Section: Energy in Living Systems

In the space provided, write the letter of the description that best matches each term.

____ 1. photosynthesis  a. involves building molecules that can be used as an energy source, or breaking down molecules in which energy is stored

____ 2. autotroph

____ 3. cellular respiration  b. the process by which plants, algae, and some bacteria use energy from sunlight to combine carbon dioxide and water, producing carbohydrates and oxygen

____ 4. metabolism  c. an organism that is able to use sunlight to make organic compounds that serve as food

d. the process by which cells get energy from carbohydrates

Determine the order in which the steps of energy flow through the ecosystem take place. Write the number of each step in the space provided.

____ 5. Animals get energy by eating autotrophs, substances produced by autotrophs, or organisms that consume autotrophs.

____ 6. Autotrophs absorb sunlight.

____ 7. Autotrophs use energy from sunlight to make organic compounds.

____ 8. Light from the sun reaches Earth.

Read each question, and write your answer in the space provided.

9. List the inputs (the products needed) for photosynthesis.

____

10. List the outputs of (what is produced through) photosynthesis.

____

11. List the inputs (the products needed) for cellular respiration.

____

12. List the outputs of (what is produced through) cellular respiration.

____

13. In which type of organelle does photosynthesis take place?
14. In which type of organelle does cellular respiration take place?

15. In the space provided, make a diagram that shows how the products of photosynthesis and the products of cellular respiration cycle through the ecosystem in the carbon cycle. Indicate the organelles involved.

16. What is the difference between getting energy from cellular respiration and getting energy from a log by burning it?

17. Why is ATP called a portable “energy currency”?

18. How is energy released from ATP?

19. What is ATP synthase, what does it do, and what is the process it powers?

20. Define the electron transport chain and describe its locations and purpose.
Section: Photosynthesis

Read each question, and write your answer in the space provided.

1. Describe the structure of a chloroplast. How do the inner membranes differ from the outer membranes?

________________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________

Complete each statement by writing the correct term in the space provided.

Flat discs inside chloroplasts that are arranged in stacks are called (2) ________________________________ (3) ________________________________ are light-absorbing substances that are inside chloroplasts. They absorb light of different (4) ________________________________ . The green pigment in plants that is essential for photosynthesis is (5) ________________________________ . Light energy absorbed by this pigment excites (6) ________________________________ . They are transferred to a(n) (7) ________________________________ . Then they move down an electron transport chain.

Read each question, and write your answer in the space provided.

8. Summarize the three steps in the electron transport chain that produces ATP.

________________________________________________________________________________________
________________________________________________________________________________________
________________________________________________________________________________________

9. Summarize the two steps in the electron transport chain producing NADPH.

________________________________________________________________________________________
________________________________________________________________________________________
Study the following stages of photosynthesis. Determine the order in which the stages take place. Write the order of each stage in the space provided.

10. Energy stored in ATP and NADPH powers the formation of organic compounds, using carbon dioxide.

11. Energy is captured from sunlight.

12. Light energy is converted to chemical energy, which is temporarily stored in ATP and NADPH.

Read each question, and write your answer in the space provided.

13. What are ATP and NADPH used for in photosynthesis?

14. Describe the four steps of the Calvin cycle?

15. What are three environmental factors that affect photosynthesis?
Section: Photosynthesis

Read the passage below. Then answer the questions that follow.

Photosynthesis is directly affected by various environmental factors. Light is the most obvious of the factors that affect photosynthesis. The rate of photosynthesis generally goes up as the intensity of light increases. That is because more and more of the pigments in the plant are being used. However, when all of the pigments are in use, the plant cannot absorb any more light. Then the rate of photosynthesis levels off. The concentration of carbon dioxide affects the rate of photosynthesis in a similar manner. The rate increases until a certain concentration of carbon dioxide is present. Even if this concentration is exceeded, the plant cannot take up and use carbon dioxide more quickly. So the rate of photosynthesis levels off.

Photosynthesis is a metabolic process. Like all other metabolic processes, photosynthesis includes many chemical reactions that are mediated by enzymes. Enzymes operate properly only within certain temperature ranges. Therefore, photosynthesis is most efficient within a certain range of temperatures.

SKILL: READING EFFECTIVELY

Read each question, and write your answer in the space provided.

