Solar Education for NY
SchoolPower ...Naturally

# Where Do Plants Get Their Food?

**SPN LESSON #39**

## TEACHER INFORMATION

***LEARNING OUTCOME***

After becoming familiar with the historical study of photosynthesis and replicating van Helmont's classic experiment, students are able to describe the role of light in plant growth.

***LESSON OVERVIEW***

This lesson engages students in thinking about the historical development of the scientific method. A changing understanding of plant nutrition (photosynthesis) is the focus. Observational science, as practiced by Aristotle, is compared to experimental science, as practiced by van Helmont.

Students design an experiment that replicates van Helmont's, using only specified materials. Students are then asked to improve upon van Helmont's procedure and also to consider the importance of a factor neglected by both van Helmont and Aristotle—light. This lesson leads into the SPN lesson #40, *A Photosynthesis Timeline*.

***GRADE-LEVEL APPROPRIATENESS***

This Level III, Living Environment, interdisciplinary lesson is intended for use with students in grades 9–10.

***MATERIALS***

- Provide each student with a copy of the Student Handout section for *Where Do Plants Get Their Food?*
- ***The materials listed below are necessary only if you plan to have students actually conduct one of the experiments they design. You may want to set some of the materials out to serve as a visual cue for students when they are developing their investigations.***

  Potting soil
  Water
  Marking pens
  Scissors
  Index cards
  Clear cellophane tape
  Planting containers (8-oz. or 10-oz. plastic cups)
  Large seeds (beans, peas, corn) or small plants (ivy, impatiens, coleus, etc.)
  Electronic balance capable of reading to 0.01 grams
  Solar cell and milliammeter/multimeter

***SAFETY***

- Handle scissors carefully.
- Do not ingest the seeds, plants, or soil.
- Do not provide students with plants or seeds that are known to be poisonous.

## *TEACHING THE LESSON*

- Begin the lesson by asking students if plants and animals carry out the same life processes. After some discussion, address nutrition more specifically by asking students a series of questions such as:
  - Where do plants get their food?
  - What is actually contained in the "plant food" you can buy at the lawn and garden center?
  - How does the "food" from the lawn and garden center help plants grow?
  - Do plants need sugar?
  - Do plants digest their food?
  - Do plants get some or all of their food from the soil?
- These represent only a few of the plant nutrition-related questions you might ask students. The questions serve both to reveal misconceptions and to set the stage for how difficult it is to investigate plant nutrition. Establish with students that food is a substance that provides an organism with both nutrients and energy. A nutrient is a mineral necessary for maintaining good health, but it doesn't provide energy. Some examples of nutrients are calcium, nitrogen, phosphorous, and potassium.
- Allow students to work in pairs when designing their version of van Helmont's experiment. Hold them to more or less replicating the steps listed but using the materials provided in Table 2. Even if they are uncomfortable with the obvious problems with van Helmont's procedure, insist that they use it.
- Allow students to continue working together to describe how their version of van Helmont's experiment can be improved and how they might use a solar cell and milliammeter to determine the role of light in plant nutrition.

## *ACCEPTABLE RESPONSES FOR DEVELOP YOUR UNDERSTANDING SECTION*

1. At the conclusion of van Helmont's experiment, how much should the soil have weighed if Aristotle's theory were correct?

| | |
|---|---|
| *77.0 kg (final mass of willow)* | *91.0 kg (initial mass of soil)* |
| *- 2.3 kg (initial mass of willow)* | *- 74.7 kg (gain in mass of willow)* |
| *74.7 kg (gain in mass of willow)* | *16.3 kg (final mass of soil)* |

2. Explain why it was important for van Helmont to cover the soil in the plant pot during his experiment.

   *Covering the soil would prevent (a) additional soil from drifting into the container and (b) soil from blowing out of the container.*

3. Given the data van Helmont obtained, why was it reasonable for him to conclude that the willow tree obtained its food from the rainwater?

   *The soil lost only a few grams of mass. The amount of mass lost was not even close to the amount of mass gained by the willow. As far as van Helmont knew, the rainwater was the only substance the willow took in.*

4. Record the steps to be followed in your version of van Helmont's experiment. Be sure to include information about amounts and materials to be used.

