Name Period Date

SECTION 4.1 | CHEMICAL ENERGY AND ATP

Reinforcement

KEY CONCEPT All cells need chemical energy.

All cells need chemical energy for their functions. The energy that your cells need comes indirectly from the food you eat. The chemical energy used by all cells is carried by a molecule called adenosine triphosphate, or ATP. **ATP** is a molecule that transfers energy from the breakdown of molecules in food to cell processes.

A molecule of ATP has three phosphate groups. The energy carried by ATP is released when the third phosphate group is removed from the molecule by a chemical reaction. When the phosphate group is removed and energy is released, ATP is converted into a molecule called adenosine diphosphate, or ADP. **ADP** is a lower-energy molecule that can be changed back into ATP by the addition of another phosphate group.

Different types of carbon-based molecules (carbohydrates, lipids, and proteins) can be broken down to produce ATP. The breakdown of the different molecules produces different amounts of ATP. Carbohydrates, especially the simple sugar glucose, are most commonly broken down to make ATP. The breakdown of a lipid produces many more ATP molecules than does the breakdown of a sugar. Proteins are the molecules least likely to be broken down, but they store about the same amount of energy as carbohydrates.

Many organisms must eat other organisms to get the carbon-based molecules they need to make ATP. Some organisms, such as plants, use a process called photosynthesis to make their own food molecules. Other organisms that survive without light can make their own food molecules through a process called **chemosynthesis.**

1. What is the function of ATP?

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_____

2. What is ADP?

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_____

3. Which types of carbon-based molecules can be broken down to make ATP?

_____

Name Period Date

SECTION 4.2

OVERVIEW OF PHOTOSYNTHESIS

Reinforcement

KEY CONCEPT The overall process of photosynthesis produces sugars that store chemical energy.

Some organisms, called producers, make their own carbon-based molecules, such as carbohydrates, that are broken down to make ATP. The process that many producers, including plants, use to make their own source of food is called photosynthesis. **Photosynthesis** is a process that captures energy from sunlight to make sugars that store chemical energy.

In plants, photosynthesis takes place in organelles called chloroplasts. Chloroplasts contain molecules, such as **chlorophyll,** that absorb energy from light. Most of a plant's chloroplasts are in leaf cells specialized for photosynthesis. Chloroplasts have two main parts used for photosynthesis: the grana, which contain disk-shaped structures called **thylakoids,** and the stroma, which is the fluid that surrounds the grana. Photosynthesis takes place in two main stages.

- The first stage is called the light-dependent reactions. In the **light-dependent reactions** chlorophyll absorbs energy from sunlight and water molecules are broken down. Energy is transferred to molecules such as ATP. Oxygen is released as a waste product.
- The second stage is called the light-independent reactions. In the **light-independent reactions** energy from the light-dependent reactions is used to build sugar molecules from carbon dioxide.

The overall, simplified chemical equation for the photosynthesis process is:

$$6CO_2 + 6H_2O \rightarrow\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow C_6H_{12}O_6 + 6O_2$$

1. What is photosynthesis?

2. Where does photosynthesis take place in plants?

3. What happens during the light-dependent reactions?

4. What happens during the light-independent reactions?

5. What are the reactants and the products of photosynthesis?

Name Period Date

SECTION 4.3 | PHOTOSYNTHESIS IN DETAIL

Reinforcement

KEY CONCEPT Photosynthesis requires a series of chemical reactions.

Photosynthesis takes place in two main stages: the light-dependent reactions and the light-independent reactions. The light-dependent reactions capture and transfer energy. The light-dependent reactions mainly take place in the thylakoid membranes through two groups of molecules, called **photosystems.**

- Photosystem II: In photosystem II, chlorophyll and other light-absorbing molecules capture energy from sunlight. The energy is transferred to electrons that travel through a series of proteins in the thylakoid membrane called an **electron transport chain.** Water molecules are broken down. Hydrogen ions from the water molecules are pumped across the thylakoid membrane.
- Photosystem I: Additional energy is absorbed from sunlight and transferred to electrons in the electron transport chain. The electrons are used to produce a molecule called NADPH, which carries energy to the light-independent reactions.
- ATP synthase: Hydrogen ions flow through a complex enzyme called **ATP synthase** that produces ATP molecules that are transferred to the light-independent reactions.

The light-independent reactions use the ATP and NADPH from the light-dependent reactions, and carbon dioxide from the atmosphere, to make sugars. The light-independent reactions take place through the **Calvin cycle.** The Calvin cycle has several chemical reactions that are necessary to produce a high-energy sugar from low-energy carbon dioxide.

1. What are the three parts of the light-dependent reactions?

2. What are the functions of photosystem II?

3. What are the functions of photosystem I?

4. What is the function of ATP synthase?

5. What happens during the Calvin cycle?

Name Period Date

SECTION 4.4 | OVERVIEW OF CELLULAR RESPIRATION

Reinforcement

KEY CONCEPT The overall process of cellular respiration converts sugar into ATP using oxygen.

