

Unit 5 Notes - Cellular Energy

B-3.1 Summarize the overall process by which photosynthesis converts solar energy into chemical energy and interpret the chemical equation for the process.

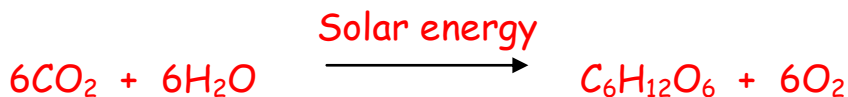
Key Concepts:

Photosynthesis: light-dependent reactions, dark (light-independent) reactions

All organisms need a constant source of energy to survive. The ultimate source of energy for most life on Earth is the Sun. Photosynthesis is the overall process by which sunlight (solar energy) chemically converts water and carbon dioxide into chemical energy stored in simple sugars (glucose). **This process occurs in two stages.**

- ✓ The first stage is called the light-dependent reactions because they require solar energy.
 - During the light-dependent reactions, solar energy is absorbed by chloroplasts (see B-2.2) and two energy storing molecules (ATP and NADPH) are produced.
 - The solar energy is used to split water molecules which results in the release of oxygen as a waste product, an essential step in the process of photosynthesis.
- ✓ The second stage is called the dark (light-independent) reactions because they do not require solar energy.
 - During the dark (light-independent) reactions, **energy stored in ATP and NADPH is used to produce simple sugars (such as glucose) from carbon dioxide.** These simple sugars are used to store chemical energy for use by the cells at later times.
 - Glucose can be used as an energy source through the process of cellular respiration or it can be converted to organic molecules (such as proteins, carbohydrates, fats/lipids, or cellulose) by various biologic processes.

It is also essential for students to understand that the process photosynthesis is generally represented using a balanced chemical equation. However, this equation does not represent all of the steps that occur during the process of photosynthesis.



- ✓ In general, six carbon dioxide molecules and six water molecules are needed to produce one glucose molecule and six oxygen molecules.
- ✓ Each of the reactants (carbon dioxide and water) is broken down at different stages of the process.
- ✓ Each of the products (oxygen and glucose) is formed in different stages of the process.
- ✓ Solar energy is needed to break down the water molecules.

B-3.2 Summarize the basic aerobic and anaerobic processes of cellular respiration and interpret the chemical equation for cellular respiration.

Key Concepts:

Cellular respiration: adenosine triphosphate (ATP)

Glycolysis

Aerobic respiration: Krebs cycle (citric acid cycle), electron transport chain

Anaerobic respiration: fermentation, lactic acid fermentation, alcohol fermentation

The ultimate goal of *cellular respiration* is to convert the chemical energy in nutrients to chemical energy stored in *adenosine triphosphate (ATP)*.

ATP can then release the energy for cellular metabolic processes, such as active transport across cell membranes, protein synthesis, and muscle contraction.

- ✓ Any food (organic) molecule, or nutrient, including carbohydrates, fats/lipids, and proteins can be processed and broken down as a source of energy to produce ATP molecules.



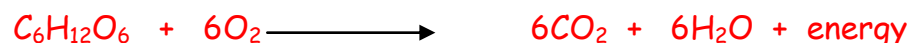
To transfer the energy stored in glucose to the ATP molecule, a cell must break down glucose slowly and capture the energy in stages.

- ✓ The first stage is glycolysis.
 - In the process of glycolysis a glucose molecule is broken down into pyruvic acid molecules and ATP molecules.
 - Glycolysis is a series of reactions using enzymes that takes place in the cytoplasm.
- ✓ If oxygen is available, the next stage is the two-step process of aerobic respiration, which takes place primarily in the mitochondria of the cell.
 - The first step of aerobic respiration is called the citric acid or Krebs cycle.
 - ◆ The pyruvic acid formed in glycolysis travels to the mitochondria where it is chemically transformed in a series of steps, releasing carbon dioxide, water, and energy (which is used to form 2 ATP molecules)

Pyruvic acid \longrightarrow carbon dioxide + water + energy (2 ATP)

