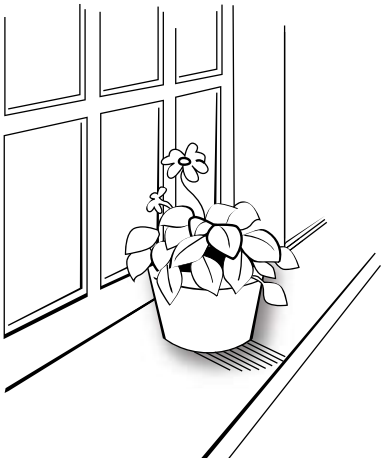
Light and Dark

Teacher Notes



Purpose

The purpose of this assessment probe is to elicit students' ideas about when the processes of photosynthesis and respiration occur. The probe is designed to reveal whether students recognize that plants respire continuously.

Related Concepts

Photosynthesis, respiration, energy, plants

Explanation

The best answer is Mika's: "Photosynthesis occurs when it is light; respiration occurs both when it is light and when it is dark." The word *photosynthesis* means to "make with light." Plants photosynthesize during the daytime when sunlight is available (or at other times when they are exposed to artificial light). They capture light energy from the Sun, which they convert into chemical energy during the process of photosynthesis. Plant cells, like all other cells, continuously need energy to carry out their life processes. Cellular respiration is the process during which cells take in oxygen to break down sugars and produce adenosine triphosphate (ATP) that can be used by the cell. This process does not require light. It requires a food molecule like glucose and oxygen (for aerobic respiration). This process (cellular respiration) occurs any time the cell needs energy to carry out its life processes, whether it is night or day. A common misconception is that plants photosynthesize during the day and conduct cellular respiration only at night. This misconception was even perpetuated when hospitals used to remove plants from a patient's room during the night to ensure an adequate oxygen supply for the patient!

Light is required to drive one of the two main photosynthetic reaction processes. This light-dependent reaction uses the energy from sunlight to produce high-energy electrons (which are stored in ATP and NADPH). This light-dependent reaction also produces oxygen (O_2) as a waste product. Simultaneously, a second set of reactions called the Calvin

cycle uses the ATP and NADPH that are formed during the light reaction to produce high-energy sugars. The Calvin cycle occurs at the same time as the light-dependent reactions inside the chloroplast. The reactions in the Calvin cycle can happen in the light or in the darkness, as they are not light dependent. This is why the reactions in the cycle also may be called the light-independent or dark reactions. However, the process of carbon fixation is light-dependent overall, because without the energy from light the chloroplasts will deplete the ATP and NADPH required for the reaction, and the Calvin cycle will stop. Students who recognize that there is a light and dark reaction may believe erroneously that the dark reaction can only occur in darkness.

Photosynthesis and cellular respiration occur in different sites within the cell. Photosynthesis occurs in the chloroplast and respiration occurs in the mitochondria. The primary purpose of photosynthesis is to manufacture the food that plants need to carry out their life processes or store for later use by the plant. The primary purpose of cellular respiration is to release energy from the food plants make to carry out their life processes. The important ideas for this probe are that photosynthesis requires light for the full process to occur and that respiration occurs continuously regardless of whether or not light is present.

Curricular and Instructional Considerations

Elementary Students

In the elementary grades, students learn that plants need water, sunlight, nutrients, and air. They are introduced to the idea that plants make their own food and need oxygen from the air. However, the details of the processes of photosynthesis and respiration should wait until middle school.

Middle School Students

In middle school, students build upon their elementary understanding that plants need sunlight, water, and air to understand the link between these needs and the processes of photosynthesis and respiration. They qualitatively learn that plants take in carbon dioxide and water and use energy from sunlight to produce sugars and oxygen. Details about the process, including formation of ATP and NADPH, are addressed later in high school. They also learn that respiration is a cellular process in which organisms take in oxygen to break down sugars and release energy. However, the way these processes are presented in the curriculum often conveys the misconception that photosynthesis is a plant process and respiration is an animal process, or that the two processes in plants are opposite—that one occurs in the daytime and one occurs at night.

High School Students

High school students build on a basic descriptive understanding of photosynthesis and cellular respiration to understand the cellular and molecular processes involved in synthesizing food and breaking it down to release energy. They move from an understanding of macro structures of a plant that take in and release water and gases and make food to an understanding of the cell organelles involved—chloroplasts and mitochondria. Students may build deeper understanding by examining the specific reactions that occur inside these structures and the arrangement within these structures that facilitates these reactions, including the light and dark reactions of photosynthesis and aerobic and anaerobic cellular respiration.

