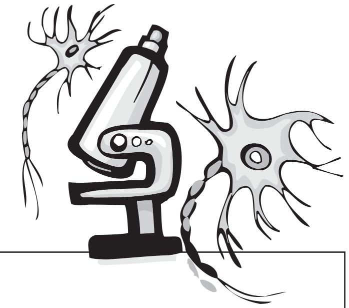
The Components of Life

Section 1.2
Organic Chemistry



Pre-View 1.2

- **Atom** – the smallest portion of an element found in the periodic chart; examples include carbon, oxygen, gold
- **Biomolecule** – an organic molecule produced by a living organism
- **Chemical bond** – a connection made between atoms when electrons are attracted, shared, or transferred
- **Condensation reaction** (or **dehydration synthesis**) – a chemical reaction that combines smaller molecules and forms water as a byproduct; the reaction is often used to form polymers
- **Covalent bond** – a chemical bond formed when elements *share* electrons
- **Hydrolysis reaction** – a chemical reaction between water and another molecule that breaks down the molecule into simpler molecules; the reaction splits a water molecule to break apart a polymer into monomers
- **Inorganic molecule** – a molecule that is not organic; most (but not all) do not include carbon; examples include water (H_2O), ammonia (NH_3), table salt (NaCl), and carbon dioxide (CO_2)
- **Ion** – an electrically charged "atom" that has either gained or lost electrons
- **Ionic bond** – a chemical bond formed when elements *transfer* (donate or accept) electrons
- **Macromolecules** (or **macronutrients**) – the large biomolecules that make up living organisms; include proteins, carbohydrates, lipids, and nucleic acids
- **Molecule** – a chemical combination of two or more atoms that forms a separate substance; for example, one molecule of water (H_2O) is made up of two hydrogen atoms and one oxygen atom
- **Monomer** – a small molecule that may be chemically bonded to other like molecules to form a polymer
- **Organic molecules** – carbon-containing molecules that are generally associated with living organisms
- **Polymer** – a long chain of monomers (small, repeating molecules)
- **Polymerization** – the chemical process of combining monomers to form a polymer; often uses condensation reactions

Chemistry Review

Atoms are the basic building blocks of the universe. An atom is the smallest possible portion of an element found in the periodic chart. You should remember that elements in the periodic chart include carbon, oxygen, nitrogen, aluminum, silver, and gold, to name a few. If you continued to split a sample of gold in half, you would eventually get a piece so small that it could not be separated anymore without losing the properties of gold. That "smallest piece" of the element gold would be one *atom* of gold.

There are only about 118 elements known to man and listed in the periodic chart. Why then do we have the incredible number of substances that exist in our world today? Many of these substances are compounds, or chemical combinations of two or more elements. The smallest unit of a chemical compound can also be called a **molecule**.

Simple Organic Molecules

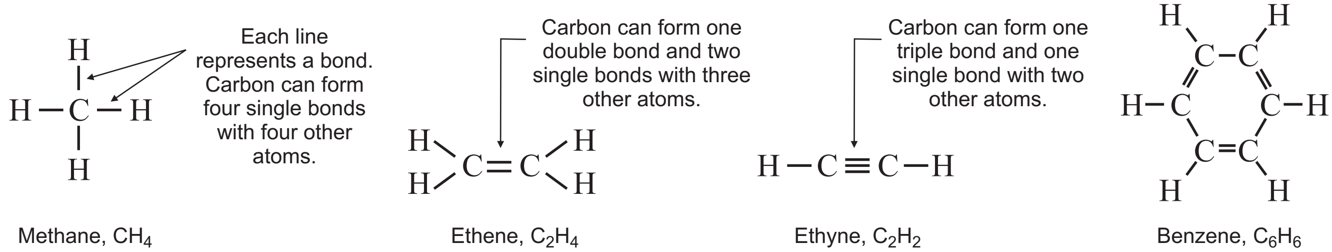


Fig. 1-2

As you can see in figure 1-2 above, carbon can form bonds with other carbon atoms. These bonds allow carbon to form straight chains, branched chains, or ring structures. In this way, carbon can form thousands of different structures, including some that are very large and complex.

