

the products of protein digestion stimulate the antrum to release additional quantities of gastrin. Gastrin then stimulates parietal cells to secrete large amounts of hydrochloric acid. As the contents of the stomach become more and more acid, the acid chyme comes in contact with the antral mucosa. This then inhibits the release of gastrin from the antrum. Thus, there is a "feedback" mechanism related to the degree of acidity of the gastric contents. When the contents of the gastric antrum are less acid the mucosa releases gastrin. When the contents of the gastric antrum are more acid the release of gastrin is inhibited.

Another humoral substance that regulates gastric secretion is enterogastrone, a gastrointestinal hormone released from the duodenum in response to stimulation by various types of food coming in contact with the duodenal mucosa. Fat is the most potent stimulus for the release of the hormone. Enterogastrone inhibits both gastric secretion and gastric motility. Thus, as food enters the duodenum from the stomach, enterogastrone acts as a brake on both gastric emptying and gastric secretion. Two additional hormones, glucagon from the pancreas and secretin from the duodenal mucosa, exert some inhibitory effects on gastric secretion.

Gastric digestion. Digestion is not carried to completion in the stomach. Experimental evidence in man shows that approximately 30 to 50 percent of ingested starches and approximately 10 to 15 percent of ingested protein may be digested in the stomach. Little, if any, of ingested fat is digested there. Thus, the stomach is not primarily a digestive organ and is not essential to life. Its main function is to convert the ingested meal into chyme by mixing it with gastric juice in preparation for delivery into the small intestine, where most of the digestive processes occur.

Digestion of carbohydrates. When a meal has been thoroughly chewed and adequately mixed with saliva, the amylase in the saliva will continue its digestive action on starches in the stomach as long as the acidity of the gastric contents is not too high. Each digestive enzyme has an optimum hydrogen ion concentration, or pH, at which it can function most effectively. The optimum pH of amylase is approximately 6.8, slightly on the acid side of neutral (7.0). Thus, as the gastric contents are mixed with gastric juice and hydrochloric acid, the pH of gastric contents decreases (*i.e.*, becomes more acid) and the amylase activity diminishes accordingly.

Digestion of proteins. The proteolytic enzyme secreted in the gastric juice is pepsin. Pepsin has an optimum pH of approximately 2.0 and splits proteins mainly into the less complex proteose and peptone fragments of the protein molecules. Few amino acids or polypeptides are released from protein by the action of pepsin. Thus, protein digestion in the stomach is only partial—about 10 to 15 percent, as mentioned previously. Gastric secretion in response to a meal will have the highest concentration of pepsin within the first hour. As the volume of gastric juice increases, the concentration of pepsin falls. During the later stages of gastric digestion, when the volume of gastric juice diminishes, the concentration of pepsin increases.

Pepsin is not the only proteolytic enzyme in gastric juice. Others include cathepsin and gastricin. These proteolytic enzymes have an optimum pH of 4.0 and 3.0, respectively. Their activity is of relatively minor importance.

Digestion of fats. Little if any digestion of fats normally occurs in the human stomach. There is some evidence, however, for a gastric lipase, a tributerase with an optimum pH between 4.0 and 5.0 and inactive at pH below 2.5. The origin of this lipase is unknown and it acts only on short-chain fats; *i.e.*, those with less than five carbon atoms. Much of the fat in the human diet contains 18 carbons in the fatty acid chains; tributerase has little if any activity on these fats and is of negligible significance.

Gastric absorption. Although the stomach absorbs few products of digestion, it is capable of absorbing a great many other substances.

Foodstuffs. Components of the diet that can be absorbed through the gastric mucosa include glucose and other simple sugars, amino acids, and some fat-soluble substances.

Water. Water moves freely from the gastric contents across the gastric mucosa into the blood. The net absorption of water from the stomach, however, is small, because water moves just as easily from the blood across the gastric mucosa to the lumen of the stomach. To demonstrate absorption of water from the stomach, isotopic, or "heavy," water is introduced into the stomach by a tube, and the presence of the isotope in the blood is then determined. In man about 60 percent of heavy water placed in the stomach is absorbed into the blood in 30 minutes. In normal young adults the mean rate of water absorption from the stomach is about 2 percent of the gastric contents per hour.

Alcohol and drugs. A number of alcohols, including ethyl alcohol, are readily absorbed from the stomach. The membranes of the cells that line the stomach are composed of lipids or fat substances, thus items in the diet that are fat soluble penetrate the membranes of the cells lining the stomach. Since ethyl alcohol and a number of other drugs are somewhat soluble in fat, they are absorbed directly from the stomach. The pH of the gastric contents also determines whether or not some substances will be absorbed. At a very low pH, for example, aspirin is absorbed almost as rapidly as water from the stomach, but as the pH of the stomach rises it is absorbed much more slowly.

Gastric emptying. Gastric emptying time is determined by the rate of the antral pumping contractions (three per minute) and the volume of material emptied into the duodenum by each antral contraction. The stroke volume of each antral contraction varies, depending upon the nature of the contents being pumped. Usually, however, this amounts to volumes of three to five millilitres for each antral contraction.

An ordinary meal is usually completely emptied from the stomach in two to three hours. Both the physical and chemical composition of the meal influence the emptying rate. Fluids are emptied more rapidly than solids, carbohydrates more rapidly than proteins, and proteins more rapidly than fats. Liquid meals that are isotonic to blood, that is, having the same osmotic pressure as blood, are emptied more rapidly than hypotonic or hypertonic liquids. Different substances are emptied from the stomach at differing rates because of the various neural and humoral factors that regulate gastric emptying.

When food is received into the stomach from the esophagus, it tends to form concentric layers. The contents at the periphery of the ingested meal are in contact with the gastric mucosa where they are mixed with the gastric secretions and subjected to the contracting waves of the wall of the stomach. As the peristaltic waves pass over the intragastric contents they tend to push the liquefied peripheral portion of the gastric contents into the antrum. When the antrum becomes compartmentalized from the body of the stomach, its liquid contents are pumped into the duodenum. The process is repetitive and constant until the stomach is emptied.

DIGESTION IN THE SMALL INTESTINE

The small intestine is the principal digestive organ of the human alimentary canal. Three principal activities within the small intestine are especially adapted for its role in digestion: (1) its motor activity allows both mixing and transport of intraluminal contents; (2) secretions into the small intestine provide the necessary enzymes and other constituents essential for normal digestion; (3) it has highly selective absorptive capabilities. These absorptive functions of the small intestine are made possible by the specialized structures of the intestinal mucosa that line the small bowel.

The morphology of the small intestine is arranged so that the inner mucosal surface, in contact with the intraluminal contents, greatly exceeds the external surface area. Some of the increased internal surface area is due to special folds in the intestinal mucosa known as plicae

Emptying
time

Morphol-
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small
intestine