Course: Animal form and function

NUTRITION AND DIGESTION

- Animal strategies for getting and using food
- Diversity in digestive structures of invertebrate and vertebrates
- The mammalian digestive system

THE MAMMALIAN DIGESTIVE SYSTEM

The process of digesting and absorbing nutrients in a mammal includes:

1) Ingestion—eating

2) Peristalsis—the involuntary, sequential muscular contractions that move ingested nutrients along the digestive tract

3) Segmentation—mixing the contents in the digestive tract

4) Secretion—the release of hormones, enzymes, and specific ions and chemicals that take part in digestion

5) Digestion—the conversion of large nutrient particles or molecules into small particles or molecules.

6) Absorption—the passage of usable nutrient molecules from the small intestine into the bloodstream and lymphatic system for the final passage to body cells.

7) Defecation—the elimination from the body of undigested and unabsorbed material as waste

GASTROINTESTINAL MOTILITY AND ITS CONTROL

- ✓ Most of the mammalian gastrointestinal tract has the same anatomical structure along its entire length
- ✓ From the outside inward is a thin layer of connective tissue called the serosa.
- ✓ This peritoneum lines the entire abdominal cavity and covers all internal organs.
- ✓ Next are the longitudinal smooth-muscle layer and circular smooth-muscle layer.
- ✓ Underneath this muscle layer is the submucosa.
- ✓ The submucosa contains connective tissue, blood, and lymphatic vessels.
- ✓ The mucosa faces the central opening, which is called a lumen

Peristalsis and Segmentation

- ✓ During **peristalsis** food advances through the gastrointestinal tract when the rings of circular smooth muscle contract behind it and relax in front of it.
- ✓ The small and large intestines also have rings of smooth muscles that repeatedly contract and relax, creating an oscillating back-and-forth movement in the same place, called **segmentation**
- ✓ Sphincters also influence the flow of material through the gastrointestinal tract and prevent backflow.
- ✓ Control of gastrointestinal activity is based on the volume and composition of food in the lumen of the gut.
- ✓ Signals from mechanical and chemical stimuli travel through nerve plexuses in the gut wall to control the muscular contraction that leads to peristalsis and segmentation, as well as the secretion of various substances (e.g., mucus, enzymes) into the gut lumen.
- ✓ In addition to this local control, long-distance nerve pathways connect the receptors and effectors with the central nervous system. Either or both of these pathways function to maintain homeostasis in the gut.
- ✓ The endocrine cells of the gastrointestinal tract also produce hormones that help regulate secretion, digestion, and absorption.

