

CK-12 Life Science For Middle School

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CHAPTER 4 Cell Functions

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Printed: April 30, 2014

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CHAPTER 4

Cell Functions	
4.1	Transport
4.2	Photosynthesis
4.3	Cellular Respiration

Introduction

Multi-celled organisms, like dolphins, are made up of trillions of cells. How do you think they work together to move an organism? How do the cells of a tree allow it to absorb water and produce leaves? How are the cells interacting with the world inside of the body and outside of the body? Do small one-celled organisms function the same way as the cells in big organisms like dolphins? We need to know how cells function, so we can understand how entire organisms, both large and small, function.

4.1 Transport

Lesson Objectives

- Describe methods of transporting molecules into and out of the cell.
- Distinguish between active and passive transport.
- Explain how diffusion and osmosis work.

Check Your Understanding

- What structure surrounds the cell?
- What is the primary part of the cell membrane?
- What does homeostasis mean?

Vocabulary

- active transport
- concentration
- diffusion
- hypertonic solution
- hypotonic solution
- isotonic solution
- osmosis
- passive transport
- phospholipid
- selectively permeable

Introduction

Cells are found in all different types of environments, and these environments are constantly changing. One-celled organisms, like bacteria, can be found on your skin, or in the ground, or in all different types of water. The cells of your body interact with the food you eat, and also with other cells in your body. All cells need a way to protect themselves. This job is done by the cell membrane.

The cell membrane is semipermeable, or **selectively permeable**, which means that only some molecules can get through the membrane. If the cell membrane were completely permeable, the inside of the cell would be the same as the outside of the cell. It would be impossible for the cell to maintain homeostasis. Homeostasis means maintaining a stable internal environment. For example, if your body cells have a temperature of 98.6 degrees F, and it is freezing outside, your cells will maintain homeostasis if the temperature of the cells stays the same and does not drop.

- How does the cell ensure it is semipermeable? How does the cell control what molecules enter and leave the cell?
- The ways that cells control what passes through the cell membrane will be the focus of this lesson.

What is Transport?

Molecules in the cell membrane allow it to be semipermeable. The membrane is made of a double layer of phospholipids (a "bilayer") and proteins (Figure below).

A single phospholipid molecule has two parts:

