Digestive system

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Functions of the digestive tract:

The digestive tract has following functions

- **Ingestion:** This is the active process of bringing material into the oral cavity.
- **Propulsion:** Ingested materials are moved through the digestive tract by swallowing and peristalsis.
- **Mechanical processing:** Material entering the digestive tract is physically reduced in size. This begins in the oral cavity where food is crushed and sheared before being propelled along the digestive tract
- **Digestion:** Following reduction in size, ingested nutrients are chemically broken down into particles small enough for absorption. Although simple molecules such as monosaccharides and amino acids can be absorbed without further reduction in size, macromolecules such as protein, DNA, polysaccharides, and triglycerides must first be reduced into smaller molecules. Specific enzymes complete such reduction.
- **Secretion:** Water, mucus, acids, enzymes, buffers, and salts are released into the lumen of the digestive tract along its length. Secretions come from epithelial cells and glandular organs.
- **Absorption:** Along the length of the digestive tract, nutrients including organic substrates, electrolytes, vitamins, and water pass from the lumen into the body. In addition to absorbing ingested nutrients, the digestive tract must absorb secreted water, salts, and other secreted material. Failure of such absorption will result in dehydration.
- **Excretion:** The digestive tract is a site of elimination of waste products.
- **Immunity**. The digestive tract provides a substantial barrier to prevent the entry of pathogens into the body. The digestive tract acts not only as a physical barrier, but also has an innate immune system.

Classification of animals according to their diet:

Animals can be classified into four groups as follows. The first group includes animals with a simple stomach, such as humans, pigs, dogs and cats. The second group is **foregut fermenters**, which includes cattle, sheep, and goats. These animals have a ruminant stomach in which they can ferment nondigestible carbohydrates. The third group consists of **hindgut fermenters** such as horses, rabbits, guinea pigs, etc. These animals rely on fermentation that occurs in the cecum and colon. The final group consists of birds in which various adaptations have occurred to both store and grind various foodstuffs.

Pregastric Physiology

- The stomach is the first major organ associated with digestion. Before food can be received by the stomach, important pregastric functions are performed to receive, prepare, and deliver a bolus to the stomach. Performance of these functions varies among the animals and depends mostly on adaptations associated with their diet.

Prehension

The first mechanical function necessary for the digestive process is prehension**.** The seizing and conveying of food into the mouth is called prehension. Lips, teeth, and tongue are the principal prehensile structures in domestic animals. The lips of the horse, the tongue of the cow and sheep, and the snout of the pig are used extensively in obtaining food.

Mastication

Mastication refers to the mechanical breakdown of food in the mouth. It is commonly called chewing. It is carried out to varying degrees by different animals. The fibrous nature of the diet of herbivores requires more chewing than the meat diet of carnivores. A bolus (rounded ball) of food is formed by the mastication process.

Deglutition

Deglutition is the act of swallowing or conveying the food mass from the mouth to the stomach. This complex process involves a number of reflexes that are coordinated by a swallowing center in the brain. There are three stages of swallowing: 1) through the mouth (voluntary), 2) through the pharynx (reflex) and 3) through the esophagus (reflex).

Saliva

Saliva consists of water (97–99.5%), and it is therefore hypoosmotic. Electrolytes in the saliva include sodium, potassium, chloride, bicarbonate, and phosphate. It tends to be slightly acidic (pH 6.75–7.00). Saliva has several functions:

1. **Solubilizes food**. Dissolves foods so they can be tasted and digestive reactions can occur.
2. **Provides alkaline buffering and fluid**. Bicarbonate and phosphate in the saliva can neutralize acidic feedstuffs. *Alkaline fluid via the saliva is particularly important in ruminants.*
3. **Removes wastes**. Metabolic waste products such as urea and uric acid are excreted in the saliva.
4. **Lubricates and binds**. The mucus in the saliva helps bind masticated food so that it can be formed into a bolus. In addition, saliva coats the oral cavity and esophagus, thus protecting the mucosa of the oral cavity and esophagus.
5. **Initiates starch digestion**. The starch-digesting enzyme amylase is present in the saliva of omnivores (pig) and to a *limited degree in horses but absent in ruminants and carnivores (dog).*
6. **Assists oral hygiene**. *Lysozyme, found in saliva, is a bacteriostatic enzyme that lyses bacteria*, thus protecting the mouth.
7. **Enables evaporative cooling.** This is particularly important in dogs, which have very poorly developed sweat glands.