Cellular respiration is a process in all eukaryotes that breaks down sugars and other carbon-based molecules to make ATP when oxygen is present. Because cellular respiration needs oxygen, it is an **aerobic** process. In eukaryotic cells, the aerobic parts of the process take place in mitochondria. The step that leads to cellular respiration takes place in the cytoplasm and is **anaerobic,** which means it does not need oxygen.

The anaerobic process that leads to cellular respiration is called glycolysis. In **glycolysis,** two ATP molecules are used to split a molecule of glucose into two three-carbon molecules, which produces four ATP molecules. Glycolysis yields a net increase of two ATP molecules. Then, if oxygen is available, the products of glycolysis are used in cellular respiration. Cellular respiration takes place in two general stages, in two different parts of the mitochondria.

- The **Krebs cycle** is a series of chemical reactions that further breaks down the three-carbon molecules from glycolysis. The Krebs cycle takes place in the matrix, or interior space, of mitochondria. These chemical reactions produce carbon dioxide, a small number of ATP molecules, and energy-carrying molecules that are used in the second stage of cellular respiration.
- An electron transport chain uses the energy-carrying molecules from the Krebs cycle to produce a large number of ATP molecules. Water, which is released as a waste product, is also formed. The electron transport chain is in the inner mitochondrial membrane.

The overall, simplified chemical equation for the cellular respiration process is

$$C_6H_{12}O_6 + 6O_2 \rightarrow\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow 6CO_2 + 6H_2O$$

CHAPTER 4 Cells and Energy

1. What is cellular respiration?

2. What is glycolysis, and why is it an anaerobic process?

3. What happens in the Krebs cycle?

4. What is the function of the electron transport chain?

Name Period Date

SECTION 4.5 | CELLULAR RESPIRATION IN DETAIL

Reinforcement

KEY CONCEPT Cellular respiration is an aerobic process with two main stages.

Cellular respiration takes place in the mitochondria of eukaryotic cells. Before cellular respiration can occur, glucose is broken down in a cell's cytoplasm during an anaerobic process called glycolysis.

- During glycolysis, two ATP molecules are used to split a glucose molecule into two three-carbon molecules that eventually become molecules called pyruvate. Four molecules of ATP (a net increase of two ATP), and two molecules of an energy-carrying molecule called NADH are formed.

When oxygen is available, the pyruvate and NADH are used for cellular respiration in the mitochondria. The first part of cellular respiration, including the Krebs cycle, takes place in the mitochondrial matrix. The second part takes place within and across the inner mitochondrial membrane.

1. Pyruvate is broken down and is linked to a molecule called Coenzyme A. This molecule enters the Krebs cycle. In the Krebs cycle, carbon-based molecules are broken down and rearranged to produce NADH and $FADH_2$, which are energy-carrying molecules, two molecules of ATP, and carbon dioxide waste.
2. Energized electrons are removed from NADH and $FADH_2$ by proteins in the electron transport chain. Hydrogen ions are pumped across the inner membrane, then flow through ATP synthase to produce ATP. Oxygen picks up the electrons that travel along the chain. Water is released as a waste product.

CHAPTER 4 Cells and Energy

1. What happens during glycolysis?

2. Describe the first stage of cellular respiration in mitochondria.

3. What is the function of the electron transport chain in cellular respiration?

4. What does oxygen do in cellular respiration?

5. What are the overall reactants and products in cellular respiration?

Name Period Date

SECTION 4.6 | FERMENTATION
Reinforcement

KEY CONCEPT Fermentation allows the production of a small amount of ATP without oxygen.

When oxygen is not available in cells, fermentation takes place instead. **Fermentation** is an anaerobic process that allows glycolysis to continue, but does not produce ATP on its own. The main function of fermentation is to remove electrons from molecules of NADH, the energy-carrier produced by glycolysis, to form NAD^+. The molecules of NAD^+ are recycled to glycolysis, which can continue to produce a small amount of ATP without oxygen. There are two main types of fermentation.

- Lactic acid fermentation: Pyruvate and NADH from glycolysis enter the fermentation process. Energy from the NADH molecules is used to convert pyruvate into lactic acid. NADH molecules are converted into NAD^+ molecules that are recycled to glycolysis to pick up more electrons. This type of fermentation occurs in many types of cells, including human muscle cells.
- Alcoholic fermentation: Like lactic acid fermentation, pyruvate and NADH from glycolysis enter fermentation. Energy from NADH is used to break down pyruvate into an alcohol and carbon dioxide. NADH molecules are converted into NAD^+ molecules that are recycled to glycolysis. Alcoholic fermentation is used by many types of yeast.

Both types of fermentation are used in various commercial processes. Lactic acid fermentation is used to make yogurt. Alcoholic fermentation is used to make dough rise.

CHAPTER 4 Cells and Energy

1. What is the function of fermentation?

2. How are lactic acid fermentation and alcoholic fermentation similar? different?

3. How is fermentation used in commercial processes?