Chapter 4

Photosynthesis and Cellular Respiration Worksheets

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- **Lesson 4.1: Energy for Life**
- **Lesson 4.2: Photosynthesis: Sugar as Food**
- **Lesson 4.3: Powering the Cell: Cellular Respiration**
- **Lesson 4.4: Anaerobic Respiration**

4.1 Energy for Life

Lesson 4.1: True or False

Name_____ **Class**_____ **Date**_____

Write true if the statement is true or false if the statement is false.

_____ 1. All life needs energy.

_____ 2. $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ is the chemical reaction of photosynthesis.

_____ 3. Glucose is a carbohydrate that stores chemical energy in a concentrated and stable form.

_____ 4. Many scientists consider photosynthesis to be the most important life process on Earth.

_____ 5. Only autotrophs can perform photosynthesis.

_____ 6. Only four types of organisms — plants, algae, fungi and some bacteria — can make food through photosynthesis.

_____ 7. ATP is the "energy currency" of the cell, so it makes sense that a molecule of ATP contains much more chemical energy than a molecule of glucose.

_____ 8. Whereas photosynthesis occurs in only some organisms, cellular respiration occurs in the cells of all living things.

_____ 9. Like matter, energy is also recycled by living organisms.

_____ 10. Heterotrophs cannot make their own food.

_____ 11. Because you are able to cook your own food in the microwave oven, you are a producer.

_____ 12. As mushrooms are fungi, they are heterotrophs.

_____ 13. A food chain shows how energy and matter flow from consumers to producers.

_____ 14. Photosynthetic animals are autotrophs.

_____ 15. Autotrophs are producers.

Lesson 4.1: Critical Reading

Name_____ **Class**_____ **Date**_____

Read these passages from the text and answer the questions that follow.

Introduction

All living things need **energy**, which is defined as the ability to do work. You can often see energy at work in living things — a bird flies through the air, a firefly glows in the dark, a dog wags its tail. These are obvious ways that living things use energy, but living things constantly use energy in less obvious ways as well.

Why Living Things Need Energy

Inside every cell of all living things, energy is needed to carry out life processes. Energy is required to break down and build up molecules and to transport molecules across plasma membranes. All life's work needs energy. A lot of energy is also simply lost to the environment as heat. The story of life is a story of energy flow — its capture, its change of form, its use for work, and its loss as heat. Energy, unlike matter, cannot be recycled, so organisms require a constant input of energy. Life runs on chemical energy. Where do living organisms get this chemical energy?

How Organisms Get Energy: Autotrophs and Heterotrophs

The chemical energy that organisms need comes from food. **Food** consists of organic molecules that store energy in their chemical bonds. In terms of obtaining food for energy, there are two types of organisms: autotrophs and heterotrophs.

Autotrophs

Autotrophs are organisms that make their own food. Most autotrophs use the energy in sunlight to make food in a process called **photosynthesis**. Only three types of organisms — plants, algae, and some bacteria — can make food through photosynthesis.

Autotrophs are also called **producers**. They produce food not only for themselves but for all other living things as well (which are known as consumers). This is why autotrophs form the basis of food chains.

Heterotrophs

Heterotrophs are living things that cannot make their own food. Instead, they get their food by consuming other organisms, which is why they are also called **consumers**. They may consume autotrophs or other heterotrophs. Heterotrophs include all animals and fungi and many single-celled organisms. What do you think would happen to consumers if all producers were to vanish from Earth?

Questions

1. What is energy? Give an example of how energy is used in a living organism.

2. Distinguish between autotrophs and heterotrophs.

3. Determine if the following are autotrophs or heterotrophs: (a) a giant redwood tree, (b) a spider, (c) a rose bush, (d) a mushroom, (e) a blue whale.

4. How is energy used in a cell?

5. Why are autotrophs considered the basis of food chains?

Lesson 4.1: Multiple Choice

Name_____ **Class**_____ **Date**_____

Circle the letter of the correct choice.