1. Write a sentence that identifies the main idea of this passage.

2. What effect would a sudden decrease in light intensity have on the rate of photosynthesis of a particular plant?

3. At what point does light intensity have little effect on the photosynthesis rate of a plant?
4. A study showed that the photosynthesis rate of a plant continually increased over a certain period. Then the rate leveled off. During the study, light intensity and temperature remained constant. The only variable was the concentration of carbon dioxide surrounding the plant. What was the cause of this variation in photosynthesis rate?

5. In another study, the photosynthesis rate of a plant sharply decreased as air temperature sharply decreased. During this study, light intensity and concentration of carbon dioxide remained constant. What can you conclude about this variation?

In the space provided, write the letter of the term that best answers the question.

6. Which of the following does not affect the photosynthesis rate of a plant?
   a. air temperature
   b. soil type
   c. light intensity
   d. carbon dioxide concentration
Chloroplasts and Mitochondria

Plant cells and some Algae contain an organelle called the chloroplast. The chloroplast allows plants to harvest energy from sunlight to carry on a process known as Photosynthesis. Specialized pigments in the chloroplast (including the common green pigment chlorophyll) absorb sunlight and use this energy to combine carbon dioxide and water and make GLUCOSE and OXYGEN. The complete the chemical reaction for Photosynthesis is:

\[ 6 \text{CO}_2 + 6 \text{H}_2\text{O} + \text{energy (from sunlight)} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{O}_2 \]

RAW MATERIALS \hspace{1cm} ENERGY \hspace{1cm} PRODUCTS

In this way, plant cells manufacture glucose and other carbohydrates that they can store for later use. Photosynthetic cells found mainly in the leaves may have thousands of chloroplasts.

QUESTIONS:
1. What type of cells contains chloroplasts?
2. What is the energy autotrophs use to make their own food?
3. The food making process is called ________________.
4. What are the raw materials for photosynthesis?
5. What simple sugar is produced?
6. What gas is USED? ________________ RELEASED? ______
7. Where are most photosynthetic cells in plants found?
8. About how many chloroplasts can be found in photosynthetic cells?

Chloroplasts are double membrane organelles with a smooth outer membrane and an inner membrane folded into disc-shaped sacs called thylakoids. Color and label the outer membrane light green. Thylakoids, containing chlorophyll and other accessory pigments (red, orange, yellow, brown), are in stacks called granum (grana, plural). Color and label the grana (STACK) dark green in Figure 1. Grana are connected to each other by structures called lamellae, and they are surrounded by a gel-like material called stroma. Color and label the lamellae brown in figure 1. Color and label the stroma light blue in Figure 1.
9. How many membranes surround a chloroplast?

10. The outer membrane is ___.

11. The INDIVIDUAL SACS formed by the inner membrane are called _____________ and are arranged in ____________ like pancakes.

12. What pigment is found inside a thylakoid? What color will it be?

13. Other pigments that trap sunlight are called A___________ pigments. What colors are these pigments?

14. STACKS of thylakoids are called G___________ (plural) or GRANUM (singular).

15. Stacks or grana are connected to each other by ____________.

Light-capturing pigments in the grana are organized into photosystems. On Figure 2, color and label a single thylakoid (SINGLE DISK) dark green. In Figure 2, color and label a granum (STACK) red.

FIGURE 2 - THYLAKOID
Mitochondria are the powerhouses of the cell because they "burn" or break the chemical bonds of glucose to release energy to do work in a cell. Remember that this energy originally came from the sun and was stored in chemical bonds by plants during photosynthesis. Glucose and other carbohydrates made by plants during photosynthesis are broken down by the process of aerobic cellular respiration (requires oxygen) in the mitochondria of the cell. This releases energy (ATP) for the cell. The more active a cell (such as a muscle cell), the more mitochondria it will have. The mitochondria are about the size of a bacterial cell and are often peanut-shaped. Mitochondria have their own DNA and a double membrane like the nucleus and chloroplast. The outer membrane is smooth, while the inner membrane is convoluted into folds called cristae in order to increase the surface area.

16. Why are mitochondria called the powerhouse of the cell?

17. What cell process occurs in the mitochondria?

18. Why do some cells have MORE mitochondria? Give an example.

19. What simple sugar is broken down in the mitochondria?

20. Where does the energy in glucose come from ORIGINALLY?

21. Where is this energy stored in glucose?

22. Why is cellular respiration an aerobic process?

23. What energy is released when the chemical bonds of glucose are broken?

24. Name two other organelles besides the mitochondria that contain DNA and have a double membrane.

25. Describe the outer membrane of the mitochondria.

26. Why is the inner mitochondrial membrane folded?

27. What are the folds called?
Color and label the outer membrane pink and the cristae red on figure 3. This greatly increases the surface area of the membrane so that carbohydrates (simple sugars) can combine with oxygen to produce ATP, adenosine triphosphate (the energy molecule of the cell). The electron transport chain takes place across the membranes of the cristae (crista, singular). Inside the folds or cristae is a space called the matrix that contains enzymes needed for the Kreb's Cycle? Color and label the matrix yellow on figure 3.

