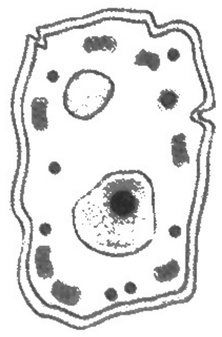
5
Photosynthesis and Respiration



Vocabulary

ATP (adenosine triphosphate)
autotrophic
cellular respiration
heterotrophic
inorganic
organic
photosynthesis

FOOD: MATTER AND ENERGY

An apple is a type of food. It contains complex organic compounds; its atoms are held together as molecules by chemical bonds that are rich in stored energy. When you eat an apple, you get both the matter and the energy you need to build your body and to stay alive.

The apple tree that produced the fruit represents the group of organisms that are **autotrophic**, meaning "self-feeding." Like other plants, the apple tree makes its own food, taking in the **inorganic** substances carbon dioxide (CO_2) and water (H_2O) and changing them into **organic** compounds, such as sugars and starches. Humans represent the other group of organisms, which are **heterotrophic**, meaning "other-feeding." Since they cannot make their own food, humans and all other animals must get their complex organic compounds by eating other organisms. (See Figure 5-1.)

Figure 5-1 The grass, like all other plants, is autotrophic because it makes its own food. The cows, like all other animals, are heterotrophic because they have to eat other organisms in order to survive.

For the apple tree to combine the inorganic raw materials of CO_2 and H_2O into organic compounds such as sugar and starch, it needs a source of energy. The rays of sunlight, as they fall on the leaves of the apple tree, provide that energy. The process of making this food, by using light as the source of energy, is called **photosynthesis**. All green plants are photosynthetic autotrophs. Without plants to capture the energy of sunlight and convert it into the chemical forms that are edible, most animals would have no constant source of food and could not exist.

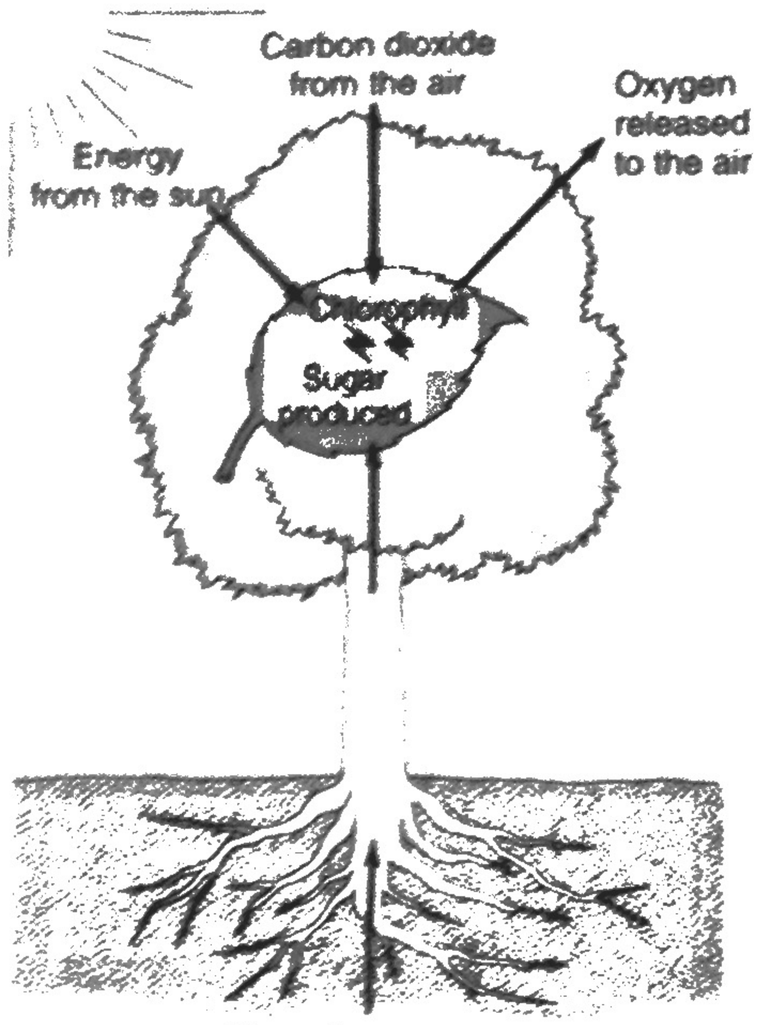


Figure 5-2 The diagram illustrates the basic process of photosynthesis—plants take in inorganic substances from the environment and produce organic substances such as glucose (a sugar).