Enteric nervous system

The digestive tract has its own nervous system called the enteric nervous system. It is composed mostly of two large plexuses:

- Submucosal plexus/Meissner's plexus: located within the submucosal layer
- Myenteric plexus/ Auerbach plexus: located between the two layers of smooth muscle fibers in the muscularis externa

Segmentation and Peristalsis

Peristalsis (*peri = around + stalsis = constriction*) can be defined as alternating waves of contraction and relaxation of muscles along the digestive tract wall.

During peristalsis, the circular smooth muscle layer behind the bolus contracts while that in front of the bolus relaxes. Conversely, the longitudinal smooth muscle layer behind the bolus relaxes while that in front of the bolus contracts. This increases the diameter of the lumen in front of the bolus while constricting the diameter of the lumen behind the bolus. This results in propulsion of the bolus down the digestive tract.

Mechanical digestion and motility in the small intestine

Small intestine motility is regulated mainly by the enteric reflex responding to the presence of materials in the intestinal lumen. There are two types of movements within the small intestine: **segmentation and peristalsis**.

Segmental contractions characterized by ring like contractions separated by relaxed areas containing a bolus of chyme. The constant formation and then relaxation of these contractual rings along the length of the small intestine result in a mixing action.

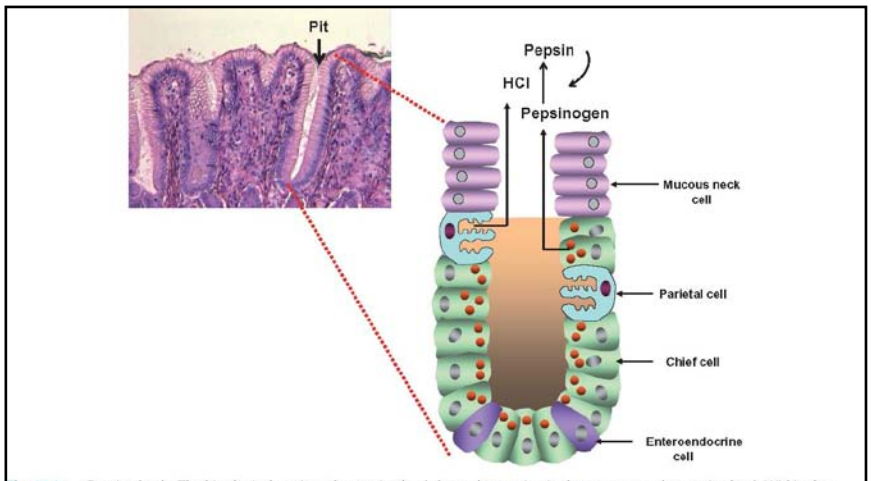


Fig. 17.14. Gastric glands. The histological section of a gastric gland shows the gastric pit, the entrance to the gastric gland. Within the gland are neck cells that secrete mucus, parietal cells that secrete HCl, chief cells that secrete pepsinogen, and enteroendocrine cells that secrete hormones. G cells, which secrete gastrin, are an example of enteroendocrine cells. Once released into the stomach lumen, pepsinogen

Gastric juice: means secretion of gastric gland into the stomach lumen by gastric glands.

Gastric juice contains water, hydrochloric acid, mucus, intrinsic factor, pepsinogen, and rennin. There are four cell types in gastric glands.

1. **Mucous neck cells.** Found in the upper, or neck, region of a gastric gland, they produce a more acidic mucus than goblet cells.

2. **Parietal cells.** Found in the middle region, they secrete hydrochloric acid (HCl) and intrinsic factor. Intrinsic factor is a glycoprotein necessary for absorption of vitamin B12 in the small intestine. The HCl decreases the pH of the stomach to 1.5– 2. This low pH has several functions: (1) It is necessary for the function of pepsin; (2) it provides a harsh environment for bacteria ingested with food; (3) it denatures proteins and inactivates enzymes in food; and (4) it breaks down cell walls of plant material and connective tissue in meat.

3. **Chief cells.** These cells produce pepsinogen, the inactive form of pepsin, and an enzyme that digests proteins. When pepsinogen is first released, it interacts with HCl and converts it to its active form, pepsin. Once activated, pepsin can convert other molecules of pepsinogen to pepsin.