   *A possible correct response is listed below, but there are many other correct responses. Students should follow van Helmont's basic procedure with slight modifications that reflect the materials available to them.*

   *(1) Dry soil by spreading it out on a paper towel and leaving it for a day or two.*

*(2) Find the mass of a plastic cup and record it. Then fill the cup three-fourths full with the dry soil. Find and record the combined mass of the cup and soil. Subtract the mass of the cup to find the mass of the soil placed in the cup.*

*(3) Moisten the soil with water.*

*(4) Find and record the mass of a large bean seed.*

*(5) Cover the pot, leaving only a hole for the bean plant to grow up through once the seed germinates.*

*(6) Keep the soil moist. Add nothing else.*

*(7) Wait for the bean plant to grow. Allow it to grow long enough so that it has several leaves.*

*(8) Remove the entire plant from the soil and record its mass.*

*(9) Dry the soil in the pot.*

*(10) Determine and record the mass of the soil. Compare the mass gained by the bean to the mass lost by the soil.*

5. (a) Before conducting your experiment, describe how its design could be improved if you were not required to follow van Helmont's basic procedure.

   *The design of the experiment could be improved by setting up several containers with beans. Also, more than one type of plant could be tested. A container of soil with no plant in it could serve as the control to see if the soil lost any mass without the plant being present.*

   (b) Explain how these improvements would make the results of your experiment more valid.

   *If you test only one plant in one cup, factors such as disease and genetics could influence the results. By doing multiple plants, this is less likely. Testing just one plant does not provide an accurate representation of the entire plant kingdom. By testing more than one species of plant, the data would be more representative of plants in general. Also, van Helmont's experiment lacked a control. A control might be a cup of soil without a plant. It should be treated the same way as the container(s) with plants. Maybe water causes the soil to lose mass or to gain mass. With a control, it will be more obvious what is influencing the results.*

6. Both Aristotle and van Helmont neglected to consider the importance of light to plant life. It wasn't until the 1700s that another scientist, Jan Ingenhousz, observed that "plant behavior begins only after the sun has risen." Describe how a solar cell connected to a device that measures small electric currents could be used in an experiment to determine how light influences plant growth.

   *More light would cause the solar cell to produce more electricity—to a point. More light would result in a plant's carrying out more photosynthesis—to a point. By placing the same types of plants in the same soil, etc., but in settings with different amounts of light, the influence of light on plant life processes could be monitored. The solar cell setup would provide accurate data regarding relative differences in the amount of light available.*

**Food for Thought**

7. (a) Which of the three experiments you explained in this activity (Analysis 4, 5, or 6) would you most like to carry out if you had the time and the materials? _______

   (b) Explain why this experiment is the one that interests you most.

   *Student responses to 7 (a) and (b) will vary. This question provides students with the opportunity to reflect on their own work.*

   (c) Check with your teacher to see if you may conduct the experiment you selected.

**Extended Activities**

*Writing*

Ask students to find out more about Aristotle and Jan van Helmont. In a short essay that describes important events and contributions to science made by each, have students explain why both men made important contributions to our understanding of photosynthesis even though their conclusions were incorrect.

*Critical Thinking Skills*

As a demonstration, grow plants of the same species and starting size under a variety of light conditions. Place one or two plants in each of the following light settings: total darkness, dim light, medium light, and bright light. Use a solar cell and milliammeter to establish relative light intensities. Or, place the lights at different distances from the same light source. Ask students to predict which plants will grow the most and the least over a one- or two-week period. Provide all of the plants with the same amount of soil, water, and so on. The only variable will be light. Students will be surprised that the plants in the dark grow the most—or at least increase in length the most.

## *ADDITIONAL SUPPORT FOR TEACHERS*

### BACKGROUND INFORMATION

Students may ask if the tiny bit of weight lost by the soil in van Helmont's experiment served as plant food. The weight difference of the soil was due to minerals that were absorbed through the willow tree's roots. The same would happen if students actually set up their own versions of van Helmont's experiment (providing they have a sensitive enough balance and good lab technique!). Plants require small amounts of minerals for a variety of life functions; minerals are needed to make the enzymes that regulate photosynthesis, respiration, and other metabolic processes.

A few students might argue that the tree did get its food from the soil. Some will claim that the minerals served as food and others will claim that minerals have no weight but served as food. These students are not using the law of conservation of matter in their thinking. Point out to them that it is impossible for the increased mass of the tree to come from minerals in the soil that possess a tiny mass.

Some students may think that the willow "defecates." In other words, these students may be thinking that soil really is food for the tree and that the mass of the soil changes very little because plants defecate.

The willow tree did get some nutrients from the soil in van Helmont's experiment. These nutrients did not provide energy for the tree to grow. Van Helmont could not use the small mass of the minerals absorbed by the willow to account for the huge change in the tree's mass. At some point, students should realize that the mass gained came largely from matter synthesized from carbon dioxide and water during photosynthesis. Thus follows the argument that many make: most of the weight of a tree comes from the carbon dioxide in the air.

