Matter and Energy in Photosynthesis

Living systems take in energy and matter and convert them to forms they can use. Plants, for example, are producers that capture light energy and convert it to chemical energy to carry out cell processes within the plant. The chemical energy takes the form of chemical bonds in sugar molecules. When a consumer, such as a panda, eats plant matter, it obtains this energy and other nutrients it needs for cell processes and growth through the process of digestion. Any matter that cannot be digested is excreted as waste.

FIGURE 2: This panda is a consumer that gets its energy and nutrients from eating leaves.

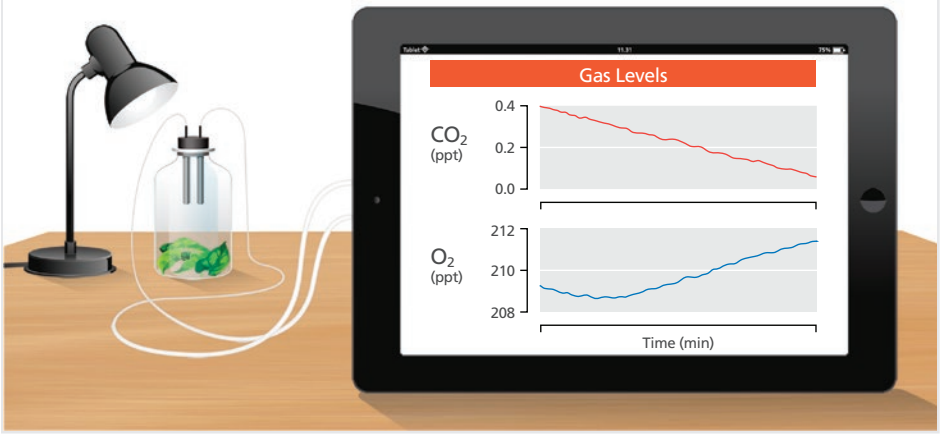
Explain Describe the transformation of energy as it is transferred from the sun to the panda.

Modeling Photosynthesis

Plants, algae, and some bacteria use a process called photosynthesis to capture and transform light energy from the sun and store it in high-energy sugar molecules. Both plant cells and animal cells use sugars made by photosynthesis as an energy source. However, photosynthesis is not just important to organisms—it also helps regulate Earth's environment. Photosynthesis produces the oxygen we breathe, and it removes carbon dioxide from Earth's atmosphere.

Organisms are complex living systems. Organisms live and interact in ecosystems, which are systems within the biosphere. All organisms play different roles in the cycling of matter and the transfer of energy in their ecosystem. To better understand the relationship between organisms and the environment, scientists collect many different types of data.

FIGURE 3: This setup shows a plant in a closed system. Sensors are measuring carbon dioxide and oxygen concentrations in the chamber. The gas concentrations are shown in parts per thousand.



Collaborate Discuss with a partner why it would be beneficial to human survival to have plants on a planet where oxygen levels are low and carbon dioxide levels are high.

Gather Evidence Identify inputs and outputs for this system. How can the data help scientists understand the relationship between plants and the environment?

Photosynthesis is important to life on Earth. Nearly all organisms on Earth depend on this process. So understanding the relationship between organisms and photosynthesis is critical. Using equipment to measure the rate of photosynthesis, for example, is one way to study the impact that organisms have on the process. Using models is another way to understand processes like photosynthesis. Scientists can study the relationship between the inputs and outputs.

Energy and Matter

Model Draw a plant and label the inputs and outputs of photosynthesis. Where should the labels for enzymes and light be placed?

The process of photosynthesis can be modeled in various ways. For example, a chemical equation is one way to represent photosynthesis.

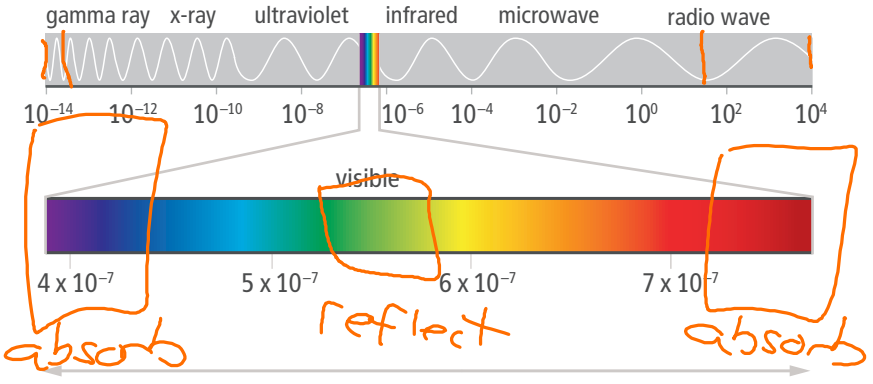
$$6CO_2 + 6H_2O \xrightarrow[\text{light}]{\text{enzymes}} 6O_2 + C_6H_{12}O_6$$

