Cellular Respiration

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CHAPTER 1

Cellular Respiration

Lesson Objectives

- Summarize what happens during cellular respiration and where it takes place.
- Outline the three stages of cellular respiration and how much ATP is made in each stage.
- Explain how cellular respiration and photosynthesis are related.
- Describe two types of fermentation.
- Identify advantages of aerobic and anaerobic respiration.

Lesson Vocabulary

- aerobic
- anaerobic
- cellular respiration
- electron transport
- fermentation
- glycolysis
- Krebs cycle

Introduction

If you're like astronaut Chris Hadfield in **Figure** 1.1, you grab a piece of fruit when you need a boost of energy. Most fruits are good sources of glucose. Glucose is the simple sugar that living things use to store and transport energy. Glucose is taken up by all of your cells. However, cells don't use the energy in glucose directly. They first need to release the energy and store it in ATP, or adenosine triphosphate. The much smaller amount of energy stored in ATP is just right for fueling cell processes. How do your cells change glucose to ATP? It happens during cellular respiration.

Using Glucose to Make ATP

Cellular respiration is the process in which cells break down glucose, release the stored energy, and use the energy to make ATP. For each glucose molecule that undergoes this process, up to 38 molecules of ATP are produced. Each ATP molecules forms when a phosphate is added to ADP, or adenosine diphosphate. This requires energy, which is stored in the ATP molecule. When cells need energy, a phosphate can be removed from ATP. This releases the energy and forms ADP again.

FIGURE 1.1

Astronaut Chris Hadfield eats a banana aboard the International Space Station.

What Happens During Cellular Respiration?

Cellular respiration involves many biochemical reactions. However, the overall process can be summed up in a single chemical equation:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy (stored in ATP)}$$

Cellular respiration uses oxygen in addition to glucose. It releases carbon dioxide and water as waste products. Cellular respiration actually "burns" glucose for energy. However, it doesn't produce light or intense heat like burning a candle or log. Instead, it releases the energy slowly, in many small steps. The energy is used to form dozens of molecules of ATP.

Where Does Cellular Respiration Take Place?

Cellular respiration takes place in the cells of all organisms. It occurs in autotrophs such as plants as well as heterotrophs such as animals. Cellular respiration begins in the cytoplasm of cells. It is completed in mitochondria. The mitochondrion is a membrane-enclosed organelle in the cytoplasm. It's sometimes called the "powerhouse" of the cell because of its role in cellular respiration. **Figure** 1.2 shows the parts of the mitochondrion involved in cellular respiration.

Stages of Cellular Respiration

Cellular respiration occurs in three stages. The flow chart in Figure don't purge me shows the order in which the stages occur and how much ATP forms in each stage. The names of the stages are glycolysis, the Krebs cycle, and electron transport. Each stage is described below.

Stage 1: Glycolysis

Glycolysis is the first stage of cellular respiration. It takes place in the cytoplasm of the cell. The world glycolysis means "glucose splitting". That's exactly what happens in this stage. Enzymes split a molecule of glucose into

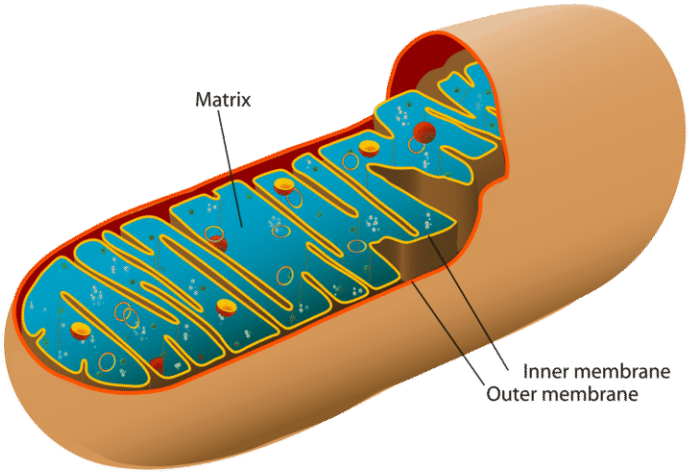


FIGURE 1.2
Cut-away view of a mitochondrion

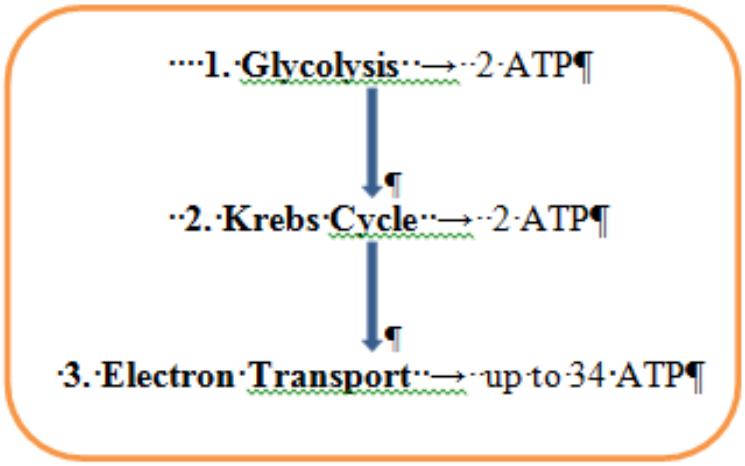


FIGURE 1.3

two smaller molecules called pyruvate. This results in a net gain of two molecules of ATP. Other energy-storing molecules are also produced. (Their energy will be used in stage 3 to make more ATP.) Glycolysis does not require oxygen. Anything that doesn't need oxygen is described as **anaerobic**.