1. Photosynthesis
   (a) uses the energy in sunlight to make food.
   (b) uses the glucose in sunlight to make food.
   (c) uses the energy in sunlight to make ATP.
   (d) breaks down glucose to form ATP.
2. Which of the following autotrophs is also a producer?
   (a) a maple tree
   (b) the blue-green bacteria known as cyanobacteria
   (c) *Laurencia*, a marine genus of Red Algae from Hawaii.
   (d) All of the above are producers.
3. In the food chain grass → grasshopper → snake → hawk, which organism(s) are the heterotrophs?
   (a) the grass
   (b) the grass and grasshopper
   (c) the hawk
   (d) the grasshopper, snake, and hawk
4. Which of the following statements is true about glucose and ATP? (1) Glucose is made during photosynthesis. (2) The energy in sunlight is temporarily stored in glucose before it is transferred to ATP. (3) ATP is the energy-carrying molecule that cells use for energy. (4) The processes that make ATP and glucose also recycle oxygen in Earth's atmosphere.
   (a) statement 1 only
   (b) statements 2 and 3 only
   (c) statements 1, 2, and 3 only
   (d) All 4 statements are correct.
5. Photosynthesis can be described as the process that
   (a) uses carbon dioxide and water, in the presence of sunlight, to produce food (glucose) and oxygen.
   (b) uses glucose and oxygen to produce energy for the cell (ATP), releasing carbon dioxide and water.
   (c) uses glucose and oxygen, in the presence of sunlight, to make ATP.
   (d) uses carbon dioxide and water, in the presence of sunlight, to produce ATP and oxygen.
6. Which statement best describes the relationship between a consumer and a producer?
   (a) A lion eating an antelope.
   (b) A caterpillar eating a leaf.
   (c) A snake eating a rat.
   (d) A flower absorbing sunlight.
7. Which of the following statements is true?
   (a) The products of photosynthesis are the reactants of cellular respiration.
   (b) The products of cellular respiration are the reactants of photosynthesis.
   (c) Both statements are true.
   (d) Neither statement is true.
8. The correct chemical formula for photosynthesis (in the presence of sunlight) is

(a) $6CO_2 + 6O_2 \rightarrow C_6H_{12}O_6 + 6H_2O$.
(b) $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$.
(c) $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
(d) $C_6H_{12}O_6 + 6CO_2 \rightarrow 6O_2 + 6H_2O$

Lesson 4.1: Vocabulary I

Name_____ **Class**_____ **Date**_____

Match the vocabulary word with the proper definition.

Definitions

_____ 1. the process in which glucose is broken down and ATP is made

_____ 2. organism at the end of a food chain

_____ 3. shows how energy and matter flow from producers to consumers

_____ 4. also known as autotrophs

_____ 5. the ability to do work

_____ 6. stores chemical energy in a concentrated, stable form

_____ 7. the energy-carrying molecule that cells use for energy

_____ 8. process that stores energy from sunlight in the chemical bonds of glucose

_____ 9. organisms that make their own food

_____ 10. all animals and fungi and many single-celled organisms

_____ 11. organisms that must eat

_____ 12. organic molecules that store energy in their chemical bonds

Terms

a. ATP

b. autotroph

c. cellular respiration

d. consumer

e. decomposer

f. energy

g. food

h. food chain

i. glucose

j. heterotroph

k. photosynthesis

l. producer

Lesson 4.1: Vocabulary II

Name_____ **Class**_____ **Date**_____

Fill in the blank with the appropriate term.

1. Heterotrophs are living things that cannot make their own _____.
2. _____ and _____ are the two types of molecules organisms use for chemical energy.
3. Glucose and _____ are the products of photosynthesis.
4. _____, water, and energy are the products of cellular respiration.
5. Photosynthesis is the process in which energy from _____ is transferred to glucose.
6. _____ is the process in which energy from glucose is transferred to ATP.
7. Without photosynthesis, there would be no _____ in the atmosphere.
8. All organisms burn glucose to form _____ during cellular respiration.
9. The chemical formula of glucose is _____.
10. Photosynthesis occurs in the _____, and cellular respiration occurs in the _____-_____.
11. _____ make their own food, whereas _____ get food by eating other living things.
12. Living organisms get their _____ from food.

Lesson 4.1: Critical Writing

Name_____ **Class**_____ **Date**_____

Thoroughly answer the question below. Use appropriate academic vocabulary and clear and complete sentences.

Draw a five level food chain, identifying autotrophs, heterotrophs, producers, and consumers.

4.2 Photosynthesis: Sugar as Food

Lesson 4.2: True or False

Name_____ **Class**_____ **Date**_____

Write true if the statement is true or false if the statement is false.

