University of Anbar
College of science
Department of biotechnology

Lectures of human physiology

Lec. 9

The Digestive System

(part 2)

By
Dr. Ali Mohammed Sameen

LARGE INTESTINE

The large intestine absorbs water, electrolytes, and certain vitamins from the chyme it receives from the small intestine. The large intestine then passes waste products out of the body.

The **large intestine,** or **colon,** extends from the ileocecal valve to the anus, framing the small intestine on three sides. Chyme from the ileum passes into the **cecum,** which is a blind pouch (open only at one end) at the beginning of the large intestine. Waste material then passes in sequence through the **ascending colon, transverse colon, descending colon, sigmoid colon, rectum,** and **anal canal**. The mucosa of the large intestine, like that of the small intestine, contains many scattered lymphocytes and lymphatic nodules and is covered by columnar epithelial cells and mucus secreting goblet cells. Although this epithelium does form crypts, there are no villi in the large intestine— the intestinal mucosa therefore appears flat. The outer surface of the colon bulges outward to form pouches, or haustra Occasionally, the muscularis externa of the haustra may become so weakened that the wall forms a more elongated outpouching, or diverticulum. Inflammation of one or more of these structures is called diverticulitis. The large intestine has little or no digestive function, but it does absorb water and electrolytes from the remaining chyme, as well as several B complex vitamins and vitamin K (fig. 1).

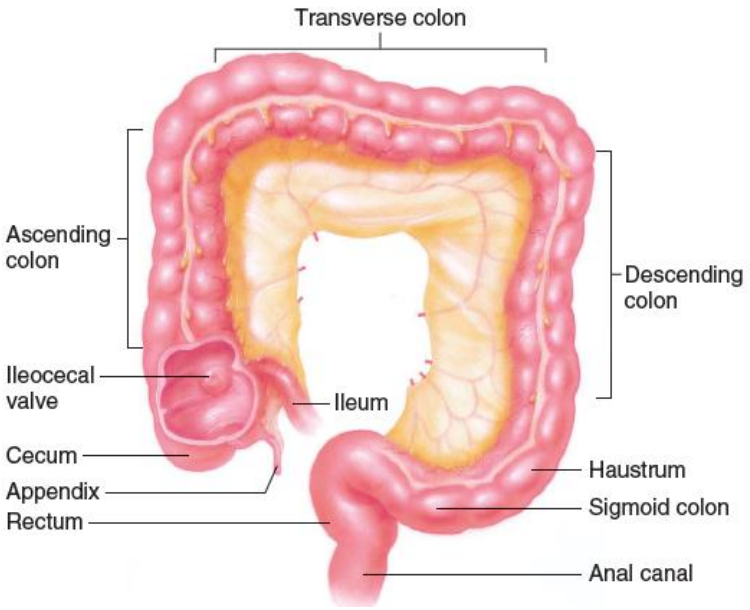

Figure 1 **The large intestine.** The different regions of the large intestine (colon) are illustrated.

Fluid and Electrolyte Absorption in the Intestine

The GI tract receives about 1.5 L per day of water from food and drink; additionally, the GI tract secretes 8–10 L/day of fluid into the lumen. This includes contributions from the salivary glands, stomach, intestine, pancreas, liver, and gallbladder. The small intestine both secretes and absorbs water accompanying different transport processes, but these are not in balance. The small intestine secretes about 1 L per day but absorbs most of the fluid in the chyme. As a result, only about 2 L per day of fluid pass into the large intestine. The large intestine absorbs about 90% of this remaining volume, leaving less than 200 ml of fluid to be excreted in the feces.

Absorption of water in the intestine occurs passively as a result of the osmotic gradient created by the active transport of ions. The epithelial cells of the intestinal mucosa are joined together much like those of the kidney tubules and, like the kidney tubules, contain Na^+ /K^+ pumps in the basolateral membrane. The analogy with kidney tubules is emphasized by the observation that aldosterone, which stimulates salt and water reabsorption in the

renal tubules, also appears to stimulate salt and water absorption in the ileum.

The handling of salt and water transport in the large intestine is made more complex by the ability of the large intestine to secrete, as well as absorb, water. The secretion of water by the mucosa of the large intestine occurs by osmosis as a result of the active transport of Na^+ or Cl^- out of the epithelial cells into the intestinal lumen. Secretion in this way is normally minor compared to the far greater amount of salt and water absorption, but this balance may be altered in some disease states.

