Lecture 8 - Digestive System

Introduction

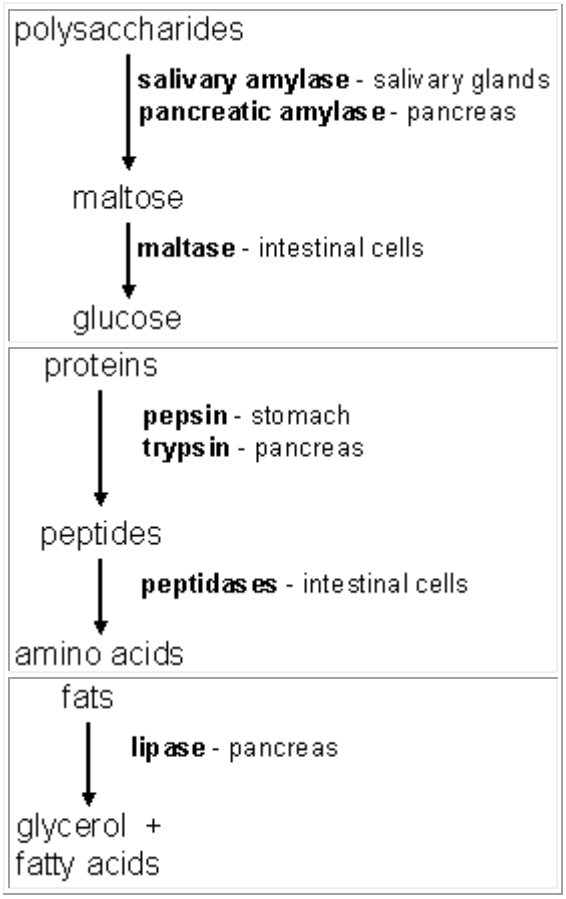
Digestion is the chemical breakdown of large food molecules into smaller molecules that can be used by cells. The breakdown occurs when certain specific enzymes are mixed with the food.

Enzymes involved in Digestion

polysaccharides → maltose → glucose

proteins → peptides → amino acids

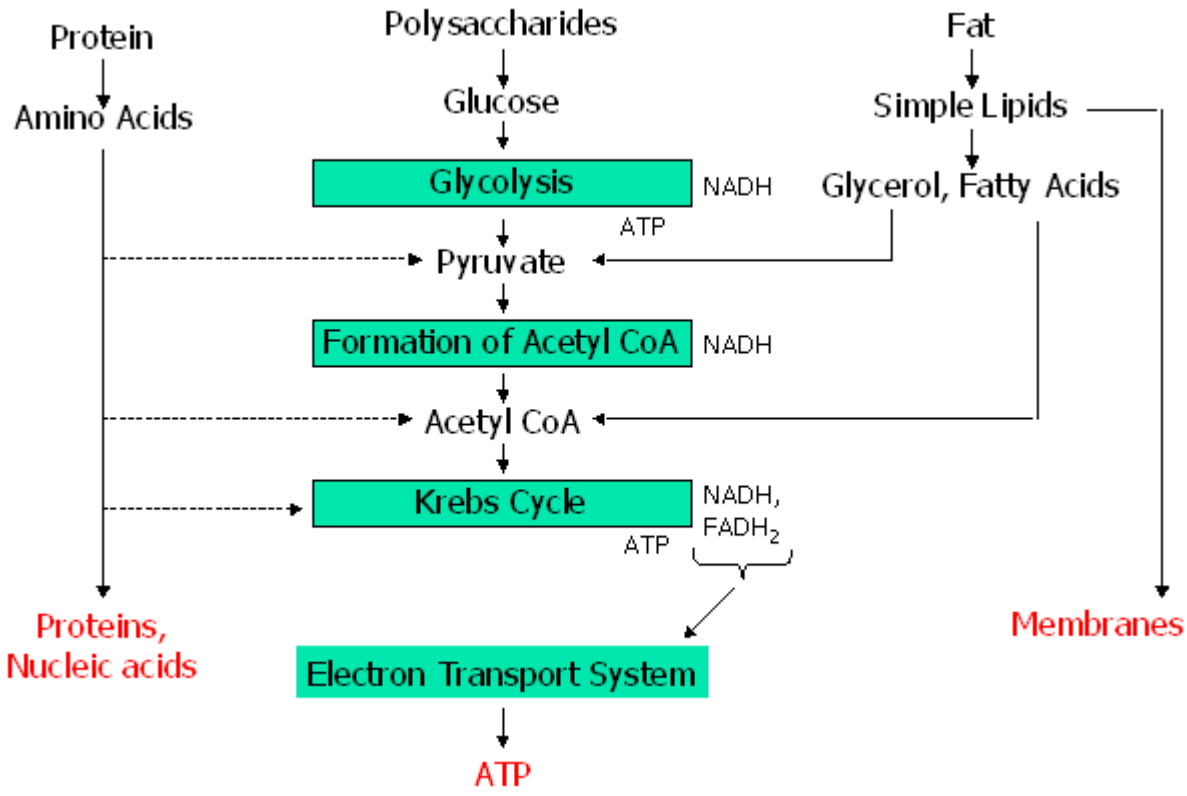
fats → fatty acids and glycerol



Carbohydrates, Proteins, Lipids

The process of digestion produces glucose, amino acids, glycerol, and fatty acids (see above). The energy in glucose is used to produce ATP via the reactions of glycolysis, cellular respiration, and the electron transport system (see diagram below). The body uses amino acids to construct

proteins. Excess amino acids can be used to synthesize pyruvate, acetyl CoA, and alpha ketogluterate, which enters the Krebs cycle. Glycerol and fatty acids can be converted to pyruvate and Acetyl CoA and then enter cellular respiration.



