Chapter 38

Transport of materials in plants

- Root system absorbs water and dissolved minerals from the soil
- Shoot system takes CO2 from the atmosphere via stomata
- Photosynthetic cells use these materials to produce organic compounds needed for growth and reproduction
- long-distance transportation occurs withing the plant body using a continuous system of conducting materials
    - Xylem
        - transport water and dissolved minerals
        - Only goes up
    - Phloem
        - transports food and other solutes (hormones)
        - Goes up and down

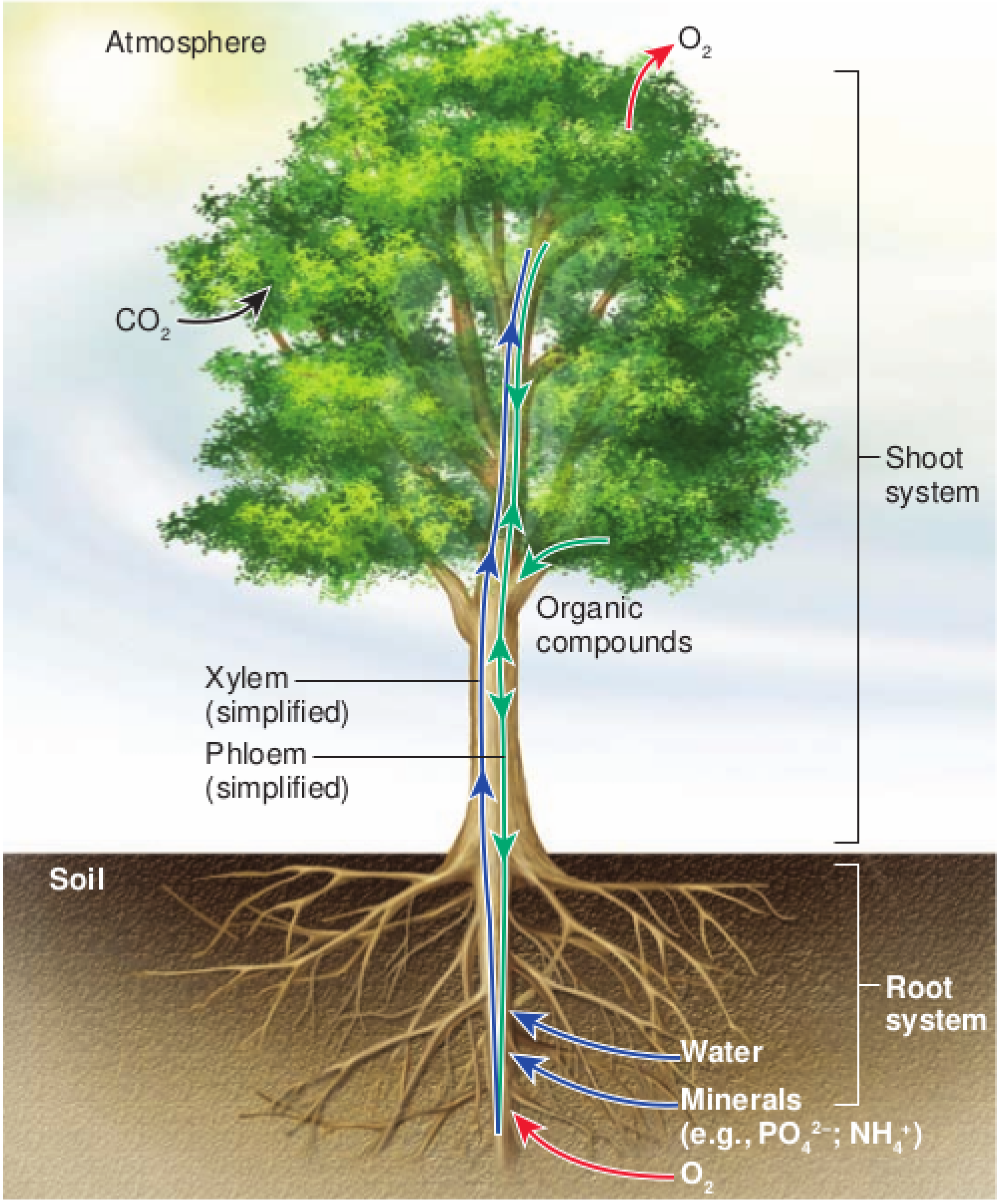


Figure 38.1 Overview of material uptake and long-distance transport processes in plants.

