the CEED

THE CENTER FOR ENERGY EFFICIENT DESIGN

Plant Respiration – What plant does it best for a "Green" roof?

Grade Level	Middle School Extension, High School	**Subject**	Biology

Objective(s):

Students will compare and contrast the structure, location and environmental factors for climate and water efficient plants.

They will identify the structure and function of the stomata and how these selected plants differ due to the environmental conditions they have adapted to live within.

Students will determine the number of stomates per mm^2 found on the surface of various plants using a microscope.

SOL Addressed:

BIO.1 The student will demonstrate an understanding of scientific reasoning, logic, and the nature of science by planning and conducting investigations in which

a) observations of living organisms are recorded in the lab and in the field;

d) graphing and arithmetic calculations are used as tools in data analysis;

h) chemicals and equipment are used in a safe manner;

BIO.2 The student will investigate and understand the chemical and biochemical principles essential for life. Key concepts include

d) the capture, storage, transformation, and flow of energy through the processes of photosynthesis and respiration.

LS.9 The student will investigate and understand how organisms adapt to biotic and abiotic factors in an ecosystem. Key concepts include

c) adaptations that enable organisms to survive within a specific ecosystem.

LS.6 The student will investigate and understand that organisms within an ecosystem are dependent on one another and on nonliving components of the environment. Key concepts include

a) the carbon, water, and nitrogen cycles;

Next Generation Science Standards:

HS-LS1-3. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.* [Clarification Statement: Emphasis is on predicting consistent patterns of interactions in different ecosystems in terms of the relationships among and between organisms and abiotic components of ecosystems.

Materials Needed Per Class of 30	Part I: Time Frame – 45 minutes For a class of 28 working in pairs: 14 light compound microscopes 28 microscope slides and 28 coverslips 14 clear metric rulers 7 – 14 bottles of clear nail polish Graph paper 4-function calculators Samples of Dicot plants – common house plants and/or annuals Samples of succulent plants – *Sedum, Delosperma, Euphorbia, Sempervivum , Festuca* Samples of short grasses – grass from the yard will work! Part II: Small potted plants – larger plants can be separated and put into plastic cups (don't use paper products as water will be absorbed!) Oven bags String pH paper strips with indicator strip reference or – baking soda or seltzer tables petri dish or small shallow container in which to react collected water with soda/seltzer
Prior Knowledge	The use of a compound microscope – Diameter of field of view on low (100x) = 1.5 mm – 1.75 mm The radius of the field of view = .175 mm The area of a circle = πr^2 The area of the field of view = πr^2 or $\pi(.175)^2$ = .096 mm^2 As plants colonized the land, selection pressures have required adaptations for water retention. Plants have also evolved a waxy cuticle as a way to reduce water loss which, unfortunately, also prevents gas exchange. Modern vascular plants came to develop the stomata. Stomates are tiny pores found on leaves. While these pores all for gas exchange to occur, some water will also exit. This process is called transpiration. Plants regulate the opening and closing of the stomata with guard cells. The guard cells, in general, close when the plant experiences water stress, or when the leaf has low levels of CO_2.
Ways to differentiate this lesson plan	• **MODIFICATIONS** – Teachers may wish to introduce monocot vs dicot differences first and then tie in the differentiation of climate specialized/tolerant plants. • **Part I: If live plants are difficult to find** – students may use collected leaves or even artificial leaves to just practice measuring surface area. • **Part II**: If probeware is available – simplify the testing for carbon dioxide by using a carbon dioxide sensor and/or compare probeware quantitative testing versus qualitative testing.