1. A head that is hydrophilic, or water-loving.
2. A tail that is hydrophobic, or water-fearing.

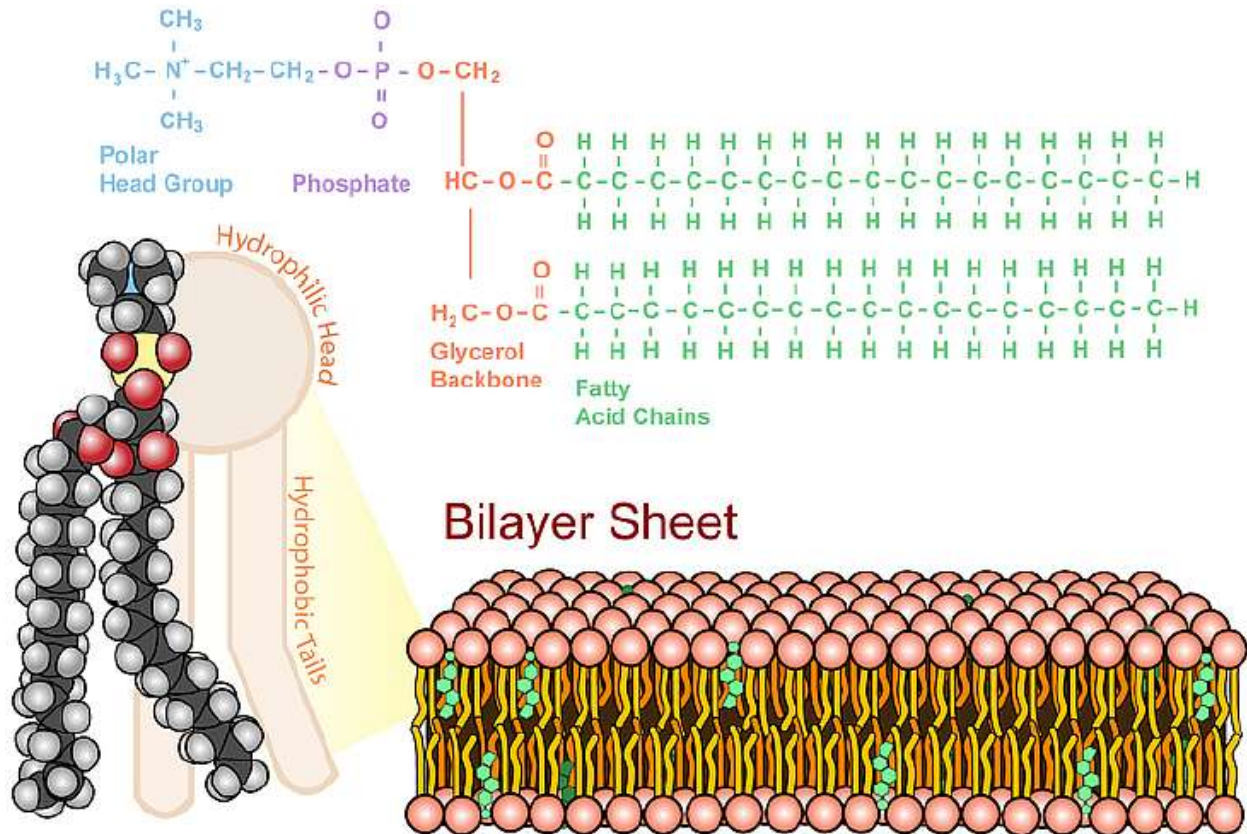


FIGURE 4.1
The cell membrane is made up of a phospholipid bilayer, two layers of phospholipid molecules.

There is water found on both the inside and the outside of cells. Since hydrophilic means water-loving and they want to be near water, the heads face the inside and outside of the cell where water is found. The water-fearing, hydrophobic tails face each other in the middle of the cell membrane because water is not found in this space. An interesting quality of the plasma membrane is that it is constantly moving, like a soap bubble. Water and small molecules such as oxygen and carbon dioxide can pass freely through the membrane, but larger molecules cannot easily pass through the plasma membrane. Some molecules need a special way to get across the membrane.

Diffusion

Small molecules can pass through the plasma membrane through a process called diffusion. **Diffusion** is the movement of molecules from an area where there is a higher concentration (larger amount) of the substance to an area where there is a lower concentration (lower amount) of the substance (Figure 4.2). The amount of a substance in relation to the total volume is the **concentration**.

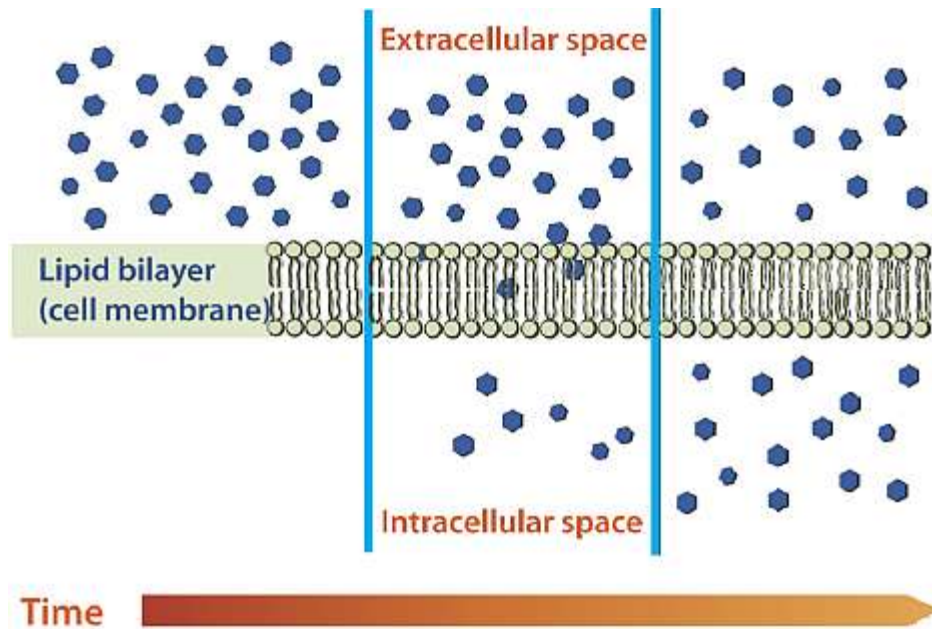


FIGURE 4.2

Diffusion is the movement of a substance from an area of a higher amount towards an area of lower amount. As time passes, equilibrium is reached when there is an equal amount on both sides of the membrane.

The diffusion of water across a membrane because of a difference in concentration is called **osmosis**. Let's explore three different situations and analyze the flow of water.