LIVER, GALLBLADDER, AND PANCREAS

The liver regulates the chemical composition of the blood in numerous ways. In addition, the liver produces and secretes bile, which is stored and concentrated in the gallbladder prior to its discharge into the duodenum. The pancreas produces pancreatic juice, an exocrine secretion containing bicarbonate and important digestive enzymes.

The *liver* is positioned immediately beneath the diaphragm in the abdominal cavity. It is the largest internal organ, weighing about 1.3 kg (3.5 to 4.0 lb) in an adult. Attached to the inferior surface of the liver, between its right and quadrate lobes, is the pear-shaped *gallbladder.* This organ is approximately 7 to 10 cm (3 to 4 in.) long. The *pancreas,* which is about 12 to 15 cm (5 to 6 in.) long, is located behind the stomach along the posterior abdominal wall.

Structure of the Liver

Although the liver is the largest internal organ, it is, in a sense, only one to two cells thick. This is because the liver cells, or hepatocytes, form hepatic plates that are one to two cells thick. The plates are separated from each other by large capillary spaces called sinusoids (fig.2). The liver sinusoids are lined by

endothelial cells with flattened processes and fenestrae — openings 150 to 175 nanometers in diameter that make the sinusoids very porous. Unlike the fenestrated capillaries of the kidneys and pancreas, the fenestrae of the hepatic sinusoids lack a diaphragm and a basement membrane. This makes the hepatic sinusoids much more permeable than other capillaries, even permitting the passage of plasma proteins with protein-bound nonpolar molecules such as fat and cholesterol. The sinusoids also contain phagocytic Kupffer cells, which are part of the reticuloendothelial system. The fenestrae, lack of a basement membrane, and plate structure of the liver allow intimate contact between the hepatocytes and the contents of the blood.

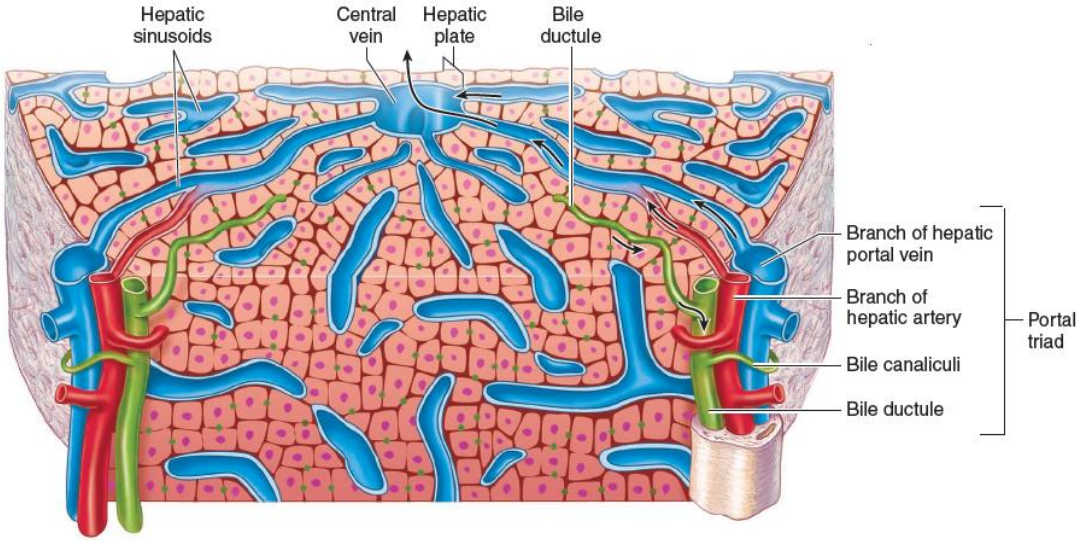

Figure 2 **Microscopic structure of the liver.**

Hepatic Portal System

The products of digestion that are absorbed into blood capillaries in the intestine do not directly enter the general circulation. Instead, this blood is delivered first to the liver. Capillaries in the digestive tract drain into the hepatic portal vein, which carries this blood to capillaries in the liver. It is not until the blood has passed through this second capillary bed that it enters the general

circulation through the hepatic vein that drains the liver. The term **portal system** is used to describe this unique pattern of circulation: capillaries ⇒ vein ⇒ capillaries ⇒ vein. In addition to receiving venous blood from the intestine, the liver also receives arterial blood via the *hepatic artery*.

