Introduction to Photosynthesis

Reflect

Suppose you place a plant on a sunny windowsill and water it regularly. At the same time, you place a similar plant in a dark closet and keep it watered too. The only difference between the two plants is the amount of light they receive. What do you think will happen to each plant after a few weeks?

You probably predicted that the plant on the windowsill will remain healthy, while the plant placed in the closet will wilt. Light is a basic need for many plants. Why is this?

During photosynthesis, energy from the Sun interacts with matter on Earth. Plants, algae (including phytoplankton), and many microorganisms require light to live. There are a few types of plants that can live without light, but most plants will die if they do not receive adequate light. Light is a form of energy that most plants take in and use to carry out photosynthesis. **Photosynthesis** is a series of chemical reactions that produces glucose, a compound plants use as food. In this way, plants use light from the Sun to make their own food. Radiant energy from the Sun is changed to chemical energy in glucose molecules. The following reaction summarizes this process:

Radiant energy from the Sun $\xrightarrow[\text{molecules}]{\text{photosynthesis}}$ Chemical energy in glucose molecules

Plants differ from animals by using radiant energy this way. Animals cannot use radiant energy from the Sun to make glucose. They must obtain energy from the environment in the form of food, which contains chemical energy. Animals have to eat in order to survive.

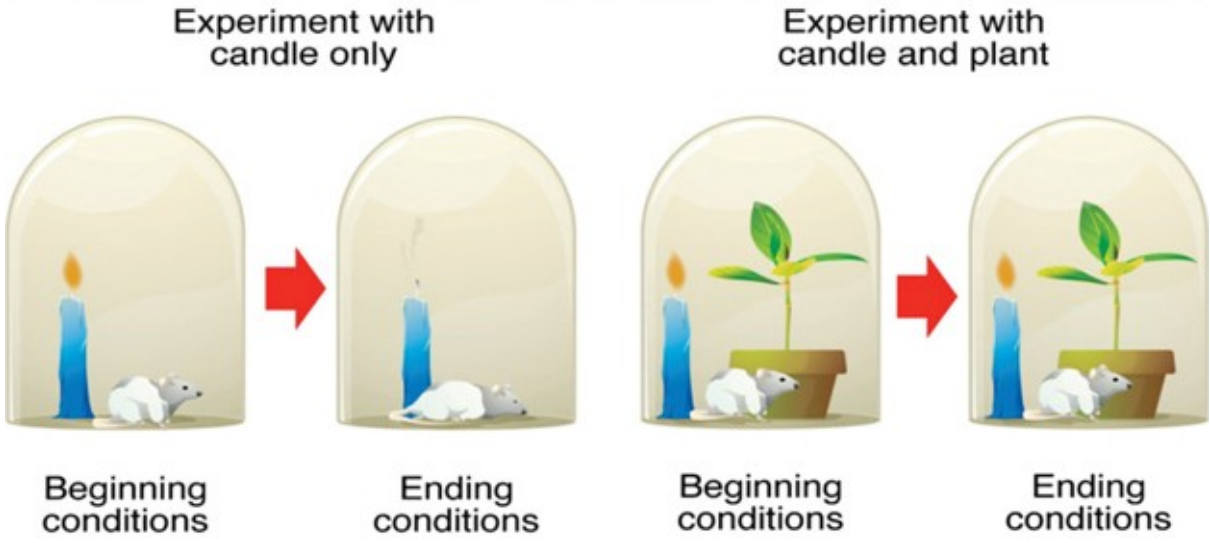
What Do You Think?

A plant called the underground orchid is native to Western Australia. The roots and stem of this plant grow completely underground. Only the flower emerges above the surface. Is it likely that these plants use radiant energy from the Sun? If not, what form of energy do they use?

Reflect

We can observe photosynthesis by using a simple experiment.
Photosynthesis is a chemical process. Because this process takes place at the level of molecules and atoms, we cannot observe it directly. However, we can observe the results of photosynthesis.

