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Digestion and Gastrointestinal Physiology

By

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Digestive system

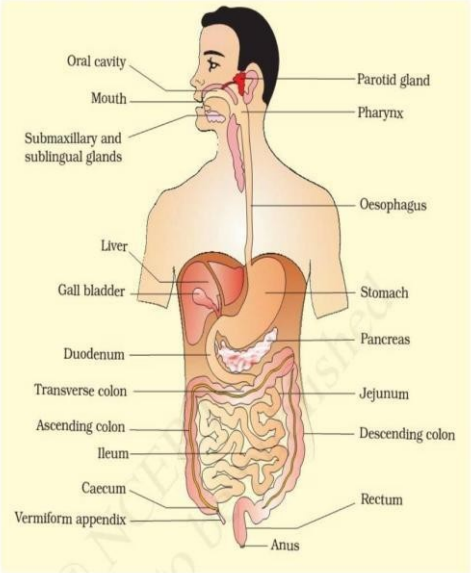


Figure 16.1 The human digestive system

Functions of the Gastrointestinal System

The two main functions of the digestive system are **digestion and absorption**

1-Is responsible for the breakdown and conversion of food into energy.

2-absorption of various foods and liquids needed to sustain life.

3-Movement of nutrient molecules from the external environment to the internal environment.

steps of food processing

Animals process food in four stages, which are : ingestion, digestion , absorption , and elimination .

These processes occur by two mechanisms:

1-**Mechanical Digestion**: larger pieces of food broken down into smaller pieces to be prepared for chemical digestion.

Mechanical digestion starts in the mouth and continues into the stomach by action of muscles

2-**Chemical Digestion**: starts in the mouth and continues into the intestines.

Several different enzymes break down macromolecules into smaller molecules that can be absorbed by chemical reactions.

Stages in the Digestive Process

Digestion of the large molecules into smaller components involves the following process:

Movement: propels food through the digestive system.

Secretion: release of digestive juices in response to a specific stimulus.
Digestion: breakdown of food into molecular components small enough to cross the plasma membrane.

Absorption: passage of the molecules into the body's interior and their passage throughout the body.

Elimination: removal of undigested food and wastes

Digestion in different parts of the digestive tract

Mouth and Pharynx

Mechanical breakdown begins in the mouth by chewing with teeth and the actions of the tongue.

The chemical breakdown of starch starts by the production of salivary amylase from the salivary glands. Salivary amylase begins the breakdown of starch.

Salivary glands: are **Parotid gland, submandibular gland, sublingual gland** , these are exocrine glands that produces saliva, which begins the process of digestion with amylase.

Salivary glands also produce an estimated three liters of saliva per day.

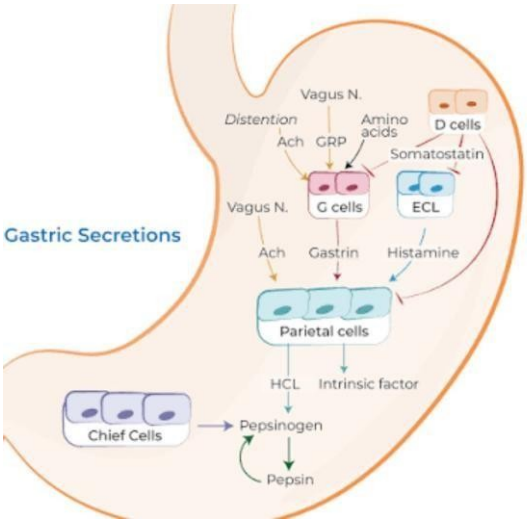
Stomach: The stomach is a thick-walled organ.

It is on the left side of the abdominal cavity; food reaches the end of the esophagus; it enters the stomach through a muscular valve called the lower esophageal sphincter.

The stomach secretes acid and enzymes that digest food.

The stomach muscles contract periodically, churning food to enhance digestion.

The pyloric sphincter is a muscular valve that opens to allow food to pass from the stomach to the small intestine.



Gastric glands:

Three types of secretory cells are found in each gland:

A-Parietal cells

B-chief cells

C-mucus cells.

Parietal cells (oxyntic cells): Secrete gastric HCl.

Chief cells (Digestive cells): They synthesize and secrete active pepsinogen, which is activated by gastric HCl into active pepsin that digests proteins by cleaving peptide bonds and breaks long polypeptide chains into shorter ones.

Food in the stomach is in a semi-liquid form, which upon completion is known as chyme.

The gastric juice is highly acidic with a **pH of 1-3**.