The hepatic portal vein drains the capillaries of the intestine, pancreas, gallbladder, and spleen, and accounts for about 75% to 80% of the blood flow to the liver. Because it contains blood coming from the intestine, the hepatic portal vein delivers nutrients and other absorbed molecules to the liver. The hepatic artery supplies the remaining 20% to 25% of the liver's incoming blood flow; however, this arterial blood flow is adjusted to compensate for changes in the blood flow through the hepatic portal vein. As a result, the total hepatic blood flow is maintained at about 25% of the cardiac output. This relatively constant hepatic blood flow is needed to maintain hepatic clearance —the ability of the liver to remove substances from the blood.

Liver Lobules

The hepatic plates are arranged into functional units called liver lobules (figs. 2 and 3). In the middle of each lobule is a central vein, and at the periphery of each lobule are branches of the hepatic portal vein and of the hepatic artery, both of which open into the sinusoids between hepatic plates. Arterial blood mixes with portal venous blood containing molecules absorbed by the GI tract, and this mixed blood travels within the sinusoids from the periphery of the lobule to the central vein. The central veins of different liver lobules converge to form the hepatic vein, which carries blood from the liver to the inferior vena cava.

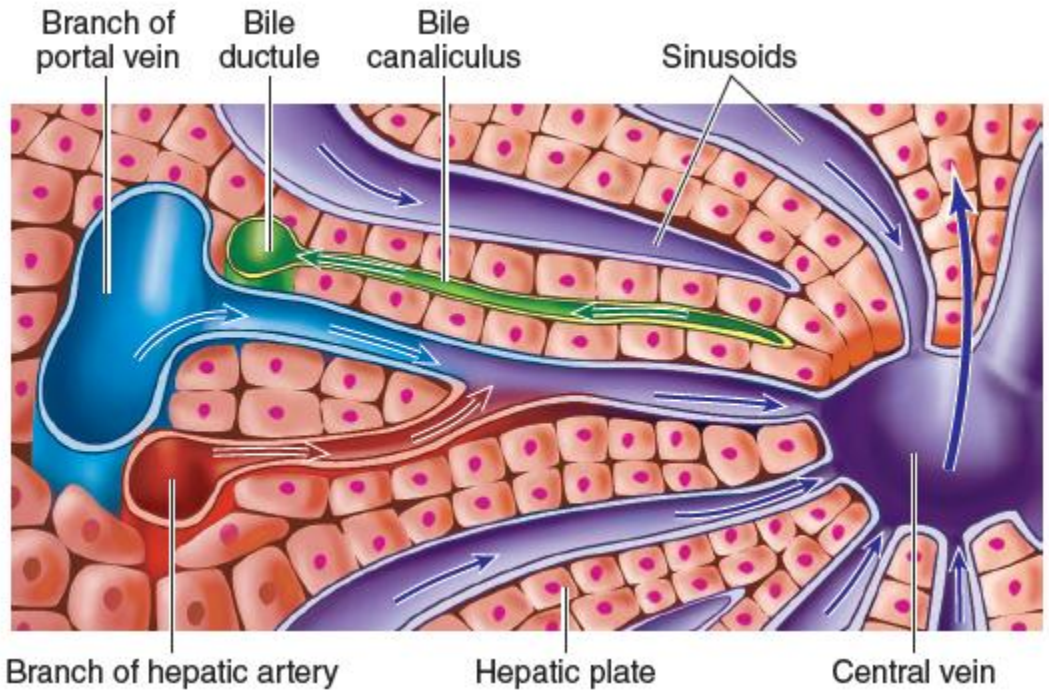

Figure 3 **The flow of blood and bile in a liver lobule.**

Functions of the Liver

1- Detoxication of Blood

- Phagocytosis by Kupffer cells.
- Chemical alteration of biologically active molecules (hormones and drugs).
- Production of urea, uric acid, and other molecules that are less toxic than parent compounds
- Excretion of molecules in bile.

2- Carbohydrate Metabolism

- Conversion of blood glucose to glycogen and fat
- Production of glucose from liver glycogen and from other molecules (amino acids, lactic acid) by gluconeogenesis.
- Secretion of glucose into the blood.

3- Lipid Metabolism

- Synthesis of triglycerides and cholesterol
- Excretion of cholesterol in bile

- Production of ketone bodies from fatty acids.

4- Protein Synthesis
- Production of albumin
- Production of plasma transport proteins
- Production of clotting factors (fibrinogen, prothrombin, and others).

5- Secretion of Bile
-Synthesis of bile salts
-Conjugation and excretion of bile pigment (bilirubin).

