Cellular Respiration

I. The Importance of Food

A. Food provides living things with the:

B. Food serves as a source of:

C. Food serves as a source of:

II. Chemical Energy and ATP

A. Inside living cells, energy can be stored in chemical compounds.

B. One of the principal chemical compounds that cells use to store and release energy is:

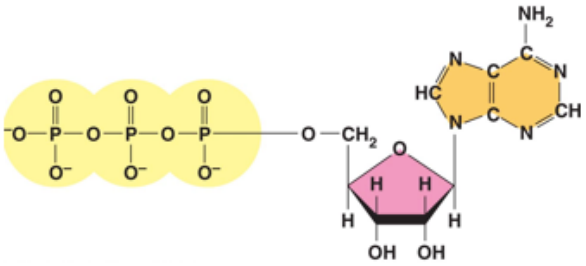
1)

2)

3)

4)

C. Structure of ATP



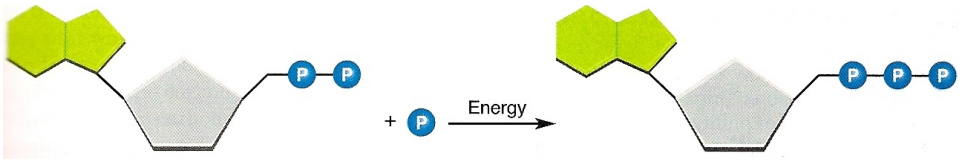
Consists of:

1)

2)

3)

D. How ADP becomes ATP:



1. ADP is a compound that looks almost like ATP. The difference is that:

2. When a cell has energy available, it can store small amounts of it by:

3. Adding a phosphate to _____ forms a molecule of _____. The addition of the third phosphate _____.

4. When a cell needs energy, the third phosphate will be _____. This releases _____.

5. ATP has enough stored energy to power a variety of cellular activities such as:
   a) c)

   b) d)

6. The ATP molecule is the _____of all living cells.

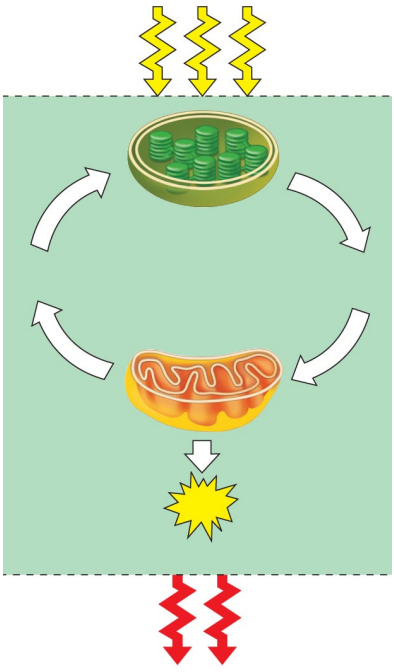
7. In a cell, ATP is used continuously and must be regenerated continuously. In a working muscle cell, 10 million ATP are consumed and regenerated per sec.

III. The Relationship Between Photosynthesis and Respiration

A. Energy flows into an ecosystem as _____ and leaves as _____. Energy is not _____. Energy follows a one-way path through our ecosystem.

B. However, the _____ essential to life are recycled.

C. Photosynthesis converts _____ energy from the sun into _____ energy, which is stored in carbohydrates and other organic compounds.



D. Photosynthesis generates the _____ and _____ used by the mitochondria of eukaryotes as fuel for _____.

E. Cellular respiration breaks down _____ into simpler substances and releases the stored _____.

F. Some of this energy is used to make _____ from ADP. Some of this energy is lost as _____.

G. The waste products of respiration, _____, are the raw materials for _____.

H. IMPORTANT NOTE: While only green plants carry out _____, ALL living things carry out _____.

IV. Overview of Respiration

A. The Definition of Respiration

1. Cellular respiration is the process that:

2. It is the process of converting:

B. Equation for Respiration

C. There is much _____ stored in this molecule of _____. This energy must be released in _____ steps. If all the energy from glucose were released at once, most of it would be lost as _____. The energy stored in glucose will be released bit by bit and this energy will be used to produce _____. The energy cannot be released from the glucose all at once. It would be the equivalent of the gas tank in your car exploding in one single reaction, rather than in the small controlled combustions that drive your car.

