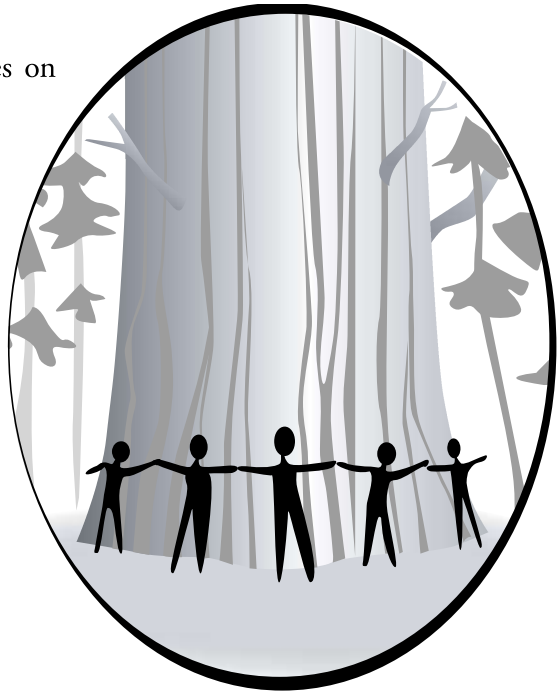
Giant Sequoia Tree



The giant sequoia tree is one of the largest trees on earth. It starts as a small seedling and grows into an enormous tree. Five children can stretch their arms across the width of the trunk of one of the large sequoia trees!

Where did most of the matter that makes up the wood and leaves of this huge tree originally come from? Circle the best answer.

A sunlight

B water

C soil

D carbon dioxide

E oxygen

F minerals

G chlorophyll

Explain your thinking. How did you decide where most of the matter that makes up this tree came from?

Giant Sequoia Tree

Teacher Notes

Purpose

The purpose of this assessment probe is to elicit students' ideas about transformation of matter. The probe is designed to reveal whether students recognize that a gas from the air (carbon dioxide) is combined with water and transformed into the new material that makes up most of the matter of the tree.

Related Concepts

photosynthesis, plants, transformation of matter

Explanation

The best response is D, carbon dioxide. Plants take in carbon dioxide (a gas) through their leaves and water from the soil and use the energy from sunlight to rearrange the atoms into new substances—sugar and oxygen. This process happens inside the leaf of the plant. Sunlight provides the energy for this process to happen. Chlorophyll is a pigment found within the leaf cells that absorbs the energy from sunlight used for the reaction. After food is made in the leaf, it travels to other parts of a

plant, where it is used for energy, tissue repair, and growth or stored for later use.

Most of the matter, including the leaves and wood, that makes up the structure of the tree can be traced back to the carbon dioxide that was transformed into sugar through photosynthesis and used for building material. The mass contributed by the carbon dioxide is much greater than the mass contributed by the water. The atomic mass of one molecule of carbon dioxide is approximately 44 atomic mass units; one molecule of water is approximately 18 atomic mass units. When wood is burned, carbon dioxide and water vapor are released and go back into the air. When the wood is completely burned, the remaining ashes consist of the small amount of minerals taken in from the soil.

Curricular and Instructional Considerations

Elementary Students

In the elementary grades students learn that plants need sunlight, water, and nutrients to grow and stay healthy. Upper elementary students begin to recognize that plants make their own food. However, it is too abstract an idea for them to understand the transformation of matter that takes place during photosynthesis and growth of a plant. Both younger and older students have difficulty accepting the idea that something as seemingly light as air could make up the bulk weight or mass of a tree, partly because students lack opportunities to recognize that air is a substance that has weight (the term *mass* can be used with older elementary students). It is critical for students to have opportunities to accept the idea early on that air is matter and has mass (*weight* for younger students). This probe is useful in identifying early conceptions students have developed about where the material that makes up a tree came from.

Topic: Photosynthesis
Go to: *www.scilinks.org*
Code: USIS2H123

Middle School Students

In middle school, students learn about chemical reactions and the types of transformations of matter that occur during these reactions. By the end of eighth grade they can begin to use the notion of atoms to explain what happens when matter is transformed in a process like photosynthesis. However, even though students can manipulate models to learn what happens during the transformation of carbon dioxide and water into sugar and oxygen, they may still refuse to recognize that a gas contributes the most mass to this reaction. It seems counterintuitive to students that most of the mass of the matter of a tree comes from carbon dioxide in the air. This probe is useful in determining whether students hold on to their intuitive idea about where most of the matter that makes up a plant comes from, even after instruction.