Importance of water

- Photosynthesis
- support of plant organs
- conduction
- cell elongation
- most chemical reactions
- Average plant is 90% water
- Solvent for most substances
  - Solution
    - Solvent
    - Solute

Properties of water

- Polar molecule
  - neutral
- Hydrogen bonding
- Cohesiveness
- Adhesiveness
- Temperature Stabilizer
- Transport medium
- Best biological solvent
- Occurs in all 3 forms of matter within earth's temperature range

Principles of movement

- Bulk\Mass flow
  - Mass movement of liquid cause by pressure and\or gravity
  - Ex: leaching
    - movement of ion though soil to plant roots
  - Faster than diffusion
- Diffusion
  - high concentration > low concentration
  - Simple diffusion
    - Movement of molecules through a phospholipid bilayer down a concentration gradient
  - Facilitated Diffusion
    - transport of molecules across a plasma membrane down a concentration gradient with the aid of membrane protiens
- Osmosis"gatekeeper"
  - Diffusion across a selectively permeable membrane in response differences in solute concentration
  - simple diffusion of water does not occur rapidly enough for rapid expansion of plant cells
  - Aquaporins
    - protein channels that allow facilitated diffusion of water

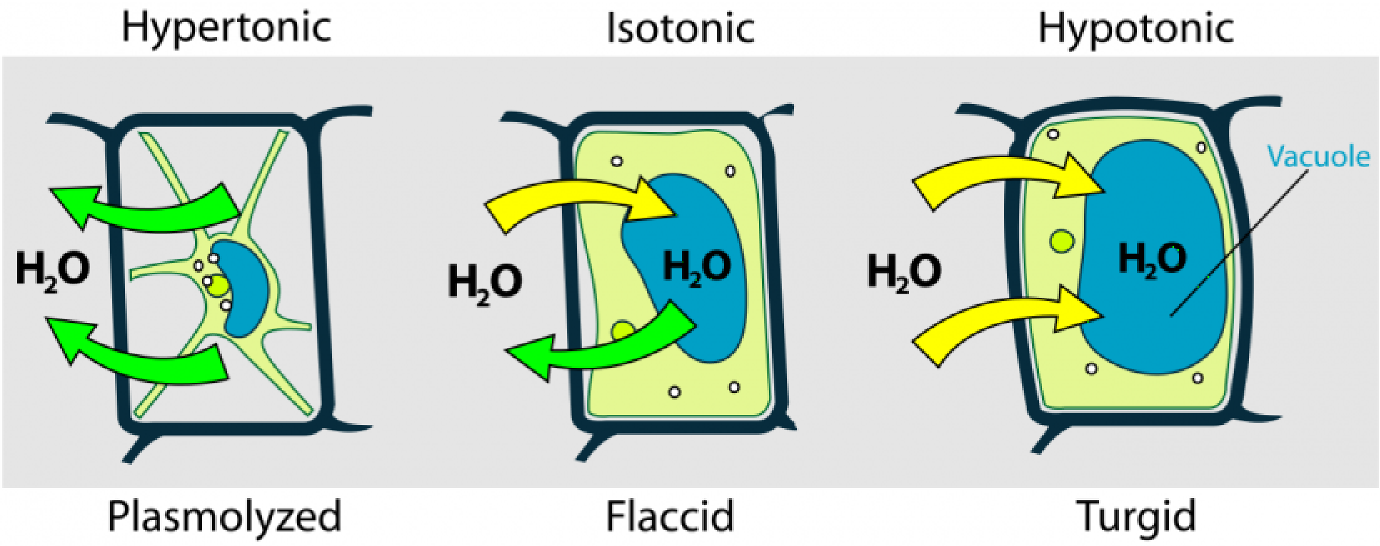
Tissue-level transport

- trans-membrane transport
  - export of material via membrane proteins, followed by import of the same substance by an adjacent cell
  - Ex. Auxin transport aided by carrier protiens
- Symplastic Transport

