Respiration and Photosynthesis

Class Work

1. Where does the energy in an ecosystem originate?
2. Define catabolism.
3. What are the two types of cellular respiration?
4. If oxygen is present, how many ATPs can the breakdown of NADH create?
5. If oxygen is present, how many ATPs can the breakdown of $FADH_2$ create?
6. When NADH is converted to NAD^+, is energy stored or released as ATP?
7. When FAD is converted to $FADH_2$, is energy stored or released as ATP?

Homework

8. Why is cellular respiration categorized as a catabolic process?
9. What is the major difference between aerobic and anaerobic respiration?
10. What is the importance of NAD^+ and FAD to respiration?
11. What does it mean to "reduce a molecule"?
12. What does it mean to "oxidize a molecule"?
13. What does the phrase "LEO says GER" stand for?
14. Write the reduction reaction for NAD^+.
15. Write the oxidizing reaction for $FADH_2$.

Class Work

16. For what type of cellular respiration is glycolysis the first stage?
17. What are the products of glycolysis?
18. What does glycolysis require in order to break down 1 glucose molecule?
19. What is the net ATP production for the anaerobic cellular respiration or 1 glucose molecule?
20. How many ATPs are needed to break down 5 glucose molecules?
21. What process follows glycolysis in anaerobic cellular respiration?
22. List the two possible products that pyruvate can from during fermentation?
23. For the first 2 billion years of Earth's formation, what type of cellular respiration were organisms undergoing?

Homework

24. What is the starting molecule of glycolysis?
25. How many ATPs in total are produced when 2 molecules of glucose undergo glycolysis? How many net ATPs are formed?
26. If 14 glucose molecules underwent glycolysis, how many pyruvate molecules would be created? What would be the net gain of ATP?
27. What happens to pyruvate and NADH if there is no oxygen present?
28. What happens to NADH during fermentation?
29. Provide a common example of ethanol fermenation.
30. Provide a common example of lactic acid fermentation.
31. Cells that undergo anaerobic respiration are found in what type of environment?

Class Work

32. List two major differences between anaerobic and aerobic respiration.
33. List the four stages of aerobic cellular respiration.
34. Identify the products and reactants of glycolysis in aerobic cellular respiration.
35. List the products and reactants of the pyruvate dehydrogenase complex?
36. Explain how the 6-carbon molecule of glucose is broken down in the first three steps of aerobic cellular respiration.
37. What is the net yield of ATP, NADH, $FADH_2$, and CO_2 in one turn of the citric acid cycle?

Homework

38. What occurred about 2.5 billion years after the Earth formed? How did this affect cellular respiration?
39. Write the balanced chemical reaction for aerobic cellular respiration.
40. What happens to the oxygen that is used in aerobic cellular respiration?
41. List two similarities between aerobic and anaerobic respiration?
42. What characteristic do both facultative bacteria and human muscles have in common?
43. What is another name for the Citric Acid Cycle?
44. How many citric acid cycles are completed for each glucose molecule that undergoes aerobic respiration?
45. What is the net yield of ATP, NADH, $FADH_2$, and CO_2 in the citric acid cycle when due to the input of 1 molecule of glucose into aerobic cellular respiration?

Class Work

46. After the Citric Acid Cycle, how many of each of the following molecules is there: NADH, $FADH_2$, and ATP?
47. What is formed across the membrane as a result of the Electron Transport Chain?
48. Which molecule is the final electron acceptor in the electron transport chain?

Homework

49. How many ATPs are produced for each NADH and $FADH_2$ respectively?
50. What is the purpose of oxidative phosphorylation?
51. Describe briefly what occurs to electrons and protons in the electron transport chain.
52. Define chemiosmosis.
53. What provides the energy necessary for ATP to form from ADP in oxidative phosphorylation?

Class Work

54. What is the net ATP gain from aerobic cellular respiration?
55. The fourth stage of aerobic cellular respiration is known as oxidative phosphorylation, but there are really two parts to this stage, what are they?

56. How are electrons able to be pulled through the electron transport chain?
57. What other organic molecules provide electrons for cellular respiration?
58. Explain how the creation of hydroelectric power relates to oxidative phosphorylation.

Homework

59. The electron transport chain can also be thought of as what?
60. Describe the function of ATP synthase in oxidative phosphorylation.
61. When the electrons bond with oxygen at the end of the electron transport chain, what molecule is formed?
62. Explain why glycolysis is thought to be one of the oldest metabolic processes.

Class Work

63. Write the balanced chemical equation for photosynthesis.
64. Define obligate anaerobes.
65. Instead of NAD^+ and FAD, what molecule is used to harness energy in photosynthesis that was not used in cellular respiration?