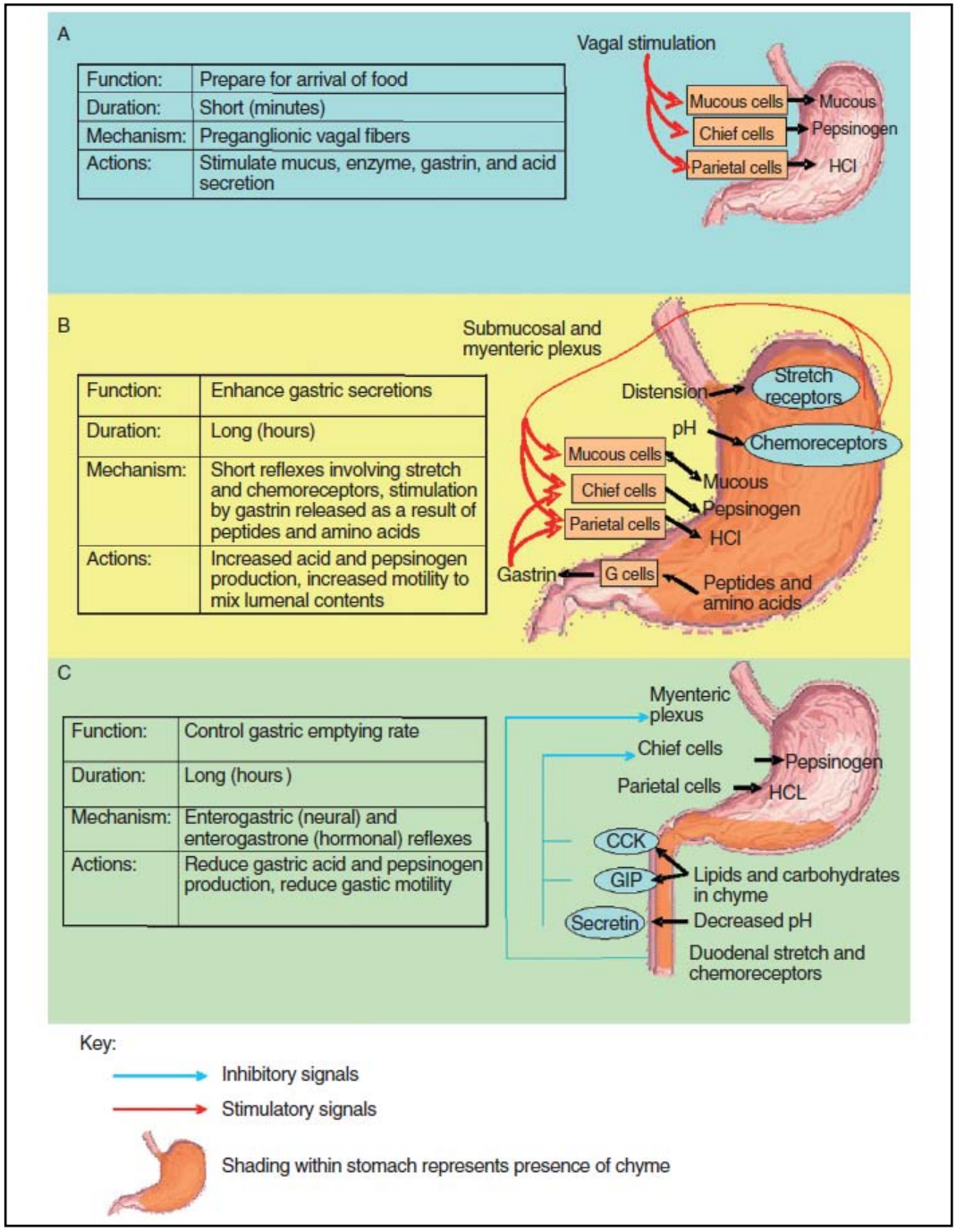


Fig. 1 Phases of Gastric secrions; A: Cephalic phase, B: Gastric phase C: intestinal phase

Regulation of gastric secretions and emptying

Gastric secretions are controlled by neural and hormonal mechanisms. Gastric secretions are controlled at three levels and can be classified into three phases: cephalic phase, gastric phase, and intestinal phase of gastric secretion. These control mechanisms can either increase or decrease gastric secretions.

Cephalic phase

The cephalic phase causes an increase in gastric secretions prior to the arrival of food. This stage is controlled by the central nervous system, and it prepares the stomach for the arrival of food. The sight, smell, and taste of food stimulate the

parasympathetic nervous system to send signals via the vagus nerve that synapse on the submucosal plexus located in the wall of the stomach. This stimulates the postganglionic parasympathetic fibers innervating mucous cells, chief cells, parietal cells, and G cells in the stomach, thus increasing gastric secretions. This phase is short, lasting minutes. Emotional responses associated with activation of the fight-or-flight response decrease gastric secretions and gastric motility.

Gastric phase

Beginning with the arrival of food in the stomach, this phase further stimulates gastric secretion and motility. This phase accounts for about two-thirds of gastric secretions.

Stimuli for the gastric phase include distention of the stomach, an increase in gastric pH, and the presence of undigested food, especially proteins and peptides.

