Name ________________________ Class __________________ Date ______

Cell Respiration

Introduction

Cellular respiration is the process by which the chemical energy of "food" molecules is released and partially captured in the form of ATP. Carbohydrates, fats, and proteins can all be used as fuels in cellular respiration, but glucose is most commonly used as an example to examine the reactions and pathways involved.

Since most textbooks provide abundant details of the chemical reactions in respiration, this tutorial will focus on how the chemical energy in glucose is converted into ATP and where respiration occurs in the cell.

1. Cellular respiration is the process by which the _________________________ of "food"

   molecules is released and partially captured in the form of _____________. (2 points)

2. Give an example of three things that can be used as fuels in cellular respiration (3 points).

3. What is the most common source of fuel for cellular respiration? (1 point)

We can divide cellular respiration into three metabolic processes: glycolysis, the Krebs cycle, and oxidative phosphorylation. Each of these occurs in a specific region of the cell.

1. Glycolysis occurs in the cytosol.
2. The Krebs cycle takes place in the matrix of the mitochondria.
3. Oxidative phosphorylation via the electon transport chain is carried out on the inner mitochondrial membrane.

In the absence of oxygen, respiration consists of two metabolic pathways: glycolysis and fermentation. Both of these occur in the cytosol.

4. What three metabolic processes can cellular respiration be divided into? (3 points)

5. Where does Glycolysis occur? (1 point)

6. What takes place in the matrix of the mitochondria? (1 point)

7. What is carried out in the inner mitochondrial membrane? (2 points)

8. In the absence of oxygen, respiration consists of two metabolic pathways:

   ____________________ and ______________________________. Both of these occur in the

   _____________________. (3 points)

In glycolysis, the 6-carbon sugar, glucose, is broken down into two molecules of a 3-carbon molecule called pyruvate. This change is accompanied by a net gain of 2 ATP molecules and 2 NADH molecules.

9. Describe what happens during glycolysis (6 points).

Concept 3: Krebs Cycle

The Krebs cycle occurs in the mitochondrial matrix and generates a pool of chemical energy (ATP, NADH, and $FADH_2$) from the oxidation of pyruvate, the end product of glycolysis.

Pyruvate is transported into the mitochondria and loses carbon dioxide to form acetyl-CoA, a 2-carbon molecule. When acetyl-CoA is oxidized to carbon dioxide in the Krebs cycle, chemical energy is released and captured in the form of NADH, $FADH_2$, and ATP.

10. In the Krebs cycle, pyruvate is transported into the mitochondria and loses carbon dioxide to form acetyl-CoA, a 2-carbon molecule. When acetyl-CoA is oxidized to ____________________________in the Krebs cycle, chemical energy is released and captured in the form of NADH, $FADH_2$, and ________________. (2 points)

Concept 4: Oxidative Phosphorylation via the Electron Transport Chain

The electron transport chain allows the release of the large amount of chemical energy stored in reduced NAD

$^+$ (NADH) and reduced FAD ($FADH_2$). The energy released is captured in the form of ATP (3 ATP per NADH and 2 ATP per $FADH_2$).

$$\mathbf{NADH + H^+ + 3\ ADP + 3\ Pi + 1/2\ O_2 \rightarrow NAD^+ + H_2O + 3\ ATP}$$

$$\mathbf{FADH_2 + 2\ ADP + 2\ Pi + 1/2\ O_2 \rightarrow FAD^+ + H_2O + 2\ ATP}$$

The electron transport chain (ETC) consists of a series of molecules, mostly proteins, embedded in the inner mitochondrial membrane.

11. The electron transport chain allows the release of the large amount of

_________________________ stored in reduced NAD^+ (NADH) and reduced FAD ($FADH_2$).

The energy released is captured in the form of ___________. (2 points)

Concept 5: Fermentation

All cells are able to synthesize ATP via the process of glycolysis. In many cells, if oxygen is not present, pyruvate is metabolized in a process called fermentation.