It may cause or compound damage to the stomach wall or its layer of mucus, causing a peptic ulcer.

Function of gastric HCl

1-It has a role in digestion.

2-Making the medium of the stomach acidic (pH-2).

3-Stimulate pancreatic and bile secretion where it enters the intestine

4- Kills many bacteria that may be ingested along with food.

5-Stops the activity of salivary amylase but promotes pepsin activity.

Phases of gastric secretion

The secretion of gastric juices occurs in three phases:

1-**Cephalic phase** - This phase occurs before food enters the stomach and involves preparation of the body for eating and digestion.

2-**Gastric phase** - This phase takes 3 to 4 hours.

It is stimulated by distension of the stomach, the presence of food in the stomach, and a decrease in pH.

3-**Intestinal phase** -The intestinal phase blocks the effect of the cephalic and gastric phases.

Control of secretion and motility

The movement and flow of chemicals into the stomach are controlled by both the nervous system and various digestive system hormones.

Gastrin hormone

That causes an increase in the secretion of HCl, pepsinogen, and intrinsic factor from parietal cells in the stomach.

It also causes increased motility in the stomach.

Gastrin is released pH normally less than 4 by G-cells into the stomach. It is inhibited by (high acid) as well as the hormone somatostatin. Cholecystokinin (CCK) has the most effect on the gall bladder, but it also decreases gastric emptying and has the most effect on the pancreas.

Gastric inhibitory peptide (GIP) and enteroglucagon decrease both gastric motility and secretion of pepsin.

Small Intestine

The small intestine is the site where most of the chemical and mechanical digestion is carried out.

Tiny projections called villi line the small intestine, which absorbs digested food into the capillaries. Most of the food absorption takes place in the Jejunum and the ileum.

The function of the small intestine is the digestion of proteins into peptides and amino acids principally occurs in the stomach, but some also occurs in the small intestine.

Peptides are degraded into amino acids; lipids (fats) are degraded into fatty acids and glycerol; and carbohydrates are degraded into simple sugars.

Two ducts enter the duodenum, which are:

1-**Common duct**, which is composed of the liver duct and bile duct, drains the gall bladder and liver secretions into the duodenum.

2-**Pancreatic duct**, which drains the exocrine product from the pancreas into the duodenum.

Parts of the intestine

- **The Duodenum:** It is the first and shortest part of the small intestine. The duodenum is also where the bile and pancreatic juices enter the intestine.
- **The Jejunum:** The inner surface of the jejunum, its mucous membrane, is covered in projections called villi, which increase the surface area of tissue available to absorb nutrients from the gut contents.
- **The Ileum:** Its function is to absorb **vitamin B12** and **bile salts.** The wall itself is made up of folds, each of which has many tiny fingerlike projections known as villi, on its surface. The villi

contain large numbers of capillaries, which take the amino acids and glucose produced by digestion to the hepatic portal vein and the liver.

Liver

It plays a major role in metabolism and has several functions. It also produces bile, which is important in digestion.

Bile can either drain directly into the duodenum via the common bile duct or be temporarily stored in the gallbladder via the cystic duct. The various functions of the liver are carried out by the liver cells or hepatocytes.

1. Detoxify blood - remove and metabolize poisonous substances.
2. Destroy old RBC - hemoglobin converted to bile -- bile stored in the gall bladder and used in the digestion of fats.
3. stores glucose as glycogen - converts glycogen to glucose to keep the blood sugar concentration in the blood constant
4. Production of urea from amino groups and ammonia.
5. Synthesis of blood proteins.
6. The liver produces and excretes bile required for dissolving fats.

7. The liver produces coagulation factors I (fibrinogen), II (prothrombin), V, VII, IX, X, and XI, as well as protein C, Protein S, and antithrombin.

Bile Release into the Small Intestine

The liver is stimulated by the hormones "secretin" and "cholecystokinin" (CCK) to produce bile.

The bile enters the right and left hepatic ducts and travels to the common hepatic duct.

The bile is stored in the gallbladder.

The gallbladder is stimulated to release the bile by the vagal nerve and CCK. The bile enters the duodenum via the bile duct.

Pancreas

It is a gland that has two types of secretions :

1-Exocrine functions: Exocrine secretion that drains in to duodenum and is called pancreatic juice, it's a **pH (8)** and contains:

i. Sodium bicarbonate – neutralizes the acidity of gastric

HCl in the duodenum. ii. Ions of Cl , So4 , Hpo4, K+ , Ca+ , Mg+ . 3-Many digestive enzymes that are:

A- **Pancreatic amylase** hydrolyzes starch.