_____ 1. Photosynthesis provides almost all of the energy used by living things on Earth.

_____ 2. Earth's oxygen comes from photosynthesis.

_____ 3. In photosynthesis, the Calvin cycle comes before the light reactions.

_____ 4. ATP and NADPH are the reactants of the light reactions.

_____ 5. Electron transport occurs in the thylakoid membranes.

_____ 6. All cells have chloroplasts.

_____ 7. During the Calvin cycle, NADPH and ATP are used to make glucose.

_____ 8. Photons of sunlight can excite and energize electrons.

_____ 9. A chemiosmotic gradient causes hydrogen ions to flow across the thylakoid membrane into the stroma.

_____ 10. Like photosynthesis, chemosynthesis also relies on sunlight.

_____ 11. Two turns of the Calvin cycle produce two molecules of glucose.

_____ 12. The Calvin cycle takes place in the stroma surrounding the thylakoid membranes of the chloroplast.

_____ 13. During the light reactions, water molecules are made.

_____ 14. Light is absorbed by photosystems in the thylakoid membranes of chloroplasts.

_____ 15. Both stages of photosynthesis need sunlight to proceed.

Lesson 4.2: Critical Reading

Name_____ **Class**_____ **Date**_____

Read these passages from the text and answer the questions that follow.

Photosynthesis Stage I: The Light Reactions

The first stage of photosynthesis is called the light reactions. During this stage, light is absorbed and transformed to chemical energy in the bonds of NADPH and ATP. You can read about this process below.

Steps of the Light Reactions

The light reactions occur in several steps, all of which take place in the thylakoid membrane.

- Step 1: Units of sunlight, called photons, strike a molecule of chlorophyll in photosystem II of the thylakoid membrane. The light energy is absorbed by two electrons ($2\ e^-$) in the chlorophyll molecule, giving them enough energy to leave the molecule.
- Step 2: At the same time, enzymes in the thylakoid membrane use light energy to split apart a water molecule. This produces:
  - two electrons ($2e^-$). These electrons replace the two electrons that were lost from the chlorophyll molecule in Step 1.
  - an atom of oxygen (O). This atom combines with another oxygen atom to produce a molecule of oxygen gas (O_2), which is released as a waste product.
  - two hydrogen ions ($2H^+$). The hydrogen ions, which are positively charged, are released inside the membrane in the thylakoid interior space.
- Step 3: The two excited electrons from Step 1 contain a great deal of energy, so, like hot potatoes, they need something to carry them. They are carried by a series of electron-transport molecules, which make up an **electron transport chain**. The two electrons are passed from molecule to molecule down the chain. As this happens, their energy is captured and used to pump more hydrogen ions into the thylakoid interior space.
- Step 4: When the two electrons reach photosystem I, they are no longer excited. Their energy has been captured and used, and they need more energy. They get energy from light, which is absorbed by chlorophyll in photosystem I. Then, the two re-energized electrons pass down another electron transport chain.
- Step 5: Enzymes in the thylakoid membrane transfer the newly re-energized electrons to a compound called $NADP^+$. Along with a hydrogen ion, this produces the energy-carrying molecule NADPH. This molecule is needed to make glucose in the Calvin cycle.
- Step 6: By now, there is a greater concentration of hydrogen ions — and positive charge — in the thylakoid interior space. This difference in concentration and charge creates what is called a chemiosmotic gradient. It causes hydrogen ions to flow back across the thylakoid membrane to the stroma, where their concentration is lower. Like water flowing through a hole in a dam, the hydrogen ions have energy as they flow down the chemiosmotic gradient. The enzyme ATP synthase acts as a channel protein and helps the ions cross the membrane. ATP synthase also uses their energy to add a phosphate group (Pi) to a molecule of ADP, producing a molecule of ATP. The energy in ATP is needed for the Calvin cycle.

Questions

1. In one sentence, describe what happens during the light reactions.

2. In which step(s) of the light reactions is sunlight absorbed?

3. Why is water "split" during the light reactions?

4. What is an electron transport chain? What is its role during these light reactions?

5. How is ATP made during the light reactions?

Lesson 4.2: Multiple Choice

Name_____ **Class**_____ **Date**_____

Circle the letter of the correct choice.