Introduction/ Anticipatory Set	**Anticipatory Set:** *"If we were to travel to the desert or even if we had a long extended period of heat – How do plants exchange gas without dying?* **Questions to ask students:** **Have a variety of plants and discuss the differences and adaptations they may have.** • Why is one plant greener than the other? • Why is surface area important? • How can surface area be detrimental? • Consider different habitats and biomes – how are the plants that inhabit those areas different from each other?	**Introduction:** The types of plants you can grow on a green roof depend on several factors: the climate, sun exposure, water requirements, soil condition, etc.. These are the same things to take into consideration when planting a traditional garden. Succulent plants are well-adapted to the conditions often found on extensive green roofs because of their ability to limit transpiration and store excess water. Species such as *Sedum*, *Delosperma*, *Euphorbia* and *Sempervivum* are popular choices. Grass species such as *Festuca (Blue fescue or Sheep fescue).* With a green roof, an additional factor is the depth of soil or growing medium on the roof. Some plants can do well in thin soils, and others require more depth for rooting. On a green roof, deeper soils mean more weight, which in turn means a stronger structure to support the roof.
Guided Practice	Why do different plants have a different number of stomata than others? What are the conditions the plants have to endure in their natural climate? What purpose is there to the opening and closing of the stomates? (The number of stomates a leaf has varies with the plant species. For some species, the stomates are found on both the upper and lower epidermis (leaf surfaces) while on others they are just found on the lower surface.)	
Independent Practice	Part II: After students have determined numbers of stomates in a variety of plants, the question(s) need to be asked are – *What other climate/ environmental factors may affect the opening and closing of the stomates? * What plants will live best in certain environmental factors – such as soil types, light intensity, temperature ranges, moisture availability, etc. * What affects on that environment does the plant species have? – The following independent activity practice investigates this question: 1. Provide different types of plant species and have students test Carbon Dioxide uptake. 2. Provide plastic bags (oven bags work well), string, funnels, plastic plates, baking soda, seltzer tablets, ph paper (if available).	

	Students need to design a method in which to collect the water (transpiration) from the plant inside of the bag and develop the procedure in which to observe, test the presence of carbon dioxide. (Hint: Hypothetically the collection of carbon dioxide within the bagged plant should change the pH of the water collected inside the bag due to transpiration and respiration methods.) Have students research what is the significance of the baking soda or the seltzer tablets. (Hint: By adding "acid" – carbonic acid (water plus carbon dioxide) – to sodium bicarbonate – a fizzing result should occur. If a fizzing occurs after the collection of the water – then a qualitative analysis should be written.)
Closure (Summary of Lesson)	What will the teacher do to bring the lesson to a close? How will the students make sense of the investigation? How could the students improve / modify for the future?
CEED Building Application/ Sensor Data	Research the construction, availability, design of green roofs. Additionally, when designing "green" buildings, what landscaping plants are more efficient for water conservation, insulation, carbon dioxide uptake, etc? Link to the Carbon Dioxide sensors and investigate trends – What operations within the building monitor and change the carbon dioxide within the building? What peaks/trends do you see when monitoring the Carbon Dioxide sensor on the outside of the building? The link to the CEED Dashboard containing this information can be found at http://dashboard.intellergy.us/ceed/index.php
Assessment	Part I: Students should document – draw, count, provide mathematical calculations to support their hypothesis regarding the number of stoma on the different leaves. Students should then provide a conclusion as to how and why different leaves have different numbers of stoma and how that relates to environmental conditions. An extension conclusion is to recommend what type of plants should be used for "green roofs". Part II: Students should document and write a conclusion based upon their hypothesis as to what plants may intake more carbon dioxide than others – basing decisions upon environmental factors as an extension. What types of plants should be used in "green roofs" in different areas – residential, urban, climate, etc?

Extensions: Greenhouse effect – Carbon Monoxide/Carbon Dioxide testing in homes, green buffers along highways and /or in urban areas.

Spiral Learning –

4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support

survival, growth, behavior, and reproduction. [Clarification Statement: Examples of structures could include thorns, stems, roots, colored petals,

Activity Procedure

In this investigation, you will count the number of stomates found on climate selected/water conserving plants – on both the upper and lower surfaces in a field of view under a light compound microscope. You will then determine the relationship between magnification and the size of the field of view when you look into a microscope. Using this mathematical relationship, you can then determine the number of stomates in a square millimeter of leaf surface.

1. Write a hypothesis concerning the number of stomates that will be found on the upper surface of a leaf versus the bottom surface of a leaf. Consider if there will be differences between the succulent and the grass.

2. Obtain a leaf from both a succulent and a grass. Apply a coat of clear nail polish approximately 1cm by 1cm to the upper and lower sides of each leaf. Be sure to do this on different areas of the leaf. (WHY?) Be careful to not layer the polish too thick.

3. While the polish is drying, determine the area of the field of view of your microscope. Lay a clear ruler on the stage of the microscope. Using the low power objective (10x), estimate the diameter of the field of view to the nearest .25mm.

    a. Diameter = _____ mm

4. Determine the diameter of the field of view on high power (40x) by doing the following calculations.