PHOTOSYNTHESIS

Plants (and algae) are able to make their own energy-rich carbon compounds. In particular, they make the simple sugar glucose, whose chemical formula is $C_6H_{12}O_6$. Plants get the carbon for these glucose molecules from inorganic CO_2 in the air. In addition, plants release oxygen (O_2) to the air. (See Figure 5-2.) Scientists discovered that photosynthesis requires the green pigment *chlorophyll*. The chemical reactions of photosynthesis occur within the chlorophyll-containing organelles called *chloroplasts*, found within plant leaves and stems. Some scientists consider this process of photosynthesis the single most important chemical reaction that occurs on Earth. This all-important reaction can be summarized by the following chemical equation:

$$6\,CO_2 + 6\,H_2O \xrightarrow[\text{CHLOROPHYLL AND ENZYMES}]{\text{LIGHT ENERGY}} C_6H_{12}O_6 + 6\,O_2$$

CARBON DIOXIDE + WATER → GLUCOSE + OXYGEN

LEAVES: PHOTOSYNTHETIC FACTORIES

The structures present inside the leaf are well organized. Such organization allows cells that contain chlorophyll to get maximum exposure to light. At the same time, the leaf controls the amount of water lost to the air. It also makes possible the movement of CO_2 and O_2 into and out of the leaf. (See Figure 5-3.)

THE RATE OF PHOTOSYNTHESIS

As with any chemical reaction, the reactions of photosynthesis can occur at different rates. The factors that affect the rate at which photosynthesis occurs are temperature, light intensity, CO_2 concentration, availability of water, and the presence of certain minerals. (See Figure 5-4 on page 40.)

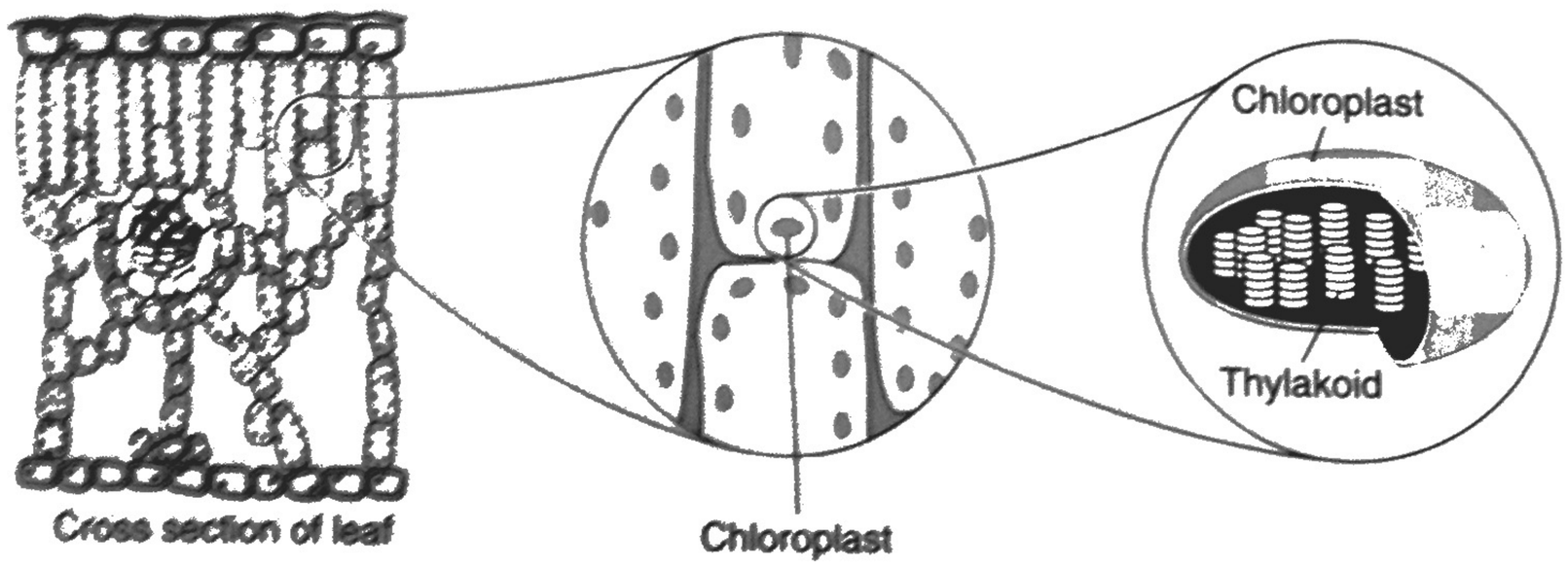


Figure 5-3 Cells inside a leaf contain chloroplasts, which capture the sunlight that is used for photosynthesis. The structure of the leaf allows these cells to get maximum exposure to the light.

