Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date \_\_\_\_\_\_\_\_\_\_\_\_\_

**Growth Strategies Worksheet**

**Background**: Photosynthesis is the process in which plants convert nutrients and carbon dioxide absorbed by leaf, using energy from the sun, into sugars. These sugar molecules provide the energy for the plants, after they are broken down using oxygen through respiration. The formula below outlines this process:

 **Carbon Dioxide + Water + Energy (produces)** **Sugar + Oxygen**

 (from the air) (from the roots) (from the sun) 

Plants convert light energy into chemical energy for use as food, and they also produce oxygen that animals breathe. Photosynthesis occurs in the leaves of a plant. Using the equation above, we know that leaves are able to do the following activities:

 1. Collect **sunlight** (energy)

 2. Collect **carbon dioxide** (CO2) from the air

 3. Store **water** (H2O) from the roots of the plant

These three ingredients are what leaves use to create simple sugars. H2O is taken up by the roots and brought to the leaves in tube-shaped cells (called **xylem**). There are holes, called **stomata**, on the underside of the leaf to let in CO2. However, while the stomata are open to let CO2 in, they are also letting H2O out through the process of transpiration. Warmer, drier conditions means more transpiration happens because more water evaporates out of the stomata. Leaf structure should reflect a balance between the need for light, CO2 and water, so variations in surface area, thickness and the number of stomata are a result of the environmental conditions surrounding leaves. For this activity we will investigate how plants manage the tradeoff between light capture, carbon dioxide collection, and water loss.

**Pre - Investigation questions:** (Circle Answer)

1. Where on a tree would the most light be available to leaves?

Top/Outer area Bottom/Inner area

1. Where on the tree would light be most limited?

Top/Outer area Bottom/Inner area

1. Where on a tree would the potential for water loss be greatest?

Top/Outer area Bottom/Inner area

1. Where on a tree would the potential for water loss be the lowest?

Top/Outer area Bottom/Inner area

*Read the article, Shade and Sun Leaves by G. Hemery and answer the reading questions for homework (separate handout). Consider the* ***tradeoffs*** *between the leaf’s need to gather light and CO2, and the need to conserve H2O and other resources. As a group, come together and review your answers. Work together to answer questions 5-7 below.*

5.a. In an environment with low sunlight (such as in the inner part or bottom of a tree), would you expect leaves to have a large surface area relative to leaves from other parts of the tree? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Why or why not?

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b. Now consider leaf surface area for a part of the tree that experiences high sunlight, such as the top or outer branches. Would you expect these leaves to be large or small? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_­

Why or why not?

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6.a. Think about leaf thickness. Would you expect leaves to be thicker from parts of the tree with a high potential for water loss? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

 Why or why not?

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b. What about leaves from an area of the tree with a low potential for water loss? \_\_\_\_\_\_\_\_\_\_\_\_\_\_

 Why or why not?

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7.a. Where on a tree would it be advantageous for leaves to have many stomata? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Why?

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 b. To have very few stomata? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Experiment**

**Materials**:

* + Clippers
	+ Scissors
	+ Ruler
	+ Microscope
	+ Plastic bags
	+ Card stock
	+ Slide
	+ Marker

**Procedure**:

1. Form a hypothesis about how leaf size, leaf thickness, and stomata density will differ between leaves that are exposed to high and low amounts of sunlight and record them on page 4. Remember, hypotheses are written in an “if… then…” format, and followed by a justification statement.
2. Choose a tree found in your woodland study plot and record the species. Gather leaves from lower level branches and from as close to the top as possible; place them in a plastic bag; mark it with the location on the tree and your name. If you cannot get leaves from the top of the tree, you can take leaves from inside the tree where they are mostly in the shade, and also from the outer layer where they are mostly in the sun.
3. Gather data on both of the types of leaves and record it in the tables on page 5.
	1. Make observations about leaf characteristics (texture; veins; # lobes; petiole; etc.).
	2. Weigh the leaves; (you need this information to calculate surface area and thickness).
4. Determine the surface area of the leaf. Instead of trying to measure an irregular area, you can use a ratio of the mass of the leaf outline on cardstock to the mass of a known area of card stock.
	1. Cut out a section of card stock with a known surface area (10 cm by 10 cm).
	2. Weigh the 10x10 piece of card stock.
	3. Carefully trace and cut out the leaf outlines on a piece of card stock.
	4. Weigh each leaf outline.
	5. Calculate the surface area for each leaf by multiplying the weight of the leaf outline by the ratio of the area of the paper square to the weight of the paper square: Leaf Surface Area = Leaf Outline Weight\*(Paper Square Area/Paper Square Weight)
5. Determine the relative thickness of each leaf by calculating the Specific Leaf Weight (leaf mass / area).
6. Determine the relative number of stomata by making a mold of the **back** of each leaf.
	1. On the bottom of each leaf, cover an area about 2cm2 with a thin layer of clear nail polish.
	2. When it has dried, place a piece of clear tape over the area, press gently, then remove the tape and polish.
	3. Stick the tape to a clean microscope slide. Label the slide with the leaf location and your initials.
	4. View the slide under the microscope; count the number of stomata in the field of view on **high** power.
	5. Move the slide and count 2 more times. Calculate the average of your counts.