Gallbladder

The gallbladder is a saclike organ attached to the inferior surface of the liver. This organ stores and concentrates bile, which drains to it from the liver by way of the bile ducts, hepatic ducts, and cystic duct, respectively. A sphincter valve at the neck of the gallbladder allows a 35- to 100-ml storage capacity. When the gallbladder fills with bile, it expands to the size and shape of a small pear. Bile is a yellowish green fluid containing bile salts, bilirubin, cholesterol, and other compounds, as previously discussed. Contraction of the muscularis layer of the gallbladder ejects bile through the cystic duct into the common bile duct, which conveys bile into the duodenum (fig. 4).

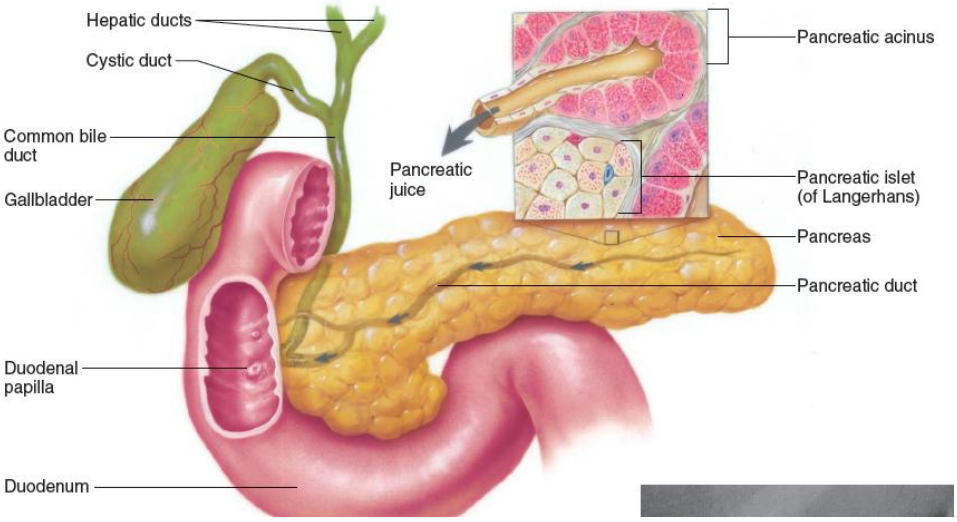

Figure 4 **Pancreatic juice and bile are secreted into the duodenum.**

Pancreas

The pancreas is a soft, glandular organ that has both exocrine and endocrine functions (fig. 5). The endocrine function is performed by clusters of cells called the pancreatic islets, or islets of Langerhans (fig. 5 a), that secrete the hormones insulin and glucagon into the blood. As an exocrine gland, the pancreas secretes pancreatic juice through the pancreatic duct into the duodenum. Within the lobules of the pancreas are the exocrine secretory units, called acini (fig. 5 b). Each acinus consists of a single layer of acinar epithelial cells surrounding a lumen, into which the constituents of pancreatic juice are secreted.

