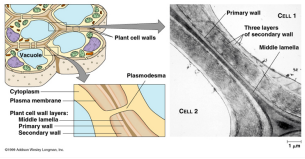
Compartments and Transport

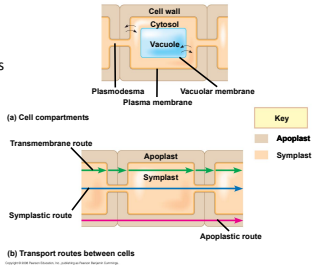
- **Plasmodesmata**
  - Channels connecting neighboring cells
  - Cell membrane and cytosol are continuous from cell to cell
- **Symplast**
  - Cytoplasmic continuum
    - Through plasmodesmata
- **Apoplast**
  - continuum of cell walls and extracellular spaces including interior of dead cells



Three Major Pathways of Transport

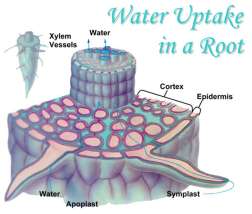
- Water and minerals can travel through a plant by three routes:

1. **Transmembrane route**
   - out of one cell, across cell wall/membrane
     - into another cell
2. **Symplastic route**
   - via the continuum of cytosol
3. **Apoplastic route**
   - inside cell walls and extracellular spaces



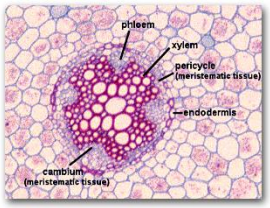
Absorption of Water and Minerals by Root Cells

- Bulk flow
- Most water and mineral absorption
  - Occurs near root tips
    - Epidermis is permeable to water
      - Location of root hairs
        - Add surface area
- Soil solution enters the roots
  - Via symplastic or apoplastic route



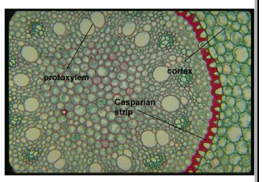
Transport of Water and Minerals into the Xylem

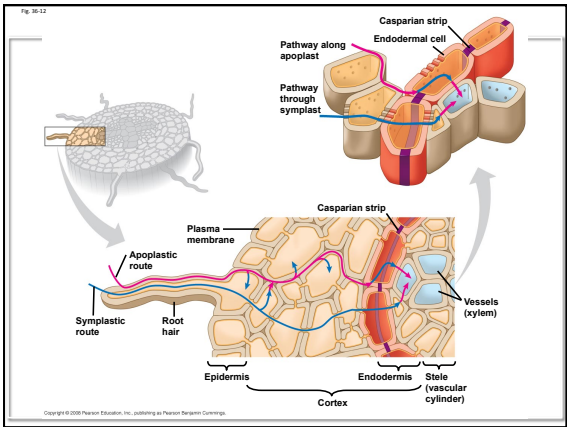
- **Endodermis**
  - Innermost layer of cells in the root cortex
  - surrounds the vascular cylinder
  - last checkpoint for selective passage of minerals
    - from the cortex into the vascular tissue



Transport of Water and Minerals into the Xylem

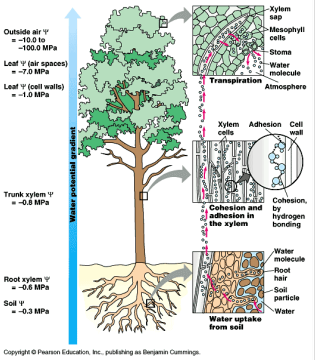
- Water can cross the *cortex* via the symplast or apoplast
- **Casparian strip**
  - Suberin layer in the endodermal wall
  - Blocks apoplastic transfer of minerals
    - from the cortex to the vascular cylinder
  - Forces the symplastic route
    - Allows filtering of soil solution by selective permeability





Bulk Flow Driven by Negative Pressure in the Xylem

- **Transpiration**
  - evaporation of water from a plant's surface
  - Plants lose a large volume of water in this way
- Water replaced by the bulk flow of water and minerals
  - called **xylem sap**
    - from the steles of roots to the stems and leaves
- Is sap mainly pushed up from the roots, or pulled up by the leaves?



