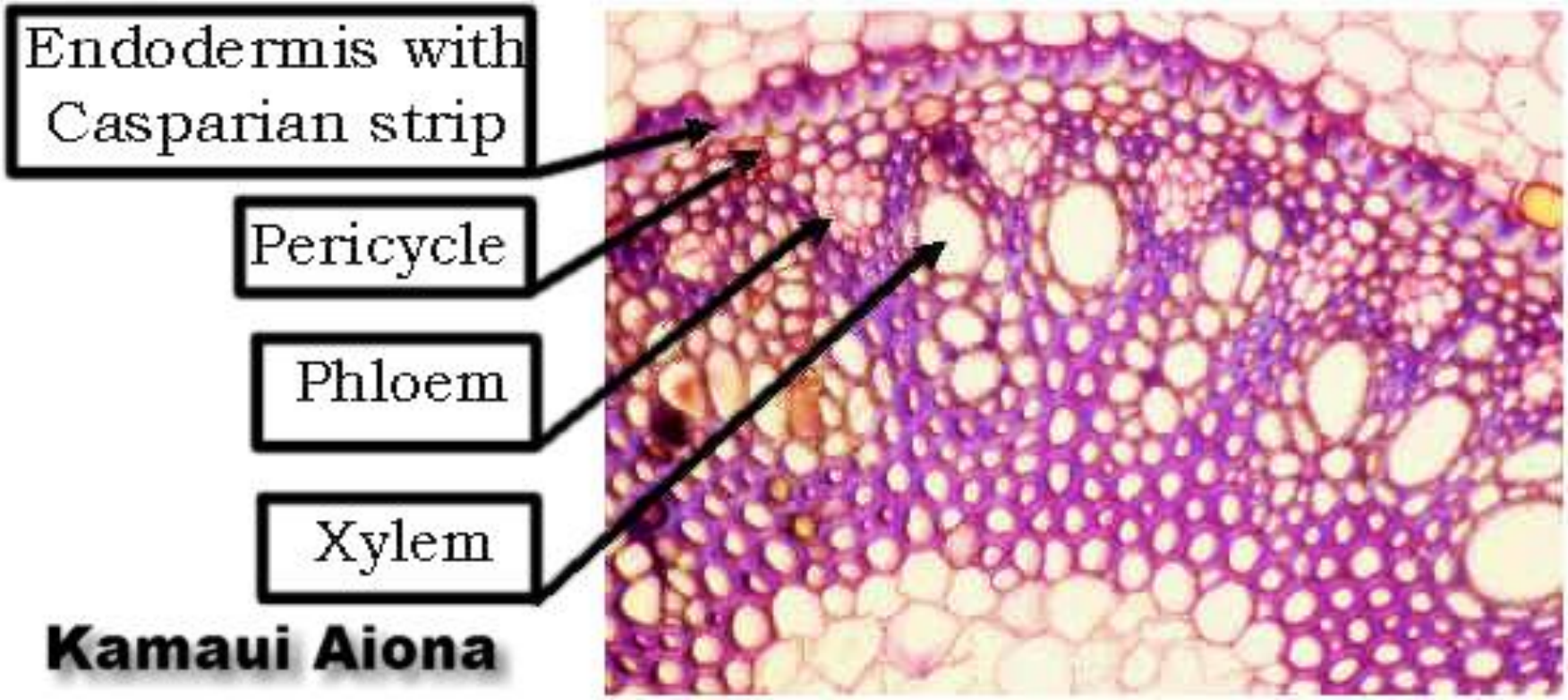
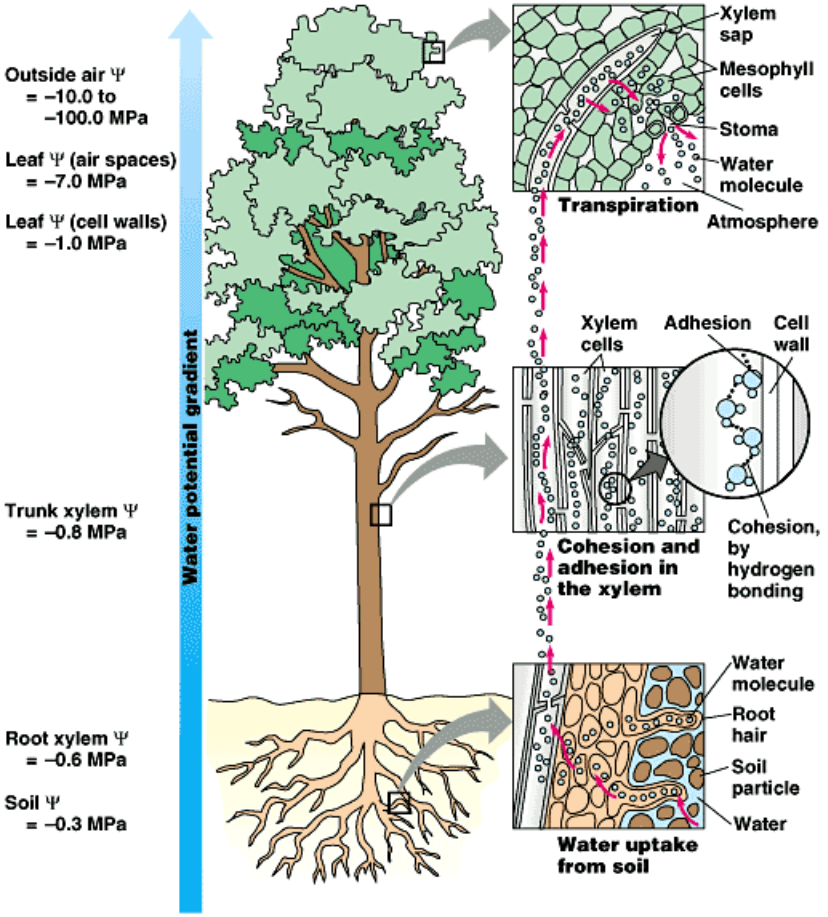


