NAME: ______________________________________________ DATE: _____________

PARTNER: ____________________________________________

# PHOTOSYNTHESIS & TRANSPIRATION

*The process of photosynthesis uses light energy obtained from the sun, carbon dioxide obtained from the air, and water obtained from the ground to make sugars and starches (long chains of sugars). Transpiration is the process by which water in leaves is released to the air, drawing water up from the roots to replace it. In this laboratory session, we will explore these functions through several activities. You will also answer several questions on photosynthesis based on information from your textbook.*

## I. TRANSPIRATION

*In this section you will study the transport of water in plants. The process of transpiration, or evaporation of water from leaves, creates a low osmotic potential in leaves. This draws water from the xylem into the mesophyll cells, where photosynthesis takes place. In turn, water is drawn up the xylem from the roots via the cohesion of water.*

### A. Visualization of xylem

1. Stalks of celery were placed in water containing food coloring overnight. Obtain a stalk of this celery.

2. Blot the celery dry, and cut across the stalk with a knife. Observe under a dissecting scope.

   a. Draw what you see here:

   b. What vascular tissue contains the food coloring? ________________________________

   c. Define cohesion, and explain how it helps food coloring travel up the celery stalk.

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**B. Movement of water through stems**

In this demonstration activity, you will observe transpiration and the movement of water in real time. Your instructor will set up Rhododendron branches so their rate of transpiration can be detected by a gas pressure sensor.

The end of the rhododendron stem is in physical contact with water in plastic tubing. This plastic tubing is attached to a tube filled with air, which is attached to a gas pressure sensor. As the rhododendron transpires, water is moved from the tube into the plant, which lowers the pressure in the air-filled tube.

Your instructor will start a demonstration, and let the experiment run for 15 minutes. At the end, the data collection will be stopped, then the class will work through the data analysis.

1. When data collection has finished, find the rate of transpiration for your plant. To do this,
    a. Move the mouse pointer to the point where the pressure values begin to decrease. Click the mouse button and drag the pointer to the end of the data, then release the mouse button.
    b. Click the Linear Fit button, , to perform a linear regression. A floating box will appear with the formula for a best fit line.
    c. Record the slope of the line, *m*, on the line as the rate of transpiration (use appropriate units!). Close the floating box. Transpiration rate: ______________________

This transpiration rate is the combined rate of all the leaves working together. If we had run this experiment with fewer leaves, the rate would be lower; if we had run it with more leaves, it would be higher. Therefore, to standardize our data, we will correct for the surface area of the leaves:

2. Determine the surface area of all your leaves as follows (use proper units!):
    a. As a class, cut all the leaves (not petioles) off your plant and determine their mass using a balance. Record their mass here: ________________
    b. Cut out a section of leaf which measures 3 cm × 3 cm (this equals 9 $cm^2$).
    c. Determine the mass for this leaf section. Record the mass here: ____________
    d. Divide by 9 $cm^2$ to find the mass of l $cm^2$ of leaf. Record that mass here: ____________
    e. Divide the total mass of the leaves by the mass of l $cm^2$ to find the total leaf surface area. Record the calculated total surface area here: ___________________

3. Calculate the rate of transpiration/surface area. To do this, divide the rate of transpiration (step 1) by the total surface area. These rate values can be expressed as $kPa/min/cm^2$. Record the rate/area here: __________________

4. What do you think would happen to the rate of transpiration if the room temperature were 10°C higher? Why? _________________________________________________________________

_____________________________________________________________________________________

5. Develop your own hypothesis about transpiration (your instructor can give you some ideas to get you started). Figure out how to test your hypothesis using the same setup. In other words, design an experiment. Use the demonstration already done as your control. Then, change one thing, repeat the experiment, and compare your data.

a. Write your hypothesis (remember, a hypothesis is stated in sentence form, as if you already know it is true): ______________________________________________________

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______________________________________________________________________

b. Perform data collection as described above, using your one changed variable. What variable did you change? ____________________________________________________

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c. Determine and record the slope of the line as described above.
Transpiration rate: _____________________________________

d. Determine the surface area of all your leaves, as described above:
Mass of all leaves: ______________
Mass of 9 $cm^2$ leaf section: ________________
Mass of 1 $cm^2$ leaf section: ________________
Total surface area: ____________________

e. Calculate rate of transpiration / surface area: ________________________.

f. Compare your results (transpiration / surface area) of your experiment to the control. Which was faster or slower?

______________________________________________________________________

______________________________________________________________________

g. Do your results support your hypothesis? (yes or no) _______. Why or why not, and if not, is there an alternative explanation (biological, not "I did the experiment wrong")?