Mouth

Chewing breaks food into smaller particles so that chemical digestion can occur faster.

Enzymes

Salivary amylase breaks starch (a polysaccharide) down to maltose (a disaccharide).

Bicarbonate ions in saliva act as buffers, maintaining a pH between 6.5 and 7.5.

Mucins (mucous) lubricate and help hold chewed food together in a clump called a bolus.

The tongue contains chemical receptors in structures called taste buds. Theses are discussed in the chapter on sensory systems.

The tongue is muscular and can move food. It pushes food to back where it is swallowed.

Pharynx

The respiratory and digestive passages meet in the pharynx. They separate posterior to the pharynx to form the esophagus (leads to the stomach) and trachea (leads to the lungs).

Swallowing is accomplished by reflexes that close the opening to the trachea.

When swallowing, the epiglottis covers the trachea to prevent food from entering.

In the mouth, food is mixed with saliva and formed into a ***bolus***.

Peristalsis refers to rhythmic contractions that move food in the gut. Peristalsis in the esophagus moves food from the mouth to the stomach.

Stomach

The stomach stores up to 2 liters of food.

Gastric glands within the stomach produce secretions called **gastric juice**.

The muscular walls of the stomach contract vigorously to mix food with gastric juice, producing a mixture called ***chyme***.

Gastric juice

Pepsinogen is converted to pepsin, which digests proteins. Pepsinogen production is stimulated by the presence of gastrin in the blood (discussed below).

HCl

Hydrochloric acid (HCl) converts pepsinogen to ***pepsin*** which breaks down proteins to peptides. HCl maintains a pH in the stomach of approximately 2.0.

It also dissolves food and kills microorganisms.

Mucous protects the stomach from HCl and pepsin.

Secretion of Gastric Juice

Seeing, smelling, tasting, or thinking about food can result in the secretion of gastric juice.

Gastrin is a hormone that stimulates the stomach to secrete gastric juice. (See the discussion of hormones below.)

Ulcer

An ulcer is an irritation due to gastric juice penetrating the mucous lining of the stomach or duodenum. It is believed that ulcers are caused by the bacterium *Helicobacter pylori*, which, can thrive in the acid environment of the stomach. The presence of the bacteria on portions of the stomach lining prevents it from secreting mucous, making it susceptible to the digestive action of pepsin.

Duodenum

The duodenum is the first part of the small intestine.

Chyme enters through a ***sphincter***.

It enters in tiny spurts.

At this point, proteins and carbohydrates are only partially digested and lipid digestion has not begun.

Pancreas

The pancreas acts as an exocrine gland by producing ***pancreatic juice*** which empties into the small intestine via a duct.

The pancreas also acts as an endocrine gland to produce insulin. (See the discussion on the Islets of Langerhans or Pancreatic Islets in the chapter on the endocrine system.)

Pancreatic Juice

Pancreatic juice contains sodium bicarbonate which neutralizes the acidic material from the stomach.

Pancreatic amylase digests starch to maltose.

Trypsin and ***Chymotrypsin*** digest proteins to peptides. Like pepsin (produced in the stomach), they are specific for certain amino acids, not all of them. They therefore produce peptides.

Lipase digests fats to glycerol and fatty acids.

Liver

The liver produces ***bile*** which is stored in ***gallbladder*** and sent to the duodenum through a duct.

Bile emulsifies fats (separates it into small droplets) so they can mix with water and be acted upon by enzymes.

Other Functions of the Liver

The liver detoxifies blood from intestines that it receives via the hepatic portal vein.

The liver stores glucose as glycogen (animal starch) and breaks down glycogen to release glucose as needed. This storage-release process maintains a constant glucose concentration in the blood (0.1%). If glycogen and glucose run short, proteins can be converted to glucose.

It produces blood proteins.

It destroys old red blood cells and converts hemoglobin from these cells to bilirubin and biliverdin which are components of bile.

Ammonia produced by the digestion of proteins is converted to a less toxic compound (urea) by the liver.