D. There are two types of respiration:

1.

2.

E. Respiration takes place in three main stages

1.

2.

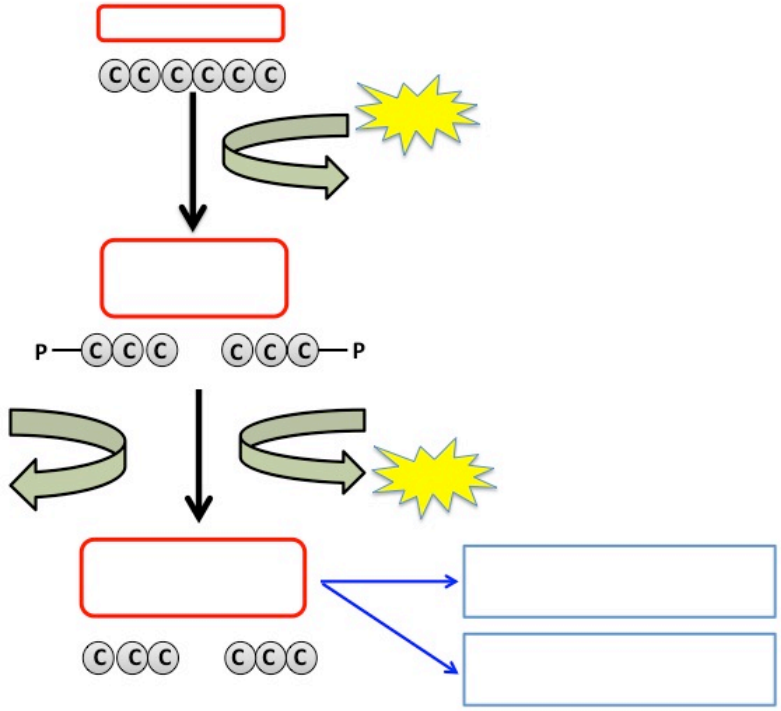
3.

F. Glycolysis occurs in the _____ , but the Krebs cycle, and electron transport chain occurs in the _____.

V. Glycolysis

A. Definition:

B. Steps in Glycolysis



1. The energy of _____ is used to convert _____ into two molecules of _____.

2. The two molecules of _____ will be _____ to produce two molecules of _____. Pyruvic acid is a _____ compound.

3. As the PGAL is oxidized, two molecules of _____ will be _____ to form two molecules of _____. These will be used in the _____.

4. The oxidation of PGAL also results in the production of _____.

5. The pyruvic acid may:
   a)

   b)

   c) We will discuss this further in the next section.

C. ATP Production:
   1. Even though cellular respiration is an energy _____ process, the cell must _____ a small amount of energy to get the reaction going.

   2. _____ are consumed at the beginning, but _____ molecules of ATP are produced by the end of glycolysis.

   3. Glycolysis has a gain of _____.

D. NADH Production:
   1. During this reaction, _____ are removed from each _____ . These electrons are passed to the electron acceptor _____.

   2. NAD^+ in respiration is similar to $NADP^+$ in photosynthesis.

   3. Each NAD^+ accepts a pair of electrons to form _____.

   4. This NADH _____ until they can be transferred to other molecules.

   5. NAD^+ helps to pass the energy from glucose to other pathways in the cells.

E. Advantages and Disadvantages of Glycolysis
   1. Glycolysis only produces a gain of _____ per molecule of _____, but the process is so fast that 1000's of ATP are produced in just a few milliseconds.