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## II. PHOTOSYNTHESIS AND RESPIRATION IN PLANTS

*Photosynthesis combines a series of reactions to convert energy from sunlight and* $CO_2$ *from the air into sugars, releasing* $O_2$ *in the process. In the first set of reactions, the light-dependent reactions (aka "light reactions"), energy from sunlight is absorbed by photopigments contained in the thylakoids of chloroplasts. This energy splits water, turning it into* $O_2$*, which is released from the plant as a waste product. The energy is transferred from Photosystem II to Photosystem I, then finally to electron carriers such as NADPH. These electron carriers are used in the second set of reactions, the light-independent reactions (aka "dark reactions") to fix* $CO_2$ *into glucose via the Calvin-Benson cycle. This glucose is used in plants – as in animals – for energy. The energy is extracted from glucose through the process of cell respiration. We will explore various facets of these processes, including the nature of the photosynthetic photopigments, and the conditions required to allow photosynthesis and/or respiration to occur, in the following activities.*

### A. Paper Chromatography of Leaf Photopigments

1. Obtain a strip of chromatography paper and a piece of spinach or other sample.

2. Use a ruler to measure and draw a light pencil line 2 cm above the bottom of the paper strip. *Do NOT use ink!*

3. Wrap a *Zebrina* leaf around a coin with the "up" side of the leaf facing outward. Now rub the leaf along the light pencil line on the paper strip until you make a dark green line. *Do NOT rub the leaf above or below the line. Rub the leaf on the line only.* Also, go outside, find another leaf of your choosing, and repeat this process on a separate strip of chromatography paper. Remember which is which (you may want to code them somehow).

4. Tape the top of the paper strips to a pencil so that the end of the strips with the green line hangs down. The pencil should be able to sit across the top of the beaker with the bottom of the paper strips just touching the bottom of the beaker. Cut off any excess paper from the top of the strip if it is too long. *Do not cut the bottom of the strip with the green line.*

5. Remove the pencil/paper strip from the beaker (for now).

6. Carefully add isopropyl alcohol to the beaker until it reaches a depth of 1 cm in the beaker.

7. Lay the pencil across the top of the beaker with the paper strip extending into the alcohol. *Make sure that the level of the alcohol is* <u>*below*</u> *the green line on your paper strip. If the alcohol is going to cover the green line, pour out some alcohol before you get the green line wet.*

8. Observe as the alcohol gets absorbed and travels up the paper. This may take up to 45 minutes. Do not touch your experiment during this time; work on other activities while you wait.

9. Using colored pencils, draw your results here:

| | *Zebrina* | Other leaf (describe) ______ |
|---|---|---|
| **Before chromatography** | | |
| **After chromatography** | | |

10. Answer the following questions to evaluate your data.

a. Did the leaf or sample you tested contain several pigments? Answer separately for each leaf you tested. Use your results to support your answer, and name some of the pigments (look in your book). ______________________________________________________________

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b. Based on what you have learned, explain why leaves tend to change color in the fall.

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**B. Respiration vs. Photosynthesis in Plants**

In this activity, you will use an indicator dye to show whether carbon dioxide, $CO_2$, is being consumed or produced in a reaction. Plants are known to perform photosynthesis, but it is less well understood by students that *at the same time* plants are also performing cell respiration. To demonstrate this, you will determine whether $CO_2$ is consumed or produced as *Elodea* is placed in either a dark or light environment. The change in $CO_2$ will be detected by the pH indicator phenol red. Photosynthesis consumes $CO_2$, causing a decrease in $CO_2$ in the environment, while cellular respiration produces $CO_2$, causing an increase in $CO_2$ in the environment. Phenol red is yellow under acidic conditions (high hydrogen ion, $H^+$, concentration), pink under basic or alkaline conditions (low $H^+$ concentration), and orange under neutral conditions. A change in $CO_2$ will cause a directly proportional change in $H^+$ concentration (i.e., as $CO_2$ goes up, $H^+$ goes up).

If $CO_2$ concentration decreases, the $H^+$ concentration will also decrease and the solution will change to **pink**, becoming basic.

If $CO_2$ concentration increases, the $H^+$ concentration will also increase and the solution will change to **yellow**, becoming acidic.

Neutral solutions of phenol red will be **orange**.

Four flasks were set up 3 days ago containing a phenol red solution. *Elodea* plant pieces were placed in two flasks; the other two remained blank as controls. One *Elodea* flask and one blank flask were placed in the light; the other *Elodea* flask and blank flask were placed in the dark. All 4 flasks were incubated for 3 days. Keep the dark ones covered in foil unless you are actually looking at them.

1. Record the colors of the solutions in the flasks.

| *Elodea* / dark | *Elodea* / light | Blank / dark | Blank / light |
|---|---|---|---|
| | | | |

2. Using the information provided above and your knowledge of photosynthesis, answer the following questions.

a. Did the *Elodea* consume or release $CO_2$ in the dark? ________________________________

b. What about in the light? ________________________________________________________

c. Why might there be a difference? ________________________________________________
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________________________________________________________________________________
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## III. PHOTOSYNTHESIS STUDY QUESTIONS

*Work with your partner to answer the following questions but be sure to record your own responses. Unless directed otherwise, use complete sentences for your explanations.*

1. Write out a simple formula to describe the **overall** process of photosynthesis (names are acceptable; chemical formulas are not necessary but may be used).

   E.g., names of reactants $\rightarrow$ names of products

2. Describe this process (both the light dependent and light independent reactions) in your own words.

3. How are these processes important to the life of the plant?

4. As before, write out a simple formula to describe the **overall** process of aerobic respiration (focus on the overall process, not the sub-pathways).

5. List the 3 processes involved in aerobic respiration and, in your own words, explain what is happening in each of those processes (use complete sentences).

6. How is this process important to the life of the plant?

7. Now, draw a simple diagram (like the one we used in class) to show how the reactants and products of these two processes are interrelated. Be sure to include the names of the processes, reactants and products.

8. How are these processes (photosynthesis and aerobic respiration) important in terms of energy flow in living systems and the cycling of nutrients between autotrophs and heterotrophs?