Homework

66. What do you notice about the chemical equations for photosynthesis and aerobic cellular respiration?
67. Where does the energy for all life processes originate?
68. Explain the oxygen catastrophe.

Class Work

69. Compare the products of cyclic and noncyclic energy transport.
70. Where do light dependent reactions occur?
71. What chemical is necessary for light dependent reactions to occur?
72. What are the products from the light dependent reactions?
73. What is another name for the light independent reactions?
74. How many carbon dioxide molecules enter the Calvin Cycle each turn?
75. How many turns of the Calvin Cycle are needed to create one molecule of glucose?
76. Define carbon fixing.

Homework

77. Describe what is necessary about the structure of a thylakoid for it to be the place where photosynthesis occurs.
78. What chemical gives plants their green color?
79. What color light does chlorophyll absorb?
80. Explain what happens to protons in photosystem II.
81. What happens to the each carbon dioxide molecule that enters the Calvin Cycle?
82. Briefly describe the carbon cycle.

Class Work

83. Explain the importance of CO_2 as a greenhouse gas.
84. How does the burning of fossil fuels contribute to the carbon cycle?
85. How has an increase in greenhouse gases in the atmosphere affected the Earth?

Free Response

1. Photosynthesis and cellular respiration can be described as complementary processes.
    a. Write the chemical formula for cellular respiration and the chemical formula for photosynthesis.
    b. Describe how cellular respiration and photosynthesis are evidence of the First Law of Thermodynamics that states, "Energy is neither created nor destroyed."

2. About 2.5 billion years ago oxygen was added to Earth's atmosphere.
    a. Describe why this is recognized as both a revolution and a catastrophe.
    b. Describe the evolutionary advantage that faculatative bacteria and human muscle cells have developed.

3. Cellular respiration is a metabolic process that occurs in all cells.
    a. Identify whether this process is catabolic or anabolic. Explain why.
    b. Compare and contrast aerobic and anaerobic cellular respiration. Provide at least 3 differences and 3 similarities.
    c. Is fermentation an aerobic or anaerobic process?
    d. Identify the two types of fermentation and the products of each.

4. Aerobic cellular respiration occurs when oxygen is present and has a higher yield of ATP.
    a. List the four stages of aerobic cellular respiration.
    b. Describe how the 6-carbon molecule of glucose is broken down in the first three stages of aerobic respiration.
    c. Identify the molecule that acts as the final electron acceptor in the electron transport chain. What product is formed through the electron transport chain?
    d. Describe how the electron transport chain powers the reaction that occurs in oxidative phosphorylation.

5. Redox reactions are used to store and release energy as needed to help drive cellular processes.
    a. Define oxidation and reduction.

    b. Write the reduced and oxidized form of two molecules used in aerobic respiration.
    c. Write the reduced and oxidized form of one molecule that is used in photosynthesis and not in respiration.

6. Global climate change is a "hot topic" among scientists and politicians.
    a. Describe the carbon cycle using the term "carbon fixing".
    b. Identify one green house gas and explain how it helps to maintain Earth's temperature.
    c. Identify the source of fossil fuels.
    d. Describe how the burning of fossil fuels is affecting Earth's average temperature.

7. Photosynthesis is a process that helps convert and provide the energy necessary for the survival of many food webs.
    a. Describe how solar energy is converted to chemical energy through the light reactions.
    b. How many turns of the Calvin Cycle are necessary to produce one glucose molecule?
    c. The Calvin Cycle is sometimes referred to as the "Dark reactions", is this accurate? Explain.
    d. Describe why the first stage of photosynthesis needs to occur in a membrane bound structure.

