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April 24, 1997

Research on the Liver and Small Intestine

What role in digestion do the liver and small intestine play?

The liver secretes bile salts in bile which emulsifies fat into smaller droplets so pancreatic enzymes may break it down into usable fatty acids. This is the only role in digestion played by the liver. The role of the small intestine in digestion is primarily the absorption of broken-down nutrients.

How does the small intestine perform digestion?

Digestion in the small intestine depends on the secretions of the **liver**, pancreas, and intestinal glands, which provide liquid for dilution and solution of the food, a reducer of surface tension for the emulsification of fat, and enzymes for the breakdown of food into smaller molecules. Digestion also depends on a great deal of metabolic activity within the columnar cells lining the small intestine and on the movement of the intestine which mixes the food with the secretions and propels it in a caudal direction toward available absorptive surfaces.

The mixture delivered to the duodenum is strongly acid with a pH of 1.5-2. One of the first functions of the duodenum is to bring the contents to, or close to, neutrality in order to facilitate the activity of pancreatic hormones.

The Optimum Conditions of All Pancreatic Enzymes: to, or close to, neutrality (**pH 7**), and body temperature (**37 degrees Celsius**). Steapsin, however, has a maximum activity at **pH 8**.

Alkaline duodenal secretions, **bile**, and pancreatic juice accomplish neutralization quickly. Excessive concentrations of sugars in the duodenum delay gastric emptying in order to protect the absorptive function of the upper jejunum. The duodenum is the equilibrator of the alimentary canal; its main function is to deliver the food chyme to the intestine in an isotonic form. Once neutrality and osmotic equilibrium have been established, digestion proceeds rapidly.

What is used to digest nutrients in the small intestine?

Pure pancreatic juice is a colorless secretion, rather viscous, with a pH of 8.4-8.9. The inorganic constituents include Na, K, and bicarbonate ions. The bicarbonate renders the juice alkaline. The organic constituents consist of proteins which contain the enzymes of the juice. The three main enzyme systems in pancreatic secretions are proteolytic, amylolytic, and lipolytic.

Three major enzyme groups:

- Trypsin: digests protein
- Amylopsin: digests carbohydrates
- Steapsin: digests fat

Trypsin is the main proteolytic enzyme formed by the pancreas. It is secreted in an inactive form to avoid self-digestion of the pancreas. Trypsinogen does not become active until it enters the duodenum; the secretions of the intestinal glands always contain the enzyme enterokinase, which splits a polypeptide from the trypsinogen at pH 5.0 to form active trypsin. Trypsin can also activate trypsinogen. Trypsin acts on proteins, some of which have been denatured by the gastric acid of the stomach to form proteoses, peptones, polypeptides, and amino acids. Trypsin is not a single enzyme but a group of enzymes called the peptidases, each member of which attacks the peptide molecule in a specific manner (carboxy-, amino-, and dipeptidases).

Chymotrypsin is another proteolytic enzyme that is secreted in an inactive form in the pancreatic juice. It is activated by trypsin to form chymotrypsin. This enzyme clots milk and hydrolyzes casein and gelatin.

Carbohydrates are acted upon by pancreatic amylase, or amylopsin, which acts like salivary amylase to hydrolyze starch first to dextrin and then to maltose. Amylopsin has maximal activity at pH 7.0. A maltase capable of splitting maltose into glucose has been identified in pure pancreatic juice.

Fats are subjected to the action of pancreatic lipase, or steapsin, which hydrolyzes neutral fat into glycerol and fatty acids; its maximal activity is at pH 8.0. The digestion of fat is enhanced considerably by the concomitant action of bile salts on the duodenal contents. Bile salts lower the surface tension between water and neutral fat so that the fat becomes emulsified into minute globules. Thus, the surface area of fat available for enzymatic activity is increased greatly, and the rate of hydrolysis is accelerated. The fat-splitting power of pancreatic juice is trebled by the presence of bile salts. Fat also aids its own digestion. Liberated fatty acids unite with alkali in the bowel to form sodium salts or soaps that have the same emulsifying action as the bile salts.