Intestinal phase

This phase functions to decrease gastric motility. Stimulation of chemoreceptors and stretch receptors triggers the enterogastric reflex. This reflex inhibits gastrin production and gastric motility, and stimulates contraction of the pyloric sphincter, thus slowing gastric emptying into the duodenum.

Pepsin secretions regulations

- Pepsin is not produced within the chief cells because this would cause the self-digestion of the cells. Instead, chief cells produce the zymogen (i.e., the precursor form of an enzyme) pepsinogen, which is activated when it enters the stomach lumen and comes in contact with HCl.
- *Protein digestion is initiated in the stomach via the action of pepsin, the only enzyme found in the stomach of adult animals*. Dietary proteins are denatured by HCl secreted by the parietal cells.

HCl secretions and regulations

HCl is not produced within the parietal cells because it would destroy the cell. Both H+ and Cl– are independently transported from the parietal cells into the stomach lumen. Hydrogen ions are generated from the dissociation of carbonic acid that is produced by the enzyme carbonic anhydrase acting upon CO_2 and H_2O. Hydrogen ions are then transported into the stomach lumen in exchange for K^+. Chloride ions enter the parietal cell in exchange for bicarbonate ions. The chloride ions then travel down their concentration gradient and enter the stomach lumen. Once in the lumen, hydrogen and chloride ions combine, producing HCl. When parietal cells are producing considerable HCl, a significant amount of bicarbonate enters the blood, thus increasing the pH (called the alkaline tide). Parietal cells respond to many signals. Located on their surface are receptors for histamine, acetylcholine (ACh), and gastrin. Histamine comes from mast cells located in the lamina propria, ACh from postganglionic parasympathetic fibers, and gastrin from G cells. Histamine acts at H_2 receptors, whereas ACh acts at muscarinic receptors. Stimulation of these receptors results in stimulation of protein kinase, other neural and hormonal stimuli such as ACh and histamine.

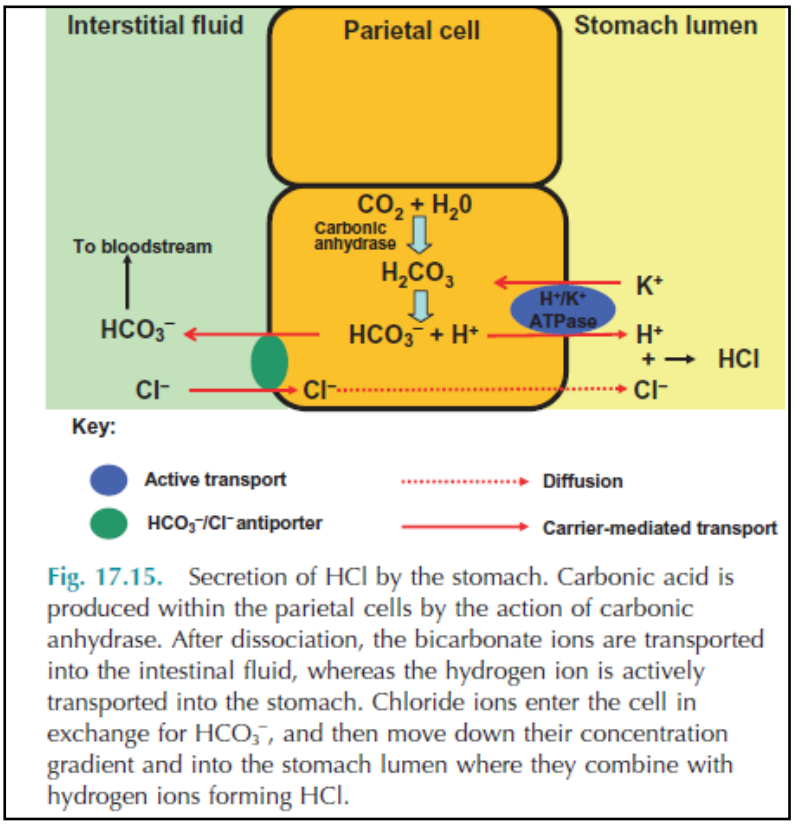


Fig. 17.15. Secretion of HCl by the stomach. Carbonic acid is produced within the parietal cells by the action of carbonic anhydrase. After dissociation, the bicarbonate ions are transported into the intestinal fluid, whereas the hydrogen ion is actively transported into the stomach. Chloride ions enter the cell in exchange for HCO_3^-, and then move down their concentration gradient and into the stomach lumen where they combine with hydrogen ions forming HCl.

