~~~ What the Heck is an Enzyme? ~~~

I know; the image has nothing to do with an enzyme *per se* - is an image of the result of the comet Shoemaker-Levy 9 fragments slamming into Jupiter as Jupiter rotated - but - certainly allows one to appreciate chemical reactions.

An enzyme is a protein or RNA (yep... some RNA molecules behave in this way - are called ribozymes) which is capable of initiating a chemical reaction that involves the formation and/or breakage of chemical bonds.

OK, let's get started..... Any chemical reaction which results in products of the reaction which exist at a lower energy level relative to the reactants which led to the product, will theoretically occur, with or without an enzyme - but - may take a thousand years, or, may never occur - unless there is a little "zip" added to the mixture.

Enzymes are catalysts - a very special kind of "organically grown" catalyst with a very precise chemical definition. A "true" catalyst in chemical terms substantially reduces the energy barrier which exists between atoms and which prevents the atoms from "getting close" enough to react and form a bond with one another. An enzyme, like all strictly-defined catalysts, is therefore said to **lower the energy of activation of a reaction; but, the catalyst is not changed in any way in the process - kind-of like a conduit - a path through which reactions occur.** All catalyst-like things, do this. Therefore, when the atoms of molecules are acted upon by enzymes, an identical reaction occurs as would have occurred without the enzyme, but, the energy hill required to overcome the getting-close barrier, is much, much smaller than would have been true without the enzyme's help. The structure of the enzyme is such that atoms of molecules can get close enough to interact, but the energy required to allow this closeness is reatively small - like going into an empty closet with someone relative to going into an empty auditorium with someone. The chances of interaction within the closet are greater than the chances within the auditorium - less energy required to move around to increase the chances of bumping into one another.

Let's look at some analogies to explain all of this energy stuff... You already know that it takes energy to climb a hill. At the bottom of the hill, you possess less potential energy than when you are finally exhausted, but are standing at the top of the hill. This gain in potential energy is partly the result of the effect of gravity, and partly the result of the transfer of energy from your muscles (they lost some to the hill and to the environment) to get you to the top. If you jumped off of the hill, your rate of fall would increase by 32 feet/second, for every second you spent flying through the air (just as it would if you jumped off of a chair) - this means that you will accelerate - and you know that getting hit on the head by a marble dropped from one inch, is not nearly as unpleasant as getting hit on the head by a marble dropped from 100 feet. You know as well as I do, that you could immediately tell the difference in energy released from the two marbles - although, in the latter case you would most likely be unconscious, and couldn't make your knowledge available to anyone.

Now, once you hit the ground, all of the energy you had accumulated at the top of the hill, would be released as heat, friction, and not worth much - no useful work - especially to your prostrate form...However, what if you had tied one end of a rope to yourself, and the other end to a person on the opposite side and at the bottom of the hill? Once you reached the end of your rope during the fall, some of the energy accumulated by you from your arduous trek up the hill and released by your fall, would be transferred to the other person connected to you - this person would probably fly up and over the hill without much effort on their part - unless the person was way bigger than you - would require more energy than you had made available to drag them up and over. Such enzyme-connected reactions are called coupled reactions. Chemical bond breakage or formation by enzymes has some aspects of this analogy. There are other aspects, however.

Now we must talk about personal relationships... you are attracted to someone, and they to you. You and they would each like to move closer to one another and form a bond between you. However, each of you may first need to overcome some barriers (shyness, self-doubt, etc.) Each of you has your own energy level (pretty high - you're out and about, looking to bond), but, your own set of inhibitions as well. So, there must be some impetus required to overcome your individual inhibitions and to push you together (might be a friend who catalyzes the interaction). Chemicals are like this, too. For atoms to get close enough to each other to form bonds between one another, an energy barrier must first be overcome (a hill); however, once this barrier is breached, the resulting reaction then occurs spontaneously, and a product is formed - which is at a lower energy level than the reactants which formed it - the reactants come together and roll down the hill to form a product. Would be similar to you climbing a hill, and when you looked over the other side you find you are standing on the edge of a cliff and there is a canyon beneath you. Would have taken energy to get you to the top, and start you over the edge, but after that, you could parachute to the bottom of the canyon without expending any energy - in fact - you would release energy - and your energy level at the bottom of the canyon would be less than the energy level you possessed prior to climbing the hill, and substantially less than the energy you possessed at the top of the hill. If this difference in energy could somehow be collected, than other useful things could be made to happen.