Bile is an orange alkaline fluid secreted by the **liver**. The principal components of bile are bile salts, bile pigments, cholesterol, and inorganic salts. The bile salts and cholesterol have a digestive function, while the other components are waste products. The bile salts are the sodium salts of glycoholic and tauroholic acid. They promote the emulsification of fat in the intestine and also keep cholesterol and lecithin in solution. Of the bile salts, 90% are reabsorbed in the small intestine and remetabolized by the body.

Cholesterol is an unsaturated secondary alcohol closely related to many hormones. In the small intestine, it aids in the emulsification and absorption of lipids. Apart from its role in the digestion of fat, whole bile in the intestine facilitates the absorption of the fat-soluble vitamins D, K, and E, and has the property of increasing intestinal motility.

How does the small intestine absorb nutrients?

Chyme passing from the duodenum reaches the jejunum, about 0.91 meters long. Here, the digested breakdown products of carbohydrates, proteins, fats, and most vitamins, minerals, and iron are absorbed. Within the ileum, a smaller, thinner-walled section than the jejunum, vitamin B_{12} is preferably absorbed.

The mucosa of the small intestine is composed of up to five million tiny fingerlike projections called villi, which increase the rate of absorption by extending the surface of the small intestine to about five times that of the skin surface area. This vast surface is made of a relatively impermeable membrane with numerous highly specific transport mechanisms for biologically required substances. The columnar cells have primarily an absorptive function. Histochemical studies indicate that hydrolytic enzymes are situated within the cells at the bases of the microvilli and that much digestive activity actually occurs inside the intestinal cells. The surface of the cell facing the lumen is arranged as a trellis of the cell with numerous minute pores which allow water and particles with a molecular size of less than 10 nanometers to pass freely. The cell membrane is lipoid in nature and permits the passage of fat-soluble materials.

Two main processes transfer nutrients through the complex columnar cells of the intestine:
passive diffusion and **active transport**.

Passive diffusion: requires no energy. Diffusion rate of nonelectrolytes depends on concentration across the membrane. Many substances, such as drugs and fat-soluble vitamins, are absorbed passively, and the rate of absorption depends upon their lipoid solubility. Water-soluble substances of high molecular weight cannot pass across the intestinal membrane.

Active transport: most nutrients are removed from the intestine by active-transport mechanisms. Can be inhibited by some cell poisons, anoxia, or low temperatures. Some substances share common transport systems so that the absorption of one is reduced when others enter into competition for a single available mechanism.

Because of the length of the small intestine, being a long, narrow tube six meters long, a large area is available for absorption to take place.

Protein Absorption

The average daily intake of protein is about 1.6 oz (45 g), broken down and absorbed completely. Gastrointestinal secretions and desquamated intestinal cells are important sources of intestinal protein and can exceed the daily oral intake in amount. The observation that isomers of amino acids were absorbed preferentially indicated the presence of active transport mechanisms. Neutral amino acids such as leucine and methionine share a common mechanism. Separate systems have been identified for basic amino acids. Part of the hydrolysis of peptides takes place within the brush border of the columnar cell, and digestion of polypeptides to amino acids is an intracellular activity. Products of the digestion of protein are absorbed in the first part of the jejunum under normal conditions. Some amino acids, such as L-tryptophane, can be absorbed by passive diffusion.

Carbohydrate Absorption

The initial splitting of carbohydrates into disaccharides occurs in the upper intestinal tract. More amylase is added to the duodenal contents by the pancreas. The disaccharides maltose, lactose, and sucrose are the products of carbohydrate digestion which enter the small intestine. Further digestion occurs in the columnar cells of the intestine; maltose is broken down to glucose, sucrose becomes glucose and fructose, and lactose is split into glucose and galactose. Active transport mechanisms exist for the transfer of simple sugars. Any disaccharide activity detected in intestinal secretions comes from enzymes within desquamated endothelial cells.