    - Movement from cytosol of one cell to cytosol of another cell via plasmodesmata
        - Cytosol
            - Everything inside the cell wall
- Apoplastic transport
    - movement along cell walls and inter-cellular spaces
    - Ex: water and disolved minerals

Cellular water content

- water content of plant cells depends on osmosis, which depends on:
    - Solute concentration
    - Turgor preassure
        - hydrostatic pressure that increases as water enters plant cells
        - cell walls restrict the extent to which the cells can swell



    - Turgid plant cell has cytosol full of water and plasma membrane pushes up against the cell wall
    - Plasmolyzed cell has lost so much water that turgor pressure is lost and the plasma membrane no longer presses on the cell wall

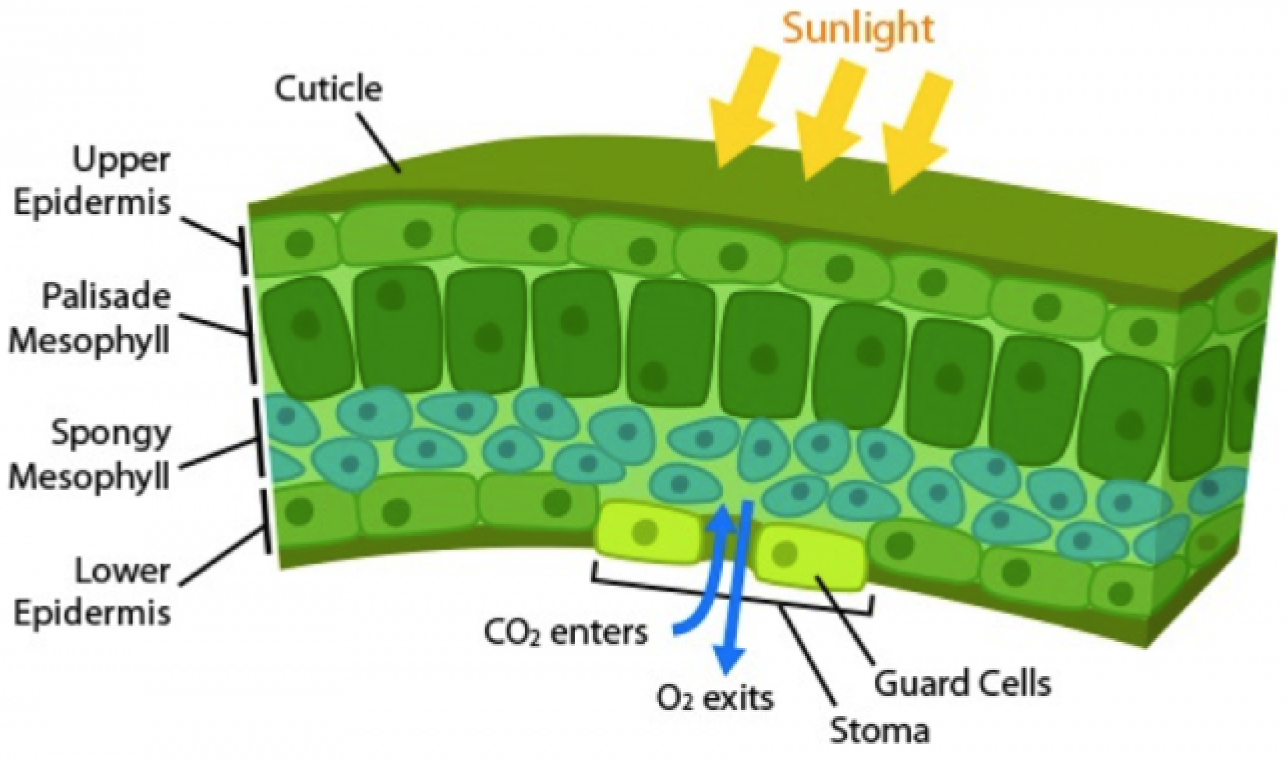
Water potential

- Potential energy of water
- Water moves from highest to lowest water potential
    - affected by
        - pressure
        - solute concentration
        - other factors (damage, temperature)

- Concept used in 2 ways
  - to understand the movement of water into and out of cells (cellular water potential)
  - to understand the movement of water between entire plants and their enviroments

Water (and soil mineral) movement through the plant

- Transpiration
  - Evaporation of water from plant surfaces
  - "cost" for the plant to live on land
  - capable of pulling water up by bulk flow
  - primary form of long distance water transportation in plants



