

Category V Life Science Examples

Guiding student interpretation and reasoning

Material A

Consider the bolded parts of the benchmark 5E6-8#1:

Food provides the molecules that serve as fuel and building material for all organisms. **Plants use the energy from light to make sugars from carbon dioxide and water.** This food can be used immediately or stored for later use. Organisms that eat plants break down the plant structures to produce the materials and energy they need to survive. Then they are consumed by other organisms. (American Association for the Advancement of Science, 1993)

In a middle school material, students are asked to read a text that describes Van Helmont's experiment. Van Helmont planted a young tree in a bucket of soil. He watered the tree regularly, but did not add any more soil. After five years, the tree gained a lot of mass, but the mass of the soil was nearly unchanged.

The body of the text includes three questions to which students are clearly expected to respond (pp. [11-12s](#)). The first question (a) asks students to record data related to Van Helmont's experiment. The second question (b) asks students to provide examples that show that Van Helmont was a careful experimenter. The third question (c) asks students to think about what was wrong with Van Helmont's conclusion that water alone was responsible for the increase in mass in plants. No questions *explicitly* ask students to make connections between Van Helmont's data and the role of water in plants making food. Questions b and c focus more on the process of Van Helmont's experimentation. Students are unlikely to be able to respond to Question c even if the question was carefully scaffolded.

Water—How Essential Is It?

When you started this chapter, you may have thought that plants get their food only from the soil. If you did, you are in good company. That's what the great philosopher Aristotle thought too! But a Belgian scientist of the seventeenth century, Jan Baptist van Helmont, questioned this belief and decided to look into the matter further. He decided to find out what role water had in plant growth.

What happens when a plant is deprived of water? You have probably seen what happens when you or somebody else forgets to water a houseplant. Plants that don't get enough water wilt. If they continue to be deprived of water, they eventually die.



The corn plant on the left is healthy because it received adequate rainfall. The corn on the right is stunted because it did not receive enough water.

Van Helmont performed an experiment that convinced him that water was so important that it was completely responsible for the great change in mass that occurs in growing plants. In other words, he concluded that water was completely responsible for growth in plants.

What do you think? Before you decide, let van Helmont tell you about his experiment, translated from his own words. Don't let the odd wording and spelling throw you. People spelled and spoke quite differently in van Helmont's day. (The masses have been changed to metric units.)

Journal

I have learned from this handicraft operation that all vegetables do immediately and materially proceed out of the element of water only. For I took an earthen vessel in which I put ninety kilograms of earth that had been dried in a furnace, which I moistened with rainwater, and I implanted therein the trunk, or stem, of a Willow tree, weighing two kilograms and about two-hundred and fifty grams. At length, five years being finished, the tree sprung from thence did weigh seventy-six kilograms. But I moistened the earth vessel with rain-water, or distilled water (always when there was need) . . . and lest the dust should be co-mingled with the earth, I covered the lip or mouth of the vessel with an iron plate covered with tin, and easily passable with many holes. I computed not the leaves that fell off, in the four autumnes. At length, I again dried the earth of the vessel, and there were found the same ninety kilograms, wanting a few grams. Therefore almost seventy-four kilograms of wood, bark, and roots arose out of water only.

Jan Baptist van Helmont

★ An Exploration Worksheet is available to accompany Exploration 2 on page 10 (Teaching Resources, page 6).

Answers to Questions, page 10

1. The leaves from a plant left in the dark have little or no starch compared with leaves from a plant that has been in bright light.
2. Both parts suggest that green plants need light to produce starch. In each case the plants (or parts of the plants) that did not receive light had less starch. However, steps 1 and 2 could not be considered without comparing the results with those from Exploration 1.
3. Steps 3 and 4 could have been done without first doing steps 1 and 2. However, steps 1 and 2 reduce the amount of starch in the plant's leaves so that the production of starch in the uncovered parts of the leaves is more apparent.

Water—How Essential Is It?

Before students begin reading, have them discuss what happens when a plant is deprived of water. (*It wilts and eventually dies.*) Help them to conclude that water is essential for healthy growth.

Have students silently read about van Helmont's experiment, or call on a volunteer to read it aloud. Monitor students' understanding of the material by having them discuss and complete the pictorial summary on page 12.

Point out to students that before the 1600s, scientists thought that plants obtained their food directly from the soil. This theory was first proposed by the Greek philosopher Aristotle (384–322 B.C.). This food was believed to have been absorbed directly by the roots and utilized by the plants without much change. Van Helmont was the first to provide experimental evidence that conflicted with this theory.

Primary Source

Description of change: excerpted from early writings by Jan Baptist van Helmont

Rationale: excerpted to focus on the importance of water to plant growth

ORGANIZER, continued

baking soda (sodium bicarbonate); 19 mL of water; wax pencil; lamp with 100 W bulb; materials to test for starch from Part 2 of Exploration 1 on page 7 (additional teacher materials: 1 g of sodium hydroxide and 24 mL of water for preparing sodium hydroxide solution; 50 mL of vinegar; a few strips of pH paper; 25 mL of 0.1 M sodium thiosulfate solution; a few sheets of old newspaper; 250 mL of water; 600 mL beaker; see Advance Preparation on page 1D.) **Exploration 4:** lamp with 100 W bulb; 2 test tubes; wooden

splint; a few matches; 50 g of baking soda (sodium bicarbonate); 950 mL of water; 2 clear plastic containers or 600 mL beakers; 2 clear funnels; elodea sprig; safety goggles

Teaching Resources

Exploration Worksheets, pp. 6, 8, and 9
Transparency Worksheet, p. 11
Transparency 1

Answers to In-Text Questions

- A** The following data complete the summary:
- mass of willow tree at the beginning of the experiment = 2 kg and about 250 g (or about 2.25 kg)
 - mass of dried earth = 90 kg
 - mass of dried earth at the end of the experiment = 90 kg, minus a few grams
 - mass of grown tree = 76 kg
- B** Van Helmont carefully planned his experiment before he began. He took careful quantitative measurements at the beginning and end of the experiment. He was careful to prevent unknown material from entering the earthen vessel he used.
- C** Van Helmont assumed that water was the only substance that entered the tree. He also assumed that the tree absorbed all of its nutrients through its roots. Van Helmont did not realize that the tree gained a nutrient (carbon dioxide) from the air.

CROSS-DISCIPLINARY FOCUS

Mathematics

Have students repeat van Helmont's experiment using some fast-growing plants, such as bean or corn plants. Students should keep careful notes and record their data in the form of graphs. They can then share the results of their work with the class.

Homework

Have students design an imaginary experiment that refutes van Helmont's conclusion that water is solely responsible for plant growth. (One example is to try to grow a plant in the absence of carbon dioxide, such as underwater or in space.)

Here is a summary of van Helmont's experiment. Fill in the missing data in your ScienceLog. **A**

Mass of dried earth = ?

Mass of willow tree at the beginning of experiment = ?



Mass of dried earth at the end of the experiment = ?



Van Helmont's experiment indicated that water was an important raw material for plants. Somehow, plants used water to build new tissues and structures. It was left to others, however, to find out exactly how the conversion of water into plant matter takes place.

Van Helmont was a careful experimenter. Can you give some examples that show this? But even though he was careful, van Helmont made a major mistake when he concluded that water alone was completely responsible for the increase in mass in plants. What do you think was wrong with his conclusion? **C**

In the next lesson you will perform Explorations involving gases that van Helmont knew nothing about. You will also be getting more information that will allow you to answer the question, "Where does the starch in plants come from?"



Mass of grown tree = ?