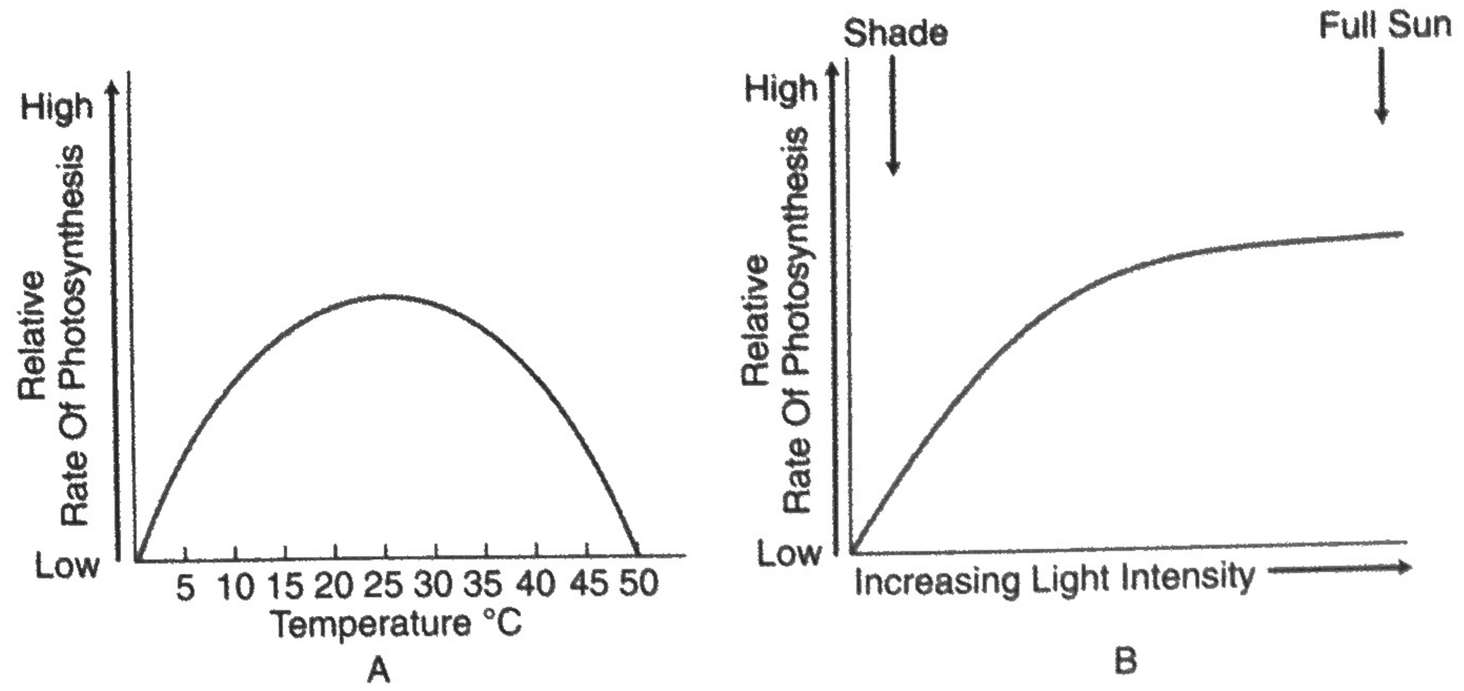


Figure 5-4 Factors that influence the rate of photosynthesis: graph A shows the effect of different temperatures, while graph B shows the effect of increasing light intensity. Other factors, such as the availability of CO_2, water, and minerals, also affect the rate of photosynthesis.

CELLULAR RESPIRATION: RELEASING THE STORED ENERGY IN FOOD

Consider the relationship between the sunlight that falls on the leaves of an apple tree and the chemical process of photosynthesis. During photosynthesis, the light energy of the sun is converted into the stored chemical energy of glucose in the apple. After you eat the apple, your cells are ready to use that stored chemical energy. How does this happen?

The release of energy cannot occur all at once. Too much heat would be released inside your cells. Instead, the release of energy occurs in a series of enzyme-controlled small steps. The energy stored in glucose is converted into a usable form, the energy source of all cells, **adenosine triphosphate**, or **ATP**. This process is known as **cellular respiration**. (See Figure 5-5.) Cellular respiration is basically the opposite process of photosynthesis, and can be summarized by the following chemical equation:

$$C_6H_{12}O_6 + 6\,O_2 \xrightarrow[\text{CHLOROPHYLL AND ENZYMES}]{\text{ENZYMES}} 6\,CO_2 + 6\,H_2O + 36\,ATP$$

GLUCOSE + OXYGEN → CARBON DIOXIDE + WATER

Instead of being produced in the cells, the energy-rich glucose molecules are taken apart to release their stored energy. Oxygen is used, and CO_2 and water are released as wastes. (Because oxygen is used to produce ATP, this is referred to as an *aerobic* process.) Cells use