Most carbon dioxide enters plants through stomata that are tiny openings guarded by cells. Most stomata are found in the leaves of plants. Click for more detail.

- Stomata
  - Opening has 2 guard cells
    - control balance of CO_2, O_2, and H_2O inside leaf

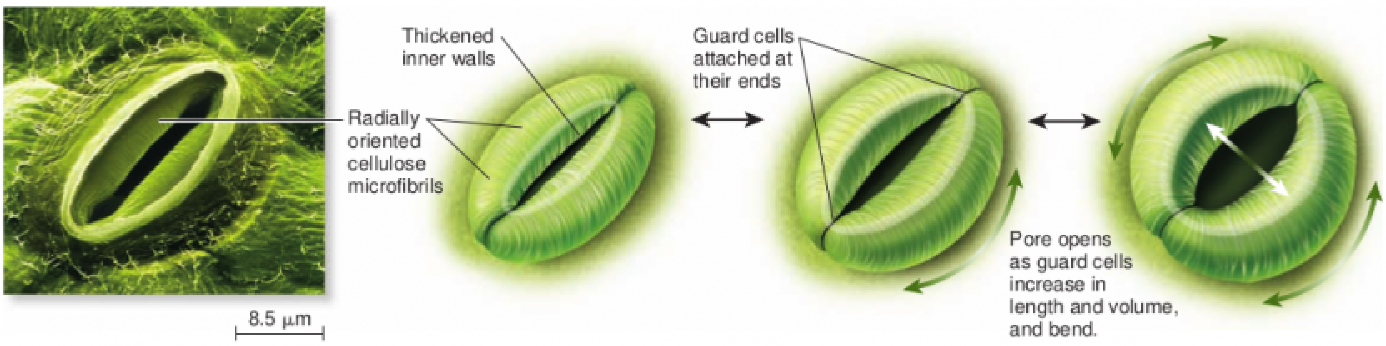
Xylem

- Flowering plant xylem consists of 4 types of cells

1. Xylem parenchyma cells
2. Thick-walled supportive fibers
    - may be alive or dead at maturity
3. vessel elements
    - Speacilized water conducting cells and are always dead and empty of cytosol when mature
    - Wide tubes
4. Tracheids
    - tracheory elements
        - Rich in lignin which offers strength, durability, and water proofing
    - Narrow tubes

Stomata

- Plants produce a waxy cuticle to prevent water loss
- stomata facilitate gas exchange
- 90% of water that evaporates from plants is lost through stomata
- when stomata are open, O2 and water vapor are released and CO2 is taken up
- controlled by guard cell pairs



(a) Stomatal guard cells

(b) The roles of radial orientation of cellulose microfibrils and thickened inner walls in opening or closing guard cells

Figure 38.17 **The structure of stomatal guard cells.** When flaccid, guard cells close stomatal pores. Turgid guard cells produce a stomatal opening. **(a)** An SEM of a stomate in a rose leaf, showing the two guard cells bordering a partly open pore. **(b)** Thickened inner cell walls and radial orientation of cellulose microfibrils in the guard cell walls explain why they separate when turgid, forming a pore.