Stage 2: The Krebs Cycle

The pyruvate molecules from glycolysis next enter the matrix of a mitochondrion. That's where the second stage of cellular respiration takes place. This stage is called the **Krebs cycle**. During this stage, two more molecules of ATP are produced. Other energy-storing molecules are also produced (to be used to make more ATP in stage 3). The Krebs cycle requires oxygen. Anything that needs oxygen is described as **aerobic**. The oxygen combines with the carbon from the pyruvate molecules. This forms carbon dioxide, a waste product.

Stage 3: Electron Transport

The third and final stage of cellular respiration is called **electron transport**. Remember the other energy-storing molecules from glycolysis and the Krebs cycle? Their energy is used in this stage to make many more molecules of ATP. In fact, during this stage, as many as 34 molecules of ATP are produced. Electron transport requires oxygen, so this stage is also aerobic. The oxygen combines with hydrogen from the energy-storing molecules. This forms water, another waste product.

Cellular Respiration and Photosynthesis

Cellular respiration and photosynthesis are like two sides of the same coin. This is clear from the diagram in **Figure 1.4**. The products of photosynthesis are needed for cellular respiration. The products of cellular respiration are needed for photosynthesis. Together, the two processes store and release energy in virtually all living things.

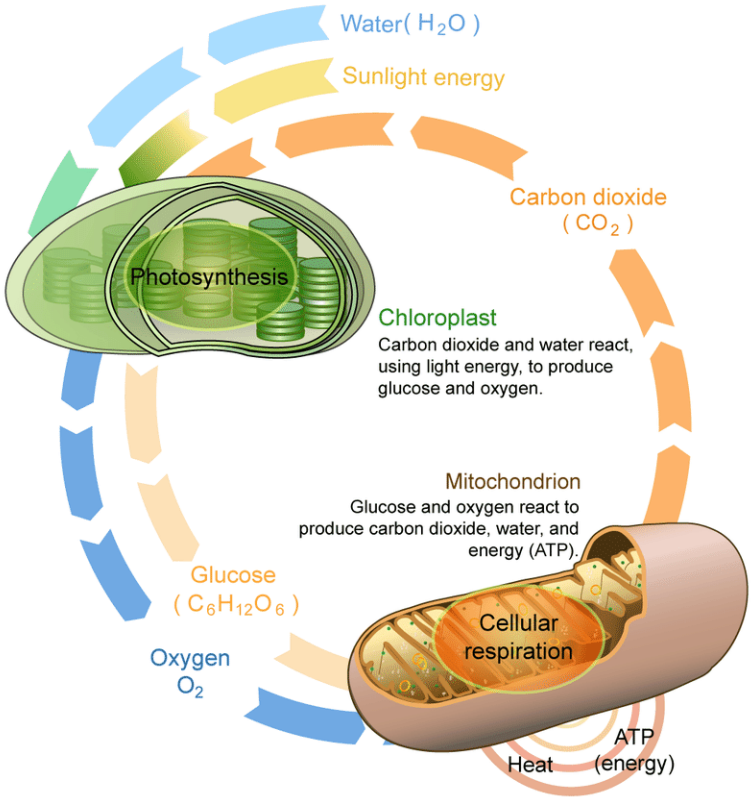
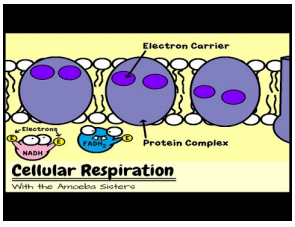


FIGURE 1.4
How photosynthesis and cellular respiration are related

Check out this video to learn more about ATP, photosynthesis, cellular respiration, and mitochondria:



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Fermentation

Some organisms can produce ATP from glucose anaerobically. One way this happens is called **fermentation**. Fermentation includes the glycolysis step of cellular respiration. However, it doesn't include the other, aerobic steps. There are two types of fermentation: lactic acid fermentation and alcoholic fermentation.

Lactic Acid Fermentation

In lactic acid fermentation, glycolysis is followed by a step that produces lactic acid. This step forms additional molecules of ATP. Lactic acid fermentation occurs in some bacteria, including the bacteria in yogurt. The lactic acid gives unsweetened yogurt its sour taste.

