Review the Concepts

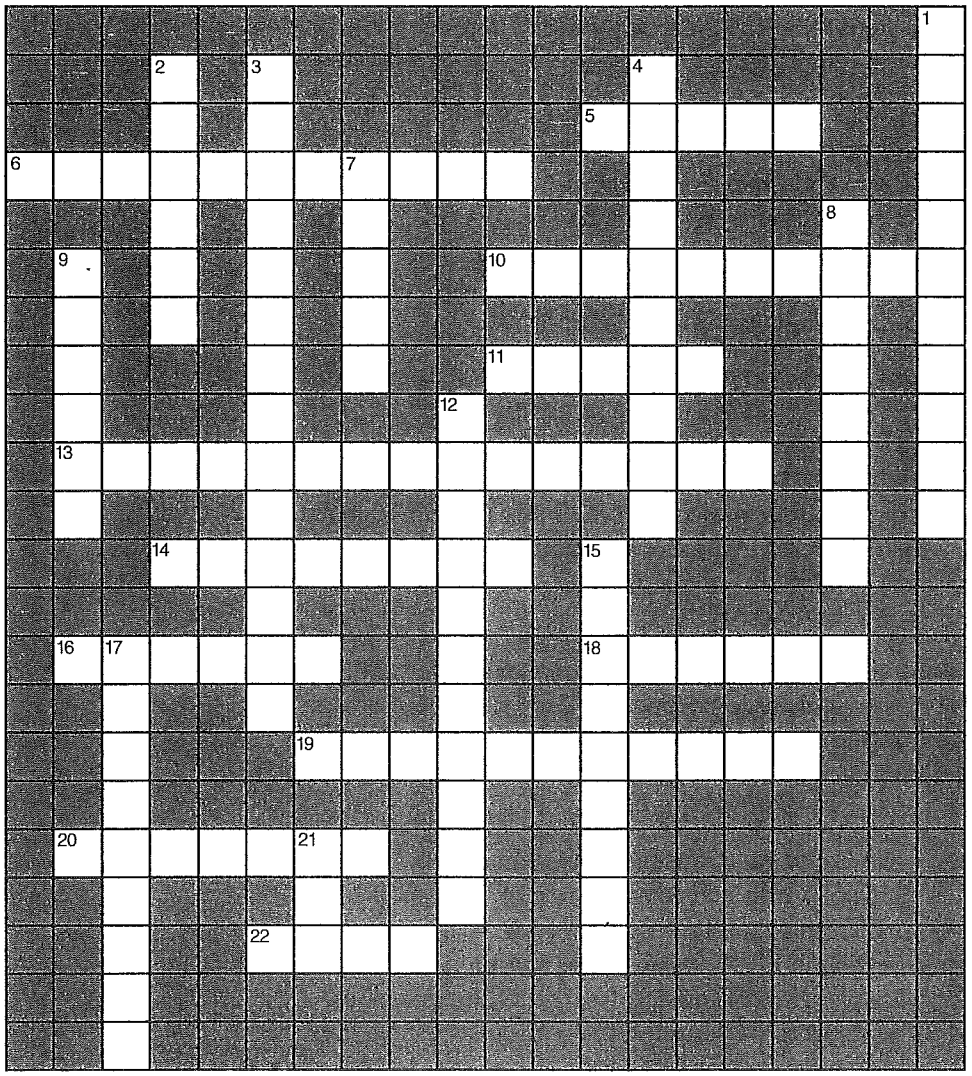
Work through the following exercises to review the concepts in this chapter. For additional review, check out the activities at www.mybiology.com. The animations are particularly helpful. The website offers a pre-test that will help you plan your studies.

Exercise 1 (Module 7.1)

Autotrophs are able to produce their own organic molecules. All organisms that use light energy to make food are called photoautotrophs. Circle all the following organisms that are photoautotrophs: mushroom, pine tree, squirrel, green bacterium, rosebush, seaweed, moss, bread mold, parasitic bacterium, alga, sponge, grass

Exercise 2 (Modules 7.1–7.7)

Review some of the basic terminology of photosynthesis by completing this crossword puzzle.



