Biology: As Scientific Inquiry

UNIT II: CELLS & CELL PROCESSES

FIFTH EDITION

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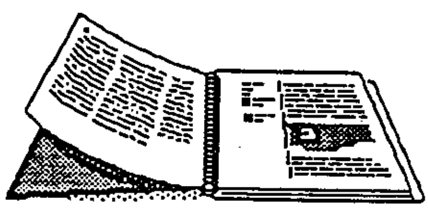

Biology: As Scientific Inquiry

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Unit II

Cells and Cell Processes

Unit Introduction

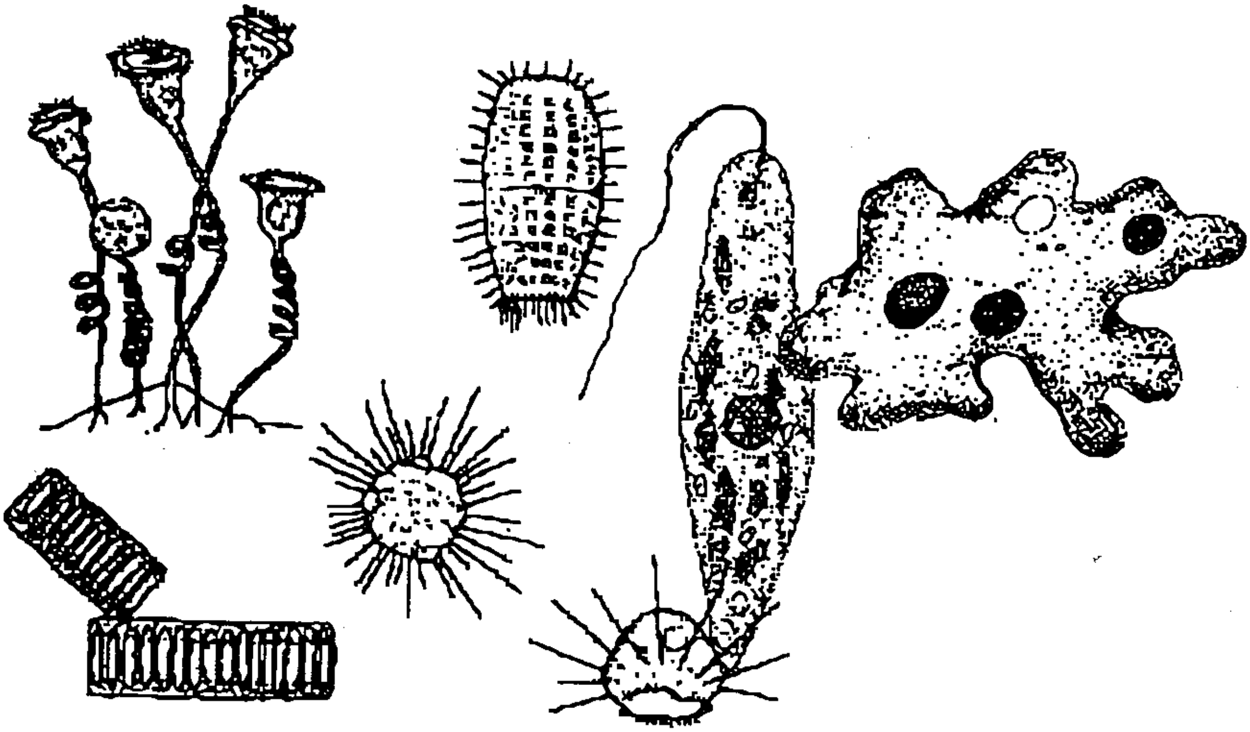
All critical processes, which take place in living organisms, take place in cells. It's essential to understand how the cell functions if we are to understand how living things perform life's activities.

Most cells are so small that they can be seen only with the aid of a microscope. Within these tiny living factories, various cell parts are absorbing or releasing energy, forming vital needed molecules, and controlling the cell's reproduction. In the human body, cells are responsible for sight, hearing, smell, memory, pain and pleasure. Most of the chemical activities that we call life, occurs within the cell's liquid interior: the cytoplasm.

In your study of cells you will learn the basic structure and function of plant and animal cell parts. You will also learn basic principles of chemistry needed to help you comprehend how the cell accomplishes so many of its astonishing processes.

CHAPTER 4

CELLS



Chapter 4

Cells

He who can no longer pause to wonder
and stand rapt in awe is as good as dead;
his eyes are closed.
Albert Einstein

4-1 Laboratory Investigation

Investigating Cell Variety

Objective

On a quiz that follows, you should be able to:
1. Identify and label cell parts in diagrams of plant and animal cells.
2. List each cell part's function.
3. Describe characteristics that distinguish plant cells from animal cells.

Introduction:

The **cell theory** states that the cell is the basic structural, functional, and developmental unit of life. If this theory is correct, then all living things should be made up of cells. It should also be true that the cells of different organisms should have some basic similarities, and at the same time, we should expect certain basic differences because of the obvious differences in cell function and type.

In this exercise you are to use the compound microscope to examine the cellular makeup of different organisms- both plant and animal. You are to look for and record the obvious similarities and differences between the cells, and make simple sketches or diagrams of each observation. Another aspect of this lab is to examine some of the cellular parts found in certain kinds of cells.

PLANT CELLS: Work independently with your own slide. You are, however, encouraged to discuss and compare what you see with your lab partner.

Elodea:

This green water plant will be found in a culture dish in your tray. It must remain in water at all times except when you are removing a leaf. Examine it. [___] Make a wet mount of a single leaf as follows:

Put 1 or 2 drops of water on your slide first so that the leaf doesn't have a chance to dry out. [___]

Pick one green healthy-looking leaf from the tip of a sprig of *Elodea* and place it top-side up in the water on the slide. The top-side of the leaf faces the small growing tip of the stem. See the diagram below. [___]

Add a cover slip as usual. [___] Scan the cells in the leaf on 4X, then 10X [___] Focus clearly on 10X and then switch to 40X. [___] If you carefully focus, up and down, you will notice that this leaf is made of two layers of cells. [___] If you do not focus clearly on just the one layer of larger cells, you will see parts of both layers and this will confuse you. [___] Focus on the layer of large cells. [___] You should be able to find and identify the following structures:

Cell Wall
The thick outer covering of each cell [___]

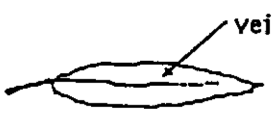
Chloroplasts
Chloroplasts are the oval green bodies seen throughout the cell. **They capture light energy for use in making sugar in photosynthesis.**

Cytoplasm The clear appearing, water substance in which the chloroplasts are floating [___]

Cell Membrane
This membrane will be pressed against the inside of the cell wall and will not be visible. Realize where it would be found, however.

Vacuole
The vacuole is a large, clear, water-filled sac in the center of the cytoplasm of the cell. It fills much of the cell and is visible only when you focus up and down to find a focus level where the chloroplasts appear around the edge of the cell only. It appears this way because a water-filled vacuole is surrounded by the chloroplasts. With this in mind, try to find the vacuole. [___] If you can't see it, go on. [___]

Examine some cells near the vein of the leaf on 10x then 40x. In this area, one can usually observe the chloroplasts moving in most instances: [___] Begin your report for this lab by answering the numbered questions that follow on your own paper. [___]



1. Describe the movement of chloroplasts - If you saw them move. (If you did not see them move, so indicate.)

2. Draw 2 Elodea cells so that each cell is at least two inches long. In one cell, label all the parts that you found. [__]
3. Your drawing should now have only those parts labeled that you were able to find. Which cell parts were you not able to find? [__]

Use the green pencil in your tray to color the appropriately colored structures.

4. Chloroplasts cannot cause their own movement. They cannot swim or propel themselves in any way. Offer a hypothesis that would explain what causes them to move within the cytoplasm of the Elodea cell.
   Leave this slide for clean-up time at the end of the period. [__]

<u>ONION SKIN CELLS:</u>

You will find sections of onion, in water, in your tray. [__] Remove one single scale of onion and return the remaining onion to the water. [__] Hold this onion scale so that the concave surface is toward you. Tear the scale in half and a transparent, paper thin layer of epidermis should become visible. [__] Place two drops of water on your slide, then remove the onion epidermis by pulling it off the concave side of the onion scale like peeling dead skin after a sunburn. <u>THROW THE REMAINING SCALE IN THE GARBAGE AND DO NOT RETURN IT TO THE BOWL WITH THE OTHER ONION SCALES</u>. With a razor blade or scissors, cut the onion epidermis so that it is smaller than a cover slip. Be careful not to let it dry out. Prepare a wet mount as before and examine the slide on 4X, then 10X. [__]

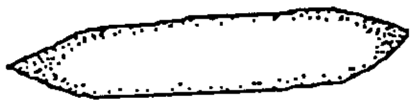
5. Make a list of the cell parts that you find on 10X. [__]

Some cell parts show up better when the cell is stained with a biological stain. To stain your onion cells, proceed as follows:

a) Remove your slide from the microscope stage. [__]
b) Gently lift the cover slip off and add one drop of either iodine or methylene blue stain. [__]
c) Replace the cover slip and return the slide to the microscope. [__]

In the onion cells, you should be able to see nuclei. They should appear as round dark-stained objects, either in the middle of the cell or at the edge of the cell. The **nucleus** is the control center for the cell. It contains chromosomes, upon which genes are located. The **nucleus** <u>controls all activities of the cell</u>. Examine and scan many cells on 4X and 10X to find what seems to be a typical cell. [__]

Examine 2-3 typical cells on 40X and locate each of the following:



Cell wall [__] Nucleus [__] The cytoplasm will appear like the dots in the diagram at the right. Note its granular nature. [__]

Vacuole - This area will be seen only indirectly as an absence of the "granular" cytoplasm in a large portion of the center of the cell. (See drawing above) [___]
Cell membrane - pressed against the inside of the cell wall and will not be visible. [___]

6. Draw and label 3 typical onion cells. Make each cell about two inches long.

7. Recalling what part of the "total" onion plant that the onion bulb came from, offer an explanation for why the onion cells do not contain chloroplasts. (Remember that the function of the chloroplast is to aid in photosynthesis. Photosynthesis is the process whereby chloroplasts in plant cells absorb light and energy, which is used to make more plant cells.)

ANIMAL CELLS:

Human skin cells

It is easy and painless to obtain epithelial skin cells from inside of the cheek. Place a drop of water on a clean glass slide. [___] Then scrape the inside of your cheek gently with a clean toothpick. The loose epithelial cells will come off onto the end of the toothpick. You will not see them on the toothpick. Place the toothpick end, with the cells, into the water on your slide. Knock the toothpick against the slide and swirl it around in the water until the water becomes slightly cloudy. [___] Add 1 full drop of iodine or methylene blue stain and then add a cover slip. [___]

Examine on 4X and 10X and scan to find various cheek cells. They will appear irregular in shape and some will be found in clusters. The nucleus will be stained darkest and will be very apparent. [___]

Find a few typical cheek cells and examine them in more detail on 40X to find the following:

Cell membrane - This will be the outer covering in animal cells. Animal cells DO NOT HAVE a cell wall. Notice the cell membrane is much thinner than the cell wall of plant cells. [___] The cell membrane controls the movements of molecules into and out of the cell. The cell membrane controls the movements of molecules into and out of the cell.

Nucleus - [___] Cytoplasm - This fills the cell in most animal cells.

8. Draw and label the parts of three different cheek cells. Make each cell at least two inches across.

Amoeba cells (prepared slide)

In your tray you will find a prepared slide. It is marked "Amoeba proteus." [___] Report any damage to this slide before you begin. [___] An Amoeba is a relatively large single-celled animal that lives in ponds and lakes. It has a very irregular shape. The Amoebas on this slide are stained various colors. The stain causes many of the cell structures to be more visible. Scan this slide on 4X and 10X to find the stained

Amoebas. Disregard the other smaller stained cells and debris. [___]

9. Examine at least three different typical Amoeba cells on 40X and draw and label 2 such cells. Make them at least two inches across. You should be able to find and label the following: cell membrane, cytoplasm, nucleus, and in some cells, a small clear vacuole. To see all parts of Amoeba cells, it will be important to focus with the fine adjustment continually while observing these cells because different cell parts are at different depths within the cell. [___]

Reread the previous paragraph to be sure that you have accomplished each task that is required of you. [___]

SUMMARY COMPARISON OF PLANT AND ANIMAL CELLS

The remaining portion of this lab can be completed outside of class. To complete the following portion, you will need your drawings of all cells made earlier in this lab.

If you were to examine a hundred more plant and animal cells, you would find, in general, that all the plant cells would resemble the onion and elodea cells. The animal cells would resemble the cheek cells and Amoeba cells. Use your cell drawings to answer the following:

10. How does the basic general shape of the plant cells differ from the general shape of the animal cells?

11. What cellular structures are found in green plant cells only? (*Elodea* is the example.)

12. What structures are present in every plant and animal cell?

On your paper, draw a generalized green plant cell and a generalized animal cell. Label each cell and the parts that are contained in each cell. These drawings will be generalized and will not represent any specific green plant cell or animal cell, and should not specifically resemble one of the species of cells you saw in lab. [___]

There are many important cell structures that cannot be seen with a light microscope like yours. These structures have been photographed with electron microscopes. You will learn about these structures later. At that time you will also learn the functions of the cell parts that you identified in this lab. This information will be presented in home assignment III-1 which is to be done before taking the quiz over cells.

In 4-2, you will work with a set of accurate drawings of a plant and animal cell parts to review for the quiz that is to follow.

13. Restate the cell theory in your own words. If you find it necessary to review the cell theory first, you will find it at the top of page 2 of this lab.

THE FAR SIDE By GARY LARSON

Working alone, Professor Dawson stumbles into a bad section of the petri dish.

4-2 Cell Theory

1. We have many different kinds of cells in our bodies. Name a few different types of cells that you have heard about and list their functions.

Every organ in your body is composed of cells. In fact, cells make up the component parts of every plant and animal. To understand how the whole organism functions, it is important to understand how individual cells function. The following analogy should be helpful: One way to determine how a company functions is to study how each department operates. Find out what each employee does and you can put together a complete picture of the function and daily operation of the company. This is how you will build understanding about how animals and plants function. You first need to have a thorough understanding of cell structure and function, then it will not be difficult to understand how the entire organism functions.

Objective

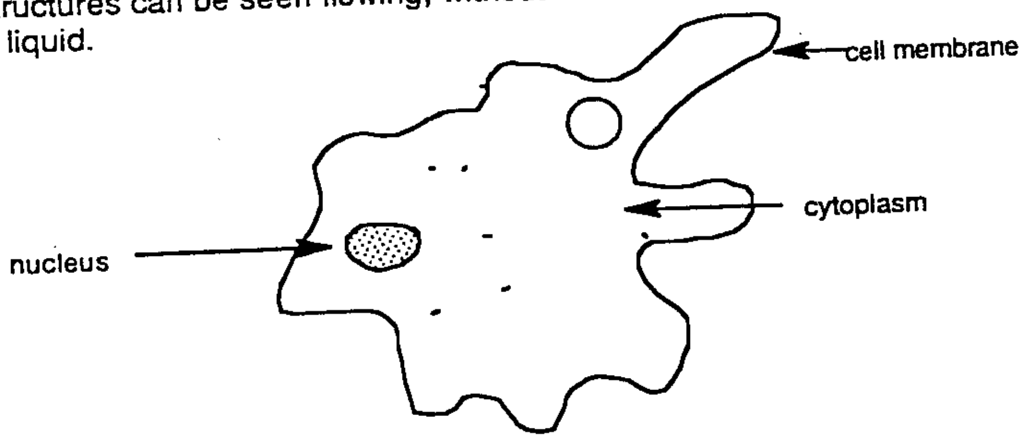
On a quiz that follows, you should be able to:

1. Identify and label cell parts in diagrams of plant and animal cells.
2. List each cell part's function.
3. Describe characteristics that distinguish plant cells from animal cells.
4. Define the cell theory.

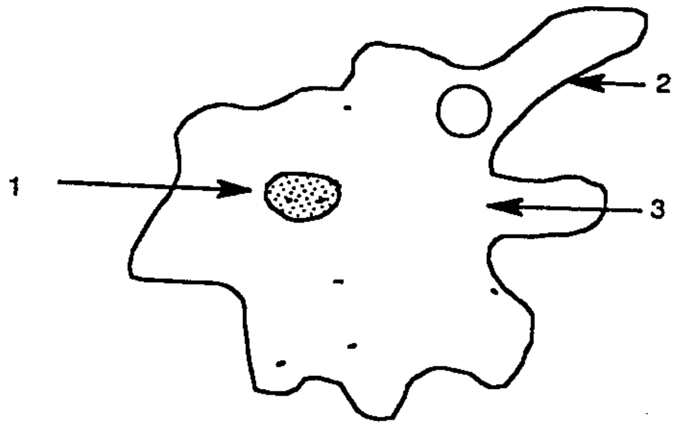
The Cell

The cell is a remarkable unit. In the human, it is responsible for thinking, seeing, hearing, moving and all other human processes. This incredibly small factory of protoplasm is alive with activity. It's difficult to comprehend the complexity of events that take place in each minute cell. It has to have a control center. It can produce exact copies of itself while also being able to create different offspring during early growth of an organism.

With a microscope, let's take a closer look at a single-celled animal called *Amoeba*. At first, the cell looks surprisingly simple. Its outer membrane, the cell membrane, undulates as the *Amoeba* slinks across the slide. The cell's liquid content, the cytoplasm, flows in an eerie fashion and appears almost as translucent silver. Many structures can be seen flowing, without resistance, within this crystal clear, gel-like liquid.



The largest visible structure is the nucleus. It is the command center of the cell. Just as a company has a president, an athletic team has a coach, or a naval vessel has a commander, the cell must have its governing center. The nucleus determines when the cell will divide. It contains all the instructions for how the organism will look and function. These instructions are programmed into the nucleus within genes found on chromosomes. In one of the most intriguing discoveries ever made, genes have been shown to store these precise molecular units in a sequence that makes up a large molecule known as DNA. You will learn a great deal about this intriguing molecule in another unit.



Let's learn the names of important structures as we go.

2. Write the names of structure 1,2 and 3.
3. What is the function of structure 2?
4. Where are the genes found?

The Cell Theory

Original observations of cells by Robert Hooke in Holland 1665 was the beginning of a vast accumulation of data, which today is called **"The Cell Theory"**. The cell theory states:

All living things are composed of cells (or cell products).
All cells come from previously existing cells.

Although these two statements may seem quite basic and acceptable today, many years of observation and analysis were required before the cell theory could be formulated. In earlier years this theory was considered to be true without exception. When scientists discovered viruses, they found that they were not composed of cells. All other living things appear to be composed of cells.

Cells reproduce to create new cells. Cells have been observed to come only from preexisting cells.

5. Why did the discovery of viruses complicate the way in which the Cell Theory had been previously stated?

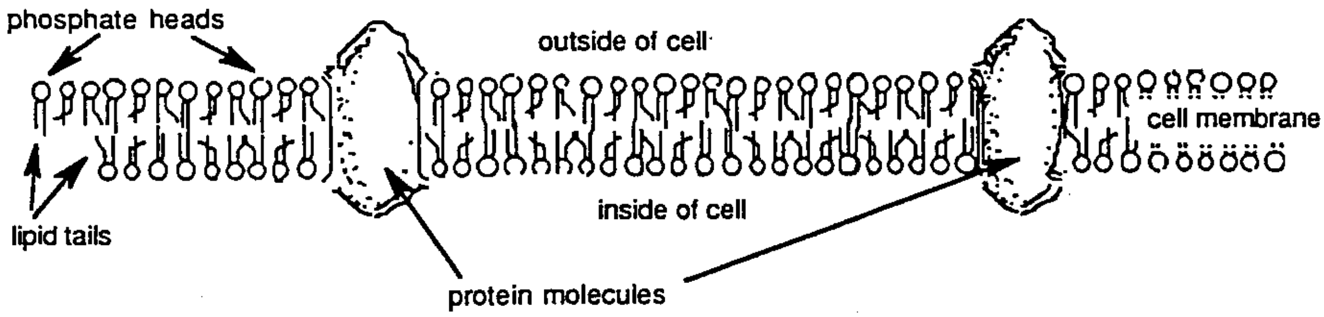
4-3 Cell Structure

1. Name as many different cell parts as you can and then describe the function of at least three of the structures.

Objective
On a quiz that follows, you should be able to:
1. Identify and label cell parts in diagrams of plant and animal cells.
2. List each cell part's function.
3. Describe characteristics that distinguish plant cells from animal cells.

Common Cell Structures: (Those structures found in both animal and plant cells)

The Cell Membrane
As you will recall from the cell lab, cheek cells have a thin outer membrane covering them. This is the **cell membrane**. It exists in plant cells also, but is not easily seen because it is pressed against the cell wall. All cell membranes are thin and flexible. Function: Materials going in or out of the cell must pass through this "cell membrane." **Cell membranes control the movement of substances into and out of the cell.** You will investigate this process in an activity later in this unit. It also keeps the cell's contents from flowing into the environment. Examine the following diagram of the molecular make-up of the cell membrane:



Within the cell membrane is a semitransparent fluid that has an appearance much like raw egg white. This fluid is called **cytoplasm.** Its **function** is to contain all the cellular parts and **provide a liquid environment for cell activities.** The "machinery" for all the cell activities is located here. The cytoplasm is also like raw egg white in its consistency (thickness). The cytoplasm is largely **water**. The cell's chemical reactions work best in a water environment. The jelly-like cytoplasm also circulates and moves in most cells. This helps to circulate nutrients and other vitally needed substances. Molecules must be able to move through liquid to get to one another in order to react during essential biochemical reactions. In lab you may have seen the cytoplasm in the *Elodea* leaf cells move, causing the green chloroplasts to move inside each cell.

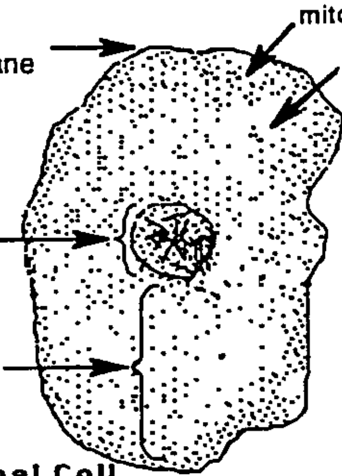
Mitochondria

Jelly-bean-shaped structures called mitochondria are observed in the cytoplasm. These are too small to be seen with our microscopes; however, they are extremely important to the cell. Function: In the mitochondria, all the chemical reactions that **provide energy for the cell** take place. The interior of the mitochondria, as viewed with an electron microscope, appears as follows:

Membrane ridges can be seen inside the mitochondria. Important energy-producing reactions called **respiration** occur on these membranes.

Vacuoles

The cytoplasm also contains sac-like structures called vacuoles. The vacuoles act as **storage sacs for cellular products and materials** required for the cell. **Water** is the main substance found in these structures in plants. Compared to those found in plants, most animal cells contain small vacuoles. Some animal cells, like fat cells, have large vacuoles. Plant cells usually have large water-filled vacuoles in the center of the cell. Since much of the material they contain is transparent, you may have had trouble seeing vacuoles in the previous lab.



Animal Cell

Nucleus

Another structure contained within the cytoplasm is the nucleus. In lab it appears in the onion and cheek cells as a dark and usually round object. The nucleus contains the **chromosomes** and genes which control cellular activities. The genes, which determine the organism's hereditary characteristics, are on the chromosomes. (Detailed study of chromosomes and genes will occur in a later unit on genetics.)

Nucleus Function - The nucleus **controls the cell's activities**. Chemical messages constantly pass from the nucleus to the cytoplasm where most of the cell's activities take place. It is the "brain" of the cell.

Surrounding the nucleus is a nuclear envelope (also called the nuclear membrane). This membrane has characteristics similar to the cell membrane mentioned earlier. Its main job is to keep the substances in the nucleus separate from the cytoplasm.

Ribosomes

Ribosomes are also found in the cytoplasm. Since they are extremely small, you will not be able to see them with our microscopes. Their **function is to make protein for the cell**. They make all the enzymes (proteins) for the cell.

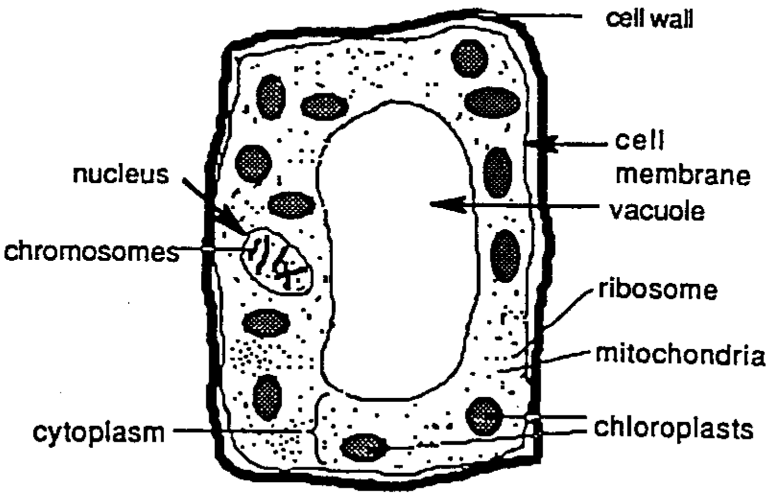
2. List the cell structures found in the cytoplasm of animal cells.

3. Why is it important for cytoplasm to be largely water?

Structures Found Only in Plant Cells

The Cell Wall

The non-living cell wall is located outside the cell membrane. It is constructed of a material called cellulose. This gives plant cells a rigid, non-flexible characteristic. The cells of the more flexible parts of plants, such as leaves, contain thinner cell walls with less cellulose. **Cell walls serve to protect the cells from injury and provide a rigid structure that helps a plant maintain its shape.**



Plant Cell

The Chloroplast

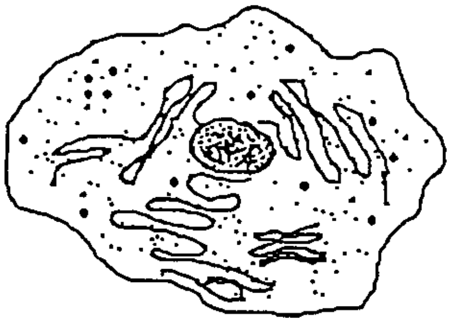
Floating in the cytoplasm of "green" plant cells is found another structure limited to plant cells only. These are oval, green-colored structures called chloroplasts. Function: These chloroplasts **absorb the sun's light energy and use it to convert water and CO_2 into food** molecules. This process is called **photosynthesis**. These food molecules serve as food for animals and are used in plant growth and other plant functions. Chloroplasts move inside the cell. Movement of the chloroplasts is a result of the movement of the cytoplasm (similar to the movement of a log floating in a stream).

Large Water-filled Vacuoles

Many animal cells have vacuoles, but they are usually small compared to the large water-filled vacuoles found in plant cells. In plants, the vacuole **stores water** for use during periods when less water is available from the ground. When the vacuoles are filled to capacity, the leaves are firm and healthy looking. During periods of dryness, less than half the usual water may be found in the vacuoles. This causes the leaves to wilt, and if the plant does not obtain water soon, it can die. The water in vacuoles often contains various stored dissolved substances. You might think of the vacuole as a reservoir for the plant cell.

4. List those cell structures that are unique to plant cells. What is the function of each of these cell parts?

Something to Think About



You now know how most cell parts function, and you have probably observed a number of cell types in the laboratory. Do you find it inspiring, as biologists do, to realize that all of these complicated activities go on inside of an area that is so small it is invisible to the unaided eye? At this point, you have learned only a small part of what occurs inside cells. A great deal more is happening. You will be learning about these cell activities in the remainder of this unit and in those to follow.

Another fascinating fact about cells is that they are **specialized for specific functions.** In the human, for example, nerve cells are specialized for carrying nerve impulses throughout the body. Cells in the retina of the eye can sense colors of light. Cells in the stomach secrete digestive juices so we can digest our food. Bone cells produce hard material for skeletal support, and your brain cells will hopefully remember this important information about cells.

Cell Organization

There are many cells that live out their lives as single cells. These organisms are called **unicellular** (uni = one). Most animals and plants that we commonly see are **multicellular**, which means that they are made up of many cells (multi = many). An adult human is composed of over 100 million million individual cells. Thousands of similar cells are arranged together into **tissues.** Different tissues are organized together to form **organs.** Organs are arranged together into **systems.** The various organ systems make up the entire **body.**

Review

5. Make a chart like the one shown below. List all the cell parts (both plants and animal), in the left column. Describe the **function** of each cell part in the column on the right opposite the appropriate structure name.

Indicate with an "*", those parts found <u>only</u> in plant cells.

Cell part	Function
1. nucleus	
2. etc.	
3.	

Cooperative Learning Groups:

When you return to class, your teacher may have you perform the following team activity:

If this cooperative activity is assigned, do not turn in your answers to 4-3 until you complete this cooperative activity.

(Appendix C contains helpful information about cooperative learning group procedures.)

In your cooperative learning group, do the following:

Review your answer to question 5 on the previous page. Check your answer to question 5 by the following procedure:

1) Each student in the group is to read the name and function of one cell structure from the review on the previous page. Others are to discuss any additions or corrections. Continue around the group until all cell structures have been discussed in this way. On your copy, make any corrections that were agreed to by the group.

2) Tear one or more sheets of notebook paper into eight pieces. Write the name of one cell part on each piece. Place them in a pile, face down, on the table. Without using notes, each person is to draw one at a time and describe the function of the part drawn . Place those done in a separate pile. Taking turns, each student is to do this until all cell parts have been described.

4-4 Creating a Cell Model (Do this lab activity at home)

Objective

Students will use a hen's egg to create a model of a cell in order to better visualize and learn the names of the parts of the cell.

Prerequisite: Be sure you have completed the lab on cells and/or the text reading assignment on cells.

MATERIALS: One raw egg in its shell, pepper, salt, small pieces of dark thread and a dish or plate.

PRELAB:

Being careful to not break the yolk, carefully crack one raw egg into a dish or plate. If the yolk breaks, open another egg. [___]

1. If this raw egg were a typical animal cell, what would the yolk and white of the egg represent?

INVESTIGATION PROCEDURE:

The egg in the dish represents a good model of a typical animal cell. To improve our model, sprinkle a little pepper onto the white of the egg. [___]

2. What possible animal cell structure(s) could the pepper represent?

Sprinkle a little salt onto the white of the egg. [___]

3. What possible animal cell structure(s) could the salt represent?

Now place 3 or 4 pieces of dark thread on the yolk of the egg. These pieces need only be 1/4 to 1/2 inch long. [___]

4. What cell structures do the thread pieces represent?

ANALYSES, INTERPRETATIONS AND/OR CONCLUSIONS:

As a review, fill in the following:

Part of egg model	Cell part it represents
yolk	
white	
outer edge of egg white	
pepper	
salt	
thread	

1. To change your cell model (egg) into a model of a plant cell, what changes would you have to make with the egg model?

2. Draw a diagram of a typical plant cell and a typical animal cell and label all of the parts clearly.

4-5 In-Depth Enrichment: Cell Structure

Objective

You should be able to state the function of the golgi apparatus, lysosomes, nucleolus and endoplasmic reticulum

The plant and animal cells described in Chapter 3 are called **eukaryotic cells.** Eukaryotic cells are the most common type of cell and all contain a nucleus. Certain cells, like bacterial cells, do not have a distinct nucleus. Cells that lack a nucleus are called **prokaryotic cells.** Prokaryotic cells have DNA, the main nuclear substance, but it is not enclosed in a nuclear envelope to form a distinct nucleus.

Golgi apparatus

Golgi apparatus

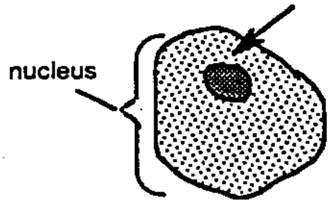
The Golgi apparatus, named for its discoverer, Camillo Golgi, is a specialized structure found in the cytoplasm of all cells. The Golgi apparatus is like the editor of a magazine who makes changes in the original story submitted. The Golgi apparatus takes in protein molecules and changes them to a different form needed by the cell. The Golgi apparatus consists of a collection of flat membrane structures.

Lysosomes

Lysosomes are found in the cytoplasm. Plant cells do not have lysosomes. When other cell parts become defective or wear out, they need to be broken down and the molecules reused or removed. This is the job of the lysosome. You might think of the lysosome as the recycling center of the cell.

Nucleolus

The nucleolus is seen as a dark spot inside the nucleus of most cells. The nucleolus consists of RNA and protein. The nucleolus produces the ribosomes.



Endoplasmic reticulum

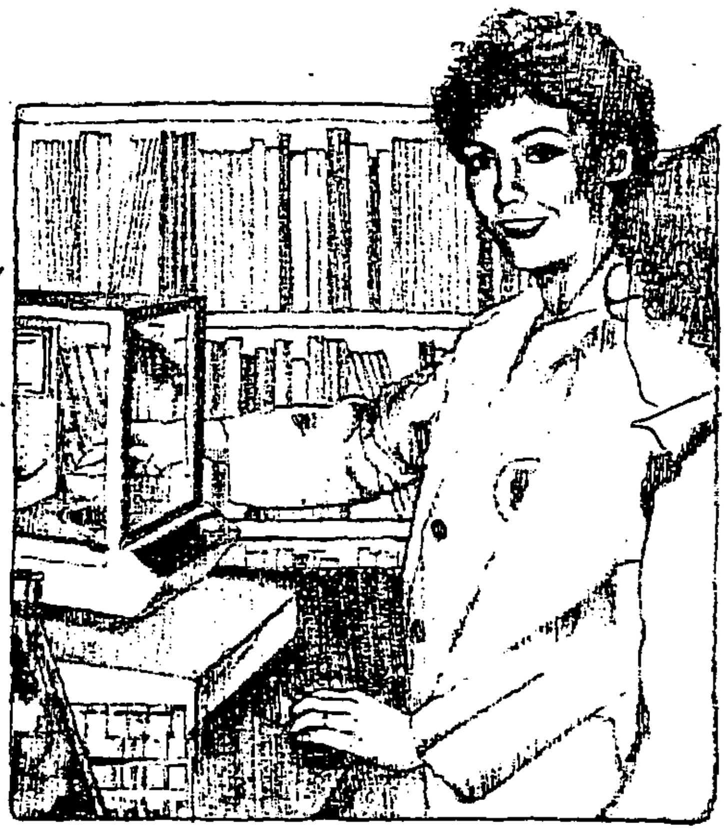
The endoplasmic reticulum consists of many layers of folded membranes within the cytoplasm. The endoplasmic reticulum helps in the altering of protein molecules made by the ribosomes which are found on the endoplasmic reticulum surface. The endoplasmic reticulum also aids in the movement of molecules within the cell.

The following review will help you learn the **structure** and **functions** of each cell part.

1. Arrange the following levels of organization in order from least organized to most organized: organ, cell, tissue, body, system
2. What is the function of the Golgi apparatus and endoplasmic reticulum?
3. If all lysosomes could be removed from a cell, what effect would it have upon the normal operation of that cell?

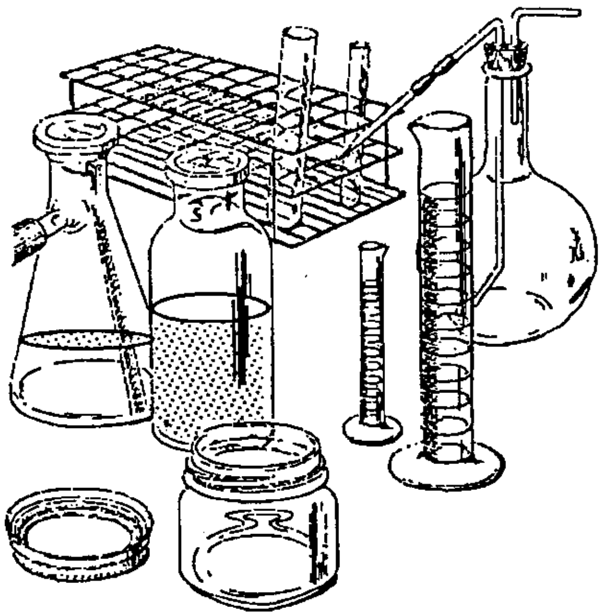
CHAPTER 5

BASIC CHEMISTRY



Chapter 5

Basic Chemistry



It's your attitude and not your aptitude that determines your altitude.
Zig Ziglar

5-1 Matter and Energy

1. After a log has burned in a fireplace to produce heat and light energy, all that remains are ashes weighing only a fraction of the weight of the original log. What do you think has happened to the parts of the log that did not change into ashes? Explain.

Objective

Define matter and energy and state the principles of conservation of mass and energy.

The scientist describes the universe as consisting of **matter** and **energy.** Matter is defined as anything that has mass and occupies space. On the earth this means that anything that has weight and occupies space is matter. Books, chairs, students, water, perfume and all physical objects that we see around us, are matter. This would seem to include just about everything. What about light, electricity and heat? Are they matter? They do not have mass and do not take up space and, therefore, do not qualify as matter. They are forms of **energy.** Can you go to the store and get a sack of light? Can you weigh 12 volts or an amount of heat? Energy does not have mass and does not take up space. Matter can change phases. Matter exists as solids, liquids or gasses. Solid ice can change to liquid water. Boil the water, and it will become water vapor (a gas).

Energy can exist in different forms. The forms of energy are potential energy (stored), kinetic energy (motion), electrical energy, light energy (radiant energy), chemical energy and heat energy. Energy is defined as the ability to do work. Electricity is energy because it can be used to do work. Electrical energy can power a drill and bore holes in wood and metal. The drill has done work for us.

Energy can change form. Solar cells can change light energy to electrical energy. A hot plate can change electrical to heat energy. In a steam engine, heat energy is changed into kinetic energy .

2. How is matter different from energy?

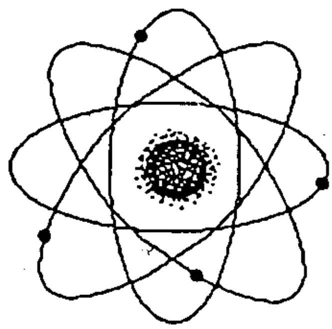
Principle of Conservation of Mass

The Principle of Conservation of Mass states that mass cannot be created nor destroyed under normal conditions on earth. Burn a piece of wood, and the wood appears to have been destroyed. The wood has changed form from solid to gasses. The weight of the wood plus the oxygen used to burn it is equal to the weight of the gasses produced from the fire. In a chemical reaction, the mass (weight) of the requirements of the reaction is always equal to the mass of the products.

Principle of Conservation of Energy

The Principle of Conservation of Energy states that energy cannot be created nor destroyed under normal conditions on earth. This means that in a chemical reaction, the energy associated with the requirements of the reaction is always equal to the energy associated with the products. As a piece of wood burns, the energy stored in it is equal to the energy given off as heat and light. When food is broken down in cells, the energy stored in a piece of food is equal to the energy given off as heat and chemical energy during burning. All living organisms require energy. You will study the details of how living things obtain this energy later in this unit.

The above principles only apply to normal chemical reactions. They do not apply to nuclear reactions. In nuclear reactions, mass can be destroyed and energy can be created. Mass is changed into energy in nuclear reactors every day. A famous equation developed by Albert Einstein shows the relationship.



$$\mathbf{E = mc^2}$$

E (energy) = **m** (mass) X **c** (the speed of light)^2

E = (25 g)(186,000 miles/second)^2 This tells us that in an atomic bomb or nuclear reactor, 25 grams of plutonium will explode or react and be converted into a considerable amount of energy. If all of the mass were converted to energy, 864,900,000,000 gram miles /sec. of energy (or 2,239,123,176,900 g Km/sec) would be obtained. But not all of the mass is converted to energy.

3. Can matter or energy be created or destroyed? Explain.

4. A reactor on a nuclear submarine used 4.3 pounds of plutonium for fuel. Calculate the amount of energy that would be obtained if all mass were converted to energy. (In actual practice, not all of the mass is converted.)

A Commentary on the Nature of Science

A few decades ago, all text books called the above principles "The Law of Conservation of Mass and the Law of Conservation of Energy." Today, scientists like to have overwhelming evidence before they apply the term "Law" to a scientific principle. In earlier years, when a principle was stated as a "Law," it was thought to be an absolute fact. So much evidence existed as to qualify the principle as a Scientific Law. The Law of Conservation of Mass was stated as, " Mass cannot be created nor destroyed under any circumstances." Prior to the nuclear age, all evidence supported this statement. As scientists learned about nuclear energy, they realized that The Law of Conservation of Mass is not true for nuclear reactions. Evidence now existed to disprove a scientific law! The Law of Conservation of Mass was revised. Some textbooks now refer to it as, "The *Principle* of Conservation of Mass." Today scientists avoid labeling any statement or principle as a Scientific Law unless there is overwhelming evidence. New evidence might just show the law to be wrong.

The above example illustrates how important it is for scientists to be tentative about their conclusions. The careful scientist says, "This is our current belief about a specific principle, based upon the evidence collected so far. If new contrary evidence is discovered, then the principle will be changed to fit the evidence." This is how hypotheses, theories and major principles are treated.

5. Why must scientists be very careful before they refer to a well established scientific principle as a "law?"

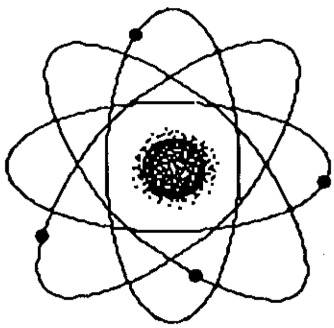
- **Science, Technology & Society**
  A Cooperative Learning Activity

(Appendix C contains background information on cooperative learning groups.)

If your teacher has assigned this group activity, do the following with your cooperative team:
1) Make a list, that all in the group can agree upon, of beneficial uses of nuclear energy in our society.
2) For each item in the above list, state a possible concern about continued use of nuclear energy for this category.
3) Make a list of negative uses of nuclear energy.

5-2 The Structure of the Atom

Introduction:



Objective

On the quiz that follows you will be expected to:
1. Name all parts of the atom
2. List the electrical charges of each part of the atom
3. Contrast nuclear fission and fusion

All matter found on earth is composed of atoms. This includes all living and non-living material. These atoms are too small to be seen by any equipment yet devised by our modern technology, yet there is a great deal of scientific evidence to support the theory that atoms exist and have the structures described below. This theory is known as the **Atomic Theory**.

Like most theories, the **Atomic Theory** has undergone changes to fit newly discovered data. The original theory is more easily understood than some of the recent additions, and will be used as a basis for this program. Revisions of the **Atomic Theory** will be discussed later.