### REFERENCES FOR BACKGROUND INFORMATION

***Video***

Private Universe Teacher Workshop video, *Lesson Pulled from Thin Air,* Annenberg/CPB, P.O. Box 2345, S. Burlington, VT 05407; phone: 1-800-532-7637; www.learner.org (also consider checking your BOCES film library).

*Books*

Allen, R. D. and Stroup, D. J. *Teaching Critical Thinking Skills in Biology.* National Association of Biology Teachers. Reston, VA, 1993.

Carey, S. S. *A Beginner's Guide to Scientific Method.* Wadsworth Publishing Company. Belmont, CA, 1994.

Crow, L. W. *Enhancing Critical Thinking.* Society for College Science Teachers. Washington, DC, 1989.

Freedman, R. L. H. *Open-Ended Questioning: A Handbook for Educators.* Addison-Wesley. Menlo Park, CA, 1994.

Miller, Kenneth and Joseph Levine. *Biology.* Pearson Education, Inc., Upper Saddle River, NJ, 2003.

## LINKS TO MST LEARNING STANDARDS AND CORE CURRICULA

**(Note: The correlation of this activity to the Living Environment Core Curriculum will vary depending on whether or not students perform the experiment they designed. This correlation is written as if students do both.)**

**Standard 1—Analysis, Inquiry, and Design:** Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.

Science Key Idea 1: The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing and creative process.

S1.1: Elaborate on basic scientific and personal explanations of natural phenomena, and develop extended visual models and mathematical formulations to represent one's thinking.

S1.1b: Measure and record experimental data.

S1.2: Hone ideas through reasoning, library research, and discussion with others, including experts.

S1.2a: Ask questions and locate, interpret, and process information from a variety of sources.

S1.2b: Make judgments about the reliability of a source and the relevance of information.

S1.3: Work toward reconciling competing explanations; clarify points of agreement and disagreement.

S1.3a: Accept scientific explanations only when they

- are consistent with experimental and observational experience
- can be used to make accurate predictions

Key Idea 2: Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity.

S2.1: Devise ways of making observations to test explanations.

S2.2a: Develop a research plan which involves researching background information and understanding the major concepts in the area being investigated.

Key Idea 3: The observations made while testing proposed explanations, when analyzed using conventional and invented methods, provide new insights into natural phenomena.

S3.1: Use various methods of representing and organizing observations (e.g., diagrams, tables, charts, graphs, equations, matrices) and insightfully interpret the organized data.

S3.3: Assess correspondence between the predicted result contained in the hypothesis and actual result, and reach a conclusion as to whether the explanation on which the prediction was based is supported.

S3.4: Based on the results of the test and through public discussion, revise the explanation and contemplate additional research.

3.4a: Hypotheses are valuable, even if they turn out not to be true, because they may lead to further investigation.

3.4b: Claims should be questioned if the data are based on samples that are very small, biased, or inadequately controlled or if the conclusions are based on the faulty, incomplete, or misleading use of numbers.

3.4c: Claims should be questioned if fact and opinion are intermingled, if adequate evidence is not cited, or if the conclusions do not follow logically from the evidence given.

S3.5: Develop a written report for public scrutiny that describes the proposed explanation, including a literature review, the research carried out, its result, and suggestions for further research.

3.5a: One assumption of science is that other individuals could arrive at the same explanation if they had access to similar evidence. Scientists make the results of their investigations public; they should describe the investigations in ways that enable others to repeat the investigations.

3.5b: Scientists use peer review to evaluate the results of scientific investigations and the explanations proposed by other scientists. They analyze the experimental procedures, examine the evidence, identify faulty reasoning, point out statements that go beyond the evidence, and suggest alternative explanations for the same observations.

**Standard 4**

***The Living Environment***

Key Idea 5: Organisms maintain a dynamic equilibrium that sustains life.

5.1: Explain the basic biochemical processes in living organisms and their importance in maintaining dynamic equilibrium.

5.1a: The energy for life comes primarily from the Sun. Photosynthesis provides a vital connection between the Sun and the energy needs of living systems.

Key Idea 6: Plants and animals depend on each other and their physical environment.

6.1: Explain factors that limit the growth of individuals and populations.

6.1a: Energy flows through ecosystems in one direction, typically from the Sun, through photosynthetic organisms including green plants and algae, to herbivores to carnivores and decomposers.

**Process Skills Based on Standard 4 (Laboratory Skills)**

i. Follows safety rules in the laboratory.
v. Makes observations of biological processes.
ix. Designs and carries out a controlled, scientific experiment based on biological processes.
xi. Differentiates between independent and dependent variables.
xiii. Collects, organizes, and analyzes data, using a computer and/or other laboratory equipment.
xiv. Organizes data through the use of data tables and graphs.
xv. Analyzes results from observations/expressed data.
xvi. Formulates an appropriate conclusion or generalization from the results of an experiment.
xvii. Recognizes assumptions and limitations of the experiment.