Respiration and Photosynthesis Answers

1. Sun
2. The breakdown of larger molecules into smaller molecules while releasing energy
3. Aerobic and Anaerobic
4. 3
5. 2
6. Released
7. Stored
8. The process of cellular respiration breaks down glucose which is a 6-carbon molecule and results in carbon dioxide, water, and ATP
9. Aerobic respiration requires oxygen; anaerobic respiration does not require oxygen.
10. They are used to store and release energy throughout the processes that drive cellular respiration
11. Add electrons to the molecule
12. Take electrons away from the molecule
13. Losing electrons is oxidation, gaining electrons is reduction
14. $NAD^+ + 2H^+ + 2e^- + \text{Energy} \rightarrow NADH + H^+$
15. $FADH_2 \rightarrow FAD + 2H^+ + 2e^- + \text{Energy}$
16. Aerobic and Anaerobic
17. 2NADH, 4ATP (2 ATP net), 2 Pyruvate
18. 2 ATP and 2 NAD^+
19. 2 ATP
20. 10
21. Fermentation
22. Lactic Acid or Ethanol and CO_2
23. Anaerobic
24. Glucose
25. 8; 4
26. 28; 28
27. They are broken down through fermentation
28. Broken down into NAD^+ and released energy
29. Alcohol & rising bread dough
30. Muscle soreness
31. Oxygen free
32. Aerobic respiration requires oxygen and produces 36-38 ATP per glucose , whereas anaerobic respiration does not require oxygen and produces only 2 ATP per glucose.
33. Glycolysis, pyruvate dehydrogenase complex, citric acid cycle, oxidative phosphorylation
34. Same as anaerobic respiration. Reactants: 1 glucose + 2 ATP + 2 NAD^+ Products: 2 pyruvate + 2NADH + 2 ATP net
35. Reactants: 2 pyruvate + 2 NAD^+ + $2O_2$ Products: 2NADH + 2 acetyl Co-A + $2CO_2$
36. In glycolysis the 6-carbon molecule of glucose is broken down into 2 3-carbon molecules of pyruvate, then in the pyruvate dehydrogenase complex each molecule of pyruvate is broken into a 2-carbon acetyl Co-A molecule. Then in the citric acid cycle, each 2-carbon acetyl Co-A molecule is made into 2 1-carbon CO_2 molecules.
37. ATP: 1, NADH: 3, $FADH_2$: 1, CO_2: 2
38. The oxygen revolution. Some organisms were able to evolve to perform aerobic cellular respiration, which requires oxygen.

39. $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_20 +$ ATP
40. It is converted to CO_2
41. Both have glycolysis as their first step, both yield ATP
42. After glycolysis they can either continue the processes of aerobic respiration or undergo fermentation depending on the availability of oxygen
43. Krebs's Cycle
44. 2
45. ATP: 2, NADH: 6, $FADH_2$: 2, CO_2: 4
46. ATP: 4, NADH: 10, $FADH_2$: 2
47. A potential gradient
48. Oxygen
49. 3 ATPs for each NADH and 2 ATPs for each $FADH_2$
50. Uses the current of protons to power the enzyme ATP synthase so ATP can be formed from ADP
51. The electrons are pumped in and out of the membrane while the protons attached to the electrons are carried to and left outside of the membrane creating a potential gradient
52. The formation of an electron potential across a membrane due to the movement of protons and electrons
53. The electric potential gradient created by the protons. As each proton travels down the gradient through ATP synthase, it turns the "motor" and provides the energy that allows a phosphate group to attach to ADP, therefore making ATP
54. 36-38 ATP
55. Electron Transport Chain and chemiosmosis
56. The negative electrons are attracted to the empty outer electron shell of oxygen
57. Proteins and Lipids
58. All the water at the top of the dam has potential energy that is transformed to kinetic energy as it flows down smaller pipes causing motors to spin and changing that kinetic energy into chemical energy. Each proton on the outside of the membrane has electrical potential energy that is changed to kinetic energy as it enters ATP synthase and causes the enzyme to shift which provides the energy necessary for ADP and phosphate to bond together to create ATP.
59. Proton Pump
60. ATP synthase is an enzyme that helps catalyze the reaction between ADP and phosphate to form ATP using the energy derived from protons passing through the enzyme into the cell
61. Water
62. Glycolysis is used by all cells and does not need or use oxygen. It was also occurring before the oxygen revolution.
63. $6CO_2 + 6H_20 + \text{Energy} \rightarrow C_6H_{12}O_6 + 6O_2$
64. Bacteria that are killed by oxygen
65. $NADP^+$
66. They are almost the exact reverse
67. The sun
68. About 2.5billion years ago, oxygen was added to the Earth's atmosphere and caused the extinction of many

anaerobic organisms that were poisoned by the oxygen.

69. Noncyclic energy transport creates ATP only and cyclic transport created ATP and glucose
70. Thylakoids
71. Chlorophyll
72. ATP and NADPH
73. Calvin Cycle
74. 1
75. 6
76. Carbon in gas form as CO_2 is turned into a solid form as glucose
77. Thylakoids are membrane bound organelles. The inside is the lumen and the outside is the stroma.
78. Chlorophyll
79. Red and Violet-Blue
80. The protons are pumped across the membrane out of the lumen and into the stroma.
81. The carbon is added to the sugar and the oxygen is released.
82. In photosynthesis the gas from of carbon as CO_2 is converted to a solid form in glucose. When respiration occurs the solid carbon in glucose is released as a gas in the form of CO_2 to then be used in photosynthesis again.
83. It helps maintain the temperature of Earth by absorbing infrared light that would otherwise carry heat away from the Earth
84. The burning of fossil fuels releases more CO_2 into the atmosphere to be used in photosynthesis and then respiration
85. The increase in greenhouse gases has resulted in more heat remaining trapped in our atmosphere causing Earth's average temperature to rise.

