The sunlight–food connection

Focus questions	What do plants need to grow? What role does photosynthesis play in plant growth? What role does photosynthesis play in the cycling of matter and the flow of energy in an ecosystem?
Learning target	Students will understand that plants use the energy in light to make sugars and oxygen out of carbon dioxide and water in the process of photosynthesis.
Vocabulary	Leaf, stem, roots, stoma/stomata, light energy, chemical energy, carbon dioxide, oxygen, glucose, chloroplasts, chlorophyll, photosynthesis, matter, autotroph, heterotroph

MS-LS1: From Molecules to Organisms: Structures and Processes

Performance expectation MS LS1-6	**Classroom connection:** Students will explore how light, water and carbon dioxide change matter into different forms (oxygen and glucose), demonstrating the cycling of matter and the flow of energy among living things.

Science and engineering practices

Constructing Explanations & Designing Solutions	**Classroom connection:** Students will construct an explanation for the cycling of matter and flow of energy during the photosynthetic process using data collected from their leaf disk experiment and research.

Disciplinary core ideas

LS1.C: Organization for Matter and Energy Flow in Organisms **PS3.D: Energy in Chemical Processes and Everyday Life**	**Classroom connection:** Students will observe and collect data on leaf disks exposed to light in a water solution to observe photosynthesis. The leaf disks will float at different levels in the water due to oxygen production when exposed to different light wavelengths. Students will make the connection that energy from sunlight drives the chemical reaction of water and carbon dioxide to produce oxygen and sugars. *This lesson focuses on the movement of matter and the flow of energy in the process of photosynthesis. This lesson does not include the biochemical mechanisms of photosynthesis.*

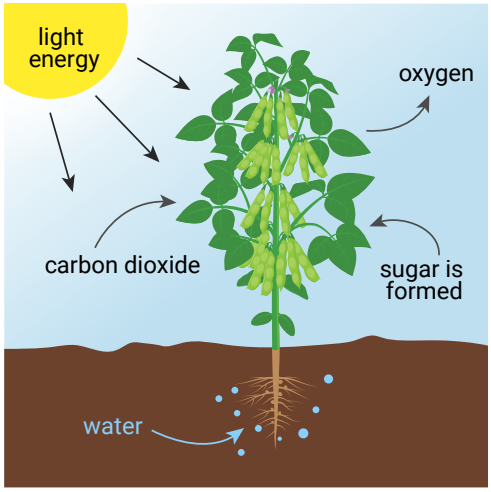
Cross-cutting concepts

Energy and matter	**Classroom connection:** Students will observe how light energy drives the photosynthetic reaction in their leaf disk experiments.

Background

This lesson will help students to determine that plants create their food (glucose) through the process of photosynthesis. Photosynthesis is a chemical process by which autotrophic organisms convert light energy (sunlight) into chemical energy (glucose) to fuel their metabolic activity. During the process of photosynthesis, plants take in carbon dioxide (CO_2) and water (H_2O) to create glucose ($C_6H_{12}O_6$) and oxygen (O_2) in the presence of light energy.

$$6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$$



To prepare for photosynthesis, plants take in water through their roots and carbon dioxide from the atmosphere through the stomata on their leaves. The oxygen that is produced during photosynthesis is released through the same stomata to the atmosphere and the glucose is stored within the plant for cellular respiration.

Photosynthesis is a complex process that takes place in two separate reactions (light-dependent and light-independent) inside the chloroplasts found within a plant's mesophyll cells. In the light-dependent reaction, the energy of light waves is absorbed and stored as ATP which is then used in the light-independent reaction to create glucose. This lesson demonstrates the first part of the photosynthetic reaction, the light dependent reaction.

One factor that affects the photosynthetic process is the quality and quantity of light energy. Light is a type of energy that exists in waves. White light, like the sun, is actually made up of different colored wavelengths including red, yellow, orange, green, blue, indigo and violet (ROY G BIV). When white light strikes an object, it will absorb all the light except the colored wavelength that we see. That color wavelength is reflected off the surface, which is why we see specific colors. When plants photosynthesize, they are using all the wavelengths of light except green. This is why plants look green.