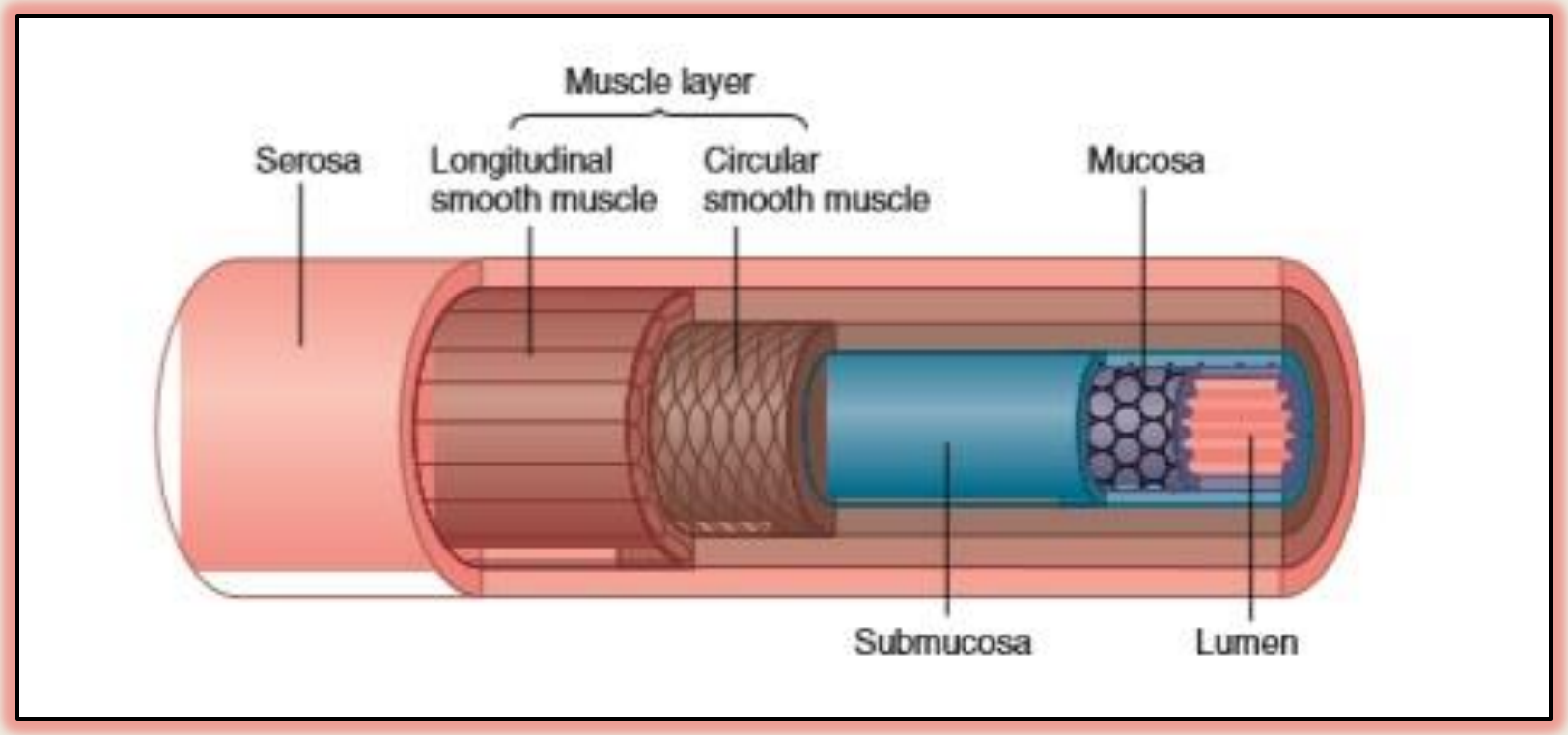


Fig: Mammalian Gastrointestinal Tract. Common structural layers of the gastrointestinal tract. The central lumen extends from the mouth to the anus

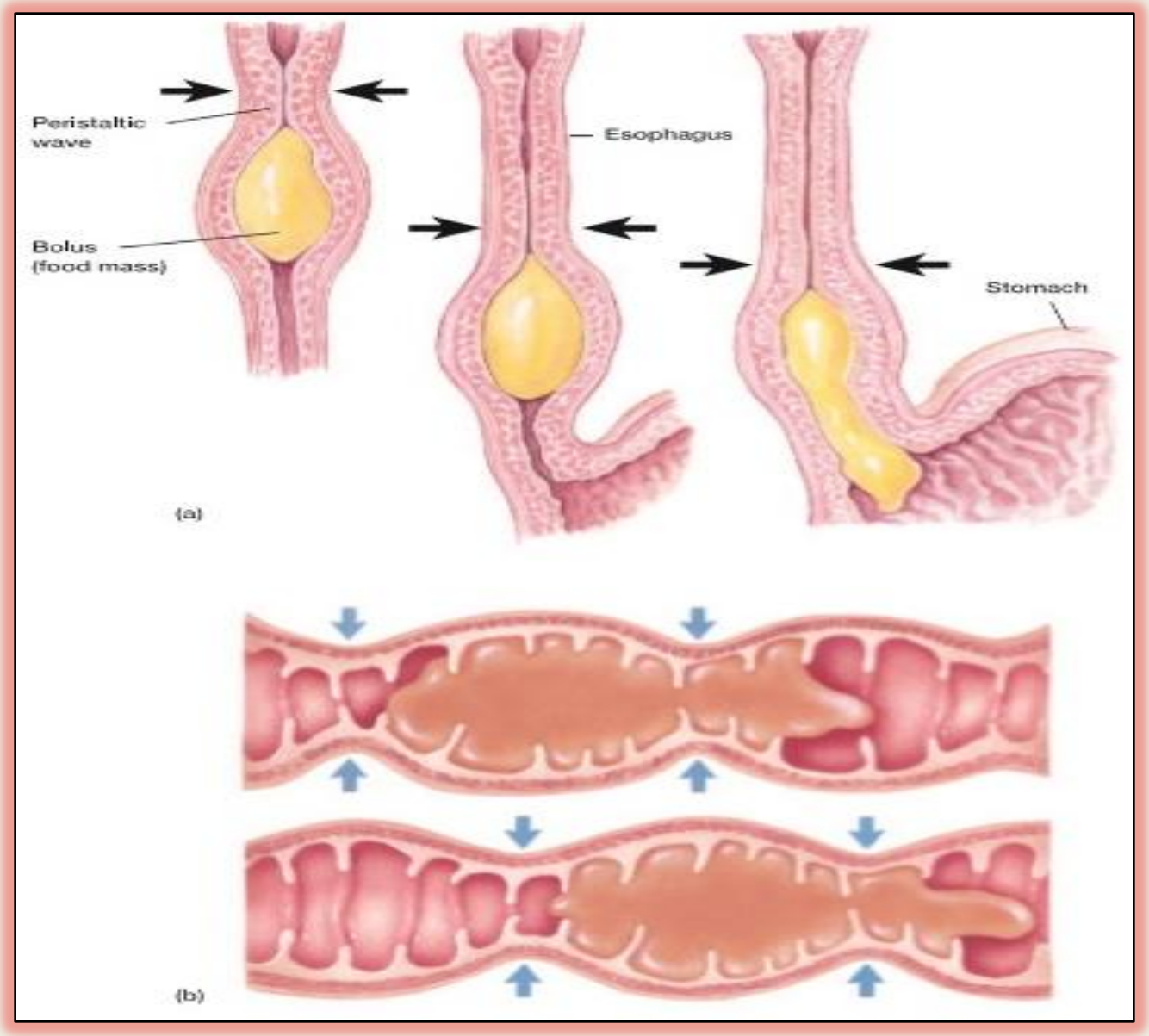


Fig: Peristalsis and Segmentation. (a) Peristaltic waves move food through the esophagus to the stomach. (b) In segmentation, simultaneous muscular contractions of many sections of the intestine (blue arrows) help mix nutrients with digestive secretions