1. A **hypotonic solution** means the environment outside of the cell has a lower concentration of dissolved material than the inside of the cell. If a cell is placed in a hypotonic solution, water will move into the cell. This causes the cell to swell, and it may even burst.
2. A **hypertonic solution** means the environment outside of the cell has more dissolved material than inside of the cell. If a cell is placed in a hypertonic solution, water will leave the cell. This can cause a cell to shrink and shrivel.
3. An **isotonic solution** is a solution in which the amount of dissolved material is equal both inside and outside of the cell. Water still flows in both directions, but an equal amount enters and leaves the cell.

How do marine animals keep their cells from shrinking? How do blood cells keep from bursting? Both have to do with the cell membrane and transport of materials. Marine animals live in salt water, which is a hypertonic environment; there is more salt in the water than in their cells. To prevent losing too much water from their bodies, these animals intake large quantities of salt water and secrete salt by active transport, which will be discussed later in this lesson. Red blood cells can be kept from bursting or shriveling if put in a solution that is isotonic to the blood cells. If the blood cells were put in pure water, the solution would be hypotonic to the blood cells, so water would enter the blood cells and they would swell and burst. This is represented in Figure 4.3.

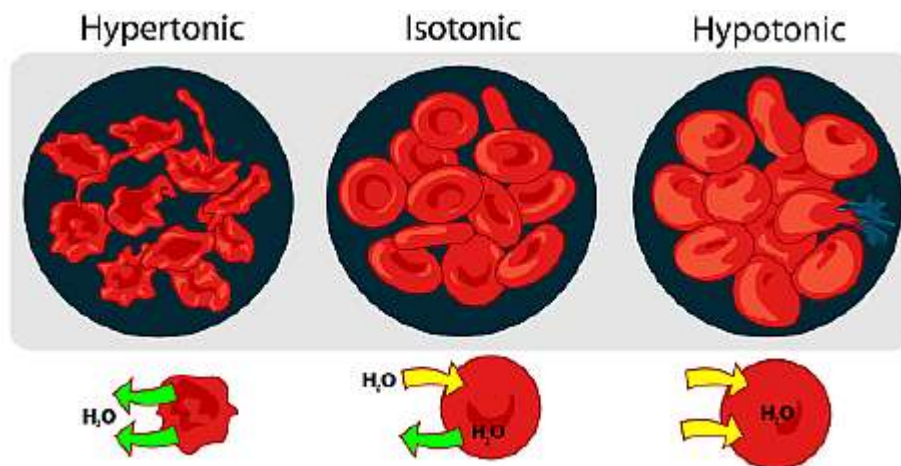


FIGURE 4.3

Osmosis causes these red blood cells to change shape by losing or gaining water.

Passive Transport

Diffusion is called **passive transport**. This means it does not require energy to move molecules. For example, oxygen diffuses out of the air sacs in your lungs into your bloodstream because oxygen is more concentrated in your lungs than in your blood. Oxygen moves from the high concentration of oxygen in your lungs to the low concentration of oxygen in your bloodstream. Sometimes, special proteins are needed to help molecules move across the membrane. These are called channel proteins or carrier proteins (Figure 4.4).

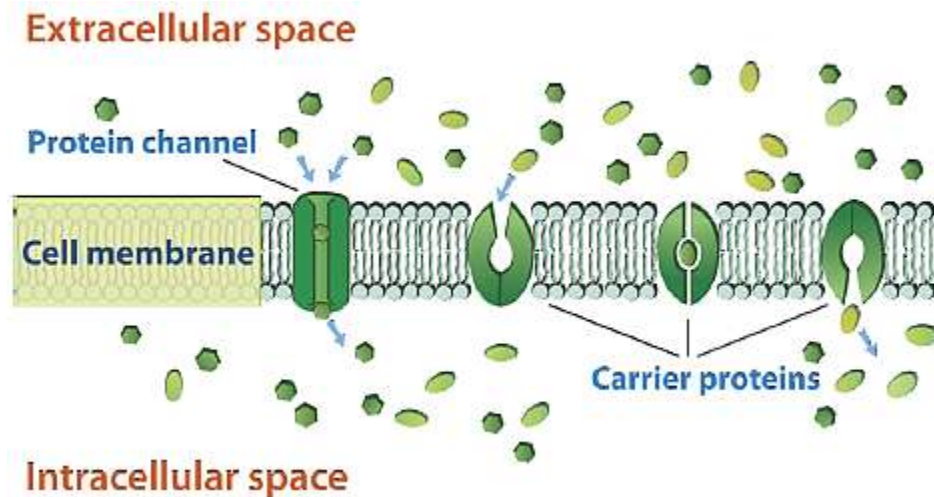


FIGURE 4.4

Protein channels and carrier proteins are involved in passive transport.

