Xylem Sap Ascent by Bulk Flow: A Review

- The movement of xylem sap against gravity is maintained by the transpiration-cohesion-tension mechanism.
- Transpiration lowers water potential in leaves, and this generates negative pressure (tension) that pulls water up through the xylem.
- There is no energy cost to bulk flow of xylem sap.

Stomata regulate the rate of transpiration

- Leaves generally have broad surface areas and high surface-to-volume ratios.
- These characteristics increase photosynthesis and increase water loss through stomata.

Stomata: Major Pathways for Water Loss

- About 95% of the water a plant loses escapes through stomata.
- Each stoma:
  - Flanked by a pair of guard cells.
  - Control the diameter of the stoma by changing shape.
Mechanisms of Stomatal Opening and Closing

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

Stimuli for Stomatal Opening and Closing

- Generally, stomata open during the day and close at night to minimize water loss
- Stomatal opening at dawn is triggered by:
  - Light
    - Blue light receptors stimulate K+ uptake
  - CO₂ depletion
  - Internal “clock” in guard cells
    - Functions even in the dark
- circadian rhythm
  - 24-hour cycles of behavior
Effects of Transpiration on Wilting and Leaf Temperature

- Plants lose a large amount of water by transpiration
  - If not replaced plant will wilt
- Transpiration also results in evaporative cooling
  - Can lower the temperature of a leaf and prevent denaturation of various enzymes involved in photosynthesis and other metabolic processes

Adaptations That Reduce Evaporative Water Loss

- Xerophytes
  - Plants adapted to arid climates
  - Have leaf modifications that 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, such as mature leaves

• Sugar sink
  – An organ that is a net consumer or storer of sugar, such as a 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 exposed to sinks

• Depending on the species
  – May move by symplastic or both symplastic and apoplastic pathways

• Transfer cells
  – Modified companion cells that enhance solute movement between the apoplast and symplast
    • Via proton pump co-transport
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 from the phloem to sink tissues
      - followed by water

Movement from Sugar Sources to Sugar Sinks
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

Movement from Sugar Sources to Sugar Sinks

- The pressure flow hypothesis
  - Explains why phloem sap always flows from source to sink
- Experiments have built a strong case for pressure flow as the mechanism of translocation in angiosperms
The symplast is highly dynamic

- The symplast is a living tissue and is responsible for dynamic changes in plant transport processes

Plasmodesmata: Continuously Changing Structures

- Plasmodesmata
  - Can change in permeability (open or close) in response to
    - Turgor pressure
    - Cytoplasmic calcium levels
    - Cytoplasmic pH
- Plant viruses can cause plasmodesmata to dilate
  - Normally ~2.5nm
  - Dilate to >10nm
    - Allowing viruses to fit through
Electrical Signaling in the Phloem

• The phloem allows for rapid electrical communication between widely separated organs
  – Responsible for rapid movements in touch sensitive plants
    • Venus flytrap
  – Can initiate changes in
    • gene expression
    • Photosynthesis
    • Respiration

Phloem: An Information Superhighway

• Phloem
  – is a passageway for systemic transport of macromolecules and viruses

• Systemic communication
  – Helps integrate functions of the whole plant
    • Ie signals for conversion of vegetative meristems to floral meristems

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
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