You know that if you place a piece of wood in an empty fireplace, that you could stare at that wood for a million years and it would never suddenly burst into flames. However, if you place some paper, and maybe a few little sticks in there, and then apply the flame of a match to the paper, there is a strong liklihood that the wood will begin to burn and will continue to burn until the wood is gone. What's happened here? First, the wood, paper and sticks are all made of cellulose - a bunch of sugar molecules (glucose) hooked together into a complex polymer. So, cellulose is nothing but lots of individual carbon, oxygen and hydrogen atoms arranged in a particular way. If more oxygen (O2, the kind that we breathe) reacts with this stuff, chemical bonds can be formed and others broken which results in the release of carbon dioxide and water from the cellulose - that's it, just CO2 and water (you have "tasted" CO2 - it's the stuff in "carbonated" water - that's where the name carbonated, comes from). As I think about it, you have most likely tasted water, as well.

Well, back to the burning wood... there is plenty of oxygen available in the room, or else you would be unconscious again, just after reviving from the marble attack..... so, why doesn't the oxygen in the air just hop onto the cellulose and react with it? Because, there is that energy hill which must first be overcome in order to allow the oxygen atoms to get close enough to the atoms within the cellulose to form a chemical bond. This extra energy is supplied by the flame of the match - increases the rate of movement (is what temperature is) of the oxygen and the atoms in the paper near the flame, accelerates them, and the atoms now have enough energy to slam together. Now, nothing would continue to happen UNLESS the products of this reaction, carbon dioxide and water, were at a lower, final energy level than the energy stored in the bonds of the cellulose. It is because of this difference in energy levels that the reaction continues spontaneously (we call this particular reaction a fire...) There are enzymes in your body and within bacteria which ultimately do **exactly** the same thing to glucose, e.g., produce CO2 (you exhale it) and water, by allowing glucose (you eat it) and oxygen (you inhale it) to react with one another.

In the fireplace, some of the energy released by the formation of CO_2 and water, is taken up by the unburned cellulose and oxygen in the air, which causes more atoms to slam together. Some of the energy remains in the bonds of CO_2 and water. Some is lost as heat up the chimney, and the rest goes out into the room. Therefore, we are warmed by the fire. This warmth is useful to us, but really doesn't perform any work. However, if we used some of this heat to boil water, to drive the liquid water molecules into a gas (steam), we could let the steam bang into a turbine blade, turn it, and produce movement... Or, better yet for us and bacteria, this energy is used to provide an ability to move, and to produce other things.

Enzymes are very particular - they won't catalyze just any old reaction, only those which are suited for the enzyme. This selectivity is because of the essentially fixed shape of the place where the molecules must get together within the enzyme's reaction site in order to get close enough to form a bond. This site may comprise only a tiny part (the closet) of the entire enzyme's structure, but all of the structure is necessary in order for the site to be shaped correctly, And, only a select few molecules for any single enzyme will fit into this site. Therefore, there are thousands of different enzymes required in order for the thousands of different molecules within a living cell to engage in reactions. It is for this reason that a change in a gene (mutation) which encodes the enzyme's structure can result in a dysfunctional enzyme and lead to an inability of a cell to properly function.

Some people cannot eat any milk products - milk contains the sugar, lactose (is where the word lactation comes from) which is made of glucose and galactose hooked together. An enzyme is required to digest the lactose and to convert it into glucose and galactose (we use both). However, if there is no enzyme (or a dysfunctional enzyme) which subsequently converts galactose into usable substances, then galactose will build-up and result in severe damage - even mental retardation. The treatment is a diet which is very low in galactose. Another example is the inability of a person to tolerate fructose (in fruits and part of the structure of sucrose - table sugar). The child has only one enzyme missing - the one which works on fructose-phosphate. This child will become severely ill, have very low blood sugar (glucose), and will be malnourished. These children, remarkably, have a natural aversion to sweets and fruits, and also very few dental caries. The treatment is to place the child on a low-fructose diet.

Bacteria too, must have functioning enzymes available. Being only a single cell with only a single chromosome, bacteria are quite astonishing in their ability to make structural and functional components of all of the things necessary for the cell to stay alive. However, not all bacteria have all of the same enzymes - therefore - different habitats and nutritional substances are required for the different species of bacteria, because they can't make all of the component parts necessary to build all of the structures - they need to be near a source of already-made substances for which they have enzymes which can utilize them. Of course, we are like this too. We depend on bacteria, plants and animals for the sources of many of the component parts which we cannot make, and our enzymes which can utilize these substances to initiate chemical reactions and build the structures necessary for life.

Believe it - enzymes are important!

- **Book: Don't Touch That Doorknob!**

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