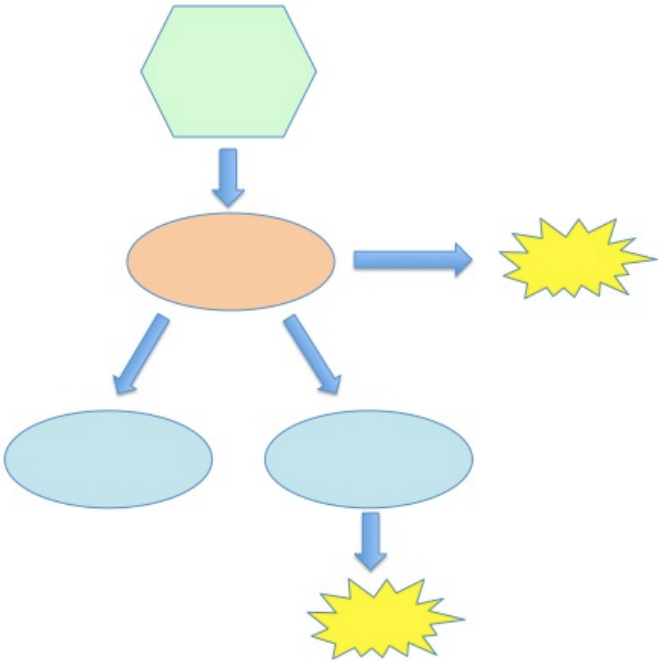
   2. Another advantage is that glycolysis does not require _____. Energy can be produced for the cell even if no oxygen is present.

   3. Disadvantage: If the cell relied only on glycolysis for ATP production, the cell would quickly run out of _____ to accept the _____. Without NAD^+, the cell cannot keep glycolysis going and _____ would stop. To keep glycolysis going, the NADH must deliver their high-energy cargo of electrons to another pathway, and then return to glycolysis to be used again.

VI. The Fate of Pyruvic Acid – What happens to it?

A. There are _____ possibilities for the path that _____ will now take. It depends on whether or not _____ is present.

B. If oxygen is present:
   1. In the presence of oxygen, the pyruvic acid will enter the _____ and undergo _____ respiration.
   2. Aerobic respiration includes the stages known as the _____ and the _____.
   3. Aerobic respiration will yield many more _____ than _____.



C. If no oxygen is available:
   1. In the absence of oxygen, the pyruvic acid will enter the _____ pathways of _____.
   2. Fermentation yields no additional _____.
   3. This occurs in the _____.

VII. Overview of Aerobic Respiration

A. Aerobic respiration has two major stages:

B. Krebs cycle:
   1.
   2. The _____ that is removed from pyruvic acid will be accepted by _____ to form _____.
   3. There will be:

C. The Electron Transport Chain
   1. The _____ that has been produced during _____ and the _____ will be used to produce _____.
   2. Most of the ATP produced during aerobic respiration is produced by:

D. In prokaryotic cells, the Krebs cycle and the electron transport chain occur in the _____ and along special structures of the _____.

In eukaryotic cells, these reactions occur inside the _____. If oxygen is available, the pyruvic acid that was produced during glycolysis will enter the mitochondria for aerobic respiration.

E. Structure of the Mitochondria

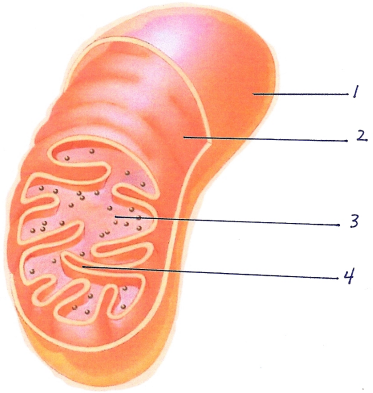
It is surrounded by a double membrane.

1.

2.

3.

4.



