WHAT ARE ENZYMES?
Enzymes are proteins that act as biochemical catalysts to control the rate of nearly all chemical reactions in living cells. Every living organism on earth produces enzymes to break down food sources and metabolic wastes as well as build structural and functional compounds necessary for growth. The human body produces thousands of different enzymes to build, repair and maintain itself. Thousands of enzymes direct the processes in the billions of cells that make up your body. Enzymes make it possible for you to see, read and understand this paper.

Each enzyme will only catalyze a certain type of reaction. For example, proteases will only catalyze the breakdown of proteins and will not react with carbohydrates or fats. The ability of an enzyme to interact with its substrate is attributed to the conformational structure of the enzyme’s active site. Simply stated, the active site of a protease will “fit” with the shape of proteins, but does not “fit” with a carbohydrate or fat. Additionally, optimal enzyme structure and function can also be impacted by temperature, pH and other environmental factors in the cell.

WHAT ARE DIGESTIVE ENZYMES?
This group of enzymes breaks down the foods we eat into their simplest components so they can be absorbed and utilized by the body. The human body is known to produce at least 22 different digestive enzymes. Salivary amylase begins the digestion of carbohydrates as soon as we start chewing. Other enzymes secreted by the pancreas and intestinal brush border membrane help to complete the digestion process. Lipases secreted in the mouth and stomach start the digestion of fats and oils. Fat digestion is finished in the small intestine by additional lipases and esterases. Protein digestion begins in the stomach with the action of pepsin and is completed in the small intestine by pancreatic proteases and brush border aminopeptidases. Figure One illustrates of where digestion occurs for each of the major types of food macromolecules.

Figure One-Enzymes in Digestion
WHY SUPPLEMENT WITH DIGESTIVE ENZYMES?
A common objection to enzyme supplementation is the belief that the human body is capable of producing all the digestive enzymes it needs. This may not be the case for everyone, however. Unfortunately, digestive enzyme shortages can and do occur in the human body. Lactase deficiency is the best known example, occurring in as much as 70 percent of the world’s adult population. Aging also impacts the body’s ability to produce digestive enzymes, some estimating as high as a 50 percent loss of digestive activity.

Research has also begun to identify the role that the intestinal microflora can play in digestion. These microorganisms can supply additional or unique digestive enzymes, providing you have the appropriate intestinal denizens. As an example, most individuals in the Orient have gut flora that produce the enzyme beta-glucosidase. This enzyme removes the sugar unit off soy isoflavones and allows their absorption. In contrast, most other human beings lack these intestinal bacteria and the activity of beta-glucosidase, causing poor absorption of soy isoflavones. Supplemental forms of beta-glucosidase, along with soy foods, may support improved absorption by cleaving the sugar unit off soy isoflavones. Other enzymes, including lactase and alpha-galactosidase, are also produced by different microorganisms, providing a natural digestive enzyme supplement.

According to Anthony Collier, president and CEO of National Enzyme Company (NEC), “Dr. Edward Howell [leading pioneer in enzyme research and founder of NEC] believed that forcing the body to build all of its own enzymes rather than utilizing naturally occurring food enzymes robs the body of energy and resources it could put to use for other metabolic functions. Supplemental digestive enzymes support digestion, nutrient absorption and can help reduce ocassional digestive discomfort caused by incomplete digestion.

DO DIGESTIVE ENZYME SUPPLEMENTS REQUIRE A PROTECTIVE COATING OR CAPSULE?
The majority of supplemental enzymes on the retail shelves do not have protective coatings, but this does not mean they are ineffective. The requirement for a protective or enteric coating is based upon the pH stability of a given enzyme. Generally, animal-based pancreatic enzymes have a narrow pH stability range and cannot survive the acidity of the stomach. Pancreatic enzymes must be enteric-coated to be most effective.

In contrast, many plant and microbial enzymes have a broad pH stability range and do not require a protective coating. In fact, a protective coating may actually decrease the efficacy of the upper stomach “pre-digestion” of these enzymes. Dr. Howell explained that natural food enzymes and supplemental enzymes begin digestion as soon as they are mixed with food. This pre-digestive process continues in the upper stomach for a half hour to one hour, or until the rising acidity inactivates the enzymes. Interestingly, in vitro studies indicate that many of these enzymes are not permanently denatured. These proteins are able to regain their functional conformation and contribute digestive activity in the small intestine.

WHAT ARE THE DIFFERENT TYPES OF DIGESTIVE ENZYMES?
Enzymes used in digestive supplements fall into three broad categories: proteases, lipases and carbohydrases. Proteases break down proteins from meats, cheese, legumes, nuts and other dietary sources. Lipases digest dietary fats, including butter and oils. Carbohydrases break down starches, sugars and other carbohydrates common in breads, cereals, fruits and vegetables.