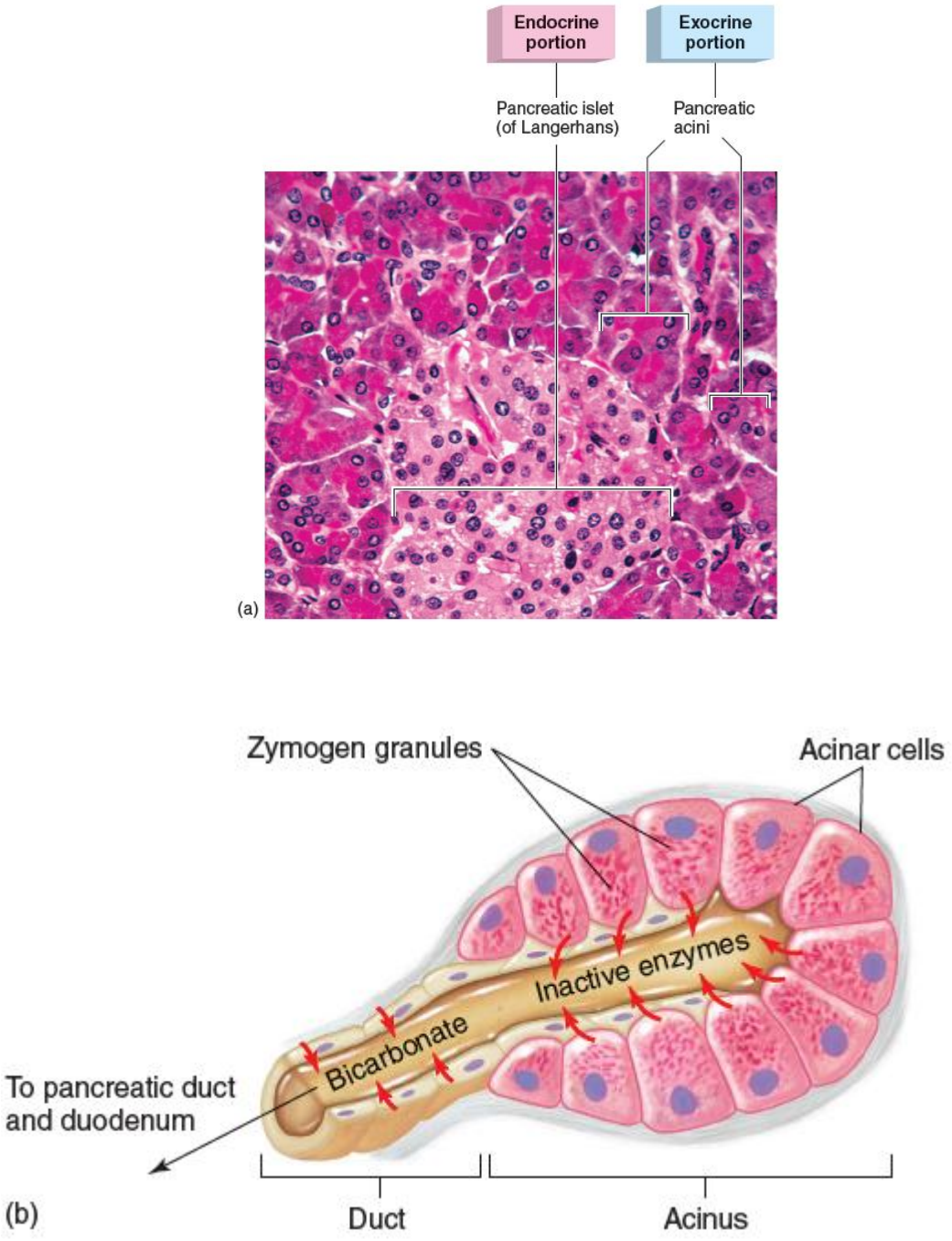

Figure 5 **The pancreas is both an exocrine and an endocrine gland.** (*a*) A photomicrograph of the endocrine and exocrine portions of the pancreas. (*b*) An illustration depicting the exocrine pancreatic acini, where the acinar cells produce inactive enzymes stored in zymogen granules

Pancreatic Juice

Pancreatic juice contains bicarbonate and about 20 different digestive enzymes. These enzymes include (1) amylase, which digests starch; (2) trypsin, which digests protein; and (3) lipase,

which digests triglycerides. Other pancreatic enzymes are listed in table 2. It should be noted that the complete digestion of food molecules in the small intestine requires the action of both pancreatic enzymes and brush border enzymes. The pancreatic acini secrete inactive enzymes in an isotonic saline solution, while the cells that line the ductules absorb the Cl^- and secrete bicarbonate (fig. 5 b). As a result, pancreatic juice contains only about 20 mM Cl^- compared to 140 mM HCO_3^- . Water follows the bicarbonate, so the ductules are responsible for secreting most of the volume of the 1–2 liters of pancreatic juice per day. The majority of the bicarbonate secreted by ductule cells is obtained from the plasma using a Na^+/ HCO_3^- cotransport carrier (fig. 6). Bicarbonate is also formed from the dissociation of carbonic acid, which is produced from CO_2 and H_2O in a reaction catalyzed by carbonic anhydrase.

