

Humans seek to harness the world around them and use it to their benefit. They are very adept at building and sustaining the very large; civilizations have created pyramids, skyscrapers, and bridges tens of miles long. Scientists have yet, however, to master the very small. True, medicine and food production have always been a chief concern of the human race, but scientists know very little about how the tools used in these fields work. Enzymes are a prime example. Scientists know the structure of enzymes, and have many uses for them, but they have not yet been able to engineer enzymes confidently or to produce the desired results. Enzymes control the rate of chemical reactions, and are already a vital part of the food industry, and scientists are looking for new ways to use enzymes to improve the quality of life.

Enzymes are useful because of their unique ability to control chemical reactions by bringing reactants closer together. They speed up reactions by lowering the activation energy, or the amount of energy required for the reaction to begin, and by placing the reactants near enough that the reaction can sustain itself. Michael Farabee, a teacher at Estrella Mountain Community College, states in his study aide “Reactions & Enzymes” that reactions caused by enzymes are “within the homeostatic constraints of a living system.” Enzymes perform functions beneficial to the “living system” as a whole. Enzymes are controlled by their very structure; they are coded to fit only a specific substrate, or reactant. Their three-dimensional structure is dependent on the string of amino acids that form them. The charges of the amino acids determine the twisted shape of the enzyme and the shape of its active site, or, according to Neil Campbell, a teacher at the University of California, Riverside, in his book Biology in the section “Enzymes,” the “enzyme’s catalytic center” (93). The active site is where the substrate bonds to the enzyme and the reaction takes place. Each enzyme’s active site will only bind with one substrate. Over two

thousand different enzymes exist, and each one is coded for a singular substrate and thus a singular reaction.

Many of the two thousand enzymes have been isolated by scientists and are currently being used in the food industry in the production of meat, biscuits, cheeses, milk, alcoholic beverages, and fruit drinks. These different enzymes vary in everything from optimal pH level to which chemical bonds they break to start reactions, but they all affect the flavors and textures of their respective foods.

For example, the enzyme papain is used to tenderize meat, and subtilisin is used to extract protein. An inactive form of the enzyme papain is injected into an animal shortly before it is killed. On death, according to the professor of applied science at London South Bank University, Martin Chaplin, in his article “Applications of Proteases in the Food Industry,” “free thiols” build up in the animal and activate the papain, which then softens the meat. However, papain works at a wide range of temperatures and is therefore “difficult to control,” so many meat producers no longer use it. Subtilisin has only to be heated slightly to be ineffective, so workers add it to excess blood and then heat, centrifuge, and filter it into a mixture to extract protein. The result is used, as Chaplin explains, in “cured meats, sausages, and luncheon meats.”

Enzymes are used in more than just meats, however. Bakers use an enzyme naturally found in fungus to perform hydrolysis and break down the gluten in biscuit dough. After the gluten is broken down, biscuit dough can be spread. The protease enzymes rennet and lactase are used in the production of cheese and milk, respectively. Chaplin explains in his article “The Use of Lactase in the Dairy Industry,” based on an excerpt from his book, Enzyme Technology, that the enzyme rennet, found in the fourth stomach of young cows, performs hydrolysis in milk and causes curds to form and grow. Cheese makers then drain the curds, compress them, and

make cheese. Other enzymes are added to cheeses later in the maturing process, and they give cheddar cheese and Italian cheeses their flavors. The other dairy enzyme, lactase, is added to milk. The lactase performs hydrolysis and breaks up lactose sugar molecules, making the milk sweeter. Lactase is also used in other dairy products such as ice cream; it prevents ice cream from crystallizing when it freezes and consequently makes it creamier and smoother.

