SA #30	INTRODUCTION TO PLANT WATER RELATIONSHIPS
BIO 2500	Stern et al., Chapter 9

LOOKING BACK: Having studied the *anatomy* of vascular plant stems and roots, we now turn to the *physiology* of plants beginning with an emphasis on *plant water relationships*. Indeed, the structure of plant cells, tissues, and organs clearly reflects "design" features necessary for dealing with water and its physical properties in the plant environment.

EMPHASIS: Based upon your studies of biology, you should be well aware of the importance of water in cellular processes and the "behavior" of water in the processes of diffusion and osmosis. In SA #30, you will be able to review the basic principles of diffusion and osmosis and then learn how the theory of *water potential* is used to account for the behavior of water in both physical models such as an osmometer and in plant cells. A Study Outline of major principles of water relationships is attached to this Guide.

READING: Read Stern, *et al.* Chapter 9, pages 150-154.

PROCEDURE: Read the pages assigned in Chapter 9. Then use the attached Study Outline which includes "Problems" and "Questions" to focus your understanding. When you can answer the LECTURE DISCUSSION QUESTIONS below you have reached the desired learning proficiency.

LECTURE DISCUSSION QUESTIONS – Complete after you have studied the Study Outline:

1. Explain what is right and wrong with the following statement: *water moves from a region of higher water concentration (purity) to a region of lower concentration*. Revise the statement to reflect the truth about water movement at all times.

2. Use the figure on the bottom of page 30.3 of your Study Outline to compare the "scale of *water potential*" or kinetic energy" with the "scale of *celsius degrees*" or thermal energy. Specifically, consider the similarities regarding the following aspects:
   a. the points of reference around which the scales are both constructed
   b. the significance of positive and negative values on the scale, and
   c. the use of any two values on the respective scales to predict the direction of *energy flow*.

3. In what way does an osmometer serve as a physical model of a plant cell? Explain with reference to how the osmometer represents the plasma membrane, cell wall, and turgor pressure.

STUDY OUTLINE -- "Major Principles of Plant Water Relationships" Chapter 9

I. WATER IS AN ESSENTIAL MEDIUM FOR PLANT CELL PROCESSES

II WATER MOLECULES POSSESS *FREE ENERGY* MANIFESTED BY CONSTANT MOTION

A. Kinetic Theory = atoms/molecules are in constant motion (except conditions of absolute zero)

B. Diffusion = net movement of a substance from one point to another as a result of random kinetic activity

>> Evidence for diffusion ? [Brownian movement, odors]

III. THE FREE ENERGY OF WATER IS EXPENDED IN DOING THE WORK OF

A. DISSOLVING SOLUTES...

1. ...by formation of hydration shells

2. ...thus, lowering free energy of water, its motion, and its tendency to diffuse

3. ...causing purer water with higher free energy to diffuse toward a region of "lower-energy"

> Figure 9.3 -- Osmometer

Osmosis = diffusion of H_2O or other solvents across a DPM (differentially permeable membrane)
> See Fig. 9.3

B. CONFIGURING PROTEINS and MEMBRANES -- "hydrophilic/phobic" -- Figure 2.13, 3.7

C. PROVIDING TURGOR PRESSURE -- for leaf/stem support, stomatal regulation

1. Diffusion of water down a free energy gradient generates pressure (Figure 9.3)
2. Free energy of water is expressed by its capacity to generate pressure

IV. FREE ENERGY (or *potential energy*) OF WATER IN A GIVEN SYSTEM DEPENDS UPON

A. Temperature -- influences velocity + number of collisions

e.g. GASES diffuse more rapidly because fewer disruptive collisions

B. Pressure -- increasing no. of molecules/volume --> increased no. of collisions

NOTE: P________________, T_________________ and C__________________ are related

C. Solute -- depletes kinetic energy that the solvent has to form hydration shells

D. Colloids -- large molecules (starch, protein), and clay minerals that bind much water

Examples: ____

NOTE: Do you see the need of a single parameter that encompasses all of the above factors to express the free energy of water? The next page introduces this parameter.

V. THE FREE ENERGY OF WATER IN A GIVEN SYSTEM, COMPARED TO PURE WATER, AT ATMOSPHERIC PRESSURE, AND AT THE SAME TEMPERATURE IS EXPRESSED AS *WATER POTENTIAL*, Ψw WHERE

A.. *Water potential* of pure water equals zero; $\Psi w = 0$

B. Water potential is expressed in *units* of pressure (force per area)

> Units = *megapascals* (MPa) [1 MPa = ~10 atmospheres
1 atmosphere = 14.7 lb pressure; equivalent to 32 ft of H_2O/atm; 760 mm Hg/atm

C. At atmospheric pressure and constant temperature, water potential depends upon *solute concentration* and *pressure* (See III. C.) as expressed by

$\Psi w = \Psi_s + \Psi p$, where

1. Ψ_s is *solute potential* which expresses the extent to which Ψw is lowered (made more negative) by presence of solutes

