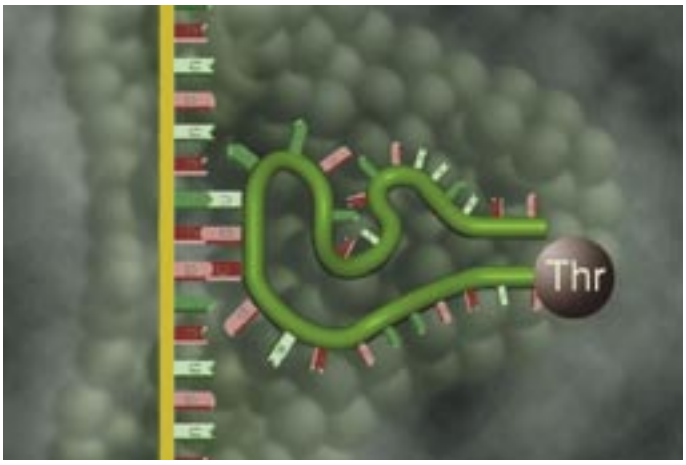
Inside the Living Cell



Study Guide for Instructors and Students

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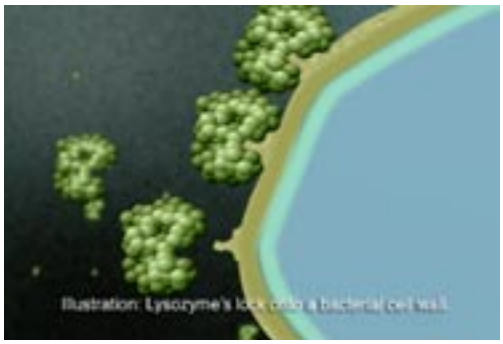
How Cells are Controlled

ENZYMES ARE LIFE'S CATALYSTS

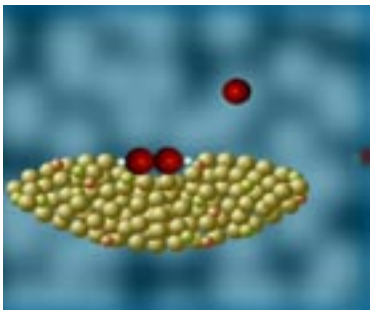
Tears convey happiness, or sadness, but they do something else as well, and exactly what was accidentally discovered in the early 1900s. A bacteriologist by the name of Alexander Fleming happened to create an inadvertent experiment when a teardrop fell into one of his bacteria cultures. It set the stage for our modern understanding of how cell processes are controlled.

Many years later the chemical in tears was isolated and described. It was an enzyme -- now called Fleming's Lysozyme. *Lyse* means to break apart, *zyme* means enzyme.

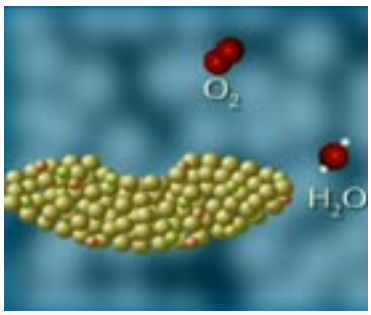


We now know how Flemming's Lysozyme works. First, like all enzymes, it's a protein, a huge molecule built from a perfectly ordered assemblage of amino acid building blocks. It's chemical structure fits molecules in the bacterial cell wall like a lock and key, and once the enzyme locks on, the bacterium's cell wall comes apart.

Pour hydrogen peroxide over a small wound to study another enzymatic reaction. You have probably done this, but did you ever wonder what actually was causing all those bubbles.



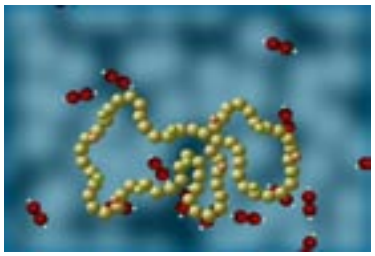
Hydrogen peroxide is an extremely reactive chemical, guaranteed to disrupt delicate cell machinery. The good news is that it will kill many of the bacteria left in a wound. Our cells produce small amounts of hydrogen peroxide during metabolism, but they also provide an enzyme that instantly renders it harmless, the enzyme catalase.



In the processes the enzyme attacks the hydrogen peroxide molecule, H2O2, and breaks off oxygen, leaving harmless H2O along with some O. Os get together to form O2, oxygen gas; that's what the bubbles are.