Free Response Answers

1.
   a. Respiration: $C_6H_{12}O_6 + CO_2 \rightarrow 6CO_2 + 6H_20 + ATP$
      Photosynthesis: $6CO_2 + 6H_20 + Energy \rightarrow C_6H_{12}O_6 + CO_2$
   b. Photosynthesis converts solar energy to chemical energy in the form of ATP and NADPH, which is then used to create glucose and carbon dioxide. As glucose is broken down through the catabolic process of respiration energy is released through the breakdown of glucose and used to create ATP. ATP is an energy-storing molecule that can be broken down to ADP to release energy to drive other cellular processes. Both photosynthesis and cellular respiration convert energy from one form to another, but neither creates nor destroys energy.
2.
   a. The addition of oxygen to the Earth's atmosphere is recognized as a revolution because it allowed for aerobic organisms to evolve and therefore more complex food webs to evolve. The addition of oxygen to the atmosphere is also referred to as an oxygen catastrophe because strict anaerobic organisms, such as obligate anaerobes, were poisoned by this addition of oxygen and died.
   b. Faculatative bacteria and human muscle cells are capable of both aerobic and anaerobic respiration. Which form of respiration these cells undergo is dependent on whether or not oxygen is available. These organisms are capable of producing ATP with or without oxygen it is just the number of ATP that vary depending on which type of respiration they undergo.
3.
   a. Cellular respiration is a catabolic process because it breaks down glucose into smaller molecules while releasing energy, the definition of catabolic.
   b. Aerobic and anaerobic respiration are alike in that they both produce ATP, both have glycolysis as the first step, and both use glucose as the starting molecule. They are different in that aerobic respiration produces more ATP than anaerobic respiration, requires oxygen and anaerobic respiration does not, and aerobic respiration uses both NADH and $FADH_2$ as energy storing molecules whereas anaerobic respiration only uses NADH.
   c. Anaerobic
   d. Lactic Acid Fermentation: Lactic Acid
      Ethanol Fermentation: Ethanol and CO_2
4.
   a. Glycolysis, Pyruvate Dehydrogenase Complex, Citric Acid Cycle, Oxidative Phosphorylation
   b. Through glycolysis the 6-carbon glucose is broken into 2 3-carbon pyruvate molecules. Through the pyruvate dehydrogenase complex

each pyruvate is broken into 2 2-carbon Acetyl CoA molecules. Through the citric acid cycle each carbon molecule is released as a 1-carbon carbon dioxide molecule.

c. Oxygen is the final electron acceptor in the Electron Transport chain and forms water.
d. As electrons are transported through the electron transport chain they move in and out of the membrane. As these electrons move from inside to outside the membrane they carry protons out with them, creating a proton gradient with more protons on the outside of the membrane than the inside. As these protons move back across the membrane down their gradient, they travel through ATP-synthase and provide the energy needed to phosphorylate ADP.

5.

a. Oxidation is the removal of electrons from a molecule and reduction is the addition of electrons to a molecule.
b. Reduced: NADH and $FADH_2$ Oxidized: NAD^+ and FAD
c. Reduced: NADPH Oxidized: $NADP^+$

6.

a. The carbon cycle is the constant changing of carbon from a gas to a solid and back to a gas depending on how it is being used. Through the process of cellular respiration carbon in a solid form as glucose is changed to a gas form as carbon dioxide. The carbon from carbon dioxide is then fixed into a solid form as it is changed back to glucose through photosynthesis.
b. Carbon dioxide is one green house gas. Carbon dioxide helps maintain the temperature of the Earth by trapping infrared light and stopping it from leaving the Earth's atmosphere and carrying heat with it.
c. Fossil fuels are created from the organisms that died during the carbon catastrophe.
d. The burning of fossil fuels is releasing a large amount of carbon dioxide that has not been in the carbon cycle, back into the cycle. This addition of carbon dioxide to the atmosphere is causing more heat to be trapped in the Earth's atmosphere and therefore raising the average temperature of the Earth.

7.

a. Solar energy is used to provide the energy to photosystem II to excite the electrons, which creates a proton gradient that then drives the phosphorylation of ADP creating the chemical energy of ATP. Solar energy is also absorbed by photosystem I and is converted to chemical energy in the form of NADPH.
b. Six turns
c. No, this is not accurate. A better term would be the light independent reactions because the Calvin Cycle can occur whether or not light is present, but it does not need light to proceed.
d. The first stage of photosynthesis needs a membrane across which to create a proton gradient that can provide the energy needed to

phosphorylate ATP, which is necessary for the Calvin Cycle. Without a membrane, there is no boundary across which the potential gradient can be formed and photosynthesis could not occur.