This model shows the inputs and outputs as reactants and products. The multiple arrows indicate that the process of photosynthesis has many steps. Light and enzymes are placed over the arrows to indicate that they must be present for this reaction to take place. In this equation, carbon dioxide and water are reactants, and oxygen and glucose are products. Plant cells use glucose to form complex carbohydrates such as starch and cellulose, which the plant uses for growth and maintenance.

Light and Photosynthesis

Light is a form of energy known as electromagnetic radiation. Electromagnetic radiation travels in waves of various wavelengths, as shown in Figure 4. Plants absorb only visible light to use for photosynthesis. Even in the visible portion of the electromagnetic spectrum, not all wavelengths are absorbed by plants. Visible light consists of different wavelengths that correspond to different colors of light.

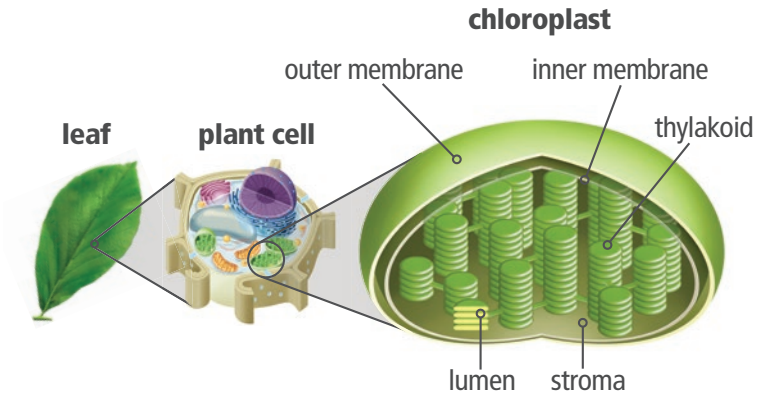
FIGURE 4: The Electromagnetic Spectrum



Analyze Think about light as a form of energy and answer the following questions: What are microwaves used for? What are radio waves used for? What do you think might happen if visible light were blocked from Earth? How would photosynthesis be impacted?

In plant cells, light absorption and photosynthesis take place inside an organelle called a chloroplast. Inside the inner membrane of the chloroplast are stacks of disc-shaped sacs called thylakoids, which contain pigment molecules called chlorophyll.

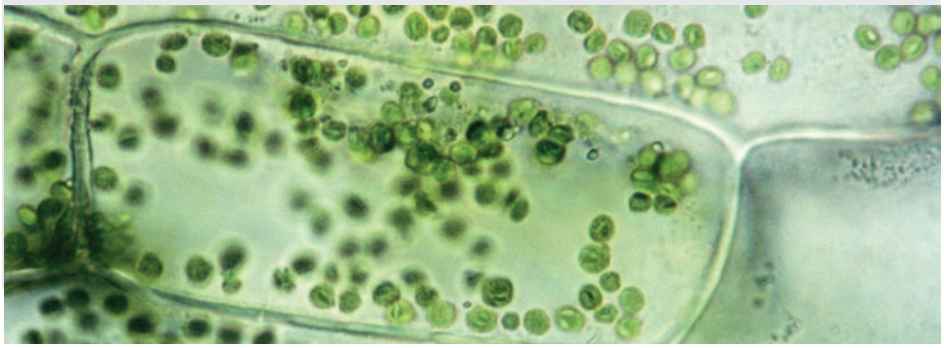
FIGURE 5: The area inside the chloroplast is the stroma. The area inside the thylakoid sac is called the lumen. The stages of photosynthesis occur across the thylakoid membrane that separates the stroma and the lumen.



Explain Place these systems in order from largest to smallest, beginning with Earth, and explain your reasoning: tree, biosphere, plant cell, chloroplast, leaf

Different types of chlorophyll absorb different wavelengths of light, transforming the light energy into chemical energy through photosynthesis. Unabsorbed wavelengths get reflected by the plant's pigments, and our eyes detect these as the plant's color.

