Laboratory 9: Transpiration

*describe how differences in water potential affect the transport of water from roots to stems to leaves
*relate transpiration to the overall process of water transport in plants
*discuss the importance of the properties of water -- including hydrogen bonding, adhesion, and cohesion -- to the transport of water in plants
*quantitatively demonstrate the effects of different environmental conditions on the rate of transpiration in plants
*identify the vascular tissues of the plant stem and describe their functions

Transpiration is the loss of water from plant surfaces, and it drives the transport of water up xylem as part of the tension-cohesion theory (TACT). As water leaves the leaves (ho-ho) through the stomata, hydrogen bonds help pull other water molecules up behind with adhesion to narrow xylem walls and cohesion to itself important contributing factors. Water potential also drives transpiration: water **always** moves from higher to lower water potential (remember, pure water is 0 potential, dry air may be -300).

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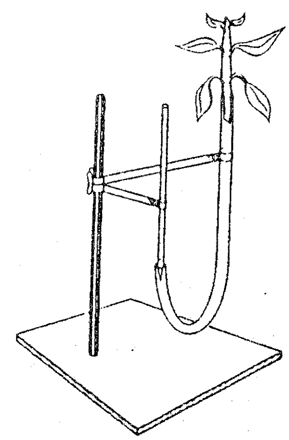
To measure rate of transpiration, a potometer is set up (see right). A carefully cut and sealed plant stem is inserted into a water-filled tube and pipette/ any water lost should result in reduction of water in tube system. Over 30 minutes, readings are made under these condition:

a *normal room conditions
b *increased light (floodlight)
c *breeze (low speed fan)
d *mist (water spray inside plastic bag)

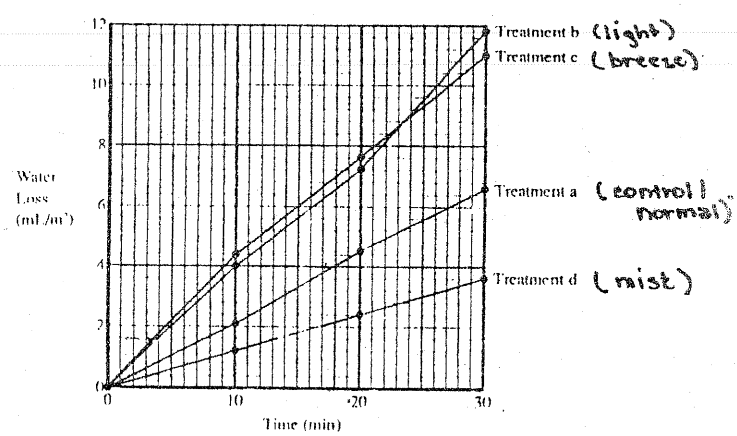


Total water loss could be graphed/ you can also estimate the water loss per square meter by figuring the leaf area by weight (grams leaf/160 grams per $meter_2$ = leaf area m_2) or by tracing leaf on 1 cm_2 graph paper and adding area.

If weight of leaves = 2.25g
and leaf surface area = weight (g) / 160 g/m²
then leaf surface area = 2.25 / 160 = .014m²

Leaf surface area 0.014 m²				
Class Averages Cumulative water loss in mL/m² at times (min)				
Treatment	0	10	20	30
a	0	2.19	4.56	6.57
b	0	4.16	7.57	11.73
c	0	4.50	7.58	11.00
d	0	1.30	2.44	3.65

