The Digestive System

Unlike plants, animals cannot synthesize the majority of their own organic building blocks, such as fatty acids, sugars, and most amino acids. Instead, animals must ingest other organisms and digest them into the essential molecules that they need. Animals get their energy from sugars, fats, and proteins, and they use them to construct more complex molecules such as enzymes. The digestive system has evolved to process the food that animals ingest by breaking it down, or digesting it, into simple building blocks that can be used by cells.

Digestion consists of two main processes: mechanical digestion and chemical digestion. Mechanical digestion refers to the physical breaking down of food into smaller particles without changing the food’s chemical nature. Chewing food is an example of mechanical digestion, as is the churning of food that takes place in the stomach. Chemical digestion, which occurs through the action of special digestive enzymes, breaks the chemical bonds in food and hydrolyzes larger molecules into simpler components.

**Simple Digestive Systems**

In the simplest of animals and in animal-like protists, much of the digestion process takes place within each individual cell. An amoeba engulfs its food by phagocytosis, and a lysosome fuses with the food vacuole and chemically digests its contents. Paramecia have a ciliated oral groove that facilitates the creation of the food vacuole. Cnidarians digest some of their food extracellularly by releasing enzymes into their water-filled gastrovascular cavity, but a large portion of their food is digested intracellularly as well. Flatworms, such as planarians, take food in through their mouth and into the gastrovascular cavity. The food is digested intracellularly by the cells that line the cavity and is absorbed into the tissues. Waste products are expelled back out of the mouth, which also serves as an anus in this case.

Most higher animals, such as annelids, arthropods, and vertebrates, possess a complete digestive tract, with a mouth that is separate from the anus. Food is moved in one direction through a tubular system that contains many specialized parts that perform different functions. In the earthworm, for example, food passes through the mouth, down a tube called the esophagus, and into a chamber known as the crop, which acts as a storage chamber. Next it enters the gizzard, which has thick, muscular walls that mechanically grind the food.

The pulverized food passes into the intestine, where enzymes chemically break it down into simpler molecules. These molecules are absorbed into the circulatory system. In the last portion of the intestine, some water is absorbed from the food, and the indigestible portions of the food are expelled through the anus.

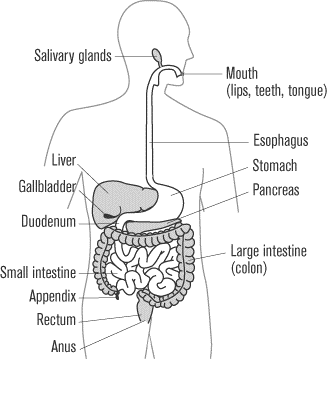
**The Human Digestive System**

The human digestive system is somewhat similar to the earthworm’s in basic design, though it is more complicated and efficient. The human digestive system is composed of the **alimentary canal**, which is the actual tube through which the food travels, and the glands that aid in digestion by releasing enzymes and other secretions into the alimentary canal.

**The Mouth**

The alimentary canal begins with the mouth, where teeth and the tongue pulverize food through mechanical digestion into what is called a bolus. The tongue also tastes the food, which helps to determine if it is fit to be ingested. Six **salivary glands** release saliva into the mouth cavity through ducts that open under the tongue and on the roof of the mouth. Saliva is composed mainly of water, but it includes mucus and an enzyme called salivary amylase. The water and mucus in the saliva help to dissolve and lubricate the food in preparation for swallowing. Salivary amylase starts the process of chemical digestion of starches by breaking down complex polysaccharides into the disaccharide maltose. When the food is sufficiently chewed, it is swallowed. The food moves through the pharynx, or throat, to the esophagus.

**The Esophagus**

The esophagus is a long tube that connects the mouth and the stomach. Food in the esophagus is propelled downward by waves of muscular contraction known as **peristalsis**. Between the stomach and the esophagus is a tight ring of muscle known as the cardiac sphincter. This sphincter, which is normally closed, acts as a valve to prevent stomach contents from moving upward into the esophagus. During peristalsis the sphincter opens to allow the food to pass into the stomach.

**The Stomach**

The stomach has thick, muscular walls that contract to churn and mix the food, continuing the process of mechanical digestion. In addition, the walls of the stomach secrete hydrochloric acid and the enzyme pepsin. The hydrochloric acid gives the stomach a pH of less than 2, and this extremely acidic environment serves to kill many microorganisms that might be ingested along with the food. Pepsin is produced by the stomach in an inactive form known as pepsinogen. Pepsinogen is only activated into pepsin in a very low pH environment, so when it comes into contact with the hydrochloric acid, it becomes pepsin. Pepsin begins the digestion of protein by cleaving long chains of amino acids into shorter chains. In addition to its roles in mechanical and chemical digestion, the stomach temporarily stores food.