2. Ψp, is *pressure potential* which expresses the extent to which Ψw is increased (made more positive) by presence of pressure in confined space

VI. WATER ALWAYS MOVES DOWN A FREE ENERGY GRADIENT FROM A HIGHER (less negative) WATER POTENTIAL TO A LOWER (more negative) WATER POTENTIAL

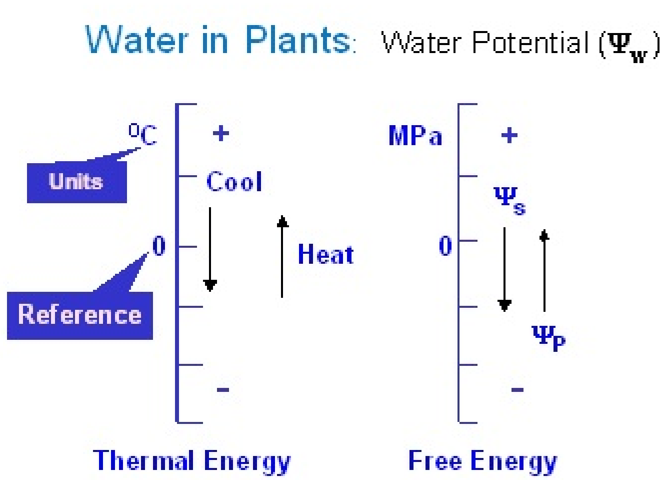
VII. WATER POTENTIAL THEORY EXPLAINS THE BEHAVIOR OF WATER IN

A. OSMOMETERS and PLANT CELLS -- Figure 9.3 and 9.4

B. SOIL-PLANT-AIR CONTINUUM ("SPAC") -- Figure 9.10 and SA #31-32

C. STOMATAL CONTROL -- Chapter 9, pages 157-158 (SA #31-32)

D. VASCULAR TRANSPORT in XYLEM AND PHLOEM -- Chapter 9, pages 155-160 (SA #31-32)



VIII. OSMOMETER AND PLANT CELL

A. OSMOMETER -- a "physical model" of a plant cell

1. ILLUSTRATION: Figure 9.3

2. **PROBLEM #1: Assume that the osmometer contains NaCl dissolved in pure water separated from a surrounding "bath" of pure water by a differentially permeable membrane (DPM):**

a. What is the Ψw of the pure water? (page 30.3) ______________________________

b. Which of the following would be the most accurate estimate of the Ψw of the salt solution? Check one: ___ +0.1 MPa ___ -0.1 MPa

Explain your choice: ____

c. Which way will water move by osmosis? Why? ______________________________

____

3. **PROBLEM #2: Which of the following statements describes the eventual equilibrium?**

a. Water, Na^+, and Cl^- will diffuse across the membrane which is equally permeable to all; and, all three will reach an equilibrium of concentrations.

b. Water will diffuse into the salt solution until the concentration of water reaches equilibrium across the two sides of the DPM.

c. Water will diffuse into the salt solution until the free energy of water (*i.e.* Ψw) reaches equilibrium across the two sides of the DPM.

Explain your choice: ____

____

d. What factor changes to produce equilibrium? ______________________________

e. Based upon PROBLEM #1, part b. above, what is the magnitude of this change? ___________________

f. At equilibrium, what is the Ψw within the osmometer? _______ Outside? _______

B. PLANT CELLS

1. If the osmometer is a model of a plant cell, what cellular feature is represented by

   a. The cellophane DPM ______________________

   b. The NaCl solution ______________________

   c. The pressure increase ______________________

2. What must be the Ψw of water surrounding a cell relative to that of the cytoplasm if

   turger pressure is to be maintained? ______________________

3. Use water potential theory to explain why application of 10% NaCl to *Elodea* cells causes *plasmolysis*?

   ____

4. What is imbibition (page 153) and how does it contribute to the emergence of a root radicle from the seed coat (See Lab Manual, Figure 10-3, *Capsella* seeds)?