High School Students

In high school students learn more about the complex reaction of photosynthesis. Transformation of matter in a biological context now

focuses more on the flow of matter through food webs. Students' increasing knowledge of chemistry, particularly carbon-based molecules, comes in handy when reasoning through a problem such as this one that involves molecular mass. When comparing molecular masses of carbon dioxide and water, carbon dioxide has more mass to contribute to the reaction. This probe is useful at the high school level because it will often reveal that even though students are taught photosynthesis and develop the idea that matter is transformed in a biological context, they may still revert to their prior conceptions about where most of the mass comes from based on their preconception that gases have negligible mass or that plants take their food in from the soil.

Administering the Probe

This probe can be used with upper elementary students by removing the choices *carbon dioxide* and *oxygen* and replacing them with *air.* The sequoia tree was used as the subject of this probe because of its massive size, but a more familiar tree may be substituted. Similar to the "seed and log" question in the Private Universe series (Harvard-Smithsonian Center for Astrophysics 1995), you might show a maple seed or acorn, a seedling of the tree, and a log cut from the tree and ask students where most of the "stuff" of the log came from as it grew from seed to seedling to large tree. The unscientific word *stuff* can be used intentionally in this probe to explore students' ideas without being hindered by their understanding of the concept of matter or mass.

Related Ideas in *National Science Education Standards* (NRC 1996)

K–4 The Characteristics of Organisms

- Organisms have basic needs. For example, animals need air, water, and food; plants require air, water, nutrients, and light.

K–4 Properties of Objects and Materials

- Objects are made up of one or more materials, such as paper, wood, and metal.

5–8 Structure and Function in Living Systems

★ Cells carry on the many functions needed to sustain life. They grow and divide, thereby producing more cells. This requires that they take in nutrients, which they use to provide energy for the work that cells do and to make the materials that a cell or organism needs.

5–8 Populations and Ecosystems

★ For ecosystems, the major source of energy is sunlight. Energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis.

5–8 Properties and Changes in Properties of Matter

- Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties.

★ Indicates a strong match between the ideas elicited by the probe and a national standard's learning goal.

9–12 The Cell

★ Plant cells contain chloroplasts, the site of photosynthesis. Plants and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy-rich organic compounds and release oxygen to the environment.

9–12 Matter, Energy, and Organization in Living Systems

★ The energy for life primarily derives from the Sun. Plants capture energy by absorbing light and using it to form strong (covalent) chemical bonds between atoms of carbon containing (organic) molecules. These molecules can be used to assemble larger molecules with biological activity (including proteins, DNA, sugars, and fats). In addition, the energy stored in bonds between the atoms (chemical energy) can be used as sources of energy for life processes.

9–12 Chemical Reactions

- Complex chemical reactions involving carbon-based molecules take place constantly in every cell in our bodies.

Related Ideas in *Benchmarks for Science Literacy* (AAAS 1993)

K–2 Flow of Matter and Energy

- Plants and animals both need to take in water, and animals need to take in food. In addition, plants need light.

K–2 The Structure of Matter

- Objects can be described in terms of the materials they are made of and their physical properties.

3–5 Flow of Matter and Energy

- Some source of "energy" is needed for all organisms to stay alive and grow.

3–5 The Structure of Matter

- When a new material is made by combining two or more materials, it has properties that are different from the original materials.

3–5 The Earth

- Air is a substance that surrounds us and takes up space.

6–8 Flow of Matter and Energy

★ Food provides molecules that serve as fuel and building material for all organisms. Plants use the energy in light to make sugars out of carbon dioxide and water. This food can be used immediately for fuel or materials, or it may be stored for later use.

- Energy can change from one form to another in living things. Animals get energy from oxidizing their food, releasing some of its energy as heat.

9–12 The Structure of Matter

- Atoms often join with one another in various combinations in distinct molecules or three-dimensional repeating patterns. An enormous variety of biological, chemical, and physical phenomena can be explained

★ Indicates a strong match between the ideas elicited by the probe and a national standard's learning goal.

by changes in the arrangement and motion of atoms and molecules.