ORAL CAVITY

- A pair of lips protects the oral cavity(mouth).
- The lips are highly vascularized, skeletal muscle tissue with an abundance of sensory nerve endings.
- Lips help retain food as it is being chewed and play a role in phonation
- The oral cavity contains the tongue and teeth.
- Mammals can mechanically process a wide range of foods because their teeth are covered with enamel and because their jaws and teeth exert a strong force.
- The oral cavity is continuously bathed by saliva, a watery fluid that at least three pairs of salivary glands secrete.
- Saliva moistens food, binds it with **mucins** (glycoproteins), and forms the ingested food into a moist mass called a bolus.
- Saliva also contains **bicarbonate ions (HCO3),** which buffer chemicals in the mouth, and **thiocyanate ions (SCN)** and the enzyme **lysozyme**, which kill microorganisms.
- It also contributes an **enzyme (amylase)** necessary for the initiation of carbohydrate digestion.

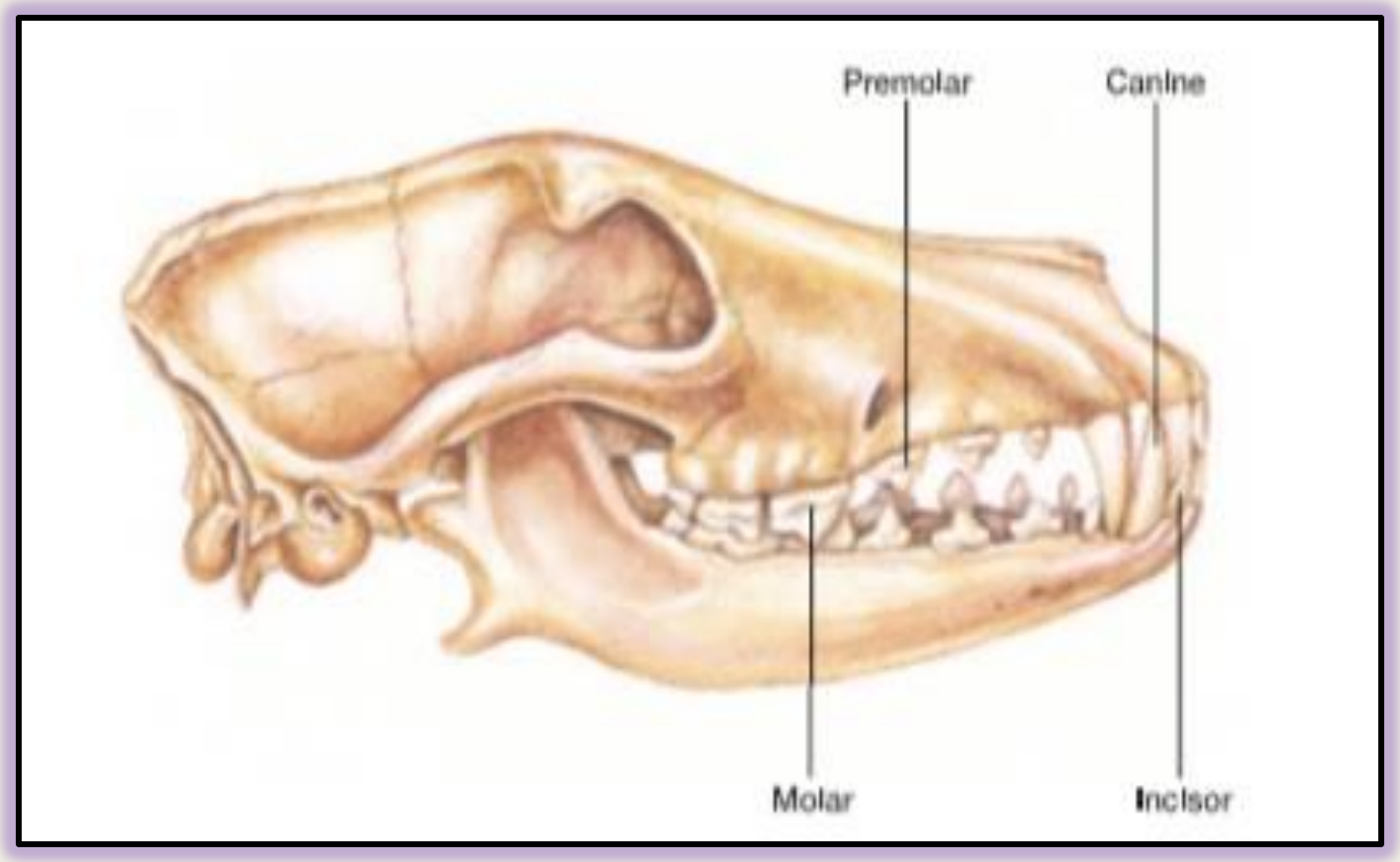


Fig: Teeth. (a) The teeth of a carnivore, such as this wolf, are specialized for slicing, puncturing, tearing, and grinding animal flesh. (b) Anatomy of a typical mammalian tooth.

