

Functions of the Digestive System

The major functions of the digestive tract include the following six processes, summarized in Figure 1:

1. Ingestion

Food must be placed into the mouth before it can be acted on. This is an active, voluntary process called ingestion.

2. Propulsion

Foods must be propelled from one organ to the next. Swallowing is one example of food movement that depends on **peristalsis**. Peristalsis is involuntary and involves alternating waves of contraction and relaxation of the muscles in the organ wall (Figure 2a). The net effect is to squeeze the food along the tract. Although **segmentation** (Figure 2b) may help to propel foodstuffs through the small intestine, it normally only moves food back and forth across the internal wall of the organ, serving to mix it with the digestive juices. Thus, segmentation is more an example of mechanical digestion than of propulsion.

3. Food breakdown: mechanical digestion

Mixing of food in the mouth by the tongue, churning of food in the stomach, and segmentation in the small intestine are all examples of processes contributing to mechanical digestion. Mechanical digestion prepares food for further degradation by enzymes.

4. Food breakdown: chemical digestion

The sequence of steps in which large food molecules are broken down to their building blocks by enzymes.

5. Absorption

Transport of digested end products from the lumen of the GI tract to the blood or lymph is absorption. For absorption to occur, the digested foods must first enter the mucosal cells by active or passive transport processes. The small intestine is the major absorptive site.

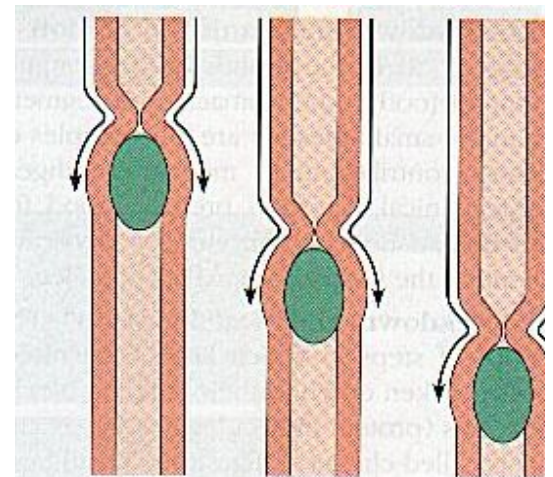
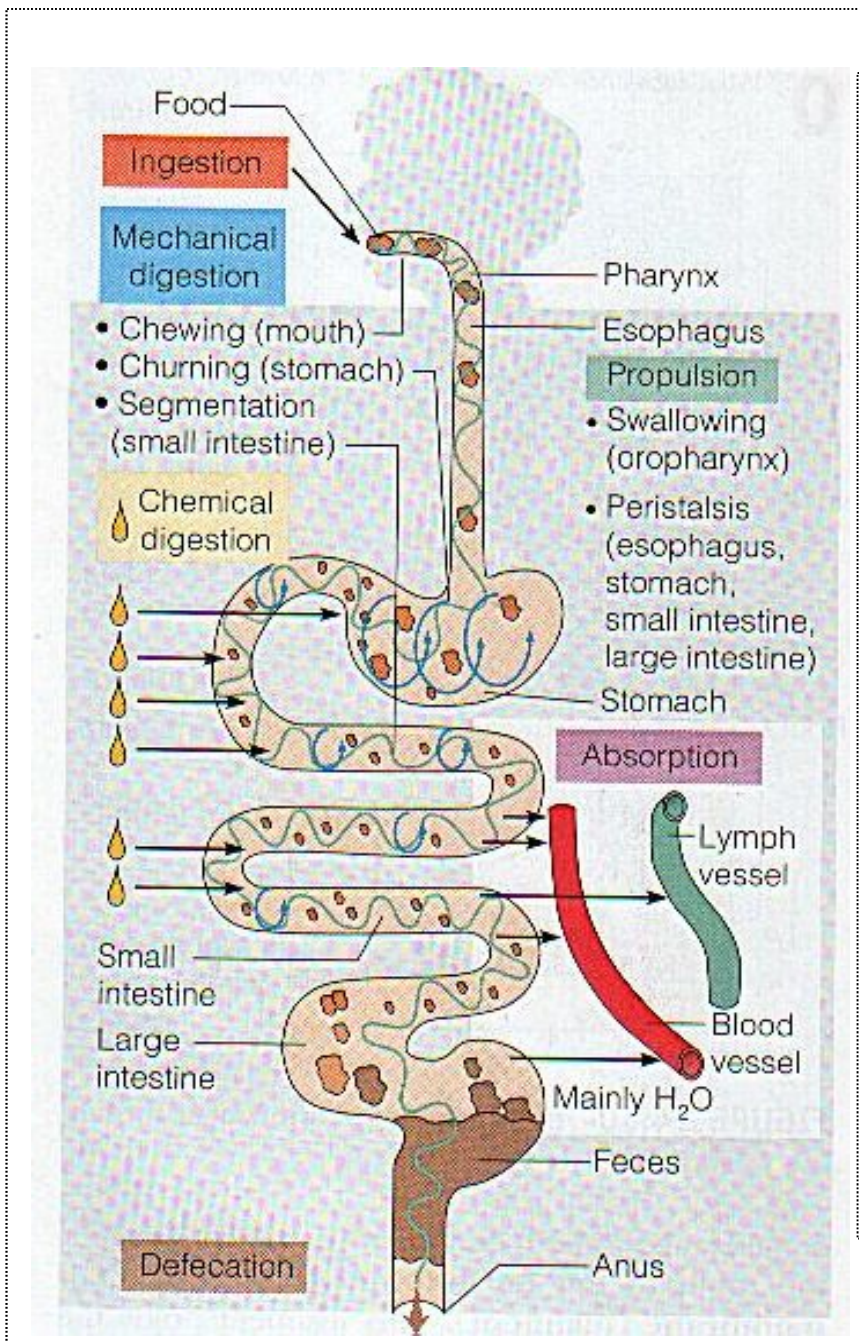
6. Defecation