**Hypotheses:**

**Leaf Size:**

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**Leaf Thickness:**

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**Number of Stomata:**

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Tree Species:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**DATA SHEET**

**All data must include correct units**

**1.** Observations:

2. Leaf masses:

|  |  |  |
| --- | --- | --- |
|  | **Top of tree (g)** | **Bottom of tree (g)** |
| **Mass of leaf**  |   |   |
| **Mass of leaf tracing**  |   |   |

3. Paper square data:

|  |  |
| --- | --- |
| **Mass of paper square (g)** |   |
| **Area of paper square (cm2)** |   |

4. Stomata counts:

|  |  |  |
| --- | --- | --- |
|  | **Top of tree** | **Bottom of tree** |
| **Stomata 1st FOV**  |   |   |
| **Stomata 2nd FOV**  |   |   |
| **Stomata 3rd FOV**  |   |   |
| **Average** |   |   |

5**.** Leaf Area and thickness:

|  |  |  |
| --- | --- | --- |
|  | **Top of tree** | **Bottom of tree** |
| **Leaf Area (cm2)** |   |   |
| **Thickness of leaf**  |   |   |

**Calculations**

**Surface Area (**How big is the leaf?)

Determine the surface area of the leaves using the outline you traced. Since the shape is irregular, we will use a ratio between the mass of a known area (the square) and the mass of the leaf cut out, according to the following formula:

 Area of paper square =  **X** (**X** = area of leaf)

 Mass of paper square Mass of leaf outline

What is the correct unit for area? \_\_\_\_\_\_\_\_ Show your work below and record your answers on the Data Sheet.

Top leaf:

Bottom leaf:

**Thickness of Leaf**

Since we cannot measure the thickness of the leaf, we will calculate it using the Specific Leaf Area (a ratio of leaf area to leaf mass).

Divide your leaf mass by the actual area of the leaf (calculated above). **Use actual leaf mass** **not the cut out of the leaf**. Show your work below and record your answers on your data sheet.

 Mass of leaf = Specific Leaf Area (the larger the number, the thicker the leaf)

 Area of Leaf

Top leaf:

Bottom Leaf:

 **Results:**

1. Record your data and class data in the table on page 7.
2. Calculate **class averages** once all data has been collected. Record the averages in the table.
3. Create 3 graphs comparing the information on the 2 types of leaves. Use the class averages for area, thickness, and stomata density.

**Class Data Table:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Group Number** | **Tree Species** | **Sun Leaves** | **Shade Leaves** |
| *Surface area* | *Thickness* | *Stomata count* | *Surface area* | *Thickness* | *Stomata count* |
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| **Class Average:** |  |  |  |  |  |  |

**Analysis and Conclusions**:

1. Describe whether the class data supports your hypothesis for:

 a. Leaf Area

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 b. Leaf Thickness

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 c. Stomata Density

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2. a. Do the class data agree with your results? List the similarities and differences.

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b. Provide at least 3 reasons why differences may exist between your data and your classmates. Make statements that can be supported with observations; consider constants & measuring and variation among individuals.

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| Reason 1:  |
| Reason 2:  |
| Reason 3:  |

 c. Why is it better to draw conclusions based on class data as opposed to using just your own?

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3. Based on the class data, make a claim about each part of your experiment, using evidence from your work and reasoning to explain the claim.

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| --- | --- | --- | --- |
|   | Claim | Evidence | Reasoning (Why) |
| *Example* | *Trees in the middle of a forest are taller.*  | *In our study plot, trees along the edge were 1.5m shorter than the trees in the interior.*  | *Trees in the middle of the forest grow taller in order to obtain sunlight for photosynthesis.*  |
| Leaf area |  |  |  |
| Leaf thickness |  |  |  |
| Stomata density |  |  |  |

4. Other than differences based on human error that are addressed in the previous question, can you come up with other factors as to why there might be differences in your data? Is there an indication that each species of tree has their own unique “growth strategy” to outcompete and survive?

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**Summary**

Write a short reflection on this activity addressing the following points:

* What would help you understand this lab better? What new things did you learn in this lab? How did this lab help you to remember or better understand the scientific process?

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