Session 11

Digestive System

Contents

Introduction

The function of the digestive system is to supply the body with the nutrients and water which cells require for normal metabolic processes, such as growth, cell division, and the production of substances for secretion. The nutrients required by cells include large quantities of carbohydrates, fats and amino acids, as well as small amounts of vitamins and minerals.

- Large amounts of "fuel" molecules, in the form of carbohydrates and fats are needed to provide energy for the formation of ATP.
- Amino acids are required for the synthesis of proteins which are used in the building of new cells and the formation of enzymes to regulate cell processes.
- Vitamins and minerals pray essential roles in many cellular processes. They need to be absorbed into the body in small amounts.

Unfortunately, the food that we take into our bodies is not usually in a form which can be used. Most of the molecules found in normal foods are large and complex. Not only are they unable to cross from the intestines into the blood but they would also not be by cells. For example, protein in the muscles of a fish that you eat would not be able to be directly incorporated into your muscles.

Some undigested food molecules can act as antigens and be attacked by the body's immune system, causing an allergic response.

Therefore, before any nutrients present in food are absorbed into the body, they need to be processed by the digestive system and be broken down into simple molecules.

- Carbohydrates are broken down into monosaccharides such as glucose and fructose
- Fats are digested to molecules of glycerol and fatty acids
- Proteins are digested into amino acids

Digestion is the process which breaks down food into particles small enough to be absorbed and used by the body. The breakdown of food involves both mechanical digestive processes, such as chewing, and chemical digestion, in which special enzymes break large organic molecules into smaller units.

Digestion takes place as food moves through the alimentary canal. This structure is a long, hollow tube, which extends from the mouth to the anus. The alimentary canal is also known as the "gastro-intestinal tract" ("GI tract") and as the digestive function. For example, the mouth has teeth which grind the food into smaller pieces, to help with swallowing, whereas the stomach is a very muscular organ, which can thoroughly mix the food with digestive enzymes.

11.1 Mechanical Digestion in the Mouth

The mouth begins the digestive process by using the teeth to mechanically break up food into smaller pieces. The smaller pieces are easier to swallow and have a larger surface area on which digestive chemicals can work. In the presence of saliva, starch-containing foods, such as fruits, nuts, potatoes, bread and other products made from flour, will begin to be digested in the mouth. Amylase, an enzyme found in saliva, begins the process of chemical digestion of food. Amylase splits starch and glycogen, which are large polysaccharides, into small maltose molecules. Maltose is a disaccharide molecule, made up of two glucose molecules.

Once food has been well mashed and mixed with saliva, it is ready to be swallowed. The tongue pushes the mass of food, called a bolus, to the back of the mouth where it stimulates receptors. A series of reflex responses occur, which result in the swallowing of the food. One important component of this reflex response is the movement of the epiglottis. This cartilage flap in the larynx briefly covers the larynx preventing food from entering the airway to the lungs. If you attempt to talk while swallowing, the epiglottis will open up and food may become stuck in the larynx or trachea, causing you to choke.

11.2 Chemical Digestion in the Stomach

The main components of gastric juice are mucus, pepsin, hydrochloric acid and water.

- Mucus is a sticky, alkaline secretion which stomach, helping to protect it from damage by the other gastric secretions.
- Pepsin is a digestive enzyme which begins the chemical digestion of the proteins found in food. Pepsin is able to break bonds in large protein molecules, forming several shorter strands of amino acids. Pepsin is actually secreted in an inactive form, as a molecule called pepsinogen. This prevents the enzyme from damaging the area around

the gastric glands' once in the stomach cavity, hydrochloric acid causes the pepsinogen molecules to change into their active form, which is the molecule called pepsin.

