BIOLOGY NOTES

October 2, 2006

Topic: Respiration

Objectives:

At the end of this topic, the students should be able to:

1. Define the term respiration.
2. Name and define the two types of respiration.
3. Give the equations in words and symbols for aerobic and anaerobic respiration.
4. Identify ATP as the energy currency of all living things.
5. State the importance of ADP and ATP.
6. List advantages to living things of using ATP as their energy currency.
7. Name processes in the body of living things that requires energy.
8. Describe applications of anaerobic respiration - brewing and lactic acid production in muscles.

What is respiration?

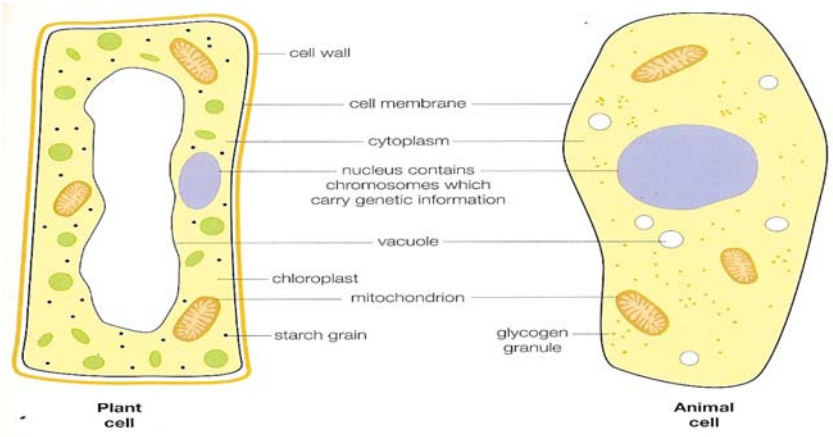
Many students, even at the senior school level, believe that respiration is the same as breathing! This is way far from the truth. Respiration is the **process by which the energy in food is made available for a cell to do the work necessary to keep it alive**. Simply put, respiration is the release of energy from food.

Types of respiration

Respiration can occur with or without oxygen. When oxygen is used in the reaction to release energy from food, it is called **AEROBIC** respiration. The process is catalyzed by enzymes and is also called ***cellular***, ***internal*** or ***tissue respiration***. When the reaction occurs in the absence of oxygen it is called **ANAEROBIC** respiration. Both aerobic and anaerobic respirations involve the breakdown of glucose, however in anaerobic respiration glucose is not completely broken down.

Aerobic respiration

Aerobic respiration takes place in an organelle in the cell called the **mitochondria,** sometimes referred to as the "powerhouse of the cell". Note the structure of the mitochondria in the cells below.



Respiration is a complex chemical process which can be summarized by a chemical equation. In both plants and animals the type of food used for making energy is usually glucose.

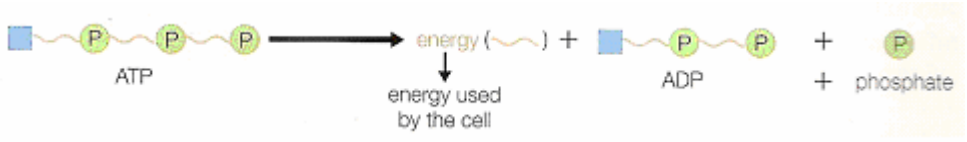
Equation

- ***in words***: glucose + oxygen → carbon dioxide + water + energy

- ***in symbols***: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + energy (2880 kJ)

<u>Adenosine diphosphate (ADP) and Adenosine triphosphate (ATP)</u>

The breakdown of glucose during respiration occurs in a series of steps. At each step in the process energy is released. **The released energy is used to convert a chemical molecule called ADP to ATP**. Each molecule of ATP acts as a little 'packet' of energy which can be stored and used later when needed. **To use the energy stored in ATP, the ATP molecule must be broken down again to ADP.**



Advantages of ATP

The advantages of storing and using energy in small packets like ATP are as follows:

1. The energy can be released from ATP wherever and whenever it is required by a cell.
2. The energy can be released rapidly.
3. Energy is not wasted. A large amount of energy is released by oxidizing one molecule of glucose resulting in the formation of many ATP molecules. A cell may not require very much energy at once. By storing the energy in small packets of ATP molecules, the cell can use small amounts of energy as required.
4. The energy can be used to drive many different chemical reactions rapidly.
5. Energy can be stored as ATP in one part of a cell and transported and used elsewhere without causing reactions in between.

<u>Uses of energy in the body of humans</u> (Refer to p. 167 of text book – Biology for Life)

- for movement (muscle contraction)
- for sending messages through nerves (transmission of nerve impulses)
- for transporting materials inside the body
- for keeping the body warm
- for growth
- for cell division
-for active transport
- for keeping us alive

<u>Anaerobic respiration</u>

Animal and plant cells can respire anaerobically but do so in different ways. Habitats such as stagnant ponds and deep underground have no oxygen. Organisms e.g bacteria

living there have adapted to survive to live without oxygen by respiring anaerobically. Living cells that respire aerobically can also respire anaerobically if oxygen is lacking. Animal and plant cells do this in different ways.