F. The _____ is the space inside the inner membrane. It contains:

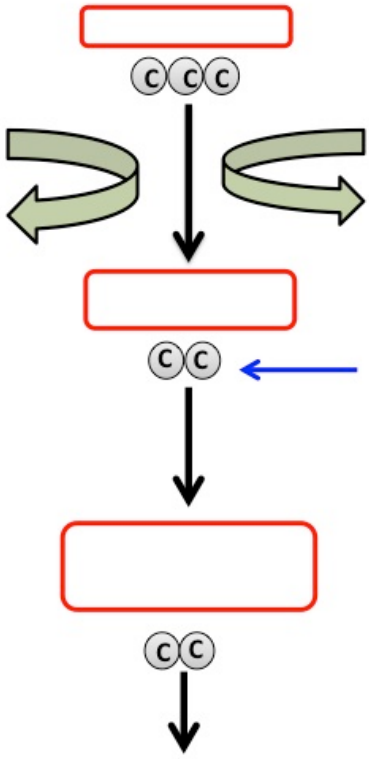
G. The inner membrane has folds and loops called _____.

The cristae:

H. The Krebs cycle occurs in the _____ and the electron transport chain occurs along the _____.

I. At the end of glycolysis, about 90% of the chemical energy that was available in the _____ molecule is still unused. This energy is locked in:

J. As the pyruvic acid enters the mitochondria, the following reaction occurs:



1. Pyruvic acid enters the mitochondria.

2. The 3-C _____ is converted to 2-C _____. This is accomplished by removing a molecule of _____ from each molecule of pyruvic acid. The carbon dioxide is _____.

3. For each pyruvic acid that is converted to _____, one molecule of _____ is converted to _____.

4. _____ attaches to the acetate to form _____. The acetyl-CoA will be used in the _____-.

5. This reaction is often referred to as "_____".
   It is the bridge between
   a)

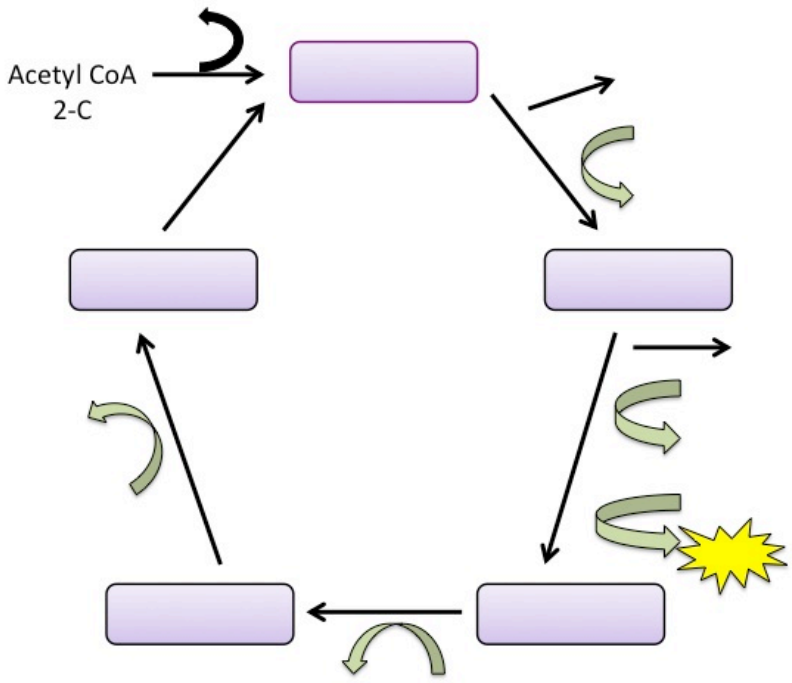
   b)

   c)

VIII. The Krebs Cycle

A. The Krebs cycle is a biochemical pathway that uses the _____ molecules from the _____ to produce _____.

B. This set of reactions occurs in the _____ of the _____.



C. The Steps of the Krebs cycle:

1. _____ attaches the 2-C _____ to the 4-C _____ to produce the 6-C compound called _____. The CoA is _____ to be used again.