- Hydrochloric acid is such a strong acid that, if you were to spill a drop onto your arm, it would cause a severe acid burn. Fortunately, the thick layer of mucous secreted by your stomach protects its lining from the hydrochloric acid. The main function of hydrochloric acid is to convert pepsinogen to pepsin and to create an acidic environment in the stomach. Gastric juice, with a pH of 2, provides the ideal conditions for pepsin, an enzyme which functions best in an acid environment.
- The acidic conditions in the stomach serve another purpose. The bacteria, parasites and other pathogens which enter the canal in food are destroyed in the stomach before they have to get into the body.
- Stomach ulcers result from damage to the wall of the stomach. They usually occur when a person is under a lot of stress but it is not clear what the underlying causes are. It may be that a mismatch occurs between the production of mucus, pepsin and hydrochloric acid, allowing pepsin and hydrochloric acid to attack the stomach lining.

11.3 Control of Gastric Secretions

Both the nervous and endocrine systems are involved in regulating the secretion of gastric juice.

- The parasympathetic nervous system is the division of the nervous system which has the most control. When you see, smell or taste food, nerve signals from the brain are sent via the parasympathetic nervous system to the gastric glands. The signals stimulate the production and release of gastric juice into the stomach. At the same time, a hormone, called gastrin (see below) is released into the blood. This effect is enhanced when food enters the stomach. Stretching of the wall occurs,

stimulating receptors that cause a reflex nervous response. The result is stimulation of the gastric glands and increased gastric juice secretion.

- Endocrine regulation involves a hormone called gastrin. Gastrin is produced by special cells in the walls of the stomach and small intestine. The hormone is released into blood in response to three major stimuli:
  - The presence of food in the stomach.
  - A rise in the pH of the stomach contents.
  - Signals from the parasympathetic nervous system.

Gastrin travels via the blood to the gastric glands where it causes an increase in their secretions, in particular in the volume of hydrochloric acid that is produced.

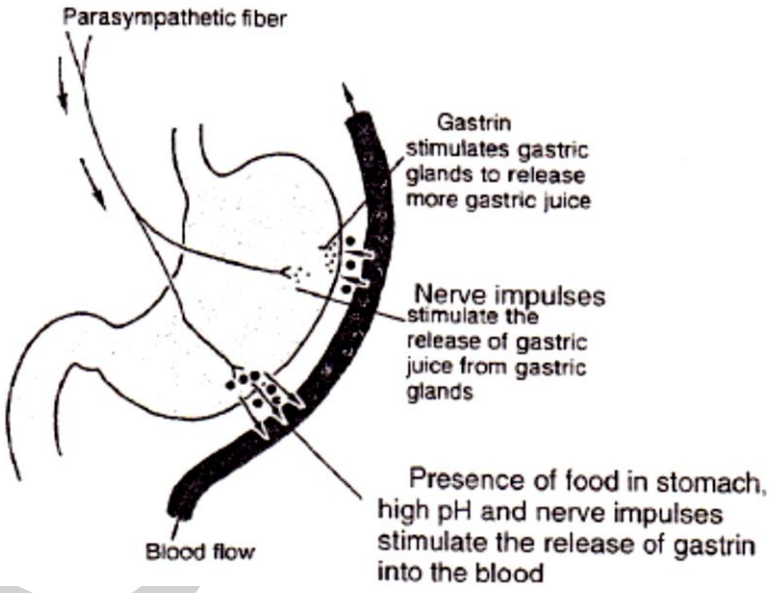

Figure 11.1: The control of Gastric Juice secretion

Food that has been well mixed with gastric juice forms a semi-liquid, acidic mass, called chyme. Peristaltic movements of the stomach force small amounts of chyme through the pyloric sphincter, into the small intestine. The pyloric sphincter is the opening between the stomach and the small intestine.

The chyme which enters the small intestine contains partially digested carbohydrates, partially digested proteins and many substances, such as fats, that have not been digested at all. Chemical digestion will be completed in the small intestine and most of the absorption of nutrients will take place in this region of the alimentary canal.

The majority of the enzymes required to complete the chemical digestion of chyme do not come from the small intestine itself. Instead, they are produced in two of the accessory organs-the pancreas and the liver. The digestive juices from these two organs then enter the duodenum via a series of ducts.