PHARYNX AND ESOPHAGUS

- The epiglottis temporarily seals off the opening (glottis) to the trachea so that swallowed food does not enter the trachea.
- Initiation of the swallowing reflex can be voluntary, but most of the time it is involuntary.
- When swallowing begins, sequential, involuntary contractions of smooth muscles in the walls of the esophagus propel the bolus or liquid to the stomach.
- Neither the pharynx nor the esophagus contribute to digestion.

STOMACH

The mammalian stomach is a muscular, distensible sac with three main functions.

(1) It stores and mixes the food bolus received from the esophagus,

(2) secretes substances (enzymes, mucus, and hydrochloric acid [HCl]) that start the digestion of proteins

(3) It helps control the rate at which food moves into the small intestine via the pyloric sphincter

Structure of Stomach

- The stomach is made up of an inner mucous membrane containing thousands of gastric glands.
- Three types of cells are in these glands.

- **Parietal cells** secrete a solution containing HCl, and **chief cells** secrete pepsinogen, the precursor of the enzyme pepsin. Both of the cells are in the pits of the gastric glands.
- The surface of the mucous membrane at the openings of the glands contains numerous **mucous cells** that secrete mucus that coats the surface of the stomach and protects it from the HCl and digestive enzymes.
- The surfaces of the upper gastrointestinal tract—the esophagus and mouth—have a much thinner mucous-cell layer than the stomach.
- **Endocrine cells** in one part of the stomach mucosa release the hormone **gastrin**, which travels to target cells in the gastric glands, further stimulating them.

Function of Stomach

- ✓ When the bolus of food enters the stomach, it distends the walls of the stomach.
- ✓ The gastric pits to secrete HCl (as H and Cl) and pepsinogen.
- ✓ The H ions cause pepsinogen to be converted into the active enzyme pepsin.
- ✓ pepsin, mucus, and HCl mix with and begin to break down proteins
- ✓ About three to four hours after a meal, the stomach contents have been sufficiently mixed and are a semiliquid mass called chyme.
- ✓ The pyloric sphincter regulates the release of the chyme into the small intestine.
- ✓ When the stomach is empty, peristaltic waves cease; however, after about 10 hours of fasting, new waves may occur in the upper region of the stomach.