2. The 6-C _____ releases a molecule of _____ to form a 5-C compound. As citric acid is oxidized, the _____ is transferred to _____ to form _____.

3. The 5-C compound releases _____ and a _____ atom forming a 4-C compound. _____ is reduced to form _____ and one molecule of _____ is produced.

4. This 4-C compound releases a _____ to form another 4-C compound. This time, the hydrogen is used to reduce _____ to _____.

5. In the last step, the 4-C _____ is regenerated which keeps the _____ going. The hydrogen that is released is used to form a final _____.

D. Summary of the Krebs cycle

1. _____ are electron carriers very similar to the $NADP^+$ that was used in photosynthesis. NAD^+ and FAD will deliver the _____ of hydrogen to the _____.

2. What is the total amount of CO_2, ATP, NADH, and $FADH_2$ that is produced during one turn of the Krebs cycle?
   a)

   b)

   c)

   d)

   The above totals are for _____.

3. Now remember that during glycolysis, _____ was broken down into two molecules of _____. Therefore, one glucose molecule causes _____ turns of the _____. What is the total amount of CO_2, ATP, NADH, and $FADH_2$ that is produced per molecule of glucose in the Krebs cycle?
   a)

   b)

   c)

   d)

4. What happens to each of these products?
   a)

   b)

   c)

5. Most of the energy contained in the original _____ molecule still has not been transferred to _____. This transfer of energy will occur in the next step, the _____.

IX. The Electron Transport Chain

A. The electron transport chain consists of a series of _____ that are embedded in the _____ of the mitochondria in eukaryotic cells. In prokaryotic cells, the electron transport chain lies along the _____.

B. In this last stage of aerobic respiration, NADH and $FADH_2$ will:

C. Electron Transport

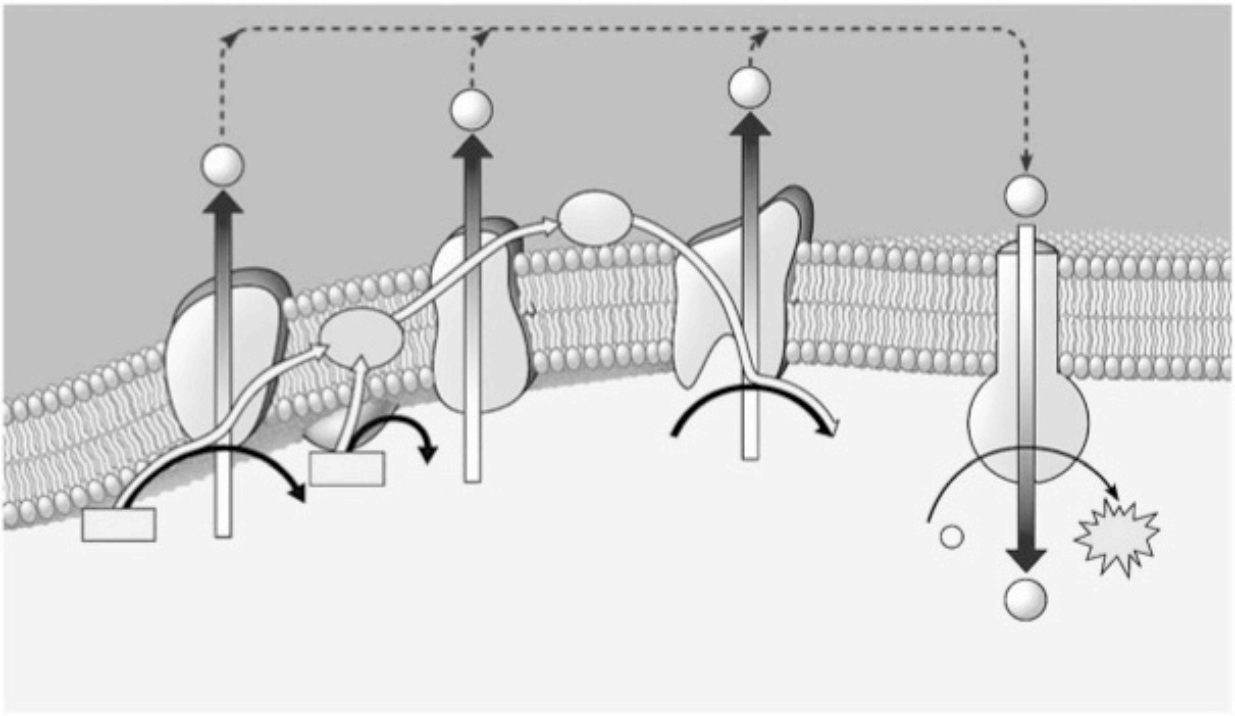
1. What is the total number of NADH and $FADH_2$ that has been produced so far?
   a)