AS YOU PROCEED, COVER THE ANSWERS IN THIS PROGRAM WITH A PIECE OF NOTEBOOK PAPER. PLACE YOUR ANSWERS ON THE NOTEBOOK PAPER AS YOU READ THROUGH THE PROGRAM. [___]

---

1. One theory concerning the origin of our solar system assumes that it resulted from an explosion in the universe. The earth was formed as molten materials and gases cooled. These materials, made of atoms, had different weights. As cooling of the molten mass occurred, some materials sank, others remained near the surface.

   Write down which you think would sink, the more dense or the less dense material. (Remember to use your own paper for answers.)

---

1. More dense

---

2. The less dense materials stayed near the surface of the earth, much like foam on milk. Among them were the elements hydrogen, nitrogen, oxygen and carbon. These are the major elements that combined to form all living things on the earth.

   List the four elements that are found in great abundance in living things.

2. carbon, oxygen, nitrogen, hydrogen

---

3. An **element** is a material composed of only one kind of atom. Examples of elements are: gold, oxygen gas, silver, diamond, hydrogen gas and mercury. The term **element** is defined as follows: An **element** is a pure substance composed of only one kind of atom. It cannot be divided into simpler substances, and still have the properties of that same element.

How many kinds of atoms would you find in a diamond?

---

3. one -- (carbon atoms)

---

4. What would be the smallest particle an element could be divided into and still retain the properties of that element?

---

4. atom

---

5. Atoms make up **molecules**. A **molecule** is defined as two (2) or more atoms bonded together. Two types of molecules exist. The type made of only one kind of atom like a molecule of gold or oxygen (O_2); and the type made up of different kinds of atoms like water (H_2O) or carbon dioxide (CO_2). Go on to the next frame.

---

6. All materials on earth are composed of elements. Therefore, all materials on the earth are made of atoms. Which of the following is true: (a) hair, skin and cellulose are not made of atoms; (b) water is not made of atoms; (c) all living and non-living things are made of atoms. (d) air is not made of atoms.

---

6. C. all living and non-living things are made of atoms.

---

7. The four most abundant types of atoms in living things are those which did not sink as the earth was cooling. These are: carbon, oxygen, hydrogen and nitrogen. The following symbols represent each type of atom:

N - nitrogen　　H - hydrogen
O - oxygen　　C - carbon

An oxygen molecule is made up of two atoms of oxygen. Draw an oxygen molecule using circles to represent the atoms.

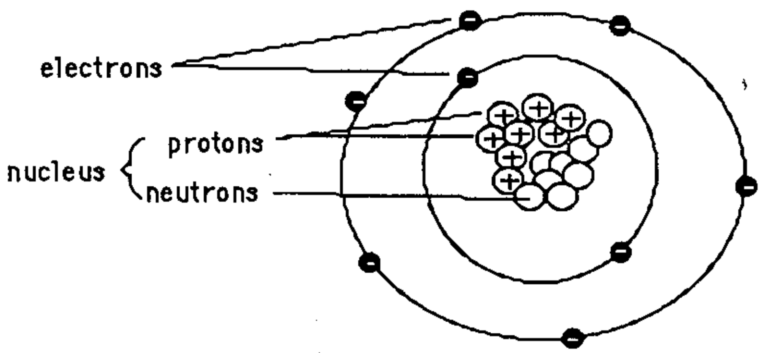
7.

8. Using the original atomic theory, let's now look at one atom in detail. We will use oxygen as an example, but any atom could be substituted.

Atoms have a central, heavy part called a nucleus (different and not to be confused with the nucleus of a cell.) The nucleus contains two types of particles--**protons** and **neutrons**. These particles are often referred to as **subatomic particles.**

Protons have a positive electrical charge. (+) **Neutrons** have no electrical charge. (O) The **electron** is negative. (-)

Examine the following diagram of an atom of oxygen:



9. Copy the chart below and complete it on your own paper.

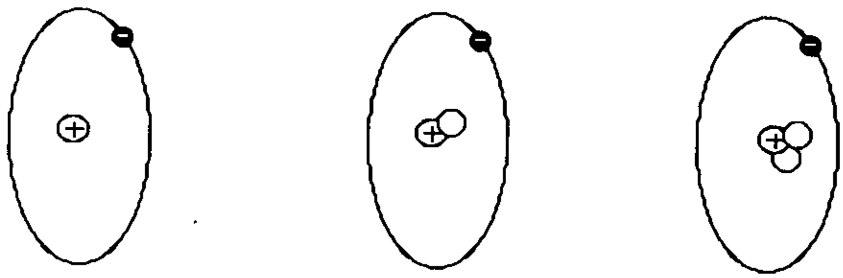
Sub-atomic particle	Charge of particle	Found inside or outside the nucleus (which?)
proton neutron electron		

9. Proton, +, inside nucleus
neutron, 0, inside nucleus
electron, -, outside nucleus

10. A hydrogen atom is the smallest atom. The most abundant form of hydrogen has only one proton and one electron. Draw a hydrogen atom using the same symbols used in # 8 above. [___]

Before looking at the answer, it's important to realize that two other forms of hydrogen exist. They are called **isotopes of hydrogen**. An **isotope** is a form of an atom that has the same number of protons and electrons as the abundant form of the atom but has a different number of neutrons. Some isotopes are **radioactive** since their nuclei are unstable. One isotope of hydrogen, called deuterium, has one neutron, one proton and one electron. Another isotope of hydrogen called tridium has two neutrons. Abundant hydrogen is also an isotope. Draw and label deuterium and tridium. [___]

10.



Deuterium and tritium are the isotopes used to make the hydrogen bomb.

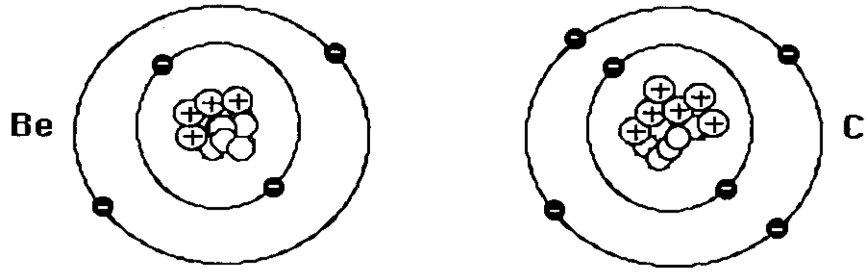
---

11. The electron that you just diagrammed in the hydrogen atom may appear to be stationary. According to one theory, the electron is actually orbiting around the nucleus. The electron moves around the nucleus much like the planets revolve around the sun.

The *Quantum Theory* describes the electrons as moving around the nucleus in all directions, but remaining approximately the same distance away from the nucleus. This theory describes the movement of the electron as forming a cloud around the nucleus and that the electron does NOT travel in exact orbits as described in the previous theory diagrammed above. The electrons seem to flit about like a moth. Why are there two theories? And why is information about the atom often changing? One reason is that no one has seen an atom. These models are built and drawn from an accumulation of data from thousands of experiments.

A **beryllium atom (Be)** has 4 protons, 5 neutrons and 4 electrons. A **carbon atom (C)** has 6 electrons, protons and neutrons. On your own paper, draw a beryllium and a carbon atom using the same symbols used earlier. [___]

11.



12. Count the number of electrons and protons in the oxygen, abundant hydrogen, beryllium and carbon atoms. What is the numerical relationship between the number of protons and the number of electrons in an atom?

Now examine the size of each of the four atoms mentioned above. How many total particles are in each atom?

Protons and neutrons weigh about the same. Electrons weigh about 1/2000th as much as a proton. Their weight is, therefore, insignificant compared to the proton or neutron. Which atom's nucleus would weigh the most? Place the above 4 atom's nuclei in order from heaviest to lightest.

---

12. The number of protons is <u>always</u> equal to the # of electrons in each atom. This is true for every atom. O = 24, C = 18, Be = 13, H = 2. O is the heaviest, then C, Be, & H.

---

13. Which of the four atoms mentioned would have the largest nucleus? Which would have the smallest nucleus?

Count the number of protons and neutrons for each atom. Are they always the same?

The number of protons and neutrons are "often" the same in many atoms. But in many atoms they are very different. Beryllium is an example.

---

13. The oxygen nucleus would take up the most space and also weigh the most .. Hydrogen would have the smallest nucleus.

No. The number of protons is <u>NOT</u> always equal to the number of neutrons.

---

number of neutrons.

---

14. When the atom was discovered many decades ago, it was thought that scientists had found the "ultimate" units of matter; the smallest known particle. More recently, scientists have suspected that there are even smaller particles than the proton, neutron & electron. About April of 1977, it was announced that many experiments show that protons, neutrons and electrons are made up of still smaller particles called **"quarks"**. The proton and the neutron are made up of at least 3 quarks each. (Maybe 4) The electrons are also made of quarks. The **quarks** in all these three particles are the same. The experiments described are interpreted by scientists as proof for the definite existence of these quarks. This discovery has tremendous significance. It means that all physical substances in the universe are made up of ONE kind of particle. Somehow their arrangement determines whether the cluster will be a proton, neutron or an electron. Do you think these quarks are the smallest and ultimate unit of matter? No one knows. Years ago, it was thought that the atom was the smallest unit. Then it was thought that protons, neutrons & electrons were the smallest. What will be discovered next?

In order to get ready for the quiz, complete the following review:

REVIEW:

15. Write the definitions of element and molecule from memory then look them up in the program to check yourself.

16. How would you diagram an O2 molecule? Respond, then check yourself by looking up the answer in answer-frame #7.

17. Name the parts of the atom and list their charges.

18. State the relationship between the number of protons and electrons.
    State the relationship between the number of protons and neutrons.

19. Define an isotope.

It's important to remember that no one has ever seen an electron, proton, neutron or quark. Evidence of their existence is indirect and from experiments.

The following appeared in a Seattle Times article and covers yet another recent finding about atoms. Read the article and answer the question that follows.

<u>The Seattle Times Monday, November 14, 1983</u>

Scientific objects that are heard of, not seen

Antimatter

Physicists have demonstrated the exsistence of subatomic particles that are oppositely charged but otherwise identical to their counterparts. In principle, then, it is possible that oppositely charged atoms and visible pieces of antimatter exist. However, any antimatter entering our world immediately clashes with ordinary matter in a mutual annihilation. Great masses of antimatter might exist in the vacuum of space. Possibly some of the observable galaxies are antimatter, but this cannot be determined at present.

20. In an atom of antimatter, what would the charge be for the electron, proton and neutron?

A LITTLE BACKGROUND ON NUCLEAR ENERGY

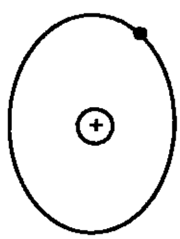
Nuclear **fission** (splitting of the nucleus of the atom) was demonstrated in the 1940's and is the nuclear energy process that is used in atomic bombs and **nuclear fission** reactors. When the atom of large atoms like uranium or plutonium is split by bombarding it with particles, large amounts of energy are given off. Nuclear radioactive waste products are also formed and can contaminate the environment. A great advantage of **nuclear fusion** (the joining or fusing of atomic nuclei) is the production of great amounts of energy with very little or no radioactive waste. Nuclear **fusion** is the process that produces energy in the sun and in hydrogen bombs.

21. What type of nuclear reaction is used in the atom bomb and what type is used in the hydrogen bomb?

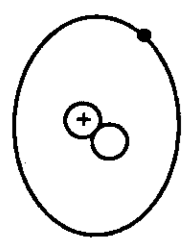
22. Which type of nuclear reaction produces the most radioactive waste products?

HOW NUCLEAR FUSION WORKS

Diagrams of regular abundant hydrogen and an isotope of hydrogen are shown below.



normal hydrogen atom



deuterium (an isotope of H)

The normal abundant hydrogen has one proton and one electron. The isotope of hydrogen, also called "heavy hydrogen" or **deuterium**, contains one proton and one neutron as well as one electron. The extra neutron makes the atom "heavy."

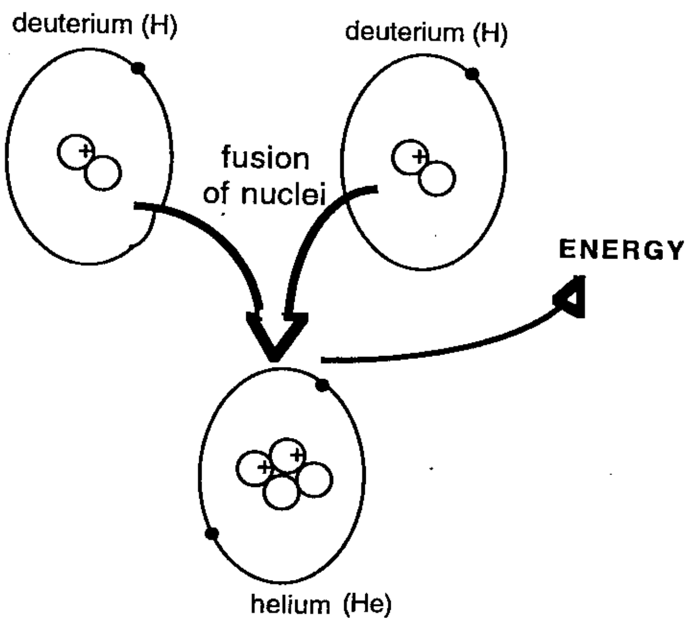
The sun initially was composed of only deuterium and another isotope of hydrogen called tritium. At great temperatures characteristic in the sun, the nuclei of two isotopes of hydrogen fuse to form the atom helium. The energy given off upon fusion in the sun is in the form of heat and light and is the greatest of any reaction in the universe per pound of reacting material. This reaction takes place at temperatures of 180,000,000 ° F.

23. What is the difference between normal abundant hydrogen and deuterium?

Scientists have worked for years to make this reaction practical under test circumstances at these high temperatures. The problem has been that more more energy must be put into the reaction than scientists get out.

Fusion on the sun

Nuclear fusion occurs naturally on the sun and in stars. The same reaction occurs in the hydrogen bomb. Nuclear fusion is illustrated in the following diagram:



As the nuclei of the two heavy hydrogen atoms fuse, great energy in the form of heat and light is given off. If fusion could be harnessed on earth, the heat created in fusion reactors could be used to generate electricity.

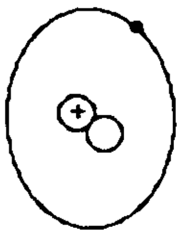
24. The resulting fused nucleus in an atom of helium contains how many protons and how many neutrons?

5-3 Are Atom Diagrams Really Accurate?

1. Do you believe that the diagrams of atoms in this manual and in other textbooks are accurate based upon what scientists understand about atoms?

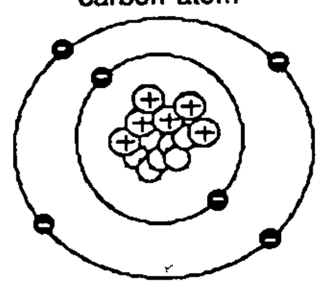
Objective

Use the information that follows to evaluate the accuracy of the atoms' diagrams used in the preceding topic.

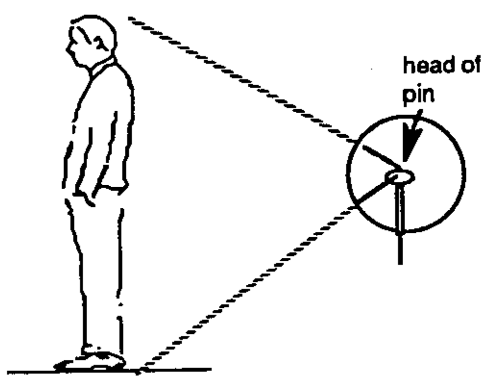


Atoms are so small that if we could line up one million hydrogen atoms side-by-side, they would measure less than the thickness of a piece of paper.

Each drop of water contains more that 100 billion billion atoms! (100,000,000,000,000,000,000) or 10^{20} atoms.



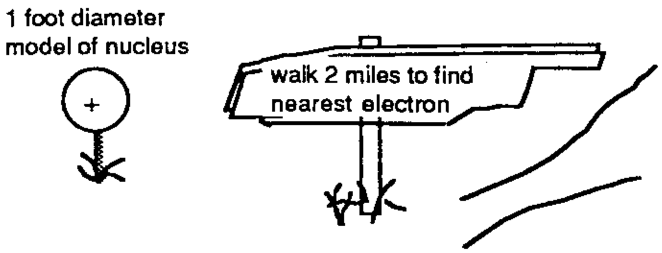
The atom, even though it is made up of protons, neutrons and electrons, is made up mostly of empty space! Compared to the size of protons, neutrons and electrons, there is great empty space between the particles in the atom. The actual "solid" matter of the atom takes up only one trillionth (1/1,000,000,000,000) of the atom's volume.



For example, if a six foot person had all the empty space between his atoms squeezed out of him, all that would remain would hardly be noticed on the head of a pin.

If we could squeeze all the empty space out of all the people in the world (5.4 billion), the remaining matter would fit into about one cubic foot of space. Of course this cannot be done, but the example helps us to realize the vastness of space within the atom.

In a scale where the nucleus of an atom is drawn to be 1 foot in diameter, the distance to the first and nearest electron would be just under 2 miles.



The mass (or size) of the proton is about 1835 times the mass of the electron. Said differently, the proton is 1835 times larger than the electron.

The mass of the proton is about the same as that of the neutron.

2. Based upon the above information, diagrams of atoms in this manual and in other text books are not accurate representations of how the atom would actually appear. How would the diagrams have to be changed if they were to provide accurate representations of atoms? Make your answer as detailed as you can.

Cooperative Learning and Interdisciplinary Math-Science Activity

In your cooperative learning groups, write a group answer to the following question:

Assume that your group is a committee established by the local science center or museum to set up a few scale models of atoms at the science center. It is requested that the protons be 6 inches in diameter. How large would the neutrons and electrons need to be in a scale model of the atom? How large an area would be needed to construct a scale model of a hydrogen atom? How large an area would be needed to construct a carbon atom?

5-4 Lab Investigation

"Don't Confuse Me with the Facts - My Mind is Made up"

(An Inquiry On Identifying A Scientific Problem and Interpreting Data)

Objective

You will observe four experiments. You will be expected to determine the **problem** that each experiment is designed to answer. The results of the experiments will be provided. You will also be asked to write **interpretations** of the data obtained in experiments.

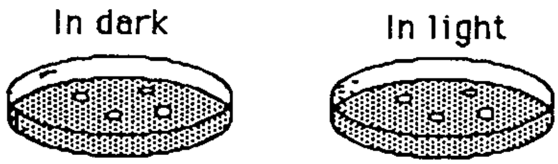
This title illustrates how some of us can become so biased that when presented with sound evidence we are still not convinced otherwise. Unfortunately, too many people in our society respond this way when evidence is presented. This is particularly true regarding social, political, racial, economic, medical and environmental issues. How many times have you wanted an individual to listen to a different point of view, only to find that they rejected the new evidence? All people do this to a certain degree, particularly when the subject involves emotions. People sometimes find themselves in trouble if they listen to their emotions when there is sound evidence indicating contrary action. We also sometimes make errors in logic when making interpretations. This inquiry and others like it will help you to develop the ability to recognize problems and make logical interpretations based upon evidence. This training, when mastered, will help you to think critically about scientific and non-scientific issues alike. Much of life can be described as a series of making one decision after another after examining available data.

In this activity you will examine a series of demonstration experiments. You will be expected to determine the **problem** that each experiment is designed to answer. The results of the experiments will be provided. You will be asked to write **interpretations** of the results. You will then be expected to demonstrate what you have learned by taking a quiz in which you will be presented with similar experimental situations.

You will find 4 experiments set up either on the lab tables or on the side counters. Move to that area at this time. Notice that each experiment is numbered. Start with any experiment and complete the rest in any order. Observe and study one of the experiments. Do not open the folder with this experiment until asked to do so.

Each of the 4 experiments is diagrammed below for your convenience. In interpreting the results of the 4 experiments, do not use information you have already learned about plants and animals. Be sure that you do not submit interpretations for which there is no evidence. You have been taught that plants and animals require certain substances. Be sure that you do not make interpretations regarding these substances if there is no direct evidence to support this point of view. Make interpretations that are based ONLY on the evidence given for each experiment. New discoveries in science sometimes contradict established theories. It is, therefore, important to not let previous knowledge bias the observer when making interpretations. A frequent mistake in interpreting these experiments is to make interpretations for which NO evidence exists.

Experiment 1:



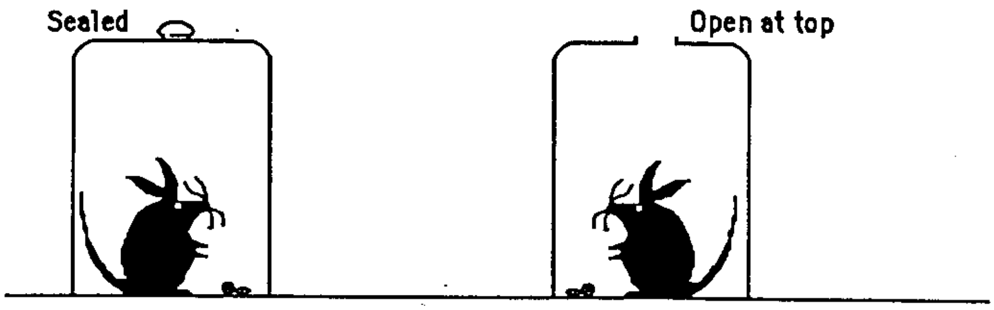
The temperature and moisture were kept the same in both cases.

1. What **problem** is the experiment designed to answer?

Now open the pamphlet accompanying this experiment. This pamphlet gives the results obtained in the experiment. [___]

2. Study the results of this experiment and then write your **interpretation** of the results. Remember that an interpretation describes what the data means. **It does not reword the results.**

Experiment 2:



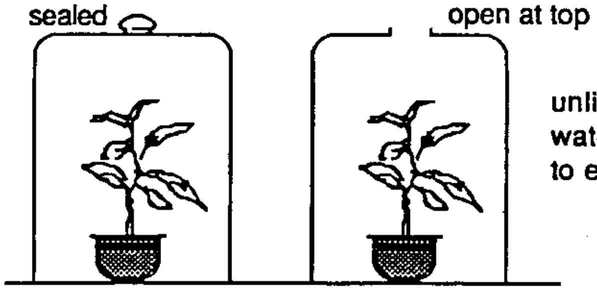
Food and water were provided in both cases.

3. What **problem** is the experiment designed to answer?

Now open the pamphlet accompanying this experiment. This pamphlet gives the results of the experiment. [___]

4. Study the results of this experiment and then write your **interpretation** of the results. Remember that an interpretation describes what the data means. **It does not reword the results.**

Experiment 3:



unlimited water provided to each plant.

5. What **problem** is the experiment designed to answer?

Now open the pamphlet accompanying this experiment. This pamphlet gives the results of the experiment. [___]

6. Study the results of this experiment and then write your **interpretation** of the results. Remember that an interpretation describes what the data means. **It does not reword the results.**

Experiment 4:

Sealed and food and water provided.

The controls for experiment 4 are experiments 2 and 3.

7. What **problem** is experiment 4 designed to answer?

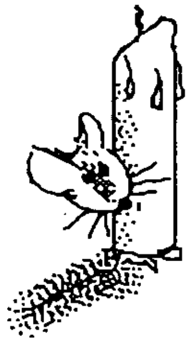
8. Now open the pamphlet accompanying this experiment. This pamphlet gives the results of the experiment. [___]

Study the results of this experiment and write your interpretation of these results.

Obtain the answer sheets for this lab from the lab assistant or teacher. As you read each answer for this lab activity, make the necessary corrections on your paper. [___] It will be very difficult to pass the quiz for this lab activity without understanding the answers provided on these answer sheets.

5-5 Joseph Priestley's Experiments with Mice,Candles, and a Mint Plant

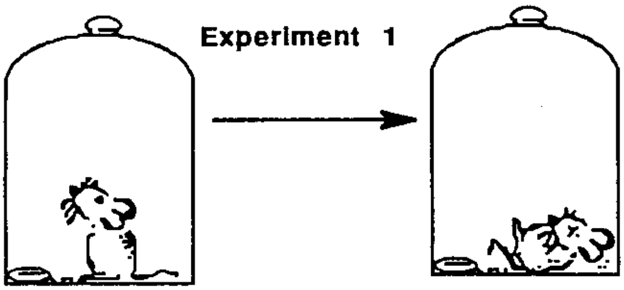
1. Most young children spend some time catching bees in a jar during the spring or summer. Why is it important to punch a few holes in the lid of the jar?



Objective

Explain how the experiments of Priestley and Lavoisier led to the understanding that mice and candles require oxygen and that mint plants give it off.

If you did the previous experiments with mice and plants, you will appreciate learning that similar original experiments were done by Joseph Priestley over 200 years ago. His experiments played a major role in determining the future direction of biological experimentation. In the early 1770's, just prior to the American Revolutionary War, an English clergyman named Joseph Priestley published the results of a number of very interesting and important experiments.

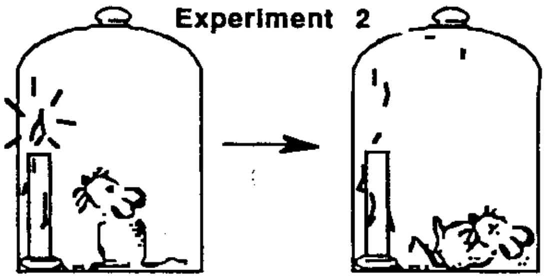


many minutes later

Joseph Priestley placed a mouse into a sealed container of air. After a short period of time, the mouse died. Priestley interpreted the results to mean that the mouse required something in the air. Oxygen had not yet been discovered and the composition of air was not known. Priestley also found that a mint plant died, and a burning candle went out when they were sealed in separate containers of air.

2. What is a reasonable interpretation for why the plant died and the candle went out in the above described experiment?

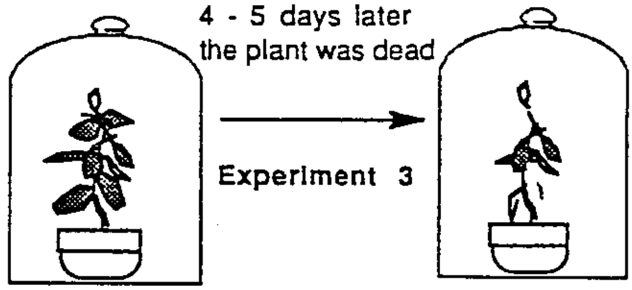
When Priestley placed a burning candle and a live mouse **into the same container** of sealed air, he observed that the mouse died and that the candle went out in less time than when they were in separate containers.



minutes later

3. What is a reasonable interpretation that would explain why the candle went out and the mouse died in less time than when they were enclosed separately?

In another experiment, Priestley placed a lighted candle into a sealed bell jar in which a mouse died. The flame flickered and went out immediately. In experiment 3, a mint plant was placed in a sealed, air-tight container. In four to five days the plant died. The plant always had a supply of water.



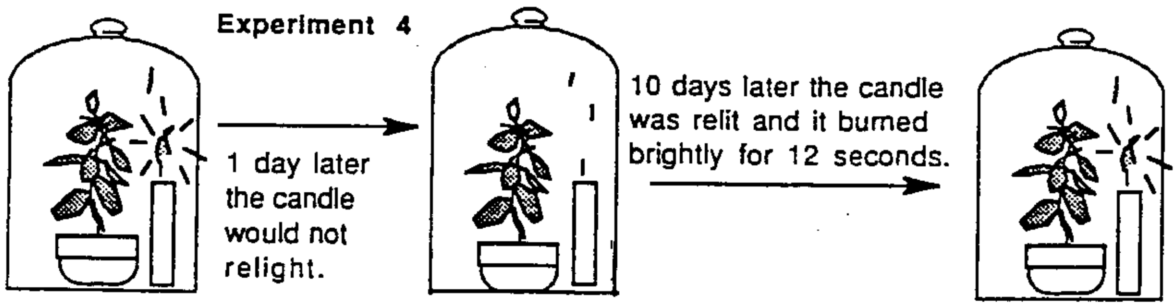
4. What is a reasonable interpretation that would explain why the plant died in the sealed container and in experiment 3?

Joseph Priestley reported the results and interpretations of the above experiments in the journal of The Royal Society, the scientific journal of the day. For experiment 1, he reported that the mouse required something in the air. Oxygen had not yet been discovered. But it was evident to Priestley that the mouse had used up something in the air that it required in order to stay alive. For experiment 2, Priestley stated that the mouse and the candle both required the same substance found in fresh air. Since the mouse died and the candle went out in less time than when the two were in separate sealed containers, he stated that they must both be competing for the same substance in the air.

5. If the mouse and the candle had each used two different substances found in air, how would the results for experiment 2 have been different?

6. What would have been an appropriate control for experiment 1? For experiment 2? For experiment 3?

In experiment 3, Priestley stated that the mint plant also required something in the air. To determine if the plant and the candle required the *same* substance, he placed both into a sealed container as shown below:



Instead of finding that the candle and the mint plant use the same substance, he found something quite the contrary.

7. What is a reasonable interpretation that would explain why the candle would not relight in one day but would relight in ten days?

Priestley also burned a candle by itself until it went out. He could only relight it if he placed a mint plant in with the candle and left it for four to five days. Priestley described the experiments in his own words as follows:

> ... on the17 th of August, 1771, I put a sprig of mint in a quantity of air in which a wax candle had burned out, and found that on the 27th of the same month another candle burned perfectly well in it. This experiment I repeated, without the least variation in the event, not less than eight or ten times in the remainder of the summer.

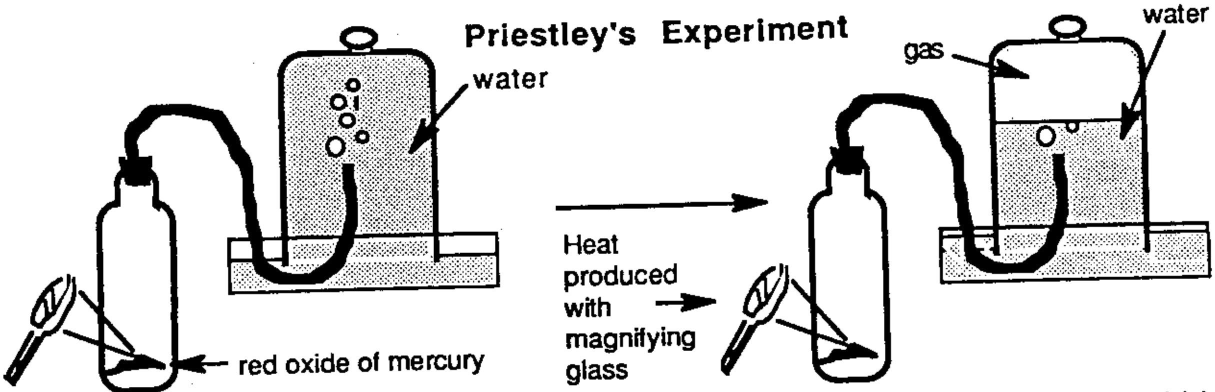
Priestley stated that the plant must be giving off some substance needed in order for the candle to burn. He did not know it was oxygen, since oxygen had not been discovered yet. From his experiments, there was no way to determine what substance was produced by the mint plant. He assumed that animals and people also require the same substance in the air that the mouse requires. Priestley had also wondered where this substance came from since it was apparent that humans and animals were constantly breathing it in. Priestley comments in his own words:

> It is evident . . . that there must be some provision in nature for this purpose, as well as for that of rendering the air fit for sustaining flame; for without it the whole mass of the atmosphere would, in time, become unfit for the purpose of animal life, and yet there is no reason to think that it is, at present, at all less fit for respiration than it has ever been. I flatter myself, however, that I hit upon [a method] employed by nature for this great purpose.

At this time Priestley was corresponding with Benjamin Franklin in America. Dr. Franklin was well known for his scientific achievements. Priestley described the experiments to Franklin. Franklin replied:

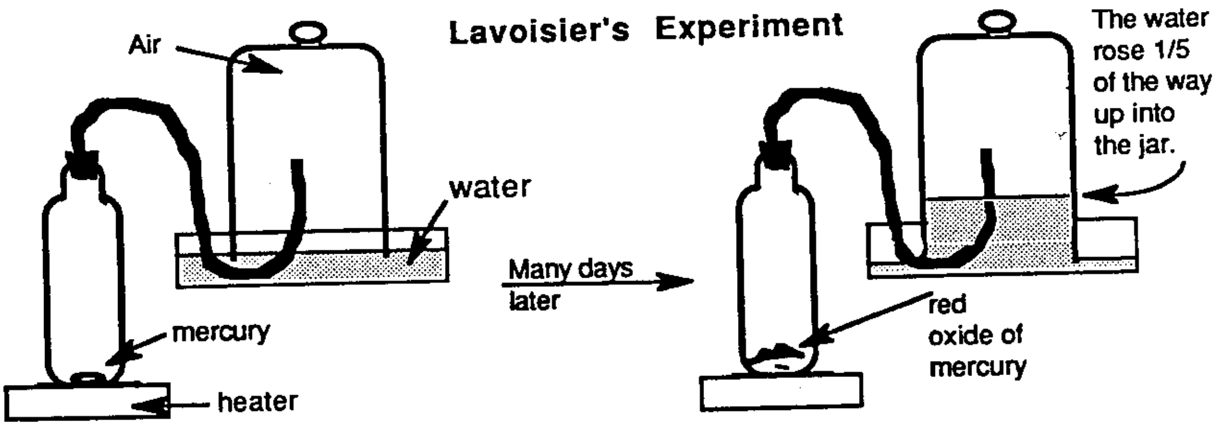
> That the vegetable [plant] creation should restore the air which is spoiled by the animal part of it, looks like a rational system . . .

During this same time in England, mercury, a liquid, silver-colored metal, was being used to block hats. The poisonous effect upon the human nervous system was not known at that time. Hat makers would absorb the mercury and slowly become "mad" as the chemical affected their brains. They were referred to as "mad hatters." Lewis B. Carroll created the well known character, the "mad hatter", in his famous story, *Alice in Wonderland.* The mercury was obtained by heating a red powder called cinnabar. Cinnabar is known today as HgS (mercuric sulfide). After heating cinnabar powder, It was observed that the amount of mercury obtained was <u>much less</u> than the amount of cinnabar at the beginning. What happened to the rest of the cinnabar? Mercury could be obtained the same way by heating a **red oxide of mercury**. Priestley decided to do an experiment. He heated some of the red oxide of mercury in a bottle that had a tube that carried gas products into a bell jar that was filled with water.



Bubbles of a gas were observed coming from the heated red oxide. They bubbled up through the water to fill the jar with the unknown gas. When Priestley collected two bell jars full of the gas, he placed one over a mouse and another over a burning candle. The mouse lived 4 - 5 times longer in this unknown gas than in air. The candle burned brightly in this gas and stayed burning longer than in air. Another individual actually discovered this gas earlier but did not publish the results. Priestley is credited with the discovery of the gas (oxygen) because he published his results.

Priestley had discussed his work with the Frenchman, Antoine Lavoisier. Lavoisier had been working on related experiments. Lavoisier hypothesized that the new gas, always present in the air, would combine with mercury and reduce the volume of air accordingly. He devised the following experiment to test his hypothesis.



Lavoisier heated mercury in the presence of air. As he heated the bright silver liquid, he observed two things:

1. The silver mercury slowly turned red and eventually changed into the red oxide of mercury powder like that used in Priestley's experiment.

2. The water in which the bell jar was sitting, rose up into the jar 1/5 of the way to the top and then stopped and would rise no more.

8. Study the results from this experiment and write an interpretation of Lavoisier's experiment that would explain the two observations above.

9. Based upon Lavoisier's experiment, what fraction of the air is oxygen? Explain.

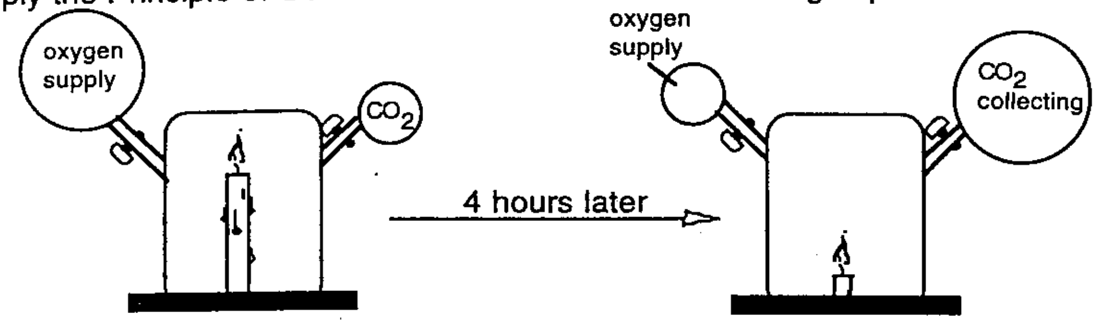
10. Compare Priestley's and Lavoisier's experiments with mercury and the red oxide of mercury and explain how they were different.

First review the Principles of Conservation of Mass and Energy in 5-1 of this chapter and then answer the questions that follow.

11. State the Principle of Conservation of Mass

12. State the Principle of Conservation of Energy

13. Apply the Principle of Conservation of Mass to the following experiment:



This entire set-up weighs 740 grams at the start of the experiment. Oxygen is supplied from the balloon on the left. Carbon dioxide from the burning candle is being collected in the balloon at the right.

The balloons changed size due to the changes in gas volumes in the two balloons. All gases used and produced were contained and none escaped.

According to the Principle of Conservation of Mass, How much will the entire apparatus weigh after the candle has burned to 1/8 its size 4 hours later?

Explain how the Principle of Conservation of Mass can be applied to arrive at the answer.

14. Explain how the experiments of Priestley and Lavoisier led to the understanding that mice and candles require oxygen and that mint plants give it off.

The experiments performed by Priestley and Lavoisier were milestones in biology. If there had been a Nobel Prize in the 1770's, these two men might have shared it for their work with mice, mint and candles. If you performed lab activity 5-4, then you drew some of the very same conclusions that these two men did. Might it be that you have the ability to do scientific research as important as this? Scientific research and the technological application of science are rewarding careers.

5-6 Laboratory Investigation

The Chemistry of Combustion

A New Problem and Hypothesis Arise From Interpretations of Earlier Experimental Data

Objective

On a quiz that follows you will be asked to:
1. Write the equation for combustion
2. Identify the reactants and products of combustion and discuss what happens to them during the reaction

Pre Lab

AS YOU PROCEED, COVER THE ANSWERS IN THIS PROGRAM WITH A PIECE OF NOTEBOOK PAPER. PLACE THE ANSWERS ON YOUR PAPER AS YOU READ THROUGH THE PROGRAM. [___] WORK INDEPENDENTLY

1. In topics 5-4 and 5-5, you concluded that mice and candles require "some substance" present in air. You also concluded that both mice and candles require the same substance. A new logical question or problem arises out of these conclusions. What is the next logical question?

---

1. What substance in the air do both mice and candles require?

---

2. The above pattern is a very familiar one in science. You begin with an **initial problem**. You solve this problem, and out of its solution comes a **new problem** that can be tested. Thus, the never-ending inquiry of science continues. It is known that air consists of about 20% oxygen, 79% nitrogen, .03% carbon dioxide and less than 1% miscellaneous gases. With this information, the problem in question 1 can be turned into a **HYPOTHESIS**. This would be a definite statement of belief based on all evidence known to you. In the answer to question #1, state the problem underlined in hypothesis form. [___]

---

2. Hypothesis: Mice require and use oxygen from air to continue living. Candles require and use oxygen from air for continued burning.

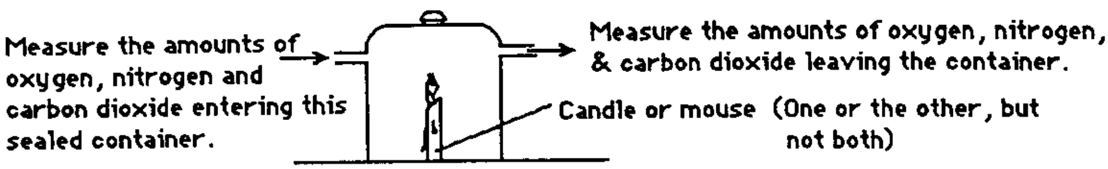
---

3. The next step, as you know, is to test this hypothesis, At this point it is useful, but not always necessary, to put the hypothesis into **"IF-THEN"** form. The **"IF"** part is a restatement of your hypothesis. The **"THEN"** part states the experimental design and results that would be obtained if the "IF" part were true. The form, more briefly stated is as follows: **IF** (*statement of belief or hypothesis*). **THEN** (*experimental design and predicted results.*) This example is a little oversimplified, but will be adequate for now. Let's limit our experiment to testing the following hypothesis:

HYPOTHESIS:

Candles require and use oxygen from air for continued burning.

There are many ways to test this hypothesis. One way is as follows:



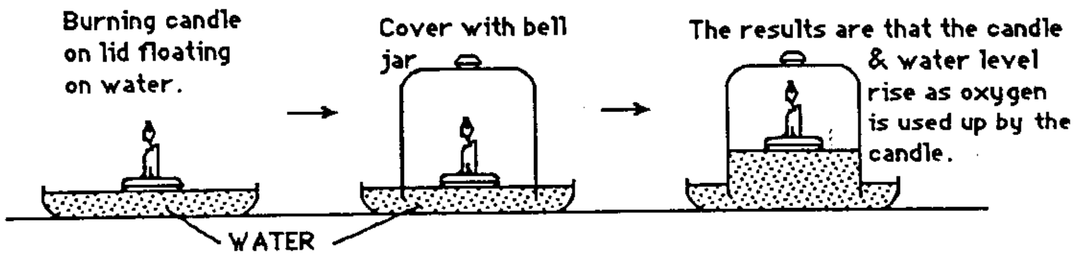
Put the hypothesis above into **IF-THEN** form assuming that you are planning to set up the above apparatus. [___]

---

3. IF candles require and use up only oxygen from the air THEN when a candle is placed in an apparatus like that diagrammed, the measured oxygen leaving will be less than the amount of oxygen entering.

---

4. If you had trouble with the "IF-THEN" form you will have another chance to try again. Remember that the **"IF"** part is a statement of belief or HYPOTHESIS, and the **"THEN"** part is the experimental design and results that would follow if the "IF" portion were true. Another ingenious experiment that can be used to test this hypothesis is diagrammed below: (It takes much less complicated equipment than the experiment in 3.)



Remembering that air is 20% oxygen, the water will rise what % of the way up into the jar? What fraction of the way up is this?

---

4. 20%, 1/5

5. Restate the hypothesis in "IF-THEN" form, so that the hypothesis to be tested applies to the experiment diagrammed above in question 4.