Emesis

Emesis (vomiting) is an emptying of the cranial part of the duodenum and stomach in an orad (toward the mouth) direction. A series of reflexes is involved to initiate antiperistalsis and closure of the epiglottis and nasal cavity. Swine, dogs, and cats vomit easily. Vomiting is a protective mechanism that helps prevent absorption of noxious substances. Vomiting in the horse is rare because of the difficulty in opening the cardia from a reverse direction. *The reflexes of vomiting are controlled by a vomiting center in the brain.*

Defecation

Defecation is a complex reflex act in which feces are evacuated from the terminal colon and rectum.The frequency of defecation varies among animals but can occur 5 to 10 times daily in vigorous horses, 10 to 20 times daily in cattle, and 2 to 3 times daily in carnivores. The reflex can be assisted or inhibited by certain voluntary muscles.

- Animals that regurgitate and remasticate their food are called ruminants.
- There are two suborders of ruminant animals: 1) Ruminantia- includes the bison, cow, sheep, goat deer, reindeer, antelope, giraffe, musk ox, and 2) Tylopoda-which includes the camel, llama, alpaca, and vicuna.
- The main difference between the two suborders is Tylopoda do not have an omasum. Another difference is that Tylopoda have cardiac glands that open into ventral surfaces of the reticulum and rumen.

Rumination

- The process of bringing food material back from the ruminant stomach to the mouth for further mastication is known as rumination. Rumination is a cycle of activity composed of four phases: 1) regurgitation (returning it to the mouth), 2) remastication, 3) resalivation, and 4) redeglutition. It is a reflex initiated by mechanical stimulation of receptors in the mucosa of the reticulum and rumen in the area of the cardia.
- The time spent in rumination each day varies with species and diet. Generally, the coarseness of the ration influences the time for rumination—cattle on a hay diet average about 8 hr/day. When only concentrates are fed, rumination time can be reduced to about 2-1/2 hr/day.

Chemical digestion in the small intestine Some/little starch digestion occurs in the mouth by the action of salivary amylase. In the stomach, some chemical protein digestion occurs as pepsin converts proteins to peptides. However, *most chemical digestion occurs within the small intestine*.

Carbohydrate digestion

Since food remains in the mouth only a short time, little starch is totally digested. Instead, pancreatic amylase completes this process. Starch and glycogen are acted upon by salivary and pancreatic amylase to form maltose, maltotriose, and α-dextrins. This is the luminal phase of carbohydrate digestion since it occurs within the lumen. The smaller di- and trisaccharides then move into contact with the brush border where mucosal digestion by brush-border enzymes digests these sugars to monosaccharides.

Protein digestion

Chemical digestion of protein begins in the stomach by the action of pepsin. Pepsin, which works optimally at a pH of 1.5–2.5, cleaves bonds involving tyrosine and phenylalanine. Pepsin digests approximately 10–15% of dietary protein before being inactivated in the lumen of the small intestine. Once in the small intestine, trypsin and chymotrypsin secreted by the pancreas break down proteins into peptides. Carboxypeptidase, another pancreatic enzyme, cleaves one amino acid at a time from the carboxyl and amino end of a polypeptide, respectively, while the brush-border enzymes aminopeptidase and dipeptidase further cleave the proteins.

