Physiological Dynamics in Animals & Plants – Lecture 4 – Transport Processes in Plants

I. Transport occurs at three levels in plants: into and out of cells; from cell to cell in tissues and organs; and between roots and shoots through xylem and phloem (long distance transport).

II. Two types of transport mechanisms occur in cells: passive and active.

  A. Definitions: solvent + solute = solution

  B. Membranes are "selectively" permeable to both solvents and solutes.

  C. Passive transport mechanisms include diffusion, facilitated diffusion, and osmosis.

    1. Passive transport does not require metabolic energy.

    2. Facilitated diffusion requires facilitated diffusion "carriers" which are membrane transport proteins.

    3. Some substances enter cells through protein "channels" along their "electrochemical" gradients.

      a. Channels are usually selective for a particular ion (e.g. potassium ion channels).

    4. Osmosis is movement of water across membranes driven by differences in solute concentrations on the two sides of the membrane.

  D. Active transport mechanisms move substances across membranes against their concentration gradients using metabolic energy (usually ATP) as an energy source.

    1. Proton pumps = proton translocating ATPases, are involved in many active transport processes.

2. Active and passive transport mechanisms may be interdependent (e.g. potassium ion uptake dependent on proton pumping).

3. Many substances enter cells by cotransport mechanisms that are coupled to proton pumping.

   a. In cotransport, the movement of one substance down its concentration gradient is coupled to the movement of another substance against its concentration gradient using a protein that carries both substances.

III. Water transport between plant cells, tissues, and organs is driven by differences in water potential.

A. Swelling of plant cells created by osmosis (osmotic pressure = osmotic potential = solute potential = psi_s) is opposed by a physical pressure of the cell wall = turgor pressure = psi_p.

B. The net suction force acting to move water into a cell (tissue, organ) is its water potential, $psi = psi_p + psi_s$.

1. Units are megapascals (MPa) = units of pressure

2. A 0.1 M (molar) solution of any solute has a water potential of about -0.23 MPa.

3. psi_s is always negative in sign; psi_p is always 0 or positive in sign.

4. Plant cells adjust to the same water potential as the external solution in which they are bathed.

   a. Adjustments may be to the osmotic potential, the turgor potential, or both - short-term adjustments are usually turgor adjustments; long-term adjustments are often osmotic adjustments.

b. When psi of the external solution is more negative than psi of the cell, plant cells plasmolyze.

c. A plant cell that has a greater solute (osmotic) potential (concentration) than its surrounding solution has a positive turgor potential and is said to be turgid.

IV. Plant cells have three compartments.

A. Vacuoles are exclusive to each cell.

B. The cells walls of plant cells adjoin each other = the apoplast.

C. The cytosols of plant cell protoplasts (protoplast = plasma membrane and everything inside) are joined by plasmodesmata = the symplast.

D. Water and solutes may travel through the apoplast, through the symplast, or through both.

V. Water and minerals move from soil-to-root-to-shoot-to-leaf-to-air along gradients of increasingly negative tissue, organ, and atmospheric water potential.

A. Root hairs, mycorrhizae, and the large surface areas of cortical cells enhance water and mineral absorption by roots.

B. Roots of plants accumulate minerals to hundreds of times their soil concentration, making plants useful in some cases for "bioremediation".

C. Water and minerals can enter the root cortex by apoplast and /or symplast, but can only enter the xylem in the stele through the symplast of the endodermis; apoplastic movement is blocked by the Casparian strip.

D. Water and minerals are passed from the endodermis into the xylem both actively and passively.

E. Water loss from plants is called transpiration.

1. External air is usually drier than air in the spaces between the cells inside the leaf.

2. Most transpirational water loss is through stomata on the surfaces of leaves.

3. Rates from a maple tree can be as high as 200L per hour

F. Water can be "pushed" up the xylem by root pressure, causing guttation through hydathodes; this is not the major mechanism of water movement through xylem in most plants.

G. Water is pulled up the plant unidirectionally through the xylem during transpiration by a cohesion-tension mechanism.

1. As air evaporates from cell walls of the leaf interior, it is replaced with water from the xylem.

2. Water in the xylem is under a "negative" tension because water is cohesive.

3. Water moves along gradients of increasingly negative water potential.

4. Water leaving the xylem enters both the symplast and apoplast of the mesophyll tissue.

5. Water can rise to heights greater than 100 meters in trees.

6. Cavitation and air embolism inactivate xylem vessels; freezing causes cavitation.

7. The degree of stomatal opening regulates rates of transpiration and determines water use efficiency (WUE).

8. Xerophytes have adaptations that reduce their transpirational water loss: small, thick leaves; thick cuticles, stomata on lower leaf surfaces only; stomata in "crypts"; leaf shedding; CAM.

V. Photosynthate moves through plants through phloem by a process called translocation.

A. Phloem sap contains sugars (mainly sucrose), minerals, amino acids, and hormones.

B. Phloem transport is variable in direction, but flow is from source to sink.

1. Mature leaves are the primary source.

2. Growing tissues are the main sinks (roots, tips of shoots, stems, fruits, etc.)

C. Phloem is composed of sieve-tube members that are arranged end-to-end to form sieve tubes.

D. Phloem must be loaded at the source and unloaded at the sink.

1. In some plants, loading from the mesophyll is entirely through the symplast; in other plants both the symplast and apoplast are involved.

2. In some plants, companion (transfer) cells facilitate loading.

3. Proton pumps may also aid in sucrose loading into phloem.

4. The pressure-flow hypothesis can be used to explain movements of phloem sap in angiosperms.