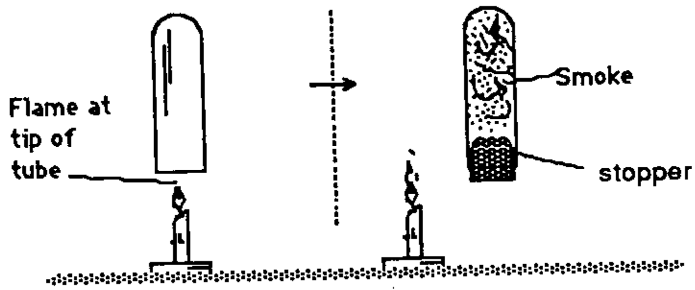
---

5. IF burning candles require and use oxygen, THEN when a burning candle floated on water is covered with a bell jar, the water level will rise 1/5 of the way into the jar to replace the oxygen used by the candle. Then the candle will go out.

---

6. You will do this experiment later, but first you will need to know an additional bit of information that may affect the experimental design. You need to know what substances are produced by a burning candle.

Investigation Procedure:
Locate a test tube in your tray. [___] It must be clean and perfectly DRY inside. [___] Locate the cork or stopper that will fit this tube. [___] Light the candle and set it on a piece of paper towel. [___]



In a test tube, collect some smoke from the burning candle. Use a test tube holder to hold the tube upside down over the flame for about 10 seconds. Lower tube slowly until the tube covers the flame. Allow the flame to touch the inside the edge of the tube. After 10 seconds, cork or stopper the tube as shown. DON'T TOUCH THE LIP OF THE TEST TUBE. IT'S **HOT**. See the drawing above. [___]

Examine the sides of the test tube carefully. You should be able to observe 2 products of combustion. Look CAREFULLY. What 2 substances do you see in the test tube?

---

6. Smoke or carbon. (You should be able to observe some black carbon near the mouth of the test tube.) This is the chemical element carbon. The other product, noticeable on the sides of the glass is water vapor. Notice the tiny droplets near the end of the tube.

---

7. You now know 2 products of combustion. There are 2 more. Open the tube just long enough to pour enough Brom thymol blue indicator into the tube to fill it 1/3 full. Brom thymol blue is yellow when CO_2 is present and blue when there is no CO_2 present. Shake and record your results. [___] What is your interpretation of these results?

How can you rule out the possibility that shaking Brom thymol blue in any test tube gives the same results?

Try your suggestion and record the results. This would constitute a control for the above test. [___]

---

7. The brom thymol blue turns yellow. The interpretation is that the tube contains carbon dioxide produced by the candle. Carbon dioxide is a product of combustion or burning.

   To rule out the possibility that any tube might give a positive test for carbon dioxide from the air, you should have tried the same shake test with a clean tube and clean stopper and found that the brom thymol without smoke in it would not turn yellow.

---

8. Another product of combustion is apparent when you observe the flame. Two obvious forms of energy are being given off. What are they?

---

8. Light and heat

---

9. List all of the **products** of combustion.

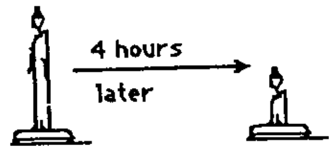
---

9. CO_2, H_2O, carbon (C) and ENERGY (heat & light)

---

10. One REQUIREMENT for combustion is O_2. The second requirement is not difficult to determine. Remember that requirements (or reactants) are used up in the reaction. Consider the following observation of a candle burning in air:

What is this second remaining requirement?



10. Wax (or fuel), which gets burned up in the reaction. The wax does not all melt. Much of it actually vaporizes and changes into the gases CO_2 & H_2O, as well as into carbon (C).

11. Since the process of burning, or combustion, is a chemical reaction, its reactants (requirements) and products can be written in a chemical equation form using pluses and arrows. Copy this form onto your paper and fill-in the blanks:

___ + ___ ----> ___ + ___ + ___ + ___

(Requirements) or reactants / (Products of reaction)

In reading the above chemical equation, the arrow is read as "yields" or "produces". Reread your equation substituting the word "yields" for the arrow. [___]

11. O_2 + fuel (or wax) -----> C + CO_2 + H_2O + ENERGY (heat & light) The products can be in any order. The requirements can also be in any order.

12. The reactants of a chemical equation are usually put on the left of the arrow, with the arrow pointing to the products on the right.

REACTANTS --------> PRODUCTS
(requirements)

The reactants can be placed in any order as long as they remain on the left side of the arrow. The products can be arranged in any order, as long as they remain on the right side of the arrow. Rewrite your equation from question 11 in different order according to the above rule. The equation for combustion is:

12. fuel (or wax) + O_2 -----------> ENERGY + CO_2 + H_2O + C
(any order) (any order)

13. The equation is not yet complete. A complete equation implies that you can combine the reactants and they will react and begin forming the products. Set your candle before you. [___] It is surrounded by oxygen in the air, and yet it does not begin to burn. An obvious missing requirement is a match. The match is called the "starter" or can be referred to as a catalyst. It starts the reaction. In writing an equation, the starter or **catalyst** is written over the arrow. Rewrite the complete combustion equation, including its catalyst, in its proper place. [___]

---

13. fuel (or wax) + O_2 $\xrightarrow{\text{starter (match)}}$ ENERGY + CO_2 + H_2O + C

(any order) (any order)

---

14. Later, you will perform the experiment diagrammed in question 4. DO NOT SET UP THE EXPERIMENT YET. Examine the diagram in question 4 again before reading on. [___] Recall that the results in this candle experiment depend upon the water rising to replace the oxygen used by the burning candle. This assumes that none of the "products" of combustion will replace the oxygen and prevent the water from rising 1/5 of the volume of the container.

What possible product might replace the O_2 used?

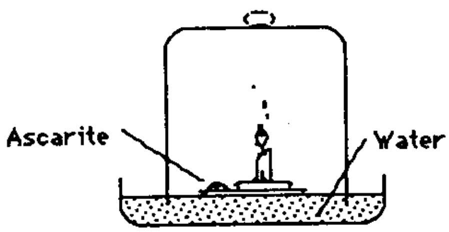
---

14. CO_2 & H_2O vapor

---

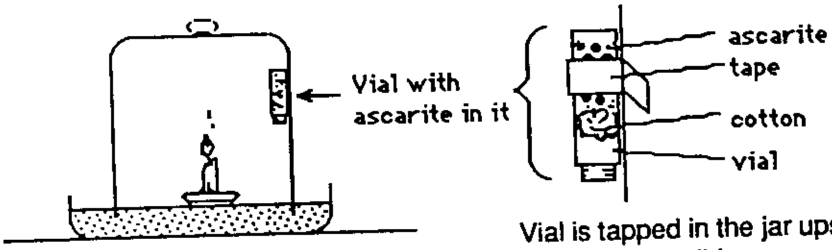
15. If the CO_2 replaces the O_2 used, then one cannot obtain an accurate measure of how much gas from the air was used. It, therefore, becomes important to somehow absorb the CO_2 from the burning candle as it is produced. Chemists use either sodium hydroxide or ascarite, among other substances, to absorb CO_2 from the air. With this new information, how would you re-design the experiment diagrammed in question 4 to absorb the carbon dioxide produced? Diagram the new experimental design with the needed changes. [___]

15.



Since one should not handle ascarite with the hands, we will make a minor change in the above diagrammed experiment.
WARNING: ASCARITE OR SODIUM HYDROXIDE ARE CAUSTIC AND WILL CAUSE SEVERE SKIN BURNS.

The ascarite has been placed in a vial so that you won't have to touch it. Find the vial of ascarite but do not set up the experiment yet. [___] Examine the following diagram and then read on.



Vial is tapped in the jar upside down with the lid removed.

PROCEDURE FOR SETTING UP THE ABOVE EXPERIMENT:

1. Remove the materials from the tray and fill the tray about one-third full of water. [___]
2. Dry the inside of the glass quart jar with a paper towel. [___]
3. Remove the lid from the vial of ascarite and tape the vial to the inside of the jar as in the diagram above. Be sure the vial is taped well. Use at least 3-4 inches of tape. [___]
4. Place the candle on a lid, light it and float it on the water as in the above diagram. [___]
5. Gently cover the burning candle with the jar so the mouth of the jar just touches the water and then gently lower the jar until the jar rests on the bottom of the tray. [___]
6. After the candle has been covered and after it goes out, be sure to wait at least 3 minutes before marking the raised water level with a small piece of tape. It takes a few minutes for the ascarite to absorb all the CO_2 produced by the candle. Also realize that the gases in the jar become heated causing them to expand. A waiting time of 3 minutes also allows the gases to cool and return to normal volume. [___]
7. After you have marked the water level with tape, lift the jar slowly to break the seal. Then remove the vial from inside the jar and replace the cap on the vial. [___]

CALCULATING WHAT PERCENT OF THE AIR WAS USED BY THE CANDLE: Interdisciplinary Math-Science Activity

16. Since the jar holds the same amount of water as it does air, how would you determine how much air the jar holds?

16. A jar will hold the same amount of water as it will hold

air. Therefore, to determine the volume of the jar, fill the jar with water and using a graduated cylinder, measure the amount of water required to fill the jar. (Determine this later.)

---

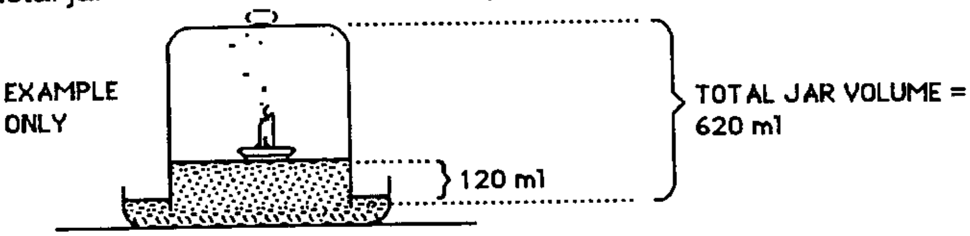
17. When you know the total volume of the jar, you need to know the volume of the water that rose to the tape mark. How would you go about determining this volume?

---

17. The easiest way is to measure how much water fills the jar to the tape mark. Then subtract this from the total volume of the jar. (Determine this later.)

---

18. Let's look at an example of how to do this by using sample numbers. To find what % of the total jar volume the risen water represents:



If the numbers indicated in the diagram were obtained by the procedures just described, we could use them to determine the volume of gas used by the candle. What % of 620 ml is 120 ml?

---

18. (120 /620) X 100 = 19.3 %

---

19. If the candle burned up all the oxygen in the air, what % would be obtained in the above calculation?

---

19. 20% (Since the air is about 20% oxygen, the water would rise close to 20% of the total volume.)

---

20. Calculate the percentage for the data you obtained in your experiment with the burning candle. To do this you will need to find the **total volume** of your jar and the volume represented by the water rise. Review frames 16-20 if necessary. [   ]

---

20. The answer will depend upon your data. You might double check the math to rule out a math error.

---

21. Is your answer close to 20%? If it is not explain why this might be.

---

21. The answer should be between 16 and 24%. If it is not, there are several explanations such as: normal variations, experimental error, measuring errors, and math error.

---

22. If the candle used up nitrogen (N_2) instead of the O_2 in the air, how far would the water have risen into the jar?

---

22. 79% or 80% or 4/5 of the way, since air is about 80% N_2.

---

23. The "IF-THEN" hypothesis from question 5 was, "IF burning candles require and use oxygen, THEN when a burning candle, floated on the water, is covered with a bell jar, the water level will rise 1/5 of the way into the jar to replace the oxygen used by the candle. Then the candle will go out." From your experimental data, what is your conclusion regarding this hypothesis?

---

23. The hypothesis is SUPPORTED if you obtained close to 20% for your answer. Note that it is not appropriate to say that the hypothesis is "proven." It takes many more experiments like this one and many quite different from this one to be able to say we have proven that candles require and use O_2.

---

24. Notice that the "IF" part says that candles use O_2 (which is 20% of the air). The "THEN" part says that if the "IF" part is true, then a certain event will follow. This event did follow in the experiment, so the "IF" portion of the hypothesis is SUPPORTED. Clean up all materials that you used. [___] Return all materials to their tray. [___]

---

25. As a review write the chemical equation for combustion.

starter (match)

25. O_2 + fuel (or wax) -----------> $CO_2 + H_2O$ + C + energy in the form of heat and light

26. In any chemical equation, the reactants are on which side of the arrow?

26. Left side of the arrow

27. In the following equation, name the products. H_2O ---------> $O_2 + H_2$

27. $O_2 + H_2$

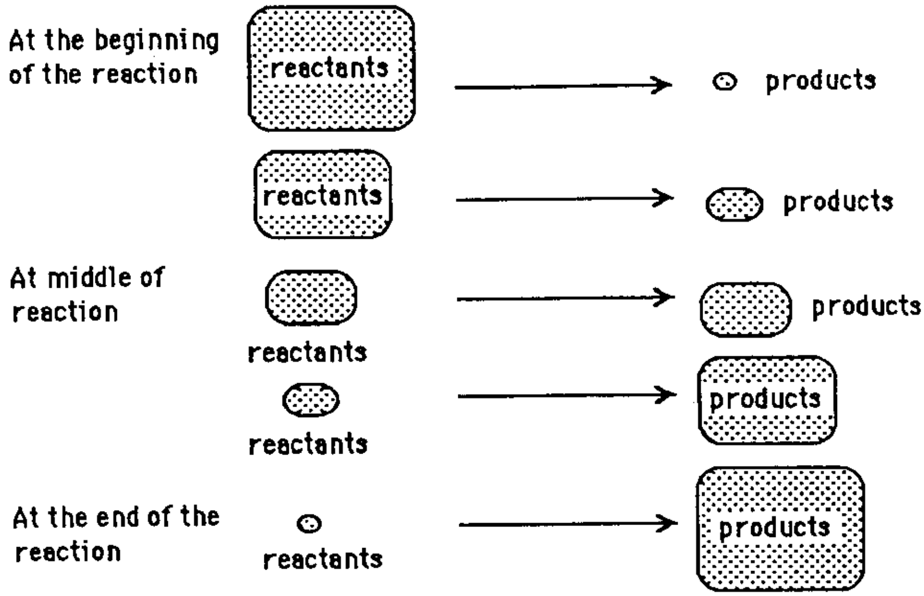
28. In an equation like combustion, which materials get used up?

28. The reactants get used up. In the case of combustion, this will be O_2 and the wax. When the reaction is complete, there will be very little or no wax left. A considerable amount of O_2 will be used up.

29. As chemical reaction proceeds, what happens to the quantity of the products?

29. The products <u>increase</u> in amount.

30. The changing amounts of reactants and products in a chemical equation can be diagrammed as follows:



31. Label the reactants and products in the following reaction:

$O_2 + H_2$ <------- H_2O

31. $O_2 + H_2$ <------- H_2O
(products) (reactants)

32. This equation is the same equation that was in question 27, but written a little differently. Remember that question 12 explained that the arrow points to the products. Sometimes it is useful to show the arrow direction reversed as in 31. Then the products are on the left and the requirements on the right. An example of arrow reversal, follows:

H_2O -------> $O_2 + H_2$
(water breaks down into the products O_2 and H_2)

H_2O <-------- $O_2 + H_2$
O_2 and H_2 can be recombined to produce water by lighting the reactants O_2 and H_2.

Sometimes an equation will be written to show that a reaction can proceed in both directions as follows: $H_2O \rightleftharpoons O_2 + H_2$

This combines both of the equations above and says that water can break up to form oxygen and hydrogen, and that the O_2 and H_2 can combine to form water. This is referred to as a **REVERSIBLE REACTION**. The reaction can proceed in one direction then reverse and go back in the other direction.

Most equations you will see will be in the common form below:

Reactants --------> Products

Here the reactants are on the <u>left</u> of the arrow and the arrow points to the right, where the products are found. At times you will see reversible reactions signified by: $\rightleftarrows$

32. When one sees a reaction written as follows: A $\longrightarrow$ B + C , it means (choose one)

    a. A can change into B & C
    b. B & C can change into A
    c. both of the above

---

32. a

---

33. If one sees a reaction written as follows: A $\rightleftarrows$ B + C, it means (choose one)
    a. A can change in B & C
    b. B & C can change into A
    c. both of the above

---

33. c

---

34. At the beginning of the reaction, A $\longrightarrow$ B + C , it was measured that A = 12 g, B = 1 g and C = 1.5 g.

    As the reaction continues, (choose one)
    a. A will increase and B will decrease
    b. A will increase and B will increase
    c. A will decrease and B will decrease
    d. A will decrease and B will increase
    e. A will decrease and B will stay the same

---

34. d

---

35. Review the objectives at the beginning of this lab investigation as you begin reviewing for the quiz.

5-7  Summary of the Cyclic Nature of the Scientific Process and Continued Inquiry

Objective

You will be expected to list the steps of the scientific process in order and explain how these steps were used to discover the details of respiration and combustion.

1. What are the first two steps in the scientific inquiry process and what is stated in each step?

Read the following examples of how each step in the scientific process was used to historically discover the details of respiration and combustion. Notice how the steps are repeated over and over to obtain a more complete understanding.

<u>ORDER OF INQUIRY</u>	<u>EXAMPLES</u>
INITIAL PROBLEM:	Do mice or candles require some substance in air?
HYPOTHESIS:	Mice and candles do require something found in air.
AN EXPERIMENT IS DESIGNED	An experiment was planned to test the initial hypothesis by placing a candle or mouse in a sealed container.
INTERPRETATION OF RESULTS:	Mice and candles require "something" found in air.
CONCLUSION:	The initial hypothesis was supported (not proved)
NEW PROBLEM:	What is it in the air that candles (or mice) require?
NEW HYPOTHESIS:	No new hypothesis could be formulated until we get more information about the nature of air. When this information became available, a new hypothesis was possible.
GET MORE INFORMATION:	(Air is a mixture of oxygen, nitrogen and carbon dioxide and rare gases.)

NEW HYPOTHESIS: Candles and mice require the component of air known as O_2.

NEW **EXPERIMENTAL DESIGNS** TO TEST THE **NEW HYPOTHESIS:**

1) Measure the O_2 entering and leaving a sealed container which has a burning candle inside
2) Floating candle experiment
3) Priestley's and Lavoisier's experiments
4) Many other experiments have been performed

INTERPRETATION: Burning candles and mice require O_2.

CONCLUSION: Hypothesis is supported.

NEW PROBLEMS: Is O_2 the only requirement?
What substances are products of this process?

OBSERVATIONS: Various observations of burning candles will lead to new hypotheses and experimental designs.

New experiments revealed each requirement and product for both the combustion and respiration reactions.

NEW INTERPRETATIONS: The products of combustion were concluded to be CO_2, H_2O, C and Energy. These interpretations led to an overall CONCEPT.

CONCEPT: In this case the concept was written as an equation. "The concept of combustion" O_2 + Fuel --------> CO_2 + H_2O + C + Energy

NEW PROBLEMS: Where does the energy given off in combustion come from? Is it stored or locked within the fuel, in the O_2, or both? Where does the CO_2, water vapor, and energy come from? Do they come from the fuel or O_2? Do mice and other living things carry out similar processes? Does fuel in combustion actually disappear, or does it get converted to something else? If students were asked to offer hypotheses that might answer these questions, they would have considerable difficulty. Sometimes scientists do not have enough knowledge to be able to formulate a testable hypothesis. Therefore, when this occurs, the next step would be to **COLLECT MORE DATA** AND INFORMATION.

In our case, the information needed in order to be able to offer new hypotheses that might answer the new problems, is information that chemists have provided. Therefore, to be able to understand how living things (or candles) obtain or produce energy, you will need to understand some basic concepts of chemistry. It is apparent that the combustion reaction is chemical in nature. Some of the next laboratory and text activities are designed to provide you with the basic chemistry needed to proceed in

your study of biology. Once you have this information,
NEW HYPOTHESES will be formed.
NEW EXPERIMENTAL DESIGNS and
NEW INTERPRETATIONS will follow.
NEW CONCEPTS will be formed. And of course, out of these new concepts,
NEW PROBLEMS will arise.
AND SO CONTINUES THE "NEVER ENDING" INQUIRY PROCESS IN SCIENCE.

2. List all of the steps in the scientific processes in order.

3. Explain or give an example of how the conclusion from one experiment leads to a new problem.

4. Describe as many experiments as you can that established our understanding of what the requirements and products are for combustion. Refer to earlier pages in this chapter if necessary.

5-8 Laboratory Investigation

Compounds, Molecules and Atoms

Objective
Demonstrate on a quiz that you can:
1. Construct models of common elements and compounds
2. Determine a compound's formula by constructing a model of the molecule
3. Distinguish between elements and compounds
4. Describe the difference between single and double bonds
5. Give examples of empirical and structural formulas

On your lab table are colored ball sets that represent atoms. The springs will be used to hold the atoms together and represent bonds. Locate a container of red, white and black atoms and a container of springs. [___]

The BLACK atoms are **CARBON**.
RED atoms are **OXYGEN.**

WHITE atoms are **HYDROGEN.**
Write this code down at the top of your paper for later reference.[___]

WORK INDEPENDENTLY

Notice that each different atom sphere has a different number of holes in it. This indicates how many other atoms that particular atom can "bond" to (or join to).

1. Examine the hydrogen atom. How many other atoms can it bond to?

---

1. 1 (Since the white hydrogen atom has only 1 hole in it)

---

2. Examine the oxygen and carbon atoms, and indicate how many other atoms each of these can bond to.

Oxygen can bond to ___ other atoms.
Carbon can bond to ___ other atoms.

---

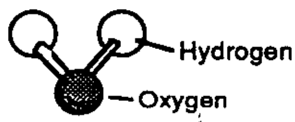
2. Oxygen 2
Carbon 4
Since this is how many holes each of these have.

---

3. Make a water molecule. (H_2O) You will be able to figure out how it goes together. There is only one way. Use springs to connect the atoms. [___] Save it and read on.
(You will be making a number of different molecules as you continue. Do not disassemble them until told to do so.)

---

3. The water molecule you built should look like the drawing at the right.



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4. In making any molecule, it is important to push quite hard to get the springs to stick in and hold the atoms together. The springs in your molecule of water represent "single" bonds. In any complete model of a molecule, all holes must be filled if the model's correctly put together.

Do you find any unfilled holes in this H_2O molecule?

4. You should not.

5. Notice that the number of holes in O, and in H determine the formula for water, H_2O. Any other combination would be unlikely. By studying the results of many experiments, chemists are quite convinced that carbon, hydrogen and oxygen each bond with the number of atoms stated. In any formula for a molecule, what does the small number after the atom's symbol indicate? (as in H_2O)

5. The small number after an atom indicates how many atoms of that kind are in the molecule. In the H_2O example, a water molecule is composed of 2 atoms of H and 1 atom of O.

6. In glucose ($C_6H_{12}O_6$) there are how many atoms of carbon in the molecule?

There are how many atoms of H in one molecule of glucose?

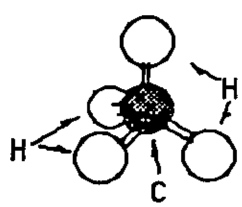
There are how many atoms of O in "two" molecules of glucose?

Remember to save the H_2O molecule.

6. 6, 12, 12 (2 X 6 atoms of O in each molecule)

7. When C and H react, under the proper conditions, they can form natural gas, which is called methane. You can determine the formula for the methane molecule by making one. Begin by trying to combine C and H in any way that you can. Remember that all holes must be filled when you are done. Use any number of atoms of each kind that will be needed. [___]
Remember to use the correct colors. [___]
When finished compare your product with the answer.

7.



8. In examining the molecule, the formula would be CH_____

8. CH_4

9. It might seem that the formula for methane could be written H_4C or that glucose could be written $H_{12}C_6O_6$, but chemists have agreed that for these kinds of molecules, that the symbols will be ordered alphabetically, therefore the correct order is CH_4 and $C_6H_{12}O_6$, and for water its H_2O not OH_2. Save this CH_4 molecule. [___]

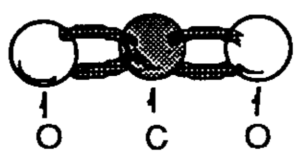
Now build an oxygen molecule. Its formula is O_2 and this molecule's construction will require a novel solution. Remember to have all holes filled. [___]

9. Oxygen (O_2)

This fills all holes and produces what is called a "double bond". It is stronger than a single bond. If your oxygen molecule does not look as the drawing does, fix it. [___]

10. Save the O_2 molecule. Now make a carbon dioxide molecule (CO_2). This molecule will contain double bonds also. Remember to check your completed molecule to be sure that no holes remain unfilled. [___]

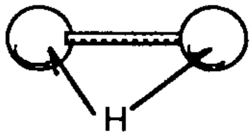
10. CO_2



11. Place all of the molecules that you have made before you. [___] All 4 of the models are MOLECULES. Write a definition of MOLECULE based on past knowledge and what you see before you. [___]

Also make a hydrogen molecule. [___]

11. A MOLECULE is 2 or more atoms bonded together.
(The atoms can be different as in H_2O or the same as in O_2)
The hydrogen molecule you made should look like the following:



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12. The distinction between an element and a compound should be observable.
Separate your molecules as follows:

compounds	elements
CO_2	O_2
H_2O	H_2
CH_4	

Notice the difference between the elements O_2 and H_2 and the compounds CO_2, H_2O and CH_4 and write a definition for the terms COMPOUND & ELEMENT on your paper.

---

12. COMPOUND: Two or more different elements chemically united in definite proportions. Compounds can be separated into different elements. ELEMENT: a pure substance that cannot be divided into simpler substances.

---

13. Notice that an important part of the definition of a compound is that the elements are combined in definite ___. H_2O is always 2 parts H and 1 part O and never 1 part H and 2 parts O, or any other definite proportion than 2 parts H and 1 part O.

---

13. proportions

---

14. Is hydrogen a compound or an element? Explain your answer.

---

14. H_2 is an element because H_2 is a pure substance and cannot be separated into 2 different kinds of substances.

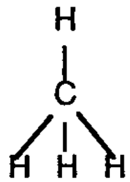
15. Another way to write the formula for H_2O is to show its structure as follows:

```
  H
 /
O        This is the "STRUCTURAL FORMULA" for water.
 \
  H
```

Each atom is symbolized by its letter and single lines show the 2 "single" bonds that hold the molecule together. Draw the STRUCTURAL FORMULA for H_2 and CH_4 below:

---

15. H-H,



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16. The structural formula for O_2 is O=O. The "double" bond is illustrated with 2 lines connecting the 2 O's. Draw the STRUCTURAL FORMULA for CO_2 below: (Look at your model of the CO_2 molecule.) Each spring represents a bond. [___]

---

16. O=C=O

---

17. O=C=O is the "structural formula" for carbon dioxide and CO_2 is called the "empirical formula" for carbon dioxide. The empirical formula simply shows the atoms or elements present in the molecule and their proportions, but does not show the detailed structure as does the structural formula. The formula for the sugar glucose was given earlier as $C_6H_{12}O_6$. What kind of formula is this?

---

17. Empirical formula

---

18. The structural formula for glucose would show the <u>position</u> of each atom and would show exactly how each atom is bonded to each other. In a later lab investigation you will make a glucose molecule, so its structural formula is important. How many C atoms in a glucose molecule?
How many H atoms in a glucose molecule?
How many O atoms in a glucose molecule?

18. 6, 12, 6

19. Review the objectives at the beginning of this topic and see if you are prepared for the quiz over this topic.

5-9 From Priestley to Present Day: Elements, Compounds and Mixtures

1. Give an example of an element, a compound and a mixture.

Objectives

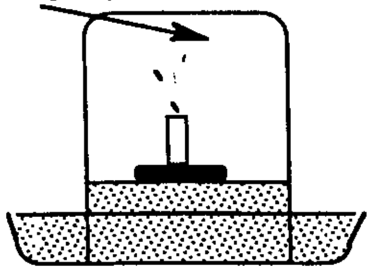
List the different components found in air
Distinguish between elements, compounds and mixtures
Describe what information the atomic number provides about an atom

You will recall that in the early 1770's, Joseph Priestley concluded that mice and candles require "something" in the air. Priestley later discovered that this required gas was **oxygen (O_2)**. We now know that all animals, not just mice, require oxygen for the respiration process. Since all of the air in Priestley's apparatus was not used by the mice and candles, he concluded that what remained must be some other gas or gases. Chemists have since determined the exact composition of air.

The Composition of Air:

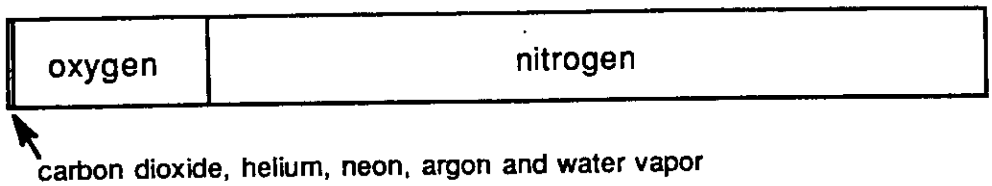
Air is an amazing substance. We often take if for granted. When we breathe its life-giving oxygen, we also breathe in any pollutants that are in it. In some cities in industrialized nations, air pollution is so bad that authorities have to issue warnings to stay indoors on specified days.

Pure air is a colorless, odorless, tasteless gas. It is all around us and dissolves in oceans, lakes and streams, providing oxygen to aquatic organisms. It fills spaces in the top soil, supplying plants and other organisms with the gases they require. Air actually has weight. A balloon filled with air weighs more than an unfilled balloon. When Priestley and Lavoisier removed the oxygen from the air, the gas that was left made up about 80% of the volume of the original air. Later, chemists identified and named this remaining gas as **nitrogen (N2).**



Chemists have also shown that air contains about 0.03% to 0.04% **carbon dioxide (CO2).** Recently scientists and the general population have become concerned about additional amounts of carbon dioxide released into the air from the increased burning of coal, gasoline, natural gas, oil and wood. There is evidence that increased carbon dioxide in the air causes a warming of the atmosphere by a phenomenon known as the "greenhouse effect." Traces of such gases as **helium, neon, argon** and **water vapor** are also found in air.

The amount of water vapor in air varies from area to area and from season to season. In some areas of the United States, 90% humidity is not uncommon. When the air contains all of the water vapor that can possibly saturate the air at that temperature and pressure, this is referred to as 100% humidity. In desert areas or other dry areas of the country, 0% humidity can be measured. The composition of air can be diagrammed as follows:



2. What is the most abundant gas found in air?
3. Which gas would vary the most from one sample of air to another?
4. Name all gasses normally found in pure air.
5. Where on the earth would you predict that one could find the purest air?

The Elements

Webster defines an element as "...one of the essential parts of anything." The ancient Greeks described the earth as made up of **four elements** that were the foundation of everything. They were identified as water, air, fire and earth. The ancient Greeks were correct in stating the **elements** were the foundation of everything. They did not realize that there were 92 of them occurring naturally. Oxygen, nitrogen, carbon and hydrogen are elements. Iron, gold, silver, copper and tin are elements. There are 84 others. Some are common and others not so common. The earth, water, atmosphere, sun and stars, and in fact all forms of matter, are composed of elements. **Elements** are, as Webster states, "...the essential parts of anything." A list of the 92 naturally occurring elements follows. Read each element name and attempt to pronounce each of the following 92 elements:

1 Hydrogen	24 Chromium	47 Silver	70 Ytterbium
2 Helium	25 Manganese	48 Cadmium	71 Luterium
3 Lithium	26 Iron	49 Indium	72 Hafnium
4 Beryllium	27 Cobalt	50 Tin	73 Tantalum
5 Boron	28 Nickel	51 Antimony	74 Tungsten
6 Carbon	29 Copper	52 Tellurium	75 Rhenium
7 Nitrogen	30 Zinc	53 Iodine	76 Osmium
8 Oxygen	31 Gallium	54 Xenon	77 Iridium
9 Fluorine	32 Germanium	55 Cesium	78 Platinum
10 Neon	33 Arsenic	56 Barium	79 Gold
11 Sodium	34 Selenium	57 Lanthanum	80 Mercury
12 Magnesium	35 Bromine	58 Cerium	81 Thallium
13 Aluminium	36 Krypton	59 Praseodymium	82 Lead
14 Silicon	37 Rubidium	60 Neodymium	83 Bismuth
15 Phosphorus	38 Strontium	61 Promethium	84 Polonium
16 Sulfur	39 Yttrium	62 Samarium	85 Astatine
17 Chlorine	40 Zirconium	63 Europium	86 Radon
18 Argon	41 Niobium	64 Gadolinium	87 Fancium
19 Potassium	42 Molybdenum	65 Terbium	88 Radium
20 Calcium	43 Technitium	66 Dysposium	89 Actinium
21 Scandium	44 Ruthenium	67 Holmium	90 Thorium
22 Titanium	45 Rhodium	68 Erbium	91 Protactinium
23 Vanadium	46 Palladium	69 Thulium	92 Uranium

It is not necessary to memorize a list of elements. The list serves as a reference.

6. Scan the list of elements and make a list of those that you recognize as common metals.

The number before each element is the element's **atomic number.** The atomic number tells us, among other things, how many protons are in the nucleus of each element's atoms. It also tells us the number of electrons in the atom when it is in its neutral state. Notice that no two elements have the same number of protons. Each element is unique and different from all the rest.

7. How many protons in oxygen? In carbon?

8. How many electrons in Uranium? In hydrogen?

Chemists define an **element** as: **A pure substance composed of atoms of only one kind.** When we say something is "elementary", we mean that it is simple. It is not complex. Gold is an element. It consists of one kind of atom only. A visible piece of gold is made of millions of individual atoms. All the atoms of gold are the same. An element cannot be divided into simpler elemental substances. Water (H_2O) is, therefore, not an element. Notice by its formula that H_2O is not made up of only one kind of atom. It can also be divided into two different elemental substances; hydrogen and oxygen. Water is a **compound.**

There are 92 "naturally occurring" elements. This means that they are found in the earth, oceans, atmosphere and in stars and our sun. Using nuclear reactors, scientists have created a number of additional elements. Some of these are 94 Plutonium, 98 Californium and 101 Mendelevium. They are not "naturally occurring" elements but elements nevertheless.

Biology students should be able to recognize the more common elements by their symbols. Elements commonly referred to in biology and high school science classes and their symbols are listed below:

1 Hydrogen	H	25 Manganese	Mn
2 Helium	He	26 Iron	Fe
3 Lithium	Li	27 Cobalt	Co
4 Beryllium	Be	28 Nickel	Ni
5 Boron	B	29 Copper	Cu
6 Carbon	C	30 Zinc	Zn
7 Nitrogen	N	47 Silver	Ag
8 Oxygen	O	50 Tin	Sn
9 Fluorine	F	74 Tungsten	W
10 Neon	Ne	79 Gold	Au
11 Sodium	Na	80 Mercury	Hg
12 Magnesium	Mg	82 Lead	Pb
13 Aluminium	Al	92 Uranium	U
14 Silicon	Si		
15 Phosphorus	P		
16 Sulfur	S		
17 Chlorine	Cl		
18 Argon	A		
19 Potassium	K		
20 Calcium	Ca		

Notice that many element symbols are created from the first letter of the element's name; hydrogen **H**, oxygen **O**, carbon **C**, nitrogen **N**, phosphorus **P** and uranium **U.** Many elements' symbols are composed of the first two letters such as **He** for helium or **Ca** for calcium.

9. Make a list of all elements and their symbols from the above list that are not symbolized with the first or first two letters of the element's name.

10. What might be the reason for not using the first letter or first two letters of the element's name for the symbols for these elements?

You should learn the element symbols for at least the following elements:

1 Hydrogen	H	20 Calcium	Ca
6 Carbon	C	25 Manganese	Mn
7 Nitrogen	N	26 Iron	Fe
8 Oxygen	O	29 Copper	Cu
12 Magnesium	Mg	30 Zinc	Zn
13 Aluminium	Al	47 Silver	Ag
15 Phosphorus	P	80 Mercury	Hg
16 Sulfur	S	82 Lead	Pb
17 Chlorine	Cl	92 Uranium	U

11. What is the chemist's definition of an element?

Compounds

Webster defines compound as "... composed of a number of parts: not simple." Chemists define **compound** as: **A chemical substance composed of two or more different elements. The elements are united to one another in definite proportions for each compound.** Water (H_2O) is a compound. It is composed of two elements, hydrogen and oxygen. The two elements are combined as a ratio of 2 parts hydrogen and 1 part oxygen. If the same two elements were combined as 2 parts hydrogen and 2 parts oxygen (H_2O_2), the resulting compound would be hydrogen peroxide, a powerful bleach, and not water at all. **A compound can be separated into simpler substances.** Water, for example, can be separated into its separate elements by a process called electrolysis. Pass electricity through a specially prepared beaker of water and the H_2O will change to hydrogen (H_2) and oxygen (O_2) gases.

12. If in an electrolysis experiment, when water was separated into H_2 and O_2, 20 mL of oxygen gas was produced, how many mL of H_2 gas would be produced in the experiment?

13. What is the ratio of elements in each of the following compounds CO_2, H_2SO_4, HCl and $C_6H_{12}O_6$?

Compounds are divided into two types. There are organic and inorganic compounds. Organic compounds are of special importance to biologists, since all living things are made up largely of organic compounds.

An organic compound is a chemical compound that contains carbon <u>and</u> is made by living organisms. Sugar, starch, protein and fat molecules all contain carbon and are all made by living cells and are appropriately called **organic compounds.**

Inorganic compounds are not made by living organisms <u>and</u> do not contain carbon. Inorganic compounds make up the earth's crust, oceans, lakes, rivers and stars. Examples of inorganic compounds are salt (NaCl), hydrochloric acid

(HCl), iron oxide (FeO), iron chloride (Fe_2Cl_3), magnesium chloride ($MgCl_2$), copper chloride ($CuCl_2$) and many others.

14. Which of the following are organic compounds and which are inorganic?
    Potassium sulfate (K_2SO_4), mercuric oxide (HgO), glucose ($C_6H_{12}O_6$), Potassium chloride (KCl), ethyl alcohol (C_2H_5OH), sulfuric acid (H_2SO_4)

Mixtures

A mixture is a combination of elements and/or compounds where the components are not chemically united and are in no definite proportions. The components of a mixture can be physically separated. For example, when iron (Fe) filings are mixed with sulfur (S), they can be separated by a magnet. Hold a magnet near the mixture and the iron will be attracted to the magnet, leaving the sulfur. Sulfur can be mixed with iron in any ratio, and the result will still be a mixture. The sulfur and iron are not chemically united to each other.

Air is a mixture. The gases in air are not chemically united, and the proportions can vary.

15. What are the gases that make up the mixture known as air?

5-10 Molecules and Atoms

1. Which is smaller, an atom or a molecule? Explain.

Objective

Define "molecule," and give examples of a few common molecules.

Molecules are Made of Atoms

A molecule is composed of two or more atoms bonded in definite proportions. The atoms that make up a molecule can be the same as in molecules of H_2, O_2 and N_2. The atoms can be different as in molecules of CO_2, H_2O and NaCl.

Examine the four molecules drawn at the right.

A molecule is the smallest unit of a compound or element that still has properties of that compound or element. The distinction between compound and molecule is often confused by beginning students in science. Remember a compound is a chemical substance composed of two or more different elements. The elements are united to one another in definite proportions for each compound. This definition might appear to be almost the same as the definition for molecule. The following examples might help you to better understand the difference. Water (H2O) is made up of two elements. It is also made up of two different atoms. It would be correct to refer to a glass of water as containing the **compound water**. It is not correct to say we have a molecule of water in the glass. If one could isolate the smallest unit of water that still has all the properties of water, this would be properly referred to as a **molecule of water.**

2. Which would be more correct, to refer to a teaspoon of table sugar (C12H22O11) as an element, molecule or compound? Explain.

5-11 In-Depth Enrichment: Details of Atomic Structure

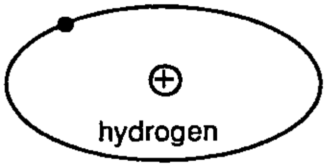
1. What particles are found in the nucleus of an atom and what are their electrical charges? What particle is found revolving around the nucleus and what is its electrical charge?

Objective

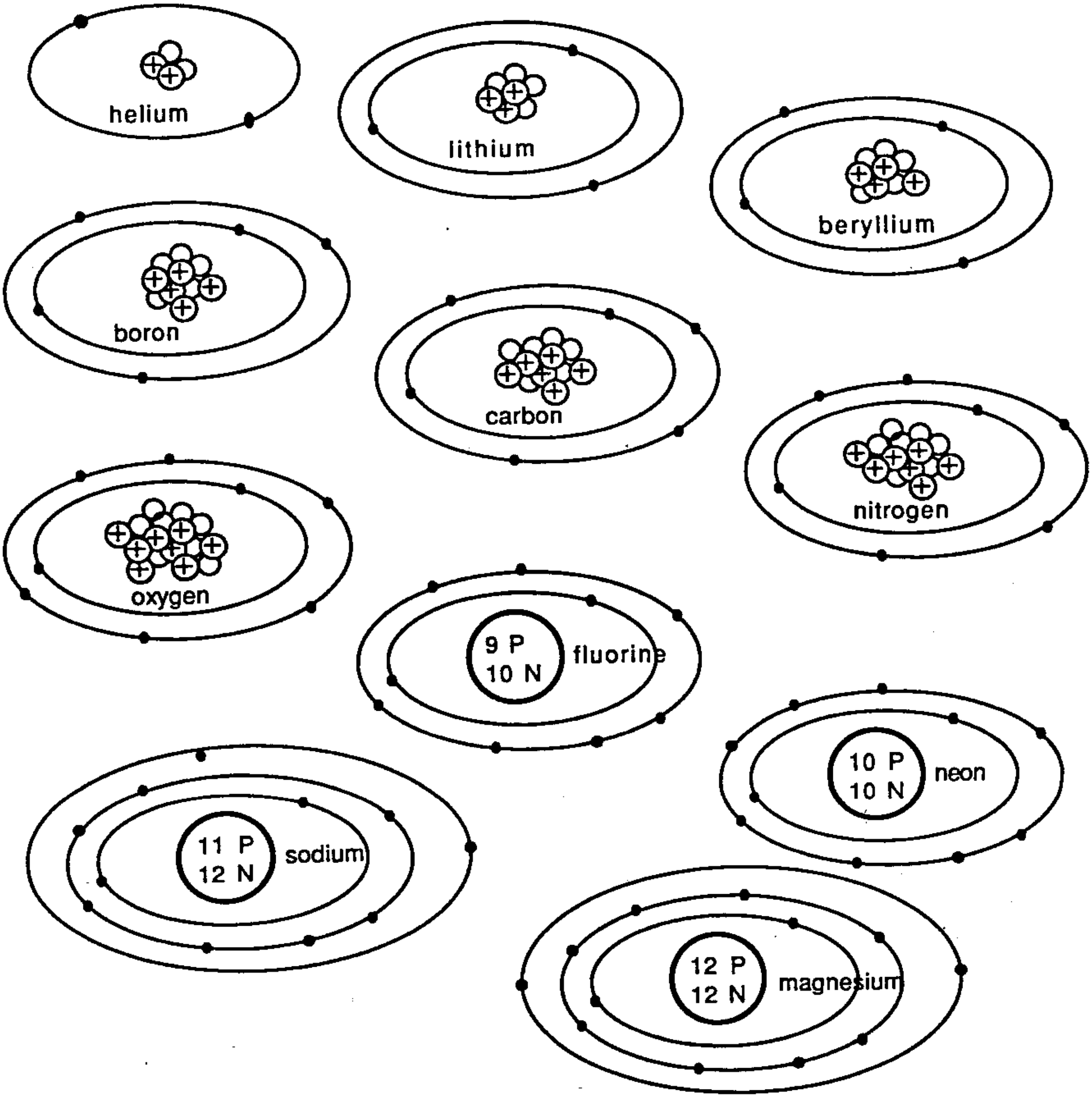
You will be expected to state the rules that describe the maximum number of electrons to be found in each electron orbit. You will also be expected to describe how each element's atomic structure is different.