Prior knowledge

In order to successfully complete this lesson students should be familiar with or have completed lessons relating to basic plant biology: plant parts, cells, organelles, and the concept that plants have the ability to create their own "food" through the process of photosynthesis.

Materials

- Foldscopes
- baking soda (sodium bicarbonate)
- gram scale
- water
- 200 mL beaker (one per student group)
- plastic straw or hole punch
- fresh spinach leaves
- 10 mL syringe (one per student group)
- color correction light gel filter sheets (transparency film plastic sheets)
- 100 W incandescent bulb with light clamp (one per student group)

Student handout

Reflection

1. What do plants need for photosynthesis?

Carbon dioxide, water, and light energy

2. What is the product of photosynthesis?

Glucose: $C_6H_{12}O_6$ (sugars)

3. What is the by-product of photosynthesis? Where does this by-product exit the leaf?

Oxygen, stoma

4. Where does photosynthesis take place in the plant?

Chloroplast

5. Write a hypothesis that this experiment is designed to test.

As light intensity increases, the rate of photosynthesis will increase.

6. What independent variable is tested for in this experiment?

Light wavelength

7. Why are the leaf disks floating? How do floating disks correspond to the rate of photosynthesis?

As photosynthesis occurs, oxygen is released. An accumulation of oxygen in the leaf disks will cause them to float. The faster the rate of the photosynthetic reaction, the greater the volume of oxygen produced and consequently the higher the leaf disks will float in the baking soda solution.

8. How did the plastic film impact the rate of photosynthesis in your spinach leaves?

The film altered the light wavelengths that were absorbed by the spinach disks. The film decreased the rate of photosynthesis and the oxygen produced.

Teacher preparation

- Prepare leaves of various plants for students to observe with foldscopes. Fresh leaves are best for student observation. If you need to gather leaves the night before the student observation, place leaves in a ziplock bag with a damp paper towel and place in a cool, dark location (fridge) until use the next day.
- Prepare the 0.1% bicarbonate solution for student use by mixing 0.5 grams (approximately ⅛ tsp.) baking soda with 500 mL (approximately 2 cups) water. Each student group will need 150 mL of solution for their experiment.
- Prepare 10 ml syringes for student use during the leaf disk experiment. *Make sure to remove needles if present.*
- Suggested timing for this lesson is 90 minutes, or two class periods.

Procedure

1. **Engage:** Show students a photograph of a seedling and a mature corn or soybean plant. Ask them what they notice and wonder about the two plants in the photograph. Students may share their comments on sticky notes, Google JamBoard, or in class discussion. Ask students what all plants need to grow and survive. How does a seedling grow into a mature plant? How do plants produce food?
2. **Explore:** Have students observe different plant leaves to see stomata in which gas exchange takes place for photosynthesis and other plant cells using their foldscopes.
3. **Explain:** Photosynthetic organisms capture energy from sunlight and use it to manufacture sugars from carbon dioxide and water, releasing oxygen into the environment.
   - Share the photosynthesis equation and ask students to demonstrate their understanding of the equation in a diagram demonstrating how plants produce food.
     $6CO_2 + 6H_2O + \text{light energy} \rightarrow C_6H_{12}O_6 + 6O_2$
4. **Elaborate:** Conduct an experiment to observe the production of oxygen from photosynthesis by viewing leaf disks that have been placed in a carbonated solution under a growth light. At any given point in this experiment, the number of floating leaf disks is an indirect measurement of the net rate of photosynthesis. In photosynthesis, plants use water, energy from the sun, and carbon dioxide (CO_2) from the air to store carbon and energy in the form of glucose molecules ($C_6H_{12}O_6$). Oxygen gas (O_2) is a byproduct of this reaction. The leaf disks will float according to how much oxygen is produced. If one disk is higher in the solution than another, it is producing more oxygen and has a higher net rate of photosynthesis.
5. **Evaluate:** Use concept mapping to assess if students are connecting key concepts being taught.
   - Write the following vocabulary words on the board: **sunlight, carbon dioxide, water, oxygen, soil, stomata, stems, roots, glucose, chloroplasts, and mass.**
   - Ask the students to connect the terms using lines/arrows. On the lines/arrows, students should write the connection between the two terms or write how the two terms relate to each other.
6. **Extend**: Students may use different colors of color correction light gel filter sheets (overlays transparency film plastic sheets) to see if the different light wavelengths have an effect on the rate of photosynthesis.