If you don't often get scrapes, you can try this experiment in the lab. Lower a little cube of liver into a hydrogen peroxide solution. Test for oxygen using a glowing splint. The splint reveals that oxygen gas is definitely being given off. Eventually all of the hydrogen peroxide has been converted to water and oxygen. But what has happened to the catalase enzymes? Fill up the flask with hydrogen peroxide solution and set off the reaction again.

HOW ENZYMES AND OTHER PROTEINS ARE MADE



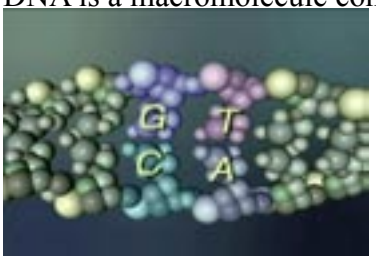
Doing their job does not destroy enzymes. One catalase enzyme can probably breakdown millions of hydrogen peroxide molecules and continue functioning. However, if you want to deactivate the enzyme, just raise the temperature to around 50 degrees Centigrade, and the enzyme action stops.

This is because the chemical bonds that hold the enzyme molecule, a giant protein, in its proper shape for dissembling hydrogen peroxide, have broken, and the misshapen enzyme no longer functions.

The shape of a protein is critical to its job. The lock-and-key fit of enzymes to their target molecules is behind the thousands of chemical reactions that keep us alive.

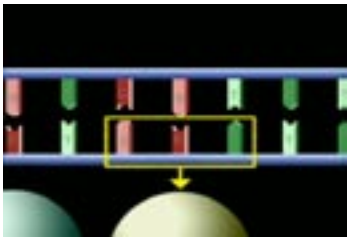
As you know, proteins are huge macromolecules made up of chains of amino acids. There are only 20 kinds of amino acids, but they can be strung together in the proper sequence to make up hair, skin, muscles, organs and, of course, enzymes. But what is the correct sequence? Where is the instruction book for putting the amino acids together in the correct order?

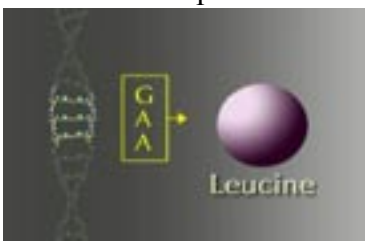
The instructions for building proteins are found in the cell nucleus, spelled out in a chemical code on molecules of DNA.
DNA is a macromolecule composed of just four kinds of building blocks:



- Adenine (A)
- Guanine (G)
- Thymine (T)
- Cytosine (C)

The code for a particular amino acid is a three-letter code. For example GAA is



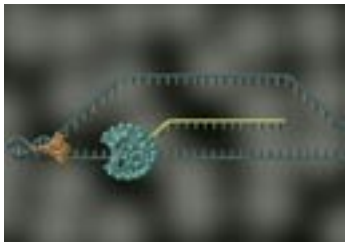


the DNA chemical code for the amino acid Leucine (again, one of twenty different amino acids).

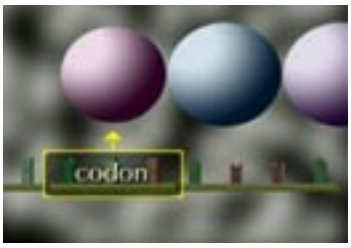
So the gene for a particular enzyme is a section or sections of DNA carrying the three letter DNA words that represent the string of amino acids that will appear in the enzyme. The three letter DNA words are like notes on a manuscript page. They represent the exact tune to be played – the exact protein to be constructed.

While the instructions for enzymes and other proteins are locked up on DNA in the cell nucleus, their actual manufacture occurs out in the cytoplasm. The building instructions found on DNA must somehow leave the nucleus and find their way to protein-building machinery found in the cytoplasm. The first electronmicrographs of the nuclear membrane gave a clue -- the membrane was festooned with pores.

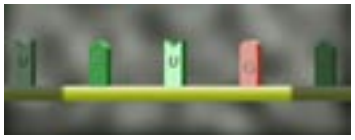
HOW ENZYMES ARE MADE - continued



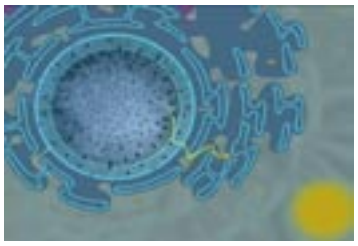
To make a protein an enzyme first opens the DNA molecule strand. Another enzyme, RNA polymerase, moves along one of the instruction strand, copying the protein-building instructions. It couples RNA nucleotides with precision onto the DNA strand, and moves on down the line until it hits an encoded termination sequence and drops off.