1. Most autotrophs make "food" through the process of
   (a) cellular respiration.
   (b) chemosynthesis.
   (c) homeostasis.
   (d) photosynthesis.
2. The correct sequence of events in the light reactions is
   (a) absorption of sunlight, electrons flow down the electron transport chain, ATP is made, NADPH is made.
   (b) absorption of sunlight, splitting of water, electrons flow down the electron transport chain, ATP is made.
   (c) electrons flow down the electron transport chain, NADPH is made, ATP is made, water is split.
   (d) absorption of sunlight, electrons flow down the electron transport chain, NADPH is made, water is split.
3. The Calvin cycle occurs
   (a) in the granum of the thylakoid membranes of the chloroplast.
   (b) in the stroma surrounding the inner membrane of the chloroplast.
   (c) in the stroma surrounding the thylakoid membranes of the chloroplast.
   (d) in the granum inside the inner membrane of the chloroplast.
4. By the end of the light reactions, energy from sunlight
   (a) has been stored in chemical bonds of NADPH and ATP.
   (b) has been transferred to glucose.
   (c) has entered the Calvin cycle.
   (d) is ready for use in the cell.
5. ATP synthase is
   (a) both an enzyme that makes ATP and a channel protein, and helps hydrogen ions cross the thylakoid membrane.
   (b) both an enzyme that makes ATP and a channel protein, and helps hydrogen ions cross the chloroplast inner membrane.
   (c) both an enzyme that makes ATP and a carrier protein, and helps hydrogen ions cross the thylakoid membrane.
   (d) both an enzyme that makes ATP and a carrier protein, and helps hydrogen ions cross the chloroplast inner membrane.
6. Essentially, the oxygen we breathe is
   (a) necessary for the light reactions to proceed.
   (b) a waste product of photosynthesis.
   (c) a reactant of the Calvin cycle.
   (d) essential for the homeostasis of the plant cell.
7. The Calvin cycle
   (a) starts with the molecule RuBP.
   (b) uses the energy in ATP and NADPH from the light reactions.

(c) turns twice to produce one molecule of glucose.
(d) all of the above

8. How do bacteria that live deep below the ocean's surface make food?

(a) by photosynthesis
(b) by chemosynthesis
(c) by cellular respiration
(d) They eat other organisms.

Lesson 4.2: Vocabulary I

Name_____ **Class**_____ **Date**_____

Match the vocabulary word with the proper definition.

Definitions

_____ 1. a green pigment

_____ 2. main product of photosynthesis

_____ 3. process in which chemical energy, instead of sunlight, is used to make "food"

_____ 4. process in which sunlight is used to make "food"

_____ 5. sac-like membranes that make up the grana within the chloroplast

_____ 6. organelle of photosynthesis

_____ 7. space outside the thylakoid membranes within the chloroplast

_____ 8. energy carrying molecule

_____ 9. series of electron-transport molecules, which pass electrons from molecule to molecule

_____ 10. groups of molecules where sunlight is absorbed during the light reactions

_____ 11. stage of photosynthesis in which the energy from sunlight is stored in ATP and NADPH

_____ 12. stage of photosynthesis in which glucose is made

Terms

a. Calvin cycle

b. chemosynthesis

c. chlorophyll

d. chloroplast

e. electron transport chain

f. glucose

g. light reactions

h. NADPH

i. photosynthesis

j. photosystem

k. stroma

l. thylakoid membrane

Lesson 4.2: Vocabulary II

Name_____ **Class**_____ **Date**_____

Fill in the blank with the appropriate term.

1. _____ are the organelles where photosynthesis takes place.
2. Stage I of photosynthesis is called the _____.
3. Stage II of photosynthesis is called the _____.
4. During the first stage of photosynthesis, a molecule of _____ gas is released.
5. Making food with chemical energy instead of sunlight is called _____.
6. Chloroplasts contain _____, which are made out of sac-like membranes, known as _____-_____ membranes.
7. Most _____ make food using photosynthesis.
8. The green pigment, _____, absorbs light to start photosynthesis.
9. During the first stage of photosynthesis, two _____ are passed from molecule to molecule down the electron-transport chain.
10. _____ turns of the Calvin cycle produce one molecule of _____.
11. During the light reactions, _____ and _____ are produced.
12. During the Calvin cycle, _____ is produced.

Lesson 4.2: Critical Writing

Name_____ **Class**_____ **Date**_____

Thoroughly answer the question below. Use appropriate academic vocabulary and clear and complete sentences.