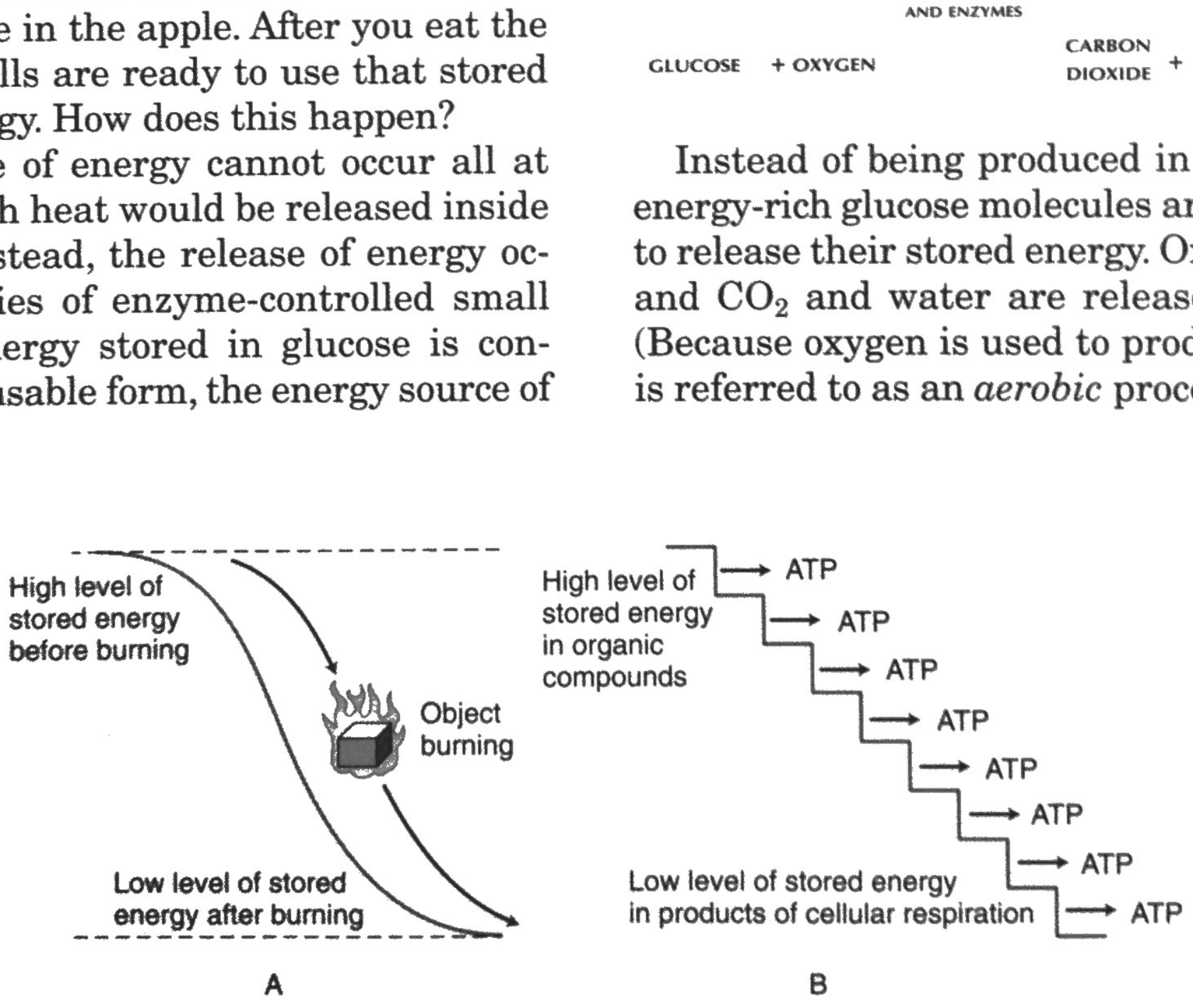


Figure 5-5 The burning of an object (diagram A) is due to the sudden release in one step of the energy stored in that object. By contrast, in cellular respiration (diagram B), energy is released from organic compounds as ATP in a series of small, enzyme-controlled steps.

the energy from ATP to perform many functions, such as obtaining materials and eliminating wastes.

A FINAL VISIT BACK TO PLANTS

A plant does not specifically go through the process of photosynthesis to make food for people and other animals. The apple tree, for example, is simply making food for itself to live long enough to reproduce successfully. The apples contain seeds, which may get carried away to new places by animals that eat the apples. This makes it possible for the apple tree to produce more apple trees in other places. However, most of the glucose made in the leaves of the tree does not go into storage in the form of apples. Rather, it gets taken to different parts of the tree and used by the tree to stay alive. In fact, the tree uses the same process as you do to get the energy it needs from the glucose it has made—cellular respiration.

To summarize: Plants are autotrophs; they are able to produce their own food by photosynthesis and use it for energy through cellular respiration. Animals are heterotrophs; they must obtain food energy from other organisms. Animals use cellular respiration, just as plants do, to obtain energy from the food they eat.

Chapter 5 Review

Part A—Multiple Choice

1. Which of the following is an autotroph?

1 lizard
2 cactus
3 shark
4 antelope

2 In heterotrophs, energy for the life processes comes from the chemical energy stored in the bonds of

1 water molecules
2 organic compounds
3 oxygen molecules
4 inorganic compounds

3. During photosynthesis,

1 animals use sunlight to convert the starch in plants into food
2 animals use the oxygen released by plants to make carbon dioxide
3 plants use the energy of sunlight to convert carbon dioxide and water into glucose and oxygen
4 plants use the energy of sunlight to convert glucose and oxygen into carbon dioxide and water