 - The second step of aerobic respiration is the electron transport chain.
 - ◆ Most of the energy storing ATP molecules is formed during this part of the cycle.
 - ◆ The electron transport chain is a series of chemical reactions ending with hydrogen combining with oxygen to form water. Carbon dioxide is released as a waste product as it is formed in several stages of the Krebs cycle.
 - ◆ Each reaction produces a small amount of energy, which by the end of the cycle produces many (up to 36) ATP molecules.
 - ◆ The ATP synthesized can be used by the cell for cellular metabolism

The process aerobic respiration is generally represented using a balanced chemical equation. However, this equation does not represent all of the steps that occur during the process of aerobic respiration.



- ✓ In general, one glucose molecule and six oxygen molecules are needed to produce six carbon dioxide molecules and six water molecules.
- ✓ Each of the reactants (glucose and oxygen) is used during different stages of aerobic respiration.
- ✓ Each of the products (carbon dioxide and water) is formed during different stages of the process.
- ✓ The energy that is released is primarily used to produce approximately 34 to 36 molecules of ATP per glucose molecule.

If no oxygen is available, cells can obtain energy through the process of *anaerobic respiration*. A common anaerobic process is *fermentation*.

- ✓ Fermentation is not an efficient process and results in the formation of far fewer ATP molecules than aerobic respiration.
- ✓ There are two primary fermentation processes:
 - *Lactic acid fermentation occurs* when oxygen is not available, for example, in muscle tissues during rapid and vigorous exercise when muscle cells may be depleted of oxygen.
 - ◆ The pyruvic acid formed during glycolysis is broken down to lactic acid, and in the process energy is released (which is used to form ATP).

Glucose → Pyruvic acid → Lactic acid + energy

- ◆ The process of lactic acid fermentation replaces the process of aerobic respiration so that the cell can continue to have a continual source of energy even in the absence of oxygen, however this shift is only temporary and cells need oxygen for sustained activity.
 - ◆ Lactic acid that builds up in the tissue causes a burning, painful sensation.
- *Alcohol fermentation* occurs in yeasts and some bacteria.
 - ◆ In this process, pyruvic acid formed during glycolysis is broken down to produce alcohol and carbon dioxide, and in the process energy is released (which is used to form ATP).

Glucose → Pyruvic acid → alcohol + carbon dioxide + energy

B-3.3 Recognize the overall structure of adenosine triphosphate (ATP)—namely, adenine, the sugar ribose, and three phosphate groups—and summarize its function (including the ATP-ADP [adenosine diphosphate] cycle).

Key Concepts:

ATP structure: nitrogenous base (adenine), ribose, phosphate group

ATP-ADP cycle

Adenosine triphosphate (ATP) is the most important biological molecule that supplies energy to the cell. A molecule of ATP is composed of three parts:

1. A nitrogenous base (adenine)
2. A sugar (ribose)
3. Three phosphate groups (therefore the name triphosphate) bonded together by "high energy" bonds

ATP-ADP cycle

- ✓ Cells break phosphate bonds as needed to supply energy for most cellular functions, leaving adenosine diphosphate (ADP) and a phosphate available for reuse.
 - When any of the phosphate bonds are broken or formed, energy is involved.
 - ◆ Energy is released each time a phosphate is removed from the molecule.
 - ◆ Energy is used each time a phosphate attaches to the molecule.
 - To constantly supply the cell with energy, the ADP is recycled creating more ATP which carries much more energy than ADP.
- ✓ The steps in the ATP-ADP cycle are
 - To supply cells with energy, a "high energy" bond in ATP is broken. ADP is formed and a phosphate is released back into the cytoplasm.
$$\text{ATP} \rightarrow \text{ADP} + \text{phosphate} + \text{energy}$$
 - As the cell requires more energy, ADP becomes ATP when a free phosphate attaches to the ADP molecule. The energy required to attach the phosphate to ADP is much less than the energy produced when the phosphate bond is broken.
$$\text{ADP} + \text{phosphate} + \text{energy} \rightarrow \text{ATP}$$