| SA #31-32<br>BIO 2500 | **MOVEMENT OF WATER IN PLANTS - "SPAC"**<br>**Chapter 5** (p.65-82), **Chapter 9** (p. 155-160) |
|---|---|

**OVERVIEW:** We have applied kinetic theory to an understanding of the behavior of water through the concept of *water potential*. The water potential concept is valuable because it can be applied to water within soil, within the plant, and within the atmosphere – that is, within the *Soil-Plant-Air Continuum* (SPAC). In this assignment, we will consider the SPAC and how water and solutes (*e.g.* nutrient ions) are absorbed by roots.

**Note:** Physiology of plant water relationships is not fully understood, and new research continues. The scope of BIO 2500 requires that we consider only a basic overview of these processes while recognizing that we risk oversimplification. You may choose to pursue a more thorough study by enrolling in BIO 3510 Plant Physiology.

**READING:** As noted in the title box above, this assignment has two parts:
**1)** Water absorption and passage through roots – Ch. 5, p. 65-70 [Emphasis will be upon "mature root," pp 67-70. Lab Manual, Ex. #12 – labeled Fig. 12-1 and 12-2 and lab notes
**2)** Control of Transpiration – Ch. 9, p. 155-158. and Lab Ex. #14 on Leaves as well as prior graphics and notes on xylem anatomy. Time permitting we will consider Phloem Transport, pp. 159-160.

**PROCEDURE:** Read and study the above pages and review your laboratory work on roots, stems, and leaves. Then, read the **STUDY OUTLINE** which highlights the major concepts. Finally, test your comprehension by completing parts of the outline that require input and answers.

**STUDY OUTLINE – "The 'SPAC;" -- Water Absorption by Roots** and **Control of Transpiration**

Water moves from *soil* to *root epidermis* and across the root to the central vascular cylinder, or *stele* where it enters the *xylem* and is transported upward to the stem and toward the leaves where eventually water diffuses into the atmosphere. Page 31.2 of this Guide provides a model of the SPAC and lists water potential values measured along the "SPAC."

**QUESTIONS:** Consult Chapter 5 and your laboratory study of root anatomy to complete the following:

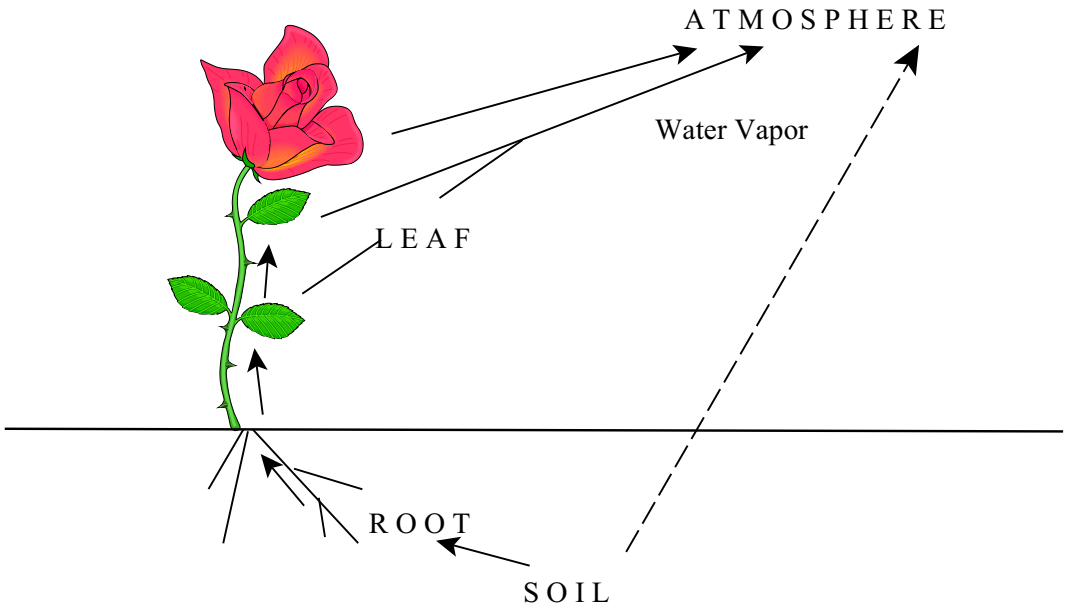
1. List the specific root tissues water would pass through on its "journey" from the soil to root xylem.