The walls of the stomach are protected from the hydrochloric acid by a thick layer of mucus. If this mucosal lining wears away, an ulcer can develop.

**The Small Intestine**

The small intestine is the major site of food breakdown, chemical digestion, and cellular absorption of food. Chemical digestion is carried out by secretions from the liver and pancreas.

When the stomach empties, the partially digested food, now called chyme, passes through the pyloric sphincter into the **duodenum**, the upper portion of the small intestine. At this point the chyme encounters bile. Bile is a complex solution of salts, pigments, and cholesterol that is produced in the liver and stored and concentrated in a small sac called the **gallbladder** before entering the duodenum. Bile does not actually change the chemical nature of the chyme; instead it emulsifies—breaks down—fats. Because fats and oils are not soluble in water, the fat content in chyme tends to separate and collect into large globules. Bile breaks these large fat globules into tiny droplets. The surface area of many droplets of fat is much greater than the surface area of a few large globules, and so by increasing the surface area of these fat droplets, bile exposes more fat to the enzymes that will eventually digest it.

The pancreas is a large gland that sits behind the stomach. As mentioned in the section on the endocrine system, the pancreas plays an important role in regulating blood sugar levels by producing the hormones insulin and glucagon. But it plays just as vital a role in the digestive system. The pancreas produces a basic secretion that helps to neutralize the stomach acid. It also produces many digestive enzymes. Lipase digests fats into glycerol and fatty acids, while trypsin and chymotrypsin continue the breakdown of amino acid chains into shorter ones. Both trypsin and chymotrypsin are produced in inactive forms in the pancreas and are not activated until they reach the small intestine; if this were not the case, the pancreas would digest itself! The pancreas also secretes pancreatic amylase, which, like salivary amylase, breaks down polysaccharides into disaccharides, but on a much larger scale.

The walls of the small intestine secrete the remaining few enzymes necessary for digestion. Maltase, lactase, and sucrase break down the disaccharides maltose, lactose, and sucrose into monosaccharides. Aminopeptidases cleave off individual amino acids from the short chains that are left after the action of trypsin and chymotrypsin from the pancreas. At this point, digestion is completed. As the digested food travels through the long, convoluted small intestine, it is absorbed through its walls into the bloodstream. The walls of the small intestine contain millions of tiny, fingerlike projections known as **villi** that increase the surface area of the intestinal wall, maximizing absorption of nutrients. The villi contain capillaries into which the digested amino acids and monosaccharides pass. Fats are processed in the cells of the intestinal lining and enter the lymphatic system before reaching the bloodstream. The blood leaving the intestines flows directly to the liver, where it enters the capillaries of the hepatic portal system for processing.

**The Large Intestine and Rectum**

The undigested food that is not absorbed in the small intestine is waste. It eventually passes into the large intestine, or colon, where its water content is reabsorbed into the body. A mutually symbiotic bacteria named *E. coli* lives in the large intestine, feeding on waste and producing vitamin K, which is absorbed by the intestine into the body. The final segment of the large intestine is the rectum, a sac that stores feces temporarily before they are eliminated through the anus, another sphincter muscle.

**Minerals and Vitamins**

In addition to the nutrients that form the building blocks of proteins, fats, and carbohydrates, the body also absorbs important minerals and vitamins during digestion. Minerals are inorganic molecules that are required by the body. Important minerals are iron, a necessary component of hemoglobin; iodine, which is essential for making thyroid hormone; and calcium, which is required by the bones and for many cellular processes. Sodium, chlorine, and potassium are important components of body fluids, and phosphorus is an important ingredient of nucleic acids.

Vitamins are more complex molecules that usually serve as coenzymes, assisting in physiological processes. Vitamin A is necessary to make retinal, an important chemical for vision. Vitamin B complex contains many molecules essential for cellular respiration and DNA replication. Vitamin C is important for making collagen, a tough material that is found in the body’s connective tissue. Vitamin **D** allows the body to absorb calcium, essential for the teeth and bones. Vitamin E helps prevent the rupture of red blood cells, and it also helps maintain healthy liver and nerve function. Vitamin Kis important in the blood-clotting process. Vitamins A, D, E, and K are the fat-soluble vitamins, while the vitamins of the B complex and vitamin C are water-soluble vitamins.