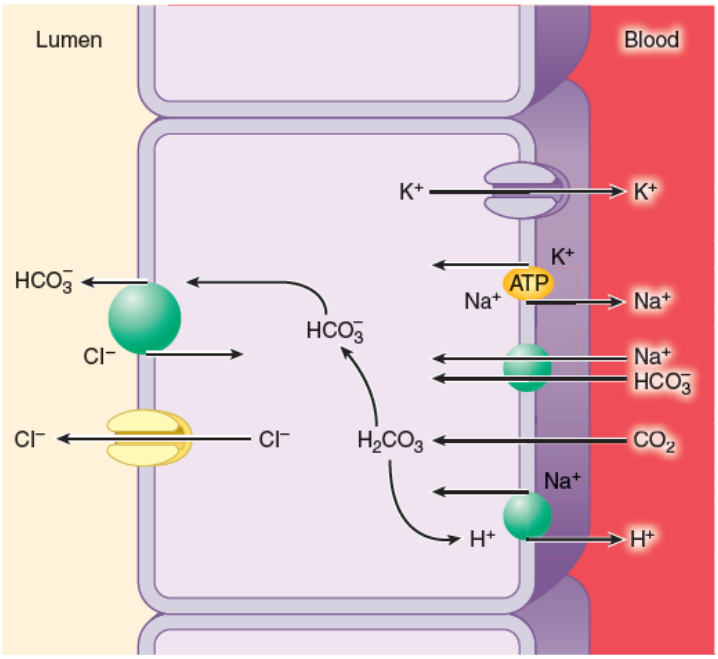

Figure 6 **Secretion of bicarbonate into pancreatic juice.**

Most pancreatic enzymes are produced as inactive molecules, or *zymogens*, so that the risk of self-digestion within the pancreas is minimized. The inactive form of trypsin, called trypsinogen, is activated within the small intestine by the catalytic action of the

brush border enzyme enterokinase (also called enteropeptidase). Enterokinase converts trypsinogen to active trypsin. Trypsin, in turn, activates the other zymogens of pancreatic juice (fig. 9) by cleaving off polypeptide sequences that inhibit the activity of these enzymes.

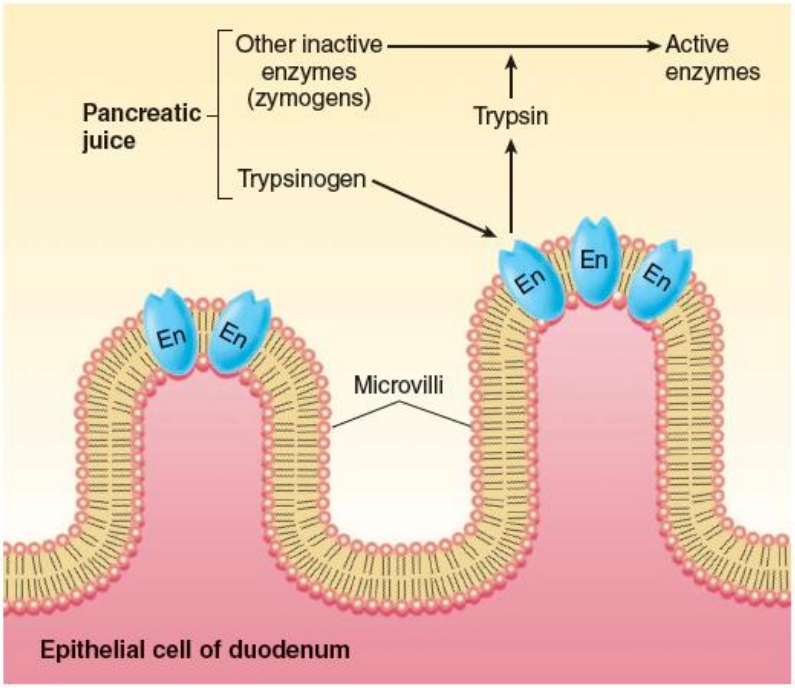

Figure 9 **The activation of pancreatic juice enzymes.**

Table 2 | Enzymes Contained in Pancreatic Juice

Enzyme	Zymogen	Activator	Action
Trypsin	Trypsinogen	Enterokinase	Cleaves internal peptide bonds
Chymotrypsin	Chymotrypsinogen	Trypsin	Cleaves internal peptide bonds
Elastase	Proelastase	Trypsin	Cleaves internal peptide bonds
Carboxypeptidase	Procarboxypeptidase	Trypsin	Cleaves last amino acid from carboxyl-terminal end of polypeptide
Phospholipase	Prophospholipase	Trypsin	Cleaves fatty acids from phospholipids such as lecithin
Lipase	None	None	Cleaves fatty acids from glycerol
Amylase	None	None	Digests starch to maltose and short chains of glucose molecules
Cholesterolesterase	None	None	Releases cholesterol from its bonds with other molecules
Ribonuclease	None	None	Cleaves RNA to form short chains
Deoxyribonuclease	None	None	Cleaves DNA to form short chains

-Reference

Fox, S. I. (2014). Fox Human Physiology.

.