What are the two stages of photosynthesis? Discuss these two stages and how they are related.

4.3 Powering the Cell: Cellular Respiration

Lesson 4.3: True or False

Name_____ **Class**_____ **Date**_____

Write true if the statement is true or false if the statement is false.

_____ 1. Like photosynthesis, cellular respiration begins with an electron transport chain.

_____ 2. Cellular respiration that proceeds in the presence of oxygen is called aerobic respiration.

_____ 3. Oxygen is the final electron acceptor during anaerobic respiration.

_____ 4. Cellular respiration occurs in the mitochondria.

_____ 5. Mitochondria posses their own DNA and ribosomes.

_____ 6. Just like the chloroplast, the stroma separates the inner and outer membranes of the mitochondria.

_____ 7. The Krebs cycle comes after glycolysis, during cellular respiration.

_____ 8. Cellular respiration begins with the absorption of sunlight by the mitochondria photosystems.

_____ 9. ATP synthase pumps, by active transport, hydrogen ions back into the mitochondria matrix.

_____ 10. The first reaction of the Krebs cycle produces citric acid.

_____ 11. One molecule of glucose holds enough energy to produce up to 38 ATP.

_____ 12. The Krebs cycle produces four ATP.

_____ 13. Whereas plants perform photosynthesis, plants and animals perform cellular respiration.

_____ 14. Aerobic respiration evolved prior to anaerobic respiration.

_____ 15. Two NADPH are made during glycolysis.

Lesson 4.3: Critical Reading

Name_____ **Class**_____ **Date**_____

Read these passages from the text and answer the questions that follow.

Cellular Respiration Stage III: Electron Transport

Electron transport is the final stage of aerobic respiration. In this stage, energy from NADH and $FADH_2$, which result from the Krebs cycle, is transferred to ATP. Can you predict how this happens? (*Hint:* How does electron transport occur in photosynthesis?)

Transporting Electrons

High-energy electrons are released from NADH and $FADH_2$, and they move along electron transport chains, like those used in photosynthesis. The electron transport chains are on the inner membrane of the mitochondrion. As the high-energy electrons are transported along the chains, some of their energy is captured. This energy is used to pump hydrogen ions (from NADH and $FADH_2$) across the inner membrane, from the matrix into the intermembrane space.

Making ATP

The pumping of hydrogen ions across the inner membrane creates a greater concentration of the ions in the intermembrane space than in the matrix. This chemiosmotic gradient causes the ions to flow back across the membrane into the matrix, where their concentration is lower. ATP synthase acts as a channel protein, helping the hydrogen ions cross the membrane. It also acts as an enzyme, forming ATP from ADP and inorganic phosphate. After passing through the electron-transport chain, the "spent" electrons combine with oxygen to form water. This is why oxygen is needed; in the absence of oxygen, this process cannot occur.

How Much ATP?

You have seen how the three stages of aerobic respiration use the energy in glucose to make ATP. How much ATP is produced in all three stages? Glycolysis produces 2 ATP molecules, and the Krebs cycle produces 2 more. Electron transport begins with several molecules of NADH and $FADH_2$ from the Krebs cycle and transfers their energy into as many as 34 more ATP molecules. All told, then, up to 38 molecules of ATP can be produced from just one molecule of glucose in the process of aerobic respiration.

Questions

1. In photosynthesis, electron transport comes at the beginning of the process. Where does electron transport occur during cellular respiration?

2. What is the role of the electron transport chain in cellular respiration?

3. Why is the role of oxygen in cellular respiration?

4. Describe ATP synthase and its role.

5. Summarize how up to 38 molecules of ATP are produced for each glucose molecule.

Lesson 4.3: Multiple Choice

Name_____ **Class**_____ **Date**_____

Circle the letter of the correct choice.