Across

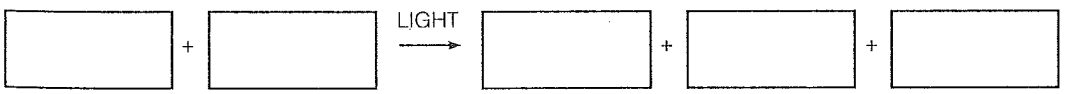
5. ____ is oxidized in the process of photosynthesis.
6. The ____ is the cell organelle where photosynthesis takes place.
10. ____ are the light-catching membranes in a chloroplast.
11. Stacks of thylakoids in a chloroplast are called ____.
13. ____ energy travels through space as rhythmic waves.
14. When chlorophyll absorbs a photon, an ____ becomes excited.
16. Sugar is actually made in the ___ cycle.
18. The Calvin cycle occurs in the ____
—the fluid of the chloroplast.
19. ____ is the green pigment in a leaf.
20. Carbon dioxide enters a leaf via pores called____.
22. Shorter wavelengths of light have____ energy than longer wavelengths.

Down

1. A ____ is a cluster of light-harvesting complexes in a thylakoid.
2. A ____ is a fixed quantity of light energy.
3. ____ is the process by which plants make food from carbon dioxide and water.
4. The color of light is related to its ____.
7. ____ is the source of energy for photosynthesis.
8. Carbon ____ is the incorporation of carbon dioxide into organic compounds.
9. The reaction ____ complex is the part of a photosystem that donates excited electrons.
12. ____ are yellow-orange pigments in a chloroplast.
15. ____ is the green tissue in the interior of a leaf.
17. An ____ is an organism that makes its own food from inorganic molecules.
21. Photosynthesis occurs in ____ main stages.

Exercise 3 (Modules 7.3–7.4)

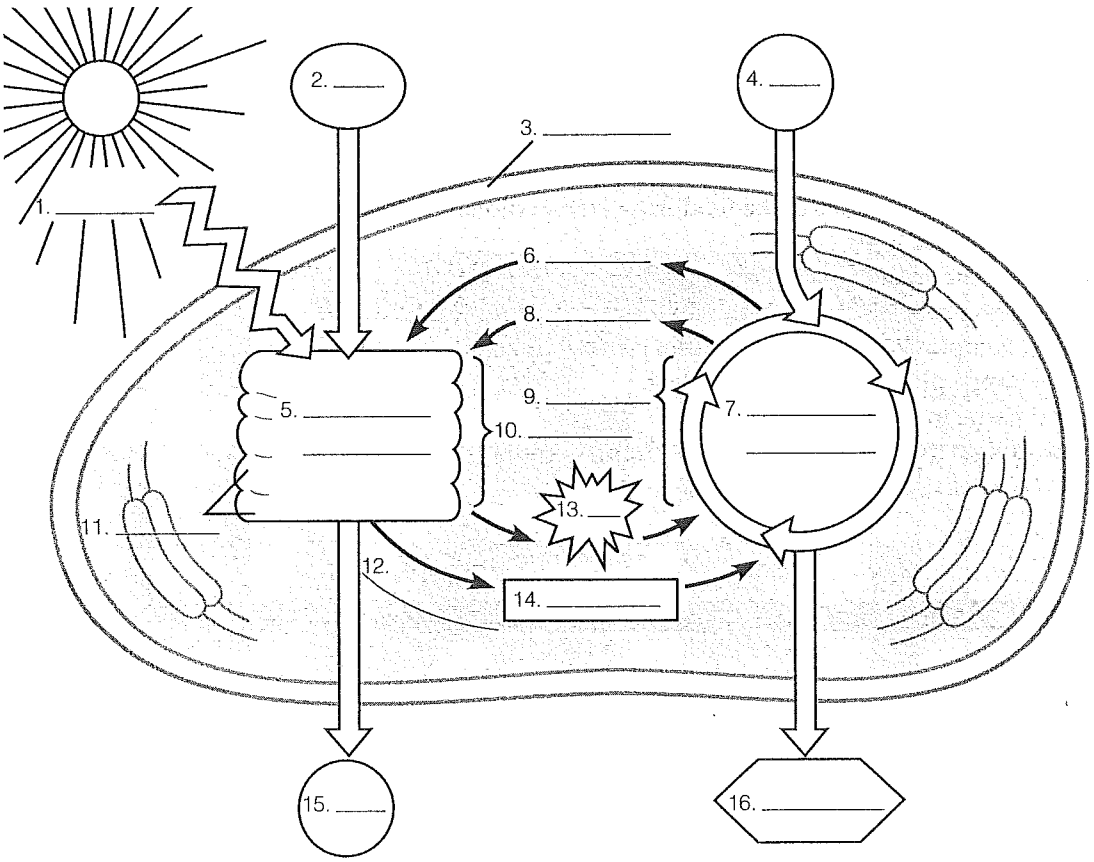
Write the overall equation for photosynthesis in the boxes below. Show the substances used on the left, and those produced on the right. Use different colors for carbon, hydrogen, oxygen in carbon dioxide, and oxygen in water, and then use your color code to show where atoms of C, H, and O on the left end up in the products on the right. On the lines under the substances used, state which is oxidized and which is reduced.



