Note: Don't forget to answer the questions that go with this article in your notebook!

Article: Energy for All

What would happen if we left a living insect in a sealed bottle for a while, even with food and water? Why does it need oxygen? Why does a lack of oxygen quickly lead to death? Clearly oxygen is essential to life.

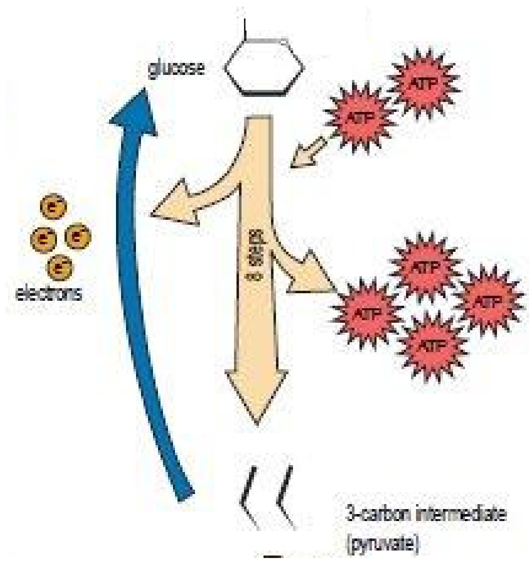
The following reading explores the role of oxygen in metabolism. It also examines how energy is obtained from the metabolism of the food you eat. As you read, keep track of what is happening to the macromolecules and where in the process energy is obtained. An analogy might help you understand energy in metabolism. Think about glucose as money stored in your bank account and ATP, the molecule that cells use when they need energy, as money in your pocket that you can spend ASAP.

From Sun to Life

Much of your previous exploration has been focused on the need of living organisms for energy and building blocks to sustain life. But where does this energy come from? The origin of energy on Earth is from the sun. Plants transform solar energy into chemical energy (sugar). Plants then use this sugar to form carbohydrates, proteins, lipids and nucleic acids. They do this through the processes of anabolism and catabolism.

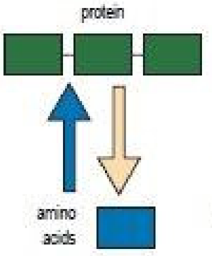
During metabolic processes, the energy from the sun flows, in the form of chemical energy, from molecule to molecule. It is used to take molecules apart and build new molecules. During **catabolism**, larger molecules are broken down; this reaction requires the input of some energy, but much more energy is released from the breaking the chemical bonds in the molecule. During **anabolism**, energy is stored in chemical bonds and this process involves small pieces being built into a larger molecule. Thus metabolic processes, or **metabolism**, are two interconnected processes: (1) breaking down molecules to make building blocks and release energy, and (2) building up molecules that store energy needed to carry out the functions of the cell.

It Takes Energy to Make Energy: *Glycolysis*



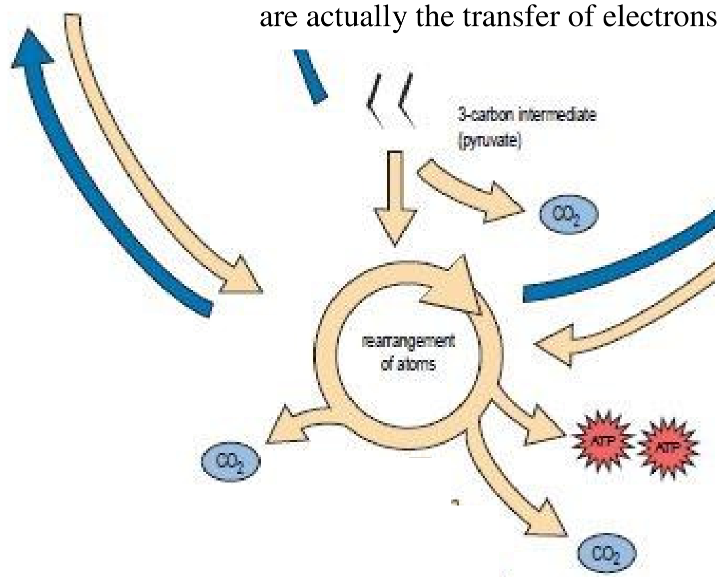
The breakdown of glucose is a multi-stepped process in living things. This process is facilitated by enzymes. Enzymes catalyze all the chemical reactions that take place in metabolism.Enzymes also catalyze the breakdown of glucose and the controlled release of energy. The bonds in glucose are broken, not in a single step as in the burning of glucose, but in nine steps. The end product of this breakdown of the 6-carbon-sugar glucose is two new molecules with three carbons each, called pyruvate. The energy released from the breaking of the bonds in glucose is transferred to a new molecule called **adenosine triphosphate**, or **ATP**.

ATP is a very important molecule to living organisms. It is used widely as an energy "holding tank" or battery in living things. This molecule holds the energy released during the catabolism of glucose until it is needed by other processes in the cell (such as movement, fighting invaders, etc.) At the end of glycolysis, there is a net gain of 2 ATP molecules. In the big picture of the energy needs of a living thing, 2 ATP is not nearly enough. The energy transferred to ATP in glycolysis represents only 2% of the energy stored in the original glucose molecule. How does the organism tap into the rest of that potential energy?



The Krebs Cycle : Setting the Stage for Things to Come

The end products of glycolysis, those 3-carbon molecules called pyruvate, enter yet another pathway to further transfer energy. In this pathway, the pyruvate molecules are broken down, rearranged, and rejoined in a series of steps. These steps create new molecules that can be the starting material for other important molecules like lipids and proteins. During the course of this pathway, electrons are transferred from molecule to molecule. (Note: chemical reactions are actually the transfer of electrons.)



This transfer of electrons also involves the transfer of energy that is contained in the electrons. It is the energy in the electrons that is ultimately transferred to ATP. Carbon dioxide is released at this point as a waste product. From the beginning of the breakdown of glucose, a net gain of only 4 ATP has been made. Still not enough energy! During the pathway, many high-energy electrons have changed "hands" (actually molecules). But there is still a lot of energy to be had. How can the organism get more of this available energy converted to ATP?

Electron Transport Chain: Let's Get Oxidized!

Oxygen is the organism's key to finally obtaining most energy that was trapped in glucose. Look back at the metabolism diagram. High-energy-containing electrons were transferred to molecules whose main purpose is to pass them on. The energy present in these electrons when they enter this transport system is gradually transferred, in a series of steps to form ATP. The net gain of ATPs from this transfer of electrons is 32. Oxygen, which organisms have taken from the air is the final acceptor of the electrons after they have transferred much of their energy to ATP.

At the end of all the reactions, the electron has "lost" its high energy because the energy was transferred to ATP. These electrons are now waste; finally, we see a role for oxygen. Oxygen removes the spent electrons that are the by-products or waste products of metabolic processes. The final product of this reaction is water. (Oxygen + electrons + H^+ = water) Thus, two waste products, carbon dioxide, and water, are generated by the catabolic reactions we just examined. The products gained by these reactions are building materials to maintain healthy cells and energy in the form of 36 ATP. This transport of electrons to oxygen and the generation of ATP along the way is referred to as **cellular respiration**.