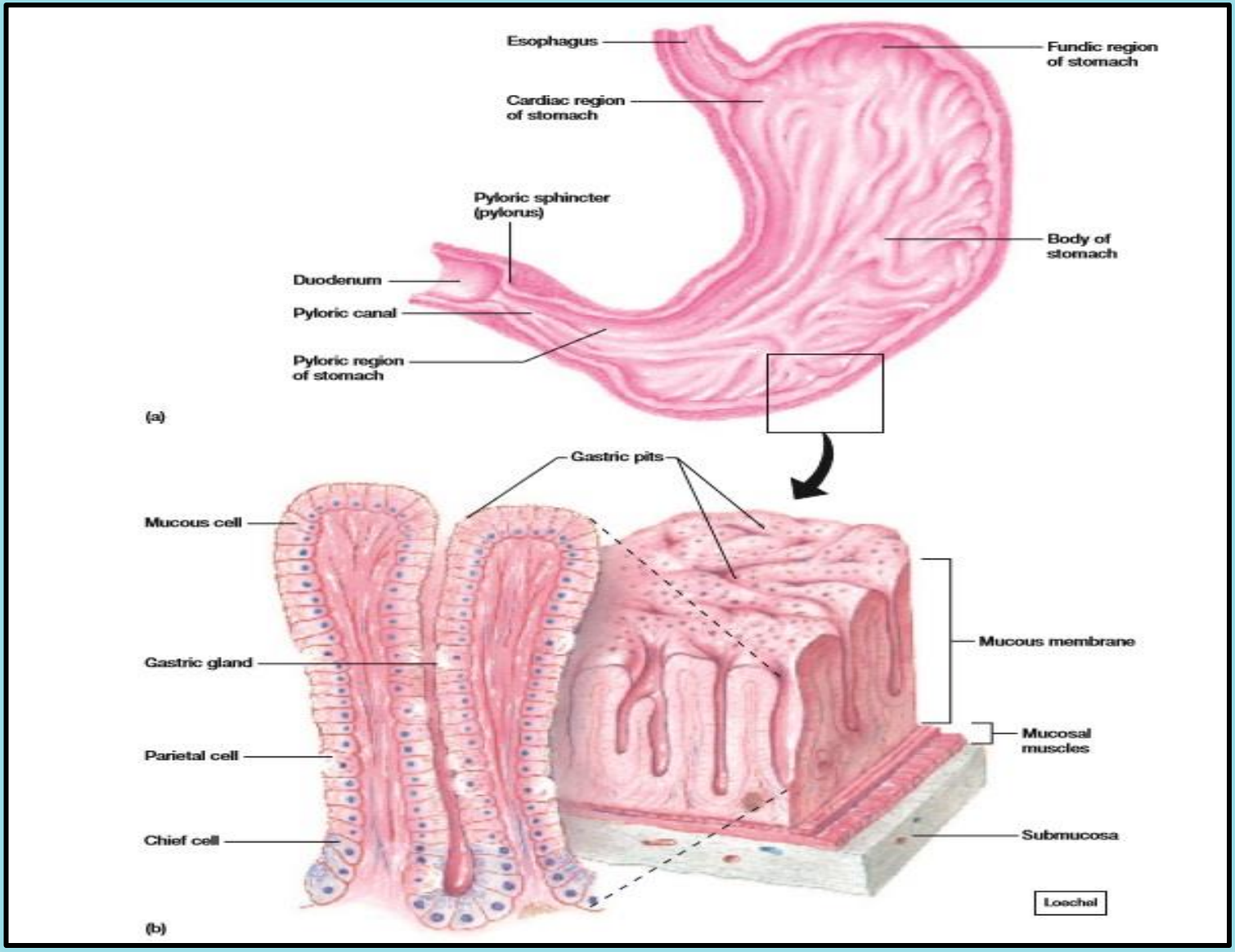


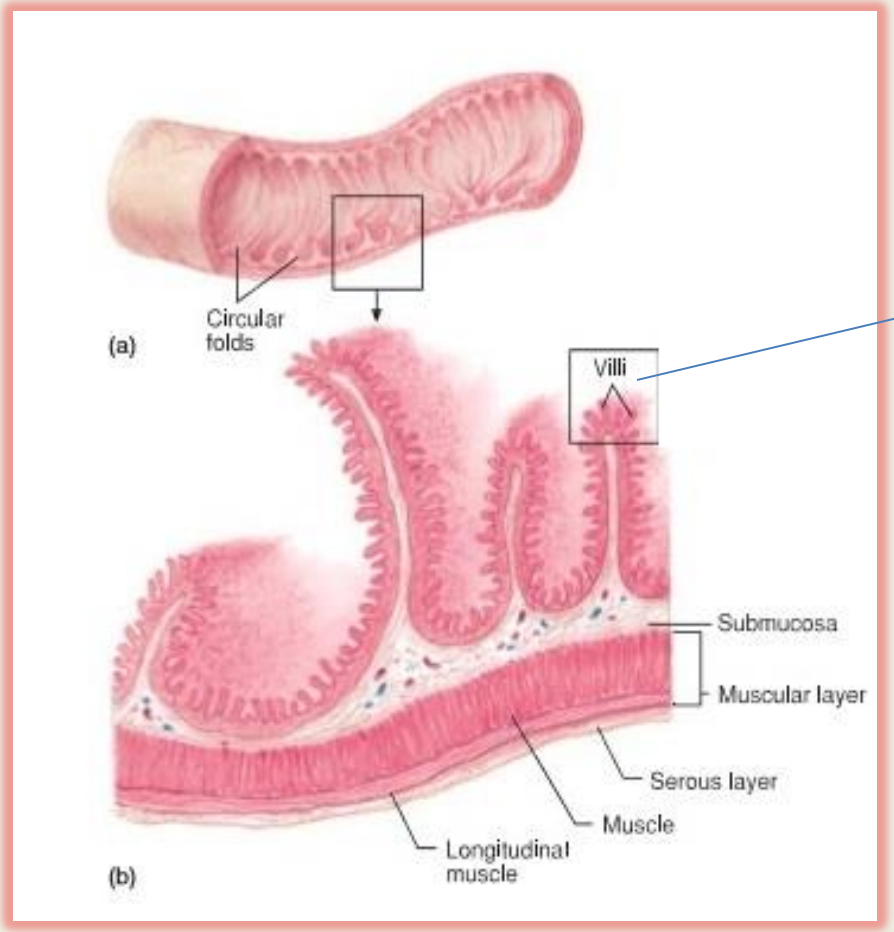
Fig: Stomach. (a) Food enters the stomach from the esophagus. (b) Gastric glands cover the mucosa of the stomach and include mucous cells, parietal cells, and chief cells. Each type produces a different secretion.

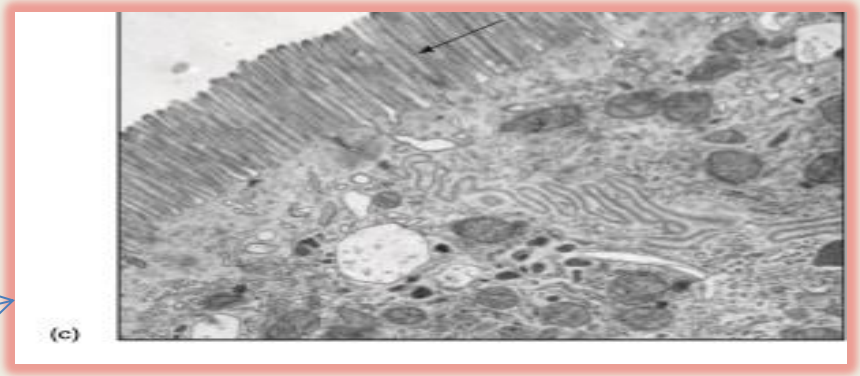
SMALL INTESTINE: MAIN SITE OF DIGESTION

- ✓ Most of the food a mammal ingests is digested and absorbed in the small intestine.
- ✓ The human small intestine is about 4 cm in diameter and 7 to 8 m in length.
- ✓ The length of the small intestine directly relates to the total surface area available for absorbing nutrients, as determined by the many circular folds and minute projections of the inner gut surface.
- ✓ On the circular folds, thousands of fingerlike projections called villi project from each square centimeter of mucosa.
- ✓ Simple columnar epithelial cells, each bearing numerous microvilli, cover both the circular folds and villi.

