Biochemical Concepts

Section 4.6
The Chemistry of Water

Pre-View 4.6

- **Polar molecule** – a molecule that has a partial positive charge on one end and a partial negative charge on the other end
- **Hydrogen bond** – in the case of water molecules, the weak bond that occurs when the hydrogen in one water molecule is attracted to the oxygen in another water molecule
- **Cohesion** – the attraction between molecules of the same kind
- **Surface tension** – the film-like quality on the surface of a liquid that is caused by the attraction of the liquid molecules to themselves
- **Adhesion** – the attraction of one type of molecule to a different type of molecule
- **Capillary action** – the tendency of a liquid to draw up into a narrow tube due to the liquid's properties of cohesion and adhesion
- **Specific heat** – the amount of heat needed to raise the temperature of one gram of a substance one degree Celsius
- **Solvent** – a substance that dissolves another

Water — good old H_2O — is the most abundant compound in most living organisms, but it's made of only two elements, hydrogen and oxygen. What makes it so special?

Water has many qualities that make it important to living things:
- It is transparent, so it lets sunlight pass through it to reach organisms that live underwater.
- It can form positively or negatively charged particles called ions.
- It is a universal solvent that can dissolve many substances easily so that they can be transported by the blood or other body fluids.
- It is found inside our cells and around our cells.
- It exists as a liquid at room temperature, and its frozen state floats and does not sink.

A Covalent Polar Molecule

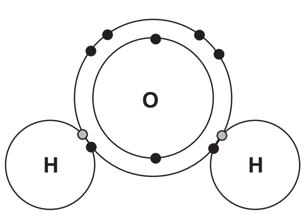


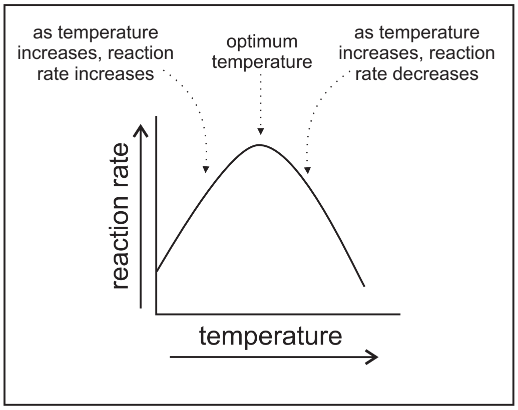
Fig. 4-9
Water Molecule

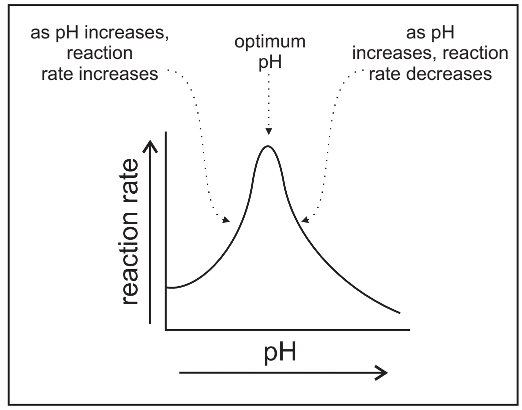
In a water molecule, covalent bonds hold the oxygen and hydrogen atoms to each other. Remember, a covalent bond is a bond formed by the *sharing* of electrons.

In a water molecule, however, the electrons are not shared equally. Since an oxygen atom has 8 protons (with 8 positive charges) and the two hydrogen atoms have one proton each (one positive charge each), the oxygen atom in a water molecule attracts electrons more strongly than the hydrogen atoms. The oxygen has more positive charge to attract the negative charge of the electrons. The unshared electrons in the oxygen atom push the hydrogen atoms down at an angle, so the water molecule ends up looking like the diagram in figure 4-9.

Section 5.6, continued
Enzymes

Both temperature and pH will change the shape of an enzyme. Since the shape of the enzyme affects how well it works on a substrate, enzymes work best at an optimum temperature and pH. Look at the graphs below that show how temperature and pH generally affect reaction rate.