Kamaui Aiona

Transport of Xylem Sap

- Negative pressure in xylem
- Transpiration: loss of water vapor from leaves
  - This *pulls* water from roots (transpirational pull); cohesion and adhesion of water in xylem
- Root pressure: at night (low transpiration), roots cells continue to pump minerals into xylem; this generates pressure, *pushing* sap upwards



Pushed up by root pressure

- Water flows into stele due to high mineral content in root cells
  - Only moves water up a few meters

- Guttation = appearance of water droplets on some leaves in the morning (not dew)
  - Caused from more root pressure entering leaves than is transpired
  - This pressure will not be able to keep pace with transpiration after sunrise, so what can help? …

Pulled up by transpirational pull

- Moves water up the whole length of the plant

- **Transpiration-cohesion-tension theory** = states that for each molecule of water that evaporates from a leaf by transpiration, another molecule of water is drawn in at the root to replace it
- Cohesion and adhesion of water molecules up the xylem contributes to transpirational pull

Steps of Transpirational Pull

- Water vapor diffuses through stomata
- Water vapor is lost from the water around the cell walls of the mesophyll cells
- Creates curve of surface tension between cells which creates a negative pressure potential (decreases water potential)
- Water from cells are transported to the surrounding cells and air spaces in leaves
- Water from xylem is pulled into the surrounding cells to replace ones lost

Stomata

- Guard cells = modified epithelium with chloroplasts and changes shapes to open and close stomata
  - Absorb water (turgid) – curve and open stomata due to cellulose microfibril's arrangement in the cell wall
  - Lose water (flaccid) – stomates close

Factors That Open Stomata

- Depletion of CO_2 within air spaces
  - Beginning of photosynthesis
- Opening correlates with H^+ actively moving out of guard cells
- Increase K^+ in guard cell and decrease water potential so water comes into cells which causes cell to swell
- Stimulation of blue light receptor (sensor) in guard cell
  - Increase activity of proton pumps which increases K^+ uptake

Factors That Close Stomates

- Lack of water → flaccid cells
- High temperature will increase cell respiration and increase CO2 in air space
- Abscisic acid (produced in mesophyll cells) due to dehydration