Defecation is the elimination of indigestible residues from the GI tract via the anus in the form of feces.

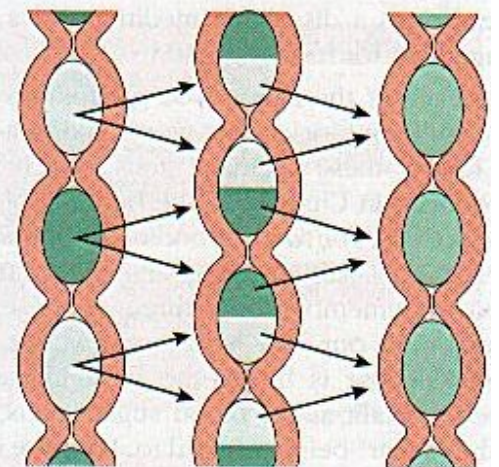
Some of these processes are the job of a single organ. For example, only the mouth ingests, and only the large intestine defecates.

Digestive activity is mostly controlled by reflexes via the parasympathetic division of the autonomic nervous system. The sensors (mechanoreceptors, chemoreceptors) involved in these reflexes are

located in the walls of the alimentary canal organs. When these receptors are activated, they start reflexes that activate or inhibit (1) the glands that secrete digestive juices into the lumen or hormones into the blood, and (2) the smooth muscles of the muscularis that mix and propel the foods along the tract.



(a)



(b)

Fig. 2:(a)
peristalsis

(b) segmentation

Fig. 1: The major functions of GIT.

Activities Occurring in the Mouth, Pharynx, and Esophagus

Food Ingestion and Breakdown

Once food has been placed in the mouth, both mechanical and chemical digestion begin. First the food is *physically* broken down into smaller particles by chewing. Then, as the food is mixed with saliva, salivary amylase begins the *chemical* digestion of starch, breaking it down into maltose.

Saliva is normally secreted continuously to keep the mouth moist; but, when food enters the mouth, much larger amounts of saliva pour out. The reflexes initiated by different stimuli, are brought about by parasympathetic fibers in cranial nerves. Essentially no food absorption occurs in the mouth.

The pharynx and esophagus have no digestive function; they simply provide passageways to carry food to the stomach.

Food Propulsion—Swallowing and Peristalsis

Food must first be swallowed. **Swallowing** is a complicated process that involves the coordinated activity of several structures (tongue, soft palate, pharynx, and esophagus). It has two major phases:

1. The voluntary **buccal phase**, occurs in the mouth. Once the food has been chewed and well mixed with saliva, the bolus is forced into the pharynx by the tongue.
2. The involuntary **pharyngeal-esophageal phase**, transports food through the pharynx and esophagus. The parasympathetic division of the autonomic nervous system controls this phase.

Food is moved through the pharynx and then into the esophagus below by wavelike peristaltic contractions of their muscular walls—first the longitudinal muscles contract, and then the circular muscles contract.

Activities of the Stomach

Food Breakdown

Secretion of **gastric juice** is regulated by both neural and hormonal factors. The sight, smell, and taste of food stimulate parasympathetic nervous system reflexes, which increase the secretion of gastric juice by the stomach glands. In addition, the presence of food and a falling pH in the stomach stimulate the stomach cells to release the hormone **gastrin**. Gastrin prods the stomach glands to produce still more of the protein-digesting enzymes (pepsinogens), mucus, and hydrochloric acid. Under normal conditions, 2 to 3 liters of gastric juice are produced every day.