Biomolecules and Macromolecules

Organic molecules that are specifically produced by living organisms are called **biomolecules**. Biomolecules include vitamins, hormones, and ATP, to name a few. Biomolecules can be simple organic molecules, or they can be long and complex. A special class of biomolecules are long, complex molecules called **macromolecules**. The four main types of macromolecules are carbohydrates, proteins, lipids, and nucleic acids. These macromolecules are sometimes called **macronutrients**. The elements responsible for forming the basis of most biomolecules are carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), and sulfur (S). Remember these as CHONPS (like CHOMPS, but with an N instead of an M).

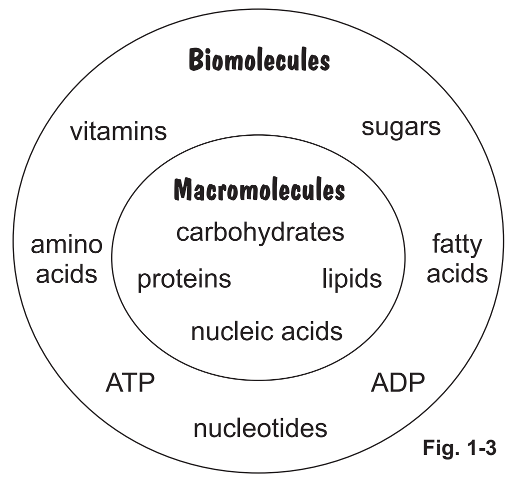
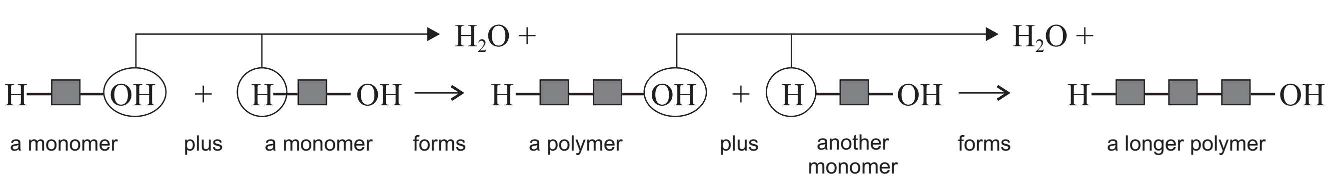


Fig. 1-3

Polymerization

Macromolecules are formed when smaller molecules called **monomers** are joined together in a process known as **polymerization** (figure 1-4). Polymerization forms **polymers**, which may be made from hundreds or thousands of monomers. Monomers combine to form a polymer by using a **condensation reaction** (also called **dehydration synthesis**). This type of reaction forms a molecule of water every time a monomer is added.

Example of Polymerization (Condensation Reaction/Dehydration Synthesis)



Condensation reactions build polymers and form water molecules.

Fig. 1-4

Fatty Acids

Before reviewing the different types of lipids and their chemical structures, let's review fatty acids, which are a component of some lipids. A **fatty acid** is an organic acid that is made up of a long chain of hydrocarbons. At first glance, a fatty acid looks similar to a carbohydrate because it contains a straight chain of carbon atoms bonded to hydrogen atoms along this chain. However, unlike a carbohydrate, a fatty acid typically contains an even number of carbon atoms and contains a carboxyl group at one end of the chain. The carboxyl group has the chemical formula of -COOH, which makes the compound an acid. Look at figure 1-9 and notice the carboxyl group at the left end of each fatty acid chain. Fatty acids make up a part of fats, phospholipids, and waxes.

