Nutrition and Water Transport in Plants
Excerpts from Chapters 8, 32, 33, 34

II. Sugar Movement Occurs in Phloem

A. Sucrose is formed in the photosynthetic region of the plant (a source)
   1. Moves from source to sink (site of insoluble starch storage or usage) via the phloem
   2. Moves up AND down the plant

B. The Pressure-Flow Hypothesis
   1. Protons: sieve tube cells ? phloem parenchyma via active transport
   2. Protons move back into the sieve tube cells by co-transport with sucrose from leaf mesophyll cells (where sugar produced)
   3. Solutes: in the sieve tubes
   4. Water from nearby xylem to rushes into the phloem sieve tubes, hydrostatic pressure increases, forcing the sugars away from their entry site

D. A Method to Study Phloem
   1. Phloem fluid flow is difficult to study
      Any disturbance mixes contents with contents of other cells
   2. Aphids have evolved to direct their mouthparts directly into the phloem
   3. Biologists allow aphids to insert mouthparts into the phloem – then cut off the body with a laser beam!
   4. Can follow movement of phloem by examining the tiny droplets of fluid that continue to flow out of the embedded mouthpart
   5. Allows analysis of phloem fluids

Rays, Chains of Parenchyma, Provide Lateral Movement of Water and Nutrients

Cross Section of Tree Trunk: Heartwood and Sapwood

- Heartwood
  - Dark, full of waste products:
  - Tannins, pigment, gums & resins
  - Resistant to decay
• Sapwood
  – Functioning xylem
  – Carries nutrients and water

III. Water and Nutrient Transport from the Roots
A. Water and dissolved nutrients enter the roots
  1. ? root xylem: system of dead tracheid and vessel element cells of the
  2. Movement of water into the root is rapid; pulled to the top of the tree because of differences in the water potential

B. Water potential (?) refers to the free energy of water; another way to describe osmosis
  1. ? pure water = 0 megapascals (MPa)
  2. Solute lowers the ? – decrease the relative amount of free water; solutions have ? <0
  3. Water moves from regions of high to low water potential

C. Soil water potential varies
  1. If wet, potential is high; if dry, potential is low (why?)
  2. Usually the water in the plant contains more concentrated solute than the soil
  3. Water therefore moves by osmosis into the plant

D. Transpiration—pull of water from top of the plant
  1. Atmospheric ? very low
  2. Water lost through leaf stomata
  3. Water flows into leaf vessels to replace lost water
  4. Water flows up stem xylem to replace leaf water; flow due to capillary action—adhesion and cohesion
  5. Water from root xylem replaces stem water
  6. Water flows into roots to replace root xylem water

E. Transpiration -- Water Loss Through Leaves
• Transpiration = brings water into and through the plant from the root system
• ~99% of this water is lost through aerial parts; mainly via the leaves, through stomata
• Helps in nutrient transport and evaporative cooling
• Excessive transpiration causes temporary wilting; if prolonged, permanent wilting may kill plant
• Provides moisture to the atmosphere; is critical to many local climates; helps control climates globally
F. Root Pressure
1. Roots strengthen the osmosis mechanism by actively pumping ions into their xylem cells
2. This results in osmosis into the xylem as the water follows the solutes
3. Water accumulates and develops ~2 MPa in the root – forces water into the stem xylem
4. *Guttation*, the production of water at the tip of the plant, usually at leaf edges in shorter plants, is a manifestation of root pressure
5. Root pressure is not a significant water movement mechanism in tall trees

Water Movement in Vascular System

V. Plant Associations
1. Plants form associations with other plants and other organisms via their roots
2. Some plants’ roots grow together to form a *graft*
   – Share nutrients, hormones, and sometimes disease
3. Most plants form *mutualistic relationships* with other organisms – usually bacteria or fungi
4. Fungal associations cause formation of *mycorrhizae* allow sharing of nutrients between species
   – Ectomycorrhizae surrounds root
   – Endomycorrhizae penetrates root
5. Bacterial associations are common
   – Such bacteria are called *rhizobia*; form *nodules*
   – Bacteria receive photosynthetic products from plants
   – Nitrogen fixation in bacteria provides essential nutrients to plant

VI. Soil

A. Introduction
1. Thin layer of Earth’s crust – can be a thin film or up to 3m deep
2. Essential elements mainly derived from soil minerals
3. Minerals originate from rock weathering via freeze-thaw cycle, wind and water erosion, etching by lichens, action of plants on rocks

37  B. Soil Components
1. ~45% is mineral materials
2. ~5% is organic matter: humus from partly decomposed organisms
3. ~25% is water
4. ~25% is air
5. Components vary in ratio from soil type to soil type
6. Larger particles (0.02-2 mm) called sand
7. Medium are silt (0.002-0.02 mm)
8. Smallest are clays (< 0.002 mm); their surface area is very large

38  C. Clays
1. Clays are charged with K\(^+\), Mg\(^{2+}\), Ca\(^{2+}\) other important ions
2. Root hairs secrete acid (H\(^+\)) that performs ion exchange with the clays
3. Thus, root hairs absorb mineral nutrients

39  D. Soil Pore Space
a. Wet soils have little air space
b. Dry soils have water surrounding soil particles

40  E. Soil pH
- Different nutrients soluble at different pHs
- Acid soils can cause the release of potentially toxic elements such as aluminum and manganese
  - Some elements become bound up in acid soils, for example phosphorus
  - Acid soils can excessively leach out important mineral nutrients
- Pollution that produces sulfuric and nitric acids can have profound effects on soil

42  F. Human Impact on Soil Resources
1. Mismanagement of soil resources can be devastating: e.g., erosion, nutrient depletion, increased acidity, increased salinity
2. Complex, organic fertilizers that slowly release nutrients are supportive of soil composition
3. Commercial inorganic fertilizers are rapidly absorbed by plants
  - Can be very supportive to growth of plants and other organisms
  - Easily leached away because they are soluble chemical additives
  - Pollute rivers, marine habitats causing local algal problems

43  G. Salinity
1. Improper irrigation can cause the accumulation of salt in soil
2. Irrigation water often is held in place by dams
3. Water evaporates in place, leaving salts carried by the water in place
4. Water moves out of plant into soil: dehydration, nutrient uptake