Activity 11.1

1. List the stomach secretions which make up gastric juice and give the functions of each secretion.
2. Explain how the secretion of gastric juice is regulated.
3. Explain what gastrin is.
4. Describes what its function is.

Pancreatic Juice

The arrival of chyme in the stomach promotes the release of pancreatic juice. The juice has two major components, produced by the cells of the acini:

- Digestive enzymes, consisting of three types of enzymes (amylase, lipase and peptidase). Between them, these three enzymes are capable of digesting almost all the nutrients found in food.
- A watery, alkaline secretion, which contains large quantities of sodium bicarbonate. This secretion helps to neutralize the acidic chime, which enters the intestine from the stomach. The pH pancreatic juice is about 8.

Secretion of pancreatic juice is mainly regulated by the endocrine system. When acidic chime from the stomach enters the duodenum, it causes cell located in the wall of the duodenum to release two hormones, secretin and cholecystokinin (CCK, pronounced "cole-ee-systo-k-eye-nin"). These two hormones travel in the blood to the pancreas where they stimulate the production and release of pancreatic juice (Fig.11.2). As we will see later, secretin and CCK also influence the production and release of bile.

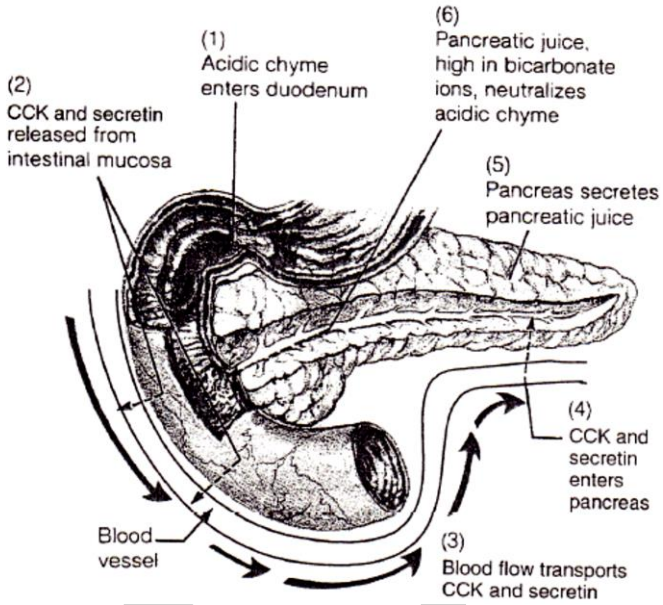

Figure 11.2: The regulation of pancreatic juice secretion

Activity 11.2

1. List the components of pancreatic juice and describe its digestive function.
2. Describe how the release of pancreatic juice is regulated.

11.4 Chemical Digestion in the Small intestine

As already mentioned, the small intestine does not secrete digestive enzymes. Instead, enzymes and other substances from the pancreas and liver are released into the organ. Several digestive enzymes are found attached to the epithelial cells of the villi but are not secreted as a part of intestinal juice:

Pancreatic juice, bile and the intestinal enzymes attached to the villi regulate the chemical digestion which takes place in the small intestine:

- Pancreatic juice is produced in the pancreas. It contains several types of enzymes, including amylase, lipase and peptidase.
- Amylase digests polysaccharides, such as starch, to maltose (a disaccharide). It is similar to the amylase enzyme found in saliva.
- Lipase digests fats to glycerol and fatty acid molecules.
- Peptidases break up long amino acid chains into shorter ones.

Pancreatic juice contains a lot of sodium bicarbonate and alkaline. This helps to neutralize the acidity of chyme and alkaline environment that the pancreatic enzymes need in function properly.

Bile is a yellowish-green liquid. It is produced by liver cells and it can be either released into the duodenum, via a series of ducts, or it can be stored in the gall bladder for release into the small intestine when required.
Bile contains water, bile salts, cholesterol, bilirubin and other substances.
Bile salts are important in the digestion of fats. They break large pieces of fat into smaller drops, which lipase can digest.