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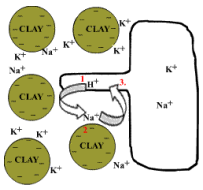
Pushing Xylem Sap: Root Pressure

- At night
  - transpiration is very low
  - root cells continue pumping mineral ions
    - into the xylem of the vascular cylinder
      - lowering the water potential
- Water flows in from the root cortex
  - generating positive **root pressure**

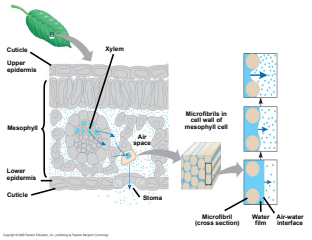


Pushing Xylem Sap: Root Pressure

- **Guttation**
  - Root pressure
    - sometimes results in the exudation of water droplets on tips or edges of leaves

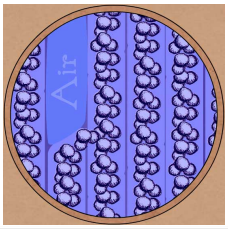
Pushing Xylem Sap: Root Pressure

- Positive root pressure
  - is relatively weak
  - minor mechanism of xylem bulk flow
- Negative pressure
  - Water is pulled upward in the xylem
- Transpirational pull
  - produces negative pressure (tension) in the leaf
    - Exerts a pulling force on water in the xylem, pulling water into the leaf



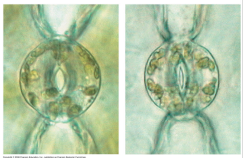
Cohesion and Adhesion in the Ascent of Xylem Sap

- Cavitation
  - Formation of a water vapor pocket in xylem
    - By a break in the chain of water molecules
    - Caused by drought stress or freezing



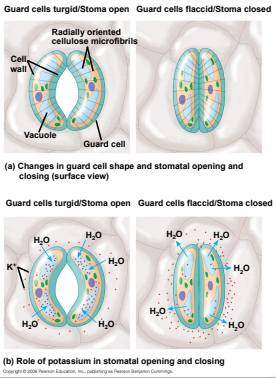
Stomata regulate the rate of transpiration

- Leaves generally have broad surface areas
  - and high surface-to-volume ratios
    - increases photosynthesis
      - But also increases water loss through stomata
        - ~95% of plant water loss
- Each stoma
  - Flanked by a pair of guard cells
  - Control opening of stoma by changing shape



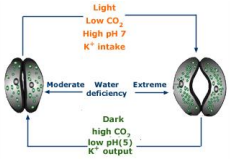
Mechanisms of Stomatal Opening and Closing

- Changes in turgor pressure in guard cells
  - open and close stomata
    - primarily from reversible uptake/ loss of potassium ions
    - K+ co-transported by proton pumps



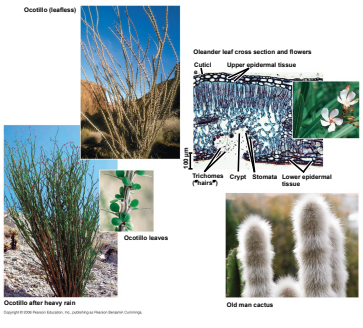
Stimuli for Stomatal Opening and Closing

- Generally
  - stomata open during the day
  - close at night
    - to minimize water loss
- Stomatal opening at dawn is triggered by:
  - Light
    - Blue light receptors stimulate K+ uptake
  - CO_2 depletion
  - Internal "clock" in guard cells
    - Functions even in the dark
    - **circadian rhythm**
      - 24-hour cycles of behavior