Examples of Fatty Acids

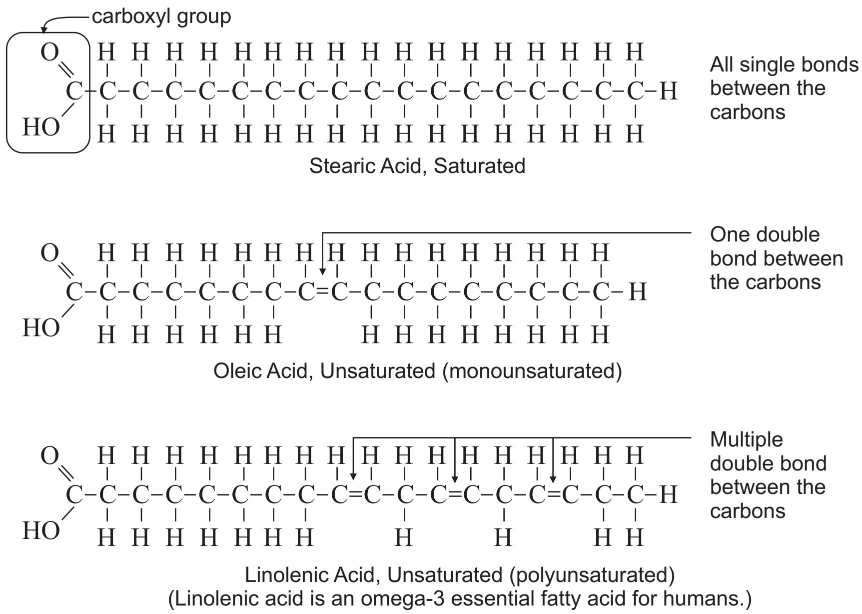


Fig. 1-9

Fatty acids can be saturated or unsaturated. When every carbon atom in the fatty acid chain has a single bond with another carbon atom, the fatty acid is saturated. Being saturated means that it has the maximum number of hydrogen atoms possible. An unsaturated fatty acid has one or more double carbon to carbon bonds.

Fats

Fats, also called *triglycerides*, are made of a glycerol molecule bonded to three fatty acid molecules (figure1-10). Fats can be classified as saturated or unsaturated depending on the types of fatty acids they contains. Refer to figure 1-9 for the types of fatty acids.

Fats that are solid at room temperature, such as butter, shortening, and lard, are usually **saturated fats**; they are made up of saturated fatty acids, which contain only single carbon to carbon bonds.

General Structure of a Fat

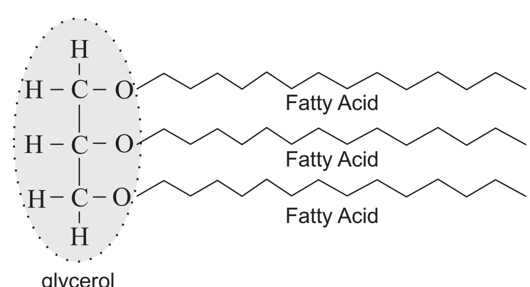
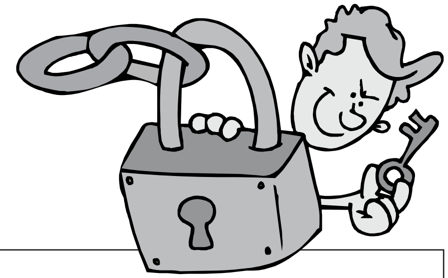


Fig. 1-10

Unsaturated fats have one or more double bonds in their fatty acids and are classified as either monounsaturated or polyunsaturated. Unsaturated fats are usually liquid at room temperature. **Monounsaturated fats** have one double carbon to carbon bond, and **polyunsaturated fats** contain fatty acids with more than one double bond. Nuts, seeds, avocados, olive oil, and peanut oil contain monounsaturated fatty acids. Vegetable oils, nuts, seeds, and cold-water fish contain polyunsaturated fatty acids. You may have seen these terms on food labels.