_____ _____

Exercise 4 (Modules 7.3–7.5)

Label this diagram summarizing the two stages of photosynthesis. Include **outer membrane of chloroplast, thylakoids, granum, stroma, light reactions, Calvin cycle, light, H_2O, O_2, electrons, NADPH, ATP, CO_2, sugar, ADP + P,** and **$NADP^+$.** (Note: 5 and 7 are processes, 3, 9, 10, and 11 are places or structures, and the rest are inputs and outputs.)



Exercise 5 (Modules 7.3–7.5)

Refer to the equations and diagrams in the modules to match each of the phrases on the right with one of the ingredients or products of photosynthesis listed on the left.

_____ 1. Oxidized in the light reactions
_____ 2. Reduced in the Calvin cycle
_____ 3. Carries H and electrons from the light reactions to the Calvin cycle
_____ 4. Food produced by photosynthesis
_____ 5. Source of H and electrons that end up in glucose
_____ 6. Source of O atoms that end up in glucose
_____ 7. Where O atoms from water end up
_____ 8. Oxidized in the Calvin cycle
_____ 9. Reduced in the light reactions
_____ 10. Supplies energy to the Calvin cycle
_____ 11. Where C and O atoms in carbon dioxide end up
_____ 12. Recycled from the Calvin cycle to make ATP
_____ 13. Supplies energy to the light reactions
_____ 14. Gas produced by reactions in the thylakoids
_____ 15. Gas consumed by reactions in the stroma
_____ 16. Source of carbon for carbon fixation
_____ 17. Source of H for the Calvin cycle
_____ 18. Picks up energized electrons from reactions in the thylakoids

A. Carbon dioxide, CO_2
B. Water, H_2O
C. Glucose, $C_6H_{12}O_6$
D. Oxygen, O_2
E. ADP + P
F. ATP
G. $NADP^+$
H. NADPH
I. Light

Exercise 6 (Modules 7.6–7.7)

Order the following forms of electromagnetic energy from the shortest wavelength (1) to the longest (9). Which photons have the most energy? Which are used by plants in photosynthesis?

_____ a. Green light
_____ b. Radio waves
_____ c. X-rays
_____ d. Red light
_____ e. Ultraviolet light
_____ f. Infrared
_____ g. Microwaves
_____ h. Blue light
_____ i. Gamma rays

Exercise 7 (Modules 7.7–7.11)

To review photosynthesis, fill in the blanks in the following story.

The next time you eat an apple, reflect on the apple tree's ability to make the sugars it contains, using sunlight to assemble simple substances from air and soil. This process is called [1]_____. It takes place in structures called [2]_____ in cells of tissues called the [3]_____ inside the leaves of the apple tree. Photosynthesis actually consists of two processes: In the

[4]_____ reactions, [5]_____ molecules, in chloroplast membranes called [6]_____, capture light energy. In the [7]_____ cycle, which takes place in the fluid [8]_____ surrounding the thylakoids, this energy is captured in molecules of [9]_____.

Chlorophyll molecules absorb [10]_____, packets of light energy. Chlorophyll absorbs only certain wavelengths, or colors, of light, mainly in the [11]_____ and [12]_____ parts of the spectrum. It reflects [13]_____ light. Other pigments, such as [14]_____, can absorb colors that chlorophyll cannot use directly, and transfer this energy to chlorophyll. Chlorophyll, other pigments, and proteins are clustered on the thylakoid membranes in groups called photosystems. A photosystem consists of several pigment-and-protein light-harvesting complexes, which act as antennas to capture light energy. They pass their energy on to a central [15]_____, which consists of two chlorophyll molecules and a protein called the primary electron acceptor. There are two kinds of photosystems, photosystem I and photosystem II, which absorb slightly different colors of light.