   Soil –> _____ –> xylem

2. Based upon the data in the SPAC Model (next page), what must be true of $\Psi$w values in order for water to move from soil to root xylem? _____

3. As the soil becomes drier between rains, soil $\Psi$w (check one) __ Increases __Decreases.
4. Assuming the $\Psi$w of the root hairs remains at -2 atmospheres, water uptake would cease when the soil $\Psi$w reaches _____ atmospheres. Explain._____
5. Water entering root hair cytoplasm can diffuse across the root (see 1. above) from cell to cell without crossing the plasma membrane again because of the existence of _____.
6. Some water also can diffuse across the cortex via the interconnected cell walls, but it cannot cross the endodermis in this way because of the _____ *strips* composed of _____.
7. The plasma membrane thus divides the root into two interconnecting compartments known as the *symplast* (interconnected cytoplasm) and the *apoplast* (extracellular, or cell wall, space).
8. How is the endodermis like a "check point" to control the ionic content of water entering the stele?

# Soil - Plant - Air Continuum




PLANT RECEIVES WATER FROM SOIL AS LONG AS:

$\Psi_W$ > $\Psi_W$ > $\Psi_W$ > $\Psi_W$ > $\Psi_W$

**S O I L** **ROOT HAIRS** **ROOT XYLEM** **MESOPHYLL** **A I R**

**EXAMPLE DATA:**

$\Psi_W$ = - 0.5 - 2 - 5 - 15 - 1000 atm

**FACTORS:**

**FIELD CAPACITY**

**ROOT SURFACE**

**COHESION-TENSION**
**VESSEL-TRACHEID DIAMETER**

**CUTICLE,**
**STOMATAL RESISTANCE**
**LEAF MORPHOLOGY**

**HUMIDITY**

## I. MOVEMENT OF WATER AND MINERALS IN THE XYLEM

A. PROBLEM: Water is continually being lost from plant leaves and stems as *water vapor* by the process of *transpiration*. Water must be absorbed from the soil and transported to plant shoots to replace what is lost.

B. TRANSPIRATION RATE: Give one or two estimates of transpiration rates from Stern, *et al.*:

_____

C. PATH of WATER – Suggest an experiment to verify that water is transported in a tree from the roots to shoots via the *xylem*, not phloem. _____

D. MECHANISM – Note how each of the following fail to account for the ascent of water:

1. Capillarity Hypothesis – water rises only about 1 m in xylem by capillarity; air bubbles inhibit
2. Suction Hypothesis (Atmospheric Pressure pushes water up) – accounts for 34-ft maximum
3. Pumping Cell Hypothesis – requires living cells; vessels and tracheids function after death
4. Root Pressure Hypothesis – roots act like an osmometer; water rises by osmotic pressure
   a. What causes *root pressure*? _____
   _____
   b. What is *guttation*? _____
   When is it observed? Why? _____
5. Cohesion-Tension Theory (Transpiration-Cohesion) – most excepted hypothesis; next section

E. According to the "Cohesion-Tension Hypothesis", explain the role of each of the following:

1. Solar-powered *transpiration*: _____
2. $\Psi$w gradients in mesophyll: _____
3. Leaf vein endings in mesophyll: _____
4. $\Psi$w gradient down stem to roots: _____
5. Microscopic size of vessels/tracheids: _____

QUESTION: Which cells would be most susceptible to air bubbles forming under tension, Vessels ___ or Tracheids ___. Why?_____

F. SUPPORTING EVIDENCE -- water is under tension ( -$\Psi$p) within xylem; varies with time of day

## II. STOMATAL CONTROL OF TRANSPIRATION

A. FACTORS AFFECTING TRANSPIRATION RATE – List three ***environmental factors*** involved:

| Environmental Factor | Explanation of Effect on Plant |
|---|---|
| 1. | |
| 2. | |
| 3. | |

**Note**: Try to relate this study exercise to the leaf *morphological adaptations* encountered in lab.

B. STOMATAL STRUCTURE

1. Based upon your lab study of *guard cells* and *stoma* of *Tradescantia* or *Sedum*, what composes the *stomatal apparatus*? _____
2. The range of densities of stomata in most species is between 1,000 and 100,000 stomata/$cm^2$
3. According to Stern, of the total transpiration, what percentage is lost through cuticle? ~____%
4. How do *turgor* and *cell wall microfibrils* combine to make guard cells "bow apart?" _____