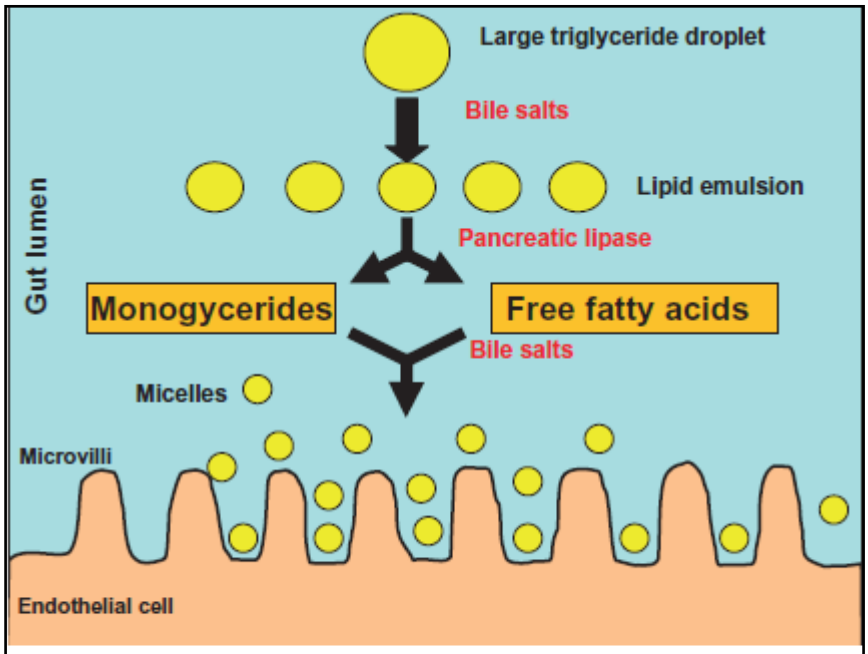


Fig. 17.33. Lipid digestion in the small intestine. Lumenal digestion of lipids results in the production of monoglycerides and free fatty acids. With the help of bile salts, these then form water-soluble micelles that can move toward the microvilli located on the epithelial cells lining the villi of the small intestine.

Lipid digestion

Triglycerides are the most abundant lipid in the diet. Triglycerides and phospholipids are digested by lipases. Bile salts assist in emulsifying dietary lipids within the aqueous environment found in the small intestine lumen. During this emulsification process, large lipid masses are converted into small droplets (Micelle) which allows water-soluble pancreatic lipase to act more efficiently. *Pancreatic lipase cleaves off two fatty acids from triglycerides producing two free fatty acids and monoglyceride.*

Absorption in the small intestine

Absorption is the process whereby compounds and ions move through the epithelial cells lining the mucosa and pass into the bloodstream or lymphatic system. About 90% of absorption occurs within the small intestine with the rest occurring in the stomach and large intestine. *Absorption occurs via diffusion, facilitated diffusion, osmosis, and active transport.*

Table 17.4. Digestive enzymes.

Enzyme	*Source*	*Substrate*	*Products*
Saliva			
Salivary amylase	Salivary glands	Starch and glycogen	Maltose (disaccharide), maltotriose (trisaccharide), and α-dextrins
Lingual lipase	Gland in the tongue	Triglycerides and other lipids	Fatty acids and diglycerides
Gastric Secretions			
Pepsin	Chief cells	Proteins	Peptides
Gastric lipase	Chief cells	Short-chain triglycerides	Fatty acids and monoglycerides, α-dextrins
Pancreatic Secretions			
Trypsin	Pancreatic acinar cells	Proteins, chymotrypsinogen, procarboxypeptidase	Peptides
Chymotrypsin	Pancreatic acinar cells	Proteins	Peptides
Elastase	Pancreatic acinar cells	Proteins	Peptides
Carboxypeptidase	Pancreatic acinar cells	Terminal amino acid at carboxyl end of peptides	Peptides and amino acids
Pancreatic lipase	Pancreatic acinar cells	Triglycerides	Fatty acids and monoglycerides
Ribonuclease	Pancreatic acinar cells	Ribonucleic acid	Nucleotides
Deoxyribonuclease	Pancreatic acinar cells	Deoxyribonucleic acid	Nucleotides
Brush-Border Enzymes			
α-Dextrinase	Membrane microvilli	α-Dextrins	Glucose
Maltase	Membrane microvilli	Maltose	Glucose
Sucrase	Membrane microvilli	Sucrose	Glucose and fructose
Lactase	Membrane microvilli	Lactose	Glucose and galactose
Enterokinase	Membrane microvilli	Trypsinogen	Trypsin
Aminopeptidase	Membrane microvilli	Terminal amino acid	Peptides and amino acids
Dipeptidase	Membrane microvilli	Dipeptides	Amino acids
Nucleosidases	Membrane microvilli	Nucleotides	Nitrogenous bases, pentoses, and phosphates
Phosphatases	Membrane microvilli	Phosphorylated nutrient molecules	

Absorption of amino acids, dipeptides, and tripeptides

Although it was once believed that only amino acids are absorbed, it is now well established that di- and tripeptides are also actively absorbed in the small intestine. Some amino acids enter the epithelial cells by a secondary active transport system similar to that described for glucose and galactose. There are some amino acids that utilize a sodium-independent cotransporter in which the amino acids enter along with H+ instead of Na+. In this case, H^+ is pumped into the intestinal lumen in exchange for Na^+. The Na^+ is then pumped out of the cell by the Na^+-K^+-ATPase on the basolateral membrane. This creates a concentration gradient for H^+, which is high concentrations within the lumen. As H^+ enters the epithelial cells, selected amino acids are cotransported. Peptides are absorbed via this sodium-independent co-transporter. Once inside the epithelial cell, the peptides are hydrolyzed to single amino acids,