Concept check: How could you make a physical model that would illustrate how guard cell structure affects its function?

Mechanisms of Guard cells

- Daytime/sunlight
    - CO2 is low in leaf
- Guard cells "pump" in K (potassium)
    - Changes solute concentration
- H2O from xylem moves by osmosis onto guard cells
    - cells become turgid
- Guard cells swell and open stomata
    - CO2 diffusion into leaf
- "Pump" out K (potassium)
    - H2O moves out by osmosis out of guard cells causing shrinking

- Pumping
    - Expenditure of ATP energy

Causes of water loss

- Sunlight energy
    - heats up leaf causing evaporating of H_2O from mesophyll cells
    - Causes a decrease in H_2O concentration causing a "pull" of H_2O
    - This "pull" moves H_2O though the "Transpiration stream"

Transpiration Stream

- Soil H_2O (and nutrients)
- root epidermis
- root cortex
- endodermis
- root xylem
- stem xylem
- leaf xylem
- mesophyll
- Vapor into atmosphere

Unidirectional movement
Only goes UP!

C-A-T Mechanism

- Occurs once the stomata are open
- Purely a physical process
- "pull" of H_2O one molecule at a time
- unidirectional movement
- **C**ohesion
    - H_2O molecules stick together
- **A**dhesion
    - H_2O adheres to cellulose in cell walls
- **T**ension
    - "pull" due to H_2O loss from mesophyll
- NO ENERGY expended
- Only energy is sunlight heating leaf

Solute movement in plants

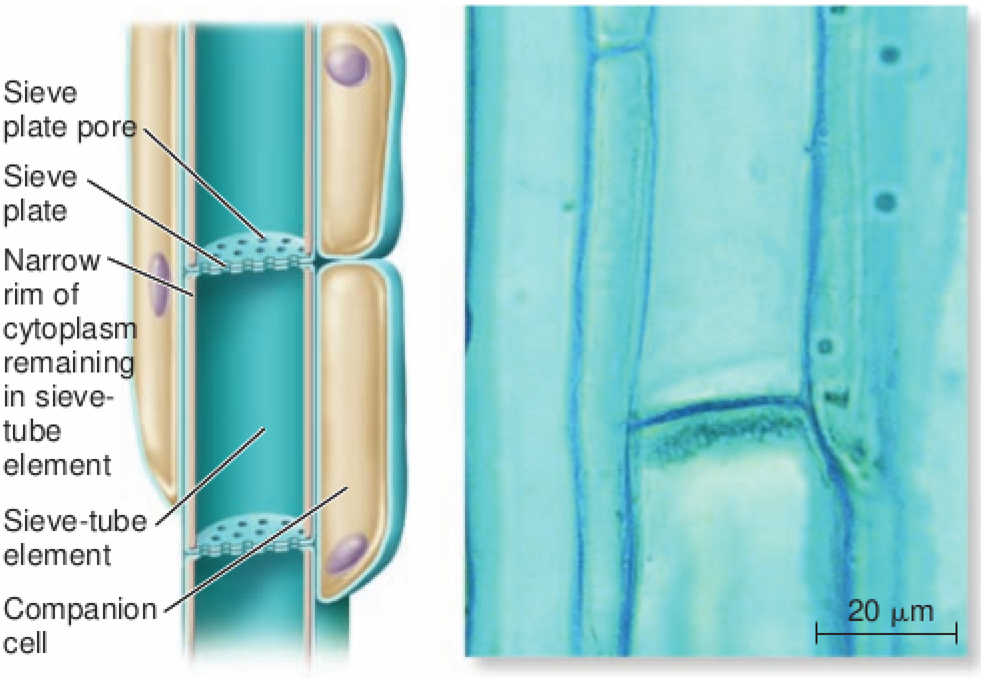
- Translocation
  - movement of solutes in plants
- food
  - dissolved in H_2O
  - Moved in form of Sucrose
- Goes form Source to Sink
  - Site with excess of carbohydrate
  - Site where the carbohydrate is stored or immediately needed
- Bidirectional