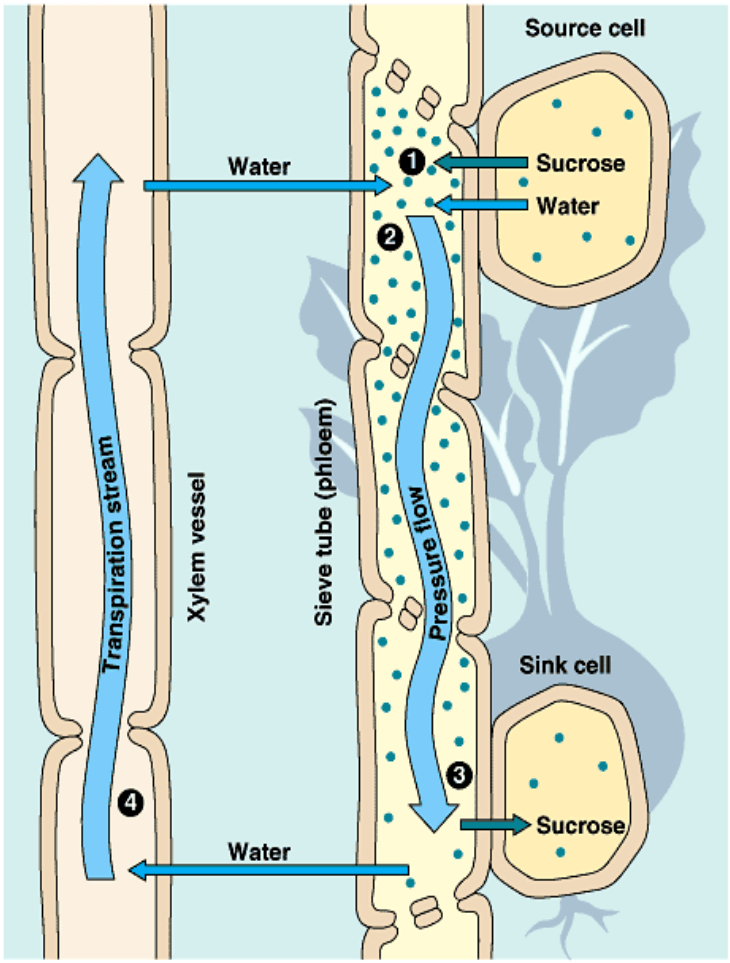
Translocation of Phloem Sap

- Translocation: food/phloem transport
  - Phloem sap contains mostly sucrose, and then amino acids, hormones, and minerals

- Sugar source: sugar production organ (mature leaves)
- Sugar sink: sugar storage organ (growing roots, tips, stems, fruit)

Phloem Sap

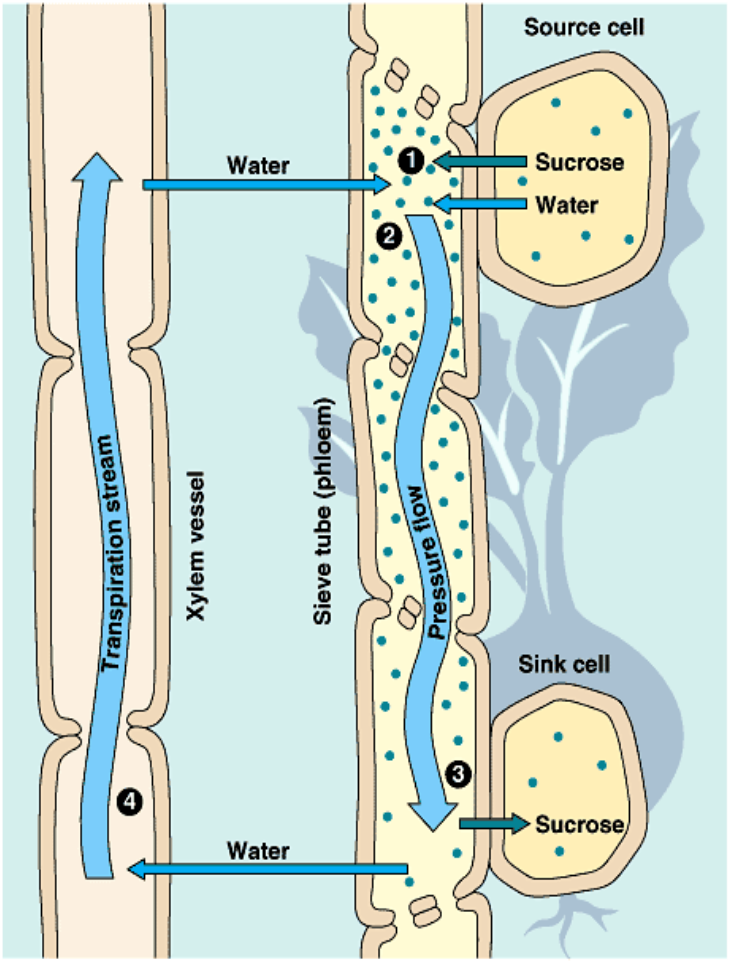
- Sucrose can move through the symplast to the sieve-tube elements or through the apoplast and actively transported into the sieve tube
- Loading of sugar into sieve tube at source reduces water potential inside; this causes the sieve tube to take up water from surroundings by osmosis
- This absorption of water generates positive pressure that forces sap to flow along the tube