The Components of Life

Section 1.6
Enzymes



Pre-View 1.6

- **Activation energy** – the energy needed for a chemical reaction to take place
- **Active site** – the part of an enzyme that “attaches to” a substrate
- **Catalyst** – a substance that speeds up a chemical reaction without being consumed in the reaction
- **Denature** – to change the structure of a protein so that it no longer functions in the same way
- **Enzyme** – a biological catalyst that enables chemical reactions to take place in cells
- **Enzyme-substrate complex** – the structure that is formed when a substrate binds to the active site of an enzyme
- **Metabolic pathway** – a series of reactions, one after another, that occurs in a cell
- **pH** – a measure of the acidity or alkalinity of a substance
- **Substrate** – a substance that is changed by an enzyme

Organisms rely on thousands of chemical reactions to occur in cells in order to live. To make these reactions possible, special proteins called **enzymes** are used.

Enzymes and Activation Energy

The energy needed for any chemical reaction to take place is called the **activation energy** (abbreviated E_A). In living cells, most of the required chemical reactions occur too slowly or require too much energy to take place on their own. Enzymes act as catalysts to lower the activation energy. (A **catalyst** is a substance that speeds up a chemical reaction without itself being affected by the reaction.) In other words, enzymes speed up the reactions by lowering the amount of energy needed for the reactions to occur.

In figure 1-15, the two lines represent the same reaction pathway, one catalyzed (with enzymes) and one uncatalyzed (without enzymes). Notice that the catalyzed reaction requires less energy.

Enzymes Lower Activation Energy

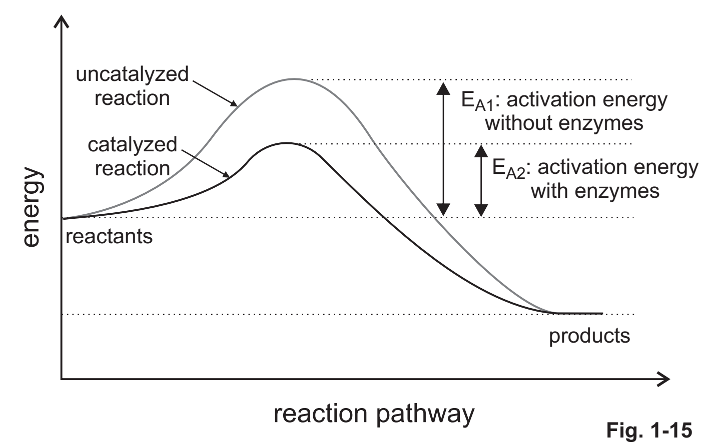


Fig. 1-15

How Enzymes Work

Enzymes are very large molecules that provide a location where the reactants of a reaction can be brought together. These reactants are also called the **substrates**. An enzyme is very specific in that it will only work with specific substrates.

Section 2.2, continued
Prokaryotic and Eukaryotic Cells

You'll see more about specific organelles in Section 2.3. For now, review the similarities and differences in these two types of cells in the following chart.

Similarities and Differences in Prokaryotic and Eukaryotic Cells

	PROKARYOTIC CELLS	EUKARYOTIC CELLS
Average Cell Size	1-10µm	10-100µm
Have a Cell Wall?	YES, most do	SOME
Have a Cell Membrane?	YES	YES
Have a Nuclear Membrane/Nucleus?	NO	YES
Have Cytoplasm?	YES	YES
Have DNA?	YES, in cytoplasm	YES, in nucleus
Have Ribosomes?	YES	YES
Have Membrane Enclosed Organelles?	NO	YES
Mode of Locomotion?	May have one or more flagella for locomotion	May have one or two flagella or cilia for locomotion
Found in —	bacteria only	fungi, protists, plants, animals

Both prokaryotic bacteria and single-celled eukaryotic organisms can have one or more **flagella** for locomotion. A flagellum (singular) is a long, hair-like filament that propels a cell forward.

Eukaryotic cells may also have **cilia**, which are shorter hair-like projections used like oars for movement. Multicellular organisms may have ciliated cells to produce movement, not necessarily for the cells themselves, but to produce the movement of debris. For example, cells in your nose are ciliated to move mucus and debris!