**FIGURE 3 - MITOCHONDRIA**

*Mitochondria*

---

Adenosine triphosphate (ATP) is the energy molecule used by all cells to do work. It is a nucleotide consisting of a nitrogen-containing base (adenine, thymine, cytosine, or guanine), a 5-carbon sugar, and 3 phosphate groups. ATP is able to store and transport chemical energy within cells. The LAST TWO phosphate groups (PO4), are joined by HIGH-ENERGY bonds. When these bonds are broken, energy is released for cells to use and ADP forms. Enzymes help to break and reform these high-energy bonds.

28. What does ATP stand for?

29. What three main things make up an ATP molecule?

30. How many high-energy bonds does ATP contain?

31. Where are these high-energy bonds found in ATP?

32. What helps weaken these bonds so energy can be released and then later help reform them?

33. When ATP loses a phosphate group ______ is released for cells and a molecule of ______ forms.
In Figure 4, COLOR the 5-carbon sugar RED and LABEL it RIBOSE. COLOR and LABEL the nitrogen-base DARK BLUE. COLOR and LABEL the 3 phosphate groups YELLOW, and COLOR & LABEL the 2 high-energy bonds GREEN.

**FIGURE 4 - ATP MOLECULE**

Questions:
34. What is the energy molecule of the cell called?

35. What macromolecule made by plants is "burned" in the mitochondria?

36. Where is chlorophyll found in the chloroplast?

37. In which part of a plant would you expect to find the most chloroplasts and why?

38. How would the number of mitochondria in an insect’s wing compare to the amount found in other cells in an insect’s body? Explain your answer.

39. What are the raw materials for photosynthesis?

40. What product of photosynthesis is used in cellular respiration?

41. What is the advantage of having a folded inner membrane in the mitochondria?

42. What is the energy for photosynthesis?

43. Besides chlorophyll, what other pigments are found in the chloroplasts?
### Comparison: Photosynthesis vs Cell Respiration

**Chemical Equation**
- **Photosynthesis:** $6 \text{CO}_2 + 12 \text{H}_2\text{O} \rightarrow C_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 + 6\text{H}_2\text{O}$
- **Cell Respiration:** $C_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{energy ATP}$

**Raw Materials**
- **Photosynthesis:** Sunlight, CO$_2$, H$_2$O
- **Cellular Respiration:** C$_6$H$_{12}$O$_6$, O$_2$

**Products**
- **Photosynthesis:** C$_6$H$_{12}$O$_6$, O$_2$
- **Cellular Respiration:** CO$_2$, H$_2$O, energy ATP

**Organelle**
- **Photosynthesis:** Chloroplast
- **Cellular Respiration:** Mitochondria

**Energy Source**
- **Photosynthesis:** Sunlight
- **Cellular Respiration:** Chemical bonds in food

**When**
- **Photosynthesis:** in presence of sunlight
- **Cellular Respiration:** All the time

**Enzymes Needed**
- **Photosynthesis:** Yes
- **Cellular Respiration:** Yes
C₆H₁₂O₆ + 6O₂ → 6CO₂ + 12H₂O + 38ATP

Glycolysis

Glucose → 2ATP

2 Pyruvate

Net 2 ATP

4 ATP

2 Pyruvate

2H₂O → 4 H₂ atoms

Aerobic respiration → pyruvate + CO₂ → ATP

O₂ needed

in mitochondria

“power house”

2H₂O → 4 H₂ atoms

O₂ needed

Krebs cycle → 20 H₂ atoms

2 ATP

12 ATP

3 x 3 NAD

12 ATP

Electron transport chain

3 x 3 ATP

2 ATP

Ethanol + CO₂

Fermentation

Yeast → beer, wine

Muscle cells → vinegar

Lactic acid → yogurt, sour cream

Buttermilk, cooking butter

Sourdough, cheese

Ethanol + CO₂

Glycolysis

Cellular Respiration
Comparison of Photosynthesis and Respiration

<table>
<thead>
<tr>
<th>Cellular Respiration</th>
<th>Photosynthesis</th>
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</thead>
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<td>Reduction of carbon compounds</td>
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<tr>
<td>Releases Energy</td>
<td>Requires (Stores) Energy</td>
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<tr>
<td>Releases Carbon Dioxide</td>
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<tr>
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<td>Occurs in Plants and Animals</td>
<td>Requires Chlorophyll-Plant Cells Only</td>
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<tr>
<td>Glycolysis, Krebs Cycle and ETS</td>
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</table>