Structure and Function of Small Intestine:

- ✓ The first part of the small intestine, called the duodenum, the next part is the jejunum, and the last part is the ileum.
- ✓ The duodenum contains many digestive enzymes that intestinal glands in the duodenal mucosa secrete.
- ✓ The jejunum and ileum absorb the end products of digestion (amino acids, simple sugars, fatty acids, glycerol, nucleotides, water).
- ✓ Sugars and amino acids are absorbed into the capillaries of the villi, whereas free fatty acids enter the epithelial cells of the villi and recombine with glycerol to form triglycerides.
- ✓ The triglycerides are coated with proteins to form small droplets called chylomicrons, which enter the lacteals of the villi.
- ✓ From the lacteals, the chylomicrons move into the lymphatics and eventually into the bloodstream for transport throughout the body.





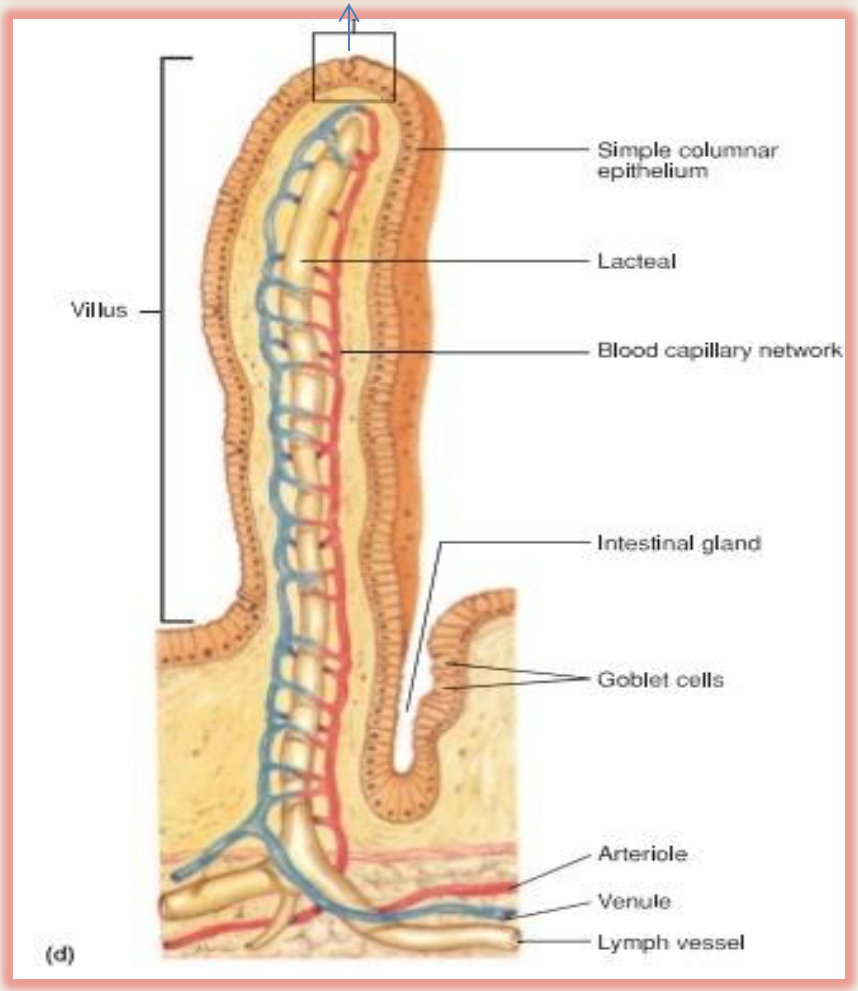


Fig: Small Intestine. The small intestine absorbs food over a large surface area. (a) The lining of the intestine has many circular folds. (b,d) Fingerlike villi line the intestine. A single villus contains a central capillary network and a lymphatic lacteal, both of which transport nutrients absorbed from the lumen of the intestine. (c) The plasma membrane of the simple columnar epithelial cells covering the villi fold into microvilli (arrow), which further increase the surface area facing the lumen.

LARGE INTESTINE

- ✓ The large intestine has no circular folds, villi, or microvilli; thus, the surface area is much smaller.
- ✓ The small intestine joins the large intestine near a blind-ended sac, the cecum.
- ✓ The human cecum and its extension, the appendix, are storage sites and possibly represent evolutionary remains of a larger, functional cecum, such as is found in herbivores.
- ✓ The appendix contains an abundance of lymphoid tissue and may function as part of the immune system.
- ✓ Many bacteria and fungi exist symbiotically in the large intestine. They feed on the food residue and further break down its organic molecules to waste products.
- ✓ In turn, they secrete amino acids and vitamin K, which the host's gut absorbs.