When you compare the two diagrams given in figures 2-1 and 2-2 below, you can tell how much more complex eukaryotic cells are than prokaryotic cells. The eukaryotic cell has more organelles. Examples of cell organelles are ribosomes, mitochondria, endoplasmic reticulum, etc.

Prokaryotic Cell

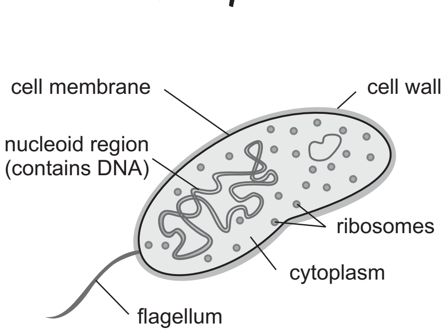


Fig. 2-1

Eukaryotic Cell

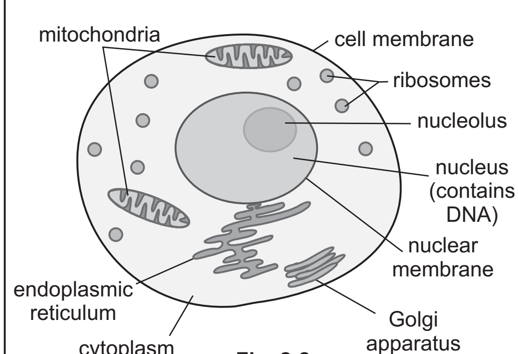


Fig. 2-2

Hint: To help you remember that eukaryotic cells are the cells that make up most organisms, including humans, think about how eukaryote is pronounced. It sounds like "you," and you are human!

Viruses

Figure 2-13 shows a diagram of the lytic cycle and the lysogenic cycle for a *bacteriophage*, a type of virus that infects bacteria.

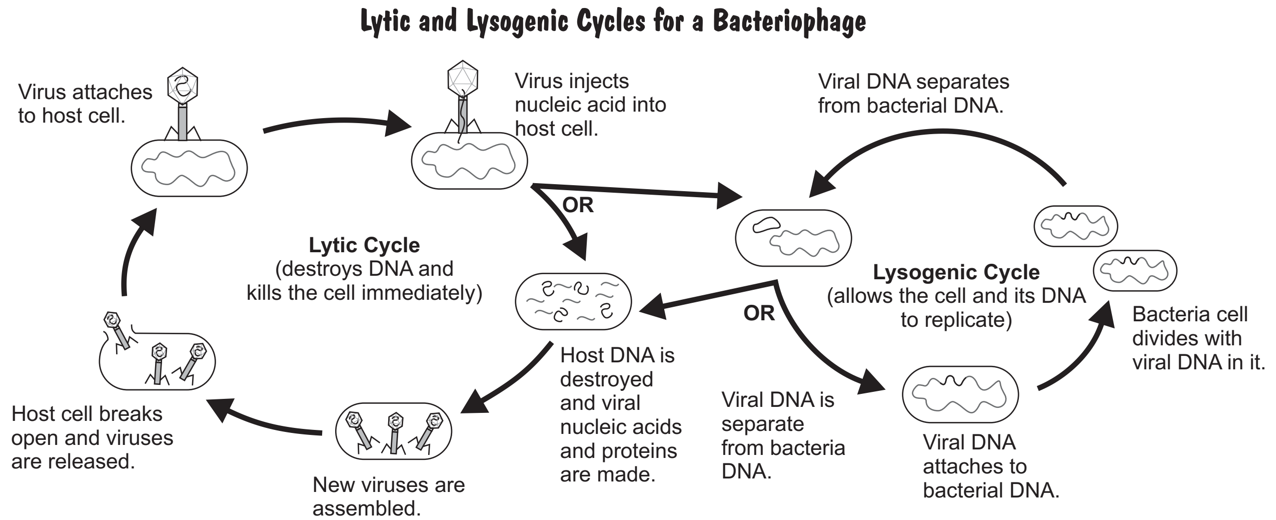


Fig. 2-13

Viruses: Living or Nonliving?

