LESSON 2

Photosynthesis

BIO.A.3.1.1, BIO.A.3.2.1, BIO.A.3.2.2

You may obtain energy by eating a bowl of macaroni and cheese. Similarly, a fungus may obtain energy from the tree stump it slowly digests, and a protist may obtain it from the bacterium it engulfs. What is the source of this food energy? Some organisms, including plants, algae, and certain prokaryotes, make their own food via photosynthesis.

Photosynthesis and Cellular Respiration

Photosynthesis is a process that converts light energy from the sun into chemical energy stored in compounds such as glucose.

Photosynthetic organisms use the energy in sunlight to produce glucose and oxygen from carbon dioxide and water. The net equation for photosynthesis requires six molecules of carbon dioxide (CO_2) and six molecules of water (H_2O). It produces one glucose molecule ($C_6H_{12}O_6$) and releases six molecules of oxygen (O_2) to the environment. The chemical equation below describes what happens during photosynthesis.

$$\underset{\text{(carbon dioxide)}}{6CO_2} + \underset{\text{(water)}}{6H_2O} + \underset{\text{(sunlight)}}{\text{energy}} \longrightarrow \underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(oxygen)}}{6O_2}$$

Photosynthesis is a biological process in which light energy is used to produce glucose. Photosynthesis uses up carbon dioxide and water and produces oxygen.

Some ATP is also produced directly by photosynthesis.

The glucose made from photosynthesis provides the plant with energy. Plants can use this chemical energy right away, or store the sugars as starches for later use. Like animals, plants carry out **cellular respiration.** In fact, photosynthesis and aerobic respiration may be considered opposite processes. The chemical equation below shows aerobic respiration.

$$\underset{\text{(glucose)}}{C_6H_{12}O_6} + \underset{\text{(oxygen)}}{6O_2} \longrightarrow \underset{\text{(carbon dioxide)}}{6CO_2} + \underset{\text{(water)}}{6H_2O}$$

Glucose produced by photosynthesis may be broken down in **cellular respiration,** providing energy for the plant. It may also form the cellulose that strengthens plant cell walls or be stored in a macromolecule such as starch for later use.

Plants increase the net supply of oxygen because they produce more oxygen via photosynthesis than they consume in cellular respiration.

Which of the following best explains the relationship between photosynthesis and cellular respiration?

A Both produce carbon dioxide and oxygen.

B Both require energy from the sunlight to occur.

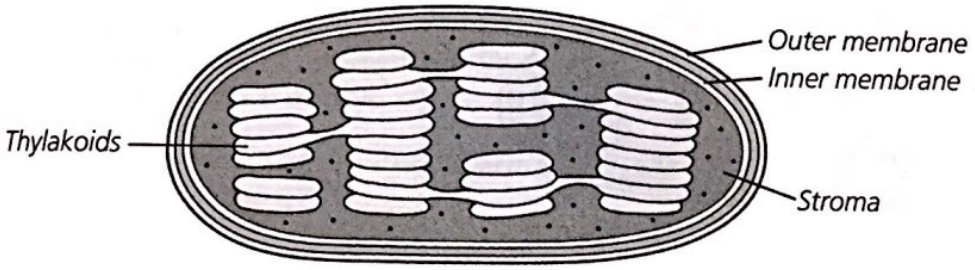
C The products of one are the reactants of the other.

D A plant can carry out either one process or the other.

Choice A is incorrect because photosynthesis produces only oxygen, while cellular respiration produces only carbon dioxide. Choice B is incorrect because cellular respiration does not require sunlight to occur. Choice D is incorrect because a plant has the capability to complete both photosynthesis and cellular respiration. Choice C is correct because the products of photosynthesis are used as reactants for cellular respiration and vice versa.

Chloroplasts and Photosynthesis

Photosynthetic eukaryotic cells contain organelles called **chloroplasts.** A chloroplast has two membranes that surround the stroma, or inner fluid. In the stroma are stacks of "disks" known as thylakoids. The membranes of the thylakoids are important in photosynthesis. They contain *chlorophyll,* the pigment that can capture the energy in sunlight. This energy drives the chemical reactions of photosynthesis.



Glucose is produced in the chloroplasts of plant cells.

In most plants, photosynthesis takes place primarily in the leaves. Therefore, leaf cells need carbon dioxide and water as raw materials for photosynthesis. Leaves take in carbon dioxide from the atmosphere through openings called *stomata* (singular, *stoma*), which are small pores on the underside of the leaf. Plants open their stomata to take in carbon dioxide and release oxygen. They can close them to prevent water loss when temperatures are high.

Most plants take in water from the soil through roots anchored in the ground. This water travels to the cells in their leaves through tube-like vascular tissues.

Chloroplasts are the organelles where photosynthesis takes place in eukaryotic cells.

Chlorophyll is a green pigment that captures the energy in sunlight. Pigments are molecules that absorb visible light. Chlorophyll gives leaves their green color.