The chemical processes which occur in anaerobic respiration can be summarized by chemical equations as follows:

In animal cells:

Words: Glucose → lactic acid + energy

Symbols: $C_6H_{12}O_6 \rightarrow 2C_3H_6O_3$ + energy (150 kJ)

In plant cells:

Words: Glucose → ethanol + carbon dioxide + energy

Symbols: $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ + energy (210 kJ)

Summary of the differences between aerobic and anaerobic respiration

Aerobic respiration	Anaerobic respiration
uses oxygen	does not use oxygen
• in plants and animals: $C_6H_{12}0_6 + 60_2 \sim$ energy + $6H_20$ + $6C0_2$ water and carbon dioxide are waste (by) products	• in animal cells: $C_6H_{12}0_6 \sim$ energy + $2C_3H_60_3$ lactic acid is the waste (by) product • in plant cells: $C_6H_{12}0_6 \sim$ energy + $2C_2H_sOH$ + $2C0_2$ ethanol and carbon dioxide are waste (by) products
large amounts of energy produced (2880 kJ) for the breakdown of each molecule of glucose	_ small amounts of energy are produced (150 kJ per glucose molecule in animals and 210 kJ **in** plants)
glucose is broken down completely to inorganic molecules	glucose is not broken down completely - ethanol and lactic acid are organic molecules that still contain useful energy
occurs in the mitochondria of the cell	occurs in the cytoplasm of the cell

Anaerobic respiration in plants - the brewing process

The brewing process is used for making alcoholic beverages such as beer and wine. This process is also called **fermentation.** Beer is made from barley wheat. The grain, which contains malt sugar (maltose), is mashed with water and the resulting liquid is given the right flavor by boiling with hops.

Note: Maltose is a disaccharide made up of two monosaccharide units of glucose.

Yeast (a fungus) is then added and fermentation commences. The sugar is gradually converted by an enzyme in yeast into alcohol. All of these reactions take place in the absence of oxygen.

Anaerobic respiration in humans – lactic acid production in muscles

Human cells respire normally aerobically. However, during strenuous exercise, muscle cells need more energy for the extra work that they are doing. The breathing rate and then heart rate increase in an attempt to get more oxygen to the muscle cells. However, after a while of sustained exercising, the oxygen supply becomes inadequate. This is because the demand for oxygen now far exceeds what the lungs can supply. At this point, the muscle cells begin to respire anaerobically and produce **lactic acid** along with small amounts of energy. The small amount of energy produced allows the muscles to still continue to do work (contract and relax).

Lactic acid is a waste product of this reaction. It builds up in the muscles and cause them to ache. This is often called **fatigue**. Sometimes a sticky pain, commonly called 'stitches' develops toward the sides of the abdomen due to the lactic acid accumulation.

After exercise, the body has to get rid of the lactic acid as quickly as possible. This is done by using oxygen to change it back to a chemical like glucose so that it can be broken down completely in aerobic respiration.

This is why a person will continue to 'breathe hard' or pant for some time after exercise as oxygen is needed to get rid of the lactic acid. The oxygen required to get rid of the lactic acid is called the **oxygen debt**.

Assignment questions

1. The equations P and Q show two chemical reactions.

P

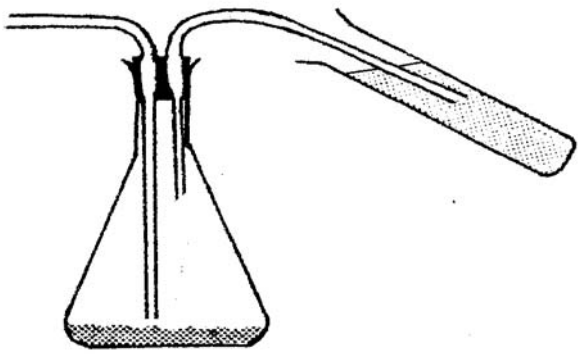
$$6O_2 + C_6H_{12}O_6 \longrightarrow 6CO_2 + 6H_2O + 2880\ kJ\ energy$$

Q

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2 + 210\ kJ\ energy$$

(a) (i) Name the chemical reactions shown in equations P and Q. (2)
(ii) Name ONE organism whicxh carries out the reactionb Q. (1)
(iii) Explain the commercial importance of reaction Q. (1)
(b) (i) What are TWO advantages of adenosine triphosphate (ATP) molecule to a living organism? (2)
(ii) What is the energy relationship between ATP and ADP? (2)
(c) What are TWO uses of energy in the body of a human? (2)

2. Yeast cells respire aerobically when surrounded with oxygen. However, they respire anaerobically when little or no oxygen is available. The diagram represents an experiment to show that yeasts respire.



Aerobic respiration may be summarized by the equation:

food + oxygen → carbon dioxide + water + energy

(a) (i) Name the by-products shown in the equation. (2)

(ii) Name the factors that are necessary for yeast to respire aerobically. (2)

(iii) Which liquid would be used in the test tube to show that carbon dioxide is produced. State what effect the carbon dioxide would have on this liquid. (2)

(b) (i) Explain what must be done to the apparatus in the diagram in order to produce anaerobic conditions inside the flask? (1)

(ii) Which "food" substance is used to produce alcohol for the Bahamian beer Kalik? (1)

(c) State an advantage of aerobic respiration over anaerobic respiration. (1)

(d) Write the word equation that summarizes anaerobic respiration in yeast. (1)