Amount of Transpiration vs. Physical Factors



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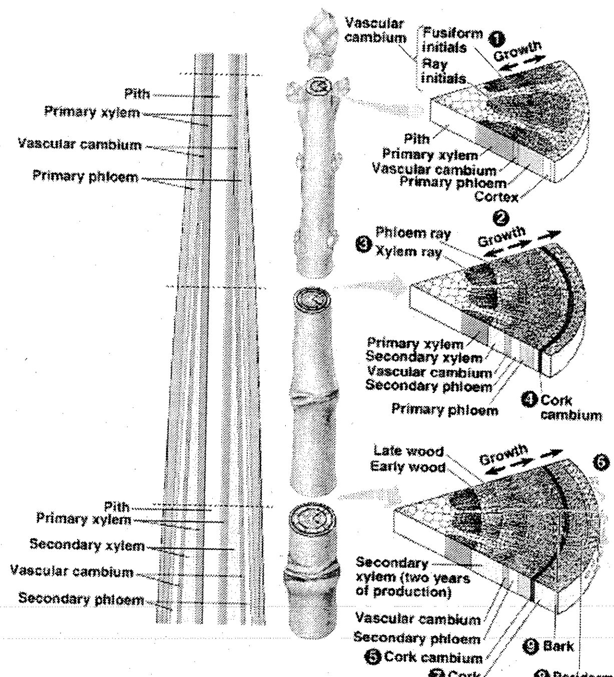
The structure of a plant stem and its xylem and phloem can be observed by preparing a plant cross-section. Obtaining a nut-and bolt microtome, a piece of plant stem can be placed in the nut and melted paraffin added. As the wax hardens, it should hold the stem securely and allow it to be slices into thin pieces with a razor blade. The sections can be moved to dishes of ethanol for dehydration; then to stain for clarification. The following cell types should be visible:

- parenchyma: most abundant cell type/ unspecialized, include mesophyll, fruit flesh, pith and cortex of roots and stems
- sclerenchyma: fibers in leaves, stems, fruits, usually found in bundles and often just outside the vascular tissue
- collenchyma: support cells with thickenings at corners
- xylem: water conducting tissues of tracheid and vessel cells, dead when they function
- phloem: nutrient conducting tissues of sieve tube and companion cells, alive when functional
- epidermis: outermost protective cell layers/ often have cutin; guard cells are specialized members



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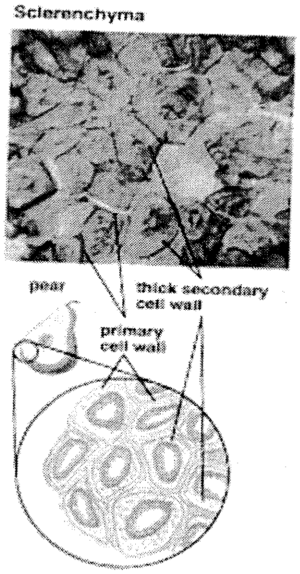
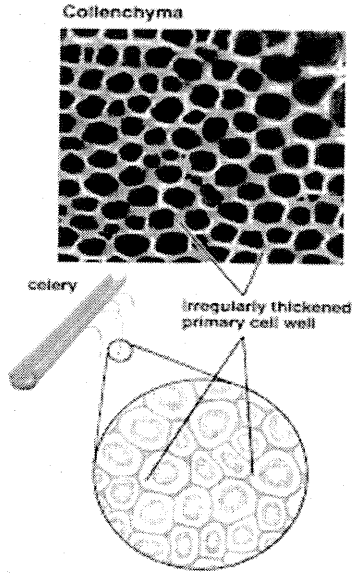
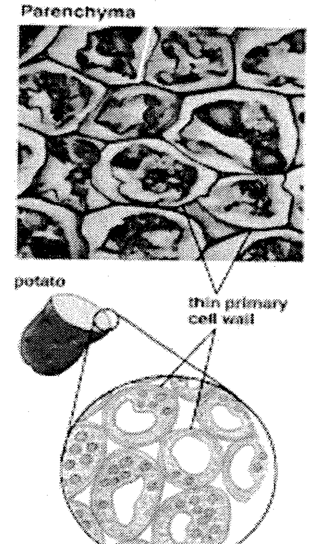
Sclerenchyma



Collenchyma



Parenchyma



1991 Lab 9--Transpiration Lab FR

A group of students designed an experiment to measure transpiration rates in a particular species of herbaceous plant. Plants were divided into groups and were exposed to the following conditions.

Group I - Room conditions
(light, low humidity, 20° C, and little air movement)

Group II - Room conditions with increased humidity

Group III - Room conditions with increased air movement (fan)

Group IV - Room conditions with additional light

The cumulative water loss due to transpiration of water from each plant was measured at 10-minute intervals for 30 minutes. Water loss was expressed as milliliters of water per square centimeter of leaf surface area. The data for all plants in Group I (room conditions) were averaged. The average cumulative water loss by the plants in Group I is presented in the table below.

Average Cumulative Water Loss by the Plants in Group I

Time (minutes)	Average Cumulative Water Loss (milliliters H_2O/centimeter^2)
10	3.5×10^{-4}
20	7.7×10^{-4}
30	10.6×10^{-4}

a. Construct and label a graph using the data for Group I. Using the same set of axes, draw and label three additional lines representing the results that you would predict for Groups II, III, and IV.