C. STOMATAL PHYSIOLOGY -- Explain the *cause-effect* relationship among each of the following:

1. Light (the *cause*) and $CO_2$ concentration, or [$CO_2$], inside leaf: (the *effect*)_____

   _____
2. [$CO_2$] and guard cell membrane $H^+/K^+$ ATPase: _____
3. [$K^+$] and $\Psi w$ inside guard cells: _____
4. Guard cell $\Psi w$ and osmosis: _____
5. Osmosis and $\Psi p$ within guard cell _____

   Summary:

D. PROTECTION AGAINST DESICCATION:

1. Explain how stomates close when transpiration exceeds water supply from xylem.

   _____

   _____
2. The stomatal apparatus must have *receptors* that can detect environmental *stimuli* related to opening and closing. List three environmental *stimuli* noted or implied in the stomatal mechanisms above: _____

IV. PHLOEM TRANSLOCATION – [May be abbreviated or omitted depending on time available.]

A. PHLOEM ANATOMY

1. How do sugars, etc. move through from one *sieve cell* to another? _____

2. Cite one source of evidence that phloem contents are under a positive pressure ($+\Psi p$)

_____

3. What prevents plants from "bleeding" sugary sap when cut? _____

_____

B. PHLOEM PHYSIOLOGY -- What drives the movement of organic substances?

1. In your own words, state the *pressure-flow hypothesis*: _____

_____

_____

2. Explain how a physical model (p. 30.6 and Fig. 9.17 in Stern) supports the pressure-flow hypothesis.

3. nswer the following with respect to a growing watermelon plant with melons developing:

a. What portion(s) of the plant are source? _____ Explain _____

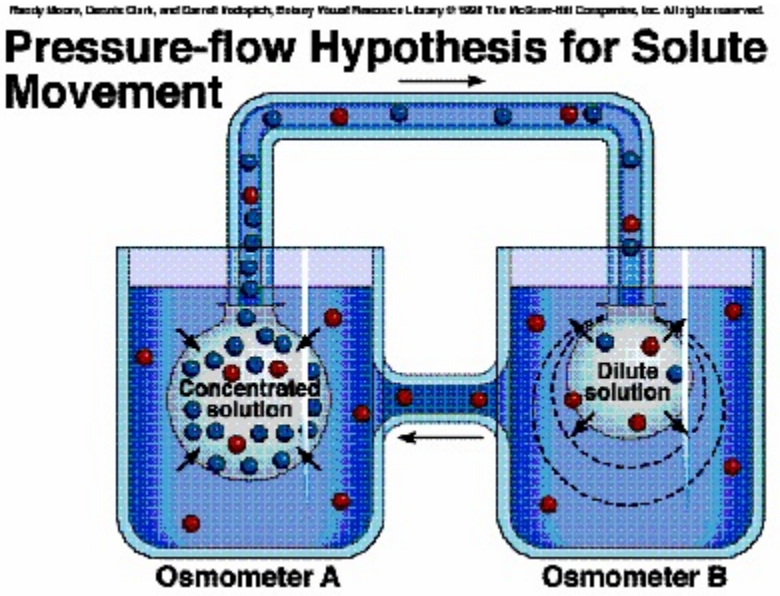
_____

b. What portions of the plant are sinks? _____

Explain _____

4. NOTE: We will not study *phloem loading* in detail although you should be aware that phloem translocation is an *energy-requiring* process because membrane ATPase activity is responsible for pumping sugars, etc. into sieve cells in source leaves.

5. Application Question: How would removal of a 30-cm wide band of tree bark cause death of the tree? Describe the primary and secondary affects of this “invasive surgery.”




SUMMARY REVIEW EXERCISE
Complete the Table Comparing Three Mechanisms of Transport in Plants

| | Transpiration | Guttation | Phloem Transport |
|---|---|---|---|
| Plant Tissues Involved | Xylem | | |
| Visible Manifestation or Experimental Verification | Humidity increases in atmosphere around an enclosed plant in light | | C-14 labeled assimilates are translocated to sinks from source leaves exposed to $^{14}CO_2$ |
| Necessary Environmental Conditions | Sunny conditions with high soil Ψw and low atmospheric humidity | | Sunny conditions with high soil Ψw, thus favoring photosynthesis |
| Driving Force | | Active transport and accumulation of solutes within the root xylem in the stele | |
| Magnitude and (+ or -) of Ψp within Conductive Tissue | | $+\ \Psi_p$ | |
| Other Notes: | | | |