4. The following equation represents an important biological process. This process is carried out within a cell's

carbon dioxide + water $\longrightarrow$ glucose + water + oxygen

1 mitochondria
2 cell membranes
3 ribosomes
4 chloroplasts

5. The source of energy for photosynthesis is

1 oxygen
2 sunlight
3 carbon dioxide
4 glucose

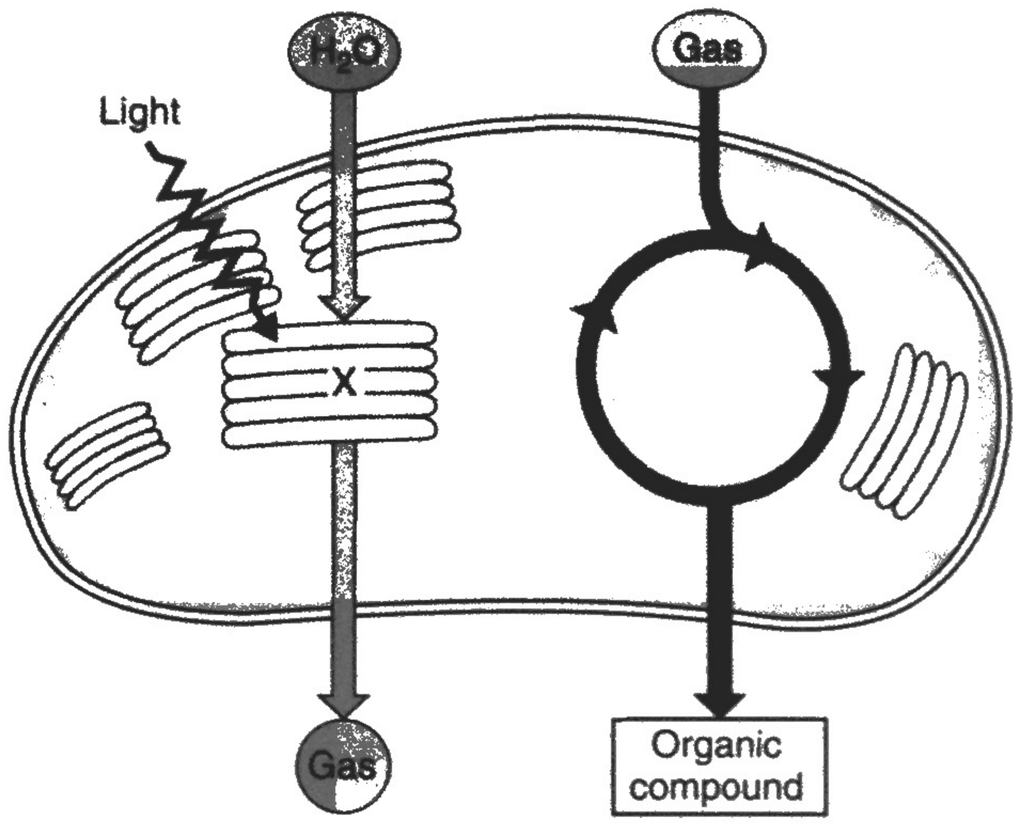
6. To occur, photosynthesis requires the presence of the green substance

1 tree sap
2 glucose
3 chlorophyll
4 copper

7. The approximate mass of a field of corn plants at the end of its growth period was 3 tons per hectare. Most of this mass was produced from

1 water and organic compounds absorbed from the soil
2 minerals and organic materials absorbed from the soil
3 minerals from the soil and oxygen from the air
4 water from the soil and carbon dioxide from the air

8. The diagram below represents part of the life process that occurs inside a leaf chloroplast. If the process were to be interrupted by a chemical at point X, there would be an immediate effect on the release of which substance?



1 chlorophyll
2 carbon dioxide
3 nitrogen
4 oxygen

9. The food produced by plants during photosynthesis is used

1 by the plants themselves only
2 by animals that eat them only
3 by both the plants and the animals that eat them
4 up at the end of the reaction

10. If stored energy were to be released too quickly, a cell would

1 release too much heat
2 produce ATP molecules
3 become an autotroph
4 become a heterotroph

Answer question 11 based on the following information and word diagram.

The flow of energy through an ecosystem involves many energy transfers. The diagram below summarizes the transfer of energy that eventually powers muscle activity.

11. The process of cellular respiration is represented by

1 arrow A only
2 arrow B only
3 arrow C only
4 arrows A, B, and C

12. How do humans and plants interact in terms of the two gases involved in photosynthesis?

1 Humans take in the CO_2 released by plants and release O_2 to the plants.
2 Humans take in the O_2 released by plants and release CO_2 to the plants.
3 Plants and humans usually compete for the same O_2 available in the air.
4 Plants and humans usually compete for the same CO_2 available in the air.

13. Cellular respiration occurs in

1 autotrophs only
2 heterotrophs only
3 autotrophs and heterotrophs
4 humans only

14. Eating a sweet potato provides energy for human metabolic processes. The original source of this energy is the energy

1 in protein molecules stored within the potato
2 that is made available by photosynthesis
3 from starch molecules absorbed by the potato plant
4 in vitamins and minerals found in the soil

15. In nature, during a 24-hour period, green plants *continuously* use

1 carbon dioxide only
2 oxygen only
3 both carbon dioxide and oxygen
4 neither carbon dioxide nor oxygen