Formula for Respiration

\[ C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 36 \text{ ATP} \]

Formula for Photosynthesis

\[ \text{Light} + 6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2 \]
Section: Cellular Respiration

Complete each statement by writing the correct term or phrase in the space provided.

1. Cells harvest the energy in organic compounds to make ATP through a process called _____________________________.

2. In this process, cells transfer energy from organic compounds to _____________________________.

3. The primary fuel for cellular respiration is _____________________________.

4. The first stage of cellular respiration is called _____________________________.

Read the question, and write your answer in the space provided.

5. There are three main steps in glycolysis. What are the starting and ending products for each step?

__________________________________________________

__________________________________________________

__________________________________________________

__________________________________________________

__________________________________________________

__________________________________________________

__________________________________________________

Complete each statement by writing the correct term in the space provided.

6. Glycolysis takes place without oxygen, so it is _____________________________.

7. Metabolic processes requiring oxygen are _____________________________. They release ____________________________ energy than processes that don’t require oxygen.

8. The first stage of aerobic respiration is the _____________________________. It begins with _____________________________. The end product of glycolysis. It can result in the production of up to ___________ molecules.
Read the question, and write your answer in the space provided.

9. What happens during the Krebs cycle when carbon-carbon bonds are broken or rearranged?

10. What happens during the Krebs cycle as electrons pass down the electron transport chain? Where does this step take place?

11. How does the electron transport chain active during the Krebs cycle affect the hydrogen ion concentration in a mitochondrion?

12. What is the role of ATP synthase in the Krebs cycle?

13. How is water formed as a by-product of the Krebs cycle?

Complete each statement by writing the correct term or phrase in the space provided.

14. When oxygen is not present, the ____________________________ does not function.

15. Two types of fermentation are ____________________________ and ____________________________ fermentation.

16. The role of fermentation in cellular respiration is to recycle ____________________________ so that ____________________________ can continue to be made by ____________________________.

Read the question, and write your answer in the space provided.

17. Which is most efficient in producing ATP: glycolysis, fermentation, or the Krebs cycle? Why?
Section: Cellular Respiration

Read the passage below. Then answer the questions that follow.

Cellular respiration begins with the breakdown of glucose. This process is called glycolysis, and it occurs in the cytoplasm of cells. Glycolysis is an enzyme-assisted, anaerobic process. During glycolysis, one six-carbon molecule of glucose is converted to two three-carbon molecules of pyruvate. The pyruvate molecules produced during glycolysis still contain some of the energy that was stored in the glucose molecule when it was first made through photosynthesis. In the process of glycolysis, two molecules of ATP are used and four molecules of ATP are produced.

SKILL: READING EFFECTIVELY

Read each question, and write your answer in the space provided.

1. How and where does cellular respiration begin?

2. Glycolysis is classified as an anaerobic process. What does this indicate?

3. What happens to a six-carbon molecule of glucose during glycolysis?

4. What is the original source of the energy contained in the pyruvate molecules produced through glycolysis?

5. Which of the following are produced as a result of glycolysis?
   a. two molecules of pyruvate
   b. six ATP molecules
   c. two glucose molecules
   d. Both (a) and (b)
Using the terms and phrases provided below, complete the concept map showing the characteristics of cellular respiration.

- anaerobic process
- glucose
- NAD^+
- electron transport chain
- glycolysis
- pyruvate
- fermentation
- Krebs cycle

Cellular respiration

often begins with

1. __________

which is broken down during

2. __________

which is an

3. __________
as is

4. __________

which produces

5. __________

which involves the

6. __________

aerobic respiration

that is used in

7. __________

which recycles

8. __________
Test Prep Pretest

In the space provided, write the letter of the term or phrase that best completes each statement or best answers each question.