Intestinal enzymes, attached to the epithelial cells of villi, include peptidase, which completes the digestion of peptides to amino acids; lipase, which completes the digestion of fats to glycerol and fatty acids, and sucrose, maltase and lactase, which digest the disaccharide molecules sucrose, maltose and lactose, to monosaccharides such as glucose and fructose. (Remember, the names of most enzymes end in -ase. For example, lactase is the enzyme which digests lactose, a disaccharide sugar found in milk.)

Most babies have sufficient lactase to digest the lactose in the milk that they drink. As a person ages, however, the amount of lactase found in the walls

of the small intestine decreases. As a result, many adults are lactose intolerant .They are unable to eat or drink dairy products because their digestive systems cannot digest lactose molecules. The lactose cannot be absorbed and enters the large intestine. Here it creates an osmotic imbalance, causing water to be drawn into the intestine, producing diarrhoea. At the same time, bacteria in the large intestine feed on the lactose, producing gas which causes cramps and discomfort.

11.5 Absorption in the Small intestine

The length of the small intestine and its large surface area, means that by the time chyme has travelled along its length, virtually everything that has a nutritive value and has been digested to small molecules, will be absorbed into the blood. Each type of organic molecule has its own transport mechanism, to ensure that the molecules are moved into blood.

- Carbohydrates, in the form of monosaccharides such as glucose and fructose, are absorbed via carrier proteins, which transport the molecules across the epithelial cell layers into the blood. The process may be either active (using energy in the form of ATP) or passive.

- Proteins, which have been digested to amino acids, enter the brood via active transport mechanisms, involving the use of carrier proteins and ATP.

- Fats are digested to glycerol and fatty acids. These molecules are lipid soluble and can diffuse across the epithelial layers to the lacteals. The lacteals, the fats will be transported through the lymphatic system and eventually enter the blood.

It is important to note that many other important substances, such as water, electrolytes (sodium, potassium, calcium and others) and vitamins are also absorbed as the chyme passes through the small intestine.

The mass of chyme that reaches the end of the small intestine contains mainly water and undigested material. Peristaltic movements will allow the mass to enter the large intestine, via the ileocecal, or valve sphincter. This sphincter gets its name from the fact that it occurs between the ileum of the small intestine and the cecum of the large intestine.

Very little digestion takes place in the large intestine. Its main function is to absorb water and electrolytes, such as sodium and potassium, from the chyme. It also forms and stores faeces (the undigested material which is excreted) until defecation takes place and the faeces are expelled from the body.

Unlike the situation in other parts of the alimentary canal, peristalsis in the large intestine only occurs a few times a day. Wave-like contractions of the intestinal wall occur, forcing the faeces into the rectum. As pressure builds up in the rectum, a defecation reflex occurs. Stretch receptors in the sigmoid colon and rectum trigger the reflex, which coordinates strong peristaltic movements in the large intestine with opening of the anal sphincters. Faeces are then excreted from the body.

Summary

- In this session, you have learned how the food that you eat is digested and then absorbed, and how the undigested portion is excreted.
- As an exercise, think about the food you ate at your last meal. On a piece of paper, write down what types of organic molecules you think the food may have contained and then try to work out where the digestion of each type of food would have taken place in your digestive system.

- As a rule, most meats and animal products are rich in protein and fat, whereas grains (such as rice), vegetables and fruits contain a lot of carbohydrates in the form of starch and sugars.
- Most nuts and beans, including lentils, are rich in carbohydrates and protein. Nuts have a high fat content as well.

Learning Outcomes

At the end of the session, you should be able to:

- Discuss the digestive functions of the small intestine and its secretions
- Explain how nutrients are absorbed in the small intestine
- Discuss mechanical digestion
- Explain chemical digestion

Review Question

Explain how nutrients are absorbed in the small intestine.