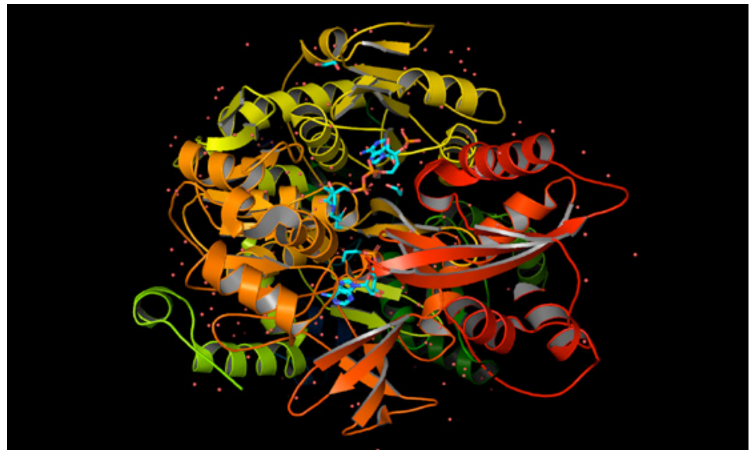
Chapter 4

How Cells Work



Summary of Terms

- **Active transport** Transport across the cell membrane that requires energy from the cell.
- **ATP** Adenosine triphosphate, the molecule that provides the energy for most cellular processes.
- **Cellular respiration** The aerobic breakdown of glucose to produce ATP.
- **Chloroplasts** The organelles within plant cells in which photosynthesis occurs.
- **Diffusion** The passive movement of molecules from an area of high concentration to an area of low concentration.
- **Enzymes** Complex proteins that catalyze chemical reactions in living organisms.
- **Fermentation** The anaerobic breakdown of glucose that results in the production of ethanol and carbon dioxide (alcoholic fermentation) or lactic acid (lactic acid fermentation).
- **Mitochondria** Eukaryotic organelles that break down organic molecules to produce ATP.
- **Passive transport** Transport across the cell membrane that does not require energy from the cell.
- **Photosynthesis** The process in plants and some other organisms in which light energy from the Sun is converted into chemical energy in organic molecules.

Detailed Chapter Summary

In this chapter we looked at how cells work. We began by looking at how molecules are able to get into and out of cells. Small molecules are able to pass right through the phospholipid bilayer of the cell membrane. In *diffusion*, molecules move from a region of high concentration to one of lower concentration. This is a natural kind of motion, and no energy from the cell is required to make it happen. Molecules can also cross the cell membrane via *transport proteins* embedded within the cell membrane. When molecules move from an area of high concentration to one of lower concentration, this process is called *facilitated diffusion*. With or without the transport protein, these are examples of *passive transport*. Specialized transport proteins, however, are able to allow the passage of molecules from a region of low concentration to one of higher concentration. This process requires the use of energy, which can be supplied by an energy molecule such as *ATP*. This is called *active transport*. *Endocytosis* and *exocytosis* are examples of active transport on a grander scale where larger groups of molecules are passed into or out of the cell all at once.

Cells can communicate with each other by the exchange of molecules. One cell may release a specific molecule that binds to a receptor on the surface of another cell. Upon binding, there is a cascade of chemical events that results in some change within that cell. This can happen over long distances within the body. Between adjacent cells, local messages pass directly through a *gap junction* in animals or through *plasmodesmata* in plants.

All chemical reactions follow the laws of thermodynamics. This includes chemical reactions occurring within the body. These laws specify that energy cannot be created nor destroyed and that energy tends to disperse from where it is concentrated to where it is dilute. Many chemical reactions within the cell are endothermic, which means they require the input of energy to occur. A common source of this energy is the molecule ATP. An example was provided to show how ATP promotes the movement of sodium and potassium ions against concentration gradients.

The amount of energy needed to drive endothermic reactions can be lowered using a catalyst. Large proteins behaving as catalysts work by binding a substrate to a portion of its surface called the active site. For example, it might take a large amount of activation energy to split a molecule into two smaller halves. When bound to the active site of the appropriate enzyme, however, this splitting of the molecule is much easier to do. As a catalyst, the enzyme itself is not destroyed by the process, which means it can facilitate many chemical reactions, one after the other. There are a number of ways the body controls these catalytic reactions. It can block the active site with an alternate molecule, which competes for the active site. This is called *competitive inhibition*. There may also be adjacent regions on the protein that when bound upsets the shape of the active site, which makes the active site no longer effective. This is called *noncompetitive inhibition*.

Photosynthesis is a process in plant cells in which the energy of sunlight is used to convert carbon dioxide and water into glucose and oxygen. Almost all life on Earth depends ultimately on photosynthesis for organic molecules and energy. Photosynthesis involves a pigment called chlorophyll. When hit with sunlight, the chlorophyll molecule is able to extract high energy electrons from water, which produces oxygen. The electrons are then passed through a series of steps to produce the energy molecule ATP followed by NADPH. These energy molecules are then used to produce glucose from carbon dioxide. Cells use glucose as a starting point for making other carbohydrates, lipids, and, with the addition of nitrogen, amino acids and nucleic acids—in short, all the macromolecules of life.

While photosynthesis allows for the production of organic molecules from energy (sunlight), there is an opposite process called *cellular respiration* in which organic molecules are broken apart to create energy molecules, such as ATP. Cellular respiration takes place partly in the cell cytoplasm and partly in organelles called *mitochondria*. There are three distinct phases to cellular respiration. It begins with *glycolosis*, where the glucose molecule is split, yielding two molecules of ATP. This is followed by the Krebs cycle where the chemical products of glycolysis (pyruvic acid) are broken down further to produce more energy molecules including ATP, NADH, and $FADH_2$. During the third phase, called electron transport, hydrogen ions are pumped outside of the mitochondrial membrane. The energy for this to happen comes from electrons carried by the NADH and $FADH_2$ molecules produced through the Krebs cycle. The electrons are transported through a number of energetically downhill steps. With each step, more hydrogen ions are pumped outward. But all of these steps are made possible only in the presence of oxygen, O_2, which is needed to accept these electrons as they flow "downhill". That's why it's so important for us to keep breathing oxygen.

Then, much like flowing water allows for the moving of a water wheel, as the hydrogen ions naturally flow back across the mitochondrial membrane, they allow for the production of even more ATP molecules. In short, through cellular respiration, the cell breaks down glucose to make ATP.

Lastly, we looked at a process known as fermentation. Although fermentation produces no ATP, it does produce molecules that support continued glycolysis. This allows for the further generation of energy molecules but in the absence of oxygen, O_2, and is thus called anaerobic.