Active Transport

During active transport, molecules move from an area of low concentration to high concentration. This is the opposite of diffusion. Active transport is called "active" because this type of transport requires energy to move molecules. A protein in the membrane carries the molecules across the membrane. These proteins are often called "pumps", because like other pumps they use energy to move molecules. There are many cells in your body that use pumps to move molecules. For example, your nerve cells would not send messages to your brain unless you had protein pumps moving molecules by active transport. The sodium-potassium pump (Figure 4.5) is an example of an active transport pump.

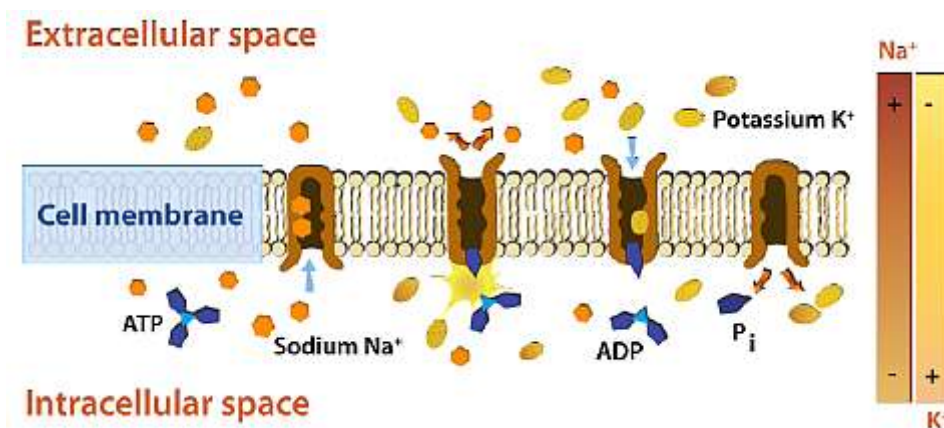


FIGURE 4.5

The sodium-potassium pump moves sodium ions to the outside of the cell and potassium ions to the inside of the cell. ATP is required for the protein to change shape. As ATP adds a phosphate group to the protein, it leaves behind adenosine diphosphate (ADP).

Lesson Summary

- The plasma membrane is semipermeable, meaning that some molecules can move through the membrane easily, while others cannot.
- Passive transport, such as diffusion and osmosis, does not require energy.
- Active transport moves molecules in the direction of the higher concentration and requires energy and a carrier protein.

Review Questions

Recall

1. What's the main difference between active and passive transport?
2. List the two types of passive transport.
3. Why is the plasma membrane considered semipermeable?
4. What is diffusion?

Apply Concepts

5. What happens when a cell is placed in a hypotonic solution?
6. What happens when a cell is placed in a hypertonic solution?

Critical Thinking

7. If a plant cell is placed in a solution and the cell shrivels up, what type of solution was it placed in? How do you know?
8. If there are 100 X molecules on the outside of a cell and 10 X molecules inside of the cell, will X molecules flow into or out of the cell? Explain why.

Points to Consider

The next lesson discusses photosynthesis.

- It is often said that plants make their own food. What do you think this means?
- What substances do you think would need to move into a leaf cell for the cell to make its own food?
- What substances would need to move out of a leaf cell?

4.2 Photosynthesis

Lesson Objectives

- Explain the importance of photosynthesis.
- Write and interpret the chemical equation for photosynthesis.
- Describe what happens during the light reactions and the Calvin Cycle.

Check Your Understanding

- How are plant cells different from animal cells?
- In what organelle does photosynthesis take place?

Vocabulary

- chlorophyll
- photosynthesis
- stomata
- stroma
- thylakoid

What is Photosynthesis?

If a plant gets hungry, it cannot walk to a local restaurant and buy a slice of pizza. So how does a plant get the food it needs to survive? **Photosynthesis** is the process plants use to make their own “food” from the sun’s energy, carbon dioxide and water. Actually, almost all organisms obtain their energy from photosynthetic organisms. For example, if a bird eats a caterpillar, then the bird gets the energy that the caterpillar gets from the plants it eats. So the bird is indirectly getting energy that began with the “food” formed through photosynthesis. Therefore, the process of photosynthesis is central to sustaining life on Earth.

During photosynthesis, carbon dioxide and water combine with solar energy to create glucose and oxygen. Glucose is a sugar that acts as the "food" source for plants. Oxygen, which is necessary for animal life, is the waste of photosynthesis.

The Process of Photosynthesis

Photosynthesis takes place in chloroplasts. Chloroplasts are one of the main differences between plant and animal cells. There are two separate parts of a chloroplast (Figure 4.6).