1. Glycolysis
   (a) uses 2 ATPs and makes 2 ATPs, 2 NADHs, and 2 pyruvates.
   (b) uses 2 ATPs and makes 4 ATPs, 2 NADHs, and 2 pyruvates.
   (c) uses 4 ATPs and makes 2 ATPs, 2 NADHs, and 2 pyruvates.
   (d) uses 2 ATPs and makes 4 ATPs, 4 NADHs, and 2 pyruvates.
2. Cellular respiration in the presence of oxygen is called
   (a) anaerobic respiration.
   (b) glycolysis.
   (c) aerobic respiration.
   (d) oxygen respiration.
3. The correct order of stages of cellular respiration is
   (a) glycolysis - the Calvin cycle - electron transport.
   (b) the light reactions - glycolysis - the Krebs cycle.
   (c) glycolysis - the Krebs cycle - electron transport.
   (d) electron transport - glycolysis - the Krebs cycle.
4. Where are the electron transport chains of cellular respiration located?
   (a) in the inner membrane of the mitochondrion
   (b) in the matrix of the mitochondrion
   (c) in the intermembrane space of the mitochondrion
   (d) in the outer membrane of the mitochondrion
5. The final electron acceptor at the end of cellular respiration is
   (a) hydrogen.
   (b) oxygen.
   (c) water.
   (d) ATP synthase.
6. The chemical formula of cellular respiration is
   (a) $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$.
   (b) $C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$.
   (c) $CO_2 + H_2O \rightarrow C_6H_{12}O_6 + O_2$.
   (d) $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$.
7. The chemiosmotic gradient of cellular respiration is an
   (a) ion gradient made by the pumping of hydrogen ions across the inner membrane using the energy of electrons as they are transported down the electron transport chain.
   (b) ion gradient made by the pumping of hydrogen ions across the outer membrane using the energy of electrons as they are transported down the electron transport chain.
   (c) ion gradient made by the pumping of oxygen ions across the inner membrane using the energy of electrons as they are transported down the electron transport chain.
   (d) ion gradient made by the diffusion of hydrogen ions across the inner membrane using the energy of electrons as they are transported down the electron transport chain.
8. In the presence of oxygen, one glucose molecule has the energy to make up to

(a) 4 $FADH_2$.
(b) 12 NADH.
(c) 38 ATP.
(d) all of the above

Lesson 4.3: Vocabulary I

Name_____ **Class**_____ **Date**_____

Match the vocabulary word with the proper definition.

Definitions

_____ 1. channel protein and enzyme that makes ATP

_____ 2. also known as the Krebs cycle

_____ 3. energy-carrying compound produced during the Krebs cycle

_____ 4. end product of glycolysis

_____ 5. cellular respiration in the absence of oxygen

_____ 6. energy-carrying compound involved in stage I and stage II of cellular respiration

_____ 7. a greater concentration of hydrogen ions in the intermembrane space than in the mitochondrial matrix

_____ 8. stage II of cellular respiration

_____ 9. "folds" created by the mitochondria inner membrane

_____ 10. glucose splitting

_____ 11. involved in stage III of cellular respiration

_____ 12. cellular respiration in the presence of oxygen

Terms

a. aerobic respiration

b. anaerobic respiration

c. ATP synthase

d. chemiosmotic gradient

e. citric acid cycle

f. cristae

g. electron transport chain

h. $FADH_2$

i. glycolysis

j. Krebs cycle

k. NADH

l. pyruvate

Lesson 4.3: Vocabulary II

Name_____ **Class**_____ **Date**_____

Fill in the blank with the appropriate term.

1. The reactions of cellular respiration can be grouped into three stages: _____, the _____-_____ cycle, and electron transport.

2. Cellular respiration in the absence of oxygen is called _____ respiration.

3. The last two stages of cellular respiration occur in the _____.

4. Most of the ATP is produced in stage _____ of cellular respiration.

5. _____ is the final electron acceptor at the end of the electron transport chain, when water is formed.

6. During glycolysis, enzymes split a molecule of glucose into two molecules of _____.

7. _____ releases the energy in glucose to make ATP.

8. During the Krebs cycle, energy is captured in molecules of _____, _____, and $FADH_2$.

9. _____ is the molecule that enters the Krebs cycle.

10. During glycolysis, _____ molecules of ATP are used, and _____ molecules of ATP are made.

11. _____ is the enzyme that produces ATP during the final stage of cellular respiration.

12. In all three stages of aerobic respiration, up to _____ molecules of ATP may be produced from a single molecule of glucose.

Lesson 4.3: Critical Writing

Name_____ **Class**_____ **Date**_____

Thoroughly answer the question below. Use appropriate academic vocabulary and clear and complete sentences.

Discuss why photosynthesis and cellular respiration can be described as a cycle.

4.4 Anaerobic Respiration

Lesson 4.4: True or False

Name_____ **Class**_____ **Date**_____

Write true if the statement is true or false if the statement is false.

