Digestion and Absorption - Part 2

Objectives

After going through this lesson, the learners will be able to understand the following:

- Digestion of Food in Mouth
- Swallowing
- Digestion of Food in Stomach
- Digestion of Food in Intestine
- Movement in Large Intestine
- Regulation of Digestive Secretions
- Diarrhoea and Constipation

Content Outline

- Introduction
- Digestion of Food in Mouth
- Swallowing
- Digestion of Food in Stomach
- Digestion of Food in Intestine
- Movement in Large Intestine
- Regulation of Digestive Secretions
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Introduction

Digestion is the breakdown of large insoluble food molecules into small water-soluble food molecules so that they can be absorbed into the watery blood plasma. In certain organisms, these smaller substances are absorbed through the small intestine into the bloodstream. Digestion is a form of catabolism that is often divided into two processes based on how food is broken down: mechanical and chemical digestion. In this module, we will discuss how food is digested in different parts of the digestive system that we discussed in the previous module.

Digestion of Food in Mouth

The buccal cavity performs two major functions, mastication of food and facilitation of swallowing. The teeth and the tongue with the help of saliva masticate and mix up the food thoroughly. Mucus in saliva helps in lubricating and adhering the masticated food particles into a **bolus**. The bolus is then conveyed into the pharynx and then into the oesophagus by swallowing or **deglutition**. The bolus further passes down through the oesophagus by successive waves of muscular contractions called peristalsis. The gastro-oesophageal sphincter controls the passage of food into the stomach. The saliva secreted into the oral cavity contains electrolytes Na^{+}, K^{+}, Cl^{-}, HCO_3^{-} and enzymes, salivary amylase and lysozyme. The chemical process of digestion is initiated in the oral cavity by the hydrolytic action of the carbohydrate splitting enzyme, the salivary amylase. About 30 percent of starch is hydrolysed here by this enzyme (optimum pH 6.8) into a disaccharide ñ maltose. Lysozyme present in saliva acts as an antibacterial agent that prevents infections.

$$\text{Starch} \xrightarrow[\text{pH 6.8}]{\text{Salivary Amylase}} \text{Maltose}$$

The masticated food then enters the Oesophagus.

Swallowing

During swallowing, food normally enters the esophagus because other possible avenues are blocked. Swallowing is a **reflex action** performed automatically (without our willing it). When we swallow, the soft palate moves back to close off the **nasopharynx,** and the trachea moves up under the **epiglottis** so that food is less likely to enter it. (We do not breathe when we swallow.) The tongue presses against the soft palate, sealing off the oral cavity, and the esophagus opens to receive a food **bolus.** Unfortunately, we have all had the unpleasant experience of having food "go the wrong way." The wrong way may be either into the nasal cavities or into the trachea. If it is the latter, coughing will most likely force the food up out of the trachea and into the pharynx again.

A rhythmic contraction called **peristalsis** pushes the food along the alimentary canal. Peristalsis begins in the esophagus and continues in all the organs of the alimentary canal. Occasionally, peristalsis begins even though there is no food in the esophagus. This produces the sensation of a lump in the throat. The esophagus plays no role in the chemical digestion of food. Its sole purpose is to conduct the food bolus from the mouth to the stomach. **Sphincters** are muscles that encircle tubes and act as valves; tubes close when sphincters contract, and they open when sphincters relax. The entrance of the esophagus to the stomach is marked by a constriction, often called the esophageal sphincter, although the muscle is not as developed as in a true sphincter. Relaxation of the sphincter allows the bolus to pass into the stomach, while contraction prevents the acidic contents of the stomach from backing up into the esophagus. **Heartburn,** which feels like a burning pain rising up into the throat, occurs during reflux when some of the stomach contents escape into the esophagus. When vomiting occurs, a contraction of the abdominal muscles and diaphragm propels the contents of the stomach upward through the esophagus.

Digestion of Food in Stomach

The stomach both physically and chemically acts on food. Its wall contains three muscle layers: One layer is longitudinal, another is circular, and the third is obliquely arranged. This muscular wall not only moves the food along, but it also churns, mixing the food with gastric juice and breaking it down to small pieces. The term *gastric* always refers to the stomach. The columnar epithelial lining of the stomach has millions of *gastric pits*, which lead into **gastric glands.** The gastric glands produce gastric juice, which contains pepsinogen, HCl, and mucus. *Chief cells* secrete pepsinogen, which becomes the enzyme **pepsin** when exposed to hydrochloric acid (HCl) released by *parietal cells*. The HCl causes the stomach to have a high acidity with a pH of about 2, and this is beneficial because it kills most of the bacteria present in food. Although HCl does not digest food, it does break down the connective tissue of meat and activate pepsin. The wall of the stomach is protected by the thick layer of mucus secreted by the *mucous cells*. If, by chance, HCl penetrates this mucus, the wall can begin to break down, and an ulcer results. An **ulcer** is an open sore in the wall caused by the gradual disintegration of tissue. It now appears that most ulcers are due to a bacterial infection *(Helicobacter pylori)* that impairs the ability of mucous cells to produce protective mucus.