Should viruses be considered living organisms? The idea that viruses are living is sometimes debated because not everyone agrees on the definition of life. The characteristics of viruses can blur the lines between living and nonliving.

In Section 1.1 and again in Section 2.1, you saw eight commonly accepted characteristics of living things. Most scientists classify viruses as nonliving because they do not meet many of the commonly cited characteristics of life. In the following chart, consider how viruses meet or fail to meet each of these common characteristics of living things.

COMMON CHARACTERISTICS OF LIVING THINGS	VIRUS?	EXPLANATION
Made of one or more cells	No	A virus is not a cell, but it contains some of the components of a cell. It contains genetic material and a protein coat, but it does not have a cell membrane or organelles.
Has a way to reproduce	Yes and No	A virus can reproduce BUT only once it is inside a host cell.
Grows and develops	No	A virus does not have stages of development. It does not grow.
Shares a universal genetic code	Yes	A virus does contain genetic information in the form of either DNA or RNA. This genetic information forms genes used to create more virus particles.

continued on the next page

Passive Transport: Osmosis

Hint: Will a cell shrink or swell if placed in a hypotonic solution? It will swell. A simple word association may help you to remember this answer. Associate "hypo" with an "o" with "hippo." Hippos are large animals. Remember that cells in a hypotonic solution will swell up to the size of a hippo.

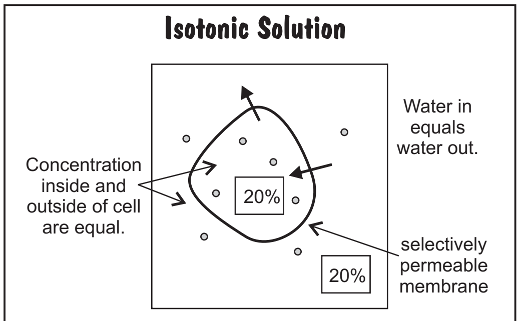


Fig. 3-9

Isotonic Solution

Isotonic (*iso = same*) means that the solution on the outside of the cell membrane has the same solute concentration as the solution on the inside of the membrane, so there is no net movement of water molecules across the membrane.

In figure 3-9, the solute concentration on both sides of the membrane is equal at 20%. Water molecules will pass in through the membrane at the same rate as they will pass out of the membrane. The cell will remain the same size since it is not gaining or losing water.

Quick Review

hypertonic	hyper = more	*more solute* and less water in the outside solution	cell shrinks
hypotonic	hypo = less	*less solute* and more water in the outside solution	cell swells
isotonic	iso = same	solute concentrates inside and outside are equal	no change in size

Effects of Osmosis on Animal Cells

Since an animal cell has only its cell membrane surrounding it, the cell is very vulnerable to the effects of osmosis. The effects of solute concentrations on a red blood cell can be seen in figure 3-10.