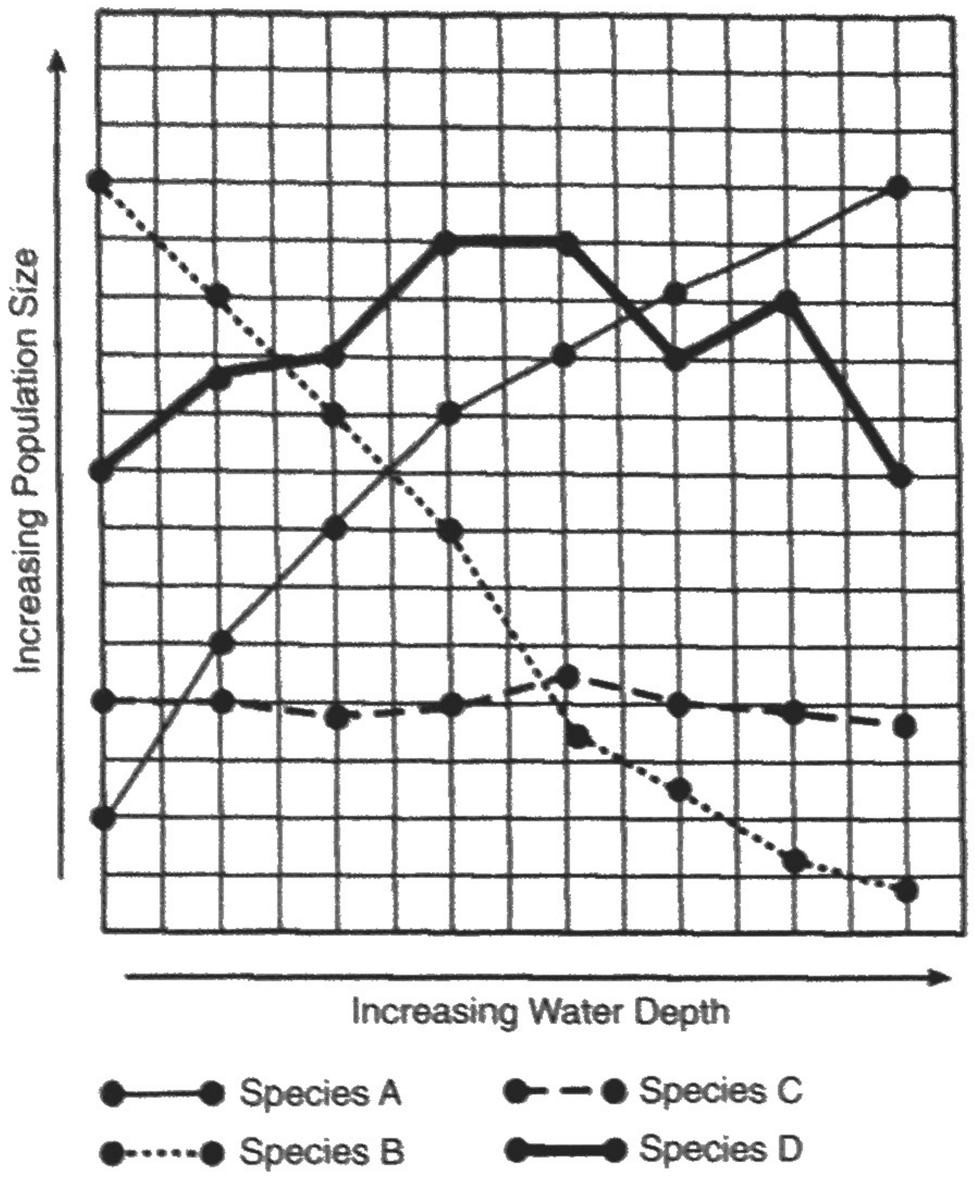
16. Plant leaves contain openings known as stomates, which are opened and closed by specialized cells, allowing for gas exchange between the leaf and the outside environment. Which phrase best describes the net flow of gases involved in photosynthesis into and out of the stomates on a sunny day?

1 carbon dioxide moves in, oxygen moves out
2 oxygen moves in, nitrogen moves out
3 carbon dioxide and oxygen move in, ozone moves out
4 water and ozone move in, carbon dioxide moves out

Part B—Analysis and Open Ended

Answer question 17 based on the following information and graph.

As the depth of the ocean increases, the amount of light that penetrates to that depth decreases. At about 200 meters, there is almost no light present. The graph below illustrates the population size of four different species at different water depths.



17. Which species most likely performs photosynthesis?

1 species A
2 species B
3 species C
4 species D

18. Explain why plants are defined as autotrophs and why animals are defined as heterotrophs.

19. Why might the process of photosynthesis be considered a "bridge" between the living and nonliving parts of the world?

20. Briefly describe *three* ways in which the structures of a leaf enable the process of photosynthesis to occur. Your answer should include the following factors:

- light
- water
- gases

Base your answers to questions 21 and 22 on the summary equations of two processes shown below and on your knowledge of biology.