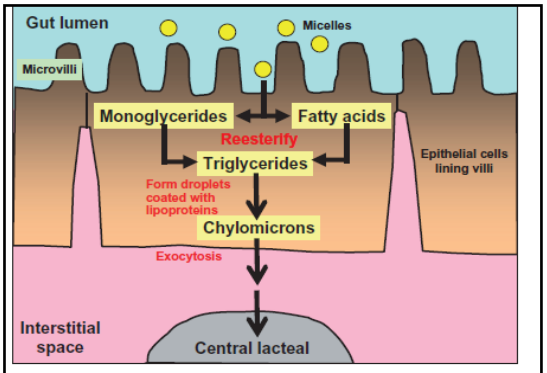


Fig. 17.35. Transport of lipids through the enterocytes. As the micelles produced in the lumen of the small intestine come in contact with the microvilli on the enterocytes lining the villi, the monoglycerides and fatty acids passively pass into the enterocytes. Inside the enterocytes, they re-esterify forming triglycerides. These form droplets that are then coated with lipoproteins, thus forming chylomicrons. The chylomicrons pass through the basal surface of the enterocytes into the interstitial space and then enter the central lacteal found in each villi.

which then move by diffusion into the hepatic portal vein

Absorption of lipids

- Since lipids are not water soluble so lipid absorption and transport within the body face unique challenges compared to carbohydrate and protein absorption.
- Within the small intestine lumen, triglycerides are broken down into fatty acids and monoglycerides. The bile salts within the gut lumen help emulsify the lipids by forming water-soluble particles (micelles), which helps the lipids migrate within the aqueous chyme found in the gut. Since lipids are fat soluble; once the micelles come in contact with the lumen wall, the monoglycerides and free fatty acids can cross the epithelial membrane by simple diffusion. The bile salts help in the formation of micelles.
- Once inside the epithelial cells lining the gut pass into the hepatic portal system similar to amino acids and monosaccharides. Within the enterocytes, absorbed monoglycerides and fatty acids are used to resynthesize triglycerides. These triglycerides combine with cholesterol and intracellular proteins and form a particle which is called chylomicrons. The chylomicrons are secreted by a process of exocytosis into the interstitial fluid of the villus. In mammals, these chylomicrons then enter the lacteal (smallest lymphatic vessels) and are carried to thoracic ducts and ultimately added to the blood.

ACCESSORY ORGANS

Pancreas

Chyme passes from the stomach to the small intestine. The chemical digestive processes that occur within the small intestine depend upon accessory organs, including the pancreas, liver, and gallbladder.

Composition and function of pancreatic juice

Pancreatic juice is a clear, colorless liquid. Containing mostly water, it also has salts, sodium bicarbonate, and enzymes. Sodium bicarbonate serves as a buffer to neutralize stomach acid within the small intestine, thus stopping the action of gastric pepsin. Neutralizing gastric acid also allows pancreatic enzymes to function. *Pancreatic enzymes include the carbohydrate-digesting enzyme* ***pancreatic amylase***; several ***protein-digesting enzymes***, including trypsin, chymotrypsin, carboxypeptidase, and elastase; the triglyceride-digesting enzyme ***pancreatic lipase***; and the ***nucleic acid-digesting enzymes*** ribonuclease and deoxyribonuclease.

Protein-digesting enzymes are produced within the pancreas in an inactive form so that they do not digest the pancreas. *Pancreatic acinar cells secrete a protein called trypsin inhibitor that prevents the activation of trypsinogen.*. Upon entering the duodenal lumen, trypsinogen is activated by the brush-border enzyme enterokinase. Trypsin then activates the remaining zymogens chymotrypsinogen, procarboxypeptidase, and proelastase producing the respective active enzymes.

Regulation of pancreatic secretions

Similar to gastric secretions, pancreatic secretions are controlled by both neural and hormonal mechanisms:

1. During the cephalic and gastric phases of gastric secretion, parasympathetic signals carried via the vagus nerve (cranial nerve X) increase secretion of pancreatic enzymes.

2. Partially digested lipids and proteins within the duodenal lumen stimulate the secretion of CCK from enteroendocrine cells in the duodenal wall. CCK stimulates the secretion of pancreatic enzymes.

3. Decreased pH in the duodenal lumen stimulates the release of secretin from enteroendocrine cells in the duonenal wall. Secretin stimulates release of bicarbonate ions from the pancreas.

Bile composition and function

Bile consists of water, bile salts, bile acids, cholesterol, the phospholipid (lecithin), bile pigments (bilirubin), and ions. The bile salts include sodium and potassium salts of bile acids, (glycocholic and taurocholic acids). Bile salts assist in emulsification of lipids within the small intestine.