Although the shapes of the curves are a little different, they both show the same trend. They simply show that as temperature or pH increases, reaction rate increases until it gets to an optimum temperature or pH. Then the reaction rate decreases when temperature or pH gets any higher. What point on the graphs represents the optimum temperature and optimum pH? The optimum is represented by the highest peak on the curve. Generally, enzymes work well in a narrower pH range than temperature range, so the "hill" of the curve is narrower and steeper on the pH graph.

Types of Enzymes

Humans produce two types of enzymes: metabolic enzymes and digestive enzymes. Humans also obtain and use a third kind of enzyme, food enzymes, from eating raw foods. Remember, enzymes are needed to speed up the rate of reaction. Reactions that could take days to complete can be completed in minutes or hours when enzymes are used.

Metabolic enzymes enable cells to perform cellular reactions. These reactions allow cells to make energy, repair tissues, and eliminate or neutralize wastes and toxic substances.

Digestive enzymes are ones that may be more familiar to you. The name of a digestive enzyme usually ends in *-ase*, and the first part of the name often indicates what it helps to digest (or break down into smaller components). Look at the chart on the right for common digestive enzymes and the substances they digest. For example, lactase is an enzyme that breaks down lactose, the sugar found in milk, into the monosaccharides of galactose and glucose. These are only a few of many. As you can see in the chart, digestive enzymes help to digest the different types of macronutrients. They allow the body to break down food in hours instead of days.

Common Digestive Enzymes

Enzyme	Breaks down —	Into products of —
amylase	carbohydrates	Disaccharides, monosaccharides
lactase	lactose (milk sugar)	galactose and glucose
sucrase	sucrose (table sugar)	glucose and fructose
protease	proteins	polypeptides, amino acids
lipase	fats	glycerol and fatty acids

Food enzymes also help to break down the foods we eat. Since food enzymes are destroyed at high temperatures, they are only found in uncooked (raw) foods or from supplements. Consuming food enzymes from raw foods helps the body to digest the foods without causing as much strain on the body to produce additional digestive enzymes.

Figure 6-5 below shows a labeled diagram of a typical plant and animal cell.

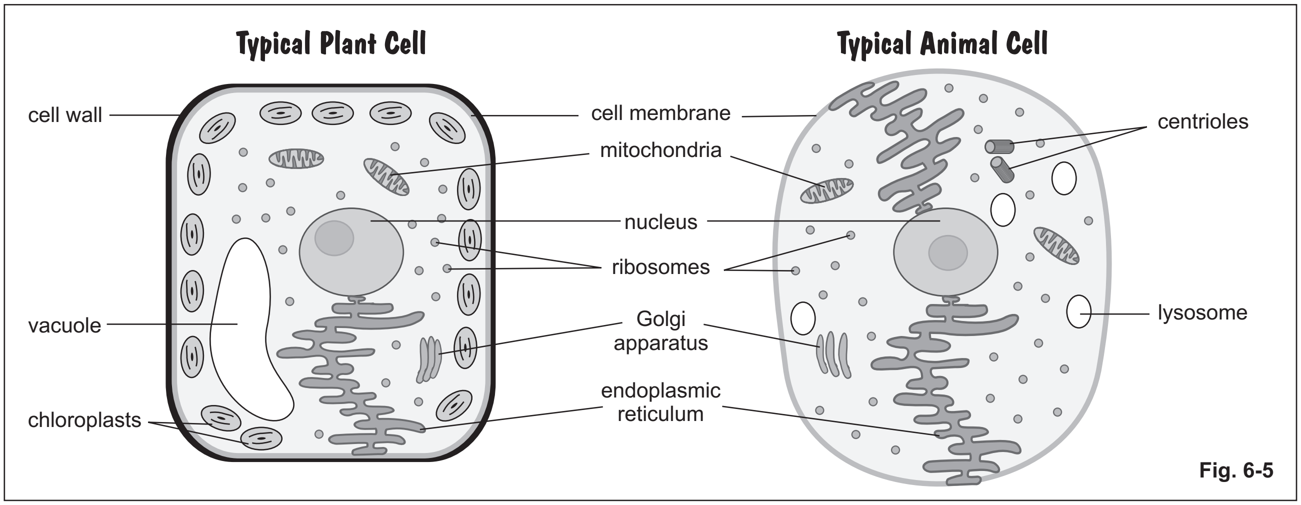


Fig. 6-5

Both plant and animal cells can reproduce, but the way that they divide into new cells is different. Both have some cell processes such as **cellular respiration** that are similar. In cellular respiration, cells use oxygen to help break down glucose to release energy and carbon dioxide. You'll see more about this process in Section 8.