Related Research

- The question in this probe is based on a similar question used in the Private Universe series where Harvard graduates were shown a seed and a log and asked where most of the mass of the log came from. Very few mentioned carbon dioxide. The most common responses were that it came from the soil or that it came from the water (Harvard-Smithsonian Center for Astrophysics 1995).
- Students have a difficult time imagining plants as chemical systems. In particular, middle school students think organisms and materials in the environment are very different types of matter. For example, plants are made of leaves, stems, and roots; the nonliving environment is made of water, soil, and air. Students see these substances as fundamentally different and not transformable into each other (AAAS 1993).
- Students have a difficult time accepting that weight increase and growth in plants is attributed to the incorporation of matter from a gas. In a study of 15-year-old students, many failed to mention carbon dioxide as the source of the increase in weight of growing seedlings, even though they knew that carbon dioxide was taken in during photosynthesis (Driver et al. 1994).
- Barker and Carr (1989) found that many children regarded sunlight as one of the reactants in photosynthesis, along with carbon dioxide and water.
- Some students consider light to be made of molecules and thus contributing to the matter of a plant (Driver et al. 1994).
- Driver's study of 759 15-year-old students who had studied photosynthesis connected the idea of growth with photosynthesis. Although about a third of the students could understand the component idea of photosynthesis, only 8% could relate it to plant growth by describing how a tree makes tissue from the constituents it takes in from the environment. Only 3 students out of 759 said that tree tissue is made from carbon dioxide and water using light energy (Driver et al. 1994).
- In Wandersee's study (1983) of 1,405 students ages 10–19, many thought that the soil in a plant pot would lose weight as the plant grows because the plant uses the soil for food.

Suggestions for Instruction and Assessment

- Before students can accept the idea that the mass of a plant comes mostly from the carbon dioxide in the air, they have to accept air as matter that has weight or mass. Students need multiple opportunities to discover that gases have significant mass.
- High school students can use molecular masses to show that even though water is taken in and transformed along with carbon dioxide, the carbon dioxide molecules contribute significantly more mass than water molecules.

- Manipulating physical models of molecules may help middle school and high school students see what happens to the carbon dioxide.
- Photosynthesis is a complex reaction that is frequently treated as an equation with little opportunity to learn how the process contributes to the growth and energy needs of a plant. Explicitly make connections between the transformation of matter that occurs and plant growth.
- If students fail to recognize that carbon dioxide as a gas has weight, show students dry ice and explain that it is a solid form of carbon dioxide. Have students put on protective gloves and hold a piece of dry ice to sense the "felt weight."
- Use Von Helmont's experiment as a context to learn how the question of where plants got the materials they needed to grow from was historically explored. Have students evaluate the results of his experiment.

Related NSTA Science Store Publications and Journal Articles

American Association for the Advancement of Science (AAAS). 1993. *Benchmarks for science literacy.* New York: Oxford University Press.

Driver, R., A. Squires, P. Rushworth, and V. Wood-Robinson. 1994. *Making sense of secondary science: Research into children's ideas.* London: RoutledgeFalmer.

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Keeley, P. 2005. *Science curriculum topic study: Bridging the gap between standards and practice.* Thousand Oaks, CA: Corwin Press.

National Research Council (NRC). 1996. Photosynthesis vignette. In *National science education standards,* 194–196. Washington, DC: National Academy Press.

Weinburgh, M. 2004. Teaching photosynthesis: More than a lecture but less than a lab. *Science Scope* 27 (9): 15–17.

Related Curriculum Topic Study Guide

(Keeley 2005)
"Photosynthesis and Respiration"

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American Association for the Advancement of Science (AAAS). 1993. *Benchmarks for science literacy.* New York: Oxford University Press.

Barker, M., and M. Carr. 1989. Photosynthesis: Can our pupils see the wood for the trees? *Journal of Biological Education* 23 (1): 41–44.

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Harvard-Smithsonian Center for Astrophysics. 1995. *Private Universe Project: Workshop 2. Biology: Why are some ideas so difficult?* Videotape. Burlington, VT: Annenberg/CPB Math and Science Collection.

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