PROTEASES
Proteins are complex molecules made up of long chains of 22 different amino acids. Protein digestion requires many different proteases with different bond specificities. Common digestive proteases found in dietary supplements include fungal protease, peptidase, neutral bacterial protease, bromelain, papain, trypsin
and chymotrypsin. Figure Two illustrates a simplified peptide chain and the interaction of various supplemental enzymes to break down the molecule. Some proteases break internal bonds and are called endopeptidases. Trypsin, chymotrypsin, bromelain and papain are examples of endopeptidases. Other proteases cleave single amino peptidases from the ends of a peptide chain. These enzymes are called exopeptidases and include both the aminopeptidases and the carboxypeptidases. Fungal proteases often include both endopeptidase and exopeptidase activity. The action of endopeptidases creates smaller peptides with more ends from which the exopeptidases can release additional free amino acids. Since each type of protease acts most effectively on the bonds associated with certain amino acids or groups of amino acids, combining different proteases from different source organisms or even different fermentation processes provides a broader range of digestive capability. These proteases work synergistically with endogenous enzymes to help digest the dietary proteins.

**LIPASES**

These enzymes catalyze the hydrolysis of triglycerides of simple fatty acid esters, yielding mono- and diglycerides, glycerol and free fatty acids. Lipases typically have broad substrate specificity on fats and oils of vegetable and animal origins. Lipases from different source organisms may have different specificities; therefore, combining different lipases from different source organisms may provide a broader range of digestive capability. Lipases work synergistically with endogenous enzymes to help digest fatty foods. Common digestive lipases are typically of either fungal or pancreatic origin.

**CARBOHYDRASES**

Carbohydrase is the generic term for any enzyme that breaks down carbohydrates. This group includes the starch-breaking enzymes, sugar-breaking and fiber-breaking enzymes. These enzymes play an important role in energy metabolism, as glucose is the primary energy source for the human body. Starch-breaking enzymes include amylase, glucoamylase and diastase. Sugar-breaking enzymes include lactase, invertase and alpha-galactosidase. Fiber-breaking enzymes include cellulase, hemicellulase, beta-glucanase, pectinase, phytase and xylanase. Fermented by intestinal microorganisms, undigested carbohydrates may pass to the intestine and cause occasional abdominal discomfort, including bloating, gas and flatus.

**STARCH-BREAKING ENZYMES**

Like protein digestion, starch digestion can be optimized by combining multiple enzymes, especially amylase and glucoamylase. Starch is made up of two different polysaccharides. Amylose consists of straight chains of glucose connected by alpha-1,4-glucosidic bonds. Amylopectin is a branched polysaccharide of alpha-1,4-glucosidic bonds with alpha-1,6-glucosidic bonds with alpha-1,6-glucosidic bonds.
creating the branching points. Figure Three illustrates the digestion of starch by amylase and glucoamylase. Amylase randomly breaks the interior alpha-1,4 bonds (black bars) that combine glucose in straight chains in amylose and amylopectin. However, alpha-1,6 bonds (blue arrows) create branches that block amylase action and produce limit dextrins (blue circle). Glucoamylase cleaves terminal alpha-1,4 bonds as well as the alpha-1,6 bonds at these branching points, which allows amylase to again begin cleaving the alpha-1,4 bonds that were previously inaccessible.

**SUGAR-BREAKING ENZYMES**

Lactase breaks down lactose, the sugar found in milk and dairy products. As we age, our lactase secretion decreases, causing occasional discomfort for many people who consume dairy products. Some ethnic groups are more likely to have low lactase levels. Worldwide estimates indicate that as much as 70 percent of the adult population suffers from lactase deficiency. Supplemental lactase works alongside any lactase the body produces to provide the benefits of dairy consumption without the occasional gastric distress often associated with lactose intolerance. Research indicates that many individuals who believe themselves to be lactose intolerant avoid consuming dairy products, which may result in a lower intake of calcium and possible nutritional and physiological consequences.

Alpha-galactosidase breaks down the indigestible sugars, often referred to as the raffinose-series sugars, found in legumes, cruciferous vegetables and other vegetables. When human beings consume these vegetables, the indigestible sugars pass into the intestines, where they are fermented by bacteria, causing occasional gas, bloating, discomfort and pain. Supplemental alpha-galactosidase digests these sugars before they reach the intestine and eliminates their availability for fermentation and gas production.

**FIBER-BREAKING ENZYMES**

This group of enzymes is capable of hydrolyzing the non-digestible carbohydrates that comprise fiber prevalent in many fruits, vegetables, grains and herbs. While fibers are an important part of a healthy diet, they can also act as anti-nutritive factors. Fibers may bind to minerals and other nutrients, blocking their bioavailability and preventing their absorption. Fiber-breaking enzymes function to break up these fibers to improve nutrient bioavailability as well and decrease the bloating effect of fibrous foods.

Naturally occurring compounds in foods often include combinations of major nutrients, such as glycoproteins, glycolipids and lipoproteins. Glycoproteins are proteins that contain oligosaccharides as part of their structure. These sugar units can inhibit digestion by the endogenous proteases of the human digestive tract. Carbohydrases must first break down the sugar component of the compound to allow proteases access to the peptide, so they work together with proteases to break down the ingested glycoprotein. Likewise, carbohydrate and lipases work together to break down glycolipids, and lipases and proteases collaborate to digest dietary lipoproteins. Another example of digestive synergism occurs with the non-digestible cell walls of plant-based foods, which may limit digestion. Fiber-breaking enzymes can help open the cell and allow the other enzymes access to the proteins, carbohydrates and fats within the cell. Like fiber, proteins known as lectins can also limit digestion as they bind carbohydrates. Supplemental enzymes also work synergistically with the digestive enzymes produced by the human body. A full spectrum blend that includes all the types of enzymes listed in this article supports a more complete digestion of food.