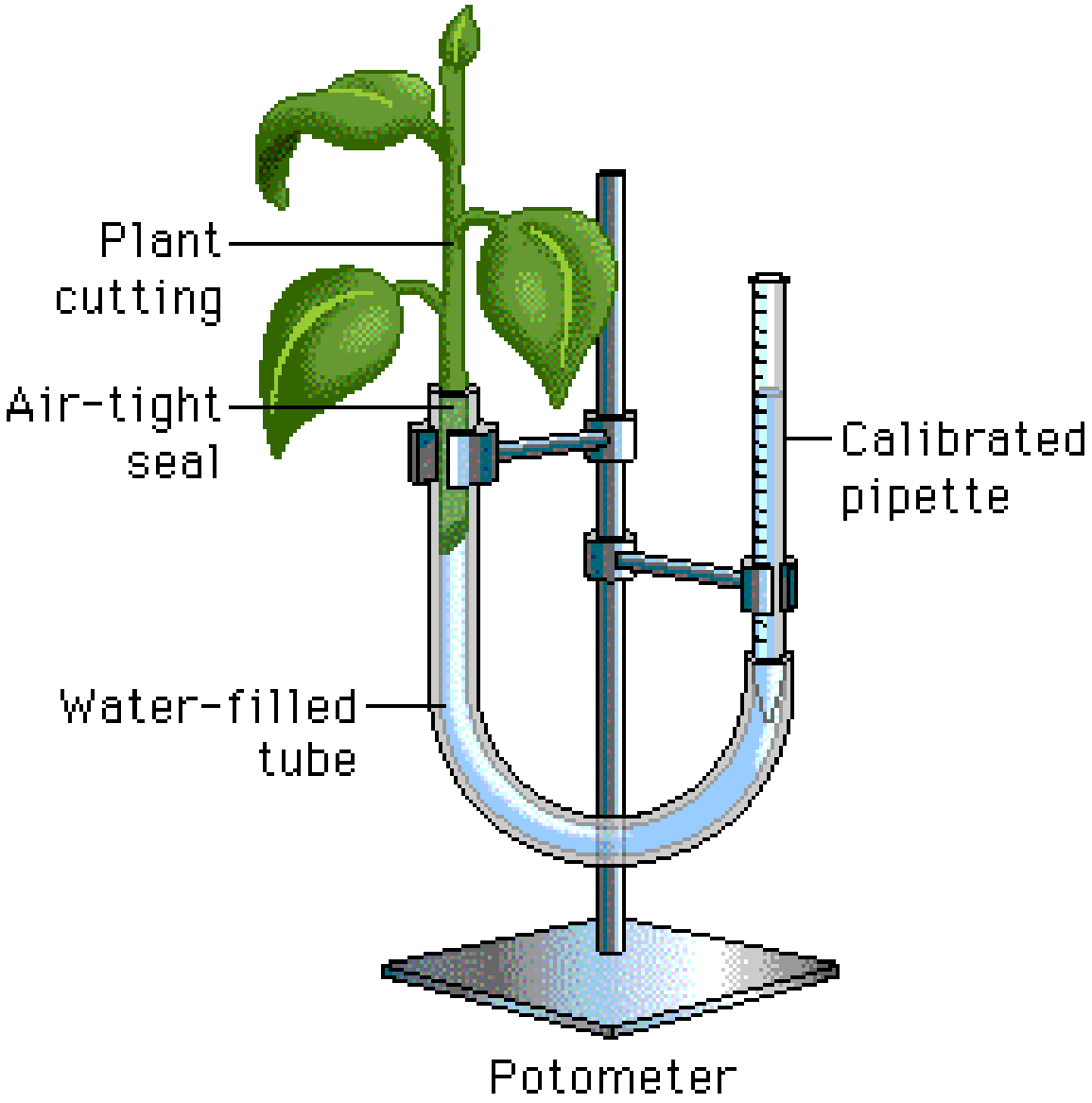


Phloem Sap

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

- Xylem then recycles water from sink to source




Plant cutting
Air-tight seal
Water-filled tube
Calibrated pipette
Potometer