



University of Alaska Fairbanks

LESSON PLAN: Stomatal Density

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Stomatal density and climate change

Overview

In this activity, students learn that physiological changes in plants (e.g., stomatal density) are related to rising levels of atmospheric carbon dioxide. Students explore the implications of such changes.

Objectives

The student will:

- Create leaf impressions in order to view stomata under a microscope;
- Compare number of stomata present in older specimens and newer specimens;
- Download leaf images and calculate stomatal density; and
- Plot stomatal density against atmospheric carbon dioxide levels and discuss reasons for the relationship between these variables.

Materials

Birch leaves (1 per pair of students)
Microscope slides and cover slips (1 per pair of students)
Dental impression glue
Clear nail polish (several bottles per class)
Microscope (1 per student pair)
Access to ARCTOS herbarium database (<http://arctos.database.museum/SpecimenSearch.cfm>)
Student Worksheet: "Stomata"
Student Worksheet: "Stomatal Density"
Handout: Carbon Dioxide at Mauna Loa

Background

During photosynthesis, plants take up carbon dioxide from the air and release water and oxygen as byproducts. Small openings on plant leaves, called stomata (singular: stoma), regulate carbon dioxide uptake and minimize water loss. The number of stomata per leaf area, also called stomatal density, is species-specific. Comparisons of 100 year-old leaves with modern specimens have shown that stomatal density is decreasing in response to rising atmospheric carbon dioxide. Here, students can compare modern day birch leaves with older birch leaves and construct this relationship using simple graphs.



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Activity Procedure

1. Ask students if plants can breathe (no). Explain that plants need to take in atmospheric gases just as humans do in order to live. Remind students that plants take in carbon dioxide and give off oxygen and water during the process of photosynthesis.
2. Explain that plants have small openings in their leaves called stomata that can open to let in carbon dioxide, and close to prevent water loss.
3. Tell students that they will be making impressions of the leaf surface that contains the stomata (mostly the underside of the leaf, rarely do stomata occur on the upper surface of leaves) and viewing them under the microscope.
4. Pass out the Student Worksheet “Stomata” and explain that students will follow the directions on the sheet to create leaf molds.
5. When students have completed the worksheet, discuss the purpose of stomata. Ask students to describe what the stomata look like.
6. Distribute the Student Worksheet “Stomatal Density.” Explain that students will be comparing leaf surfaces of plants from the early 1900’s with plants from the early 2000’s. Students will be downloading images of these plant surfaces from the UA Museum’s online database. They will also obtain atmospheric carbon dioxide concentrations, and plot these data against stomatal density. Explain that carbon dioxide concentrations from 1960-2010 were obtained with direct measurement, while carbon dioxide concentrations reported from 1900 was obtained using ice cores.
7. Ask students to follow the directions on the Student Worksheet “Stomatal Density.” Once students have completed the worksheet, discuss their answers.



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Student Worksheet: Stomata

Overview

During photosynthesis, plants take up carbon dioxide from the air and release water and oxygen as byproducts. Small openings on plant leaves, called stomata, regulate carbon dioxide uptake and minimize water loss. Each stoma is surrounded by two banana-shaped cells called guard cells, which control the opening and closing of the stomata. During this activity, you will view and sketch stomata and guard cells.

Materials

Birch leaves
Dental glue
Microscope slide and cover slip
Nail polish

Directions

1. Work in pairs. Follow the instructions on the dental glue to mix the catalyst and base together. This will make a thick, green paste.
2. Apply the paste to the underside of a birch leaf and allow to set for 5 minutes. This will create a mold of your leaf.
3. Carefully remove the leaf.
4. Apply several coats of clear nail polish, waiting 2-3 minutes between coats.
5. When the final coat is dry, place a cover slip over the top.
6. View the slide under a microscope at 40 X power.
7. Draw what you see below. Label the stomata and guard cells.





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Student Worksheet: Stomatal Density

Overview

The number of stomata on plant leaves varies depending on the plant species and the plant's environment. Here, you will compare the density of stomata on arctic birch leaves from long ago with the density of stomata on recent arctic birch leaves. You will also record carbon dioxide levels over time and plot this against stomatal density.

Directions

1. Using your internet browser, navigate to the following site:
<http://arctos.database.museum/SpecimenSearch.cfm>.
Here you can explore the database by looking for different plants (*Taxonomic Element*) and years these plants were collected (*Collected on or after*).
2. We have prepared a number of images with the Scanning Electron Microscope from Dwarf Arctic Birch (*Betula nana*). These plants were collected between 1898 to 2002. You can download particular specimen images that have high resolution views of the stomata distribution:

1898: <http://arctos.database.museum/guid/UAM:Herb:237039>

1939: <http://arctos.database.museum/guid/UAM:Herb:189494>

1939: <http://arctos.database.museum/guid/UAM:Herb:190190>

2004: <http://arctos.database.museum/guid/UAM:Herb:89336>

2002: <http://arctos.database.museum/guid/UAM:Herb:49910>

There are two types of images, those with the red spots have counts listed already, and those images that do not have red spots that you can print and count yourself.

3. Count the number of stomata on the image (red spots). Report your results below or use the images with red dots and those recorded numbers on the images.
Number of stomata on image from 1898 _____
Number of stomata on image from 1939 _____
Number of stomata on image from 2004 _____
4. The area of the images represents 1 mm² of leaf surface area, so the number of stomata you count is the number of stomata per mm² (also known as stomatal density).



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5. View the handout: “Carbon Dioxide at Mauna Loa.” Using the data on the graph, estimate the amount of carbon, in parts per million, for the following years: 1960, 1970, 1980, 1990, 2000, and 2010. Enter the values below. Note: carbon dioxide levels near the turn of the century (1900) have been estimated at 300 ppm using ice cores.

1960 _____ 1970 _____ 1980 _____ 1990 _____ 2000 _____ 2010 _____

6. Create a graph that plots stomatal density on the x axis, and carbon dioxide concentration on the y axis.

Questions:

- 1) Describe the relationship between stomatal density and carbon dioxide concentration.

- 2) What are some possible reasons for this relationship? _____

- 3) How will increased carbon dioxide emission (climate change) affect stomatal density or the distribution of plants in Alaska?