_____ 1. Fermentation is the process of making ATP in the presence of oxygen.

_____ 2. Aerobic respiration evolved after oxygen was added to Earth's atmosphere.

_____ 3. Anaerobic respiration lets organisms live in places where there is little or no oxygen.

_____ 4. Alcoholic fermentation explains why bread dough rises.

_____ 5. Fermentation recycles $NADP^+$.

_____ 6. Anaerobic respiration is a very slow process.

_____ 7. Some plants and fungi and many bacteria do not need oxygen.

_____ 8. Some organisms may not be able to survive in the presence of oxygen.

_____ 9. Alcoholic fermentation explains why your muscles are sore after intense exercise.

_____ 10. There are three types of fermentation: anaerobic, aerobic, and cellular.

_____ 11. Some organisms can use both aerobic and anaerobic respiration.

_____ 12. Most living things use glucose to make ATP from oxygen.

_____ 13. Bread rises because of alcoholic fermentation.

_____ 14. Fermentation allows glycolysis to continue in the absence of oxygen.

_____ 15. Anaerobic respiration produces much more ATP than aerobic respiration.

Lesson 4.4: Critical Reading

Name_____ **Class**_____ **Date**_____

Read these passages from the text and answer the questions that follow.

Fermentation

An important way of making ATP without oxygen is called **fermentation**. It involves glycolysis but not the other two stages of aerobic respiration. Many bacteria and yeasts carry out fermentation. People use these organisms to make yogurt, bread, wine, and biofuels. Human muscle cells also use fermentation. This occurs when muscle cells cannot get oxygen fast enough to meet their energy needs through aerobic respiration. There are two types of fermentation: lactic acid fermentation and alcoholic fermentation. Both types of are described below.

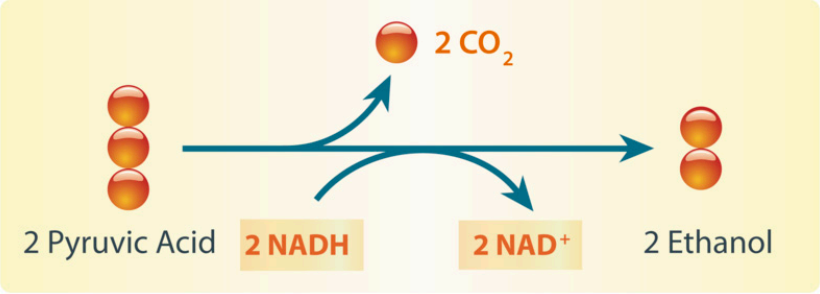
Lactic Acid Fermentation

In **lactic acid fermentation**, pyruvic acid from glycolysis changes to lactic acid. In the process, NAD^+ forms from NADH. NAD^+, in turn, lets glycolysis continue. This results in additional molecules of ATP. This type of fermentation is carried out by the bacteria in yogurt. It is also used by your own muscle cells when you work them hard and fast.

Did you ever run a race and notice that your muscles feel tired and sore afterward? This is because your muscle cells used lactic acid fermentation for energy. This causes lactic acid to build up in the muscles. It is the buildup of lactic acid that makes the muscles feel tired and sore.

Alcoholic Fermentation

In **alcoholic fermentation**, pyruvic acid changes to alcohol and carbon dioxide. NAD^+ also forms from NADH, allowing glycolysis to continue making ATP. This type of fermentation is carried out by yeasts and some bacteria. It is used to make bread, wine, and biofuels.



Alcoholic fermentation produces ethanol and NAD^+. The NAD^+ allows glycolysis to continue making ATP. *(Image courtesy of CK-12 Foundation and under the Creative Commons license CC-BY-NC-SA 3.0.)*

Have your parents ever put corn in the gas tank of their car? They did if they used gas containing ethanol. Ethanol is produced by alcoholic fermentation of the glucose in corn or other plants. This type of fermentation also explains why bread dough rises. Yeasts in bread dough use alcoholic fermentation and produce carbon dioxide gas. The gas forms bubbles in the dough, which cause the dough to expand. The bubbles also leave small holes in the bread after it bakes, making the bread light and fluffy.

Questions

1. What is fermentation?

2. Why is NAD^+ so important in fermentation?

3. Both lactic acid fermentation and alcoholic fermentation begin with the same molecule. What is that molecule and where did it come from?