Atoms, in one sense, are ageless. Almost all of the atoms present when the earth was first formed are still here. Atoms combine with other atoms and then recombine again. This is what happens in chemical reactions. The same atoms can be involved over and over again. They bond to one kind of atom and then to another. Isn't it amazing to realize that the entire universe, including all living and non-living things on earth, are made up of three primary particles: protons, neutrons and electrons! It is the ways in which they are combined that make the difference. How atoms bond to one another determines what compounds are common and how they will react with other compounds. To understand chemical bonding, one must first understand how the electrons are distributed in layers or shells around the nuclei of atoms.

Let's first look at the smaller atoms. The smallest atom is hydrogen. Hydrogen has an atomic number of 1. You might remember that some forms of hydrogen exist with one neutron in addition to the proton. A third form has two neutrons and one proton in the nucleus. These two forms of hydrogen are called **isotopes** of hydrogen. Most isotopes are radioactive. An **isotope** is a form of an element with the same number of protons as the abundant form but has different numbers of neutrons than found in the abundant form.



Study the following drawings of atoms with atomic numbers of 2 through 8.



Atoms Have Energy
The preceding diagrams show the electrons in shells. The electrons are in constant motion around the nucleus. They occupy certain regions near or further out from the nucleus. The closer the electrons are to the nucleus, the less energy they have. Those electrons farther away from the nucleus have greater energy. To help explain bonding of atoms, scientists have developed the **shell model of the atom.** According to this model, atoms are visualized as having electrons arranged in successive spherical shells.

Answer the following questions based upon the preceding atom diagrams.

2. What is the atomic number of oxygen?

3. Are there any of the diagrammed atoms that do not have the same number of electrons as protons? If so name the atom(s).

4. Are there any of the diagrammed atoms that do not have the same number of neutrons as protons? If so name the atom(s).

5. What is the maximum number of electrons found in the innermost shell (first shell) of any atom?

6. What is the maximum number of electrons found in the second shell of any atom?

7. What is the maximum number of electrons found in the third shell of any atom?

If you answered the last three questions correctly, you have discovered an important principle and rule based upon the shell model of the atom. These important rules are as follows:

> The **first shell** of an atom contains up to a maximum of **2 electrons.**
> The **second shell** of an atom contains up to a maximum of **8 electrons.**
> The **third shell** of an atom contains up to a maximum of **18 electrons.**
> (The first orbit or sub shell of the third shell contains up to a maximum of 8 electrons.)

You may not have gotten the answer correct for question 7 above because the atoms diagrammed did not have enough electrons to illustrate that the third shell can hold a maximum of 18. To complicate matters, the first sub shell or orbit in the third shell contains a maximum of 8 electrons.

Notice that if we could add one proton and one electron to hydrogen, it would become helium. Add one proton, and electron to helium and it would become beryllium, and so on. Atoms (between atomic number 1 and 20) are most stable when the outer shell has 2 in the first orbit or 8 in the second and third orbit.

8. How is each element's atomic structure unique and different from every other

element?

9. What is an isotope?

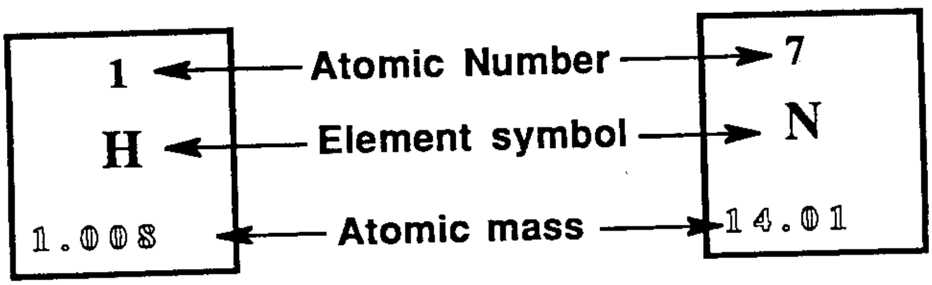
5-12 In-Depth Enrichment: Using the Periodic Chart of the Elements to Determine Atomic Structure

1. What information does the Periodic Chart of the Elements provide?

Objective

You will be expected to use the periodic chart of the elements to determine how many protons, neutrons and electrons are in the first 20 elements.

Examine the PERIODIC CHART in appendix D at the end of the manual . Glance over the symbols and numbers and notice that the elements are arranged in rows designated as I, II, III, IV, V, VIII. [___] Find the elements hydrogen (symbol H) which in number 1 and nitrogen, atomic number 7. You will see 3 designations in each square. The following examples show the designations provided for each element:



The **atomic number** tells us the number of protons in the element. It also tells us the number of electrons in the neutral atom. The **atomic mass** tells us the mass of the atom. On earth, this is the weight in **atomic mass units.** Hydrogen weighs 1 atomic mass unit and nitrogen weighs 7 atomic mass units. Nitrogen weighs 7 times the weight of hydrogen. This is because each proton weighs one atomic mass unit. Remember that the electron is 1/1835th the size of the proton and its mass adds little to the weight of the atom. Since the neutron is the same size as the proton, it also weighs one atomic mass unit.

Nitrogen has seven protons and seven neutrons in its nucleus. Since each proton and neutron weigh one atomic mass unit, the weight of a nitrogen atom is fourteen atomic mass units because nitrogen has seven protons and seven neutrons. Notice that the atomic mass shown on the periodic chart for nitrogen is 14.0067, which is close to fourteen. The reason that the number is slightly more that fourteen is because 14.0067 is an average mass for all forms of nitrogen including the isotopes. Some isotopes have eight neutrons and when these are averaged with the thousands of atoms with seven neutrons, the average is 14.0067. This is also true for the other atoms. One can generally subtract the atomic number from the nearest whole number to the atomic mass and obtain the number of neutrons in an atom. For example:

Nitrogen atomic mass =	14	(nearest whole number to 14.01)
Nitrogen atomic number =	7	= the number of protons
Difference	7	= the number of neutrons

Hydrogen atomic mass =	1	(nearest whole number to 1.008)
Hydrogen atomic number =	1	= the number of protons
Difference	0	= the number of neutrons

Use the Periodic Table in Appendix D to answer the next few questions:

2. Now find the element calcium (symbol Ca) which is number 20. You will see 3 numbers in the Ca square. Which number represents the atomic number?

3. Which number in the Ca square represents the atomic mass?

4. How many protons does Calcium have?

5. How many electrons does Ca have? How many neutrons?

6. The symbol for potassium is K. It's # 19 on the chart. How many protons in K? How many neutrons and electrons?

7. List the number of protons, neutrons and electrons in helium, lithium and chlorine.

8. Draw diagrams of the following atoms showing the number of protons, neutrons and electrons in correct number of orbits according to preceding rules: magnesium, sodium, chlorine

9. How many electrons are in the outer orbits of each of the atoms listed in 8 above and how does this correspond to the column number in which they are located on the periodic chart?

10. How many electrons are in the outer orbits of hydrogen, carbon and oxygen and how does this correspond to the column number in which they are located on the periodic chart?

11. What appears to be the relationship between the number of electrons in the outer orbit of an atom and the periodic chart column number in which they are found?

5-13 Ions: The Charged Particles of the Universe
In-Depth Enrichment

1. Ions are like small charged magnets. They can attract and repel each other. What happens when you place the positive ends of two magnets together?

2. What happens when you place the negative ends of two magnets together?

3. What happens when you place the positive end of one magnet near the negative end of another ?

Objective
You will be expected to define "ion" and describe how ions are formed from neutral atoms. You should be able to draw a few common ions and explain why they bond together.

To understand chemical bonding, one must also understand what an ion is. Remember that protons are positively charged; electrons are negatively charged and neutrons have no electrical charge. Also recall that in a neutral atom, the number of protons equals the number of electrons. Ions are atoms that become charged positively or negatively. Once charged, positive ions are attracted to negatively charged ions. The attraction and joining of these ions is called an ionic bond which results in the formation of a molecule. Cover the answers in the following program and place all answers on your own paper.

---

4. How many protons in carbon? How many electrons?

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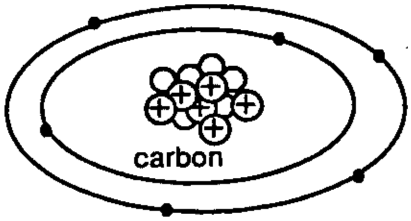
4. 6 protons, 6 electrons

---

5. How many of the electrons would be in the first shell of carbon? How many in the second?

---

5. 2, 4



6. Each proton has a +1 electrical charge. The 6 positive protons in carbon give the nucleus a +6 charge. Each electron has a -1 charge. The 6 negative electrons produce a -6 charge. What is the charge of the entire atom?

---

6. A entire atom of carbon then has no charge because +6 and a -6 add up to zero. Each +1 charge is neutralized by a -1 charge. Since all neutral atoms have an equal number of protons (+ charges) and electrons (- charges), they will have no net electric charge. (+2-2=0, +3-3=0, +4-4=0, etc.) Therefore, it is said that all neutral atoms have no charge.

---

7. Most of the atoms around us exist in their neutral form. If this were not so and objects were charged, they would constantly be attracted to each other. This would create all kinds of problems. Since negative and positive attract each other, negative objects would adhere to any positive object. What are some examples of practical problems that this would create?

---

7. All matter is composed of atoms. If most atoms were charged, objects would either be attracted or repelled by other objects. We could not set pens, pencils paper, etc., on a desk without them sticking to one another or repelling one another.

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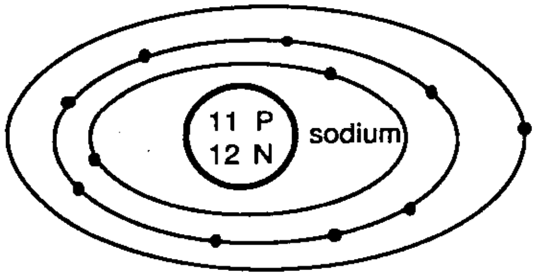
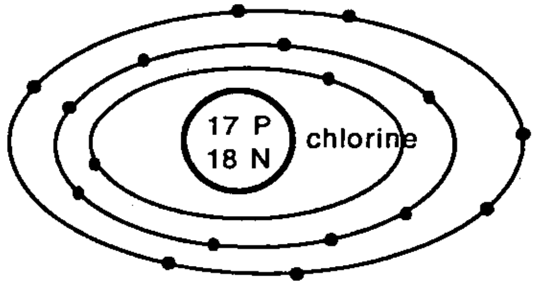
8. Atoms, nevertheless, do become charged. They remain that way for only a small time. A charged atom is called an **ion.** To understand how atoms become charged, let's first examine the neutral sodium atom and chlorine atom.





How many electrons in the outer orbits of sodium and chlorine?

8. Na = 1, Cl = 7

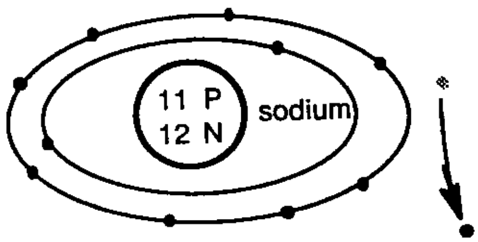
9. How many electrons does sodium need in its outer orbit to become stable? How many electrons does chlorine need in its outer orbit to become stable?

9. Sodium needs 7 and chlorine needs 1

10. Where do you predict that the chlorine atom might get the number of electrons that it needs to become stable?

10. Chlorine could get the 1 electron it needs from sodium.

11. There is a tendency for electrons of certain atoms to fly off the atom in order for the atom to have a complete stable number in its outer orbit. Notice that sodium has one electron in its outer shell. Sodium is more stable if its outer shell contains 8 electrons. This can happen by sodium gaining 7 electrons in the outer shell or by losing 1 electron, creating 8 electrons in the second shell.

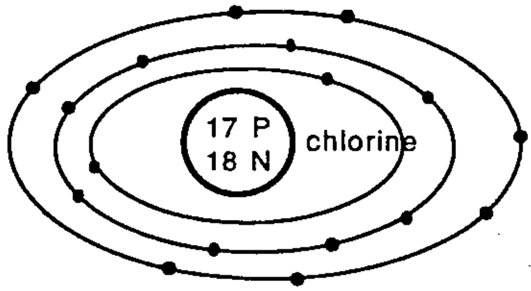


It takes less energy to lose the 1 electron than it does to gain 7. Once the sodium atom has lost 1 electron, what will the net charge be for the atom?

11. Sodium has now become an **ion. An ion is an electrically charged atom.** The sodium ion has 11 protons (+11) and 10 electrons (-10). +11 and -10 = +1. The sodium ion has a +1 electrical charge.

12. Chemists symbolize the sodium ion as **Na+.** Now let's look at the chlorine atom.

How many electrons are their in the outer orbit of Cl?



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12. 7 electrons

---

13. Since the outer orbit of chlorine has 7 electrons and it needs 8 to become stable, what would you predict will happen in order for chlorine to become more stable?

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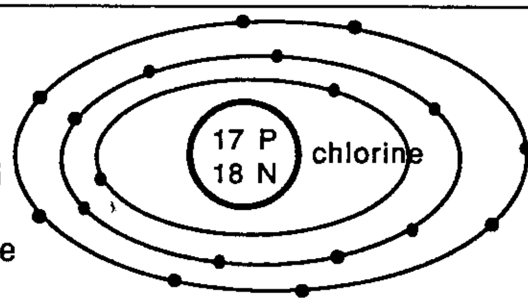
13. If you predicted that Cl would gain 1 more electron, you are correct. Chlorine would gain 1 electron in its outer shell to have the stable 8. The chlorine ion is diagrammed at the right:



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14. How many protons are in a chlorine ion? The nucleus of a chlorine ion has what charge?

---

14. 17 protons, the nucleus has a + 17 charge

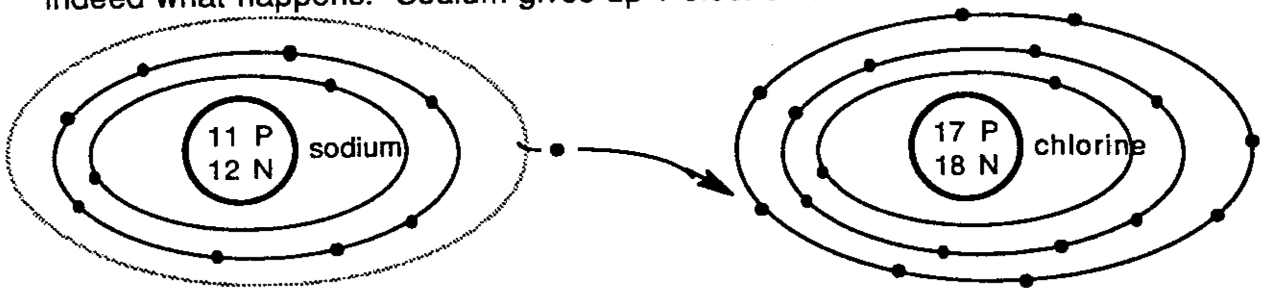
---

15. Chemists symbolize the chlorine ion as **Cl -.** How many electrons are in a **chlorine ion**? What is the net charge of the entire **chlorine ion**?

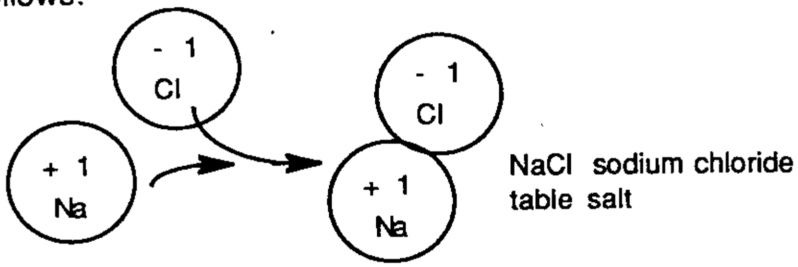
---

15. The chlorine ion has 18 electrons all of which are negatively charged. The net charge of the entire **chlorine ion** is -1. (+17 and - 18 = -1)

16. Under the right conditions, when sodium and chlorine are together, here is what happens. Since chlorine can gain 1 electron and become stable, and sodium can lose 1 electron, they would appear to be a perfect match for each other. This is indeed what happens. Sodium gives up 1 electron to chlorine.



Now the +1 sodium ion will be attracted to the -1 chlorine ion. The two ions bond, forming sodium chloride (NaCl) commonly know as table salt. Another way to show this is as follows:

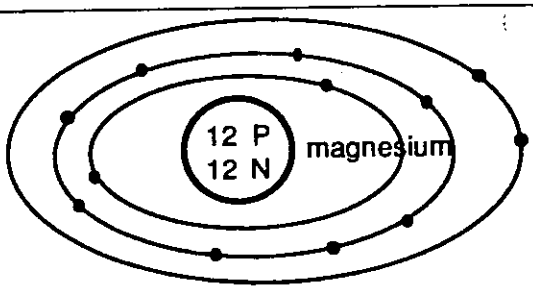


Another way this is written is as follows: Na+ + Cl- ---------> NaCl

Remember that when an ion forms, the neutral atom either gains or loses electrons to become charged. The number of electrons lost or gained depends upon the number of electrons in the outer orbit. Atoms gain or lose electrons to become stable and have 8 electrons in the outer orbit shell. For atoms with atomic numbers of less than 6, these atoms will lose electrons to have either 2 or 0 electrons in the outer and only shell.

Draw the magnesium atom showing the electrons in appropriate orbits.

16.



17. When magnesium becomes an ion, what will its charge be?

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17. + 2 (Magnesium will lose the outermost 2 electrons to give 8 in the 2nd shell. 12 positive protons and 10 negative electrons adds to +2 net charge.) Chemists symbolize the magnesium ion as **Mg++**, using 2 pluses to show the +2 charge of the ion.

---

18. When fluorine becomes an ion, what will its charge be?

---

18. -1 (Fluorine will gain the 1 electron to give 8 in the 2nd shell. 9 positive protons and 10 negative electrons adds to -1 net charge.) (F^-)

---

19. When hydrogen becomes an ion, it loses its only electron. What is the charge of the hydrogen ion? (Indicate the number and + or - charge)

20. When lithium fluoride forms from lithium and fluorine, what is the formula of the compound? Explain how you arrived at your answer.

5-14 In-Depth Enrichment: Chemical Bonding

5-13 on "ions" is a prerequisite for this topic. Be sure you have completed 5-13 before you begin this topic.

1. When two or more atoms bond together they form a unit called what?

Objective
You should be able to define ionic and covalent bonding. You will be expected to contrast the two types of bonding and predict the formulas of molecules resulting from both kinds of bonds.

Ionic Bonding

When two or more atoms become charged oppositely like sodium and chlorine, they are attracted to each other and form an **ionic bond** as they join.

2. Explain what causes sodium and chlorine ions bond to form sodium chloride.

3. When sodium and chlorine ions bond to form sodium chloride why is the formula for the salt NaCl and not Na_2Cl or $NaCl_2$?

4. When the magnesium ion (Mg^{++}) bonds ionically with the chloride ion (Cl^-), what will the formula for magnesium chloride be? Explain how you arrived at your answer.

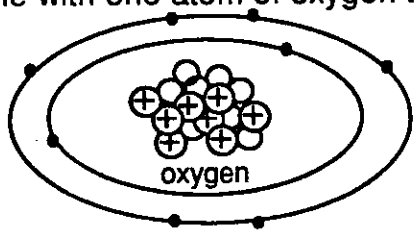
5. Iron ions (Fe^{+++}) combine with fluorine ions (F^-) to form iron fluoride. What will the formula be? Explain how you arrived at your answer.

6. Use the periodic chart to figure out what the formula will be when aluminium (Al) and chlorine (Cl) bond to form the compound aluminum chloride.

Certain atoms will bond together by a means which is different than ionic bonding. This other form of bonding is called **covalent bonding.**

Covalent Bonding

In ionic bonding, electrons are lost or gained to create ions which then are attracted to each other. In covalent bonding, **electrons are shared between the bonding atoms.** Atoms that typically form ions tend to bond ionically. Atoms that <u>do not</u> tend to form ions bond by **covalent bonds.** The water molecule is an example of covalent bonding. Review the electron structures of oxygen and hydrogen below:
Two hydrogen atoms combine with one atom of oxygen to form



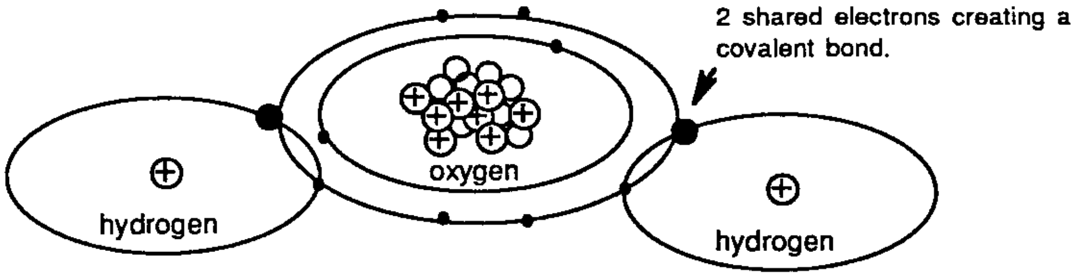
Hydrogen electrons are enlarged to distinguish them from oxygen electrons

7. How many electrons does oxygen need to have the stable number in the outer orbit?

8. How many electrons does hydrogen need to have the stable number in its outer

orbit?

Notice that H lacks 1 electron in its outer orbit to become stable. O lacks 2 electrons in its outer orbit to become stable. When bonding occurs, the oxygen atom shares two electrons from the 2 hydrogen atoms. Joining and sharing of electrons looks like the following:



$$2H + O \text{ --------> } H_2O$$

The electron from each H atom revolves around the H atom and then around the O atom. Some chemists have described the electron's path as that of a "figure 8", revolving alternately around the O and then the H. The oxygen atom shares one electron from each of the hydrogen atoms in the same way. Examine the drawing again and you will notice that as a result of electron sharing, the oxygen nucleus has 8 electrons revolving around it (2 shared with hydrogen), and each hydrogen nucleus has two electrons revolving around it (2 shared with oxygen). [___]

Each of the atoms has the stable number of electrons in its outer orbit, and the three atoms are held together as a result of the electron sharing. The three atoms come together in the 2:1 ratio because this ratio satisfies the stability requirement for the number of electrons in the outer orbits of each atom. This is why the formula for water is H_2O and not H_3O or HO_2.

You will now have a chance to apply what you have been learning. When carbon and hydrogen react to produce methane (natural gas), they form covalent bonds.

9. Using the rules for covalent bonding, draw how H and C would bond and determine how many C atoms will bond with how many H atoms. Draw the resulting methane molecule showing all H and C atoms. (Remember that each atom must have the stable number of electrons in the outer orbit for that atom.)

10. Based upon your drawing of methane, what is the formula for methane?

11. Describe the difference between ionic and covalent bonding. How are they different? How are they the same?

5-15 Chemical Reactions

1. Describe the changes one would observe after iron has rusted.

When iron (Fe) rusts, it combines with the oxygen in the air (O_2) to form a rust-colored powder called iron oxide (FeO). This change is an example of a chemical reaction.

Objective

You should be able to describe what happens to the reactants and products during a chemical reaction.

In chemical reactions, the bonds are broken between certain molecules, and the separate atoms rearrange and bond to form different molecules. Sometimes this requires energy, and sometimes energy is produced in the reaction. Let's examine the reaction where water changes into hydrogen and oxygen. When chemical reactions are written, they are referred to as **equations.**

$$2\,H_2O + \text{electrical energy} \longrightarrow 2H_2 + O_2$$

The above **equation** should be read as follows: Two molecules of water plus electrical energy produce two molecules of hydrogen gas plus one molecule of oxygen gas. The **reactants** are on the left side of the above equation and the **products** are on the right side.

2. When you read a chemical equation, what word is substituted for the arrow in the equation?

The 2 before the H_2O, tells us that 2 molecules of water are needed to produce 2 complete molecules of H_2 and one of O_2. The 2 after the H in H_2O, tells us that there are 2 atoms of H in the water molecule. The reaction shows that as the electrical energy is passed through the water, the molecules of water are broken apart by the energy, and the atoms rearrange into 2 molecules of H_2 and 1 molecule of O_2.

3. If four molecules of water were converted into H_2 and O_2, how many molecules of each product would be produced?

The following equation shows how natural gas burns in a furnace:

$$2O_2 + \underset{\text{(methane)}}{CH_4} \longrightarrow 2H_2O + CO_2 + \text{heat energy}$$

The reaction is called methane combustion.

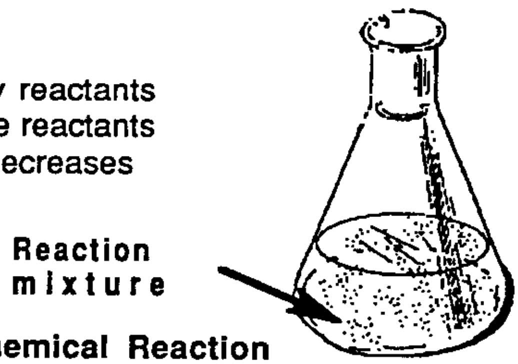
4. List the products of methane combustion.

5. List the reactants of methane combustion.

6. In methane combustion, how many molecules of methane are needed to produce 3 molecules of CO_2?

7. In the methane combustion, how many molecules of O_2 are needed to produce 4 molecules of H_2O?

At the beginning of any reaction, there are only reactants and no products. As the reaction takes place, the reactants change into products. The amount of reactants decreases as the reaction continues and the amount of the products increases.



Optional Home Laboratory Activity: A Chemical Reaction

Materials Needed:

Vinegar and baking soda and two drinking glasses

Objective

If you elect to perform this optional activity, you will set-up and demonstrate a common chemical reaction.

Procedure

1. Add about 1/4 glass of water to each of two glasses. [ ]
2. Add a tablespoon of vinegar to the water in one glass.[ ]
3. Add a teaspoon of baking soda (sodium bicarbonate) to the water in the second glass and stir to dissolve. [ ]
4. Hold the two glasses over the sink and pour one into the other. [ ]

Analysis

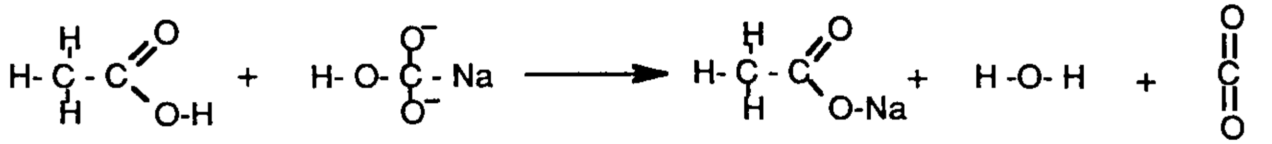
1. Describe what happened when you poured the two solutions together.

What you observed is a classic acid-base reaction. The chemical name for vinegar is acetic acid. The formula for acetic acid is CH_3COOH. The chemical name for baking soda is sodium bicarbonate and the formula is $NaHCO_3$. The equation that describes what happened as the reaction occurred is as follows:

$$CH_3COOH + NaHCO_3 \longrightarrow CO_2 + H_2O + CH_3COONa$$

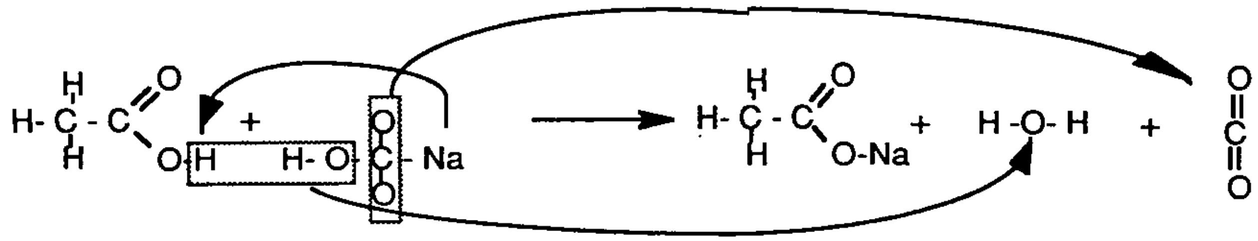
acetic acid + sodium bicarbonate → carbon dioxide gas + water + sodium acetate

The above equation shows empirical formulas. The equation is rewritten below using structural formulas. This will help you to understand how groups of atoms disconnect and rearrange into new molecules during this reaction. Study the equation in its different forms below, and then answer the questions that follow:



acetic acid + sodium carbonate ————> sodium acetate + water + carbon dioxide

The equation below shows you the transfers taking place in the above equation.



2. In the above reaction, what are the reactants?

3. In the above reaction, what are the products?

The product, carbon dioxide is what created the bubbles when the reaction was observed.

4. What molecule(s) did the carbon dioxide come from? Explain.

5. What molecule(s) did the water come from? Explain.

6. What happened to the sodium ion during the reaction?

In this reaction, an acid (acetic acid) was mixed with a base (sodium carbonate). In such a reaction, the acid neutralizes the base. The acid part of the acetic acid (the H ion) combines with the base part of the sodium carbonate (the OH ion) and forms water, which is neither acid or base. Thus, the acid neutralizes the base. You will learn more about acids and bases in the next section.

5-16 Acids and Bases

1. What effect does a strong acid have on the skin? Are you aware of any acids that we use for food? If so, what are they?

Objective

You should be able to describe how acids and bases are measured and explain how the pH scale is used to measure acids and bases.

Most students learn about **acids and bases** early in their study of science. You might have placed litmus paper into an acid solution and watched it turn red. When litmus paper is placed into a basic solution, it turns blue. Litmus is a **chemical indicator** for acids and bases. You may have learned that you should keep strong acids and bases off your skin and clothing and anything else that you do not want damaged. This is because acids and bases are very reactive. This means that they will react with flesh and other substances, eroding the surface. Weaker acids and bases do not cause the same problems. In fact, we eat and drink many **weak acids**. Some examples are lemon juice, orange juice, grapefruit juice, most carbonated beverages and vinegar. Some household bases are soap and baking soda. Hydrochloric acid (HCl) and sulfuric acid (H_2SO_4) can be mixed to form very **strong acids**. Our stomachs produce strong hydrochloric acid, and the lining of the stomach produces a special coating to protect the lining of the stomach from being eaten away by the acid. If too much acid is produced or if the protective coating is not adequate, the acid attacks the cells lining the stomach, causing an **ulcer.** An example of a strong base is sodium hydroxide (NaOH).

How are Acids and Bases Measured?

Acids and bases can be measured on a scale just as temperature and length can be measured. Chemists have developed what is known as the **pH scale.** The pH scale ranges from 0 to 14 and is used to indicate if a solution is acidic, basic or neutral.

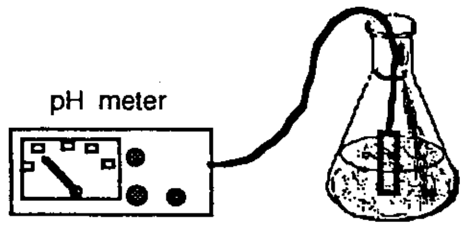
Ph Scale---

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

acid **neutral** **basic**

Hydrochloric acid from the stomach has a pH of about 2. Pure distilled water has a pH of 7 and is **neutral,** neither acidic nor basic. A substance with a pH of 12 is 10 times stronger that a substance with a pH of 11. A substance with a pH of 2 is 10 times stronger that a substance with a pH of 3. Strong acids range from pH of 0 to about 3.8. Weak acids range form a pH of about 3.9 to 6.5. Weak bases range for a pH of about 7.3 to 10.5. Strong bases range form 10.6 to 14. The neutral pH range is close to 7.0.

Ph can be measured in a variety of ways. Chemical indicators made of paper and colored indicator solutions are both common methods. When one of these chemical indicators is placed into an acid or base, it changes color. Color charts are used to tell the pH number. An electrical meter called the pH meter is also used to measure pH. When a student places a probe into an acid, the needle on the meter will point to the pH number for that solution.



When an amount of acid at pH 4 is carefully added to an equal amount of base at pH 10, the resulting solution will have a neutral 7 pH. **Acids neutralize bases.**

2. List some common acids and bases.

3. What pH numbers indicate the acid range?

4. What pH numbers indicate the basic range? The neutral range?

5-17 In-Depth Enrichment: Acid-Base Dynamics

What Causes a Solution to be Acidic or Basic?

1. If an auto mechanic spills battery acid, he or she pours a basic solution on it before cleaning it up. Why do you think this is the standard procedure?

Objective

You should be able to describe what makes acids different from bases and explain how acids neutralize bases.

Examine a few formulas for acids and bases that follow:

Acids		**Bases**	
HCl	(hydrochloric acid)	NaOH	(sodium hydroxide)
H2SO4	(sulfuric acid)	KOH	(potassium hydroxide)
H2CO3	(carbonic acid)	NH3OH	(ammonium hydroxide)

2. What do the three acids have in common?

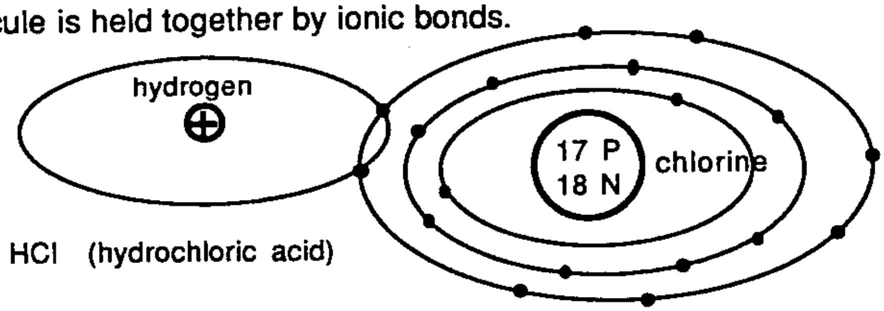
3. What do the three bases have in common?

When acidic molecules are dissolved in water, the **H** ions separate from the rest of the molecule. The accumulation of **hydrogen ions** in the solution causes the solution to become acidic with a pH of between 0 and 6.9. Hydrogen ions are written as H^+.

When basic molecules are dissolved in water, the **OH** ions separate from the rest of the molecule. The accumulation of OH ions (called hydroxide ions) in the solution causes the solution to become basic with a pH of between 7.1 and 14. The hydroxide ion is written as OH^-. In a neutral solution the numbers of H^+ and OH^- are equal.

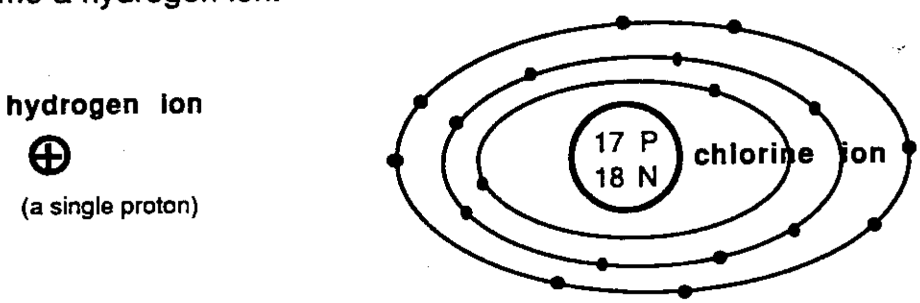
What Makes HCl Acidic?

Let's look at the electron structure of the HCl (hydrochloric acid) molecule once again. The molecule is held together by ionic bonds.



HCl (hydrochloric acid)

When the HCl is dissolved in water, the hydrogen's proton separates from the chlorine ion to become a hydrogen ion.



When HCl is placed in water, the hydrogen ion, H^+, (a single positive proton) separates from the chlorine ion. The H's electron stays with the chlorine atom producing a chlorine ion.

4. How many protons and electrons are in the Cl ion?

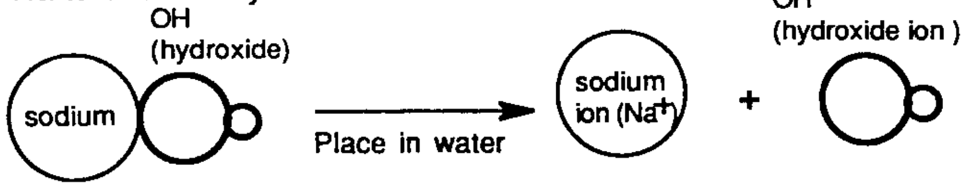
5. What is the charge of the Cl ion?

6. What is the charge of the H ion?

The accumulation of these H^+ ions cause the solution to be acidic.

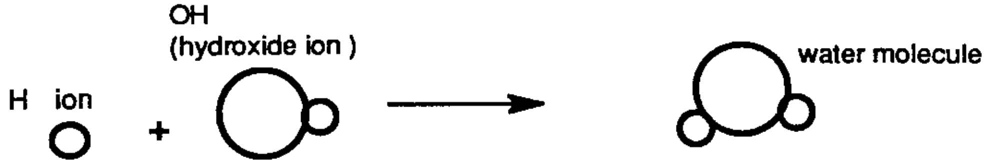
What Makes NaOH Basic?

When NaOH (sodium hydroxide) molecules are dissolved in water, the OH separates from the Na to become hydroxide ions.



The accumulation of these OH^- ions causes the solution to be basic.

The reason a base can neutralize an acid is because the H^+ ions in the acid combine with the OH^- ions from the base to form a neutral H^+-OH^- (H_2O).



Just as illustrated above, the H and the OH combine to form water in the reaction below:

Na**OH**	+	**H**Cl	$\longrightarrow$	**H-OH**	+	NaCl
sodium hydroxide		hydrochloric acid		water		salt (sodium chloride)

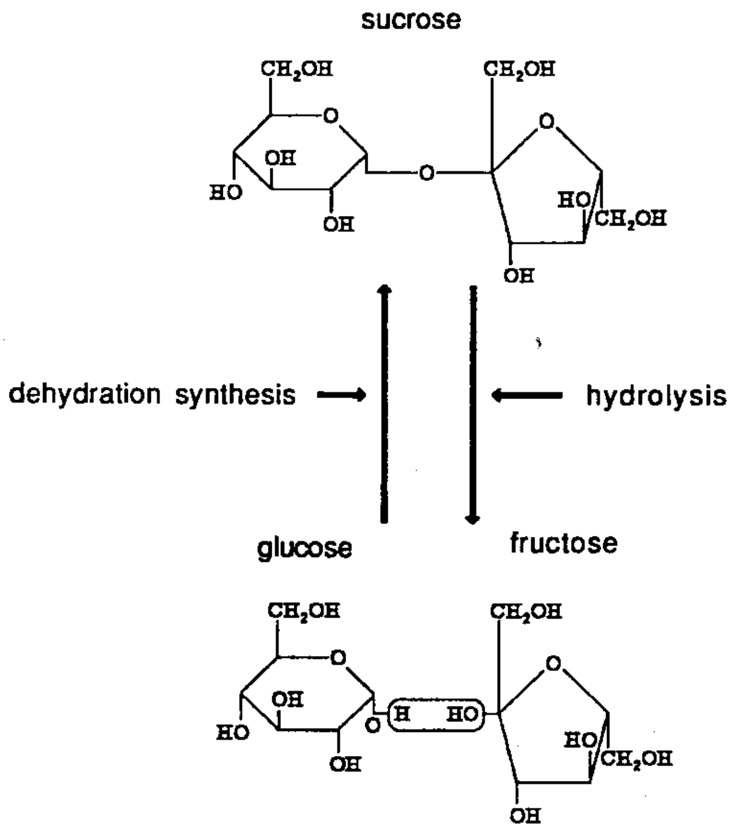
7. Predict what products would be obtained if HF (hydrofluoric acid) is combined with KOH, (potassium hydroxide). Show the equation.

8. Reread your answer to question # 1. Do you have any corrections or additions to make in the answer now that you have completed this topic?

CHAPTER 6

COMPOUNDS IN LIVING THINGS

DISACCHARIDES



MONOSACCHARIDES

Chapter 6

Compounds in Living Things

The difference betweeen ordinary and
extraordinary is that little extra.
Zig Ziglar

6-1 Introduction

1. How is a compound different than an element?

In Chapter 5, you learned that there are inorganic and organic compounds. An **organic compound** is a compound that contains the element carbon and is made by living organisms. An **inorganic compound** is a compound that does not contain carbon and is not made by living organisms and is found in the earth's crust.

Many living organisms require complex organic molecules. They obtain these compounds in nutrients they take in. All organisms produce a wide variety of organic molecules. There are many organic molecules that the human body cannot produce and we, therefore, must obtain them in food. Vitamin and amino acid molecules are examples. Glucose is an important organic molecule you will study in connection with respiration and photosynthesis. The chlorophyll molecule found in chloroplasts is a large, organic molecule produced in green plant cells. Most organic molecules are large molecules. Chemists call large molecules macromolecules.

Macromolecules
The prefix "macro" means large, as opposed to "micro" which means small. Macromolecules are large molecules. Some macromolecules have over 200,000 atoms in one molecule. The four basic classes of macromolecules that are found in foods and living organisms are **carbohydrates, proteins, fats** and **nucleic acids**. The first three will be most important to us in this unit.

6-2 Carbohydrates

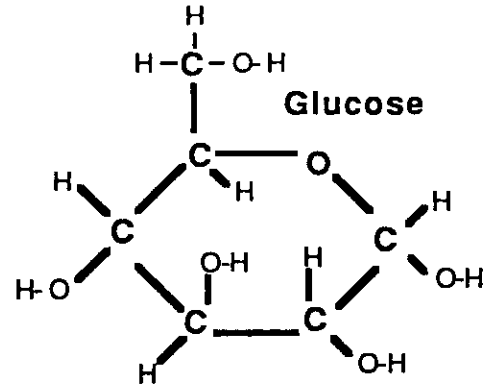
1. Name a few common foods that are high in carbohydrates.