Photosynthesis

$$\text{Water} + \text{Carbon Dioxide} \xrightarrow{\text{ENZYMES}} \text{Glucose} + \text{Oxygen} (+ \text{Water})$$

Respiration

$$\text{Glucose} + \text{Oxygen} \xrightarrow{\text{ENZYMES}} \text{Water} + \text{Carbon Dioxide}$$

21. Choose *one* of the processes shown above and identify the following:

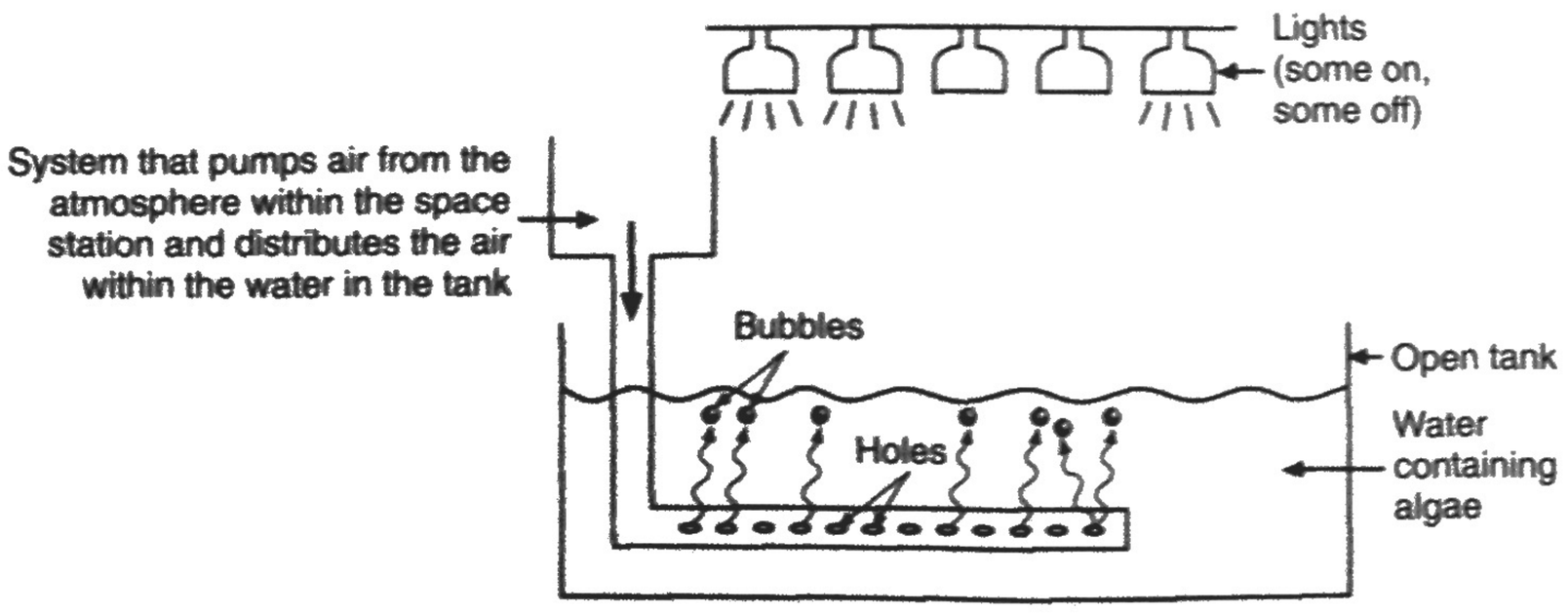
a. the source of the energy in the process you chose; and
b. where the energy ends up at the end of that process.

22. State *one* reason why *each* of the following processes is important for living things:

a. respiration; and
b. photosynthesis.

Base your answers to questions 23 to 25 on the information and diagram below and on your knowledge of biology.

The diagram represents a system in a space station that includes a tank containing algae. An astronaut from a spaceship boards the space station.



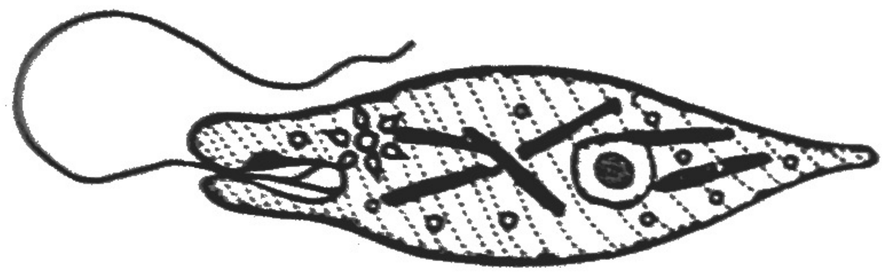
23. Identify *one* process that is being controlled in the setup shown in the diagram.

24. State *two* changes in the chemical composition of the space station atmosphere as a result of the astronaut coming on board the station.

25. State *two* changes in the chemical composition of the space station atmosphere that would result from turning on more lights.

Base your answers to questions 26 and 27 on the information and diagram below.