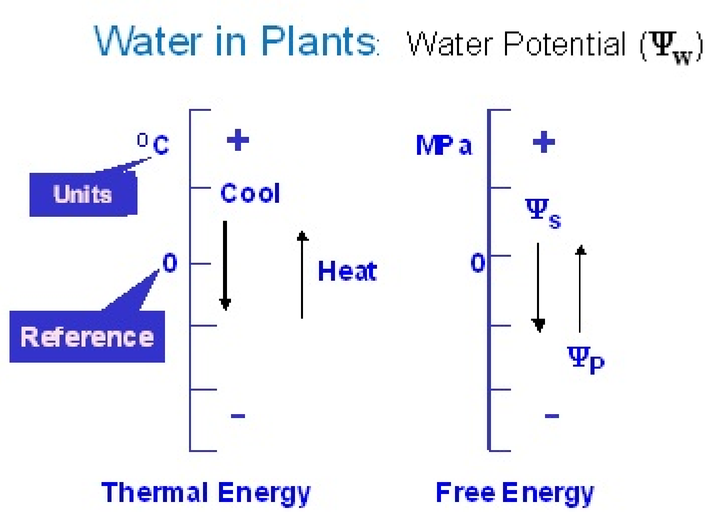
   ____

   ____

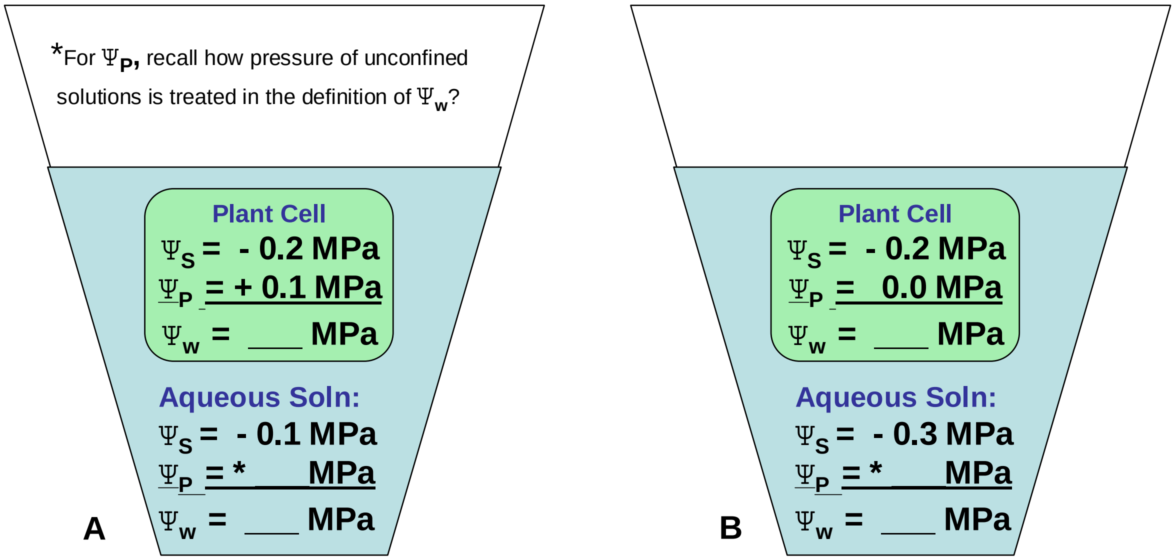
5. Why do cells require ATP (from photosynthesis or respiration) to maintain

   turgor? ______________________

RECAP: When you have learned the basics of "water potential theory"above, you will be ready to apply this theory to some of the questions plant physiologists are asking about water movement in plants.

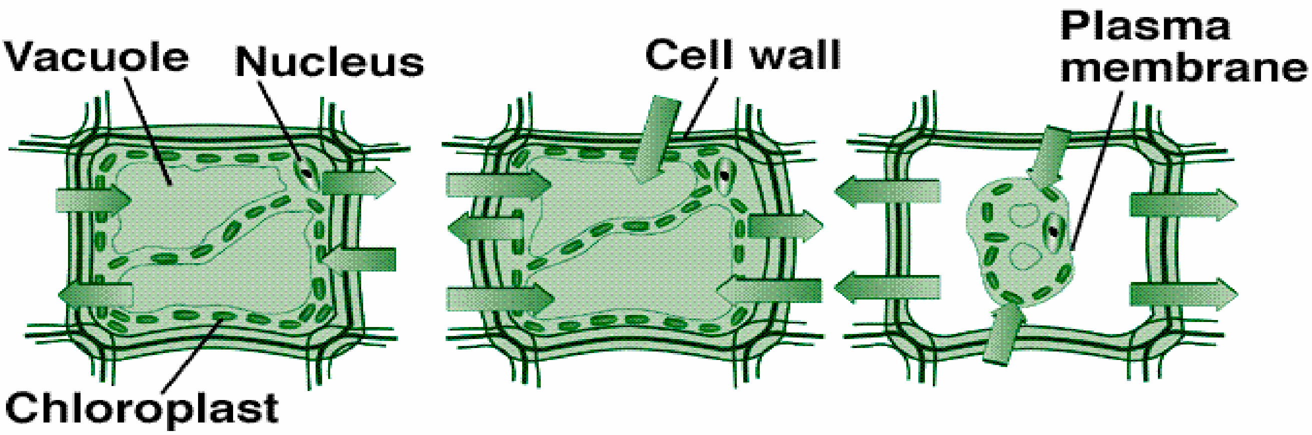


Review Problem for Understanding Water Potential



1. **Compute water potential for each cell and aqueous solution.**
2. **Which cell is in osmotic equilibrium with its aqueous environment?**
3. **Explain the cell-to-environment relationship of A and B in terms of tonicity (see below).**
4. **Modify your answers to #3 using *water potential* terminology.**

Osmosis in Plant Cells



(a) Isotonic (b) Hypotonic (c) Hypertonic