Special Animal Organelles

Animal cells contain centrioles and lysosomes, neither of which are found in plant cells. Remember, centrioles play an important role in cell division, and lysosomes store enzymes that keep the cell free from debris.

Special Plant Organelles

From the chart on the previous page and the diagrams above, can you summarize a few things that are different between plant cells and animal cells? Hopefully, you see that the presence of a cell wall, the size of vacuoles, and the presence of chloroplasts make plant cells different. Let's take a closer look at each of these.

The Cell Wall

Plant cells have cell walls, but animal cells do not. The cell wall in a plant cell is made of **cellulose**, a material unique to plant cells. Similar to starch, cellulose is a type of carbohydrate. (Cellulose is also known as "fiber," an important part of a human diet.) The cell wall gives support and extra protection to the plant cell.

Vacuoles

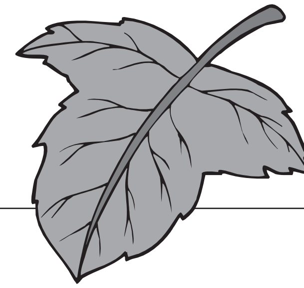
Many plant cells have one large vacuole that is filled with water. The vacuole may take up 50% or more of the space inside the cell. Vacuoles are used to store water, salts, sugars, wastes, etc. In plants, they can help provide support for the cell. Most animal cells do not contain vacuoles, and when found in cells other than plant cells, the vacuoles are small. Single-celled organisms such as paramecium contain contractile vacuoles that help control fluid balance.

Chloroplasts

Only plant cells (and some types of algae) have chloroplasts, so they can go through a special process called **photosynthesis**. In photosynthesis plant cells use light energy, carbon dioxide, and water to produce oxygen and glucose. Remember that glucose is a monosaccharide carbohydrate, or in other words, a simple sugar. Also remember that glucose and other carbohydrates store energy. (See Section 5.2 if you need more review on carbohydrates.) Glucose molecules "link" together to form starch molecules, which are stored in plant cells for future use.

Cellular Energy

Section 8.3
Photosynthesis



Pre-View 8.3

- **Heterotrophs** (also called ***consumers***) – organisms, such as animals, that obtain energy by consuming plants and other animals
- **Autotrophs** (also called ***producers***) – organisms, such as plants, that usually use energy directly from the sun to produce glucose and other carbohydrates
- **Carbon fixation** – the process of converting the inorganic carbon found in carbon dioxide to organic carbon in glucose
- **Photosynthesis** – process used by autotrophs that uses the sun's energy to convert water and carbon dioxide to glucose (simple sugar) and oxygen
- **Chlorophyll** – the green pigment found in the chloroplasts of plant cells that absorbs energy from the sun and uses that energy in the first stage of photosynthesis
- **Calvin cycle** – the stage of photosynthesis that does not require light

You know that all living things need energy, but where does that energy come from? In Sections 8.1 and 8.2, we discussed how energy comes from converting glucose (or simple sugar) into ATP, but where does the glucose come from? The sun is actually the main source of energy for living organisms although many organisms can't use that energy in its original form. All living organisms live by releasing energy found in chemical compounds such as glucose, but some can also use energy directly from the sun to make glucose.

Living organisms can be divided into two main groups: autotrophs and heterotrophs. **Heterotrophs** are organisms, such as animals, that get energy from the sun indirectly by consuming foods that have energy stored in them. Heterotrophs are also called ***consumers*** since they must consume food for energy. **Autotrophs** are organisms, such as plants, that can directly use the sun's energy to produce energy-containing chemical compounds such as glucose and other carbohydrates. Autotrophs are also called ***producers*** since they can produce their own food.