Objective
On a quiz, you should be able to name common carbohydrates and list the elements that compose them. You should be able to draw a starch molecule and name the sub-units found in starch and cellulose.

All carbohydrate molecules are composed of the elements, carbon, hydrogen and oxygen. These three elements can be arranged in a variety of ways in the form of sugars, starches, cellulose and other less common carbohydrates.

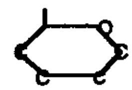
Sugars

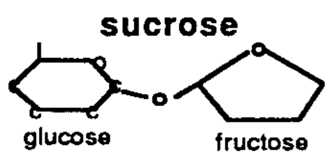
All sugars, also called saccharides, are carbohydrates. The sugar **glucose** is of great importance in the study of biology. Energy for animal processes come from glucose. The empirical formula is $C_6H_{12}O_6$ and the structural formula is shown at the right.



2. How many C, H and O atoms do you count?

Fructose and galactose are also simple sugars with the same empirical formula, $C_6H_{12}O_6$. What makes them different is their structural formulas. One C, H and O are each in different places. A simplified symbol for glucose can be drawn as shown at the right:



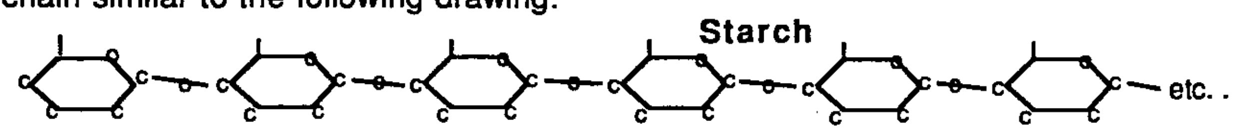


Simple sugars link up to produce double sugars. **Sucrose**, common table sugar, is a double sugar. It is made up of one unit of glucose and a fructose unit. Single sugars are called monosaccharides (one sugar). Double sugars are called disaccharides (two sugars).

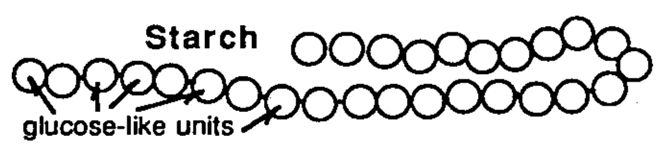
3. When we digest sucrose, enzymes break the molecule at the middle O atom. What would you predict the products of sucrose digestion to be?

Starch

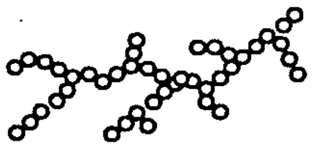
A starch molecule is made up of many thousands of glucose-like units connected in a chain similar to the following drawing:



Sometimes a model of starch is made using beads, arranged as in a necklace, to represent a short segment of a starch molecule. Starch molecules often average 10,000 glucose-like units in length.



4. When starch is digested in the intestine, starch molecules are broken down into smaller units. What smaller units do you predict will be produced?



Cellulose

Starches are called polysaccharides (many sugars). Another example of a polysaccharide is **cellulose**, a common component of wood and paper. Cellulose is made up of long chains of glucose-like units also. The difference between starch and cellulose is that in cellulose, the glucose units branch and connect differently. See the drawing at the left.

Foods high in starch are bread, cereals, pastas and potatoes to mention a few.

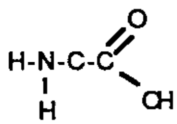
6-3 Proteins, Fats and Macromolecule Reactions

1. Name some common foods that you believe are high in protein and fat.

> **Objective**
> On a quiz, you should be able to describe the structure of protein and fat molecules and list the elements found in each. You will be expected to identify the products of each macromolecule reaction.

Proteins

Protein molecules always contain carbon, hydrogen, oxygen and nitrogen atoms. They sometimes contain phosphorus (P) and sulfur (S). The molecules are made of long chains of 20 different amino acid molecules. One **amino acid**, the amino acid glycine, has the structure shown at the right:



There are 19 other amino acid molecules with different structures. If each amino acid is represented with a different textured sphere, a protein molecule would be represented as follows:

Protein molecule

Different amino acid molecule units

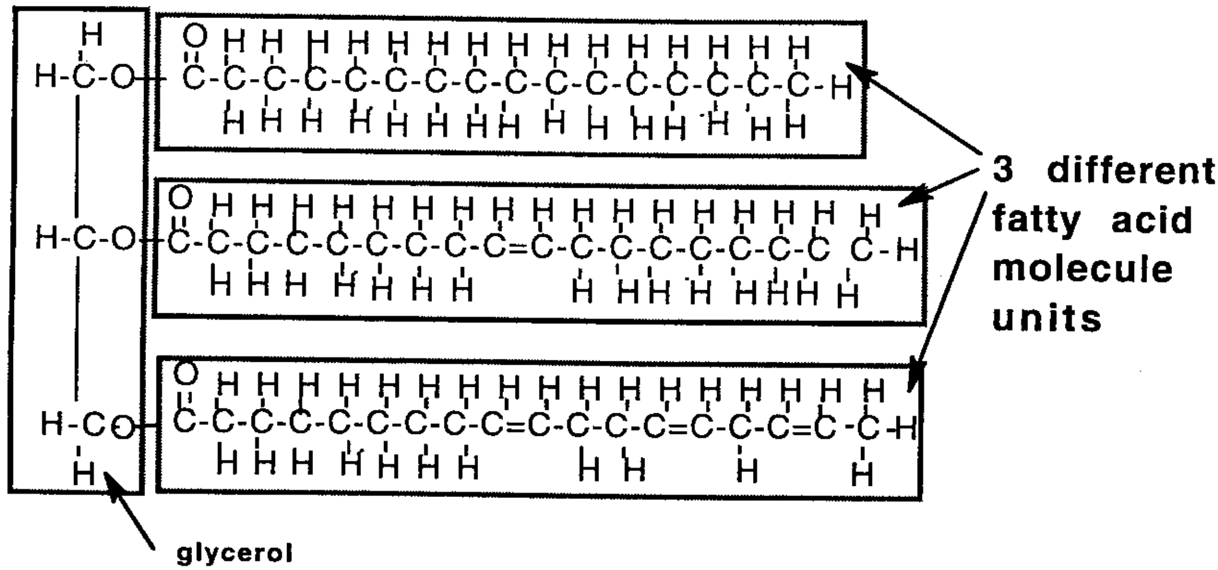
2. Protein molecules are digested by enzymes in our stomachs. When enzymes break proteins into smaller units, what units do you suppose are produced?

Protein molecules often contain 200-300 amino acid units. Foods rich in protein are milk, beans, peanuts, egg white, beef, fish and poultry.

Fats

Fat molecules are made up of **C, H & O** atoms just as carbohydrates are, but fat molecules have a smaller proportion of oxygen making them almost all C and H. Fat molecules are not as large as proteins and starches and are made of 3 fatty acid units and 1 glycerol unit. Chemists call fat molecules **lipids**. Study the following diagram of a typical lipid molecule:

Fat molecule



3. How many C atoms are in the glycerol unit of the fat molecule?

4. Briefly explain how the three fatty acid molecule units are different from each other.

5. When fat molecules are digested by enzymes, what do you predict the products to be?

Nucleic Acid Molecules

Nucleic acid molecules are important macromolecules and will be covered in great detail in the unit on genetics.

6. Based upon the name, where in the cell would you expect to find most nucleic acid molecules?

The most well known nucleic acids are **DNA** and **RNA.** DNA is the molecule that makes up the gene, the carrier of hereditary information. RNA is a helper molecule that aids the DNA (the gene) in its expression.

Macromolecule Reactions

Macromolecules become involved in reactions in cells and digestive organs. Enzymes can break them down into the sub-units that make them up.

Chapter 7

Respiration and Photosynthesis

7-1 Laboratory Investigation

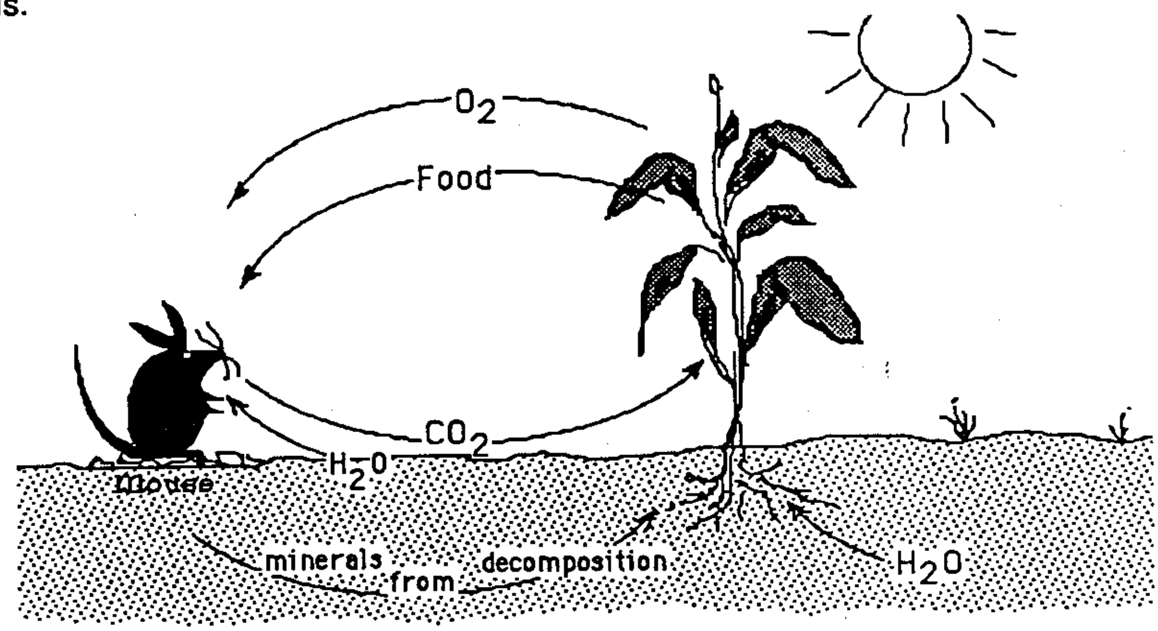
Can You Design an Experiment to Test a Hypothesis?

Objective

You will be expected to design and conduct an experiment to determine the relationship between a pond snail and the aquatic plant, *Elodea*

INTRODUCTION:

Examine the following diagram that shows an interdependence between plants and animals.



1. Do you think that this diagram would apply to every plant and every animal? (Give the reason for your answer.)

MATERIALS AVAILABLE FOR THE EXPERIMENTS THAT FOLLOW:

Glass vials with screw cap lids
pond water
2 - 3 pond snails
labeling tape
Bromthymol blue indicator
straw
2 - 3 pieces of *Elodea* (pond plant)

In this lab activity you will be designing your own original experiments to determine if the relationships in the drawing above apply to a pond snail and pond plant (*Elodea*). Then you will conduct your experiments as planned and collect and interpret the data. Finally, you will indicate your conclusion about whether the hypothesis was supported by the data or not.

PRE LAB
In this investigation, you will use a chemical indicator called **bromthymol blue.** To discover its properties, perform the following brief procedure:

a. Fill a small beaker or similar container about 1/3 full of tap water. [___]
b. Add about 7 drops of bromthymol blue indicator. [___]

2. What color is the resulting solution?

If the solution is not blue, add 1 drop of NaOH solution and stir. ***Caution: Sodium hydroxide is corrosive. Avoid contact with the skin. If sodium hydroxide gets on the skin, flush the area with water and notify your teacher.*** Add drops until the solution is blue. Do not add beyond this point. When bromthymol blue indicator is blue, this indicates that no carbon dioxide is present in the solution. Human breath contains carbon dioxide. Use a straw to gently blow your breath through the bromthymol blue solution in the beaker until no more change takes place. [___]

3. What color did the solution finally become as you blew through the straw?

4. What other colors did you observe as the solution was turning to its final color?

5. What color is bromthymol blue indicator when carbon dioxide is present in a solution?

NaOH removes carbon dioxide from a solution. Now add enough drops of .01 NaOH to the solution containing carbon dioxide to turn it back to blue. Once the solution is blue, it contains no carbon dioxide. [___]

6. Copy the following into your report and complete each sentence:
When bromthymol blue is **blue**, it means _____
When bromthymol blue is **yellow**, it means _____
When bromthymol blue is **green**, it means _____

If the relationships in the drawing on page 1 are suspected as being true for the snail and *Elodea*, then one hypothesis could be written as follows:

HYPOTHESIS 1: Snails give off CO_2.

Copy this hypothesis into your lab report and label the statement as "**HYPOTHESIS 1**". [___] Label the next section of your report as "EXPERIMENTAL DESIGN FOR HYPOTHESIS 1" [___] Under this title, draw two boxes as follows:

EXPERIMENTAL DESIGN:

Experimental set-up	Control set-up
______________________	______________________
______________________	______________________

In the boxes on your paper, now draw how you would set-up an experiment using the materials listed on page 1, to test hypothesis 1. You don't need to use all the materials listed. Take time to think through what would be needed. Be sure to include what needs to be set-up as a control. Add any written description on the lines below each box. [___]

PREDICTION OF RESULTS:

Next add the label heading "PREDICTION OF RESULTS" to your report just below the two experimental design boxes.[___] Now write what results you would "expect" **if** hypothesis 1 were true. Write the expected results for the experimental set-up and the control set-up. [___]

LEAVE ABOUT THREE BLANK LINES IN YOUR REPORT AT THIS POINT FOR TABULATING THE RESULTS OF THE EXPERIMENT THAT YOU WILL OBTAIN IN A DAY OR TWO. [___]

HYPOTHESIS 2: *Elodea* take in CO_2.

Now copy the above heading and hypothesis into your report after the spaces left for the results for hypothesis 1. [___]

Go through the same steps for hypothesis 2 as you did for hypothesis 1 and use the same headings as before.
Experimental Design: (With the 2 boxes)
Prediction of Results:
Space for Results: [___]

READ THE FOLLOWING HYPOTHESES, EACH OF WHICH WERE WRITTEN FROM EXAMINING PARTS OF THE DRAWING ON PAGE 92:

Hypothesis 3: ***Elodea*** **use CO2 snails give off.**
Hypothesis 4: **Snails give off CO2 in the dark.**
Hypothesis 5: ***Elodea*** **take in CO2 in the dark.**
Hypothesis 6: ***Elodea*** **use CO2 that snails give off in the dark.**
Hypothesis 7: ***Elodea*** **give off CO2 in the dark.**

Continue copying each hypothesis, and then design experiments to test each one. Use the following steps for each of the 7 hypothesis:

Copy the hypothesis:
Experimental Design: (With the 2 boxes)
Prediction of Results:
Space for results, interpretation and conclusion: [___]

DAY 2:

CONDUCT THE EXPERIMENT AS PLANNED:

Your teacher may assign certain hypotheses for you to set-up while others set up experiments for the other hypotheses. Follow the directions you wrote for your experimental designs. **Set up the experiments and controls for the hypothesis assigned to you.** [___] Have your teacher check all vials for your table before you place them in the designated light or dark cabinets. [___] Your teacher will announce the location of the light and dark cabinets where you will place the vials to allow them to set overnight. All caps should be left loose. All vials should be filled to one half inch of the top with water. [___] Whenever a snail or *Elodea* is required, use only one. The *Elodea* piece should be the length of the vial. [___] Place a **label** on each vial with the following: Name, hypothesis number. [___]

DAY 3

RECORDING THE EXPERIMENTAL RESULTS:

After you have set up the experiments and let them set overnight, examine your tubes and record the results under the report heading **Experimental Results.** Record the

results for each experiment that was done at your table. Only record the colors obtained. [___] Also go to a table next to you to obtain the results of the other experiments that your table did not set up. [___] Be sure to record the color for each control and any other observations about the snails or Elodea. [___]
You should have the results of experiments for hypotheses 1 through 7. [___]

Clean up the vials only when all students have had a chance to obtain the data. To clean up the tubes, place the snails and *Elodea* in the containers set up to receive them. Remove the labels from the vials and wash and rinse them. Return the clean vials and lids to your tray. [___]

INTERPRETATION OF RESULTS:

For each hypotheses, add the title **Interpretation,** in the blank space below the results. [___] Interpret the results for each hypothesis by writing a statement about what the data means in each experiment. Statements about CO2 use or production are appropriate.

[___]

CONCLUDING STATEMENTS ABOUT THE HYPOTHESES:

For each hypotheses, add the title, **"Conclusion",** in the blank space below the interpretation. [___] Now insert your concluding statement about each hypothesis according to the data you obtained. Select one of the following for each hypothesis: **hypothesis supported, hypothesis contradicted or hypothesis not supported**. [___]

ANALYSIS AND CONCLUSIONS

How does the use and production of carbon dioxide by snails differ in the dark and in the light? How is it different for the *Elodea?*

7-2 How Plants and Animals Obtain Energy: An Introduction

1. How do plants and animals get energy? Are the processes the same or different?

Objective

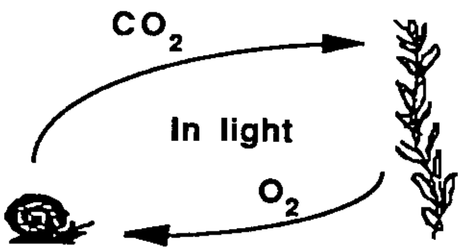
You should be able to diagram the gasses used and produced by animals and plants during respiration and photosynthesis.

If you performed Lab Investigation 7-1, answer the following 3 questions:
(If you did not perform the lab, skip the following three questions.)

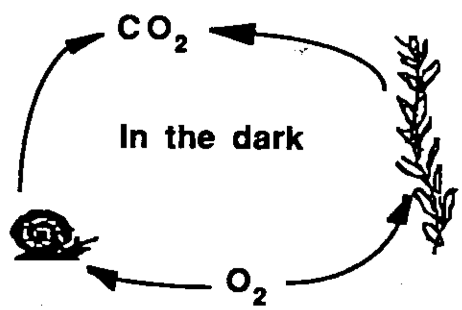
2. Based upon the experiment, what is the relationship between the snail and carbon dioxide in the light? In the dark?

3. Based upon the experiment, what is the relationship between the *Elodea* and carbon dioxide in the light? In the dark?

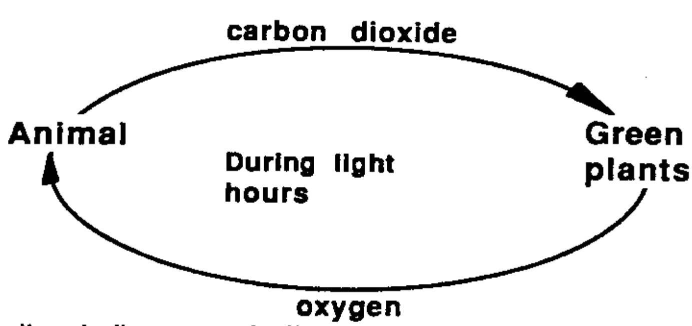
In the light, snails give off carbon dioxide and *Elodea* takes it in.



In experiment 7-1, there was no way to tell if the *Elodea* was giving off a gas that the snail took in. If you performed additional experiments, you would find that the plant gives off oxygen and that the snail takes it in.



In the dark, the snail and *Elodea* both give off carbon dioxide. They also both take in oxygen. Biologists have tested hundreds of different animals and find that they all produce the same results as the snail. Hundreds of different green plants have also been tested and the results show that all green plants provide the same results as the *Elodea*. For these reasons, the above diagram can be generalized as follows:



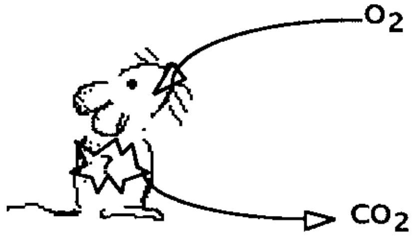
4. Draw a generalized diagram similar to the one above that shows the relationship

between oxygen, carbon dioxide, green plants and animals during hours of darkness.

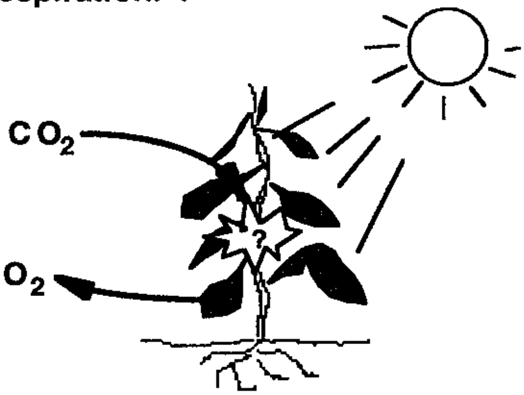
5. Can a candle be substituted for the animal when light is available? Explain.

6. Can a human be substituted for the animal when light is available? Explain.

Notice that during the hours of daylight, a cycle exists where green plants and animals are interdependent. Also recall that in the late 1700's, the English scientist, Priestley, showed that mice and mint plants each produce a substance that the other requires. Priestley found that one of the gasses is oxygen. Later, other scientists showed the other gas to be carbon dioxide.



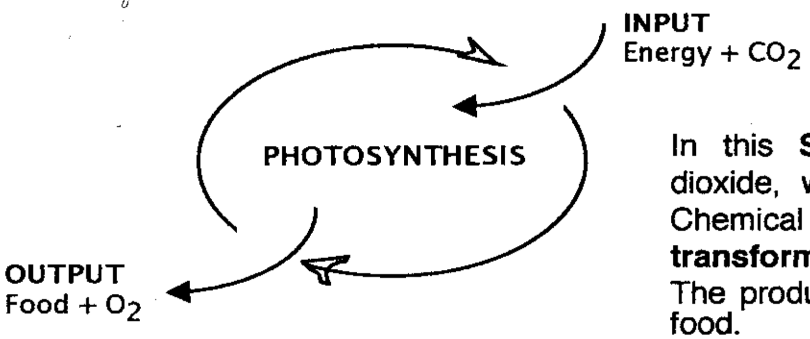
What happens inside of an animal that requires oxygen and produces carbon dioxide? The chemical process that requires the oxygen and produces carbon dioxide is called **respiration.** .



What happens inside a green plant that requires carbon dioxide and produces oxygen? The chemical process involved is called **photosynthesis.** Plants also carry out respiration during the day. It takes special procedures to measure this since some of the very same oxygen produced in photosynthesis is used for respiration. The opposite is true for carbon dioxide. During the night, green plants carry out respiration only.

The next laboratory investigation will help you to understand the chemistry that takes place in plant and animal cells during respiration and photosynthesis.

7. Two mice and four corn plants (containing ears of corn) were sealed in a large airtight glass cube. The glass cube was kept outside. The plants were watered by an automatic system and water accumulates for the mice also. Predict how long the mice and plants would remain alive under these circumstances. Explain.



In this **SYSTEM**, the **INPUT** is carbon dioxide, water and energy from the sun. Chemical reactions in the plant cells **transform** the water and carbon dioxide. The products, or **OUTPUT** are oxygen and food.

7-3 Laboratory Investigation

The Chemistry of Respiration and Photosynthesis

Objective
On the quiz that follows this lab activity you should be able to write balanced equations for respiration and photosynthesis and explain how the two equations are related.

Pre lab
The chemistry of RESPIRATION and PHOTOSYNTHESIS are probably two of the most important concepts in biology. In order to understand many of the processes that take place in living organisms, each student will need to have a complete understanding of the details of these processes.

At the end of this laboratory activity you will be expected to write the equations for combustion, respiration and photosynthesis. You should be able to list differences and similarities between the equations. Some of the quiz questions are designed to determine if you understand what a chemical equation represents. The processes of ANIMAL RESPIRATION and PLANT PHOTOSYNTHESIS are key processes to the understanding of most concepts and processes to follow in this course. It is therefore essential that you take extra time now to thoroughly comprehend these processes.

As you recall from lab activity 5-6, the equation for combustion is:

O_2 + Fuel -------------------> H_2O + CO_2 + C + Energy (heat & light)

Let's compare this with the animal respiration process. You have learned that animals require O_2 and food. Food is a type of "fuel" for animals. You also learned that animals produce CO_2. Do animals produce water or water vapor? You can answer this yourself. What happens when you blow your breath on a cold car window?

This is an indication of the production of water vapor. All animals produce it. Is it also apparent that you, as well as other animals, produce energy? You do not produce light energy, but you do produce energy that is in the form of heat and muscle energy. Humans do not produce carbon (C) in the respiration process.

Be sure to cover the answers as you proceed and place all answers on your own paper.
[___]

1. Write an equation for the process of animal respiration using the requirements and products described above.

---

1. O_2 + food --------> $CO_2 + H_2O$ + E

2. Compare this RESPIRATION EQUATION to the combustion equation. How are they different?

2. The combustion equation has carbon as a product and the respiration process does not. The respiration equation involves food, a specific type of fuel.

3. The process called plant photosynthesis also has certain requirements and products. You may be able to guess what the requirements are. Think through what requirements you would need to provide for a plant that you would grow. What requirements would you want to provide?

3. water, light, soil (Minerals) and CO_2

4. In placing the requirements into an equation, you would write the following:
$H_2O + CO_2$ + light energy --->

The soil minerals are plant requirements, but they do not react in this particular reaction, so they are not included in the photosynthesis equation. You will learn more about this later. There are two products of photosynthesis that belong on the right side of the arrow. Can you recall them?

$H_2O + CO_2$ + E -----------> +

4. O_2 + food

5. In Unit I you learned that plants GIVE OFF O_2. As the plant leaves grow, the new leaf material is "FOOD" for some animal. The wood produced in trees can be used as "FUEL" for burning. (A requirement for combustion)

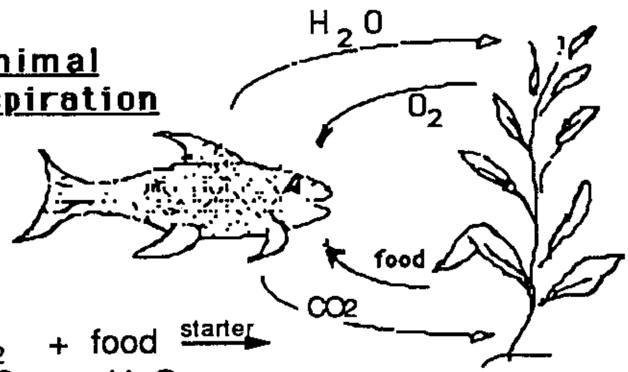
This reaction also has a starter. It is the green chlorophyll in the leaves. Rewrite the equation with the chlorophyll in the appropriate place. It is neither a reactant nor product.

5. $CO2 + H2O +$ energy $\xrightarrow{\text{chlorophyll}}$ $O2 +$ food

6. The interdependences between these animal and plant processes can be diagrammed as follows:

Animal Respiration

Plant Photosynthesis



$CO_2 + H_2O +$ energy $\xrightarrow{\text{chlorophyll}}$ $O_2 +$ food

$O_2 +$ food $\xrightarrow{\text{starter}}$ $CO_2 + H_2O +$ energy

What do you notice when you compare the requirements of "respiration" with the products of "photosynthesis"?

6. They are the same.

7. What do you notice when you compare the products of "respiration" with the requirements of "photosynthesis"?

7. They are the same.

8. When you compare the RESPIRATION EQUATION to the PHOTOSYNTHESIS EQUATION, one thing noticeable is that one is just the ___ of the other.

8. reverse

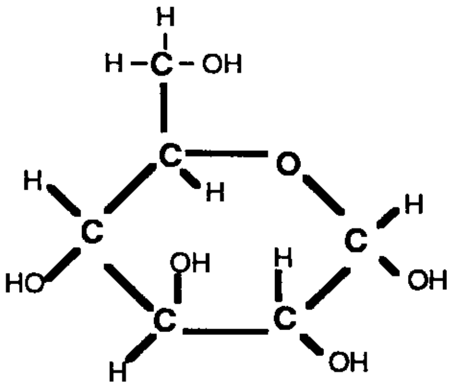
9. In fact, this is a good example of a reversible reaction.

To further understand how animals can obtain and use the "energy" in the food they eat, and how plants can trap "light energy" and impart that light energy into food, it will be necessary to study a little basic chemistry. The specific food substances from which animals get energy is a sugar called GLUCOSE. Glucose has the chemical formula $C_6H_{12}O_6$ and is probably the most important molecule you will learn about in this course. You will learn a lot about the compound, and about how it chemically reacts with oxygen (O_2) in your body to produce carbon dioxide (CO_2), water (H_2O) and energy.

The best way to learn about a glucose molecule is to build one. BUT DON'T START TO BUILD ONE UNTIL ACTUALLY INSTRUCTED TO DO SO. On your lab table are colored balls that represent atoms. The springs will be used to hold them together. Locate a container of red, white and black atoms and a container of springs.
[___] Review the colors that represent the three different atoms.

The BLACK atoms are CARBON.
RED atoms are OXYGEN.
WHITE atoms are HYDROGEN.
Write this code down at the top of your paper for later reference. [___]

10. Remember that the empirical formula for glucose is $C_6H_{12}O_6$. The structural formula for glucose is ⟶



Remember, do not begin building the glucose molecule until actually instructed to do so. An important thing to notice is that the molecule has a "ring" structure composed of 5 **C** atoms and 1 **O** atom. The 6th atom is seen sticking up from the ring. See the drawing above. [___] What is the emperical formula for glucose?.

---

10. $C_6H_{12}O_6$

---

11. In actual atoms, there are no springs to hold them together. In the kinds of atoms that you made today, the atoms are held together by electrons from each atom that are shared by the two atoms. Each single bond represents the sharing of 2 electrons. This kind of bond is called a COVALENT BOND. How many electrons would be shared in a double bond?

---

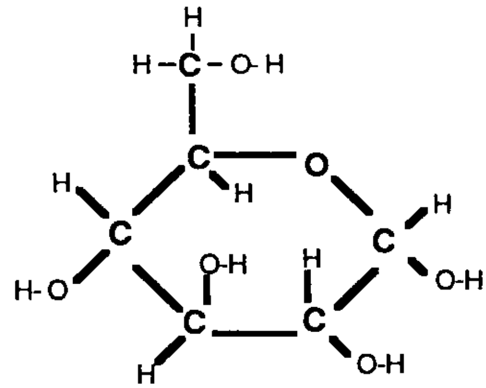
11. 4

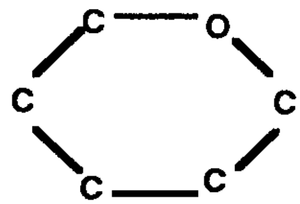
Investigation Procedure

12. The following part of this lab activity will require most of the laboratory period. Do

not start to build the glucose molecule unless half or more of the period remains.

You will now make one of the most important molecules found in living systems. Make a glucose molecule by following the next few steps. First study the structural formula for glucose for a moment.





First make the basic "ring" of 5 **C** atoms and 1 **O** atom as shown below. You may work in pairs or individually if you have no partner. There are only enough atoms to make 2 molecules of glucose per table. [___]

You will need to connect these atoms tightly or the molecule will fall apart later. The best way is to apply pressure in a straight line as shown:

Apply this kind of pressure to all bonds in the ring. [___]

Add the remaining atoms. [___] When complete remember that no holes should remain. Also count the number of C, H and O atoms to be sure that you have not missed any. [___] When the molecule is complete you might admire it for a moment since they are not easy to build. [___] On your table you may have a small amount of powdered glucose. Examine it and taste it if you like. Remember, this is what scientists "believe" the molecules of this powder to look like, even though no one has ever seen a glucose molecule. If you were to connect this glucose molecule to hundreds of others, in a chain, the result would be starch. **Save this glucose molecule.**

---

13. Construct six molecules of O_2. Remember O_2 that contains double bonds. [___] Save the O_2 molecules for the next step. [___]

---

14. Remembering that the equation for respiration included food as a requirement, and that the "specific" food involved is GLUCOSE, rewrite the respiration equation using the empirical formula for glucose.

---

14. $O_2 + C_6H_{12}O_6 \longrightarrow CO_2 + H_2O + E$

15. Write the equation for respiration, with $C_6H_{12}O_6$ substituting for "food", from this point on. Now write the equation for photosynthesis.

15. $CO_2 + H_2O + E \dashrightarrow O_2 + C_6H_{12}O_6$

(Notice that the food actually produced is glucose.)

16. The molecules of O_2 and $C_6H_{12}O_6$ that you have just constructed are the requirements for which process?

16. respiration

17. With these molecular requirements, you can demonstrate to yourself what happens when O_2 and $C_6H_{12}O_6$ react. This will graphically show you where the products CO_2, H_2O and energy come from. It should help you understand the respiration reaction much more clearly.

The equation for respiration tells us that the O_2 and $C_6H_{12}O_6$ will break apart and become rearranged as CO_2 and H_2O. To form these products, what will you have to do with your glucose molecule?

17. The glucose molecule will have to be pulled apart.

18. Before you do this, it is helpful to know that this process is occurring in your cells at the moment. The glucose in you is carried to each cell by your blood stream. The O_2 entering your lungs is carried to each cell by the blood stream. There the glucose molecules are pulled apart by enzymes and the parts of the glucose molecule rearranged into CO_2 and H_2O.

In making CO_2 and H_2O from $C_6H_{12}O_6$, is it necessary to break every bond in the glucose?

18. No it is not. It is easier to break off just enough of the glucose molecule so that minor changes are needed to form CO_2 and H_2O.

19. The cells do not go through any extra work. They conserve their energy. Proceed to break apart both the $C_6H_{12}O_6$ and the O_2 when needed, to form CO_2 and H_2O molecules. Break apart only those bonds needed to create the CO_2 and H_2O. Use all the O_2 and form as many CO_2 and H_2O molecules as you can. [___]
When you have completed the reaction, count the number of CO_2 molecules and H_2O molecules that you have. There are ___ CO_2 molecules and ___ H_2O molecules.

---

19. 6 CO_2 and 6 H_2O. (If you do not have 6 complete CO_2 and 6 H_2O molecules, your reaction is not complete. Complete the reaction and get help if needed.)

---

20. You have just demonstrated which process? ____ When you pulled apart the glucose molecule and O_2 molecules with your hands, that represented what the cell accomplishes using _____.

---

20. respiration, enzymes

---

21. The energy that is shown as a product in the respiration equation is stored in the bonds that hold the glucose molecule together. When these bonds are broken by enzymes, the energy is liberated. It takes energy to hold the atoms of glucose together. Break these bonds and the energy will be released and can be available to heat the animal or can be used for muscle energy.

How many molecules of glucose did you start with?
How many molecules of O_2 did you start with?
How many molecules of CO_2 did you end up with?
How many molecules of H_2O did you end up with?
Do not take apart these molecules.

---

21. 1, 6, 6, 6

---

22. The respiration equation can be rewritten with the number of molecules needed, substituted for the blanks below:
___ O_2 + $C_6H_{12}O_6$ ------------> ___ CO_2 + ___ H_2O + Energy
Place the numbers that belong in the blanks on your own paper.

---

22. 6, 6, 6 Notice that when only 1 molecule of glucose ($C6H12O6$) is involved, the number 1 is not placed before the formula for glucose.

The above is what is called a BALANCED EQUATION, because it accounts for every molecule required and shows exactly how many molecules of CO_2 and H_2O are produced. In any chemical equation, the number appearing before the molecule's formula tells how many molecules are involved.

Review: When one sees a formula as follows: **6 CO_2**

The number **6,** which precedes the molecule, tells the reader the number of **CO_2** molecules. The subscript **2**, tells the number of atoms of **O** in 1 CO_2 molecule. Disassemble the molecules if time is completely up. Otherwise continue and do not disassemble the molecules. [___]

PHOTOSYNTHESIS

If you had to disassemble your products of respiration, remake them. Make 6 H_2O molecules and 6 CO_2 molecules. [___]

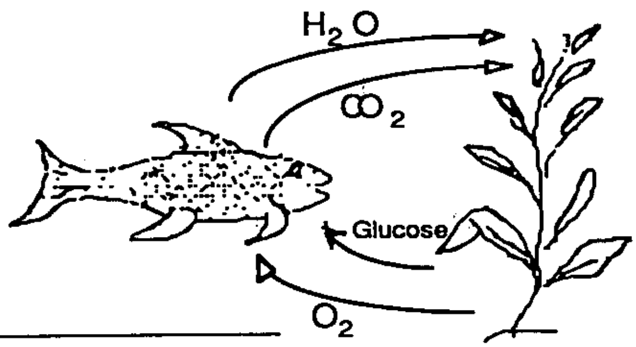
23. In nature, what becomes of these products of respiration given off by you and by other animals?

---

23. They are taken in by plants. The CO_2 and H_2O actually mix with the CO_2 and H_2O in the atmosphere or pond, lake or ocean, and eventually are taken in by plants.

---

24. Examine the drawing at the right. What happens to these products of respiration after they enter the plants? What process do they get involved in?



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24. photosynthesis

25. Write the equation for photosynthesis.

$$CO_2 + H_2O + \text{light energy} \xrightarrow[\text{chlorophyll}]{\text{enz.}} C_6H_{12}O_6 + O_2$$

25. (Notice that the food produced is glucose.)

---

26. In plant leaf cells, where photosynthesis occurs, the CO_2 and H_2O react. The light energy is absorbed by chlorophyll and is used for breaking apart the molecules of CO_2 and H_2O. Enzymes aid in this break up, and other enzymes put the pieces of CO_2 and H_2O together into 1 large glucose molecule . The remaining oxygen atoms combine as O_2. The sun provides the energy used to bond the atoms together into the glucose molecule. This energy becomes stored in the BONDS of the glucose molecule.

    Break just enough bonds in your 6 CO_2 and 6 H_2O molecules to be able to construct 1 $C_6H_{12}O_6$ molecule with the CO_2 and H_2O parts. Form the ring portion first, then add the other parts until you have a glucose molecule. [___]

    When your glucose molecule is complete, count the C, H and O atoms to be sure you have not missed any atoms. [___] Are there any empty holes in any of the atoms of your glucose molecule? How many oxygen atoms remain on the table?

---

26. There should be no holes in any atoms of the glucose molecule. There should be 12 individual atoms of Oxygen.

---

27. The O atoms remaining react to form molecular oxygen, O_2. Combine all of them into a number of distinct O_2 molecules. [___]

    How many O_2 molecules are produced? This O_2 leaves the leaf and can be taken in by an animal.

---

27. You should be able to form 6 O_2 molecules.

---

28. It's interesting to contemplate that what you just performed during this class period is taking place in the plant leaf that is on the table before you. [___] Examine the leaf and be aware that this photosynthesis process which you just duplicated, takes only

seconds in the cells of the plant.

Write the number of molecules of each kind involved in the photosynthesis reaction below:
______CO_2+ ______H_2O + E --------> ______$C_6H_{12}O_6$ + ______O_2

---

28. 6, 6, 1,6

---

29. Notice that the products of photosynthesis are the (products or requirements) of the respiration process. [Select the appropriate word in the parentheses.] Also notice that when the products of photosynthesis have completely formed, the requirements for photosynthesis no longer exist.

---

29. requirements

---

30. Notice that the energy from the sun is now locked back into the glucose molecule. When an animal eats the leaf, it takes in glucose. Through the respiration process, the animal breaks the bonds of glucose again and obtains energy to move. And so the process of respiration repeats itself again, and the SAME ATOMS of C, H and O are shuttled back and forth between plants and animals for as long as this planet exists. A brief summary follows:

$$6\,O_2 + C_6H_{12}O_6 \underset{\text{photosynthesis in plants}}{\overset{\text{respiration in animals}}{\rightleftharpoons}} 6\,CO_2 + 6\,H_2O + E$$

This "reversible" reaction continues; respiration in animal cells and photosynthesis in plant cells.

Dismantle your molecules and place the atoms and springs in their appropriate containers. [___]

Complete the following review which should help you prepare for the quiz to follow. [___]

REVIEW:

31. Write the balanced equation for respiration.

---

31. $6\ O_2 + C_6H_{12}O_6 \xrightarrow{\text{enzyme}} 6\ CO_2 + 6\ H_2O + E$

Be sure to not omit ENERGY from the equation, since its production is the reason for the existence of the process of respiration. IMPORTANT: At the beginning of this activity the equation for respiration was written as:

$6\ O_2 + \text{food} \longrightarrow 6\ CO_2 + 6\ H_2O + E$. Food was used in the equation because the student was not yet familiar with $C_6H_{12}O_6$ as the sugar requirement in respiration. Remember that from this point on, the equation is to be written with $C_6H_{12}O_6$ and **not** food. This is how you will be expected to write it on tests & quizzes.

---

32. Write the equation for combustion.

---

32. $O_2 + \text{fuel} \longrightarrow CO_2 + H_2O + C + E$

---

33. This reaction, which is so similar to respiration, occurs in the same chemical manner as does respiration. In fact, fuels such as wax, wood and gasoline contain C, H and O.

List each substance found in the respiration equation on your own paper under the following headings:

COMPOUNDS ELEMENTS MOLECULES ATOMS

---

33. COMPOUNDS: $C_6H_{12}O_6$, CO_2, H_2O

ELEMENT: O_2

MOLECULES: $C_6H_{12}O_6$, CO_2, H_2O, O_2

ATOMS: NONE (Unless you made reference to the individual atoms of C, H, and O within the other molecules)

---

34. Write the balanced equation for photosynthesis.

What type or form of energy is required by plant cells to put the glucose molecule together?

A substance that helps put the atoms together and arrange them as glucose is called ___.

The carbon atoms in the photosynthesis product, $C_6H_{12}O_6$, come from what reactant molecule?

All the hydrogen atoms found in glucose come from what reactant?

---

34. $6\ H_2O + 6\ CO_2 + E \xrightarrow{\text{chlorophyll \& enzymes}} C_6H_{12}O_6 + 6\ O_2$,

Light energy, enzymes, CO_2, H_2O.

---

35. In photosynthesis, how many oxygen molecules are produced for every 1 glucose molecule produced?

What "type" of formula is CO_2? What "type" of formula is O=C=O?

---

35. 6, empirical, structural

---

36. What kind of bonds are seen in the CO_2 molecule? (O=C=O)

---

36. double

---

37. The chlorophyll needed for photosynthesis is found in what plant cell structure?

---

37. chloroplasts

---

38. The definition for compound is: A substance that is composed of ____. It (can or cannot be) separated into simpler substances.

---

38. 2 or more different elements chemically united, (can)

---

39. An element (can or cannot be) separated into simpler substances. A molecule is composed of ____.

---

39. cannot be, 2 or more atoms in definite proportions.

---

40. The "products" of photosynthesis are the ________ for respiration. The energy that an animal obtains from respiration comes from ______.

40. requirements or reactants, the glucose molecule bonds. When they break, they give off energy.

Review the objective stated at the beginning of this lab activity and spend out-of-class time preparing for the quiz over this topic.

7-4 Respiration and Energy Transfer

If you completed the previous lab activity, you now know some of the details of the respiration process. You will find that this knowledge will enable you to understand many other important biological concepts.