Administering the Probe

This probe is appropriate for middle and high school students who have prior knowledge of the general processes of photosynthesis and respiration. It is also useful to give to high school

students after they have learned about the "light and dark" reactions of photosynthesis to check for misconceptions. See the vignette in the introduction to this book on pages 1–6 for an example of how to use the "sticky bars" FACT with this assessment probe.

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.

5–8 Structure and Function in Living Systems

- Cells carry out the many functions needed to sustain life.

5–8 Populations and Ecosystems

- Plants and some microorganisms are producers—they make their own food.
- For ecosystems, the major source of energy is sunlight. Energy entering ecosystems as sunlight is transferred by producers into chemical energy by photosynthesis.

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

- Plants capture energy by absorbing light and using it to form strong (covalent) chemical bonds between the 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.
- The chemical bonds of food molecules contain energy. Energy is released when the bonds of food molecules are broken and new compounds with lower energy bonds are formed. Cells usually store this energy temporarily in phosphate bonds of a small, high-energy compound called ATP.

Related Ideas in *Benchmarks for Science Literacy* (AAAS 2009)

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.

3–5 Flow of Matter and Energy

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

6–8 Flow of Matter and Energy

- Plants use the energy from light to make sugars from carbon dioxide and water.
- Organisms get energy from oxidizing their food, releasing some of its energy as thermal energy.

Related Research

- Some students think of respiration as synonymous with breathing and therefore do not think of plants as respiring (Driver et al. 1994).
- Several studies reveal that students think of respiration as being the opposite of photosynthesis: with photosynthesis occurring during the day and respiration occurring at night (Driver et al. 1994).

Suggestions for Instruction and Assessment

- Combine this probe with "Respiration" from *Uncovering Student Ideas in Science, Vol. 3: Another 25 Formative Assessment Probes* (Keeley, Eberle, and Dorsey 2008).

- At the high school level, avoid using the term *dark reaction of photosynthesis*. Instead, it is better to use the term *light-independent reaction* so that students don't think photosynthesis can take place in the dark. Sometimes, the multiple terms used confuse students—*light-independent reactions, Calvin cycle,* and *carbon fixation* all mean the same thing. It may be best to use the term *carbon fixation* so that students get the idea that plants need to get carbon from somewhere to make sugar, which is a carbon-based molecule. This reinforces the need to realize the necessity of carbon dioxide as a carbon source.
- Avoid teaching photosynthesis and respiration as opposite processes. Although photosynthesis and respiration are "opposite" in terms of their chemical equations, they are not truly opposite processes in terms of when or where they occur. For example, photosynthesis takes place in the light; respiration in the light and dark. Plant cells have chloroplasts for photosynthesis and mitochondria for cellular respiration; animal cells have mitochondria for cellular respiration but no chloroplasts, because they do not photosynthesize.
- A kinesthetic activity that shows that photosynthesis and respiration are not really opposite processes can be done by handing out cards with the components of the two simplified equations for photosynthesis and respiration and have the students arrange themselves (while standing) to form first one equation or the other. Then have them rearrange themselves to form the other equation. This activity makes it evident which molecules just move from one side of the equation to the other and which parts are different (light energy needed for photosynthesis, ATP produced in respiration, and light-dependent reactions). Collect the cards and do it again with different students holding different components of the equations. Repeat several times, sometimes starting with photosynthesis and sometimes with respiration.

Related NSTA Science Store Publications, NSTA Journal Articles, NSTA SciGuides, NSTA SciPacks, and NSTA Science Objects

American Association for the Advancement of Science (AAAS). 2001. *Atlas of science literacy.* Vol. 1. (See "Flow of Matter in Ecosystems" map, pp. 76–77, and "Flow of Energy in Ecosystems" map, pp. 78–79.) Washington, DC: AAAS.

Koba, S., with A. Tweed. 2009. *Hard-to-teach biology concepts: A framework to deepen student understanding.* (See Chapter 4, "Photosynthesis and Respiration," pp. 119–141.) Arlington, VA: NSTA Press.

Mundry, S., P. Keeley, and C. Landel. 2009. *A leader's guide to science curriculum topic study.* (See Module B6, Photosynthesis and Respiration Facilitation Guide, pp. 144–149.) Thousand Oaks, CA: Corwin 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 (in Keeley 2005)
"Photosynthesis and Respiration"

References

American Association for the Advancement of Science (AAAS). 2009. Benchmarks for science literacy online. *www.project2061.org/publications/bsl/online*

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

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

Keeley, P., F. Eberle, and C. Dorsey. 2008. *Uncovering student ideas in science, vol. 3: Another 25 formative assessment probes.* Arlington, VA: NSTA Press.

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academies Press.