- The inner compartments formed by the flattened sacs, or **thylakoids**, are called the thylakoid space. Energy from sunlight is absorbed by the pigment chlorophyll in the thylakoid membrane.
- The interior space that surrounds the thylakoids is filled with a fluid called **stroma**. This is where carbon dioxide is used to produce glucose.

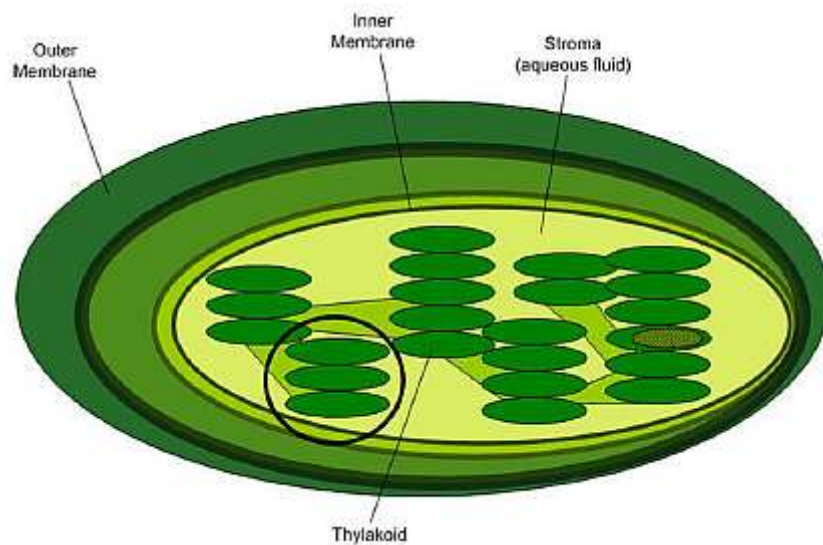


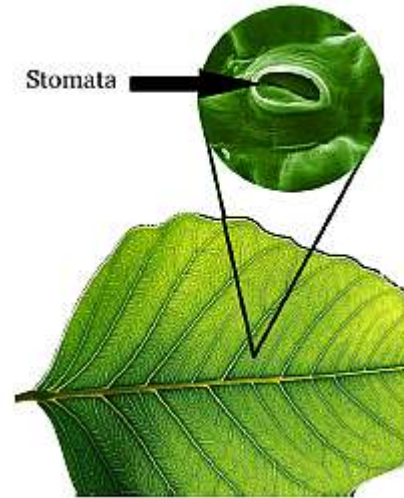
FIGURE 4.6

The chloroplast is the photosynthesis factory of the plant.

The Reactants

What goes into the plant cell? The reactants of photosynthesis are carbon dioxide and water, and the energy from sunlight. This means that carbon dioxide, water, and the sun's energy are necessary for the chemical reactions of photosynthesis.

- **Chlorophyll** is the green pigment in leaves that captures energy from the sun.
- The veins in a plant carry water from the roots to the leaves.
- Carbon dioxide enters the leaf from the air through special openings called **stomata** (Figure 4.7).



Stomata are special pores that allow gasses to enter and exit the leaf.