1. Why must animals obtain energy?

Objective

You will be required to write a balanced equation for animal respiration and explain where the energy produced comes from and how it is stored.

This equation goes on in every animal and plant cell twenty-four hours a day. That's right, even in plant cells. During the day, the plant cell is carrying out photosynthesis which masks respiration and makes it difficult to detect. Here's how it works:

In light: (The size of letters indicates the amount of reaction taking place.)

$$(1)\ CO_2 + H_2O + \text{light energy} \xrightarrow{\text{enz.}} O_2 + C_6H_{12}O_6$$

$$(2)\ O_2 + C_6H_{12}O_6 \xrightarrow{\text{enz.}} CO_2 + H_2O + \text{energy}$$

2. What are the names for equations (1) and (2)?

3. Which equation requires CO_2 and which equation produces CO_2?

At night, when the sun sets, the photosynthesis reaction stops but the respiration reaction continues:

$$O_2 + C_6H_{12}O_6 \xrightarrow{\text{enz.}} CO_2 + H_2O + \text{energy}$$

This is why plants like *Elodea* can be shown to use CO_2 in light and give off CO_2 in the dark. The balanced equation for respiration is as follows:

$$6\ O_2 + C_6H_{12}O_6 \xrightarrow{\text{enz.}} 6\ CO_2 + 6\ H_2O + \text{energy}$$

Balanced equations show the number of molecules of each required reactant and the number of each product molecule.

4. In respiration, how many molecules of water will be produced for every one molecule of glucose that breaks apart?

5. In respiration, how many molecules of oxygen will be required for every 12 molecules of carbon dioxide produced?

During the respiration reaction, the $C_6H_{12}O_6$ and O_2 molecules are pulled apart by enzymes. As the bonds in the glucose and oxygen molecules are broken, the atoms rearrange into the products carbon dioxide and water, releasing energy in the process.

6. During respiration, which reactant molecules do the C atoms in CO_2 come from? Do they come from the oxygen or the glucose? Explain your choice.

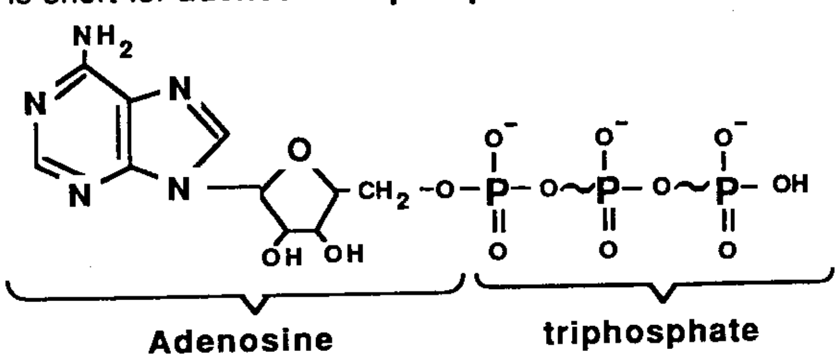
In respiration, humans breathe oxygen into their lungs. The **oxygen** enters the blood stream which takes it to all body cells. The blood also brings needed **glucose** from the digestive system to the cells. Each cell now uses numerous respiration enzymes to help break the $C_6H_{12}O_6$ and O_2 apart. As the gucose is pulled apart, the **energy** that is holding the glucose molecule together is transferred to another form and is stored for later use by the cell. In muscle cells, great amounts of energy need to be stored to be available for muscle contraction. The energy produced in respiration is stored by a unique molecule known to biochemists as **ATP**.

7-5 In-Depth Enrichment: ATP, The Energy Storage Units of the Cell

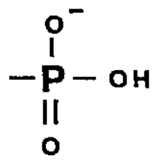
Objective

You should be able to describe how ATP and ADP are involved in the storage and release of energy produced during respiration.

ATP is short for **adenosine triphosphate.** Examine the following structure of ATP:



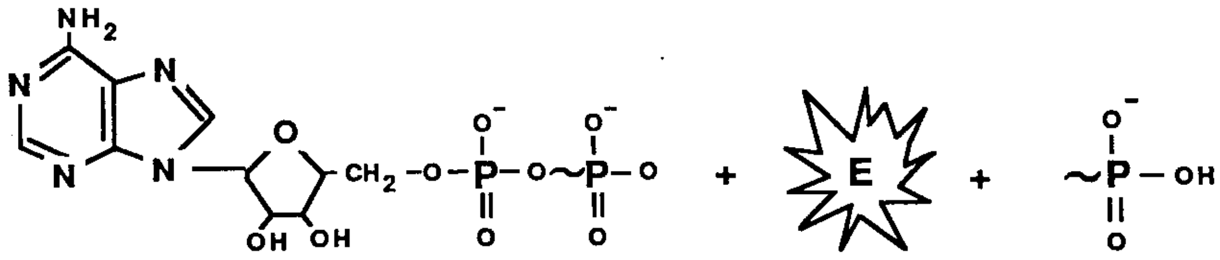
The hexagon and pentagon symbols in **ATP** are used by chemists to represent rings of C atoms. C atoms are found at the points of the hexagon and pentagon. One half of the molecule is called **adenosine** and the other half consists of **3 phosphate groups.** A phosphate group is made of one phosphorus (P) atom with 3 O atoms and one H atom clustered around the P atom as shown at the right. The **phosphate group** can be symbolized as a circle with a P in the middle. Using these symbols, ATP can be symbolized in the following way:



1. What atoms are found in each phosphate group?

2. Draw the actual structural formula for the adenosine part of the ATP molecule that shows where each C, H, O and N atom is located.

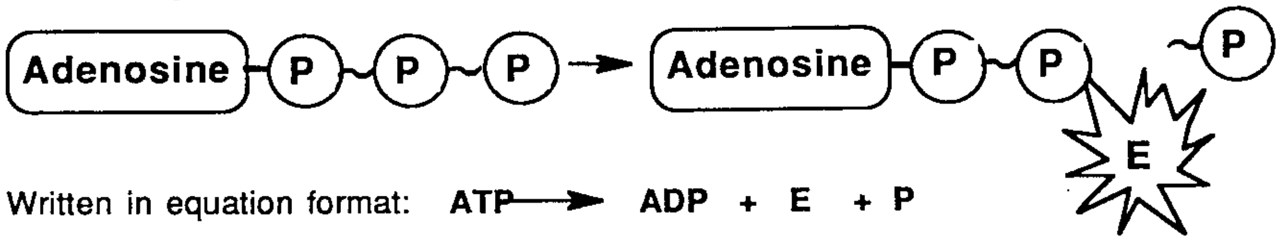
The bonds between phosphates are represented with a ~ . This symbol represents a **high energy bond.** When a high energy bond is broken, the amount of energy released is greater than when a regular bond is broken. ATP stores its energy in these high energy bonds. **The energy comes from respiration.** When the high energy bond connecting the last phosphate group to ATP breaks, the energy is released and the products are symbolized as follows:



Adenosine diphosphate (ADP) + energy + phosphate

Notice that when one phosphate group breaks off of the larger part of the ATP molecule, the remainder is called adenosine **di**phosphate because it has only **two** phosphates attached.

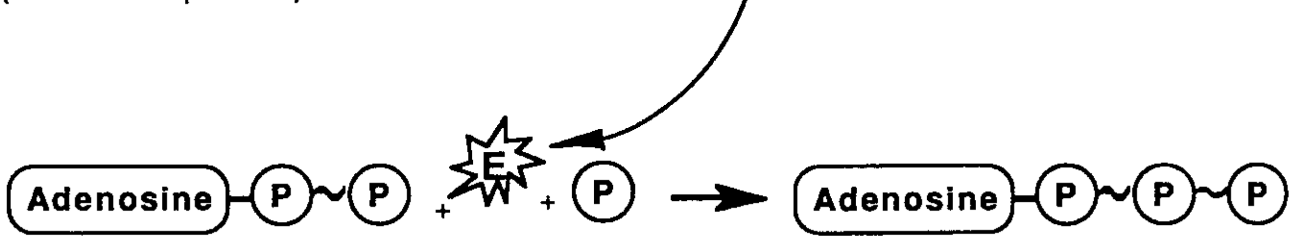
Another way to visualize how ATP stores and releases energy is as follows:



Written in equation format: ATP ⟶ ADP + E + P

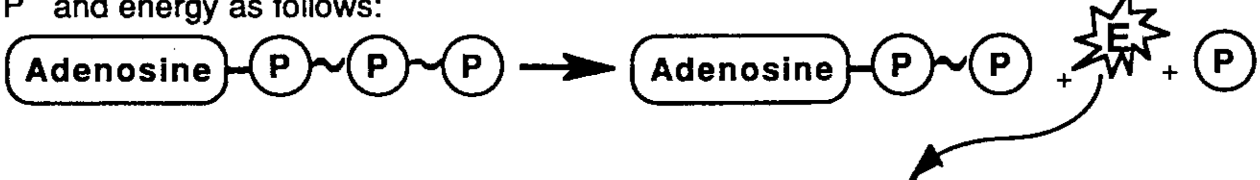
Adenosine triphosplate (ATP) breaks apart to produce adenosine diphosphate (ADP), energy (E) and phosphate (P). The following diagram shows the energy for the breaking of bonds in glucose during respiration, transferring to ATP:

O_2 + $C_6H_{12}O_6$ ⟶ CO_2 + H_2O + energy
(Cellular respiration)



The above shown in the short version: ADP + E + P ⟶ ATP

The energy given off from respiration is used to link the phosphate (P) to the ADP molecule. The resulting product is **ATP**. The ATP stores this energy from respiration in the last bond to the last P group. Millions of ATP molecules are built when energy requirements are low. When the cell needs energy, it converts the ATP back to ADP and P and energy as follows:

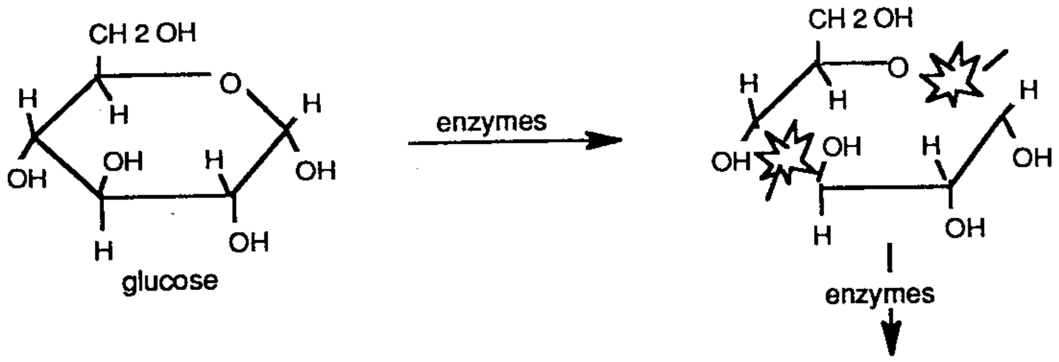


Energy available for muscle contraction and other cell activities

The above can be shown in the short version as follows:

ATP ⟶ ADP + P + E

The energy is used by the cell for any cell activity requiring it. In muscle cells, the released energy can be used to contract the muscle. In summary, this is how it works. The glucose, shown below, is broken apart in steps by a series of enzymes. Each time a bond in glucose is broken, the energy previously holding the atoms of glucose together, is released and will be transferred to ADP molecules.
The energy is represented by 

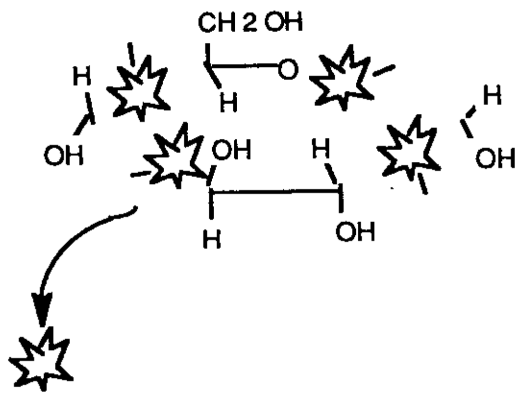


The energy from the bonds of glucose unites the P to ADP creating a molecule of ATP:

E + P + ADP ⟶ ATP

When the cell needs energy, the reaction reverses, and the ATP breaks apart to produce ADP, P and the needed **energy.**

For each one molecule of glucose that breaks down, 38 molecules of ATP are produced.



+ P + ADP ⟶ ATP

Respiration and ATP formation takes place in the **mitochondria** of every plant and animal cell. The steps involved in the breakdown of glucose are actually more complex than diagrammed above and are cyclic in nature. The cyclic part of the breakdown is known as the **Krebs Cycle.**

3. Explain how the energy in glucose is released during respiration and how it become stored in ATP. Use diagrams if you like.

4. Explain how ATP provides energy for the cell. Use equations or diagrams to supplement your explanation.

7-6 Photosynthesis: The Prime Energy Capturing Reaction for all Life on Earth

1. Briefly describe what happens in plant photosynthesis.

Objective

You will be required to write a balanced equation for plant photosynthesis and explain where the required energy comes from. You will also be required to draw a diagram of the carbon cycle and explain the interdependence between animals and plants.

In the unit, *Plant Processes,* you will learn details about photosynthesis that go beyond that covered in this chapter. In this chapter it will be satisfactory to have a general understanding of the equation for plant photosynthesis.

All green plants carry out photosynthesis. In the process, the green **chlorophyll** in leaves traps the sun's light energy. This energy is then made available to rearrange carbon dioxide and water molecules to form glucose and oxygen molecules. The general equation is written as follows:

$$CO_2 + H_2O + \text{light energy} \xrightarrow[\text{enzymes}]{\text{chlorophyll}} O_2 + C_6H_{12}O_6$$

The balanced equation is as follows:

$$6CO_2 + 6H_2O + \text{light energy} \xrightarrow[\text{enzymes}]{\text{chlorophyll}} 6O_2 + C_6H_{12}O_6$$

2. How many molecules of water would be required to produce 3 molecules of glucose?

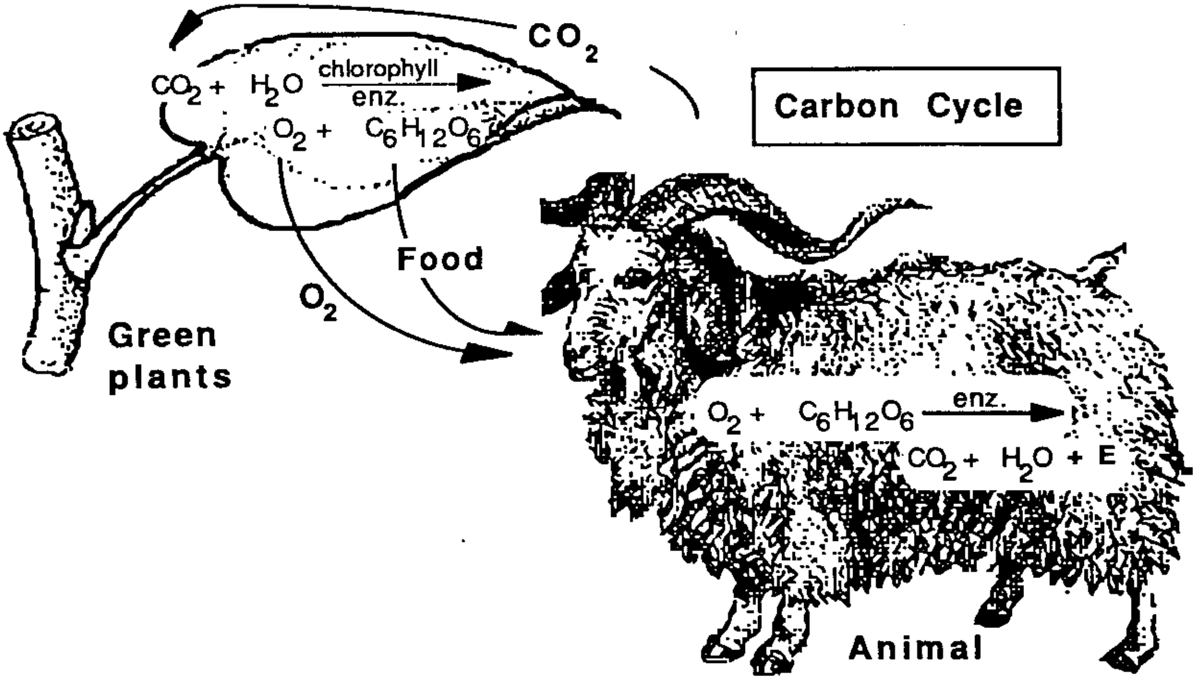
Photosynthesis takes place within the **chloroplasts** of plant cells found in the leaves of green plants. The chloroplasts contain the green pigment **chlorophyll**, which is able to absorb and trap certain colors of light energy. The trapped **light energy** is used to break apart the 6 CO_2 and 6 H_2O molecules and rearrange them into one $C_6H_{12}O_6$ and six O_2 molecules. This is precisely what the equation shows.

3. Based upon the equation, do the H atoms in glucose come from the water or carbon dioxide molecules? Explain your choice.

4. How is the equation for animal respiration different from the equation for plant photosynthesis? In your opinion, what is the reason for this difference?

The Carbon Cycle on Planet Earth

You have no doubt noticed that the equation for animal respiration is the opposite of plant photosynthesis. That is, the products of respiration are the same as the requirements (reactants) for photosynthesis. Study the diagram below :



5. What substances produced by green plants are required by animals?

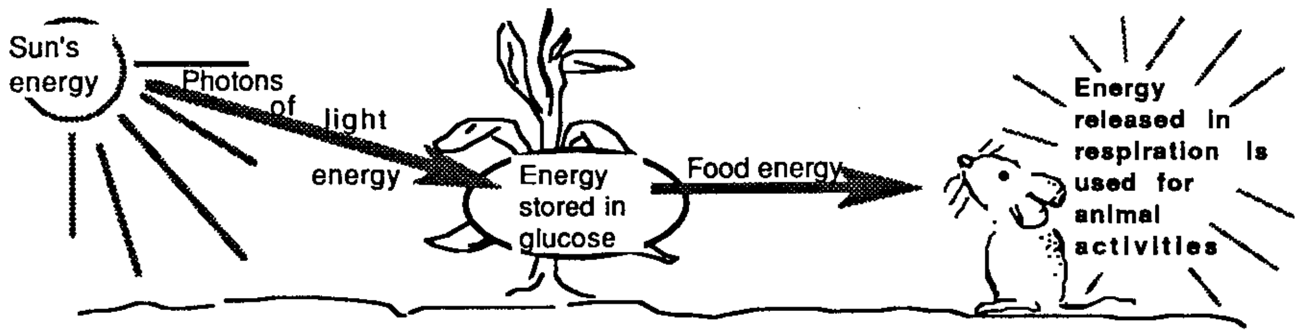
6. What substances are required by plants that are produced by animals?

7. What changes would occur on the planet if all of the green plants were to die tomorrow?

In the **Carbon Cycle**, the same atoms might be used over and over again. The products of plant **photosynthesis**, the oxygen and glucose, are taken in by animals. All the oxygen present in our atmosphere comes from photosynthesis. The oxygen and glucose are used in **respiration.** The products of animal respiration, carbon dioxide and water are required by the plant for photosynthesis. And the cycle goes on. Without it, life on earth would cease to exist.

Energy Flow

The energy from the sun is effectively transferred to plant glucose during photosynthesis. The energy stored in glucose is released when animals use it in respiration. The energy released in respiration becomes available for animal and human activity.



8. What is the original source of energy that ultimately is needed or used to enable you to walk?

Since the equation for photosynthesis is the reverse of respiration, you might suspect that the details for photosynthesis are the reverse of respiration. In general, this is true. The details of the photosynthetic process are complex. A greatly simplified optional version of the details of photosynthesis follow:

7-7 In-Depth Enrichment: Details of Photosynthesis

Objective

You will be required to explain the events in the **light** and **dark reactions** and account for how the requirements of photosynthesis become the products of photosynthesis. You should also be able to explain the roles of ATP and ADP in the process.

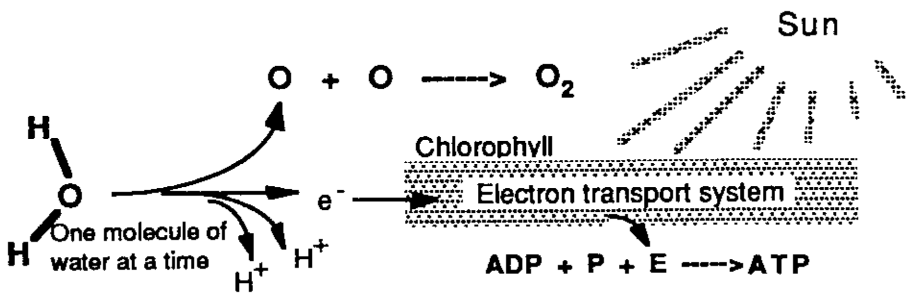
1. Write the balanced equation for photosynthesis.

Be sure you have completed In-Depth Enrichment: 7-5, ATP, The Energy Storage Units of the Cell, before beginning this topic.

2. What is ATP and how does it store and release energy?

The Light Reaction

Photons of light strike special molecules in the chlorophyll in leaf cells. The atoms in these molecules absorb certain colors of light; mainly the orange and blue colors. In the process, electron energy is passed from one molecule to another in an **electron transport system.** Some of this energy combines with ADP and P to form ATP. The ATP will later make this energy available for building glucose, a product of photosynthesis. Study the diagram of the light reaction below and continue reading:



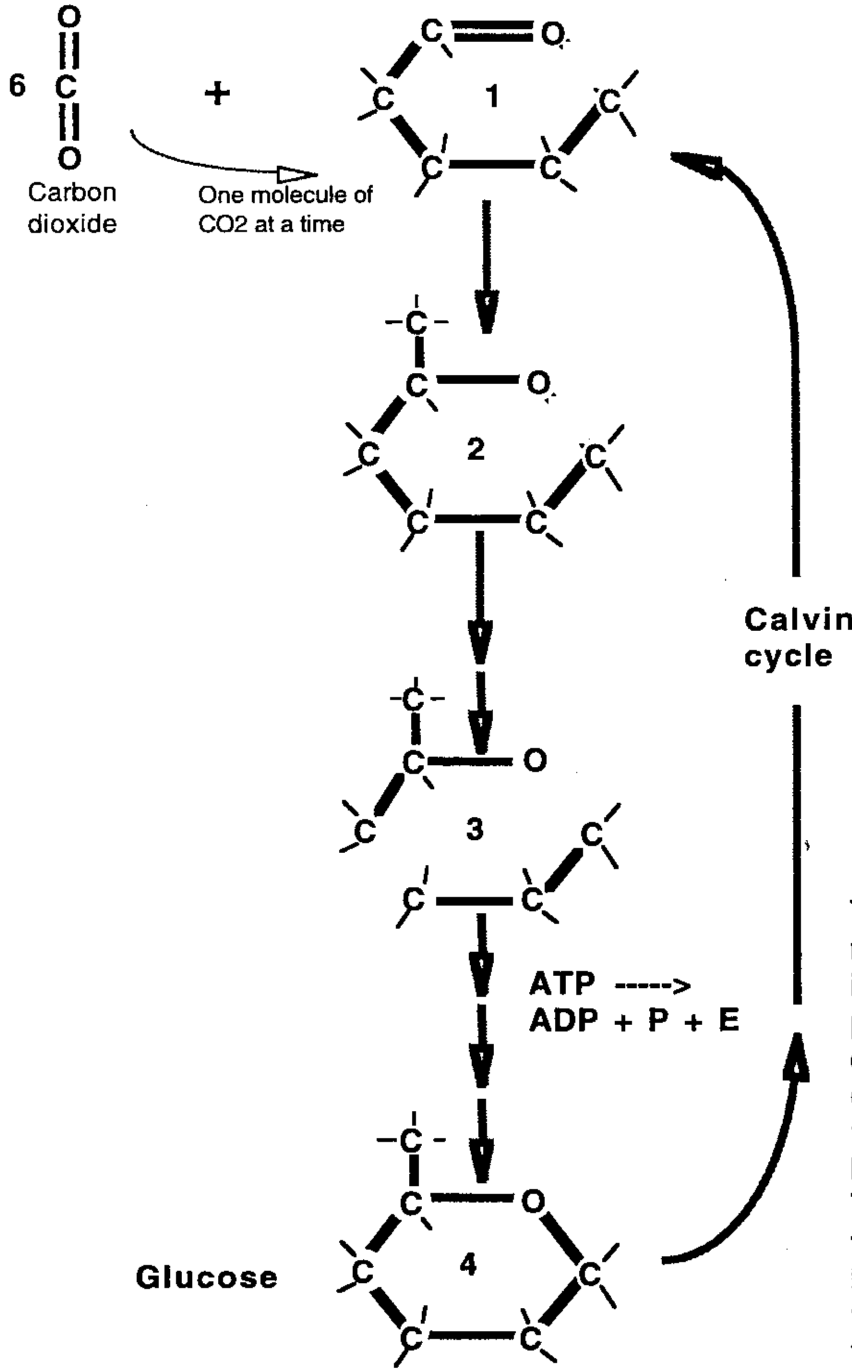
Water molecules are broken apart one at a time. The two hydrogen atoms separate from the oxygen. After two molecules of water break apart, two atoms of oxygen are formed. These two oxygen atoms combine to form O_2, the other product of photosynthesis. The oxygen gas leaves the leaf through small openings in the leaf. Next the hydrogen atoms that separated from the oxygen do something rather strange. Remember that an H atom is made of one negative electron and one positive proton. The electron (e^-) separates from the proton (H^+). The electrons move along the **electron transport system**, producing more ATP from ADP and the **energy** associated with the electron. The reaction is named the **light reaction** because of the requirement for light. Now let's look at the rest of the process to see how glucose is formed from the CO_2 and H atoms from the light reaction.

3. Explain what happens to the water molecules required for photosynthesis.

The Dark Reaction

The dark reaction does not have to take place in the dark; it is called the dark reaction because light is not required for it to occur. It can actually occur in the light.

Study the sequence of diagrams that follows. All formulas are the structural formulas which show the shape of the molecules involved. What is shown is how carbon dioxide, one at a time, joins with a 5-carbon molecule which then moves through what is called the **Calvin Cycle.**



The molecules represented by rings of C atoms or partial rings are made up of C, H and O atoms. Only the C atoms are shown to simplify a very complicated process. The lines extending from the C atoms show where H and O atoms attach. The hydrogen ions from the light reaction are added at specific steps in the **Calvin Cycle**. Study the changes that take place in each numbered step and be prepared to answer the questions that follow:

The glucose that is formed, moves out of the cycle and is the main product of photosynthesis. In the cycle, the ATP formed during the light reaction, releases energy needed to build the glucose molecule. The energy from the light, therefore, ends up in the bonds of glucose and is what holds the molecule together.

4. How is molecule 2 different from molecule 1?

5. Where did the extra C atom come from in molecule 2?

6. What change occurred when molecule 2 became two molecule 3's?

7. How is molecule 4 different from the two molecule 3's?

Believe it or not, the above description of the light and dark reactions are greatly simplified. These two reactions are very complex and many in-between steps exist and are understood by biochemists.

Summary of the Light and Dark Reaction

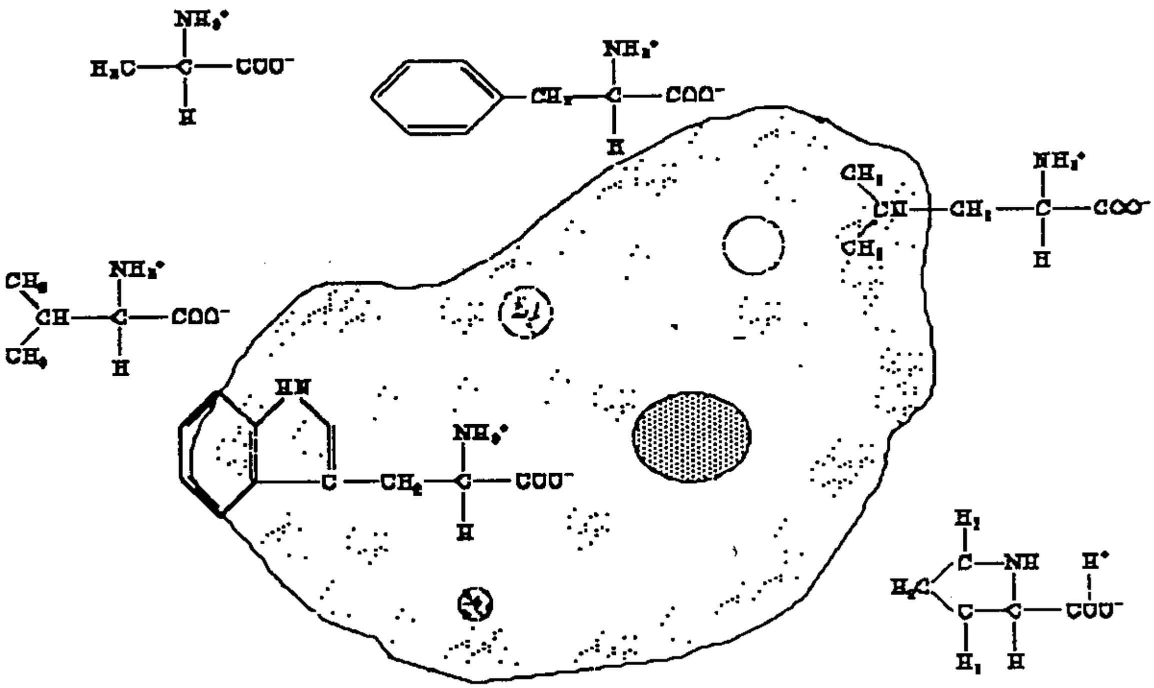
In the **light reaction**, light is absorbed by chlorophyll and H_2O is broken apart and ATP is formed. O_2 is given off. In the **dark reaction**, the CO_2 reacts with molecules in the Calvin Cycle. H+ ions from the water from the light reaction are added to Calvin Cycle molecules and $C_6H_{12}O_6$ is eventually formed. ATP provides the energy for linking the atoms together to form glucose.

8. Explain how glucose is formed from carbon dioxide in the Calvin Cycle.

9. How many molecules of carbon dioxide are required to form one molecule of glucose?

CHAPTER 8

MEMBRANES AND MOLECULES



Chapter 8

Membranes and Molecules

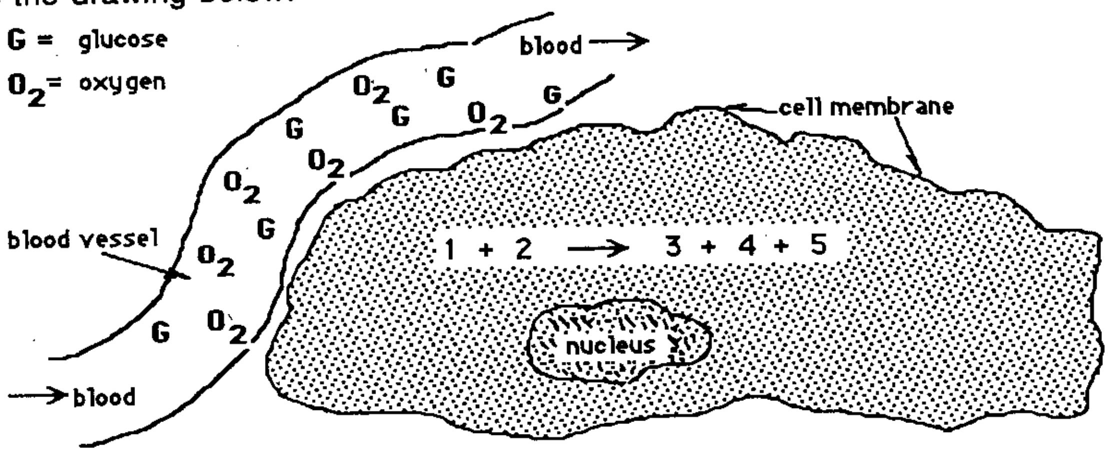
Anyone who stops learning is old,
whether at twenty or eighty. Anyone who keeps
learning stays young. The greatest thing in life is to keep your mind young.
Henry Ford

8-1 Laboratory Investigation:

How Do Molecules Enter Cells?

Objective
You will be required to plan and conduct an experiment to determine if certain molecules can pass through a membrane.

Many of the old problems have been solved. One problems was "How does an animal or human obtain its energy?" The answer is that animals obtain energy by **respiration** where enzymes break down glucose that is present in many foods, and convert it to CO2 and H2O with production of energy from the chemical bonds broken in glucose. The requirements for respiration are found both in an animal's blood stream and in its cells. The new, yet unanswered problem is "How does the O2 and glucose get into the cell and how do the products of respiration get out?" Remember that all cells have a cell membrane that surrounds the cell.
Examine the drawing below:



ANIMAL CELL

1. The respiration equation is represented in the cell above as 1 + 2 ---> 3 + 4 + 5. As a review, write the requirements that 1 + 2 represent.

2. What respiration products are represented by 3 + 4 + 5?

PRE-LAB:

You will need to know how to make certain chemical tests in order to design your own experiment. Perform the following test at this time.

To learn how to make tests for the presence of glucose and starch, do the following:

GLUCOSE TEST:

Clean two test tubes and fill one test tube with **tap water.** [___] Test the water with a"**glucose test strip**" for the presence of glucose as follows: Remove one drop of the tap water and place it on the pad of the glucose test strip. See the possible color results and directions on the side of the test strip container [___] Always wait 2 minutes before recording the results since it sometimes takes this long to produce any change.

3. Is glucose present?

If glucose is present, this is referred to as a **POSITIVE TEST**. If glucose is absent, this is referred to as a **NEGATIVE TEST.**

4. Did tap water show a positive or negative test for glucose?

5. What % glucose was present? (See the "glucose test strip" container)

Now test the solution of glucose on your table in the same manner.

6. What were the color results from the glucose test?

7. Would this be called a positive or a negative test for glucose?

STARCH TEST:

To conduct a starch test you need to use another chemical indicator. Remember that a **chemical indicator** is a substance that will tell you whether certain chemicals are present or not. The CHEMICAL INDICATOR usually shows this by changing color. The **CHEMICAL INDICATOR** that you will use to test for the presence of STARCH is **LUGOL'S IODINE** solution. **Be careful when handling Lugol's Iodine solution. It can damage the eyes and skin and will stain clothing.**

8. If you tested pure, clean tap water, would you expect to find STARCH in the water?

How to perform the STARCH TEST:

Clean 2 test tubes at the sink and fill one about 1/4 full with tap water and return to your table. [___] To the other test tube, add 2 to 3 ml. of starch solution. [___] Now add 3 drops of LUGOL'S IODINE solution to both test tubes. [___]

9. What color is obtained when iodine was added to plain water and what color was obtained when iodine was added to the starch solution?

10. Since a positive test is when the starch is found to be present, what color indicates a POSITIVE TEST for starch?

11. If you had a solution of various chemicals, what chemical indicator would you use to determine if GLUCOSE was present in the solution?

12. What chemical indicator would you add to find out if STARCH was present in the same solution?

<u>IMPORTANT PROCEDURAL NOTE</u>: If you need to test the same solution for BOTH glucose and starch, always test for glucose first. The reason is too complicated to explain at this time. It is usually best to separate a solution you wish to test into two quantities and then test both quantities separately.

Before beginning the actual experiment, copy the chart below onto your own paper. Then fill in the spaces in the chart as a review:

test	Using the following CHEMICAL INDICATOR	Color obtained in POSITIVE TEST	Color obtained in NEGATIVE TEST
STARCH			
GLUCOSE			

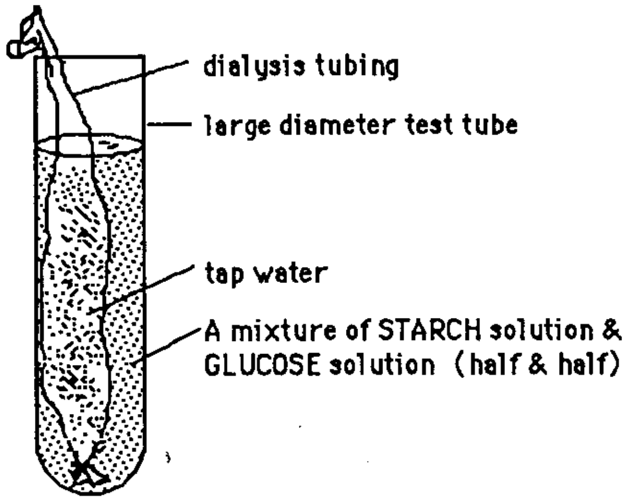
It's quite difficult to do experiments with cells because of their extremely small size. One can do experiments with cell membranes or cell membrane-like materials, however. On your lab table is a type of cellophane membrane called **dialysis** tubing. It is not living material but is known to have properties similar to living cell membranes. This dialysis tubing could be used in your experiment. You will find the dialysis tubing in a beaker of water. [___] Remove one piece and examine it. [___] What looks like a flat piece of cellophane is actually a flattened cellophane tube with the sides sticking together. With your fingers, pinch the tubing and slide your thumb from side to side to open the tubing. Keep it moist while doing this. [___] If you can't get the tubing open, get help. [___] Later you will be able to tie one end of the tubing with string so that the tubing can be filled with solutions. The other end can then be tied, and you would have a closed system resembling a cell surrounded by a membrane. Do <u>not</u> set up any parts of the dialysis tube experiment until later.

You are now ready to begin writing your report for this lab activity. You will not perform the experiment until you get to the middle of the report and are told to do so. Write your report on your own paper and all future reports of this type by using an OUTLINE FORM. In your OUTLINED report, use Roman numerals and follow the Roman numerals with the appropriately termed steps in the INQUIRY PROCESS, as follows:

I. **PROBLEM**: Can starch and glucose pass through a cell membrane? (dialysis membrane)?

II. **HYPOTHESIS**: (In this case, state the precise hypothesis that you think is being tested in the experiment diagrammed below.) DO NOT SET UP THIS EXPERIMENT UNTIL TOLD TO DO SO IN V BELOW. Be sure to use the words starch and glucose in your hypothesis. [___]

You must tie the bottom of the tubing tightly with string, but it's not necessary to tie the top.



III. **HYPOTHESIS IN IF-THEN FORM**:

IV. **EXPERIMENTAL DESIGN**: Draw the diagram of the experiment as shown in the previous drawing. It is hoped that you realize this is not all you need to do in the experiment.

13. After the experiment is set up as shown, what else would have to be done? Describe any tests that you feel need to be a necessary part of the experimental design.

V. **PERFORM EXPERIMENT**: Perform the experiment exactly as you described in your experimental design in IV above. There is one factor you may not realize that will be important. After setting up the experiment as diagrammed, be sure to let it set for at least 5 minutes before making any tests on the solutions. WORK IN PAIRS OR INDIVIDUALLY. Be sure to tie the bottom of the tubing tightly with string. It will not be necessary to tie the top. [___]

VI. **EXPERIMENTAL RESULTS**: Record and tabulate all data clearly and neatly since your report will be mainly judged upon these factors. Do not hand in partially completed reports.

VII. **INTERPRETATIONS**: Interpret the recorded results in VI above.

VIII. **CONCLUSION**: What is your conclusion regarding the hypothesis stated in II above. HYPOTHESIS SUPPORTED, NOT SUPPORTED OR CONTRADICTED?

14. Based upon your data, which molecule(s) passed through the membrane?

PART 2

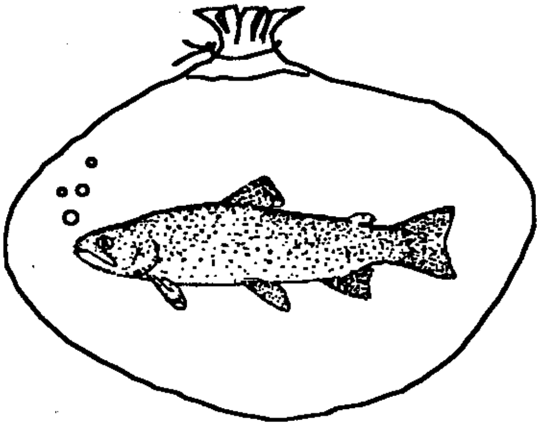
Start a separate piece of paper for this part. You will be writing up a new report and answering a series of questions.

GOLDFISH EXPERIMENT:

You will find the goldfish experiment already set up on one of the counters in the room. Find the experiment and then continue reading. [___]

There are two reactants for respiration, and they both must enter the cell before respiration can take place. You have found, we hope, that glucose is capable of passing through cell membranes. What about O2? Examine the goldfish experiment realizing that the polyethelene membrane is similar to a cell membrane. [___] Then prepare a report for the goldfish experiment that deals with the following steps:

I. Problem
II. Hypothesis being tested.
III. Hypothesis stated in "if-then" form
IV. Drawing of experimental design (Apparatus setup)
V. Data and observations
VI. Interpretations
VII. Conclusion



DIFFUSION

Label this report "Lab 8-1, Part 2," and then answer the review quesitons that follow. Review the experiment that you performed in Lab 8-1 (Part 1) [___]

1. Was the glucose able to pass through the cellophane membrane?

The movement of such substances will be described more fully later. This movement is termed **DIFFUSION**. Glucose is said to diffuse through the membrane.

2. How did you explain the movement of glucose molecules through an "apparently" solid membrane?

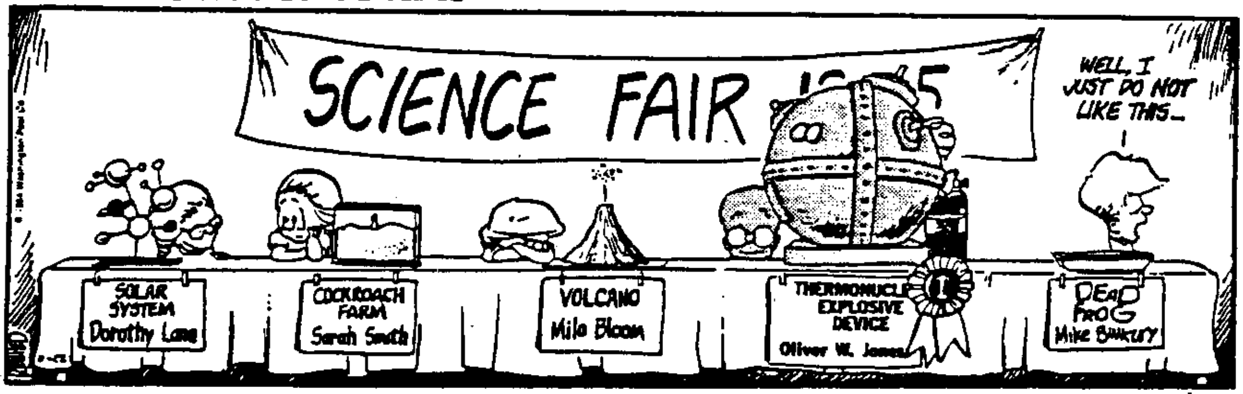
3. Did the starch pass through the membrane?