Chloroplasts surround the large central vacuole of a plant cell.

Plant vascular tissue consists of *xylem* (for water and minerals) and *phloem* (for sap).

When temperatures become too warm, leaves close their stomata to conserve water. How will high temperature **most likely** affect the rate of photosynthesis?

When temperature is high, stomata close to prevent water loss from the plant. This reduces the plant's ability to take in carbon dioxide for photosynthesis. Therefore, the rate of photosynthesis is likely to decrease in higher temperatures.

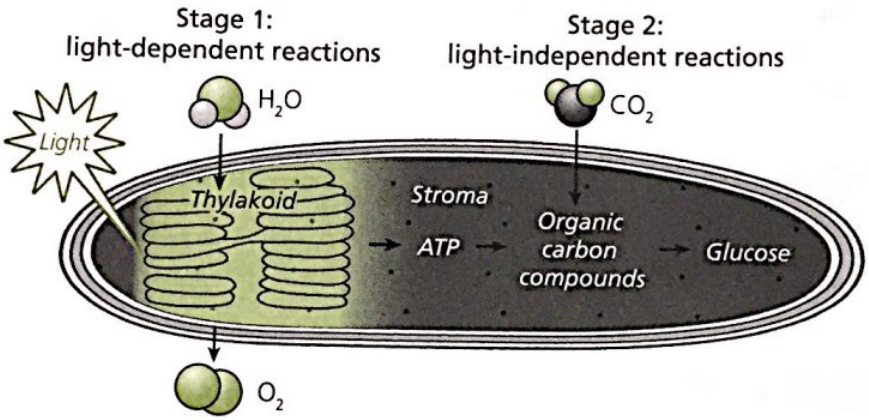
Two Stages of Photosynthesis

Photosynthesis has two stages, which occur in different parts of the chloroplast. The first stage consists of the *light-dependent reactions.* Sunlight energizes chlorophyll. This leads to a series of chemical reactions that harness the energy necessary for the next stage of photosynthesis. This first stage

- uses chlorophyll and other molecules built into the thylakoid membranes,
- captures energy from sunlight,
- produces ATP and other energy-rich molecules,
- splits water molecules (the hydrogen atoms and electrons are needed in the next stage), and
- releases oxygen gas from the leaf.

The *light-dependent reactions* of photosynthesis take place in the thylakoid membranes, which contain chlolophyll.

The rate of photosynthesis can be influenced by light intensity, air temperature, carbon dioxide levels, and water availability.



Photosynthesis involves both light and dark reactions.

In the first stage, water molecules are split to form oxygen gas.

In the second stage of photosynthesis, carbon dioxide is consumed.

The second stage of photosynthesis, the *light-independent reactions,* requires no light, but does use the products that were obtained in the first stage. This stage

- takes place in the stroma of the chloroplast,
- depends on energy from light-dependent reactions,
- uses the hydrogen atoms and electrons obtained from water in the first stage, and
- converts carbon dioxide into organic molecules such as glucose.

The *light-independent reactions* of photosynthesis are also called the *Calvin cycle* or the *dark reactions,* because they use light indirectly.

Organic compounds contain carbon and hydrogen. They are used to build glucose and other important molecules.

Scientists supply plants with water molecules containing a heavier-than-usual oxygen isotope, oxygen-18. Which of the products of photosynthesis will contain this isotope? Explain.

The oxygen released by the light-dependent reactions will contain the oxygen-18 isotope. Oxygen gas is produced by splitting the water molecule. The oxygen is released; it is not incorporated into organic carbon compounds.

IT'S YOUR TURN

Please read each question carefully. For a multiple-choice question, circle the letter of the correct response. For a constructed-response question, write your answers on the lines.

1 Which is a difference between photosynthesis and cellular respiration?

A Photosynthesis can produce glucose without oxygen.

B Photosynthesis occurs only in plants, and respiration occurs only in animals.

C Cellular respiration stores energy, but photosynthesis releases energy.

D Cellular respiration releases oxygen, but photosynthesis releases carbon dioxide.

2 Which statement describes what occurs in the stroma of the chloroplast?

A Oxygen is released.

B Carbon dioxide reacts.

C Water molecules are split.

D Chlorophyll absorbs energy.

3 How would the environment change if there were fewer plants to carry out photosynthesis?

A It would have more oxygen.

B It would have more glucose.

C It would have more ATP energy.

D It would have more carbon dioxide.

4 Which pair of compounds are both products of photosynthesis?

A water and glucose

B oxygen and glucose

C glucose and carbon dioxide

D oxygen and carbon dioxide

5 The law of conservation of energy states that energy cannot be destroyed or created. It can only change in form and move from place to place. An ATP molecule in an animal cell is used for energy.

A Explain how the energy reached the ATP molecule from its original source.

B Describe how energy changed in form from its original source to the ATP molecule.

C Explain how the energy changes when the ATP molecule is converted to ADP and phosphate.