Fat Absorption

The absorption of dietary fat is almost complete; very small amounts go to waste. Quantitatively, triglyceride is the most common fat in the diet. Animal fat contains stearic, palmitic, and oleic acids. Fat is absorbed mainly in the terminal part of the duodenum and upper jejunum, but the reserve capacity of the intestine to absorb fat is considerable. Pancreatic lipase hydrolyzes fat in the intestine first to diglycerides and then to glycerol and free fatty acids. This last step is an irreversible one.

Fat digestion is limited if bile is blocked from the intestine. Bile is required to bring monoglycerides and fatty acids into a special type of solution--a micellar solution. The molecules of bile salts and cholesterol form aggregates of micelles, and substances which are insoluble in water can be brought into solution by combination with micelles. Fatty acids and monoglycerides are brought into solution in micelles, and this is the final common pathway for the absorption of dietary fat and other water-insoluble molecules. Glycerol and short-chain fatty acids are water soluble and are absorbed in the same way as simple sugars and amino acids.

The mechanism whereby long-chain glycerides enter the body is of interest. The mucosal cell can resynthesize triglyceride from absorbed fatty acids with the help of coenzyme A and ATP. Electromicrographs of intestinal cells during absorption of fat suggest that particulate absorption can occur by endocytosis, but the quantitative importance of this infolding of micelles of glycerides and fatty acids into the intestinal cells is difficult to measure.

Absorption of Fluids and Electrolytes

The gastrointestinal membrane plays little part in the normal control of the body's composition of fluid and electrolytes, even though the daily transfer across the intestinal membrane is very great. Gastric secretion, bile, pancreatic juice, and intestinal secretions provide 2.1 gallons (8 liters) of fluid for the small intestine to deal with daily, yet only 6.1 cubic inches (100 ml) of fluid is actually excreted in the feces each day. Electrolytes pass both ways across the intestinal membrane in health, and the rate of transfer can be demonstrated easily by isotopes.

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Report on the Liver and the Small Intestine

Overall, there are four questions that must be answered in this lab. First, what role in digestion does the liver and small intestine play? Second, how does it perform this function? How does it do it? Thirdly, what is used? And finally, what are the optimum conditions?

These questions were answered through research on the digestive enzymes that cause food to break down further once it passes through the duodenum of the small intestine. The small intestine's role is mainly the absorption into the body of the various nutrients formed from food. No other organ has the absorptive quality of the small intestine. The liver's only role in digestion is to secrete bile salts in bile, which help to emulsify the fats in food. Enzymes found in pancreatic secretion are the main catalysts of food breakdown in the small intestine; the three main enzymes are trypsin, amylopsin, and steapsin, all functioning best near a neutral pH of 7 and at normal body temperature, 37 degrees Celsius.

The purpose of this lab is to support the research--exactly what kind of food does the enzyme trypsin break down? Protein, carbohydrate? Fat? Research has found, as the hypothesis of this experiment, that trypsin will break down protein into amino acids. The enzyme amylopsin will break down carbohydrates into monosaccharides, and steapsin will break down fat into fatty acids with the help of the bile salts, which emulsify fat into smaller droplets to promote quicker enzyme activity. Once all of the nutrients have been broken down, they should be able to be absorbed through the intestinal lining into the surrounding body tissues.

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Conclusion

The four main questions--the role indigestion, how the role is performed, what is used to perform it, and what the optimum conditions are to perform it--were answered clearly in the data table. Organizing all the results of each experiment, it was found that pancreatic enzymes are the main catalysts of food breakdown in the small intestine. Trypsin acts on protein to produce amino acids, amylopsin acts on carbohydrates to form monosaccharides, and steapsin acts on fat to produce fatty acids. All enzymes function best at or near a neutral pH of 7 and at normal body temperature. The bile salts, though they are not true enzymes, do promote fat disintegration into smaller droplets. And, once all nutrients have been broken down into a biologically acceptable form, they can be absorbed through the intestinal lining.

However, the most interesting conclusion drawn from this lab, and probably the most important, is that no digestion can occur without the help of enzymes. A reaction that takes three hours to complete could never happen without the help of enzymes. In neither of the control groups did broken-down nutrients appear in solution. Therefore, in order for the body to gain the nutrients it needs to live, it must rely on the work of the liver and small intestine.