B- **pancreatic lipase** hydrolyzes fats.

C- **trypsin** hydrolyzes proteins.

D- **Chymotrypsin** hydrolyzes proteins.

E- - **Elastase** hydrolyzes proteins.

F- **Carboxypeptidases** hydrolyze polypeptides.

G- **nucleases** hydrolyze nucleic acids.

2-Endocrine functions:

Endocrine secretions from islets of Langerhans include the following hormones: **insulin, glucagon,** and **somatostatin**.

o **Somatostatin**:inhibits the function of insulin. Produced if the body is getting too much glucose.

o **Glucagon** :stimulates the stored glycogen in the liver to convert to glucose.

Produced if the body does not have enough glucose.

o **Insulin:** made in the beta cells of the Islets of Langerhans of the pancreas.

Insulin is a hormone that regulates blood glucose.

Regulation of Pancreatic Secretion

1. **parasympathetic:** causes release of pancreatic exocrine secretion during the cephalic and gastric phases of gastric secretion

2. **secretin – hormone:** that causes the release of "bicarbonaterich" pancreatic juices in response to the presence of HCl.

3. **cholecystokinin – hormone**: that causes the release of "enzyme-rich" pancreatic juice in response to the presence of proteins and fats.

Digestion of foods

Fat digestion: All fats ingested are digested into three types of molecules, which are: Glycerol, Triglycerides, and Fatty acids.

These products are absorbed into the intestinal lymphatic circulation, not into the blood circulation.

And then they pass to the fat deposits of the body, either in the abdomen or under the skin.

Lipid Absorption

Micelles - tiny balls of fats that result from bile salt emulsification and "lecithin". contain **cholesterol** and **fat-soluble vitamins**, diffuse through the lipid bilayer of the membrane.

1. **Chylomicrons** - micelles combined with associated proteins within the cell; enter the lacteals of the lymphatic system.

Carbohydrate digestion

Starches are broken down into sugars (glucose and fructose) by **amylase** and **hydrochloric acid** in the stomach.

DNA and RNA digestion

DNA and RNA are broken down into mononucleotides by the nucleases deoxyribonuclease and ribonuclease (**DNase** and **RNase**) from the pancreas.

Nucleic Acid Absorption: pentoses, nitrogen bases, phosphates - absorbed by similar processes as sugars and amino acids.

Digestion of protein

Ingested proteins are broken down into amino acids by enzymatic activity: Food protein by action of pepsin converted to long-chain peptides, then by action of trypsin changed to short-chain peptides, then by action of Erepsin, converted to amino acids.

Protein (Amino Acid): Absorption by facilitated diffusion - amino acids and small peptides (coupled with Na+ active transport), "carrier molecule" has binding sites for both amino acid and Na+; relies on Na+ gradient. Vitamin Absorption

A- **fat-soluble - Vitamins A, D, E, and K** are absorbed by epithelial cells along with lipid micelles by aid of bile juice.

B- **water soluble - Vitamins B & C** absorbed by diffusion.

C- **Vitamin B12** - large and electrically charged, must bind with "intrinsic factor" before being taken into the cell by endocytosis.

Electrolyte Absorption

1. Fe and Ca - primarily absorbed in small intestine

2. Na - exchanged for sugars and amino acids

3. Cl - absorbed into cells and exchanged for HCO3

4. K - absorbed into cells due to osmotic gradients

Water Absorption

1. small intestine - 95% of water is absorbed by the small intestine following the transport of solutes

2. large intestine - absorbs remaining water before moving the chyme onto the rectum

Control of Digestion

1- **by Nervous System:** Two Phases controlled by the N. system:

A- **Cephalic Phase** - Triggered by the site, smell, and taste of food. This stimulates the stomach to prepare for the entry of food.

B- **Gastric Phase** - Stomach distension by food stimulates the release of gastric juices.

2- **by Hormones**

A- **Gastrin** - Produced by the stomach; stimulates the release of gastric juices.

B- **Secretin** - Produced by the small intestine; stimulates the pancreas and gall bladder to release pancreatic juices and bile.

C- **Cholecystokinin (CCK)** - Produced by the small intestine; stimulates the pancreas and gall bladder to release pancreatic juices and bile.

Large Intestine

The large intestine (colon) extends from the end of the ileum to the anus. It is about 5 feet long, being one-fifth of the whole extent of the intestinal canal.

The large intestine is divided into

a) Cecum
b) Colon (ascending, transverse, and descending)
c) Rectum
d) Anal canal

Small and Large Intestine