Function of large intestine

- ✓ The major functions of the large intestine include the reabsorption of water and minerals, and the formation and storage of feces.
- ✓ As peristaltic waves move food residue along, minerals diffuse or are actively transported from the residue across the epithelial surface of the large intestine into the bloodstream.
- ✓ Water follows osmotically and returns to the lymphatic system and bloodstream.
- ✓ When water reabsorption is insufficient, diarrhea results.
- ✓ If too much water is reabsorbed, fecal matter becomes too thick, resulting in constipation.

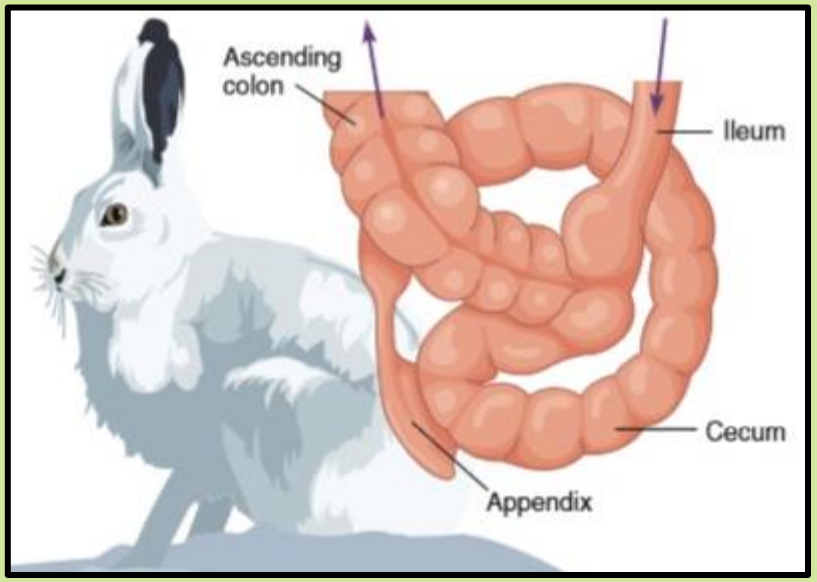


Fig: Extensive Cecum of a Non ruminant Herbivore, Such as a Rabbit.