Long-distance transport in phloem

- Phloem transports sugars from where they are produced and\or stored to other sites where they are stored and/or needed
  - Source > Sink
- Primary Phloem
  - Occurs in the vascular bundles of herbaceous plants
- Secondary Phloem
  - Occurs as the inner bark of woody plants

Phloem Structure

- Phloem of flowering plants in composed of **supporting fibers**, **parenchyma cells**, **sieve-tube elements**, and **adjacent companion cells (members)**
- Sieve-tube members (STM) are arranged end-to-end , and together with companion cells, form a system to transport soluble organic substances
  - Sieve-tube members lose their nucleus and most of the cytoplasm to reduce obstruction to bulk flow
  - phloem sap passes through sieve plate pores



(a) Sieve-tube elements and companion cells

(b) Light micrograph of phloem stained with blue dye, showing sieve-tube elements

Figure 38.21 Sieve-tube elements and companion cells.

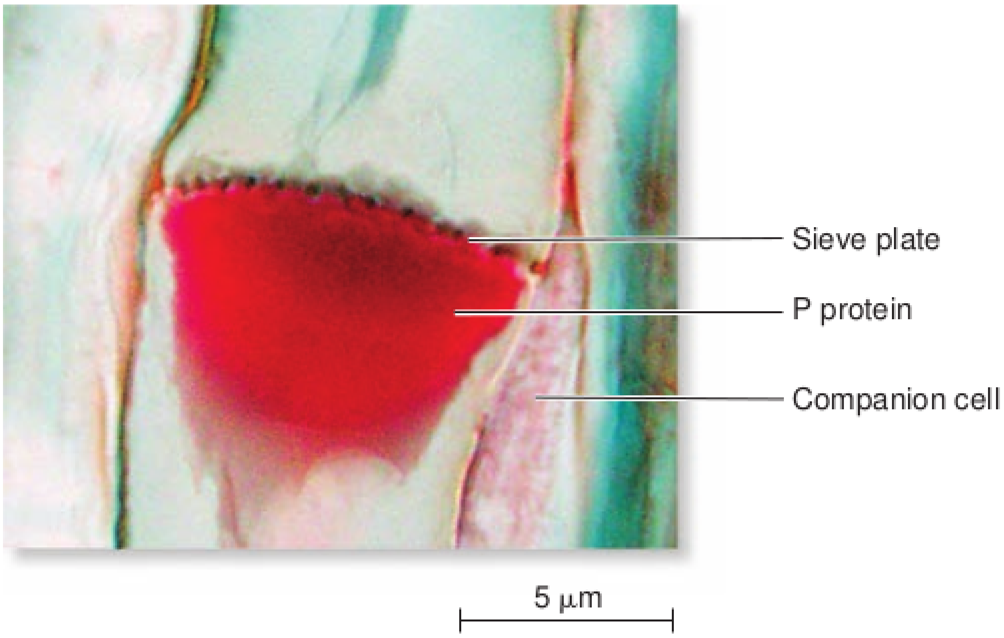


Figure 38.22 **Phloem wound response.** When phloem is damaged, the cytoplasm of a sieve-tube element surges toward the sieve plate, depositing P protein, stained red in this light micrograph. In this location, P protein helps to prevent infection and leakage of solutes.