Alcohol is absorbed in the stomach, but food substances are not. Normally, the stomach empties in about 2-6 hours. When food leaves the stomach, it is a thick, soupy liquid called **chyme.** Chyme enters the small intestine in squirts by way of the pyloric sphincter, which acts like a valve, repeatedly opening and closing.

In the stomach, gastric juice secreted by gastric glands has a very low pH—about 2—because it contains hydrochloric acid (HCl). The precursor, pepsinogen, is converted to the enzyme

pepsin when exposed to HCl. Pepsin acts on protein to produce peptides:

Pepsin

$$Protein + H_2O \rightarrow Peptides$$

Peptides vary in length, but they are usually too large to be absorbed and must be broken down further.

Digestion of Food in Intestine

It has been suggested that the surface area of the small intestine is approximately that of a tennis court. Three features contribute to increasing its surface area: circular folds, villi, and microvilli. The **circular folds** are permanent transverse folds involving the mucosa and submucosa of the small intestine. The **villi** (sing., villus) are fingerlike projections of the mucosa into the lumen of the small intestine. The villi are so numerous and closely packed that they give the wall a velvet-like appearance. A villus has an outer layer of columnar epithelial cells, and each of these cells has thousands of microscopic extensions called **microvilli.** Collectively, in electron micrographs, microvilli give the villi a fuzzy border known as a "brush border" (Fig. 15.7*d*). Because the microvilli bear the intestinal enzymes, these enzymes are called brush-border enzymes.

The digestive process is brought to completion in the small intestine. Ducts from the gallbladder and pancreas join to form one duct that enters the duodenum (see Fig. 15.8). The small intestine receives bile from the gallbladder and pancreatic juice from the pancreas via this duct. **Bile** emulsifies fat—emulsification causes fat droplets to disperse in water. The intestine has a slightly basic pH because pancreatic juice contains sodium bicarbonate (NaHCO3), which neutralizes chyme. The enzymes in pancreatic juice and the enzymes produced by the intestinal wall complete the process of food digestion. The other primary function of the small intestine is *absorption of nutrients*. The tremendous increase in surface area created by the circular folds, villi, and microvilli makes this an efficient process—the greater the surface area, the greater is the volume of intake in a given unit of time. Also, a villus contains a generous supply of blood capillaries and a small lymphatic capillary, called a **lacteal**.

The lymphatic system, as you know, is an adjunct to the cardiovascular system; its vessels carry a fluid called lymph to the cardiovascular veins. Sugars (digested in part from carbohydrates) and amino acids (digested from protein) enter the blood capillaries of a villus. Glycerol and fatty acids (digested from fats) enter the epithelial cells of the villi, and within these cells are joined and packaged as lipoprotein droplets, which enter a lacteal. After nutrients are absorbed, they are eventually carried to all the cells of the body by the bloodstream.

As we noted previously, a third function of the small intestine is movement of undigested remains to the large intestine. The wall of the small intestine has two types of movements: segmentation and peristalsis. Segmentation refers to localized contractions and constrictions that serve to bring chyme into contact with digestive juices and to encourage absorption. Peristalsis in particular then moves undigested remains toward the large intestine.

In the small intestine, starch, proteins, nucleic acids, and fats are all enzymatically broken down. Pancreatic juice, which enters the duodenum, has a basic pH because it contains sodium bicarbonate (NaHCO3). One pancreatic enzyme,

pancreatic amylase, digests starch:

Pancreatic amylase

$$Starch + H_2O \rightarrow Maltose$$

Another pancreatic enzyme, **trypsin,** digests protein:

Trypsin

$$Protein + H_2O \rightarrow Peptides$$

Trypsin is secreted as trypsinogen, which is converted to trypsin in the duodenum. **Lipase,** a third pancreatic enzyme, digests fat molecules in the fat droplets after they have been emulsified by bile salts:

Bile salts

$$Fat \rightarrow Fat\ droplets$$

Lipase

$$Fat\ droplets + H_2O \rightarrow Glycerol + Fatty\ acids$$

As mentioned previously, glycerol and fatty acids enter the cells of the villi, and within these cells, they are re-joined and packaged as lipoprotein droplets before entering the lacteals. **Peptidases** and **maltase**, enzymes produced by the small intestine, complete the digestion of protein to amino acids and starch to glucose, respectively. Amino acids and glucose are small molecules that cross into the cells of the villi. Peptides, which result from the first step in protein digestion, are digested to amino acids by peptidases:

Peptidases

$$Peptides + H_2O \rightarrow Amino\ acids$$

Maltose, a disaccharide that results from the first step in starch digestion, is digested to glucose by maltase:

Maltase

$$Maltose + H_2O \rightarrow Glucose + Glucose$$

Other disaccharides, each of which has its own enzyme, are digested in the small intestine. Table 16.1 lists some of the major digestive enzymes produced by the alimentary canal, salivary glands, or the pancreas. Each type of food is broken down by specific enzymes.