Differentiation

Other ways to connect with students with various needs:

- **Local community:** Create a coloring book for a student to share with a student in a younger grade, using illustrations to demonstrate the student understands the concepts being discussed.
- **Students with special needs (language/reading/auditory/visual):**
  - How Do Seeds Become a Plant? **youtu.be/tkFPyue5X3Q**
  - Plant Needs song by Generation Genius **youtu.be/HDElY8zB5JY**
  - Photosynthesis **youtu.be/3pD68uxRLkM**
  - "The Amazing Life Cycle of Plants" by Kay Barnham **youtu.be/zP00YV8qVY4**
- **Extra support:** See above videos.
- **Extensions:**
  - Connection to current events: This is an interesting link about climate adapted plant breeding and how it is impacting the characteristic outcomes in plants. Students could read and write a reflective piece in his or her science interactive notebook about what they still wonder about this article.
    sciencedaily.com/releases/2020/11/201111123945.htm
  - Scientific Peer Review: Make notes on Alex's research project abstract below:
    "The purpose of my project is to possibly end world hunger and global warming.The information I gathered can improve our lives by stopping global hunger and global warming. In my experiment, I tested to see if the amount of carbon dioxide will affect algae growth. Order an Algae Research Supply algae research kit. Mix in the salt and nutrients with algae. Hook up the CO_2 tank to the CO_2 regulator, then hook that up to the cut pieces, then hook the airline tube to 4 of the 8 culture tubes. Let sit for 2 weeks. Then observe. The results were that the algae grew at around the same rate. The conclusion was that you don't need to add extra carbon dioxide to grow algae."
  - Write a response in your science interactive notebook that is a letter to Alex about her project. In the body of the letter, include what is strong about her project (at least 3 observations) and what you wonder about her project (at least 3 things).
  - Design a follow up experiment to Alex's project. What might you investigate further? Be certain that your experiment follows the scientific method.

Assessments

Rubric for assessment

Skill	Developing	Satisfactory	Exemplary
Student understands that a transfer of energy drives the change of matter in an ecosystem.	The student can identify that light is energy and is required for photosynthesis.	The student can describe that light energy is necessary for photosynthesis and is absorbed by the plant (chloroplasts) to begin the photosynthetic reaction.	The student can describe that light energy is necessary for photosynthesis and is absorbed by the plant (chloroplasts) to begin the photosynthetic reaction. The student can provide evidence from the investigation that photosynthesis has taken place.
Student understands how light energy, water, and carbon dioxide change into different forms in an ecosystem.	The student can illustrate the inputs and outputs of photosynthesis.	The student briefly describes how light, water, and carbon dioxide change into different forms.	The student accurately describes, using correct vocabulary, how light, water, and carbon dioxide change into different forms, demonstrating the cycling of matter in an ecosystem.
Student constructs an explanation based on evidence and reasoning that the photosynthetic process changes matter into different forms and that energy is necessary for this to occur.	The student collects data from their experiment.	Student identifies and describes evidence necessary to construct an explanation for photosynthesis.	Student identifies and describes evidence necessary to construct an explanation for photosynthesis and the cycling of matter and flow of energy that takes place during the photosynthetic process.

Rubric for self-assessment

Skill	Yes	No	Unsure
The student can describe that light energy is necessary for photosynthesis and is absorbed by the plant (chloroplasts) to begin the photosynthetic reaction.			
The student briefly describes how light, water, and carbon dioxide change into different forms.			
Student identifies and describes evidence necessary to construct an explanation for photosynthesis.			