PHYSIOLOGY OF THE STOMACH

The stomach is a large muscular sac connected at its opening to the esophagus and at its end to the duodenum of the small intestine. Two sphincters, the cardiac and the pyloric, act as unidirectional flow valves permitting food to move into and out of the stomach. The stomach functions as a reservoir, receiving the ingested food in one portion. It disinfects the food, mixes the bolus with the gastric juice, and partially digests the ingested proteins. Finally, the stomach delivers a well-mixed, soupy chyme to the small intestine, in regular intervals, for further processing.

STOMACH SECRETIONS. Numerous exocrine gastric glands (pits) secrete mucus, acid, and enzymes into the stomach lumen. Each gland contains three types of cells, which together produce the bulk of gastric juice. The cells near the gland's neck (mucous cells) secrete the gastric mucus. (Mucus is also secreted by the cells lining the stomach's inner surface.) In the gland's deeper zone, there are two other cell types: the chief cells secrete the proenzyme pepsinogen, which is later converted to the gastric enzyme pepsin in the stomach's lumen; the parietal cells (also called the oxyntic cells) secrete a concentrated solution of hydrochloric acid (H+Cl⁻). Other, rarer cell types (endocrine or paracrine) present in the glands secrete hormones into the blood capillaries or tissue spaces.

ACTIONS OF STOMACH SECRETIONS. Stomach acid has several functions. The acidic gastric juice acts as a superior solvent, dissolving foodstuffs not soluble in water. Acid is necessary to activate the gastric enzyme pepsin (see below). Acid is a strong disinfectant, killing bacteria and other microorganisms in the ingested food. Finally, acid has a regulatory function: it stimulates the duodenum to secrete hormones to release bile and pancreatic juices (plate 70).

Pepsin is the only digestive enzyme of any significance produced in the stomach. It cleaves food proteins, forming small peptides. This action is probably not crucial for protein digestion because one of the proteases of the pancreatic juice (chymotrypsin) performs a similar function later in the small intestine. Pepsin may serve a regulatory function: the small peptides produced stimulate the sensory receptors in the gastric mucosa to initiate hormonal and nervous signals aimed to increase stomach motility and secretion (see plates 70, 71). When secreted by the chief (zymogen) cells, pepsin is in its inactive form, a larger protein called pepsinogen. Acid in the lumen promotes conversion of pepsinogen to pepsin. Pepsin, once formed, also attacks pepsinogen, producing more pepsin molecules (autocatalysis).

The stomach mucus, in addition to providing similar functions as the salivary mucus, forms a thick protective coat covering the inner linings of the stomach in order to protect it from mechanical damage and, perhaps, from the corrosive actions of the acid in the gastric juice. The breakdown of this coat is one of the causes of ulcers.

CELL PHYSIOLOGY OF ACID SECRETION. Stomach glands secrete a concentrated solution of hydrochloric acid that may reach a pH value near 1. If placed on the skin, this acid would cause serious burns and tissue damage. Gastric wall cells' impermeability to acid, as well as the protective action of the alkaline stomach mucus, prevents this damage from occurring in healthy individuals. Parietal cells secrete acid by directly pumping hydrogen ions from inside the cell out into the gland lumen, using an active transport mechanism. The pump obtains hydrogen ions from the dissociation of intracellular water (H₂O → H+ + OH⁻). The hydrogen ions are pumped out in exchange for K⁺ ions, which are pumped in. Parietal cells contain many mitochondria, which utilize oxygen heavily and produce much ATP. The pumping mechanism, which consists of enzymes associated with intracellular canaliculi membranes, use the ATP. The parietal cell canaliculi are modified endoplasmic reticulum. Upon hormonal or nervous stimulation, the active transport mechanism is activated, resulting in hydrogen ions being secreted into the canaliculi, which converge and open into the gland lumen. Parietal cells also contain large amounts of carbonic anhydrase, an enzyme that promotes carbon dioxide hydration: (C₀₂ + H₂O →[H₂C₀₃] → H⁺ + HC₀₃⁻). The hydrogen ions produced in this reaction will combine with the hydroxyl ions left from water dissociation to form a new water molecule, replacing the one utilized by the pump. The parietal cell at the serosal (blood side) border then exchanges bicarbonate (HC₀₃⁻) ions produced in the above reaction with chloride ions; the chloride ions move in, and bicarbonate ions move out of the cell. The chloride-bicarbonate exchange is also an active transport mechanism, involving pumping and ATP utilization. The chloride ions are then transported across the cell and out into the stomach gland's lumen, where they combine with the hydrogen ions to form hydrochloric acid.

GASTRIC MOTILITY. Shortly after food enters the stomach, when sufficient gastric juice has been produced, special weak contractions (mixing waves) begin in stomach fundus and spread to pylorus. These waves (occurring every 20 sec.) help mix the food with the gastric juice. Later on, less frequent but much stronger peristaltic waves occur and force the chyme against the closed pyloric sphincter, resulting in chyme back flow. This movement vigorously mixes food with gastric juice, forming a soupy solution (chyme), which can now be processed by the intestinal enzymes. Gradually, the pyloric sphincter opens a little, allowing, with each peristaltic wave, delivery of some chyme into the duodenum. The rate of this process depends on the food content: carbohydrates empty rapidly; fats slowly; protein-rich foods, at an intermediate rate. This differential rate is regulated by hormones and nerves (see plates 70 and 71).