Major Digestive Enzymes				
Enzyme	**Produced by**	**Site of action**	**Optimum pH**	**Digestion**
Salivary amylase	Salivary glands	Mouth	Neutral	Starch + $H_2O \rightarrow$ maltose
Pancreatic amylase	Pancreas	Small Intestine	Basic	
Maltose	Small Intestine	Small Intestine	Basic	Maltose + $H_2O \rightarrow$ glucose + glucose
Pepsin	Gastric glands	Stomach	Acidic	Protein + $H_2O \rightarrow$ peptides
Trypsin	Pancreas	Small Intestine	Basic	

Peptidases	Small Intestine	Small Intestine	Basic	Peptide + $H_2O \rightarrow$ amino acids
Nuclease	Pancreas	Small Intestine	Basic	RNA and DNA + $H_2O \rightarrow$ nucleotides
Nucleosidases	Small Intestine	Small Intestine	Basic	Nucleotide + $H_2O \rightarrow$ base + sugar + phosphate
Lipase	Pancreas	Small Intestine	Basic	Fat droplet + $H_2O \rightarrow$ glycerol + fatty acids

Movement in Large Intestine

Feces are three-quarters water and one-quarter solids. Bacteria, **fiber** (indigestible remains), and other indigestible materials are in the solid portion. Bacterial action on indigestible materials causes the odour of feces and also accounts for the presence of gas. A breakdown product of bilirubin (see page 310) and the presence of oxidized iron cause the brown color of feces. For many years, it was believed that facultative bacteria (bacteria that can live with or without oxygen), such as *Escherichia coli,* were the major inhabitants of the colon, but new culture methods show that over 99% of the colon bacteria are obligate anaerobes (bacteria that die in the presence of oxygen). Not only do the bacteria break down indigestible material, but they also produce B-complex vitamins and most of the vitamin K needed by our bodies.

In this way, they perform a service for us. Water is considered unsafe for swimming when the coliform (non-pathogenic intestinal) bacterial count reaches a certain number. A high count indicates that a significant amount of feces has entered the water. The more feces present, the greater is the possibility that disease-causing bacteria are also present.

Regulation of Digestive Secretions

The secretion of digestive juices is promoted by the nervous system and by hormones. A **hormone** is a substance produced by one set of cells that affects a different set of cells, the so-called target cells. Hormones are usually transported by the bloodstream. For example, when a person has eaten a meal particularly rich in protein, the stomach produces the hormone gastrin. Gastrin enters the bloodstream, and soon the stomach is churning, and the secretory activity of gastric glands is increasing. A hormone produced by the duodenal wall, GIP (gastric inhibitory peptide), works opposite to gastrin: It inhibits gastric gland secretion. Cells of the duodenal wall produce two other hormones that are of particular interest—secretin and CCK (cholecystokinin). Acid, especially hydrochloric acid (HCl) present in chyme, stimulates the release of secretin, while partially digested protein and fat stimulate the release of CCK. Soon after these hormones enter the bloodstream, the pancreas increases its output of pancreatic juice, which helps digest food, and the gallbladder increases its output of bile. The gallbladder contracts to release stored bile. Figure 15.8 summarizes the actions of gastrin, secretin, and CCK.

Summary

The food we eat is utilized at the cellular level in chemical reactions involving; synthesis of proteins, carbohydrates, hormones, and enzymes; cellular division, growth and repair; and production of heat. To become usable by cells, most food must first be mechanically and chemically reduced to forms that can be absorbed through the intestinal wall and transported to the cells by the blood. The process involved with digestion include:

Ingestion: Taking food into the mouth (mechanical process)

Mastication: Chewing food (mechanical process)
Salivary action (chemical process)

Deglutition: Swallowing (mechanical process)

Peristalsis: Wavelike contractions that move food through the GI tract (mechanical process)

Absorption: Passage of food molecules from GI tract into the circulatory or lymphatic system (mechanical and chemical process)

Defecation: Elimination of indigestible waste (mechanical process)