   b)

   c) The purpose of NADH and $FADH_2$ is to:

   d) The electron transport chain uses these high-energy electrons to convert _____

D. Steps of the Electron Transport Chain



1. The high-energy electrons from _____ are passed along the electron transport chain, from one protein to the next.

2. At the end of the electron transport chain, the _____ will be combined with _____ to form _____.

3. Oxygen is the final _____. Oxygen is essential for getting rid of _____.

4. As these electrons move down the electron transport chain, they release _____. This energy is used to pump _____ across the membrane from the _____ to the _____. The hydrogen protons are pumped _____ the concentration gradient from an area of _____ concentration in the matrix to an area of _____ concentration in the inner membrane space.

5. A concentration _____ has now been established. There is a high concentration of hydrogen in the _____ and a low concentration in the _____.

6. Also embedded in the mitochondrial membranes are enzymes called _____. Hydrogen ions flow through _____ back to the _____, the area of _____ concentration.

7. As the hydrogen flows through ATP synthase, it _____. Each time it rotates, a _____ is attached to _____ to form _____.

8. Recap of Electron Transport:
   a) This system couples the movement of _____ with the production of _____.

   b) As the high-energy electrons move down the electron transport chain, they release _____.

   c) This energy is used to move _____ across the membrane.

   d) These ions then rush back across the membrane, producing:

X. ATP Accounting

A. Let's summarize what has happened prior to the electron transport chain:

   1. Glycolysis →

   2. Bridge reaction →

   3. Krebs cycle →

B. Each NADH has enough energy to produce _____. Each $FADH_2$ has enough energy to produce _____.

C. 10 NADH =

   2 $FADH_2$ =

D. Glycolysis →

   Krebs cycle →

   Electron Transport Chain →

E. One molecule of glucose has produced _____.

F. Only about 40% of the energy contained in the glucose molecule has been converted to _____. The remaining 60% is given off as _____.