FIGURE 6: Chlorophyll is a pigment molecule in chloroplasts. Plants have two main types of chlorophyll, called chlorophyll *a* and chlorophyll *b*.



Analyze Which colors of light are absorbed, and which colors are reflected by most plants?

Engineering

Choosing a Light Source

Scientists and engineers may study the inputs and outputs of a system as part of optimizing the system. For example, different light sources can affect the rate of photosynthesis in a plant system. Different light sources emit light with a variety of wavelengths. Light emitting diodes, or LEDs, can be designed to only give off certain colors, such as red, blue, or green, which correspond to different wavelengths of visible light. Applying specific light sources to plants is one way to optimize the rate of photosynthesis.

Explore Online

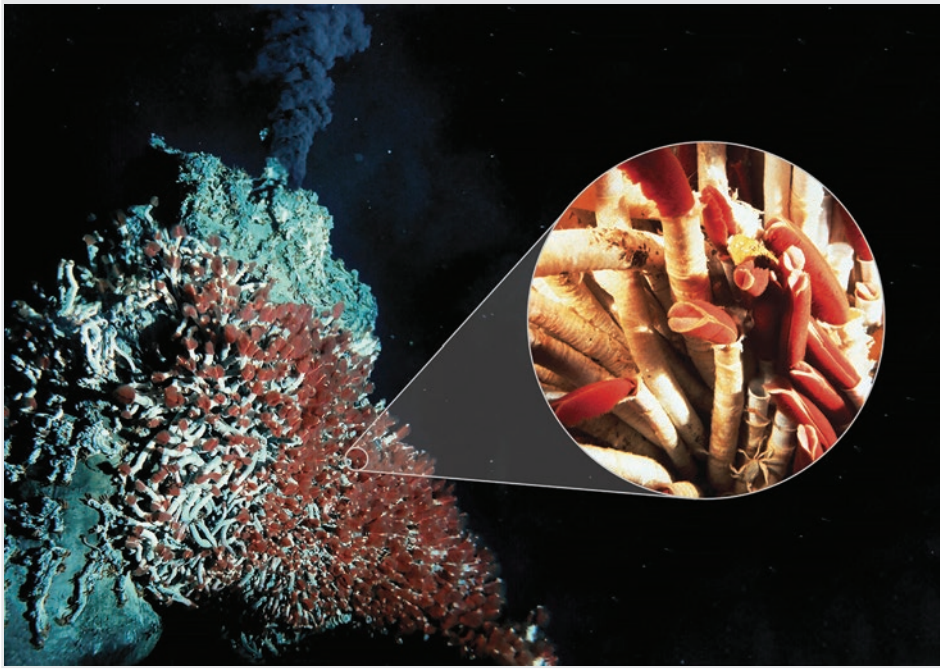
Hands-On Lab

Investigating Light Sources and Photosynthesis Design an experiment to investigate the effect of different light sources on the rate of photosynthesis.

Comparing Producers

Most, but not all, organisms rely directly or indirectly on sunlight and photosynthesis. Places such as deep oceans and dark caves have thriving populations despite never receiving any sunlight. The very hot water found near cracks in the ocean floor, called hydrothermal vents, is one such environment. These vents release chemical compounds such as hydrogen sulfide (H_2S) that serve as an energy source. Hydrothermal vents support a dense ecosystem made up of organisms completely dependent on the chemicals coming out of the sea floor.

FIGURE 7: Chemosynthetic microbes live on or below the sea floor, and inside the bodies of other vent animals. Tubeworms grow in clumps around the vents.



Chemosynthesis is the process of using chemical energy to make sugars from carbon dioxide for energy storage. Like plants that rely on photosynthesis, chemosynthetic organisms make their own food, but the raw materials differ.

The producers that live around hydrothermal vents carry out a process represented by the following chemical equation. The process produces the carbohydrates these producers need for energy.

$$6CO_2 + 24H_2S + 6O_2 \longrightarrow C_6H_{12}O_6 + 24S + 18H_2O$$

Model Make a graphic organizer to compare the inputs and outputs for chemosynthesis and for photosynthesis.

Analyze Think back to the question about growing plants on another planet and answer the following questions:

1. What inputs would you need to provide in order for plants to carry out photosynthesis?
2. What are the outputs from plants that are needed for human survival?
3. How would producers that carry out chemosynthesis differ from photosynthetic producers as a possible food source?