Regulation of bile secretion

In those animals that have a gallbladder, bile is stored between meals. The sphincter of the hepatopancreatic ampulla (sphincter of Oddi) restricts the entrance to the duodenum. There are neural and hormonal stimuli that can stimulate bile secretion:

1. Parasympathetic signals traveling along the vagus nerve can stimulate bile production by the liver.

2. Fatty acids, particularly medium- and long-chain, and amino acids in the chyme cause duodenal enteroendocrine cells to secrete CCK. CCK causes the smooth muscle cells of the gallbladder to contract, and bile is squeezed into the cystic duct and through the common bile duct. CCK also relaxes the sphincter of the hepatopancreatic ampulla.

Functions of the liver: The liver is a vital organ. It performs many functions:

1. **Carbohydrate metabolism**. The liver plays a vital role in maintaining blood glucose levels. When blood glucose levels are high, the liver converts glucose to glycogen (glycogenesis) and triglycerides so that energy can be stored until needed. When blood glucose levels drop, the liver can break down glycogen to glucose (glycogenolysis) and release the glucose into the bloodstream. In addition, the liver can convert certain amino acids to glucose (gluconeogenesis), as well as lactic acid to glucose.

2. **Lipid metabolism.** Hepatocytes can store triglycerides as well as use fatty acids to synthesize ATP. In addition, hepatocytes synthesize lipoproteins that carry fatty acids, triglycerides, and cholesterol throughout the body. Cholesterol can be synthesized in the liver, and cholesterol is used to make bile salts.

3. **Protein metabolism**. Hepatocytes remove the amino group (deamination) of amino acids so they can be used for ATP synthesis. Hepatocytes also synthesize carbohydrates and fats from certain amino acids. Hepatocytes can synthesize various plasma proteins such as albumin, prothrombin, fibrinogen, and alpha and beta globulins (needed for hemoglobin synthesis).

4. **Removal of waste products**. The liver detoxifies substances such as alcohol and antibiotics, and can alter and excrete steroid hormones. The liver is an important site of detoxification of ammonia, which is converted to the less toxic urea, which is excreted in the urine. The waste product of red blood cell destruction, bilirubin is eliminated via the bile.

5. **Synthesis of bile salts**. The bile salts necessary for lipid emulsification within the small intestine are synthesized in the liver.

6. **Storage**. The liver is the primary storage site of fat-soluble vitamins (A, D, E, and K), as well as vitamin B12. Glycogen and certain minerals (Fe and Cu) are also stored in the liver.

7. **Phagocytosis**. Kupffer cells destroy aged blood cells and microbes that may have entered via the hepatic portal blood.

8. **Activation of vitamin D**. The liver combines with the skin and kidneys to synthesize the active form of vitamin D.

Large intestine

The terminal portion of the digestive tract is the large intestine. It extends from the end of the ilium to the anus. The primary functions of the large intestine are electrolyte and water absorption, microbial digestion and vitamin production, formation of feces, and expulsion of feces. These functions require considerable time, so transit time through the large intestine is slow

Table 17.5. Hormones controlling digestion.

Hormone	*Site of Secretion*	*Stimulus for Secretion*	*Actions*
Gastrin	Enteroendocrine G cells in the pyloric antrum mucosa, also secreted from duodenal mucosa	Stomach distention, partially digested protein, high pH in the stomach	Increases secretion of gastric juice, increases gastric motility, stimulates growth of gastric mucosa, constricts lower esophageal sphincter while relaxing ileocecal sphincter
Secretin	Enteroendocrine S cells in duodenal mucosa	Acidic pH in duodenal lumen	Stimulates pancreatic secretion rich in bicarbonate ions
Cholecystokinin (CCK)	Enteroendocrine CCK cells in duodenal mucosa	Partially digested proteins, medium and long-chain fatty acids	Stimulates pancreatic secretion rich in enzymes, gall bladder bile ejection, opens hepatopancreatic ampulla, inhibits food intake peripherally and in the central nervous system

Chemical digestion in the large intestine

Although no chemical digestion occurs in the large intestine, considerable fermentation takes place, especially in those animals that are hindgut fermenters. Microbes ferment any remaining carbohydrates releasing hydrogen, carbon dioxide, and methane. These gases lead to flatulence in the large intestine. Amino acids are converted to indole, skatole, hydrogen sulfide, and fatty acids. Indoles and skatole are eliminated in the feces, contributing to its odor, while some of the remaining products are absorbed and transported to the liver. The microbes synthesize B vitamins and vitamin K, which are also absorbed by the large intestine.

Micelle: small droplets formed in the intestinal chymes which contain lipids, bile salts, and products of lipid digestion.

Emulsification: The process of breakdown of fat globules into smaller globules by the bile salts.