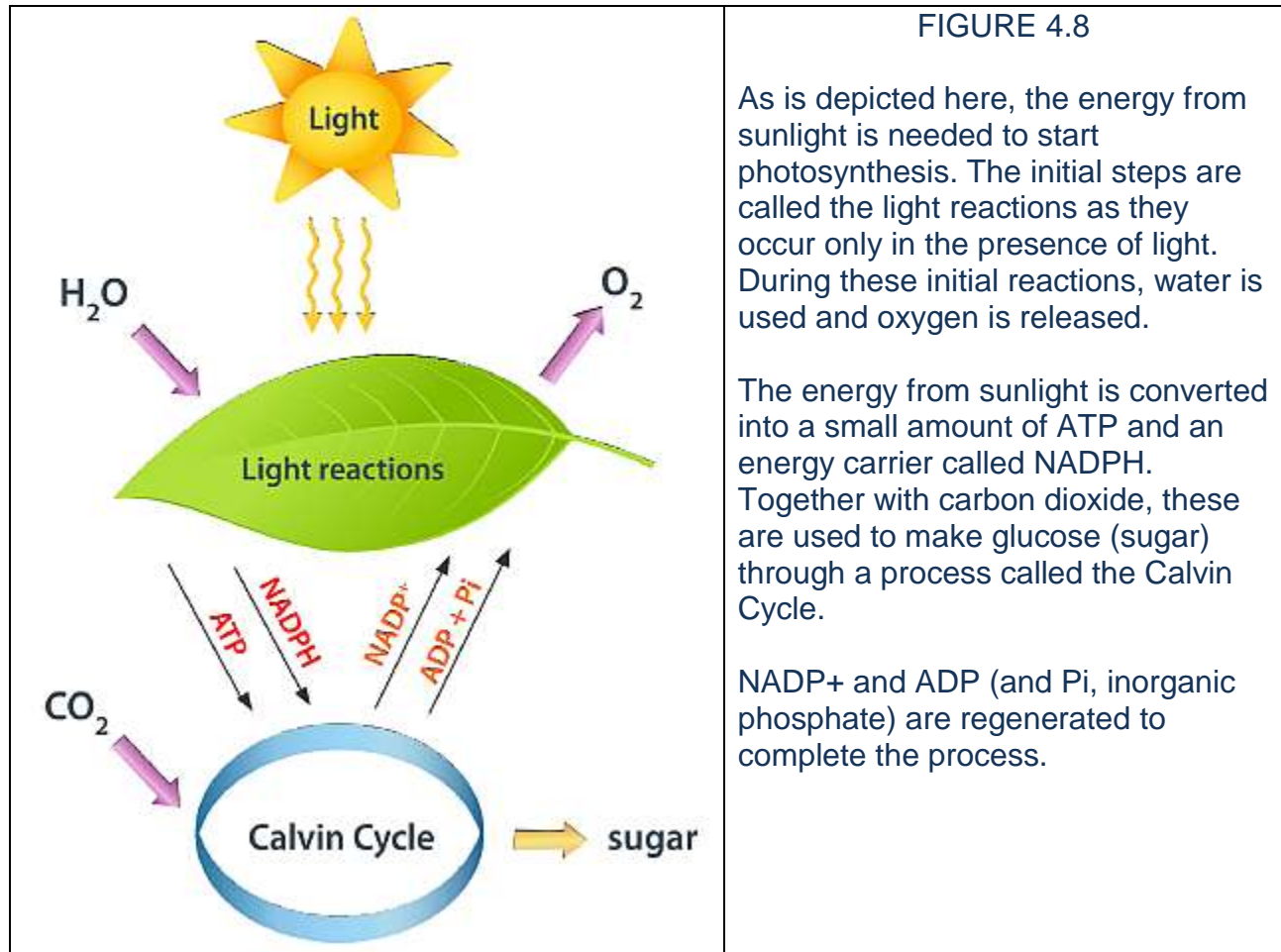
The Products

What is produced by the plant cell? The products of photosynthesis are glucose and oxygen. This means they are produced at the end of photosynthesis.

- Glucose, the food of plants, can be used to store energy for later in the form of carbohydrate molecules.
- Oxygen is a plant waste product. It is released into the atmosphere through the stomata. As you know, animals need oxygen to live. Without photosynthetic organisms like plants, there would not be enough oxygen in the atmosphere for animals to survive.

The Chemical Reaction

The overall chemical reaction for photosynthesis is 6 molecules of carbon dioxide (CO₂) and 6 molecules of water (H₂O), with the addition of solar energy. This produces 1 molecule of glucose (C₆H₁₂O₆) and 6 molecules of oxygen (O₂) (Figure 4.8).



Using chemical symbols the equation is represented as follows:



Lesson Summary

- The net reaction for photosynthesis is that carbon dioxide and water, together with energy from the sun, produce glucose and oxygen.

Review Questions

Recall

1. What are the reactants required for photosynthesis?
2. What are the products of photosynthesis?

Apply Concepts

3. What happens to the glucose produced from photosynthesis?
4. Why is it important to animals that oxygen is released during photosynthesis?
5. Describe the structures of the chloroplast where photosynthesis takes place.

Critical Thinking

6. What would happen if the stomata of a plant leaf were glued shut? Would that plant be able to perform photosynthesis? Why or why not?

Points to Consider

The next lesson is about Cellular Respiration.

- How do you gain energy from the food you eat?
- Which do you think provides more energy- a bowl of pasta or a small piece of candy?
- What “waste” gas do you exhale?

4.3 Cellular Respiration

Lesson Objectives

- Write and explain the chemical formula for cellular respiration.
- Explain the two states of cellular respiration.
- Compare photosynthesis with cellular respiration.

Check Your Understanding

- Where does the energy captured at the beginning of photosynthesis originate from?
- What is the form of chemical energy produced by photosynthesis?
- What occurs in oxidation and reduction reactions?

