12 October 2016

Transportation in Plants

I. Water and Solute Transport in Plants
   a. Water and minerals
      i. Root to shoot (important to growth and stature)
   b. Food (sugars and amino acids)
      i. Photosynthetic/storage tissues to:
         1. Areas of growth, roots/stems, areas of storage, reproductive tissues

II. Transport in Plants
   a. Uses molecular pumps that move solutes into and out of cells
   b. Exploit physical properties of water to create water flow

III. Transport Routes
   a. Individual cells- Water potential
   b. Within tissues- symplast and apoplast
   c. Long distance- xylem and phloem

IV. Individual Cell Transport Routes
   a. Passive transport
      i. Moves solutes with concentration or electrochemical gradient
      ii. Does not directly need energy
      iii. Done by transporters and channels
   b. Active transport
      i. Moves solutes against concentration or electrochemical gradient
      ii. Needs lots of energy
      iii. Done by molecular pumps
   c. Plasma Membrane ATPase
      i. Most important molecular pump in plants
      ii. Pumps protons out of cell
         1. Makes proton (pH) gradient
         2. Makes electrochemical gradient (voltage)
      iii. Responsible for most energy consumption
      iv. Consumes ATP
   d. Electrochemical gradient is a form of stored energy
      i. Tapped by plants to accumulate and concentrate minerals from the dilute solution outside
      ii. Water then enters cell by osmosis
      iii. Water flows from low to high salt concentration

iv. In a turgid cell, solute potential equals the negative of pressure potential so that water potential equals zero
v. Water always flows from site of high osmotic potential to site of low osmotic potential OR low salt to high salt

V. Water Potential
a. Plasmolysis- water leaves the cell and cell membrane shrinks
b. Flaccid- water enters the cell at the same rate it leaves the cell
c. Turgid- water enters the cell and pushes on the cell wall

VI. Tissue Transport Routes
a. Apoplastic pathway- through cell wall
i. Endodermis- blacks apoplastic flow; allows plants to discriminate what enters the stele
1. All soil minerals have to pass through at least one live cell (endodermis) before reaching shoot
b. Symplastic pathway- through cytoplasm
c. Root Pressure
i. Created by flow of water into stele by chemiosmosis
ii. Pressure can drive water up without transpiration
1. Short plants- grasses in high humidity can have guttation
2. Sap flow up trees in spring
3. Bleeding of tree stumps

VII. Long Distance Transport Routes
a. Hydrogen bonding of water
b. Cohesion-tension (water sticks to itself and to hydrophilic surfaces because of hydrogen bonds)
c. Transpiration pull (as water leaves via transpiration, water is pulled up)
i. Powered by evaporation rate (difference in humidity)
ii. Unavoidable if plants want to obtain CO_2 and release or obtain O_2
iii. Needed for evaporative cooling
iv. Methods for control of transpiration
1. Stomata
2. Leaf/plant architecture
3. Modifications of metabolism
d. Stomata
i. Two cells border each stoma known as guard cells
1. Guard cells use turgor pressure to regulate opening of stomata
2. Guard cells take up ions (K^+ and Cl^-) through ion channels and pumps and water moves in the cell as a result. Cell expands.

            a. Guard cells “puff out” when expanded and open pore
        3. No plasmodesmata in guard cells; isolated from other cells and often photosynthetic
    e. Leaf/Plant Architecture
        i. Thick cuticle
        ii. Recessed stomata
        iii. Epidermal hairs (boundary layer)
        iv. Reduce surface area
            1. Eliminate leaves
            2. Drop leaves
            3. Thick leaves (succulents)
        v. Create water storage tissues
        vi. Avoid dry seasons
    f. Modifications of Metabolism
        i. Improve CO_2 fixation
        ii. C4 Metabolism
            1. Concentrate CO_2 from air by incorporation into C4 organic acids
        iii. Crassulacean Acid Metabolism (CAM)
            1. Fixation of CO_2 at night when humidity is higher
        iv. Reason for C4 and CAM Metabolism
            1. Rubisco is bad at fixing CO_2
            2. It often uses O_2 (not efficient) when plant only wants it to use CO_2
                a. Photorespiration- when rubisco uses O_2, it forms PG (2 carbons instead of 3-carbon PGA). Plant does not want PG so it has to convert it back to RuBP
        v. C4 and CAM allows plants to sue enzyme that is better at CO_2 fixation (PEP Carboxylase)- sugar cane and corn use C4, pineapple uses CAM
            1. C4- moves CO_2 to bundle-sheaths where rubisco is isolated from O_2
            2. C4-PEP carboxylase just allows more capture of CO_2 in mesophyll cells
            3. CAM- stomata in leaves remain shut during day but open at night

VIII. Long Distance Phloem Transport
    a. Ingredients in phloem
        i. Sugars (up to 30% sucrose)
        ii. Amino acids (fixed nitrogen)
        iii. Hormones

iv. Water

b. Transport is always source to sink

c. Source

i. Leaves

ii. Storage organs

iii. Seeds

d. Sink

i. Developing leaves, buds, flowers, fruits, seeds, roots, non-green stems, and storage organs

e. Uses bulk flow driven by water potential

f. Sucrose is loaded in phloem and companion cells along with protons