Fermentation complements glycolysis and makes it possible for ATP to be continually produced in the absence of oxygen. By oxidizing the NADH produced in glycolysis, fermentation regenerates NAD^+, which can take part in glycolysis once again to produce more ATP.

12. Fermentation complements ________________ and makes it possible for ATP to be

continually produced in the absence of ____________________. (2 points)

Concept 6: Glucose and Energy

The chemical energy stored in glucose generates far more ATP in aerobic respiration than in respiration without oxygen (glycolysis and fermentation).

Each molecule of glucose can generate 36-38 molecules of ATP in aerobic respiration but only 2 ATP molecules in respiration without oxygen (through glycolysis and fermentation).

13. During aerobic respiration, each molecule of glucose can generate how many molecules of ATP? (1 point)

14. During anaerobic respiration, each molecule of glucose can generate how many ATP

molecules? (1 point)

Self-Quiz

1. In aerobic respiration carbohydrates are ultimately broken down into:
   a. acetyl-CoA
   b. CO_2
   c. O_2
   d. H_2O
   e. heat

2. Most ATP in eukaryotic cells is produced in the:
   a. mitochondria
   b. nucleus
   c. cytoplasm
   d. rough endoplasmic reticulum
   e. peroxisome

3. Most ATP produced in aerobic respiration occurs in the process of:
   a. glycolysis
   b. the formation of acetyl-CoA
   c. the Krebs cycle
   d. chemiosmosis

e. substrate-level phosphorylation

4. In aerobic respiration, the energy in 1 mole of glucose is capable of producing how many ATP molecules:

a. 2 molecules of ATP

b. 38 molecules of ATP

c. $2 \times (6.02 \times 10^{23})$ molecules of ATP

d. $38 \times (6.02 \times 10^{23})$ molecules of ATP

5. Products of glycolysis include:

a. pyruvate

b. ATP

c. NADH

d. two of the above

e. all of the above

6. In glycolysis the most reduced compound formed is:

a. pyruvate

b. NAD^+

c. lactate

d. O_2

e. H_2O

7. In glycolysis, the activation of glucose is accomplished by:

a. NADH

b. coenzyme A

c. ATP

d. CO

2

e. O_2

8. Products of the Krebs cycle include:

a. carbon dioxide

b. NADH

c. $FADH_2$

d. two of the above

e. all of the above

9. The final electron acceptor in aerobic respiration is:

a. pyruvate

b. carbon dioxide

c. oxygen

d. water

e. NAD^+

10. In the presence of oxygen, all cells synthesize ATP via the process of glycolysis. Many cells also can metabolize pyruvate if oxygen is not present, via the process of:

a. fermentation

b. aerobic respiration

c. oxidative phosphorylation

d. electron transport

e. photophosphorylation

11. The net result of the breakdown of glucose in glycolysis and fermentation is the production of:

a. 38 ATP

b. 36 ATP

c. 2 ATP

d. NADH

e. NADH, $FADH_2$, and ATP

12. Which stage of aerobic respiration requires ATP?

a. glycolysis

b. Krebs cycle

c. electron transport chain

d. fermentation

e. none of the above

13. Which stage of aerobic respiration requires CO_2?

a. glycolysis

b. Krebs cycle

c. electron transport chain

d. fermentation

e. none of the above

14. Which stage of aerobic respiration produces ATP and NADH and releases CO_2?

a. glycolysis

b. Krebs cycle

c. electron transport chain

d. fermentation

e. none of the above

15. The high concentration of protons in the inner mitochondrial space relative to the

mitochondrial matrix represents:

a. magnetic energy

b. kinetic energy

c. potential energy

d. photonic energy

e. none of the above

16. As protons flow through the _______ , energy is released and exploited to combine ADP and inorganic phosphate to form ATP.

a. electron transport chain

b. outer mitochondrial membrane

c. cytochrome oxidase

d. ATP synthase

e. NADH