XI. Fermentation

A. Fermentation occurs when _____.

B. Since no oxygen is required, fermentation is an _____ process.

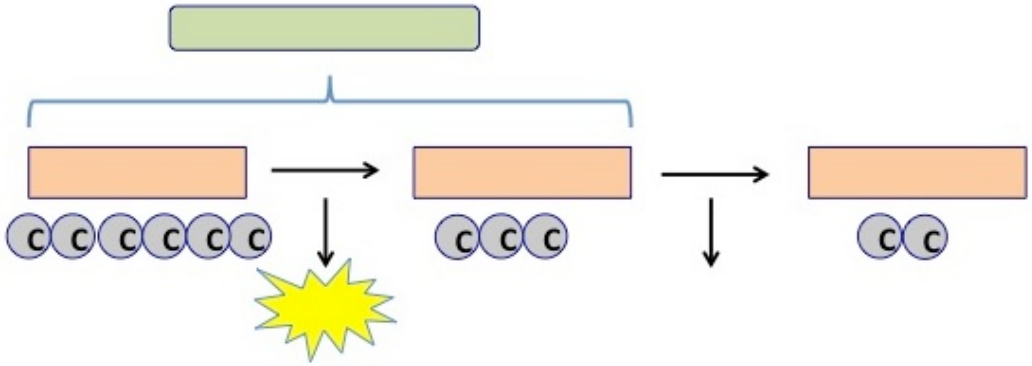
C. The anaerobic pathways are not very efficient in transferring energy from _____ to _____. Fermentation will yield only a gain of _____ per molecule of _____.

D. There are two main types of fermentation:
   1.

   2.

E. Alcoholic Fermentation
   1. _____ perform alcoholic fermentation. Yeasts convert _____ into _____ when they run out of _____. Yeasts are used to make breads and alcohol.

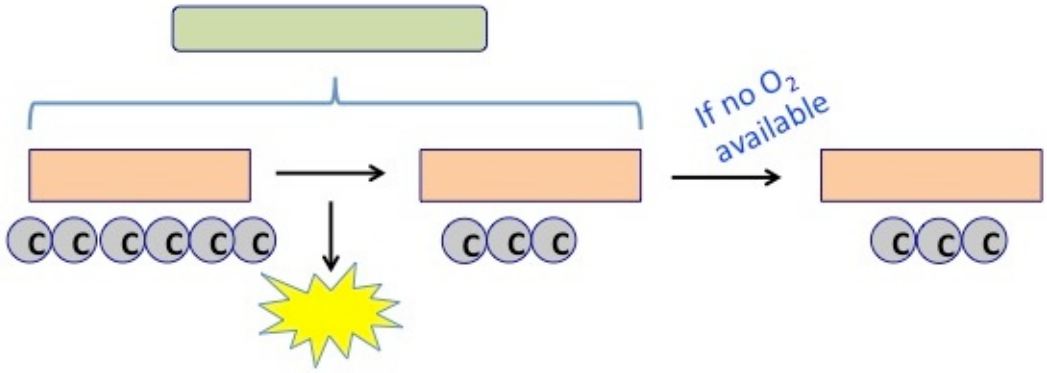
   2.



   3. Yeasts are used in this way in both the _____ and the _____ industries. The alcohol makes alcoholic beverages. The _____ that is given off causes bread dough to _____. Small bubbles are formed in the dough, making the bread rise. (The alcohol evaporates during the baking process.)

F. Lactic Acid Fermentation

1.



2. _____ is converted to _____ by _____ cells when there is a shortage of _____.

3. It is produced in muscle cells during strenuous exercise because the muscles are using up the _____ that is present and the body is not supplying the muscle tissue with enough additional oxygen.

4. This causes _____ because it lowers the _____ of the muscle and reduces the muscle's ability to _____.

5. When oxygen _____ to the muscles, the _____ will be converted back to _____. The pyruvic acid will then go into _____ respiration.

6. A wide variety of foods are produced by bacteria using lactic acid fermentation:

G. Evolution of Anaerobic Pathways

1. The _____ pathways probably evolved very early in the history of life on Earth.

2. The first organisms were _____ and they produced all of their _____ through _____.

3. It took over a _____ years for the first _____ organisms to appear on Earth.

4. These photosynthetic organisms began to fill the atmosphere with _____, which stimulated the evolution of organisms that use _____ respiration.

5. The anaerobic pathways provide enough energy for only _____.

6. Larger organisms have much greater _____that cannot be satisfied by _____ respiration alone. Larger organisms rely on the more energy efficient pathways of _____ respiration.

XII. Comparing Photosynthesis to Respiration

	Photosynthesis	Respiration
Function		
Location		
Reactants		
Products		
Equation		