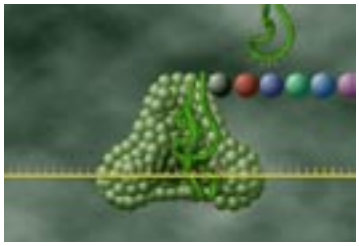
The long molecule of RNA that results is an exact copy of the gene, spelled out in matching building blocks. The three-letter code for a particular amino acid is called a "codon". But this transcription must start at exactly the right place to avoid a disaster. If it started just one letter off, all to the triplet code words would be wrong, and a garbled protein would be the result. The universal start signal is the AUG codon and in the protein making process it stands out like a green light.



The RNA transcript is called messenger RNA (m-RNA), for good reason. It slips out through one of those pores in the nuclear envelope and is picked up by one of the tiny organelles where the actual translation into an amino acid chain will occur. This two-part organelle, itself made from a special kind of RNA, is called the Ribosome and cells contain them by the thousands.



To make proteins an animal must have a stockpile of amino acids in its cells, ready for assembly. It gets them from digested proteins, from food. The amino acids and other building block molecules resulting from digestion are carried from intestine to body cells by the blood stream.



So, it's now a matter of lining up an amino acid with its RNA code word, or codon. This happens with the aid of another kind of RNA --transfer RNA, or tRNA. There is a kind of tRNA for each of the 20 kinds off amino acids. The tRNA has two bonding sites: one recognizes its particular amino acid; the other contains the anticodon for that amino acid -- the same three letter code word found on the original instructing strand of the gene.

As the ribosome passes along, reading the mRNA instruction tape, matches are found; and amino acids are added to the growing chain. In fact, an assembly line begins as a number of ribosomes travel along the mRNA, each one transcribing the message into identical protein chains.

At the finish, the protein will have twisted into its functional shape, ready to perform its function, whatever that may be.

TURNING-ON BACTERIAL GENES

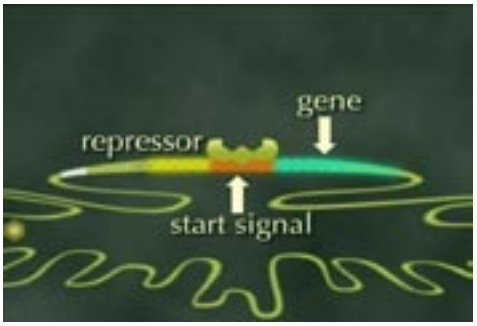
In the case of enzymes, they often aren't assembled by your cells until they are needed for a specific job. How does a cell know when turn on a gene for making a particular enzyme?

We know something about this "turning-on of genes" from experiments with bacteria. The selected subject for study: yogurt.

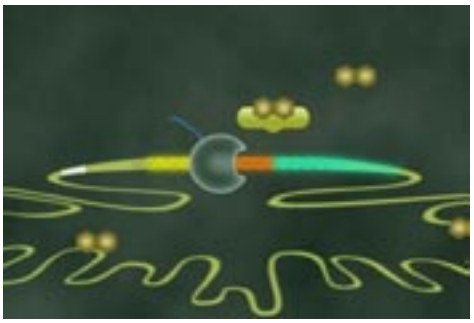
Yogurt is really milk, processed by some friendly bacteria. Breaking down the milk is accomplished by specific enzymes the bacteria produce.

Bacteria break down milk sugar, lactose, using an enzyme they produced called galactosidase.

When there is no lactose around the bacteria don't bother making galactosidase, but if they encounter molecules of lactose, they start producing the enzyme.



On the bacterium's DNA is the gene for the galactosidase enzyme. The gene has a start signal. Hanging on to it is a protein called a repressor. The repressor's molecular structure recognizes the lactose molecule.



When a lactose molecule bonds on, the repressor releases its grip. RNA polymerase can then slip in and transcribe the galactosidase gene. Soon the bacterial ribosomes are turning out enzymes that will break down the lactose into something the bacterium can use. In the process the bacteria create a tasty treat for us.