Your own muscle cells can also undertake lactic acid fermentation. This occurs when the cells are working very hard. They use fermentation because they can't get oxygen fast enough for aerobic respiration to supply them with all the energy they need. The muscle cells of the hurdlers in **Figure** 1.5 are using lactic acid fermentation by the time the athletes reach finish line.

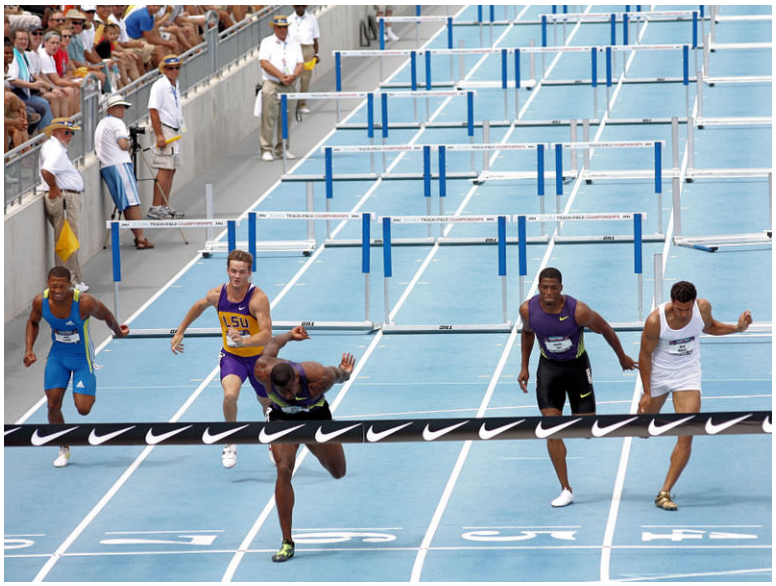


FIGURE 1.5

The muscles of these hurdlers are working too hard for aerobic respiration to keep them supplied with energy.

Alcoholic Fermentation

In alcoholic fermentation, glycolysis is followed by a step that produces alcohol and carbon dioxide. This step also forms additional molecules of ATP. It occurs in yeast, such as the yeast in bread. Carbon dioxide from alcoholic fermentation creates gas bubbles in bread dough. The bubbles leave little holes in the bread after it bakes. You can see them in the bread in **Figure** 1.6. The holes make the bread light and fluffy.

FIGURE 1.6

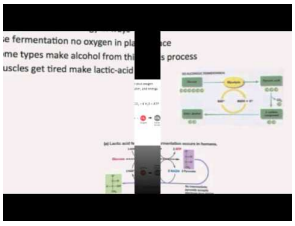
Bread has little holes in it from carbon dioxide produced by yeast.

Aerobic vs. Anaerobic Respiration

Both aerobic and anaerobic respiration have certain advantages.

- Aerobic respiration releases far more energy than anaerobic respiration does. It results in the formation of many more molecules of ATP.
- Anaerobic respiration is much quicker than aerobic respiration. It also allows organisms to live in places where there is little or no oxygen, such as deep under water or soil.

For an entertaining review of aerobic and anaerobic respiration, watch this creative music video: http://www.youtube.com/watch?v=FHWbjnzfi_U .



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Lesson Summary

- Cellular respiration is the process in which cells break down glucose, release the stored energy, and use it to make ATP. The process begins in the cytoplasm and is completed in a mitochondrion.
- Cellular respiration occurs in three stages: glycolysis, the Krebs cycle, and electron transport. Glycolysis is an anaerobic process. The other two stages are aerobic processes.
- The products of cellular respiration are needed for photosynthesis, and vice versa. Together, the two processes store and release energy in virtually all living things.
- Some organisms can produce ATP from glucose anaerobically. One way is by fermentation. There are two types of fermentation: lactic acid fermentation and alcoholic fermentation.
- Both aerobic and anaerobic respiration have certain advantages.

Lesson Review Questions

Recall

1. Define cellular respiration, and state where it takes place.
2. Identify the three stages of cellular respiration. How many molecules of ATP are produced in each stage?
3. What is fermentation?

Apply Concepts

4. Many bacteria live in the human intestines. Like all other cells, these bacteria must obtain ATP from glucose. Do you think intestinal bacteria use aerobic or anaerobic respiration for this purpose? Explain your answer.

Think Critically

5. Explain how cellular respiration and photosynthesis are related.
6. Compare and contrast aerobic and anaerobic respiration.

Points to Consider

Obtaining energy from glucose is one of the basic functions of cells. Another basic function of living cells is dividing.

1. How does a cell divide?
2. Do all cells divide the same way?

References

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5. Phil Roeder. Anaerobic respiration occurs if oxygen cannot be obtained at a sufficient rate . CC-BY 2.0
6. Laurentbonneau. The holes in bread are created by yeast fermentation . CC-BY 3.0