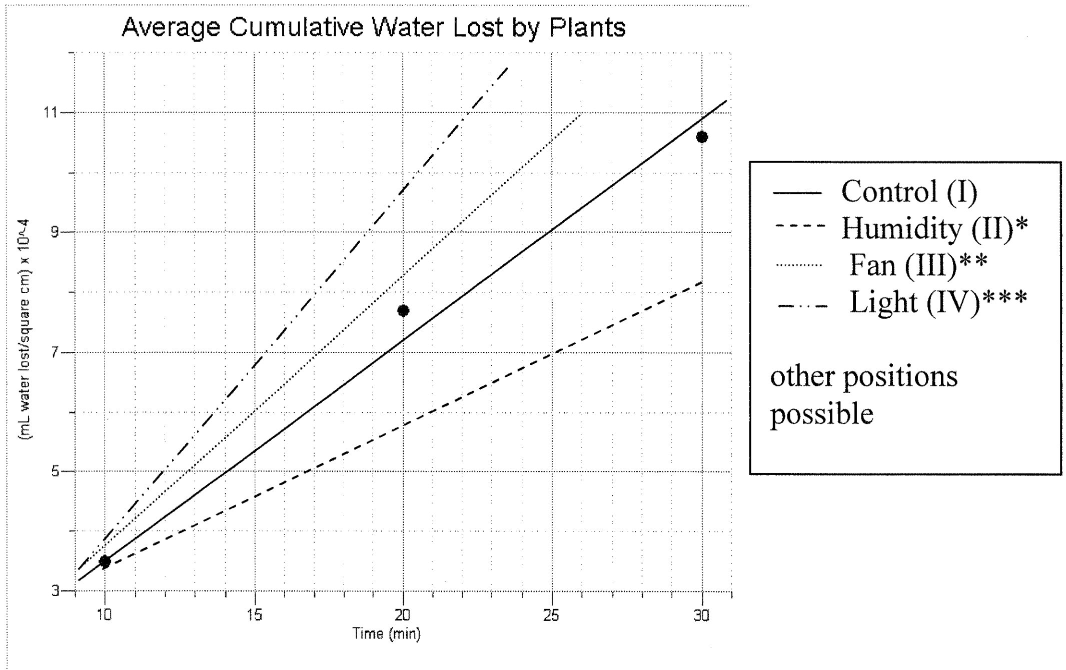
b. Explain how biological and physical processes are responsible for the differences between each of your predictions and the data for Group I.

c. Explain how the concept of water potential is used to account for the movement of water from the plant stem to the atmosphere during transpiration.

Lab #9
Transpiration

1991 Transpiration Lab FR STANDARDS:

A. GRAPH: (Max of 3 points)



- Correct Orientation of X (independent) and Y (dependent) axes
- Scale and proper labels
- Group I - properly graphed (3.5/7.7/10.6) [solid line above]

B. BIOLOGICAL/PHYSICAL PROCESSES FOR DIFFERENCES:
(Max of 5 points)

- Control (I) - function of
- Transpiration / Photosynthesis (description of)
- Humidity (II) - thus increase water potential surrounding leaf - thus curve will be *BELOW control (inside constant/outside increased)
- Fan (III) - water potential decreased surrounding leaf - therefore curve will be **ABOVE control (inside constant/outside decreased)
- Fan (III) - wind shear (fan close) stomates closed - therefore curve BELOW control
- Fan (III) - cools because of evaporation (decreases kinetics) - therefore curve BELOW control

(Max of 2 points for Fan)

- Light (IV) - stomates open (or) increase water usage via photosynthesis - curve ***ABOVE control

- Light (IV) - heat - physical (increased kinetic energy) - curve ***ABOVE control
- Light (IV) - heat - stomates closed - therefore curve BELOW control

(Max of 2 points for Light)