Joseph Priestley was one of the first scientists to observe a product of photosynthesis. He conducted an experiment in which he placed a burning candle and a mouse under a glass dome. After a few minutes, the flame went out and the mouse died. Priestley showed that the gases in this dome could not keep the mouse alive. However, if the experiment was repeated with a plant present under the dome, the mouse remained alive. What change had the plant made to the dome?



The plant replaced the oxygen that had been used up by the burning candle. Oxygen is a colorless, odorless gas that humans cannot observe directly. However, its presence is required for animals, such as mice, to live. Priestley demonstrated that the plant could produce oxygen. Oxygen is one of the products of photosynthesis.

Reflect

Photosynthesis involves three elements: carbon, hydrogen, and oxygen.
You have seen that the products of photosynthesis are oxygen and glucose. Their chemical formulas are shown below. What elements make up these molecules?

Products of Photosynthesis		
Name:	Oxygen	Glucose
Chemical formula:	O_2	$C_6H_{12}O_6$

Only three elements are present in the products of photosynthesis: carbon, hydrogen, and oxygen. These same elements are present in the reactants of photosynthesis.

Reactants of Photosynthesis		
Name:	Water	Carbon dioxide
Chemical formula:	H_2O	CO_2

Photosynthesis occurs when water and carbon dioxide react to form oxygen and glucose. Below is the chemical equation showing this process:

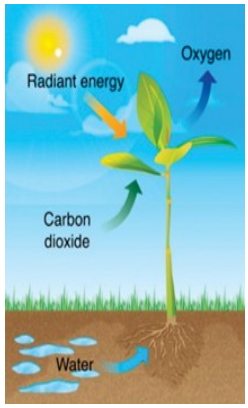
$$6H_2O + 6CO_2 \xrightarrow{\text{Radiant energy}} 6O_2 + C_6H_{12}O_6$$

Notice that it takes six molecules of water and six molecules of carbon dioxide to make one molecule of glucose.

The diagram at the right shows the inputs and outputs of photosynthesis. Carbon dioxide in the air enters a plant through its leaves. Water in the soil enters through a plant's roots. Oxygen exits from the leaves. Glucose can be used immediately as food or can stay behind to make other structural molecules for growth.

Look Out!

The process of photosynthesis is actually a complex series of many different chemical reactions. The equation shown above represents the overall reaction. This equation shows only the beginning and ending chemical compounds. There are many more steps in between.



Look Out!

Photosynthesis is necessary for life on Earth.
Humans require oxygen to survive. Many other animals also require oxygen. However, Earth's atmosphere has not always contained oxygen gas. During its first 2.3 billion years of existence, Earth had an atmosphere that contained water vapor, nitrogen, carbon dioxide, sulfur dioxide, and hydrogen sulfide. What changed that led to oxygen gas becoming part of the atmosphere?

The answer is that microorganisms capable of photosynthesis arose on the planet. These microorganisms are called cyanobacteria. Cyanobacteria live in both fresh water and salt water environments. Millions and millions of these tiny creatures produced enough oxygen to change the composition of Earth's atmosphere. Oxygen became established in the atmosphere as a result of photosynthesis. Since this shift, many organisms have evolved to depend on oxygen. Photosynthesis is necessary to continue supplying oxygen to these organisms.

A scientist takes a sample of cyanobacteria from the surface of a lake. When cyanobacteria populations grow too quickly in a body of water, they can harm other organisms in the ecosystem. This situation is called an algal bloom.

In addition, all life forms depend on photosynthesis as the mechanism for capturing and using radiant energy. Plants benefit from this directly because they use photosynthesis to make the glucose molecules that are their food sources. Animals benefit indirectly because they, too, must have sources of food. Animals either eat plants to obtain chemical energy in the form of glucose or they eat other animals that eat plants. Energy moves from the Sun to plants to animals. Photosynthesis is necessary for that energy flow.

Looking to the Future: Can humans make use of photosynthesis to produce fuels?
The same microorganisms that created our oxygenated atmosphere could be used to develop new fuels. Think about it. Food is a kind of fuel that we need to run our bodies. If photosynthesis can produce the kind of fuel that our bodies use, it could also produce the kinds of fuels that cars or airplanes use.