1. Which of the following correctly sequences the flow of energy through an ecosystem?
   a. bacteria, water, algae, fish
   b. bacteria, sun, grass, deer
   c. sun, grass, rabbit, fox
   d. algae, sun, small fish, shark

2. What is the purpose of cellular respiration?
   a. to store carbohydrates
   b. to produce energy from carbohydrates
   c. to produce oxygen
   d. to store oxygen in water

3. What is the main way cells get energy from ATP?
   a. by using water to release energy from the molecule
   b. by breaking the single phosphate bond in the molecule
   c. by breaking one of the two phosphate bonds in the molecule
   d. by breaking one of the three phosphate bonds in the molecule

4. ATP synthase gets the energy it needs to make ATP directly from
   a. hydrogen ions diffusing through the channel in the protein.
   b. hydrogen ions it pumps out of the cell, across the cell membrane.
   c. electrons in pigments that have absorbed sunlight.
   d. electrons that have bonded to carbohydrate molecules.

5. Electron transport chains are a series of molecules
   a. on the inner membrane of some organelles that accept excited electrons and use their energy to move H⁺ ions across the membrane.
   b. on the outer membrane of some organelles that accept H⁺ ions and use their energy to move electrons across the membrane.
   c. on the inside of some cell membranes that accept H⁺ ions and use their energy to move protons out of the cell.
   d. on the outside of some cell membranes that accept excited electrons and use their energy to move H⁺ ions into the cell.

6. How do plants get energy from light?
   a. Light excites hydrogen ions in the outer membrane of chloroplasts.
   b. Light excites electrons in a special chlorophyll molecule.
   c. Light excites ATP synthase in the membrane of plant cells.
   d. Light excites electron carriers in carotenoids.

7. Which do plants need to complete making sugars via photosynthesis?
   a. glucose
   b. oxygen
   c. alcohol
   d. carbon dioxide

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Holt Biology 21 Photosynthesis and Cellular Respiration
8. Which of the following environmental factors does not directly influence the rate of photosynthesis?
   a. light intensity  
   b. oxygen concentration  
   c. carbon dioxide concentration  
   d. temperature

9. In glycolysis,
   a. glucose is produced.
   b. aerobic processes produce energy-storing sugars.
   c. one molecule of ATP and one molecule of NADPH are produced.
   d. one molecule of pyruvate and four molecules of ATP are produced.

10. Which of these occurs during the Calvin cycle?
    a. An animal cell produces a net total of two molecules of ATP.
    b. An animal cell produces up to a net total of 36 molecules of ATP.
    c. A plant cell produces one energy-storing sugar molecule.
    d. A plant cell produces up to 36 energy-storing sugar molecules.

11. Which of these are end products of the Krebs cycle?
    a. ATP, NADH, and FADH₂
    b. ATP and oxygen
    c. ATP and pyruvate
    d. ATP and energy-storing starch

12. Which of the following is never part of cellular respiration?
    a. an electron transport chain
    b. glycolysis
    c. the Krebs cycle
    d. the Calvin cycle

13. The most efficient form of cellular respiration requires
    a. carbon dioxide as a source for making energy-storing molecules.
    b. water as a source of excited electrons in electron transport chains.
    c. oxygen as an electron acceptor so electron carriers can be recycled.
    d. lactic acid as an electron acceptor so electron carriers can be recycled.

Question 14 refers to the figure below, which shows a chloroplast.

C 14. The reactions of the electron transport chains occur in the structure labeled
   a. A.  
   b. B.  
   c. C.  
   d. D.
15. Which substances are involved in two different types of fermentation?
   a. ethanol and lactic acid
   b. glucose and ethanol
   c. glucose and oxygen
   d. lactic acid and glucose

16. What is the net maximum number of ATP molecules that can be produced through cellular respiration?
   a. 41
   b. 38
   c. 34
   d. 2

Complete each statement by writing the correct term or phrase in the space provided.

17. During photosynthesis, organisms called __________________________ convert
    __________________________ energy to __________________________ energy.

18. Cells gradually release energy in chemical reactions that are assisted by
    catalysis called __________________________.

19. Light-absorbing __________________________ are located in the membranes of
    flat sacs called __________________________, which are stacked inside
    __________________________.

20. During the light reactions of photosynthesis, one __________________________
    __________________________ uses energy from
    excited electrons to make __________________________ the other uses energy from excited
    electrons to make __________________________. These molecules are used in the
    __________________________ of photosynthesis.

21. Some organisms use the process of fermentation to resupply electron acceptors
    for __________________________, so that ATP can be produced in the absence of
    __________________________.

22. Aerobic respiration occurs in the __________________________ of eukaryotic cells.