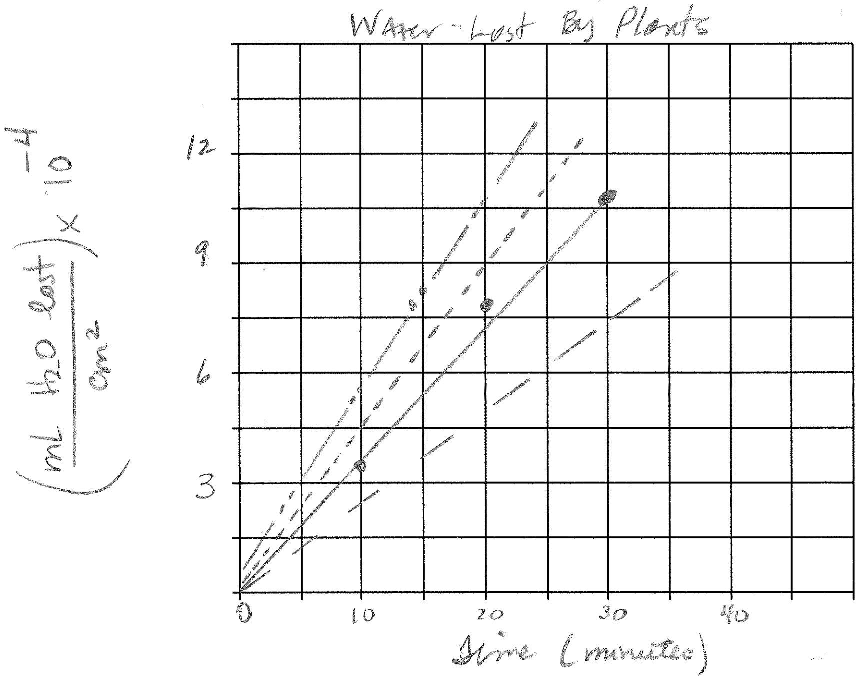
- Curves (graphs) - all correspond to description (hypothesis testing)
- Mechanism of stomates close/open (CO_2 / K^+ flux / etc.)

C. CONCEPT OF WATER POTENTIAL: FROM STEM - LEAF - ATMOSPHERE: (Max of 4 points)

- Concept of water potential (high to low)-(diffusion/osmosis)-relationship to solute
- Water movement (Cohesion-Tension Theory)
    - Properties of water (adhesion, cohesion, hydrogen bonding, capillary action)
    - Tension "transpirational pull" - gradient xylem to outside
    - Negative pressure
- Pressure potential/Osmotic potential
- Air space of leaf has higher water potential than air outside leaf; Water moves out through stomata
- Mesophyll cells higher water potential than surrounding air spaces of leaf Water moves out into leaf air spaces
- Solute in mesophyll cells becomes more concentrated when less water present -- therefore, less water potential (Mesophyll hypertonic to xylem)
- Xylem has higher water potential than mesophyll cells -- water moves out of xylem into mesophyll cells

1991
Transpiration
(10)

a)



(1pt) time on x & H_2O lost / cm^2 on y

(1pt) scale + labels

(1pt) proper points plotted

b) For group I, the control, the rate of H_2O lost increased directly with time. Since light was available, photosynthesis was taking place & H_2O was being split so more water was absorbed by the plant to replace the water used in photosynthesis. Transpiration was also occuring so water was being lost.

Rate = H_2O lost / time = slope

For group II, humidity, the water potential surrounding the leaf was increased, therefore the rate of transpiration (slope of line) was less steep than group I. 1pt
so less H_2O was lost.

For group III, fan, the "wind" caused more H_2O to evaporate from the leaf surfaces (water potential lower on surface of leaf) so more water was lost & rate of transpiation increased — more steep slope than group I. 1pt 1pt

For group IV, light, the increased light increased

1 pt 1 pt
the rate of photosynthesis, so more H_2O was split. The hot light also warmed the plant so the stomates open. Both allow for a high rate of transpiration so the slope (rate of transpiration) is higher than group I

c.) Transpiration is the loss of H_2O from plant surfaces + it causes H_2O to travel through the xylem UP from the roots to the leaves to replace the H_2O that just left. H_2O molecules stick to to each other (H-bonding + cohesion) & use capillary action (adhesion) to "climb" against the pull of gravity. 1 pt
1 pt
Water always moves from higher to lower water potential. Pure H_2O has potential of zero while the air is negative since it has solutes. 1 pt
1 pt
(Water vapor leaves the leaf through the open stomata.) Airspace of the leaf has a higher water potential than outside air so $H_2O_{(g)}$ moves out the stomata into the open air + leaves the leaf. 1 pt