*Produced by the Research Foundation of the State University of New York with funding from the New York State Energy Research and Development Authority (NYSERDA)*
www.nyserda.org

Should you have questions about this activity or suggestions for improvement, please contact Bill Peruzzi at billperuz@aol.com

(STUDENT HANDOUT SECTION FOLLOWS)

**Name** ___________________________________

**Date** ____________________________________

# Where Do Plants Get Their Food?

## Background Information

Imagine that you are asked to observe and record the activities of two organisms for five minutes. You are given a mouse (that is not asleep!) and a bean plant. Your list of the mouse's activities would probably be quite long. It would be difficult to accurately record everything it did during the five-minute observation period. The bean plant's activities would likely be very easy to record.

A data table comparing your observations of the mouse and the bean plant might look like Table 1: Plant and Animal Comparisons.

**Table 1: Plant and Animal Comparisons**

| Type of Activity Observed | Animal (mouse) Examples | Plant (bean) Examples |
|---|---|---|
| Movement | walking and running | nothing |
| Eating | chews on seeds | nothing |
| Breathing | sides go in and out | nothing |
| Waste Elimination | small dark objects come out of its posterior | nothing |
| Response | mouse goes to food put in cage | nothing |

In order for it to be alive, the bean plant must carry out the activities listed in the chart. Plants require energy, respire, eliminate wastes, and so on. Aristotle, a Greek scholar who lived from 384 to 322 B.C., observed plants. He is possibly one of the first to carefully record plant activities. He concluded that plants get everything they need from the soil through their roots. However, Aristotle wasn't sure what plants needed or how their roots obtained it. He did not conduct any experiments. What he did was discuss his observations with others. This is the way science was done at that time.

For many years, people accepted what Aristotle said about plants obtaining necessary materials from the soil. It wasn't until 1610 that a Belgian scientist, Jan van Helmont, questioned the concept. In order to determine the accuracy of what Aristotle said, he designed and conducted an experiment.

Below is a step-by-step description of van Helmont's procedure:

(1) Dry soil in a furnace.

(2) Place 91 kg of the dried soil in a large plant pot.

(3) Moisten the soil with rainwater.

(4) Find and record the mass of a small willow tree—2.3 kg.

(5) Cover the pot, leaving only a hole for the willow tree's trunk.

(6) Keep the soil moist with rainwater. Add nothing else.

(7) Allow five years to pass.

(8) Remove the entire tree from the soil and record its mass—77 kg. (Note: Leaves that fell off the tree each year were not massed.)

(9) Dry the soil in the pot.

(10) Determine and record the mass of the soil—90.94 kg.

**Develop Your Understanding**

1. At the conclusion of van Helmont's experiment, how much should the soil have weighed if Aristotle's theory were correct?
2. Explain why it was important for van Helmont to cover the soil in the plant pot during his experiment.
3. Given the data van Helmont obtained, why was it reasonable for him to conclude that the willow tree obtained its food from the rainwater?

**Investigation**

Scientists are expected to make the results of their experiments public. An investigation should be described in such a way that others can repeat the work. Given the procedure van Helmont followed, design an investigation that repeats his work. Since waiting for five years is not practical and 90 kg is a lot of soil, your experiment should be designed to run for two or three weeks and use the materials listed in Table 2: Materials.

| **Table 2: Materials** | |
|---|---|
| Index cards | Scissors |
| Water | Large seeds (beans, peas, corn) or small plant |
| Potting soil | Clear cellophane tape |
| Marking pens | Planting containers (8-oz. or 10-oz. plastic cups) |
| Paper towels | Electronic balance capable of massing objects to 0.01g |

**Analysis**

4. Record the steps to be followed in your version of van Helmont's experiment. Be sure to include information about amounts and materials to be used.
5. (a) Before conducting your experiment, describe how the design might be improved if you were not required to follow van Helmont's basic procedure.

   (b) Explain how these improvements would make the results of your experiment more valid.
6. Both Aristotle and van Helmont neglected to consider the importance of light to plant life. It wasn't until the 1700s that Jan Ingenhousz observed that "plant behavior begins only after the sun has risen." Describe how a solar cell connected to a device that measures small electric currents could be used in an experiment to determine how light influences plant growth.

**Food for Thought**

7. (a) Which of the three experiments you explained in this activity (Analysis 4, 5, or 6) would you most like to carry out if you had the time and the materials? ________

(b) Explain why this is the one that interests you most.

(c) Check with your teacher to see if you may conduct the experiment you selected.