In addition to dairy and baking, protease enzymes are used in the brewing industry. For a liquid, such as grape juice, to ferment and form wine, two ingredients are needed: sugar and time. Time cannot be slowed down or sped up, but the amount of sugar in a liquid can be changed with the help of enzymes. Martin Chaplin explains in his article “Enzymes in the Fruit Juice, Wine, Brewing, and Distilling Industries” that “barley malt” is added to the beer before it is fermented. The enzymes in the malt convert present starches to sugar, a process known as “saccharization.” However, not all of the starch should be converted, or the final product will lack “body,” so the mixture is heated above fifty degrees Celsius, the enzymes denature, and the saccharization stops. Eventually, Chaplin says, scientists hope to engineer a brewing enzyme with “greater heat stability and [a] lower pH optimum.”

Scientists are currently looking for new ways to engineer and to use enzymes. To engineer an enzyme, according to the “Enzyme Engineering” page on the Molecular Plant Biotechnology website, is to improve “in the activity and usefulness of an existing enzyme or” to create “a new enzyme activity by making changes in its amino acid sequence.” Scientists achieve these objectives with two methods: they use recombinant DNA to move genes that code for a specific enzyme from a slow or dangerous organism to an organism that is either safer or has a faster production rate, or they change the amino acid sequence of the enzyme itself. Changing the sequence and producing the desired results are very difficult to achieve

simultaneously because only certain parts of the sequence affect the active site of the enzyme (remember, the active site is where the reaction takes place). Predicting which parts of the sequence affect the shape will become easier with new technology. Scientists are constantly working to find new ways to use enzymes in industry, but they are only partially successful because of the lack of proper technology and tools. Most engineered enzymes are either useless or unable to function.

For example, newly engineered enzymes are often not used because they have no “industrial relevance,” states Martin Chaplin in his article “Enzyme Engineering.” Projects are chosen based on simplicity and likelihood of success because scientists can not yet predict what changes will occur in the three-dimensional structure of an enzyme when a change in the amino acid sequence, or primary structure, is induced. Chaplin also says that enzyme engineering is a “hit or miss” process with a low probability of success. Another problem with enzymes is their cost; they are not cost-effective because of the prices involved in testing and the lack of demand in major markets.

But sometimes scientists get it right and create an enzyme that does exactly what they want it to do. For example, scientists isolated the penicillin-producing gene and successfully inserted it into a colony of *E. coli*, many of which began producing *E. coli* penicillin in “considerably higher quantities,” says Chaplin in “Enzyme Engineering.” These *E. coli* bacteria now produce much of the world’s supply of penicillin. The enzyme subtilisin, the very same used to extract protein in the meat industry, is also used in detergents. Scientists successfully engineered a version of this enzyme that is more stable at higher temperatures and pH levels.

Enzymes are useful because of their unique control of chemical reactions, are currently a vital part of the food industry, and are being investigated for further uses. One possible future

use of enzymes lies in a treatment for one of the most pervasive and incurable diseases of this day and age: HIV. According to Minkel, a writer for Scientific American, in his 2007 article “Designer Enzyme Cuts HIV Out of Infected Cells,” scientists have just recently developed a “custom enzyme” that “snipped HIV DNA out of chromosomes.” The enzyme, Cre recombinase, “exchanges any two pieces of DNA” as long as their ends are coded with the correct nucleotide sequence. If this technology were perfected, curing Human Immunodeficiency Virus (HIV) would be as easy as coding the enzyme to cut out HIV and replace that part of the DNA with something harmless. With this knowledge, one would expect the market for enzymes to increase dramatically and the related technology to advance exponentially. But enzyme engineering may be too expensive to fund on a large scale. The processes in place in the food industry are efficient as is, and a complete switchover to new technology would be extremely costly. As Feliza Mirasol, a chemical market reporter, explains in her article, “Enzymes Poised for Comeback in Several Industrial Markets,” “even if you have better technology, it doesn’t mean that someone is willing to change the process.” One hopes that, as technology improves, enzyme engineering will become cost effective, and cures for diseases such as HIV will become a reality. Humanity will at last have mastered the small scale.

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