4. Why is bread light and fluffy?

5. Why do your muscles get sore after intense activity?

Lesson 4.4: Multiple Choice

Name_____ **Class**_____ **Date**_____

Circle the letter of the correct choice.

1. Complete this sentence: Most living things use _____ to make _____-from glucose.
   (a) oxygen, ATP
   (b) ATP, oxygen
   (c) NADH, NAD^+
   (d) oxygen, NAD^+
2. Which of the following organisms can perform alcoholic fermentation? (1) yeast, (2) humans, (3) bacteria.
   (a) 1 only
   (b) 1 and 2
   (c) 1 and 3
   (d) 1, 2, and 3
3. Which of the following is true about anaerobic respiration?
   (a) It is a very fast process.
   (b) It allows organisms to live in places where there is little or no oxygen.
   (c) It evolved before aerobic respiration.
   (d) All of the above are true.
4. In alcoholic fermentation
   (a) carbon dioxide is released.
   (b) NADH is recycled.
   (c) lactic acid is produced.
   (d) all of the above
5. Fermentation involves which stages of cellular respiration? (1) glycolysis, (2) the Krebs cycle, (3) electron transport.
   (a) 1 only
   (b) 1 and 2
   (c) 2 and 3
   (d) all three stages
6. In lactic acid fermentation
   (a) carbon dioxide is released.
   (b) NADH is recycled.
   (c) lactic acid is produced.
   (d) all of the above
7. After intense activity, your muscles feel sore because of
   (a) the accumulation of NAD^+.
   (b) the accumulation of lactic acid.
   (c) the accumulation of ATP.
   (d) the accumulation of carbon dioxide.
8. Both alcoholic fermentation and lactic acid fermentation
   (a) start with pyruvic acid.

(b) recycle NAD^+ from NADH.
(c) allow glycolysis to continue.
(d) all of the above

Lesson 4.4: Vocabulary I

Name_____ **Class**_____ **Date**_____

Match the vocabulary word with the proper definition.

Definitions

_____ 1. an important way of making ATP without oxygen

_____ 2. respiration in the absence of oxygen

_____ 3. makes your muscles feel tired and sore after intense exercise

_____ 4. recycles during fermentation

_____ 5. perform cellular respiration in the presence of oxygen

_____ 6. can use lactic acid fermentation for energy

_____ 7. can use alcoholic fermentation for energy

_____ 8. stage of cellular respiration that occurs with or without oxygen

_____ 9. product of glycolysis

_____ 10. energy in the cell

_____ 11. fermentation in which pyruvic acid from glycolysis changes to lactic acid

_____ 12. fermentation in which pyruvic acid changes to alcohol and carbon dioxide

Terms

a. aerobic organisms

b. alcoholic fermentation

c. anaerobic respiration

d. ATP

e. fermentation

f. glycolysis

g. lactic acid

h. lactic acid fermentation

i. muscle cells

j. NAD^+

k. pyruvic acid

l. yeast

Lesson 4.4: Vocabulary II

Name_____ **Class**_____ **Date**_____

Fill in the blank with the appropriate term.

1. A way of making _____ without oxygen is called fermentation.
2. During lactic acid fermentation, NAD^+ cycles back to allow _____ to continue.
3. Fermentation involves _____, but not the other two stages of cellular respiration.
4. Aerobic respiration evolved after _____ was added to Earth's atmosphere.
5. In _____ fermentation, pyruvic acid changes to alcohol and carbon dioxide.
6. Organisms that can make ATP without oxygen include some plants and _____ and also of many bacteria.
7. In _____ fermentation, pyruvic acid from glycolysis changes to lactic acid.
8. The small holes in bread are formed by bubbles of _____ gas, which is produced by alcoholic fermentation in yeast.
9. Without oxygen, organisms can just split glucose into _____ molecules of pyruvate.
10. _____ in bread dough use alcoholic fermentation and produce carbon dioxide gas.
11. Aerobic respiration produces much more _____ than anaerobic respiration.
12. Most organisms use oxygen to make _____ from glucose.

Lesson 4.4: Critical Writing

Name_____ **Class**_____ **Date**_____

Thoroughly answer the question below. Use appropriate academic vocabulary and clear and complete sentences.

Compare aerobic and anaerobic respiration, and discuss the advantages of each.