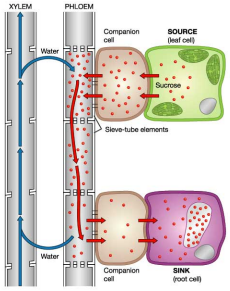
Adaptations That Reduce Evaporative Water Loss

- **Xerophytes**
  - plants adapted to arid climates
  - leaf modifications
    - reduce the rate of transpiration
- **Crassulacean acid metabolism** (CAM)
  - Specialized form of photosynthesis
    - where stomatal gas exchange occurs at night



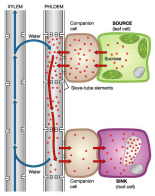
Sugar Transport

- **Translocation**
  - Process of transporting the products of photosynthesis through phloem



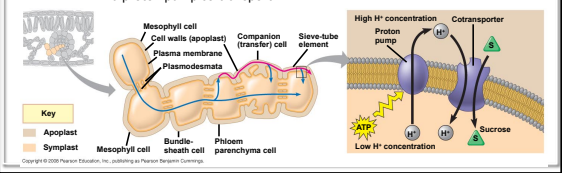
Movement from Sugar Sources to Sugar Sinks

- **Phloem sap**
  - Aqueous solution that is high in sucrose
  - Travels from a sugar source to a sugar sink
- **Sugar source**
  - An organ that is a net producer of sugar
    - mature leaves
- **Sugar sink**
  - An organ that is a net consumer or storage unit of sugar
    - tuber or bulb
- A storage organ can be both a sugar sink in summer and sugar source in winter



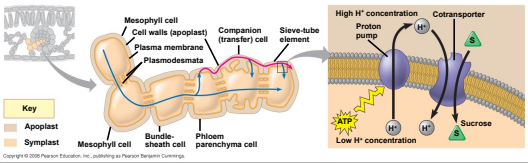
Movement from Sugar Sources to Sugar Sinks

- Sugar
  - Must be loaded into sieve-tube elements before being traveling to sinks
- Depending on the species
  - May move by symplastic or both symplastic and apoplastic pathways
- **Transfer cells**
  - Modified companion cells
    - enhance solute movement between the apoplast and symplast
    - Via proton pump co-transport



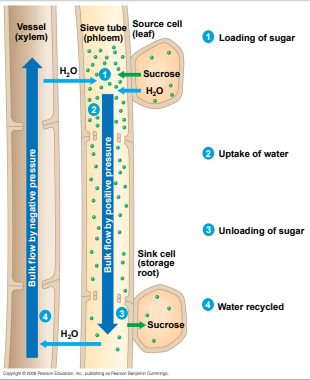
Movement from Sugar Sources to Sugar Sinks

- In many plants
  - Phloem loading requires active transport
- Proton pumping and cotransport of sucrose and H^+
  - Enable the cells to accumulate sucrose
- At the sink
  - Sugar molecules diffuse (facilitated) from the phloem to sink tissues
    - followed by water



Bulk Flow by Positive Pressure

- Sap moves through a sieve tube by bulk flow driven by positive pressure
  - Called pressure flow
    - Increasing pressure at source end
    - Reduced pressure at sink end



You should now be able to:

1. Describe how proton pumps function in transport of materials across membranes
2. Define the following terms: osmosis, water potential, flaccid, turgor pressure, turgid
3. Explain how aquaporins affect the rate of water transport across membranes
4. Describe three routes available for short-distance transport in plants

You should now be able to:

5. Relate structure to function in sieve-tube cells, vessel cells, and tracheid cells
6. Explain how the endodermis functions as a selective barrier between the root cortex and vascular cylinder
7. Define and explain guttation
8. Explain this statement: "The ascent of xylem sap is ultimately solar powered"
9. Describe the role of stomata and discuss factors that might affect their density and behavior
10. Trace the path of phloem sap from sugar source to sugar sink; describe sugar loading and unloading