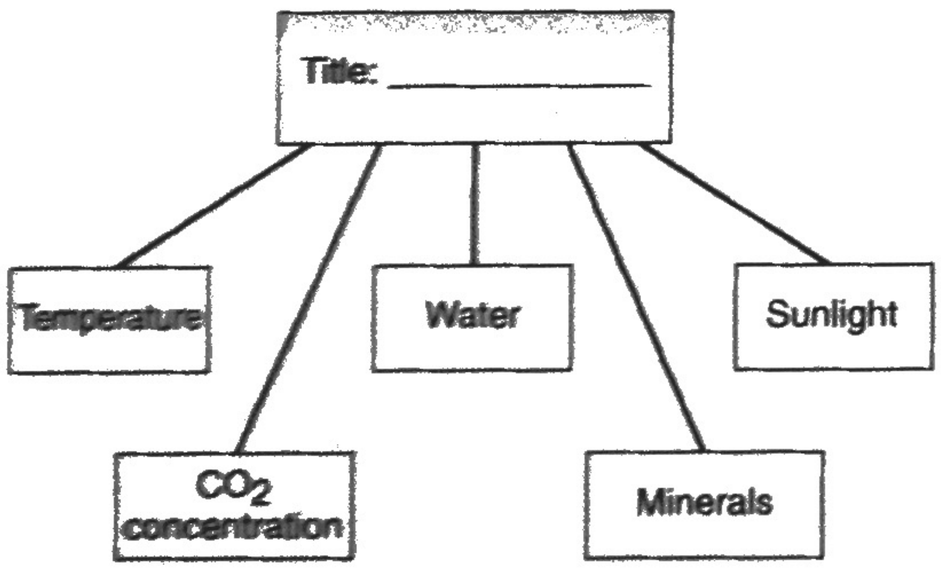
The diagram represents a single-celled organism known as *Euglena*. This organism is able to carry out both photosynthesis and cellular respiration.



26. Choose *one* of the two processes that *Euglena* carries out. Write down the word for it; then use words or chemical symbols to summarize the reaction for the process you chose.

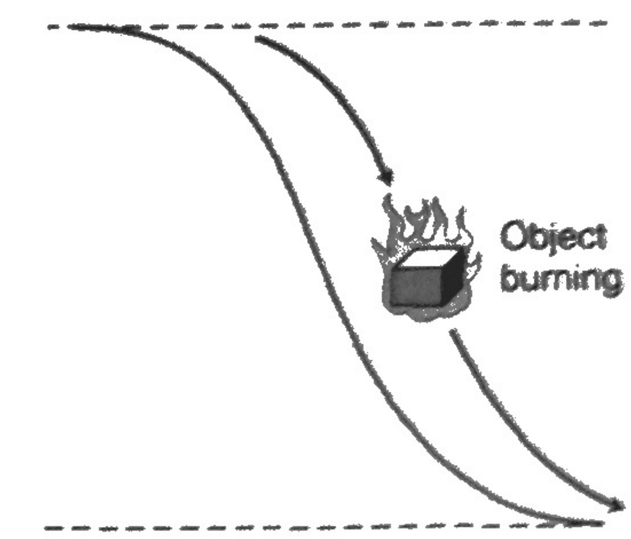
27. State *one* reason why the process you chose is essential for the survival of the *Euglena*.

28. Look at the chart below to answer this question. Which phrase would you choose to fill in the missing title?

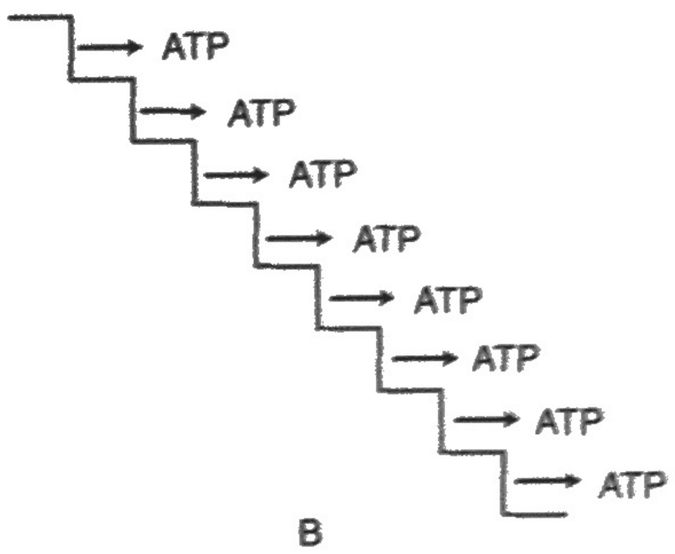


1 Some Living Factors in the Environment
2 The Chemical Process of Photosynthesis
3 Factors that Affect the Rate of Photosynthesis
4 The Nonliving Things that Make Up a Plant

29. Look at the following diagrams (A and B) to answer this question. The energy change in diagram B is different from the energy change in diagram A because, in diagram B,



A



B

1 energy is released suddenly in one step
2 the energy is released in a series of steps
3 there is less stored energy at the beginning
4 there is less stored energy remaining at the end

Refer to the chemical equation below to answer questions 30 and 31.

$$CO_2 + H_2O \xrightarrow[\text{CHLOROPHYLL}]{\text{LIGHT ENERGY}} C_6H_{12}O_6 + O_2 \ (+ H_2O)$$

30. What important life process is described by this equation? What are the two vital products of this reaction?

31. Explain why "cellular respiration is basically the opposite" of the process shown in the equation. What are the two waste products of cellular respiration?