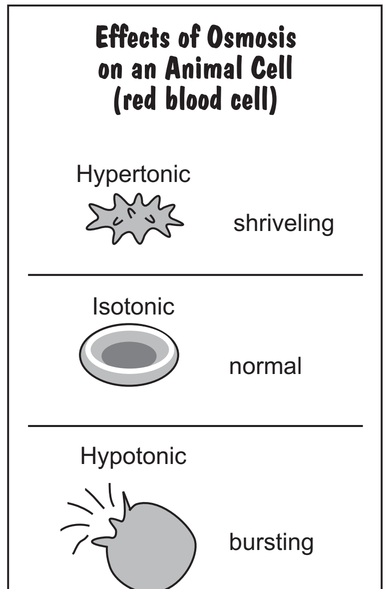


Fig. 3-10

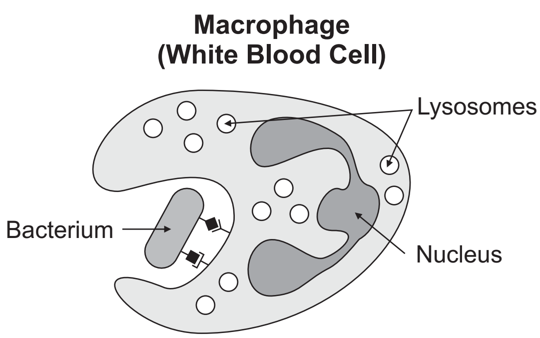
Hypertonic solutions will cause animal cells to shrink, causing a shriveled or "spiked" appearance. If the concentrations are very different inside and outside the cell, an animal cell in a hypertonic solution will shrivel and die. For example, salt water is hypertonic to the cells of most vertebrates that live in the ocean. To avoid dehydration that could be fatal to them, these animals constantly drink sea water and then desalt it by pumping the salt out of their gills using *active transport*. (We'll get to that next.) You may have seen pictures of marine turtles that blow salt out of special glands on their noses for the same reason. If a freshwater animal, however, is put in salt water for an extended period of time, its cells will lose too much water in the hypertonic solution, and the animal will die of dehydration.

In a hypotonic solution, animal cells swell. If the cell membrane is not strong enough, the cells will burst. For example, a red blood cell that contains almost 1% solutes will burst if it is put in pure water (0% solute). A saltwater fish that is put in fresh water will eventually die because its cells will gain too much water.

15. **In plants, root hairs are responsible for both water and mineral uptake. Water is not required for the root hairs to absorb the minerals. Minerals such as potassium (K^+) are absorbed via membrane transport proteins against as much as a ten thousand-fold concentration gradient. This uptake of minerals through plant root hairs is an example of —**

Ⓐ osmosis.
Ⓑ facilitated diffusion.
Ⓒ active transport.
Ⓓ diffusion.

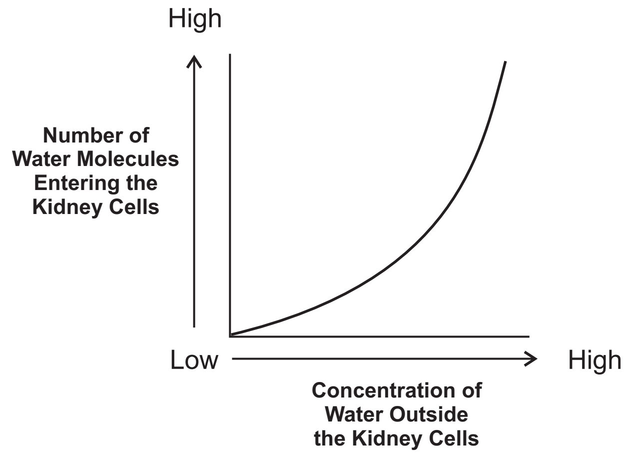
16. **Human macrophages are specialized white blood cells that are able to attack and "swallow" bacteria in order to fight or prevent bacterial infection. Macrophages have many lysosomes that contain enzymes to dissolve the engulfed bacterium cell. See the diagram below.**



What process are these cells specifically designed to carry out?

Ⓐ osmosis
Ⓑ endocytosis
Ⓒ facilitated diffusion
Ⓓ exocytosis

17. **Human kidney cells function to regulate the concentration of water and minerals in the blood. Study the graph below.**



The graph shows that as the concentration of water increases outside the cells, more and more water molecules enter the cells. Which <u>two</u> statements are accurate conclusions that can be drawn from this graph?

Ⓐ Water is nonpolar.
Ⓑ The lysosomes are regulating the action of the kidney cell membranes.
Ⓒ The kidney cell membranes are selectively permeable to water.
Ⓓ The movement of water across the kidney cell membranes requires energy.
Ⓔ Water enters kidney cells through the process of osmosis.

18. **Which <u>two</u> substance would animal intestinal cells most likely take in via facilitated diffusion?**

Ⓐ glucose
Ⓑ calcium ions
Ⓒ carbon dioxide
Ⓓ oxygen
Ⓔ hormones