Pressure Flow Hypothesis

At source

1. Companion cells "pump" sucrose into STM (STP expended)
2. As sucrose concentration increases in STM, water potential (concentration) decreases within STM
3. Adjacent Xylem has higher water potential than STM, H2O moves into STM by osmosis

Bulk flow of Sucrose
Higher Pressure > lower Pressure

At sink

1. Companion cells unload sucrose (ATP expended)
2. Sucrose converted into starch for storage in root cortex
3. Without sucrose, higher H2O potential in STM
4. H2O moves from STM to adjacent Xylem by osmosis

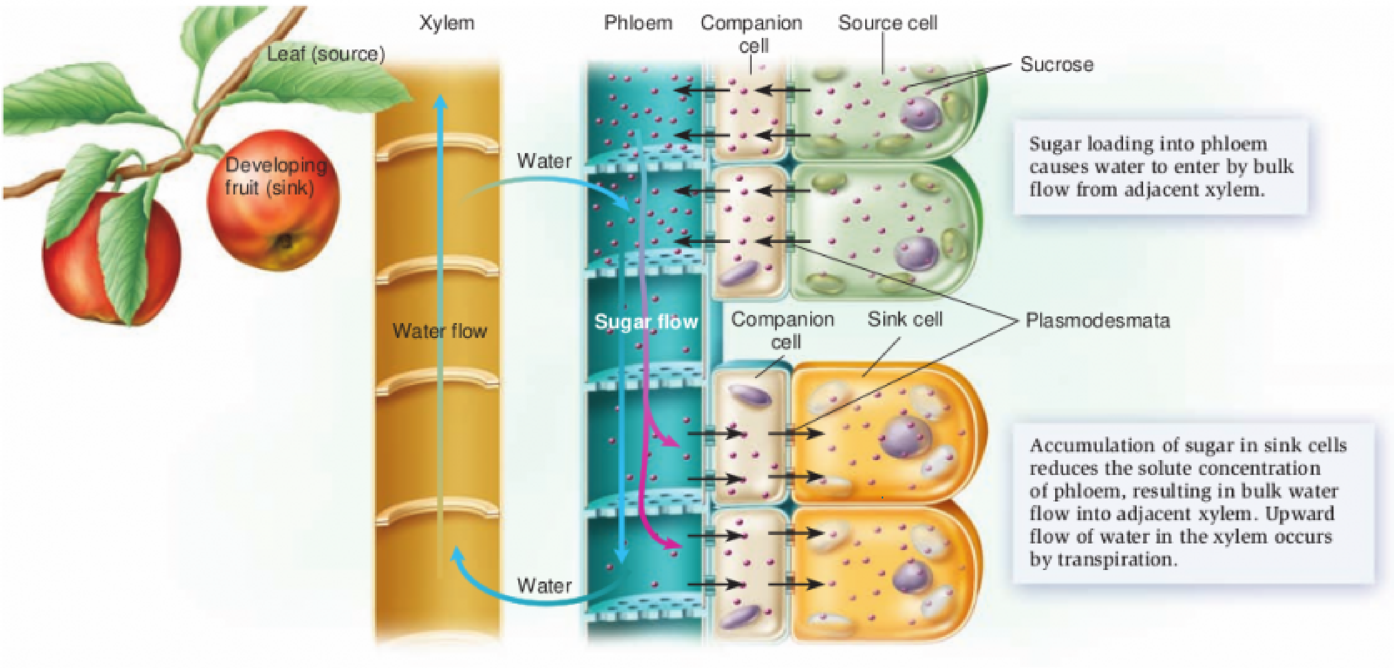


Figure 38.24 Pressure-flow hypothesis for phloem transport.

- ATP spent only by companion cells at source (loading) and sink (unloading)
- Bulk flow (pressure/potential differences) and osmosis (H2O potential\concentration differences)
  - No energy Expended

Similarities Between Translocation and Transpiration

- Both involve conduction

- both involve physical properties of H2O

Translocation	Transpiration
• Phloem • Bidirectional • Must expend ATP energy by plant	• Xylem • Unidirectional • Sunlight energy (no expenditure by plant)

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