Through the process of **photosynthesis**, most autotrophs use the energy in sunlight to change water and carbon dioxide (CO_2) into glucose and oxygen. The net equation for photosynthesis is shown in figure 8-10 below:

Photosynthesis

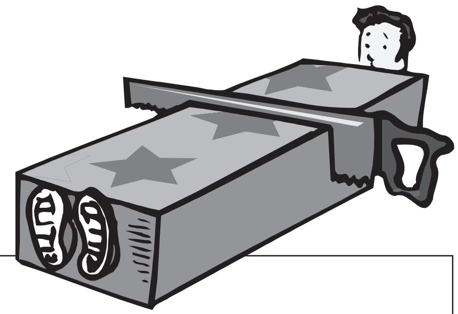
$$\underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O} \xrightarrow[\text{enzymes and chlorophyll}]{\text{light energy}} \underset{\text{glucose (simple sugar)}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2}$$

Fig. 8-10

Do you remember the difference between organic and inorganic compounds that you saw in Section 4.1? You may remember that carbon dioxide is an inorganic compound even though it contains carbon. Glucose, on the other hand, is an organic compound. So photosynthesis converts carbon from an inorganic compound into an organic one. This conversion is called **carbon fixation**. (Hint: Carbon dioxide cannot be used as food for us as humans. Once plants convert it into glucose, it is "fixed" into food that we can eat. The glucose made by photosynthesis helps to make up the potatoes, apples, lettuce, wheat, etc. that we eat.)

Cellular Reproduction

Section 9.2
Sexual Reproduction and Meiosis



Pre-View 9.2

- **Somatic cells** – all cells except sex cells; for example: blood cells, liver cells, skin cells
- **Sex cells** (or **gametes)** – the cells other than somatic cells that are formed through a process called meiosis
- **Meiosis** – the process that forms the sex cells called gametes (ova and sperm cells)
- **Haploid cells** – sex cells produced through the process of meiosis that contain half the number of chromosomes for that organism; have an *n* number of chromosomes
- **Diploid cells** – somatic cells produced through the process of mitosis that contain the full number of chromosomes for that organism; have a 2*n* number of chromosomes
- **Homologous chromosomes** (or **homologues)** – the two chromosomes that make up each pair of human somatic cells (23 pairs for a total of 46 chromosomes in humans)
- **Sex chromosomes** – the pair of chromosomes that determines gender (male or female)
- **Autosomes** – the pairs of chromosomes that do not include the one pair of sex chromosomes and that do not determine gender
- **Tetrad** – homologous chromosomes paired together side by side during meiosis
- **Crossing over** – the exchange of DNA between paired homologous chromosomes during meiosis

Gametes (Sex Cells)

Organisms that reproduce sexually have two types of cells. As we reviewed in Section 9.1, the cells that make up the body of the organism are called **somatic cells,** and they reproduce through the process of mitosis. The other cells are called **sex cells** or **gametes,** and they are formed using a process called **meiosis**.

Meiosis occurs only in reproductive cells to form egg cells and sperm cells. Unlike mitosis, meiosis does *not* produce two new genetically identical cells. Instead, the cells produced by meiosis are called **haploid cells**. Haploid cells have only half the usual number of chromosomes that other cells have. These cells are said to have an *n* number of chromosomes. Somatic cells are said to be **diploid** and contain the full number of chromosomes for any given organism. Somatic cells are said to have a 2*n* number of chromosomes. For example, human somatic cells have 23 pairs of chromosomes for a total of 46 chromosomes. The diploid number of chromosomes for humans is 46.

Human egg and sperm cells are haploid, which means they have only 23 chromosomes, not 23 pairs. When one egg with 23 chromosomes is fertilized by one sperm with 23 chromosomes, the offspring will have 46 chromosomes (23 pairs), the correct number for humans. If gametes were produced by mitosis, then each gamete would have 46 chromosomes, and the first set of offspring would have 92 chromosomes — twice as many as normal!

Somatic cells in an organism contain pairs of chromosomes that carry similar genetic information. The two chromosomes that make up each pair are called **homologous chromosomes** or **homologues**. One chromosome from each pair came from the mother's egg cell, and the other chromosome for each pair came from the father's sperm cell. Each pair of homologues contains similar information. For example, one pair of homologues will contain genes that determine eye color. One of the chromosomes may have information for blue eyes from the mother, and the other may have information for brown eyes from the father.