When light strikes a leaf, and pigment molecules absorb photons, they pass their energy to a photosystem II reaction center complex, and there the energy excites a chlorophyll [16]_____ to a higher energy level. This electron is passed to the primary electron acceptor and on to an electron transport chain. On their way down the electron transport chain, electrons from photosystem II perform important work. One of the electron carriers in the chain uses the energy released by the electrons to transport [17]_____ ions from the [18]_____ into the space inside the [19]_____. This creates a buildup of H^+ ions, a concentration [20]_____ of H^+ across the membrane. The H^+ ions then diffuse through the membrane via a protein complex called [21]_____, which captures their energy to make [22]_____. In photosynthesis, this chemiosmotic production of ATP is called [23]_____, because its energy source is light.

How does photosystem II replace its lost electrons? It gets them by splitting [24]_____. When the electrons of photosystem II are jarred loose, its reaction center complex develops a strong attraction for electrons. It obtains them by breaking apart a molecule of [25]_____. This leaves two H^+ ions (which pass into the thylakoid space) and an [26]_____ atom. This atom combines with one from another water molecule to form a molecule of [27]_____ gas, which diffuses out of the leaf—a product of photosynthesis important to us and other animals.

Meanwhile, [28]_____ energy excites an electron in a [29]_____ molecule in the reaction center complex of photosystem I. (This electron is replaced by one from the electron transport chain from photosystem II.) The primary electron [30]_____ passes the electron via a short electron transport chain to $NADP^+$, reducing it to a molecule of [31]_____.

At this point in the story, the cells of the apple leaf have captured the energy of the sun in molecules of NADPH and ATP, and its leaf has released some O_2 gas, but so far no sugar has been produced. NADPH and ATP are used, and sugar is made, in the [32]_____ cycle, the second portion of [33]_____ that takes place in the [34]_____ of the chloroplast, around the thylakoids. Using carbon from [35]_____ obtained from the air, energy from [36]_____, and hydrogen and high-energy electrons carried by [37]_____, the enzymes of the Calvin cycle construct [38]_____, a high-energy three-carbon sugar molecule. In a series of steps, these molecules are combined to form the important six-carbon sugar [39]_____ and other organic compounds. This incorporation of carbon from CO_2 into organic molecules is called carbon [40]_____.

The cellulose that gives an apple its crunch and the sugar that gives it its sweet taste are made from the glucose made in photosynthesis. In your intestine, the sugars enter your blood and are transported to your body cells. There the chemical pathways of cellular [41]_____ release the energy in the sugar molecules and use it to build [42]_____, which is in turn used to power cellular work. Energy from the sun, captured by the apple and passed on to you, enables you to see, to move, and to contemplate this amazing story.

Exercise 8 (Module 7.12)

Plants employ a variety of ways of fixing CO_2 and saving water. State whether each of the following statements relates to **C_3** plants, **C_4** plants, or **CAM** plants.

_____ 1. Tend to waste energy on photorespiration on a hot day
_____ 2. Enzyme in mesophyll cells fixes carbon in 4-C compound, for use by bundle-sheath cells
_____ 3. Corn and sugarcane
_____ 4. Open stomata and trap CO_2 in five-carbon compound at night, for later use during daytime
_____ 5. Most plants
_____ 6. Soybeans, oats, wheat, rice
_____ 7. Can grow in hot, dry climates
_____ 8. Also can grow in hot, dry climates
_____ 9. Pineapple and many cacti
_____10. Calvin cycle uses CO_2 directly from the air

Test Your Knowledge

Multiple Choice

1. The ultimate source of energy in the sugar molecules produced by photosynthesis is
   a. sugar.
   b. the sun.
   c. oxygen.
   d. ATP.
   e. chlorophyll.

2. Which of the following is produced by the light reactions of photosynthesis and consumed by the Calvin cycle?
   a. NADPH
   b. O_2
   c. H_2O
   d. sugar
   e. ADP + P

3. Which of these wavelengths is *least* useful for photosynthesis?
   a. green
   b. yellow
   c. blue
   d. orange
   e. red

4. When chloroplast pigments absorb light,
   a. they become reduced.
   b. they lose potential energy.
   c. their electrons become excited.
   d. the Calvin cycle is triggered.
   e. their photons become excited.

5. The light reactions of photosynthesis generate high-energy electrons, which end up in ____. The light reactions also produce ____ and ____.
   a. ATP . . . NADPH . . . O_2
   b. O_2 . . . sugar . . . ATP
   c. chlorophyll . . . ATP . . . NADPH
   d. water . . . sugar . . . O_2
   e. NADPH . . . ATP . . . O_2

6. The overall function of the Calvin cycle is
   a. capturing sunlight.
   b. making sugar.
   c. producing CO_2.
   d. splitting water.
   e. oxidizing glucose.