Vocabulary

- aerobic respiration
- alcoholic fermentation
- anaerobic respiration
- ATP
- cellular respiration
- fermentation
- lactic acid fermentation

What is Cellular Respiration?

How does the food you eat provide energy? When you need a quick boost of energy, you might reach for an apple or a candy bar. But cells do not "eat" apples or candy bars, these foods need to be broken down so that cells can use them. Through the process of **cellular respiration**, the energy in food is changed into energy that can be used by the body's cells. In other words, glucose and oxygen are converted into ATP, carbon dioxide, and water. **ATP**, or **adenosine triphosphate**, is chemical energy the cell can use. It is the molecule that provides energy for your cells to perform work, such as moving your muscles as you walk down the street.

The Process of Cellular Respiration

What happens inside of the cell? Glucose is broken down in the cytoplasm of the cells and then transported to the mitochondria, the organelles known as the energy "powerhouses" of the cells (Figure 4.9). Inside the mitochondria, the "broken-down" glucose is broken down again to release ATP. Oxygen is needed to help the process of turning glucose into ATP. The initial step releases just two molecules of ATP for each glucose. The later steps release much more ATP.

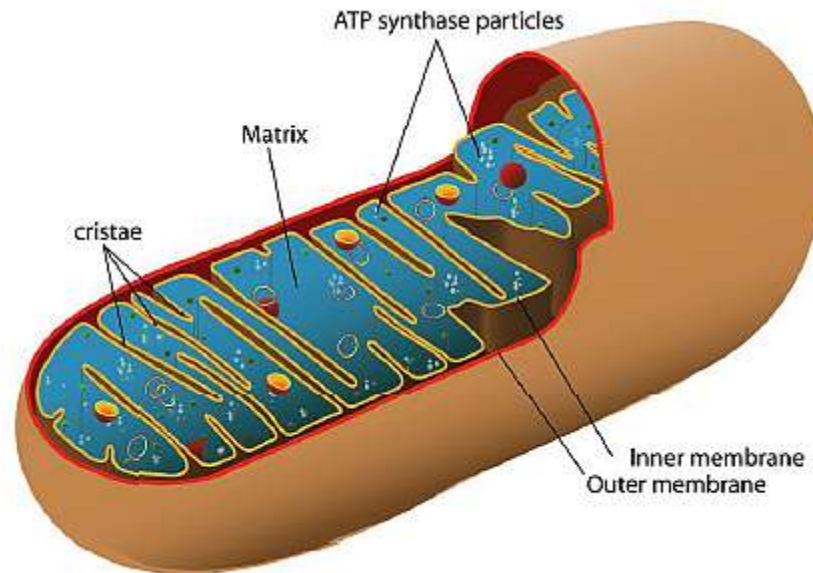


FIGURE 4.9

Most of the reactions of cellular respiration are carried out in the mitochondria.

The Reactants

What goes into the cell? Oxygen and glucose are both reactants in the process of cellular respiration. Oxygen enters the body when an organism breathes. Glucose enters the body when an organism eats.

The Products

What does the cell produce? The main product of cellular respiration is ATP. Waste products include carbon dioxide and water. Carbon dioxide is transported from your mitochondria out of your cell, to your red blood cells, and back to your lungs to be exhaled.

When one molecule of glucose is broken down, it can be converted to a net total of 36 or 38 molecules of ATP. This only occurs in the presence of oxygen.

The Chemical Reaction

The overall chemical reaction for cellular respiration is 1 molecule of glucose ($C_6H_{12}O_6$) and 6 molecules of oxygen (O_2) yields 6 molecules of carbon dioxide (CO_2) and 6 molecules of water (H_2O).

Using chemical symbols the equation is represented as follows:



Connecting Cellular Respiration and Photosynthesis

Notice that the equation for cellular respiration is the direct opposite of photosynthesis (Figure 4.10). While water was broken down to form oxygen during photosynthesis, in cellular respiration oxygen is combined with hydrogen to form water.