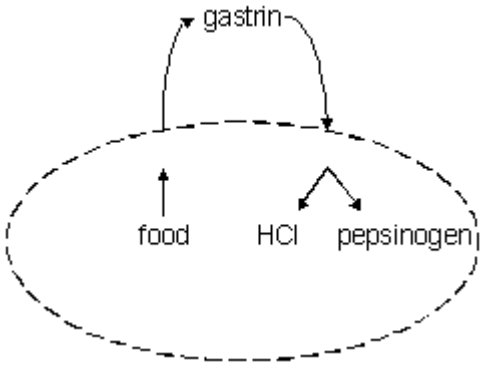
Hormones Involved in Digestion

The hormones listed below, like all hormones, reach their target cells by the circulatory system.

Gastrin

The presence of food in the stomach stimulates stretch receptors which relay this information to the medulla oblongata. The medulla stimulates endocrine cells in the stomach to secrete the hormone ***gastrin*** into the circulatory system. Gastrin stimulates the stomach to secrete gastric juice. This pathway of information is summarized below.

stretch receptors → medulla oblongata → endocrine cells in the stomach → gastrin → circulatory system → stomach → secretes gastric juice

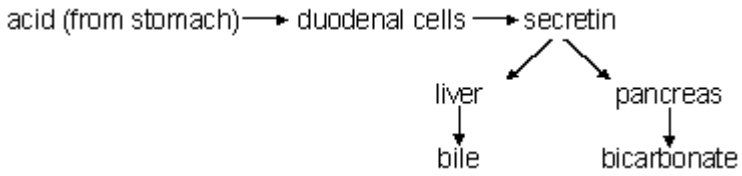


Secretin

Secretin is produced by cells of the duodenum.

It's production is stimulated by acid chyme from stomach.

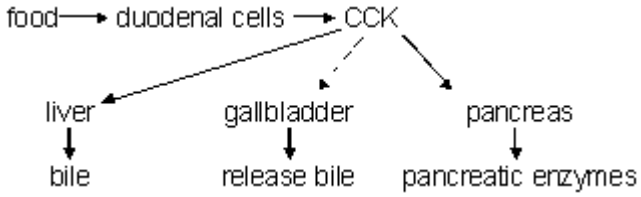
It stimulates the pancreas to produce sodium bicarbonate, which neutralizes the acidic chyme. It also stimulates the liver to secrete bile.



CCK (cholecystokinin)

CCK production is stimulated by the presence of food in the duodenum.

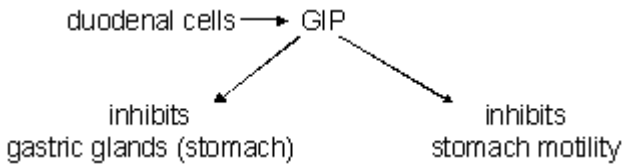
It stimulates the gallbladder to release bile and the pancreas to produce pancreatic enzymes.



GIP (Gastric Inhibitory Peptide)

Food in the duodenum stimulates certain endocrine cells to produce GIP.

It has the opposite effects of gastrin; it inhibits gastric glands in the stomach and it inhibits the mixing and churning movement of stomach muscles. This slows the rate of stomach emptying when the duodenum contains food.



Small Intestine

The small intestine is approximately 3 m long.

Like the stomach, it contains numerous ridges and furrows. In addition, there are numerous projections called ***villi*** that function to increase the surface area of the intestine. Individual villus cells have ***microvilli*** which greatly increase absorptive surface area.

The total absorptive surface area is equivalent to 500 or 600 square meters.

Each villus contains blood vessels and a ***lacteal*** (lymph vessel).

Peptidases and maltase are embedded within the plasma membrane of the microvilli.

Peptidases complete the digestion of peptides to amino acids.

Maltase completes the digestion of disaccharides.

Absorption

Absorption is an important function of the small intestine.

Active transport moves glucose and amino acids into the intestinal cells, then out where they are picked up by capillaries.

Glycerol and fatty acids produced by the digestion of fat enter the villi by diffusion and are reassembled into fat (triglycerides). They combine with proteins and are expelled by exocytosis. They move into the lacteals for transport via the lymphatic system.

Large Intestine

The large intestine is also called the colon.

It receives approximately 10 liters of water per day. 1.5 liters is from food and 8.5 liters is from secretions into the gut. 95% of this water is reabsorbed.

The large intestine also absorbs sodium and other ions but it excretes other metallic ions into the wastes.

If water is not absorbed, diarrhea can result, causing dehydration and ion loss.

It absorbs vitamin K produced by colon bacteria.

The last 20 cm of the large intestine is the rectum.

Feces is composed of approximately 75% water and 25% solids. One-third of the solids is intestinal bacteria, 2/3's is undigested materials.

The cecum is a pouch at the junction of the small intestine and large intestine. In herbivorous mammals, it is large and houses bacteria capable of digesting cellulose. In human ancestors, the cecum was larger but has been reduced by evolutionary change to form the appendix.

Polyps

Polyps are small growths in the epithelial lining of the colon.

They can be benign or cancerous and can be removed individually.

A low-fat, high-fiber diet promotes regularity and is recommended as a protection against colon cancer.

Appendix

The appendix is attached to cecum.

Appendicitis is an infection. The appendix may swell and burst, leading to peritonitis (infection of the abdominal lining).