The extremely acidic environment *is* necessary, to activate *pepsinogen* to *pepsin*, the active protein digesting enzyme. *Rennin*, the second protein-digesting enzyme produced by the stomach, works primarily on milk protein and converts it to a substance that looks like sour milk.

As food enters and fills the stomach, its wall begins to stretch (at the same time the gastric juices are being secreted). Then the three muscle layers of the stomach wall become active. They compress and pummel the food so that the semi-fluid chyme is formed.

Food Propulsion

Once the food has been well mixed, a rippling peristalsis begins in the lower half of the stomach. The pylorus of the stomach, which holds about 30 ml of chyme, acts like a meter that allows only liquids and very small particles to pass through the pyloric sphincter. When the duodenum is filled with chyme and its wall is stretched, a nervous reflex, the *enterogastric reflex*, occurs. This reflex slows the emptying of the stomach. Generally, it takes about 4 hours for the stomach to empty completely after eating a well-balanced meal and 6 hours or more if the meal has a high fat content.

Activities of the Small Intestine

Food Breakdown and Absorption

Food reaching the small intestine is only partially digested. Carbohydrate and protein digestion have been started, but virtually no fats have been digested up to this point. Here the

process of chemical food digestion is accelerated as the food takes about 3-6 hour journey through the small intestine. By the time the food reaches the end of the small intestine, digestion is complete and nearly all food absorption has occurred.

The microvilli of small intestine cells bear a few important enzymes, the so-called **brush border enzymes** that break down double sugars into simple sugars and complete protein digestion. *Intestinal juice* itself is relatively enzyme-poor, and protective mucus. However, foods entering the small intestine are literally deluged with enzyme-rich **pancreatic juice**.

Pancreatic juice contains enzymes that (1) along with brush border enzymes, complete the digestion of starch (*pancreatic amylase*): (2) carry out about half of protein digestion (via the action of *trypsin*, *chymotrypsin*, *carboxypeptidase*, and others); (3) are totally responsible for fat digestion since the pancreas is essentially the only source of *lipases*; and (4) digest nucleic acids (*nucleases*).

In addition to enzymes, pancreatic juice contains a rich supply of bicarbonate, which makes it very basic (about pH 8). When pancreatic juice reaches the small intestine, it neutralizes the acidic chyme coming in from the stomach and provides the proper environment for intestinal activity and pancreatic digestive enzymes.

The release of pancreatic juice into the duodenum is stimulated by both nerves and local hormones.

Bile is not an enzyme, acts like a detergent to emulsify, or mechanically break down, large fat globules into thousands of tiny ones, providing a much greater surface area for the pancreatic lipases to work on. Bile is also necessary for absorption of fats and other fat-soluble vitamins [K, D, and A] that are absorbed along with them.

Absorption of water and of the end products of digestion occurs all along the length of the small intestine. Most substances are absorbed through the intestinal cell plasma membranes by the process of *active transport*. Then they enter the capillary beds in the villi to be transported in the blood to the liver via the hepatic portal vein. The exception seems to be lipids, or fats, which are absorbed passively by the process of *diffusion*. Lipid breakdown products enter the capillary beds in the villi and are carried to the liver by both blood and lymphatic fluids.

At the end of the ileum, all that remains is some water, indigestible food materials (plant fibers such as cellulose), and large amounts of bac-

teria. This debris enters the large intestine through the ileocecal valve.

Food Propulsion

As mentioned previously, *peristalsis* is the major means of propelling food through the digestive tract. It involves waves of contraction that move along the length of the intestine, followed by waves of relaxation

Activities of the Large Intestine

Food Breakdown and Absorption

What is finally delivered to the large intestine contains few nutrients, but that residue still has 12 to 24 hours more to spend there. The colon itself produces no digestive enzymes. However, the bacteria that live within its lumen metabolize some of the remaining nutrients, releasing gases (methane and hydrogen sulfide) that contribute to the odor of feces. About 500 ml of gas (flatus) is produced each day.

Bacteria residing in the large intestine also make some vitamins (vitamin K and some B vitamins). Absorption by the large intestine is limited to the absorption of these vitamins, some ions, and most of the remaining water. **Feces**, the more or less solid product delivered to the rectum, contain undigested food residues, mucus, millions of bacteria, and just enough water to allow their smooth passage.

Propulsion of the Residue and Defecation

Peristalsis and mass movements are the two major types of propulsive movements occurring in the large intestine. Colon peristalsis is sluggish and, compared to the mass movements, probably contributes very little to propulsion. **Mass movements** are long, slow-moving but powerful contractile waves that move over large areas of the colon three or four times daily and force the contents toward the rectum. Typically, they occur during or just after eating, when food begins to fill the stomach and small intestine.

The rectum is generally empty, but when feces are forced into it by mass movements and its wall is stretched, the **defecation reflex** is initiated and the feces are forced through the anal canal, anus to the outside.