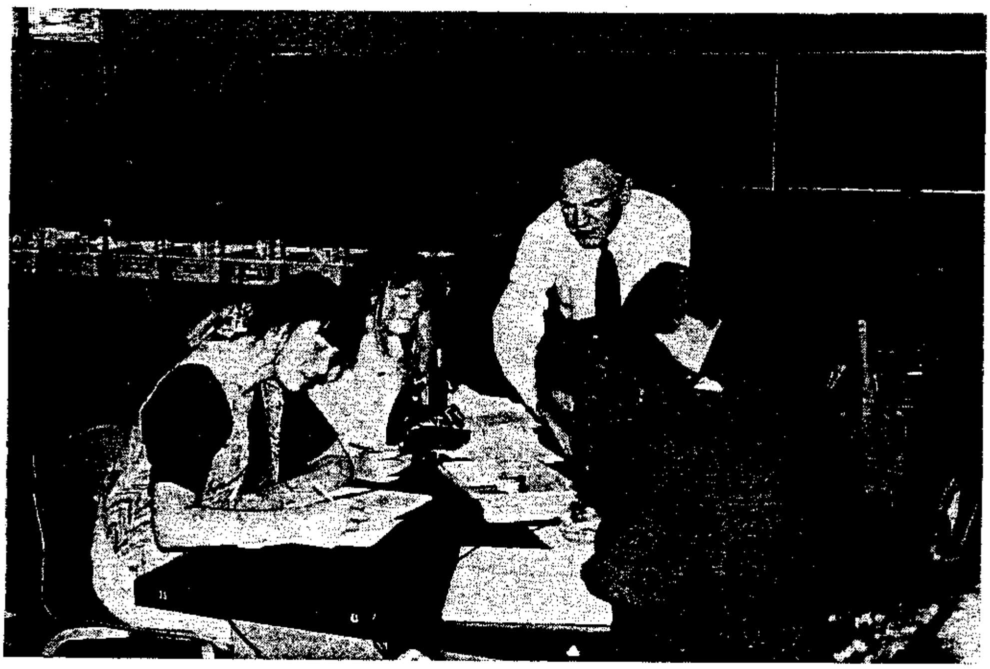
4. Is it possible for one kind of molecule to pass through a membrane and another kind of molecule to not be able to pass through that same membrane? If so, how? If not, why not?

5. Offer a hypothesis that describes the relative size of the starch molecule as compared to the glucose molecule. (Get help from your teacher if necessary.)

6. Review topic 6-2 in chapter 6 about CARBOHYDRATES to find any statements to support or contradict your hypothesis in question 5. Describe the chapter evidence.

BLOOM COUNTY / Berke Breathed





8-2 Diffusion

If you performed lab investigation 8-1, you found that molecules diffused through a cellophane (dialysis) membrane. How do these molecules move through membranes? Why do some molecules move through membranes and not others? How do they get through the membrane? These are some of the questions that will be answered in this section. You will find that some of the principles you will learn in this section will apply to a problem that will confront you if you perform the next two lab activities in this unit.

Objective

On a quiz that follows, you will be required to define diffusion and apply the principles of diffusion to solve several problems. You should also be able to describe the differences between permeable, semipermeable and non-permeable membranes.

An understanding of the concept of diffusion is important for the comprehension of many basic biological concepts that will be presented later in the course. Since most of life's processes occur in cells, the requirements for these processes must enter these cells. Waste products must leave cells. These materials must pass through the cell membrane in order to enter or leave the cell. This process of moving across a cell membrane is one type of DIFFUSION. Later, you will study how food molecules leave the stomach and intestine and enter the blood stream. This movement of molecules is diffusion. These food molecules will eventually enter various body cells in all parts of the body. How do they enter? By the process of diffusion. Oxygen must enter lung cells. Carbon dioxide must enter plant cells. These molecules enter by diffusion. These examples of concepts to be studied later are presented to stress the importance of understanding the process of diffusion early in the course. The process will be referred to throughout the course.

Review your results of Lab Investigation 8-1, then answer any questions that follow: [___]

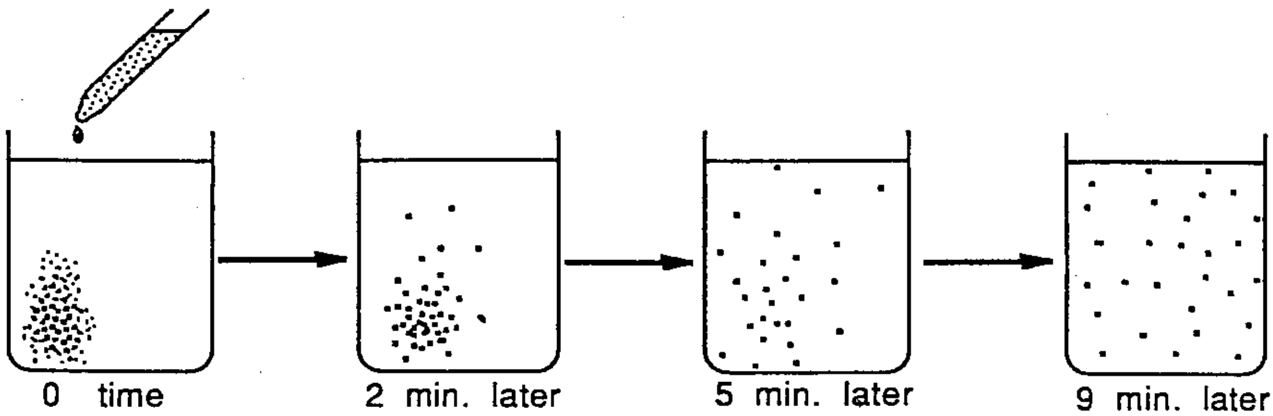
1. According to your data for part 1 of Lab Investigation 8-1, which molecules passed through the cellophane membrane? Which molecules did not pass through the membrane?

The cellophane, or dialysis, membrane appears to be solid.

2. What possible answer (hypothesis) can you give that might explain how the molecules in Investigation 8-1 passed through a membrane?

The only possible explanation is that there must be small holes or pores in the membrane. Examination of this membrane and the cell membrane, with an electron microscope, show this to be true. The dialysis membrane used in Investigation 8-1 was selected because the pore size is very similar to the pore size in living cell membranes.

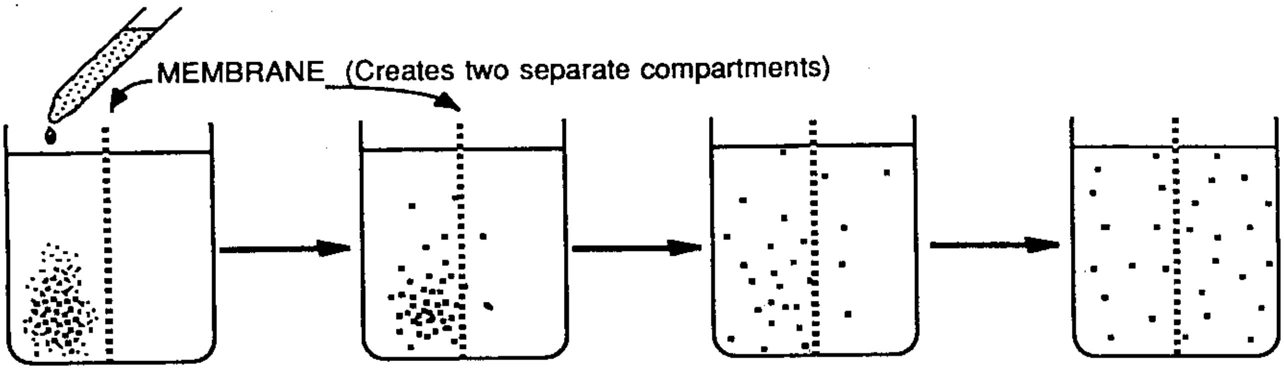
What makes the molecules want to go through the membrane pores to the other side? Why don't they just stay where they are? To understand what is happening here, let's examine a very simple example of diffusion. Diffusion does not only take place across a membrane. If you fill a glass with water and then gently place one or two drops of food coloring into the water, you will observe that the molecules of food coloring will first remain together in streaks or clumps within the remaining clear water. After a few minutes, you will notice that the molecules of food coloring will spread through the solution, slowly at first. Eventually, the coloring will be evenly distributed throughout the glass of water. If you are at home, it would only take a few minutes to try this. This will provide you with a graphic illustration of the process of diffusion. The movement of these food coloring molecules can be diagrammed as follows: The molecules are represented by dots:



As you can see in the diagram, the molecules spread out slowly until they are equally distributed throughout the solution. This is DIFFUSION. The molecules move from where they are closely packed together (high concentration), to an area where the molecules are not closely packed together (an area of low concentration). Learn the following definition:

DIFFUSION: A PROCESS WHERE MOLECULES MOVE FROM GREATER MOLECULE CONCENTRATIONS TO AREAS OF LESS MOLECULE CONCENTRATION UNTIL AN EQUAL DISTRIBUTION OF THOSE MOLECULES IS REACHED IN ALL AREAS.

This can happen in a solution, as mentioned with the food coloring, or it can happen in air or other gases. Perfume moves through the air by this same process. If a membrane was placed into the food coloring solution diagrammed above, and if the membrane had pores large enough for the food coloring molecules to pass through, diffusion would occur through this membrane. The same definition for diffusion would still apply. This is diagrammed as follows:



If all molecules in a solution are able to pass through a particular membrane in that solution, that membrane is said to be PERMEABLE to all molecules in that solution. A PERMEABLE MEMBRANE is one that all molecules "in that solution" can pass through. A membrane that has pores too small for any of the molecules in a particular solution, is said to be IMPERMEABLE or NOT PERMEABLE to those molecules. Cell membranes have pores that are large enough to allow passage of some but not other molecules in the cell's environment. This type of membrane is said to be SEMIPERMEABLE.

3. What type of membrane is the dialysis membrane that you used in Investigation 8-1?

4. Could the same membrane be semipermeable in one solution of molecules and permeable in another solution of molecules? Explain.

Molecules are constantly in motion. The warmer the temperature, the faster the molecules move. The molecules move in all directions in a "random" pattern. They bump into one another and change direction. They bounce off the sides of the vessel and off of those parts on a membrane that do not have openings in it. The factors that "cause" the bunched up molecules to want to get away from one another is complex, and its explanation requires an understanding of mathematics not usually possessed by high school students. Let's just accept the fact that molecules do have this tendency to move away from one another until an equal distribution is obtained.

To see if you understand and can "apply" the principles presented so far, answer each of the following questions in the program below on your paper. Use your paper to cover the answers provided as you read and write your answers.

APPLYING THE PRINCIPLES OF DIFFUSION

5. Write the definition for diffusion. (From memory) Cover the answers below with your paper as you complete this next programmed section.

---

5. See definition on the previous page [___]

---

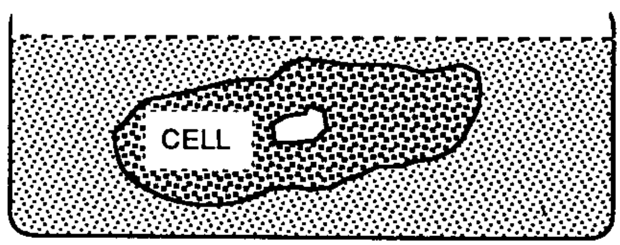
6. A membrane that allows all molecules in the solution to pass through is called what type of membrane?

6. Permeable

7. A membrane that allows some molecules, but not others, to pass through is termed a ____ membrane.

7. Semipermeable

8. Examine the following diagram and determine which molecules will move through the membrane and in which direction will each molecule move?

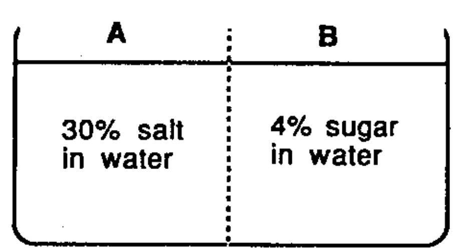


This cell's membrane is permeable to both the [large dots] and the [small dots]

8. The small dots (molecules) will diffuse into the cell and the large dots (molecules) will diffuse out of the cell.

9. Consider the container at the right which has two separate compartments separated by a permeable membrane. Determine if the salt or sugar will diffuse through the membrane.

Which molecules will move and in which directions?



9. Salt will move from A to B and sugar will move from B to A. Note that even though there is a large concentration of salt in A, that the sugar still moves into compartment A. This is because there is a lesser concentration of sugar in A than in B. So according to our definition of diffusion, the sugar will move to

where there is a lesser concentration of sugar.

---

10. After 24 hours, what will the concentrations of salt and sugar be in each of the compartments?

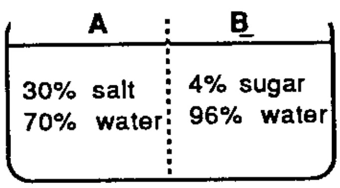
---

10. Compartment A will become 15% salt and 2% sugar, and compartment B will become 2% sugar and 15% salt. (Diffusion continues until an equal distribution of all molecules is reached)

---

11. Remember that both compartments A and B also have water in each of them. What % water is in compartments A and B at the beginning of the experiment?

11.



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12. According to the definition of diffusion, do you think that the water molecules will move across the membrane? (In the set-up above?) If so, in what direction? If not, why not?

---

12. The water molecules will move from B to A, because there is less of a concentration of water molecules in A.

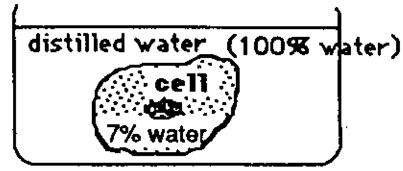
---

13. This movement of water molecules across a membrane is a special type of diffusion. It is called OSMOSIS. Learn the following definition:
Osmosis: The diffusion of water molecules, from a region of great concentration of water molecules, across a membrane, to a region of lesser concentration of water molecules.

The term OSMOSIS refers ONLY to the diffusion of water molecules. The term DIFFUSION refers to the movement of ANY molecules. Osmosis is considered a special case of diffusion because when water diffuses there is a change of volume. For example, when the water diffuses from B to A in the above diagram, the water will rise in

A and the water level will drop in B.

When water diffuses into a cell it can cause the cell to burst. If water diffuses out of a cell, it will cause the cell to shrink in size. In the diagram that follows, will water diffuse into or out of the cell? Will the cell burst or shrink?



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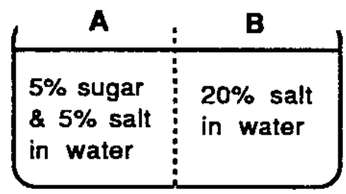
13. Water will diffuse into the cell because there is less inside the cell. This build-up of water in the cell will create pressure that will cause the cell to rupture.

---

14. Examine the apparatus drawn to the right:



The membrane is permeable to salt and water but not permeable to sugar. (a semipermeable membrane) Write an answer to each of the following questions on your own paper:

a. In what direction will the salt move?
b. In what direction will the sugar move?
c. In what direction will the water move?
d. In which compartment will the water rise?

---

14. a. Salt will move from B to A.
 b. The sugar will not move out of A because the membrane is not permeable to sugar.
 c. The water will move from A to B. (To determine this you have to first figure out how much water is in each compartment. 5% sugar + 5% salt in A = 10% solid and 90% H_2O in compartment A. In compartment B, there is 20% salt and 80% H_2O. The water will then go from 90% to 80%.) A to B.
 d. If the water goes from A to B, then the water level in B will rise.

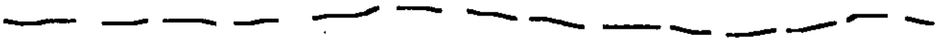
Up to this point you have learned that molecules can move through pores in membranes. Until well into the 1970's, it was believed that cell membranes had open pores that allowed molecules to pass either way through the open pore. Results from numerous experiments now show that cell membranes have quite a variety of pores and ways for molecules to get through them. What follows is only a few of the different hypotheses for different models of cell membranes.

8-3 What Research Shows About the Details of Cell Membranes and Pore Structure

1. Briefly describe how molecules move through membranes.
2. How do you determine which direction the molecules will move?

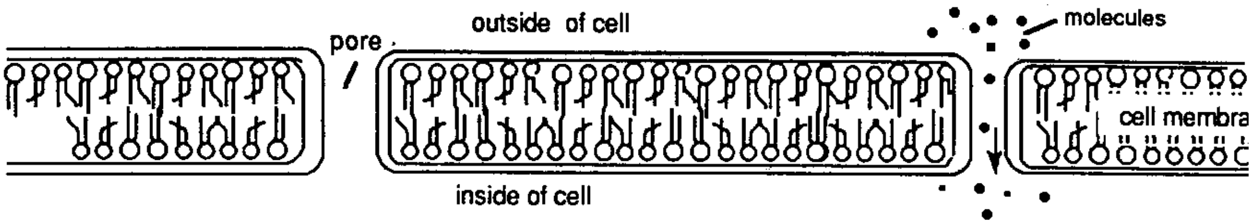
> **Objective**
>
> You will be expected to explain how the different *cell membrane models* explain the movement of molecules through cell membranes.

The membranes that you have learned about so far have been diagramed as follows:



The above line with openings represents a membrane with open pores. This membrane is thought to resemble the following more detailed drawing:

(1)



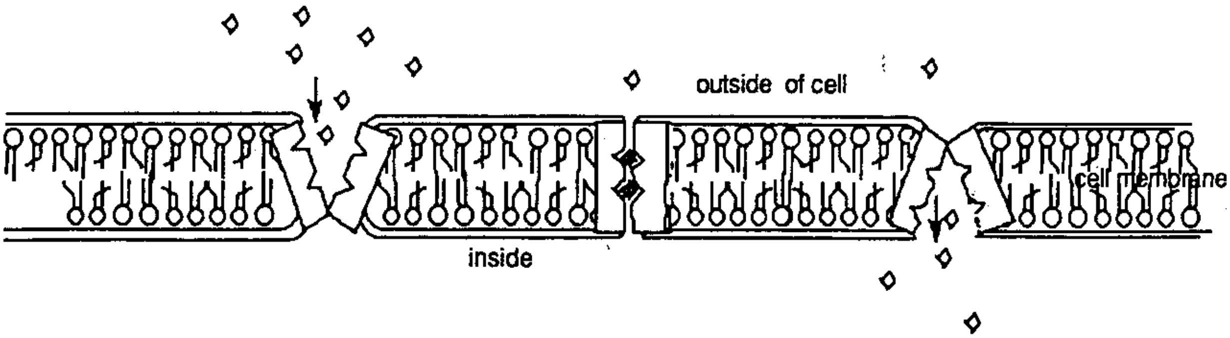
In model (1) above, the pores always remain open. This model is called the **protein channel** model.

Note the thickness of the cell membrane. Cell membranes are made mainly of fat and protein molecules shown by the circles and connecting double lines.

3. What conditions would cause molecules to pass into the cell in model (1) rather than out of the cell?

Examine model (2) below and note how a pore can open and receive molecules and expel them to the inside of the cell.

(2)

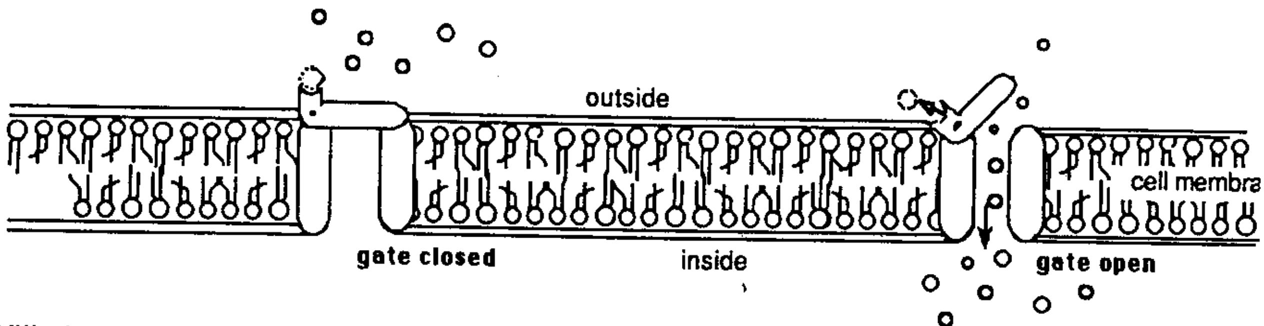


Protein units that make up the first pore at the left show how the pores open first to the outside and only take in certain molecules that fit the shape of the pore walls. The second pore shows how the pore walls close around the molecules. The third pore shows how a pore opens to the inside to release the molecules taken into the inside of the cell and into the cytoplasm. If the molecules do not fit the pore wall indentations, they will not pass through this type of pore.

4. Can molecules pass both ways through this type of pore at the same time? Why or why not?

Model (3) below shows how each pore has a door-like molecule that opens to allow molecules on the outside of the cell to enter. Notice that in the drawing that a little spherical molecule has to fit into a grove at the bottom of the door before it will open. After the door opens, the sphere moves away. This resembles a lock and key arrangement. This is similar to how the hormone **insulin** and other compounds are needed to open pores to allow glucose and other molecules to pass through. This is called the **gated channel** model.

(3)

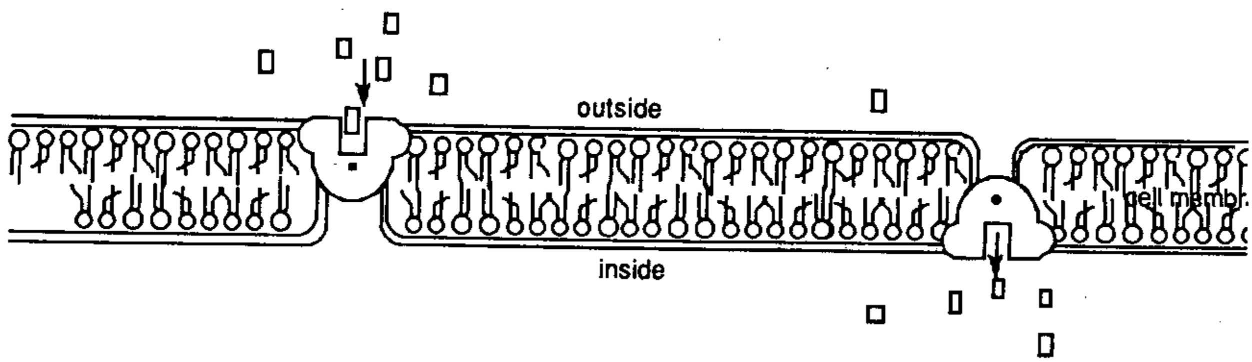


5. Will the type of pore in model (3) open without the "key molecule" of spherical shape? Explain your answer.

6. What is the chemical name of one kind of "key molecule?"

Model (4) below shows the pore at the left, with a "revolving door" protein that receives the correctly shaped molecules from the outside. The protein "revolving door" then rotates to allow the molecules to be released to the inside of the cell. This is called the **mobile carrier model.**

(4)



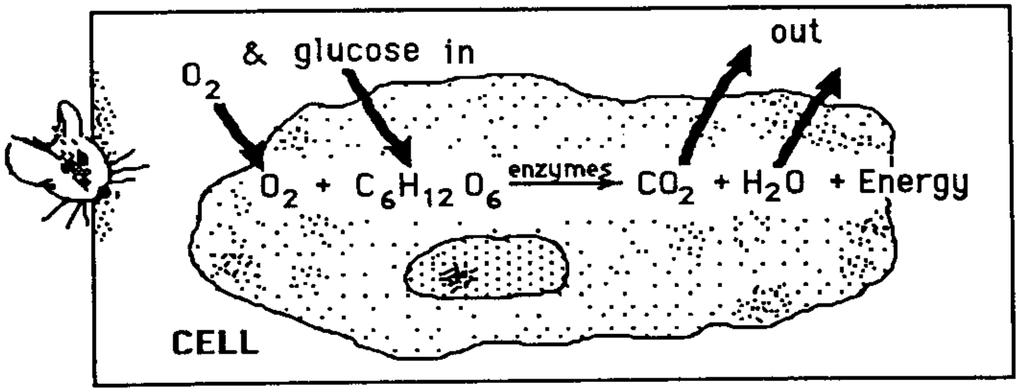
This type of movement through a cell membrane requires energy from the cell and is therefore called **active transport.** Cells that allow molecules to pass through and do not require energy are said to involve **passive transport.**

7. Would the molecules shown in connection with model (3) be able to pass through the pores shown in model (4)? Explain why or why not.

8-4 Laboratory Investigation

Osmosis: Can You Have Confidence in Your Interpretations?

If you performed the last Lab Investigation, you found that the requirements for respiration, glucose and oxygen, enter cells by passing through microscopic pores in the cell membrane. Study the diagram that follows:



Objective

You will be required to interpret the results of the experiment described.

1. In your opinion, can CO_2 and H_2O diffuse out of the cell? Give reasons for your answer.

This investigation will enable you to partially answer this question. Work cooperatively in groups of 3 or 4.

Instructions will be provided for how to set up the experiment. You will then make observations and record them clearly and accurately. Evaluation of this activity will be based upon your written report.

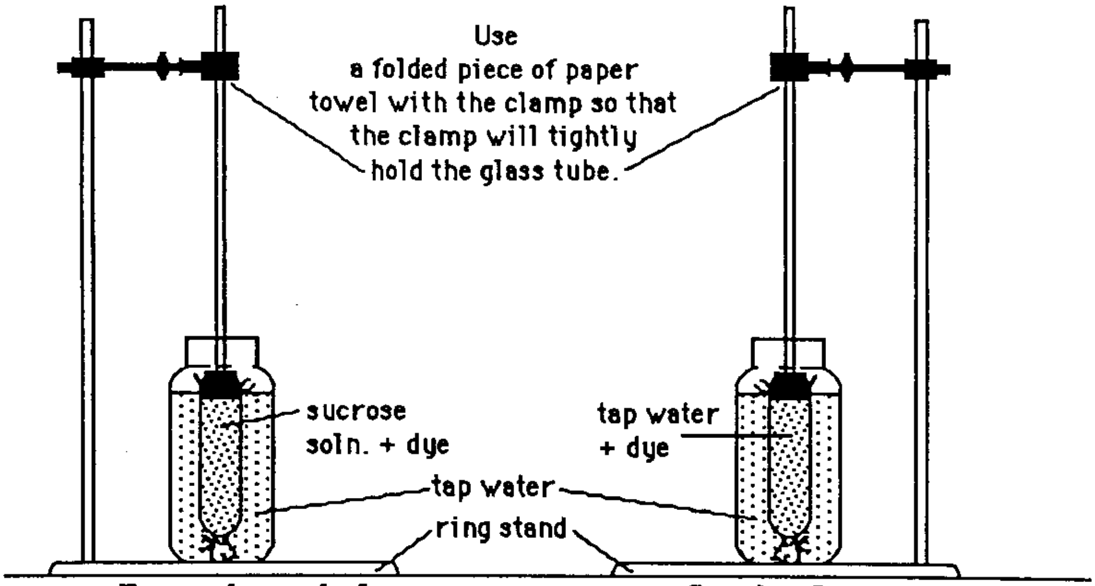
PROCEDURE: (DO NOT START THE EXPERIMENT IF LESS THAN 1/2 OF THE PERIOD REMAINS)

Study the diagram on the next page to see how the final set-up will appear. [___] Half of the table's team should set up the **experimental set-up** and the other half of the team set up the **control set-up.** The details for setting up the experiment follow. Determine who will do each set-up. The directions are the same for each group with one exception that will be called to your attention at the appropriate time. Each group proceed as follows:

1. Tie the bottom of a piece of dialysis tubing with string . Be sure the knots are tight so that there will be no leaks. [___] Remove all materials from your tray and work over your tray so that you won't spill on the table. [___] Next fill the bag with <u>sucrose solution</u> if you are setting up the **experimental set-up** or fill the bag with <u>tap water</u> if you are setting up the **control set-up.** [___] Add a few drops of congo red dye to the liquid inside the dialysis tubing. This dye is simply an indicator for leaks in the bag. [___] Pinch the open end of the dialysis tubing closed and then tip the tubing upside down and then right-side up in order to mix the dye throughout the solution. [___] Be sure the tubing is filled to within 1 inch of the top. [___]

2. Fit the glass tube and rubber stopper into the dialysis tubing. <u>Be careful here</u> so that you don't drop the materials. The red dye will be difficult to clean out of clothes. It would be best to do this part over the tray so that if the tubing drops, the liquids will drop into the tray. Wet the stopper so that it will be easier to slip it into the tubing. [__]

Tie the top portion of the bag around the rubber stopper well with string. [___] There must be no leaks. You may wish to wrap the string around once again at the top and bottom of the bag and tie a second knot. [___] You must now remove any air at the top of the tubing by twisting the **bottom** of the tubing just above the bottom knot. Twist the tubing at the bottom until the air at the top moves up into the glass tube in the stopper. When you see the liquid's level visible above the stopper, retie the bottom of the dialysis tubing so that the liquid remains visible **above** the stopper. [___] Then set up the apparatus as diagramed below so that the dialysis tubing is covered with water. [___] Any leaks should show up during the minutes that follow as a slight flow of red dye into the surrounding water. [___] If you discover a leak, add additional string. The liquid should be just visible above the stopper. If it is not, twist the dialysis tubing just above the lower knot until you see the liquid above the stopper. Then tie another string at that spot to keep the liquid in view just above the stopper. [___]



3. Mark the level of the solution within the glass tube with a piece of tape. [___]
   Record the time [___] (a.m./p.m.)

4. Measure and record the height of the solution in the glass tube every 2 minutes for all but the last 7 minutes of the period. For each minute interval, measure the distance in mm. that the solution has risen from the starting point. Record your data clearly in a data table (chart) for each set-up. [___]

When you have collected all the data required, carefully remove the dialysis tubing and throw it away. Place all liquids in the sink. [___]
Be sure to sponge the table well to get all of the sugar solution off the table. [___]

The remainder of this activity can be completed outside of class. Prepare your report as follows:

I. **Problem:** (OMIT FOR THIS EXPERIMENT)

II. **Hypothesis:** (OMIT FOR THIS EXPERIMENT)

III. **Experimental design:**
   Write, "See experimental design described on pages above."

IV. **Data:** For both groups of data place your measurements in a neat data table. Graph the results of both set-ups on one graph. Place time on the horizontal axis and distance that the solution traveled, on the vertical axis. Use graph paper. [___]

V. **Interpretation of results:** For your interpretation, answer the following questions in as much detail as you possibly can:

2. What accounts for the solution rising in the experimental set-up? (You don't have to explain how or why, but what do you think is happening?) Your answer will actually be a hypothesis since you probably have no real way of knowing.

3. What would you hypothesize about the role sucrose plays in the rising of the solution in the experimental set-up?

4. If you had weighed the dialysis tubing preparation (including glass tube, sucrose solution, dye and dialysis tubing and string) for the experimental set-up, before placing it in the jar of water, and again after leaving it in the jar of water for 10 to 15 minutes, you would find that the preparation would weigh many more grams after having been in the beaker of water for 15 minutes. This is not true for the control set-up. The weight of the control dialysis tubing preparation is found to be the same before and after the experiment. In the experimental set-up, what accounts for the weight increase in the dialysis tubing preparation?

5. Reread your answer to question 2 above. Do you have any additions or changes in your reason for how the fluid rose in one tube but not in the other? If you have a different explanation or additions, explain your new interpretations.

VI. **Conclusion:** (OMIT FOR THIS EXPERIMENT)

You would obtain the same results if you were to substitute many other compounds for the sucrose. Salt, glucose, starch, and many other substances will work. This report should be completed when you return to class. Remember, each student is to hand in his/her own report. Only the data should be similar.

8-5 Osmosis: How Does it Work?

1. Give one or two reasons for why a scientist might believe that water molecules can pass through membranes.

Objective

On a quiz that follows, you will be expected to define osmosis and apply the principle of osmosis to solve problems similar to those that follow.

Carefully review the diagram of the apparatus used in Investigation 8-4 before continuing. [___]

2. If you completed 8-4, what results did you obtain with the experimental set-up and with the control set-up?

3. Write the definition of osmosis from memory.

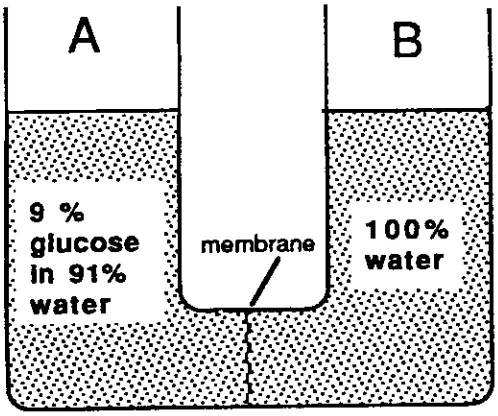
Check this definition by referring to section 8-2. [___]
Make any needed corrections in your definition written for 3 above. [___]

4. In light of this definition, and what you know about diffusion, write an explanation for the observed results obtained in Lab 8-4.

The following program will help you to evaluate whether your answer to 4 is reasonable.

5. The glass vessel shown is a special U-tube used in osmosis and diffusion experiments. It is fitted with a permeable membrane which is shown by the dotted line.

(Cover the answers with a piece of notebook paper. Write out the answers to the following questions on this paper.)

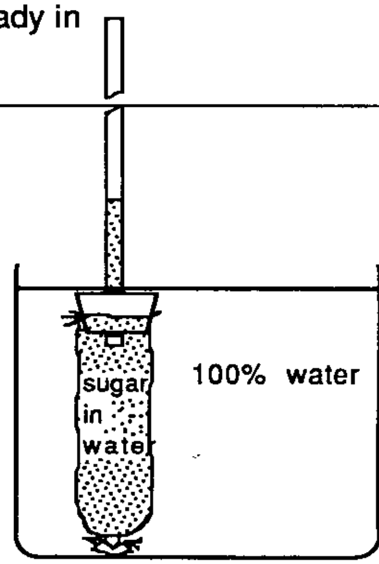


After about 15 minutes, which of the following will happen?

a. The water level in A will rise.
b. The water level in B will rise.
c. The water levels in both A and B will stay the same.

5. a. (A will rise.) This is because the water will diffuse from B to A. There was only 91% water in A and 100% water in B, so the water moves through the membrane to A where there is a lesser concentration of water. The glucose will begin moving from A to B, but will not cause the water level in B to rise. ONLY the movement of water into an area will cause the solution level to rise. This is because when the glucose molecules pass into B, they will go in between the water molecules and take up spaces that are in between these water molecules. This, then, will not create additional volume of solution. On the other hand, when the water molecules go into A, the water molecules cannot occupy any hidden spaces, and, therefore, add to the volume of solution already in that area. This causes the level of A to rise.

6. The experimental set-up used in 8-4 is shown at the right. Where is the concentration of water the greatest? Inside the sack or outside? Taking this into consideration, will water move into or out of the sack?



6. Water concentration is greatest outside the sack. It's 100% water outside and since there's sugar inside the sack, there's less than 100% water in the sack. (Notice that we don't need to know how much water is inside, as long as we know that there is less than there is outside.) Water will then move into the sack.

7. As the water moves into the sack, it will be forced up the tube since this is the only direction it can go. Later in the course, you will see that this is one of the methods by which water ascends in the stems and trunks of plants and trees. The sack in the apparatus represents the root surrounded by ground water. Refer to your answer to question 3 of this reading topic to see if you have any additions now that you have learned a little more about "osmosis". [___]

7. This response will vary with the individual.

---

8. If human red blood cells are placed into distilled water, they burst. Yet in the blood stream, they do not burst. Explain why they burst in distilled (pure) water.

---

8. The blood cells have various salts, sugars, proteins, & other substances dissolved in the water of the blood cell's cytoplasm. This makes the concentration of water less inside the cell than outside. Water diffuses into the cell causing it first to swell and later to burst.

---

9. You probably realize that when certain saltwater fish, lobsters, crabs and most other sea dwelling animals, are placed in fresh water from the tap, a stream or a lake, that these animals die. Explain the death of these animals based on the principles of osmosis.

---

9. The composition of the sea animal's cells is such that they contain dissolved substances and less water than is outside. Water enters and the cells burst.

---

10. Remember to review the objective at the beginning of this topic to find out what the following quiz will cover. [___]

8-6 Laboratory Investigation

An Application of Osmosis in Plant Cells

Objective

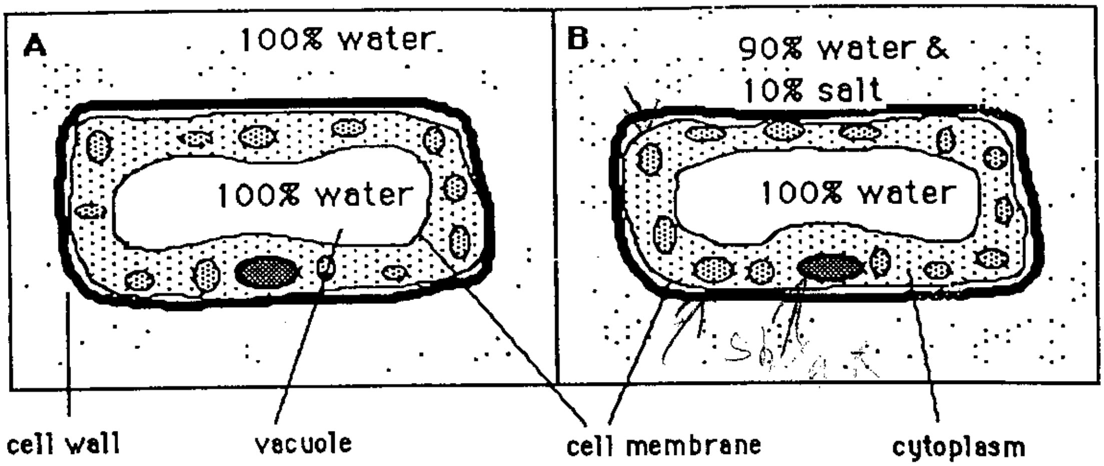
You will be expected to provide a hypothesis that explains what you observe when a plant leaf is placed in salt water.

PROCEDURE: Each student is to work independently, using his or her own microscope.

1. Make a wet mount of one leaf from the Elodea plant in the beaker in your tray using the water in the beaker. [___]
2. Examine the cells on 4X, 10X and then 40X. [___]
3. Find finely focused cells using the 40X and draw 3 cells that look typical. Make each cell at least 3 inches long. [___]
4. Label the cell wall, vacuole, chloroplasts and cytoplasm. [___]
5. Set this slide aside and save it for later without removing the cover slip. [___]
6. Now prepare another wet mount of another Elodea leaf only this time use the 10% salt solution in the dropper bottle marked salt solution instead of using water. [___]
7. Examine the cells again on 4X, 10X and then 40X as before. You should see some obvious changes in the cells. [___] Draw three cells as before from this new slide and label the cell wall, vacuole, chloroplasts and cytoplasm as before. [___]

QUESTIONS:

1. Describe the change in the cell that you observed after placing the leaf in the salt water.
2. Offer a hypothesis that could explain the change observed.
3. To help in determining if your hypothesis might be a correct explanation for the observed change in the Elodea cells, examine the drawings of cells that follow:



How can the information in the drawings be used to explain the changes observed when the cells were placed in salt water?

4. In drawing A, would water move into or out of the vacuole to the surrounding pond water? Why?

5. In drawing B, would water move into or out of the vacuole to the surrounding water? Why?

6. If all the water in the vacuole in the cell in drawing B moved from the vacuole to the surrounding salt water, how would the cell look? Describe the cell's resulting appearance and draw one cell to make your answer clear.

7. Write a summary explaining the effects that a salt water environment has on fresh water cells like Elodea.

8. How was what you observed in this lab activity related to the title selected for this activity?

8-7 Cooperative Learning Review Activity

In your assigned cooperative teams, determine your team's answers to the following:

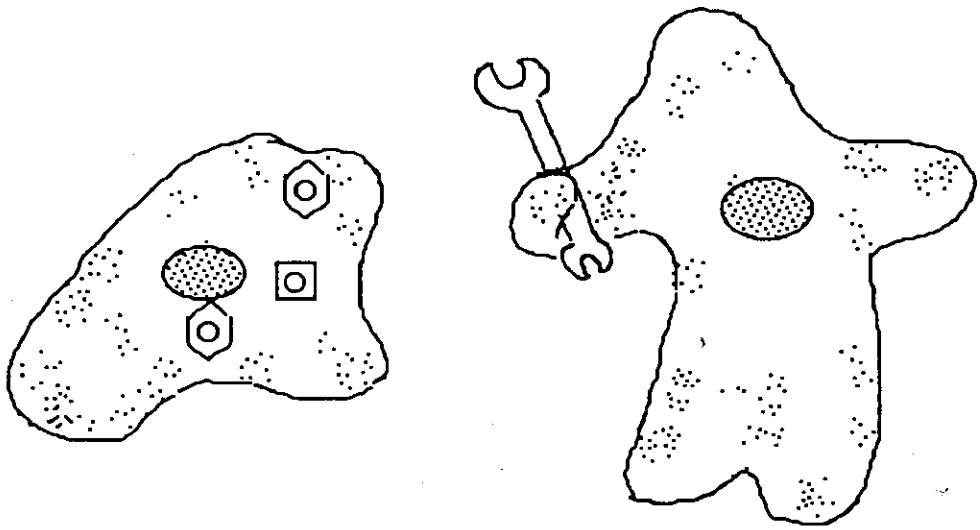
1) Define diffusion and osmosis and list the differences between them.

2) Describe the differences between permeable, semipermeable and impermeable membranes.

3) Create a question for the team next to you that would determine if that team can apply the principles of diffusion & osmosis. Diagrams of cells or apparatus are acceptable. Trade your question with the team nearest you. Answer the question and return it to the team for grading.

CHAPTER 9

ENZYMES: THE MECHANICS OF THE CELL



Chapter 9

Enzymes: The Mechanics of the Cell

The most beautiful thing we can experience is the mysterious.
It is the source of all true art and science.
Albert Einstein

9-1 Organizing Data Helps in Solving Problems

1. Why are items organized the way they are in kitchens?

Objective

You will be expected to solve a few word problems by first organizing the needed information. You will then apply this method to other word problems and to a lab problem.

INTRODUCTION:

People who work in scientific and technical jobs are called on to solve technical problems on a regular basis. The ability to solve problems is a valuable skill to possess no matter what kind of work a person does. In fact, schools are being told that this will become an ever more increasing requirement in the decades to come and that in many jobs, one's ability to solve problems will play a role in job success and promotion.

Many of life's personal decisions also require skills in problem solving. These skills, while they are not unique to science, can be learned in science since problem solving is a regular activity in science.