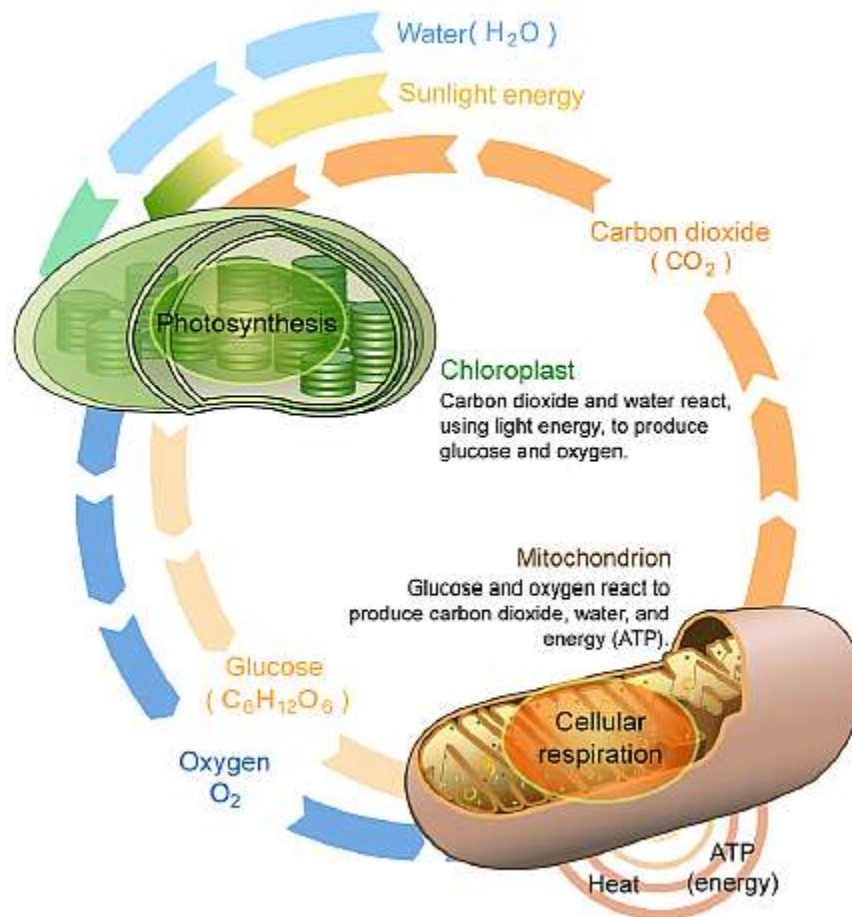


FIGURE 4.10

Cellular respiration and photosynthesis are direct opposite reactions. Some of the ATP made in the mitochondria is used as energy for work, and some is lost to the environment as heat. Can you explain what is depicted in this diagram?

While photosynthesis requires carbon dioxide and releases oxygen, cellular respiration requires oxygen and releases carbon dioxide. This exchange of carbon dioxide and oxygen in all the organisms that use photosynthesis or cellular respiration worldwide helps to keep atmospheric oxygen and carbon dioxide at stable levels.

Fermentation

Sometimes cellular respiration is **anaerobic**, occurring in the absence of oxygen. In this process, called **fermentation**, no additional ATP is produced, so the organism only obtains the two ATP molecules per glucose molecule from the initial step of this process (compare that to 36-38 ATP produced with oxygen!).

Yeasts (single-celled eukaryotic organisms) perform **alcoholic fermentation** in the absence of oxygen, making ethyl alcohol (drinking alcohol) and carbon dioxide. This process is used to make common food and drinks. For example, alcoholic fermentation is used to bake bread. The carbon dioxide bubbles allow the bread to rise, and the alcohol evaporates. In wine making, the sugars of grapes are fermented to produce the wine.

Animals and some bacteria and fungi carry out lactic acid fermentation. Lactic acid is a waste product of this process. Our muscles perform lactic acid fermentation during strenuous exercise, when oxygen cannot be delivered to the muscles quickly enough. The buildup of lactic acid is what makes your muscles sore after exercise.

Bacteria that produce lactic acid are used to make cheese and yogurt (Figure 4.11). Tooth decay is also increased by lactic acid from the bacteria that use the sugars in your mouth for energy.



FIGURE 4.11

Products of fermentation include cheese (lactic acid fermentation) and wine (alcoholic fermentation).

Lesson Summary

- Cellular respiration is the breakdown of glucose to release energy in the form of ATP.
- If oxygen is not available, the process of fermentation can break down glucose without the presence of oxygen.

Review Questions

Recall

1. What is the purpose of cellular respiration?
2. Where is glucose broken down to form ATP?

Apply Concepts

3. What are the products of alcoholic fermentation?
4. Write the chemical reaction for the overall process of cellular respiration.
5. What produces more ATP, aerobic or anaerobic cellular respiration? What is the purpose of fermentation?

Critical Thinking

6. Why do your muscles get sore after vigorous exercise?
7. Why is the cellular respiration equation the opposite of the photosynthesis equation?

Points to Consider

- What do you think could happen if your cells divide uncontrollably?
- When new life is formed, do you think it receives all the DNA of the mother and the father?
- Why do you think you might need new cells throughout your life?