This scientist is studying the production of organic compounds by cyanobacteria. If successful, she will be able to use photosynthesis to produce fuels for cars, planes, and trains.

Look Out!

These fuels would not contain glucose, but they would have other carbon-containing compounds. Such biofuels have been produced from corn, sugar cane, soybeans, and sunflowers.

Making biofuel from cyanobacteria is not hard to do. However, the process is expensive. Right now it costs too much to develop biofuel from the strains of cyanobacteria available. Each cell produces a very small amount of the compounds that serve as the raw material for biofuel production. It is also costly to provide the large quantities of water needed to grow the microorganisms. In all, the cost of making the biofuel is greater than the price at which the fuel can be sold. Scientists are doing a lot of research to find ways to bring costs down so that the process becomes economical.

Try Now

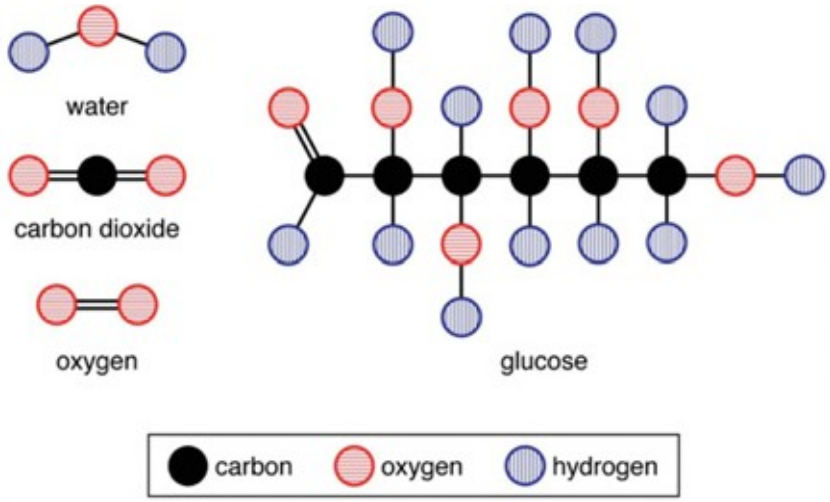
What Do You Know?
Read the following statements below. Fill in each blank with the correct word from the following list: Sun, photosynthesis, radiant energy, food, chemical energy, water, glucose, carbon dioxide, oxygen.

1. All organisms need glucose or a source of _____to carry out basic life functions.
2. Many plants obtain glucose through the process of _____.
3. Animals obtain glucose from _____.
4. Photosynthesizing organisms use ___to produce glucose.
5. The reactants of photosynthesis are _____and _____.
6. The products of photosynthesis are _and _____.
7. The _____ is the source of energy used in photosynthesis.

Connecting With Your Child

Exploring Chemical Rearrangements in Photosynthesis

To help your child learn more about the inputs and outputs of photosynthesis, you can physically manipulate models of reactants to form products. You will need a box of toothpicks, 18 red gumdrops to represent oxygen atoms, six black gumdrops to represent carbon atoms, and 12 blue gumdrops to represent hydrogen atoms. Make models of six water molecules and six carbon dioxide molecules using the gumdrops and toothpicks. Follow the patterns of atom arrangements shown in the diagrams below. Then have your child take the models apart and rearrange the atoms to form the products of photosynthesis.



Emphasize that the same number of atoms are present in both reactants and products. In other words, the number of gumdrops (atoms) does not change throughout the activity; however, you will need more toothpicks for the reactants (36) than you did for the products (32). This is because fewer chemical bonds are necessary to hold together the atoms in the products.

Here are some questions to discuss with your child:

- How many carbon atoms did you start with? What chemical compound contained these carbon atoms?
- How many carbon atoms did you end with? What chemical compound contained these carbon atoms?
- What happened to the hydrogen atoms that started out in the water molecules? Did they all end up in the same product?
- Did you have the same number of oxygen atoms at the end that you had at the beginning?
- Why is the input of radiant energy needed for the reaction that you modeled? Where is the energy stored in the products?