One barrier to solving complex problems is that the information is so complex that it requires organization before relationships or solutions become apparent. Many people give up on the problem because they don't realize the need to organize or know how to go about organizing the information needed for solving the problem. The next few problems are not necessarily scientific in nature, but they require the same approach that many scientific and other problems require. You'll start with non-science problems and later apply the technique to scientific problems.

Try your skills in solving the problem that follows:

1. Ann, Mark, Carl, and Pam like different types of books: humor, mystery, sports, and adventure. One of Ann's classmates in the group likes mystery books best. Carl and Pam do not like adventure books. Mark's favorite type of book is sports. Pam did like humor books but has changed her favorite. What is Pam's favorite book?

At first glance, the problem may have looked impossible. That's because the information was not organized. Notice how the following chart helps to first organize the data given in the problem.

	Ann	Mark	Carl	Pam
Humor				No
Mystery	No			
Sports		Yes		
Adventure			No	No

For example, since Mark's favorite type of book is sports, we can write "no" in Mark's column for every other type of book. After doing this step, we see that Ann is the only possible person to have adventure books as her favorite. Examine the chart below where more of the information has been added. You fill-in the remaining four blanks and determine what is Pam's favorite book.

	Ann	Mark	Carl	Pam
Humor	No	No	Yes	No
Mystery	No	No		
Sports	No	Yes		
Adventure	Yes	No	No	No

(Since mystery books are the only type not yet chosen, they are Pam's favorite.)

Use the chart method to solve the following problem:

2. Kathy forgot the names of her grandmother's kitten, dog, and parakeet. She knows that the pet's names are Princess, King, and Missy. Help Kathy decide which name

goes with each pet.
Clue A: Princess is smaller than the dog.
Clue B: The kitten is younger than Princess.
Clue C: The kitten is older than Missy.

NAMES

	Princess	King	Missy
Kitten			
Dog			
Parakeet			

If you are having trouble, remember that you only need to place a "no" or a "yes" in each square and use the process of elimination.

You are on your own for the next problems.

3. Robert, Sue, Nelson, and Heather are nicknamed Rocky, Stinky, Freckles, and Lefty. Read the clues below and find the nickname of each person.

Clue A: Robert is taller than Stinky and shorter than Lefty.
Clue B: Lefty is older than Nelson and younger than Sue.
Clue C: No nicknames start with the same letters as the person's real name.

4. A blue house, a red house, a white house, and a purple house are all in a row. What is their order?

Clue A: The purple house is not first.
Clue B: The red house is between the blue house and the white house.
Clue C: The blue house is between the purple house and the red house.

The above problems are just as complicated as the first was. But now that you know how to organize data into a chart, we hope you found them a lot easier and possibly more fun to work out.

Let's apply this technique to a problem where data was collected from an experiment in botany. Create a chart to help answer the questions that follow.

5. Some students were studying the water requirements for flowers and leaves. They placed flowers in vases. Some vases had a flower only on a stem. Other vases had a flower and leaves on the stem. Water was placed in each vase with the plants and left for 24 hours and the water remaining was measured. The results were as follows:

A single rose with 6 leaves on its stem was placed in 360 ml of water. The next day there were 150 ml left.
A single rose without leaves on its stem was placed in 350 ml of water. The next day there were 280 ml left.
A single carnation with 6 leaves on its stem was placed in 240 ml of water. The next day there were 120 ml left.
A single carnation without leaves on its stem was placed in 420 ml of water. The next day there were 380 ml left.

Which flower, without leaves, uses the most water in 24 hours?

6. When a rose stem has both leaves and flower, how much more water does the rose plant require than when there is a flower only on the stem?
7. Each rose leaf requires how much water?
8. Each carnation leaf requires how much water?

If you have time and want to try a more challenging problem, try the next one.

9. One evening three college roommates, Dave, Marty and Rob each watched a different television program. From the information given below, can you say who watched **which program**, and at **what time** and on **which channel** it was viewed?

Clues:

a. Their T.V. set can only get channels 4, 5 and 11.
b. Starting times for each program were 7:30, 8:30 and 9:30 PM.
c. One watched a comedy show, another watched a play and the third watched a quiz show.
d. The channel 11 program began at 7:30
e. Dave watched the quiz show, which did not start at 9:30
f. The program which Marty watched was viewed later than the comedy show; neither of these programs was shown on channel 4.

9-2 Laboratory Investigation:

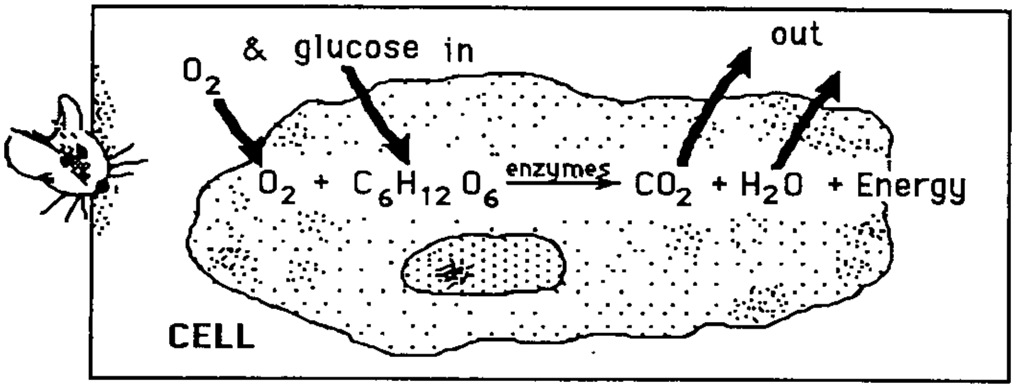
Enzyme Action: A Problem in Adequate Experimental Controls

Objective

You will be expected to perform the first part of an experiment using the enzyme amylase. You will then be expected to:

1) Determine the problem the experiment was designed to answer
2) Formulate a hypothesis for the problem
3) Design controls for the experiment and conduct them
4) Decide if your data supports or contradicts your hypothesis

If you completed the last few laboratory activities you were able to obtain evidence that O_2, glucose and water can diffuse through cell membranes. You have experimental knowledge that all requirements and products of respiration can diffuse through cell membranes except for one product, CO_2. By performing similar experiments, you could obtain evidence that CO_2 can also pass through cell membranes. This would seem logical since CO_2 is smaller than $C_6H_{12}O_6$.

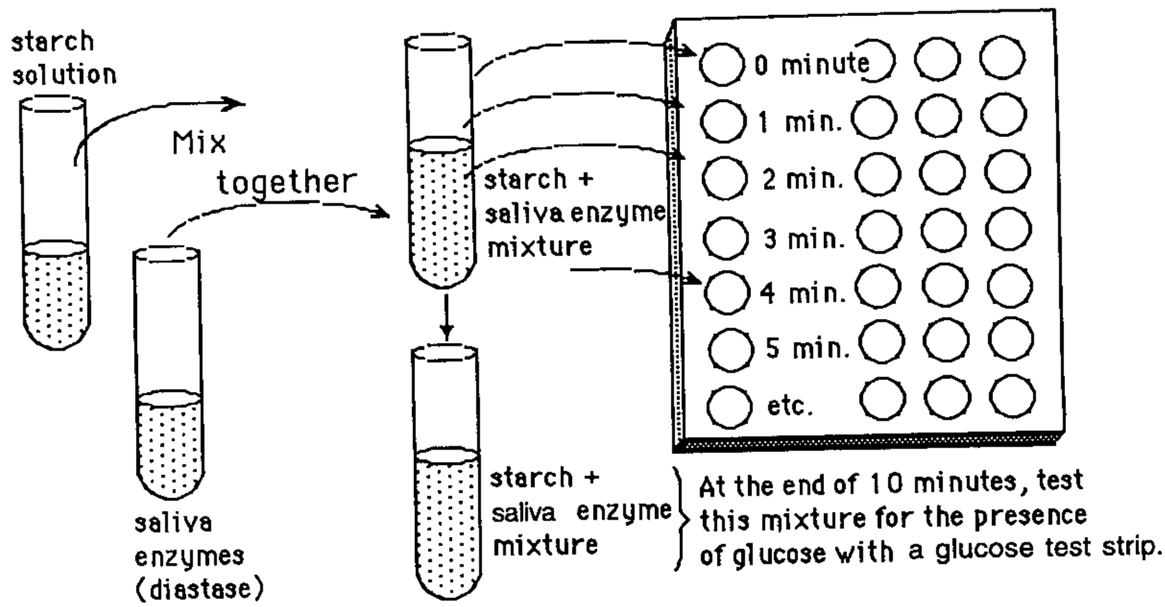


A yet uninvestigated substance's role in respiration is the role the enzyme plays in this process. Examine the drawing above. [___] Enzymes are extremely important requirements for all biochemical reactions that occur in plant and animal tissues. (The term "biochemical" simply refers to chemical reactions in living cells.) The respiration process is an example of a biochemical process.

In this investigation you will work with an enzyme found in saliva. You will set up the experiment and be expected to set up your own controls. You will determine what hypothesis this experiment is designed to test and will make your own interpretations from the data you collect. Your evaluation for this activity will be based on a written report. The format for this report will be presented after you complete a part of the experiment.

Perform this experiment with one partner or by yourself.

Sometimes it is of value to have a general idea of what one is about to do in an experiment before he actually begins. This is particularly true in this experiment where timing is important. Scientists often present this kind of overview in diagrams called "flow-charts". The following flow-chart for this experiment shows the steps involved but does not include the details such as amounts, etc. Examine the following "flow-chart" carefully before starting the experiment and do not begin the experiment until you get to the written procedure.



PROCEDURE: (Start at the beginning of a period or within the first 15 min.)

With a grease pencil, mark each depression spot on your white spot plate as shown above. Don't mark in the depression spots. Place the number 0, 1, 2, 3, etc. beside each depression. Continue into the second row so that you have enough spots for 10 minutes. [___]

One of the details that this flow-chart leaves out is that the solutions must be kept at a temperature of 40° C (100° F). Make a **water bath** by filling a 1000 ml beaker (or 600 ml or similar container) 3/4 full of warm tap water at 40° C. [___] All students at the table can use the same water bath. Many tubes can fit into it. Its sole purpose is to keep the solutions at body temperature. Be sure to mark your tubes in some way. [___]

In one test tube place 20 ml of starch solution. Place this marked tube into the water bath. [___] Locate the enzyme solution and stir well. [___]

In another test tube, place 4 ml of the solution of saliva enzymes, right after vigorously shaking so the enzyme will not settle out prior to pouring. Place this tube into the same water bath. Do not remove the tubes from the water bath during the experiment. [___]

Place exactly 1 drop of iodine solution in each of the 10 marked depressions in your spot plate. **Be careful when handling Lugol's Iodine solution. It can damage the eyes and skin and will stain clothing.** [___]

1. What color is produced when iodine reacts with starch? (If you don't remember, mix a drop of each on the spot plate and see.)

2. What role do enzymes play in cells?

Before continuing, be sure you have a medicine dropper ready to use. Rinse it yourself at the sink to insure that it is clean. [___]

Now pour the starch from its tube into the test tube of saliva enzymes and note the exact time on the clock in minutes and seconds and record it on your paper. Label this "TIME REACTANTS POURED TOGETHER" and immediately go on to the next step. [___]

Gently stir the mixture with your thermometer and immediately place 2 drops of the mixture into the depression on the plate marked "0 min." [___] In exactly 1 minute, take a dropper full of this mixture and place exactly 2 drops of the mixture on the spot plate depression marked "1 minute." [___] Return the remainder in the dropper to the test tube. [___] Keep the test starch-enzyme mixture in the water bath at all times. Transfer a similar sample each minute for at least 10 minutes and record the resulting colors for each minute under the DATA heading in your report. Remember to maintain the temperature approximately between 35° C and 38° C. [___]

If the reaction does not seem complete at 10 minutes, continue for a few more minutes.

At the end of 10 or 12 minutes, test the test tube mixture of starch and saliva enzymes for the presence of glucose with a **glucose test strip**. In making the glucose test, be sure to remove the strip from the solution immediately and wait at least 3 minutes to read this test. Never test a solution for glucose that contains iodine. Review the directions on the test strip container. [___] Record your results in your report after the sub-heading "Glucose test results on the starch-enzyme mixture at 12 minutes:" [___] KEEP THIS GLUCOSE TEST STRIP UNTIL THE END OF THE PERIOD TO SEE IF ANY ADDITIONAL CHANGES OCCUR. [___]

3. According to the spot plate results, is there any starch present in the mixture test tube at this moment? Explain how you know this answer.

4. What were the results of the glucose test on the starch-enzyme mixture after 10-12 minutes?

5. What do you think happened to the starch that was originally mixed with the enzyme? (If you have trouble with this question, review Chapter 6.)

Next in your written report label and write the **hypothesis** that you feel this experiment was designed to test. [___] You will complete this report later.

Before you can make sound interpretations or draw any valid conclusions regarding the data you have just collected, you must set up controls for this experiment. The following questions might help you think of control tests that you will conduct later:

6. How would you set up a control to determine if the heat, and not the enzyme, is breaking down the starch?

7. How would you know if the glucose found at the end of the reaction was there at the beginning of the reaction?

8. How would you know if there might be glucose in the enzyme solution to start with?

   As you think about these questions, you will see that it is necessary to rule out these factors by conducting some additional tests referred to as CONTROLS.

Run the necessary controls, then describe them in your report with your results according to the following outline to be followed in writing your report. Label each part of the report as shown.

PROBLEM:

HYPOTHESIS:

EXPERIMENTAL DESIGN:

Experimental set-up:
Write, "Performed as described and diagrammed."

Control set-ups:
Clearly describe and number each control test you made.

DATA: Present your data in chart form for the "Experimental set-up" and for each "control set-up."

INTERPRETATIONS OF RESULTS AND DISCUSSION.

CONCLUSION REGARDING HYPOTHESIS: supported, not supported or contradicted.

If you finish the required work in this unit early, you will be expected to conduct a few additional experiments. You may wish to investigate a few "new problems" that present themselves at this point. For example:

Would the same results occur at room temperature (22° C), at 0° C, or at 45° C?

Would the same results be obtained if the mixture was boiled?

Recall that it takes a specific length of time for the starch to disappear, according to the iodine spot plate tests. This time period is a measure of the rate of the reaction. How would this rate of reaction be affected by changing the variables? Some of the variables that might be varied are:

The amount of starch in the mixture.
The amount of enzyme in the mixture.
The temperature (As already described).

How would the reaction rate be affected by different pH values for the reaction mixture? (In other words, would you obtain the same results if a little acid or a little base was added to the reaction mixture?)

Would the presence of ions like lead (Pb++) mercury (Hg++) or iron (Fe++) affect the rate of reaction?

Experiments can be designed to test all of these questions. You may wish to try one or more of these experiments if you finish this unit early.

9-3 Enzyme Structure and Function

1. What is the enzyme's role in living cells?

Objective

You will be expected to describe how an enzyme can break apart a large molecule or put small molecules together to form larger ones. You should be able to list the various environmental factors that can affect enzyme reactions and state what effect each factor has on enzyme activity.

Most of life's processes are chemical in nature. This, of course, includes human life processes. ENZYMES are required in order for these chemical reactions to occur. Your thinking, breathing, heart beat, eating, walking, and all other daily activities require enzymes. As these animal and human processes are studied later in the course, you will see that your understanding of enzyme action will help you to clearly understand other animal and plant processes.

Enzymes are large protein molecules that serve as "catalysts" in cells. Most of an organism's chemical reactions occur in cells. In an earlier lab activity, you learned that enzymes performed the function of breaking apart the glucose molecule in the process of respiration. Enzymes break up the $C_6H_{12}O_6$ molecules and rearrange the parts with additional atoms taken from O_2 molecules. The result of this enzyme activity is the formation of smaller molecules of CO_2 and H_2O.

Let's review **lab 9-2** on enzymes, and figure out what happened there. Review the diagram of the experimental design on page 153 and the results you obtained and then answer the following questions: [___]

2. What happened to the starch in the mixture during the 10 to 12 minute period?

3. How long did it take for the reaction to take place? (That is, how long did it take until you observed no further color change?)

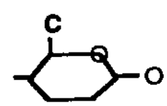
This length of time is used in determining the **"rate of the reaction"**. The RATE OF REACTION is the "time" it takes to break down a given amount of a compound. Your answer to question 3 is the time it took to break down the amount of starch in the test tube. Different student teams will obtain slightly different times for the reaction. This is due to normal experimental error. In lab 9-2, the starch-enzyme mixture contained 0.012 grams of starch. The rate of reaction, therefore, equals 0.012 g/15 minutes. This is equal to 0.0008 g/ minute.

4. Since various times were obtained by different class members for the rate of the reaction, how is the most valid value determined for this particular reaction?

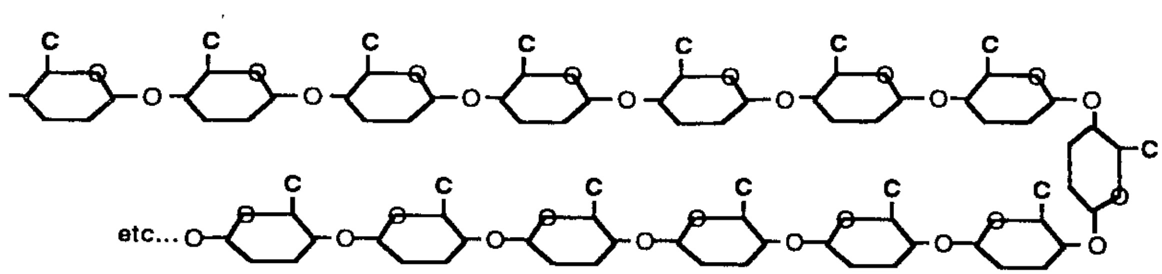
In experiment 9-2, you found that the enzyme broke down the starch into smaller molecules. You may have concluded that these smaller molecules were glucose. You may not have actually verified this in your particular experiment. Nevertheless, how does this enzyme break down the large starch molecules into smaller molecules? It is convenient to describe the process by saying that the enzyme "takes hold" of the long starch molecule and pulls to eventually break the starch molecule into smaller pieces. This description is not quite accurate and is an over-simplification. But it will help to understand what is happening. The enzyme is a large protein molecule with a special part on the molecule that physically "fits" onto the starch molecule. This will be diagrammed below, but first let's review the chemical structure of starch and of glucose.

5. Draw the "structural formula" for glucose as shown at the top of page 103 of lab 7-3.

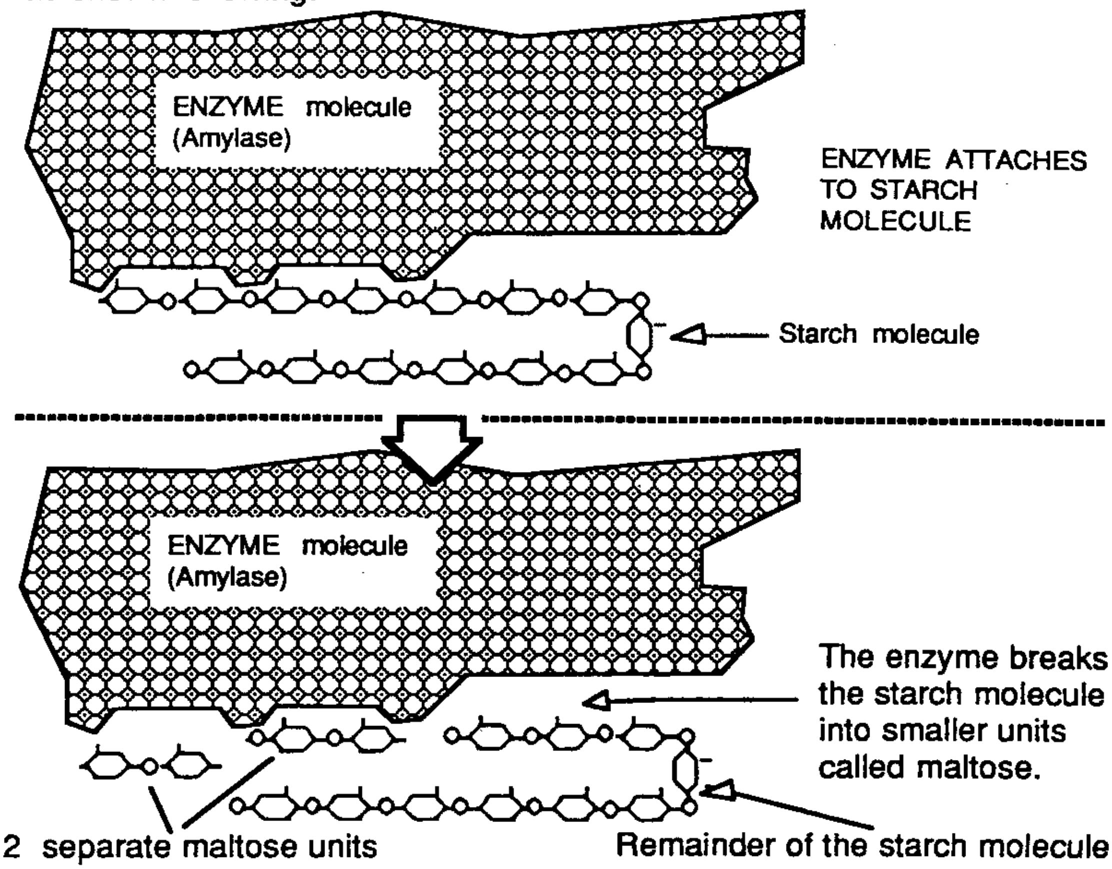
This structural formula for the $C_6H_{12}O_6$ molecule can be abbreviated by just showing the shape of the six-sided ring portion of the molecule as drawn at the right.



The only atoms shown are the oxygen atom that sticks out from the side, and a carbon atom that projects up. The rest of the C, O and H atoms are not shown. Using this abbreviated structural formula for glucose, the structural formula for starch can be shown as below:



Starch molecules range from 100 to 10,000 glucose units in length. Enzymes are huge protein molecules that are hundreds or even thousands of units long. The enzyme in saliva that breaks down the starch molecule is called "amylase". One part of the enzyme molecule, called the "active site" of the enzyme, fits onto a portion of the starch chain as shown following:

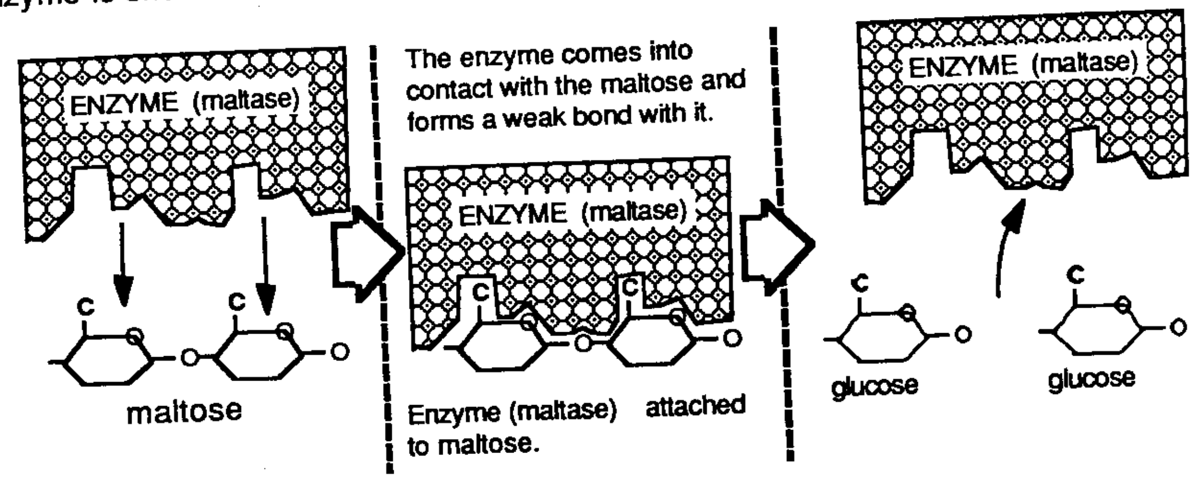


6. What has happened to the starch molecule in the above diagram?

These double units of glucose are called MALTOSE. The enzyme breaks starch down into smaller units called MALTOSE. Maltose is a sugar molecule that is composed of two units of glucose. The reaction illustrated above, is often written as follows:

$$\textbf{STARCH} \xrightarrow{\text{enzyme (amylase)}} \textbf{MALTOSE}$$

Another enzyme, not actually found in saliva, can break down maltose into glucose. The way in which this is thought to occur is diagrammed below. Only a part of the enzyme is shown because of the large size of the enzyme.



The drawings of the enzymes are only diagrammatic. Many enzymes studies have shown that the enzymes posses some structural shape that fits to the molecule that it is to act upon. The exact shapes of these enzymes at their "fitting locations" (active sites) is not actually known. Some studies have shown that the enzyme goes through a change of shape after it combines with the molecule it is to break apart. This suggests that the enzyme may stretch a little, and pull at the single bond that, in the above case, holds the two glucose molecules together. If this turns out to be true, the enzyme, in effect, pulls the molecule apart. Since enzymes work by having a particular shape that fits to the molecule it is to break apart, then one enzyme could not fit and break apart just any molecule. The enzyme above is called "maltase" and can only attach to maltose, not other molecules. Each different reaction requires a "specific" enzyme. The enzyme maltase, which breaks down maltose, cannot attach to or break down a fat molecule. The enzyme amylase, which fits to the starch molecule, will not fit a protein molecule and therefore cannot break it down. For these reasons, enzymes are said to be SPECIFIC.

In our examples, it has only been shown how enzymes break down molecules. Be sure to remember that enzymes can also PUT TWO SMALL MOLECULES TOGETHER. This is usually done by another enzyme, slightly different from the one that took apart the molecule. For example, another enzyme can attach two glucose molecules and unite them into one maltose molecule. This is another example of a reversible reaction. The reaction shown at the top of the page can also be written as follows:

enzyme[1] (maltase)
1 **MALTOSE**-------------------> 2 GLUCOSE

Or it could be written as a reversible reaction:

enzyme[1] (maltase)
1 **MALTOSE** ------------------> 2 GLUCOSE
<---------------
enzyme 2

The term SUBSTRATE, refers to the molecule that the enzyme acts upon. It is the molecule that the enzyme attaches to.

7. What is the substrate for the enzyme amylase? What is the substrate for the enzyme maltase?

At this point, a little better definition for "the rate of a reaction" can be presented.

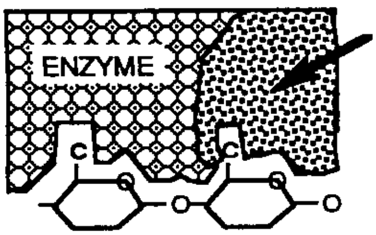
RATE OF REACTION: The rate of a reaction is the amount of time it takes to convert a particular amount of substrate to the products of the reaction.

8. If you were to add more enzyme to your reaction mixture of starch and saliva enzymes in lab 9-2 how would it affect the time required for the reaction? Would this increase or decrease the time required to break down starch? Explain.

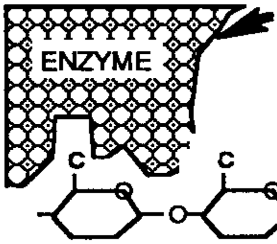
9. If you were to add more starch to this reaction mixture, how would this affect the time required for the reaction? Explain your answer. (If you have trouble with this question or with question 6, study the diagrams on pages 158 and 159 of this reading while considering these two questions.)

The effects of acids, bases and temperature, upon enzyme reactions will be considered in the next unit when you have completed an experimental problem that relates to their affects.

Many enzymes have a nonprotein portion of the enzyme molecule. Below is a drawing of how such a nonprotein part of the enzyme "might" appear:



NONPROTEIN portion of enzyme



Enzyme with the nonprotein portion missing from the enzyme.

This nonprotein part of the enzyme is sometimes formed of minerals like iron, magnesium and others. Often this nonprotein portion is composed of a vitamin.

10. Would the enzyme be able to attach and subsequently break apart its substrate molecule if its nonprotein portion were missing? Explain.

11. In light of this new information, explain why it is so important to obtain the appropriate amounts of vitamins and minerals in our diets.

One of the most important reactions in animals, the respiration reaction, requires magnesium, manganese, and other nonprotein components so that the enzymes can take glucose molecules apart and eventually produce carbon dioxide, water and energy.

Certain substances, such as mercury and lead, can attach to the enzyme in such a way as to cause the separate enzyme molecules to clump together thus rendering them inactive. The enzymes can then no longer serve their intended functions which is to assist in thousands of different biochemical reactions. This is why mercury and lead are poisonous to plants and animals.

12. In your opinion, why was this chapter titled, "Enzymes: The Mechanics of the Cell?"

13. How do mercury and lead interfere with normal cell functions?

9-4 Cooperative Learning Review Activity on Enzyme Function

In your cooperative teams, do the following:

Create a way to demonstrate how enzymes function. Your group can make simple models or devise any creative way to show how enzymes operate. Be able to show why vitamins are needed for enzyme reactions. Be prepared to demonstrate your final product either to the class or to another team.

Appendix A

Basic Chemistry for Unit II

Element: A **pure** substance not separable by ordinary chemical means into substances different from itself. Elements **are made-up of only one kind of atom.** Examples: H, C, O, Hg (mercury), Ag (silver), Na (sodium), Cl (chlorine), Au (gold), Fe (iron), etc. There are 92 natural elements.

Compound: A chemical substance composed of **two or more different elements** that are united chemically. The ratio of the combination of these elements is always the same for a particular compound. For example, the ratio of hydrogen to oxygen in water is 2:1. That's why the formula is H_2O. Other examples: NaCl, CO_2, $C_6H_{12}O_6$, CH_4, $AlCl_3$, etc.

Mixture: A combination of elements and/or compounds that are not chemically united, but are **simply mixed together**. The components of a mixture can be physically separated from each other. Examples: a mixture of salt and sugar, sulfur and iron mixture, air (which is a mixture of oxygen, nitrogen and carbon dioxide, mainly). The proportions of each mixture can vary.

Atom: The **smallest unit of an element** that still retains the properties of the element. Atoms are composed of protons, neutrons, and electrons.

Molecule: The smallest unit of a compound or an element that retains the properties of that element or compound. **Two or more atoms bonded together in definite proportions.** These atoms can be the same or different. Examples:

Organic Compound: **A compound containing carbon.** These compounds are produced by living organisms. Examples: $C_6H_{12}O_6$, CO_2, etc.

Inorganic Compound: A compound **without carbon.** These compounds are not usually produced by living organisms. Examples: NaCl, H_2SO_4, $AlCl_3$, FeO, etc.

Enzymes: An organic catalyst, made by cells, that speeds up a reaction or is required for a reaction. **Enzymes can break large molecules into smaller ones, or can put small molecules together into large molecules.**

Metabolism: Total chemical events occurring in a living organism.

Principle of Conservation of Mass: **Mass can neither be created nor destroyed**, by ordinary chemical means. (Mass can be converted to energy in nuclear reactions.)

Principle of Conservation of Energy: **Energy can neither be created nor destroyed** by ordinary chemical reactions. Energy CAN be changed from one form to another. (Different forms of energy are: heat, electrical, radiant, mechanical and chemical) Energy can be converted to mass in nuclear reactions.

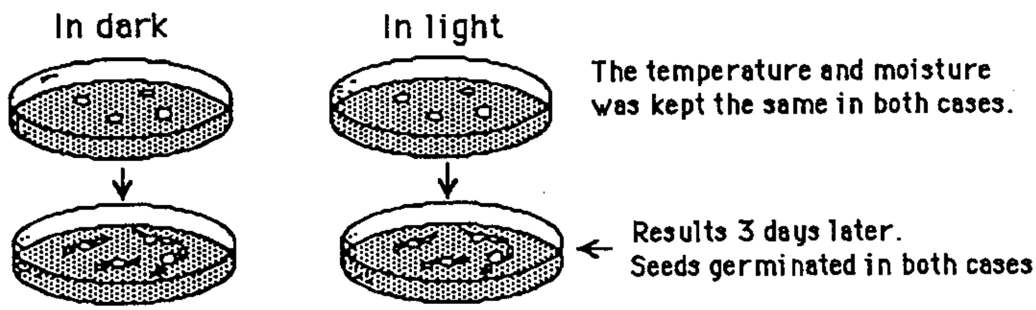
Nuclear Energy: Energy released from the nucleus of an atom by bombarding the nucleus with particles like neutrons or protons. When the nucleus breaks apart, the energy is released. In a nuclear reaction, mass (or matter) can be changed into ENERGY. In this situation mass has been destroyed and energy has been created. Therefore, in the case of nuclear reactions, the Principles of Conservation of Mass and Energy do NOT hold true.

Appendix B

ANSWERS FOR LAB INVESTIGATION 5-4

Check each of <u>your</u> answers from lab 5-4 with the following correct responses for each experiment. The following responses are the minimum that would be acceptable. Make corrections on your paper where necessary. If there are any responses that you do not understand, get help. Remember that when you complete this task, you should be ready for a quiz over similar material.

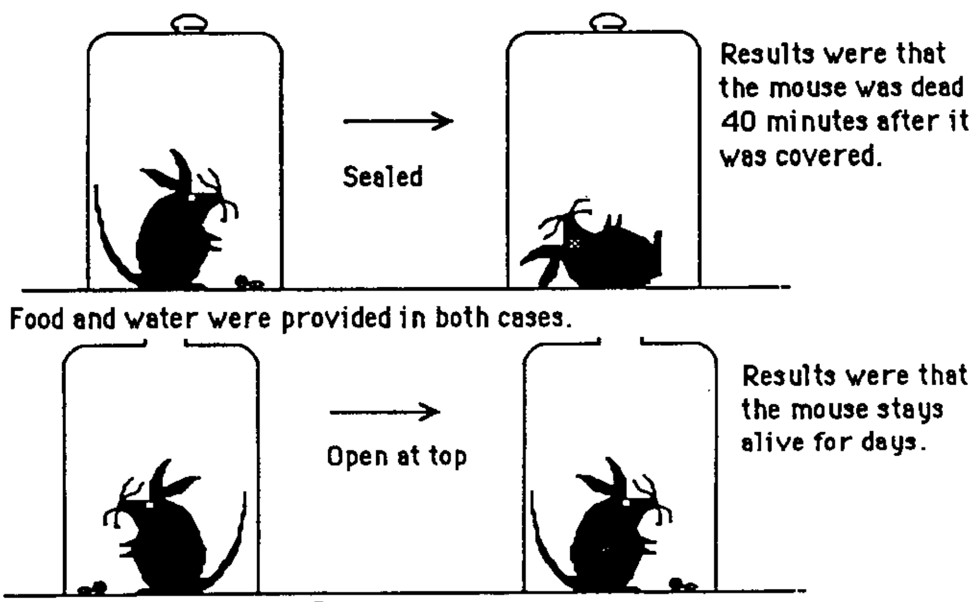
EXPERIMENT 1:



<u>Problem</u>: **Is light required in order for these radish seeds to germinate?** (germinate = sprout) Notice that all variables except light were the same in both cases.

<u>Interpretation of results</u>: **Light is not required in order for these radish seeds to germinate.**

EXPERIMENT 2:



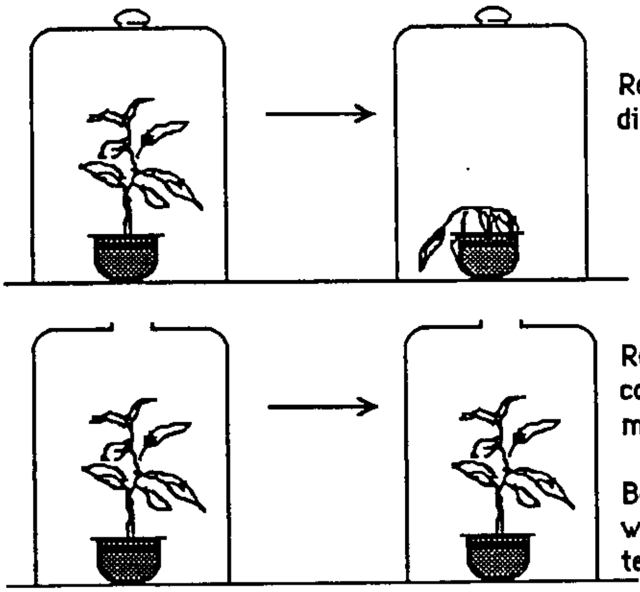
<u>Problem</u>: **Do mice require "something" in air for continued life?**
(Note: If you decided that this experiment was designed to determine if mice

require "oxygen", your decision would be incorrect! Read on for an explanation.)

<u>Interpretation of results</u>: **The mice require "something" in the air in order to remain alive.**

(Note: If you concluded that the mouse requires oxygen, you have arrived at a conclusion for which there is no evidence. Air is about 20% oxygen, 79% nitrogen, 0.03% carbon dioxide and other gases in small amounts. You have learned that mice and all animals require oxygen, and this is true. This experiment does not show this, however. The mouse actually died because he used up most of the oxygen but this particular experiment does not provide evidence that it was the OXYGEN that the mouse required. If the mouse had required nitrogen or carbon dioxide rather than oxygen, it would have died when that nitrogen was used up. Therefore, the results of this experiment show ONLY that the **mice required "SOMETHING" in the air.** It does not show which gas the mouse requires. Another experiment would have to be set up to show that the gas required was the oxygen portion of the air.) This above concept is a <u>very important</u> one and stresses the point that one must **draw conclusions only for which there is evidence.**

EXPERIMENT 3



Results were that the plant died in a few days.

Results were that the plant continued to live for months.

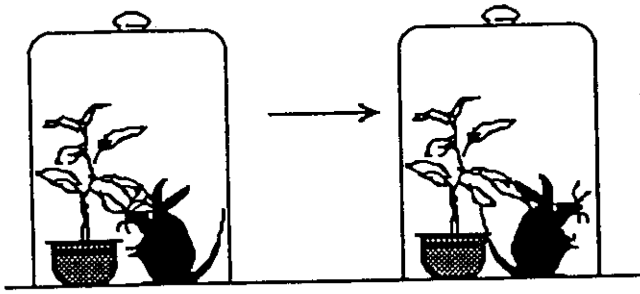
Both plants were kept watered and at the same temperature.

<u>Problem</u>: **Does this plant require "something" in the air for continued normal, healthy life?**

Interpretation of results: **The plant requires "something" in the air for continued normal, healthy life.**

Note that the same arguments for experiment 2 apply here about interpretations. It would be incorrect to conclude that plants require carbon dioxide or any other gas.

EXPERIMENT 4



Results after several days were that both the mouse and the plant remain healthy and alive.

Problem: **Can a mouse and a plant survive together in an airtight container for several days?**

A similar way of stating this problem is as follows: Taking into account the results obtained in experiments 2 and 3, **"Does the plant produce some substance required by the mouse and the mouse produce some substance required by the plant?"**

Interpretation of results: **The plant produces some substance required by the mouse and the mouse produces some substance required by the plant.**

Since a mouse or a plant cannot survive when they are by themselves in closed containers, this is the most reasonable interpretation.

It is of value to be able to decide which part of an experimental setup is the **control** and which is the **experimental set-up**. Examine experiments 2 and 3 and label the **"control container"** and the **"experimental container"** for each experiment.

Review how each experiment was interpreted. Also review how the problem was identified for each experiment. Focus particularly on corrections for any errors or omissions that you may have made. Be prepared to take the quiz over this topic. [ ]

Appendix C

GUIDELINES FOR COOPERATIVE GROUP LEARNING

Cooperative learning is not new and it is a natural way of learning. When we study with friends, we ask each other questions. We help each other understand the topic. This is cooperative learning. The process in class will be a little more structured. You will probably be in a group of three or four. The concept of cooperative learning means that you cooperate as a group to learn and help one another to understand the material and encourage each other to do the best work possible. In addition, actively discussing the unit's concepts at your table will help all members to do better. When one explains something to another, he/she learns and remembers the concept better. Learning this way is also more fun and rewarding.

The following questions will help you to begin to shift your focus to group dynamics and will help you to be successful in this new approach to learning. Form into cooperative groups as your teacher directs and read the questions and instructions that follow:

In your group, discuss each of the following questions thoroughly. Get input from all in the group. Write your group's answer to each question on one piece of paper to be turned in. Make each answer a group effort. Take turns in writing the answers to the different questions.

First Cooperative Group Activity

1. What are some ways those in the group might determine who needs extra help on any particular concept?
2. How will negative statements or put-downs about individuals in the group affect the group's success?
3. How will inappropriate socializing or wasting time effect the group's progress?
4. If certain students don't regularly turn in home assignments, or turn them in late, how will this affect your group's chances for getting bonus points?
5. What might you do as individuals to help the less active in the group to increase participation?
6. What effect will being impatient with others in the group have upon the group's ability to get bonus points.
7. Discuss your chances of being the table that gets extra points because your group obtains the highest increase for your class. (Summarize your discussion.)

GUIDELINES FOR SUCCESS WITH COOPERATIVE LEARNING

The following guidelines will help you to help your group to improve and to achieve truly cooperative learning:

I. **Be patient** with others in the group. Remember that we all learn at different rates

II. **Be kind** in the way you speak to one another in your group. This produces the desire to cooperate.

III. **Don't envy** those in the group who consistently score higher on work than you do. Remember that the better those in your group do, the greater your bonus points. Be happy for them. Don't compete, cooperate.

IV. **Don't boast or be proud** about how well you do compared to others, but instead seek to make them successful.

V. **Don't be rude or show anger** toward anyone in your group who might seem to you to not be doing enough. Be encouraging instead.

VI. **Don't think only of yourself.** Show concern for how the others are doing. Your success in getting bonus points depends upon how you do as a group, not how well only you do.

VII. If someone in your group "blows it" once in awhile on a quiz, home assignment, or exam, **don't hold it against the person**. Continue to encourage and help if you can.

VIII. **Have hope**, as a group, that you will show great improvement and share in the reward.

IX. Realize that **caring**, unlike rejection, **never fails**.

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8. In the opinion of the group, which three of the above "guidelines for success" are the most important?

9. Can you, as a group, think of any more guidelines? If you can, state them.

All members of the group should sign the paper.

Appendix D

Periodic Table of the Elements

KEY
1—Atomic number
H—Symbol
1.008—Atomic mass (weight)

I	II											III	IV	V	VI	VII	VIII (0)
1 H 1.008																1 H 1.008	2 He 4.003
3 Li 6.939	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.71	29 Cu 63.54	30 Zn 65.37	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.91	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc* (99)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (210)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)															

58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm* (147)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
90 Th 232.0	91 Pa (231)	92 U 238.0	93 Np* (237)	94 Pu* (242)	95 Am* (243)	96 Cm* (247)	97 Bk* (247)	98 Cf* (251)	99 Es* (254)	100 Fm* (253)	101 Md* (256)	102 No* (254)	103 Lw* (257)

* Does not occur naturally.