7. Which of the following correctly matches each of the inputs of the Calvin cycle with its role in the cycle?
   a. CO_2: high-energy electrons; ATP: energy; NADPH: oxidation
   b. CO_2: carbon; ATP: energy; NADPH: high-energy electrons
   c. CO_2: high-energy electrons; ATP: carbon; NADPH: energy
   d. CO_2: energy; ATP: carbon; NADPH: high-energy electrons
   e. CO_2: hydrogen; ATP: carbon; NADPH: energy

8. The main photoautotrophs in aquatic environments are
   a. plants and animals.
   b. plants and fungi.
   c. animals and algae.
   d. algae and bacteria.
   e. plants and bacteria.

9. Which of the following is *not* a product of the light reactions of photosynthesis?
   a. O_2
   b. sugar
   c. high-energy electrons
   d. ATP
   e. NADPH

10. Which of the following is oxidized in photosynthesis?
    a. O_2
    b. CO_2
    c. $C_6H_{12}O_6$
    d. ATP
    e. H_2O

11. In photosynthesis, plants use carbon from ____ to make sugar and other organic molecules.
    a. water
    b. the air
    c. chlorophyll
    d. the sun
    e. soil

12. The carbon-fixation processes in C_4 and CAM plants differs from that of the majority of plants. C_4 and CAM plants are better-adapted to
    a. hot, dry conditions
    b. polar regions
    c. living in the shade
    d. low levels of carbon dioxide
    e. growing underwater

13. Aside from their importance in passing energy on to chlorophyll, carotenoid pigments also function in
    a. the Calvin cycle
    b. C_4 metabolism
    c. photorespiration
    d. photoprotection
    e. carbon fixation

Essay

1. Photosynthesis uses water and carbon dioxide to produce sugar and oxygen gas. Scientists long wondered whether the oxygen atoms in the oxygen gas produced in photosynthesis were obtained from carbon dioxide or water. Describe the experiments that enabled them to find out and the results of these experiments.
2. Draw two squares, one labeled to represent the light reactions and the other to represent the Calvin cycle. Using arrows, show the inputs and outputs of each process. Include the following: NADPH, ADP + P, O_2, light, CO_2, sugar, H_2O, ATP, $NADP^+$, electrons.
3. Photosynthesis has been called "the most important chemical process on Earth." Explain why.
4. State two activities of humans that tend to intensify the greenhouse effect. Why are people concerned about this? State two actions we could take that would reduce our contribution to the greenhouse effect.

Apply the Concepts

Multiple Choice

1. A photon of which of these colors would carry the most energy?
    a. blue
    b. yellow
    c. green
    d. orange
    e. red
2. A plant is placed in a sealed greenhouse with a fixed supply of water, soil, and air. After a year, the plant weighs 5 kg more than at the start of the experiment, and the ____ weighs almost 5 kg less.
    a. soil in the pot
    b. water left in the room
    c. organic matter in the soil
    d. air in the room
    e. soil in the pot together with the water in the soil
3. In a rosebush, chlorophyll is located in
    a. chloroplasts, which are in mesophyll cells in the thylakoids of a leaf.
    b. mesophyll cells, which are in the thylakoids in chloroplasts in a leaf.
    c. thylakoids, which are in mesophyll cells in the chloroplasts in a leaf.
    d. chloroplasts, which are in thylakoids in the mesophyll cells of a leaf.
    e. thylakoids, which are in chloroplasts in the mesophyll cells of a leaf.
4. Certain bacteria use smelly hydrogen sulfide gas, H_2S, instead of water, H_2O, as a source of electrons and hydrogen for the light reactions of photosynthesis. If their method of photosynthesis is similar to plants in other ways, where do you think the sulfur would end up?
    a. sulfur dioxide, SO_2
    b. chlorophyll
    c. solid sulfur, S_2
    d. a sugar containing sulfur
    e. NADPH
5. The *photo* part of the word *photosynthesis* refers to _____, whereas *synthesis* refers to _____.
    a. the reactions that occur in the thylakoids . . . carbon fixation
    b. the reactions in the stroma . . . the reactions in the thylakoids
    c. the Calvin cycle . . . carbon fixation
    d. the Calvin cycle . . . the reactions in the stroma
    e. the light reactions . . . reactions in the thylakoids
6. The energy used to produce ATP in the light reactions of photosynthesis comes from
    a. the "burning" of sugar molecules.
    b. splitting water.
    c. movement of H^+ through a membrane.
    d. carbon fixation.
    e. fluorescence.