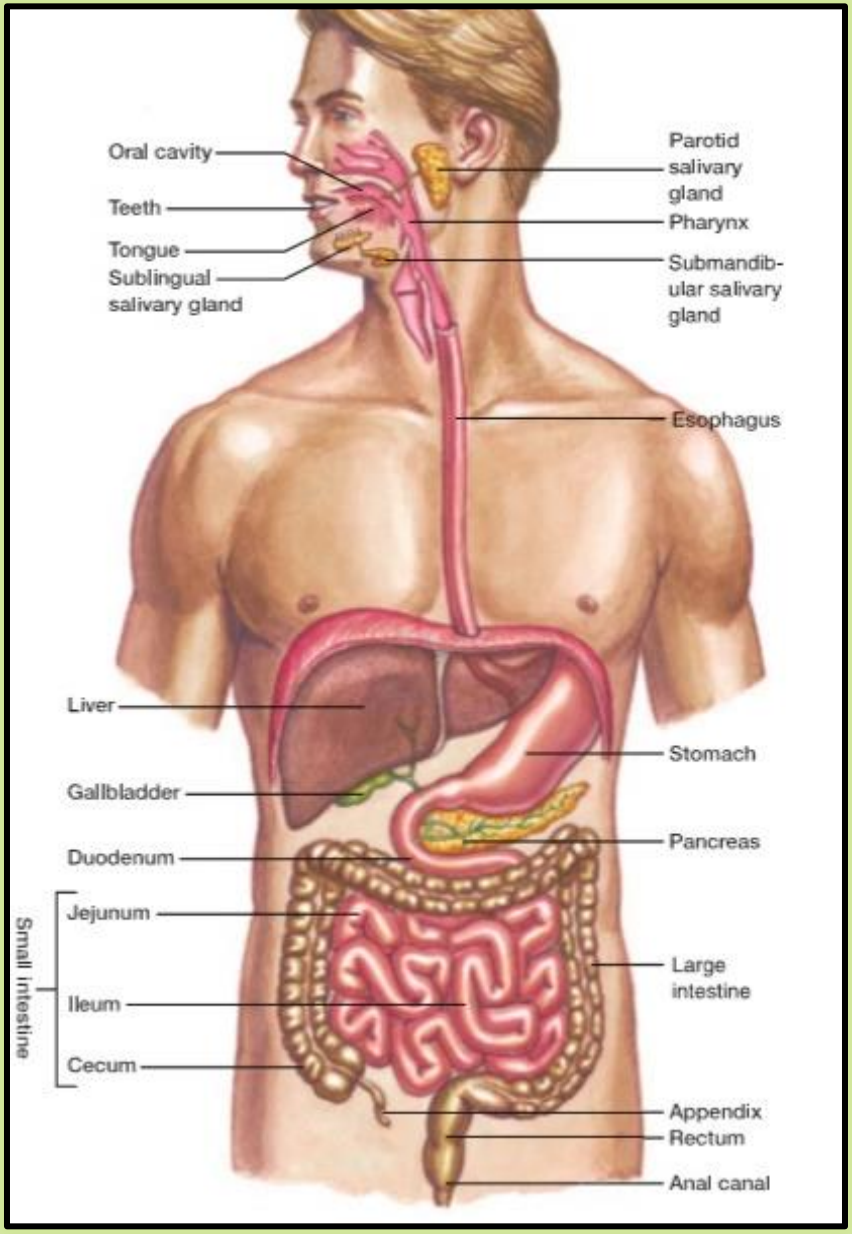


Fig: Major Organs and Parts of the Human Digestive System

ROLE OF THE PANCREAS IN DIGESTION

- The pancreas (Gr. pan, all kreas, flesh) is an organ that lies just ventral to the stomach and has both endocrine and exocrine functions.
- Exocrine cells in the pancreas secrete digestive enzymes into the pancreatic duct, which merges with the hepatic duct from the liver to form a common bile duct that enters the duodenum.
- Pancreatic enzymes complete the digestion of carbohydrates and proteins and initiate the digestion of lipids.
- Trypsin, carboxypeptidase, and chymotrypsin digest proteins into small peptides and individual amino acids.
- Pancreatic lipases split triglycerides into smaller, absorbable glycerol and free fatty acids.
- Pancreatic amylase converts polysaccharides into disaccharides and monosaccharides.
- The pancreas also secretes bicarbonate (HCO_3) ions that help neutralize the acidic food residue coming from the stomach.
- Bicarbonate raises the pH from **2 to 7** for optimal digestion. Without such neutralization, pancreatic enzymes could not function.

MAJOR DIGESTIVE GLANDS, SECRETIONS, AND ENZYMES IN MAMMALS

PLACE OF DIGESTION	SOURCE	SECRETION	ENZYME	DIGESTIVE FUNCTION
Mouth	Salivary glands	Saliva	Salivary amylase	Begins the digestion of carbohydrates; inactivated by stomach HCl
	Mucous glands	Mucus	—	Lubricates food bolus
Esophagus	Mucous glands	Mucus	—	Lubricates food bolus
Stomach	Gastric glands	Gastric juice	Lipase	Digests lipids into fatty acids and glycerol
			Pepsin	Digests proteins into polypeptides
	Gastric mucosa	HCl	—	Converts pepsinogen into active pepsin; kills microorganisms
	Mucous glands	Mucus	—	Lubricates
Small intestine	Liver	Bile	—	Emulsifies lipids; activates lipase
	Pancreas	Pancreatic juice	Amylase	Digests starch into maltose
			Chymotrypsin	Digests proteins into peptides and amino acids
			Lipase	Digests lipids into fatty acids and glycerol (requires bile salts)
			Nuclease	Digests nucleic acids into mononucleotides
			Trypsin	Digests proteins into peptides and amino acids
	Intestinal glands	Intestinal juice	Enterokinase	Digests inactive trypsinogen into active trypsin
			Lactase	Digests lactose into glucose and galactose
			Maltase	Digests maltose into glucose
			Peptidase	Digests polypeptides into amino acids
			Sucrase	Digests sucrose into glucose and fructose
	Mucous glands	Mucus	—	Lubricates
Large intestine	Mucous glands	Mucus	—	Lubricates

ROLE OF THE LIVER AND GALLBLADDER IN DIGESTION

Some major metabolic functions of the liver include:

1. Removal of amino acids from organic compounds.
2. Urea formation from proteins and conversion of excess amino acids into urea to decrease body levels of ammonia.
3. Manufacture of most of the plasma proteins, formation of fetal erythrocytes, destruction of worn-out erythrocytes, and synthesis of the blood-clotting agents prothrombin and fibrinogen from amino acids.
4. Synthesis of nonessential amino acids.
5. Conversion of galactose and fructose to glucose.
6. Oxidation of fatty acids.
7. Formation of lipoproteins, cholesterol, and phospholipids (essential cell membrane components).
8. Conversion of carbohydrates and proteins into fat.

9. Modification of waste products, toxic drugs, and poisons (detoxification).

10. Synthesis of vitamin A from carotene, and with the kidneys, participation in the activation of vitamin D.

11. Maintenance of a stable body temperature by raising the temperature of the blood passing through it. Its many metabolic activities make the liver the major heat producer in a mammal's body.

12. Manufacture of bile salts, which are used in the small intestine for the emulsification and absorption of simple fats, cholesterol, phospholipids, and lipoproteins.

13. The liver stores glucose in the form of glycogen, and with the help of insulin and enzymes, converts glycogen back into glucose as the body needs it. The liver also stores fat-soluble vitamins (A, D, E, and K), and minerals, such as iron, from the diet.

The gallbladder

- ✓ The gallbladder is a small organ near the liver.
- ✓ The gallbladder stores the greenish fluid called bile that the liver cells continuously produce.
- ✓ Bile is very alkaline and contains pigments, cholesterol, lecithin, mucin, bilirubin, and bile salts that act as detergents to emulsify fats (form them into droplets suspended in water) and aid in fat digestion and absorption. (Recall that fats are insoluble in water.)
- ✓ Bile salts also combine with the end products of fat digestion to form micelles.
- ✓ Micelles are lipid aggregates (fatty acids and glycerol) with a surface coat of bile salts.

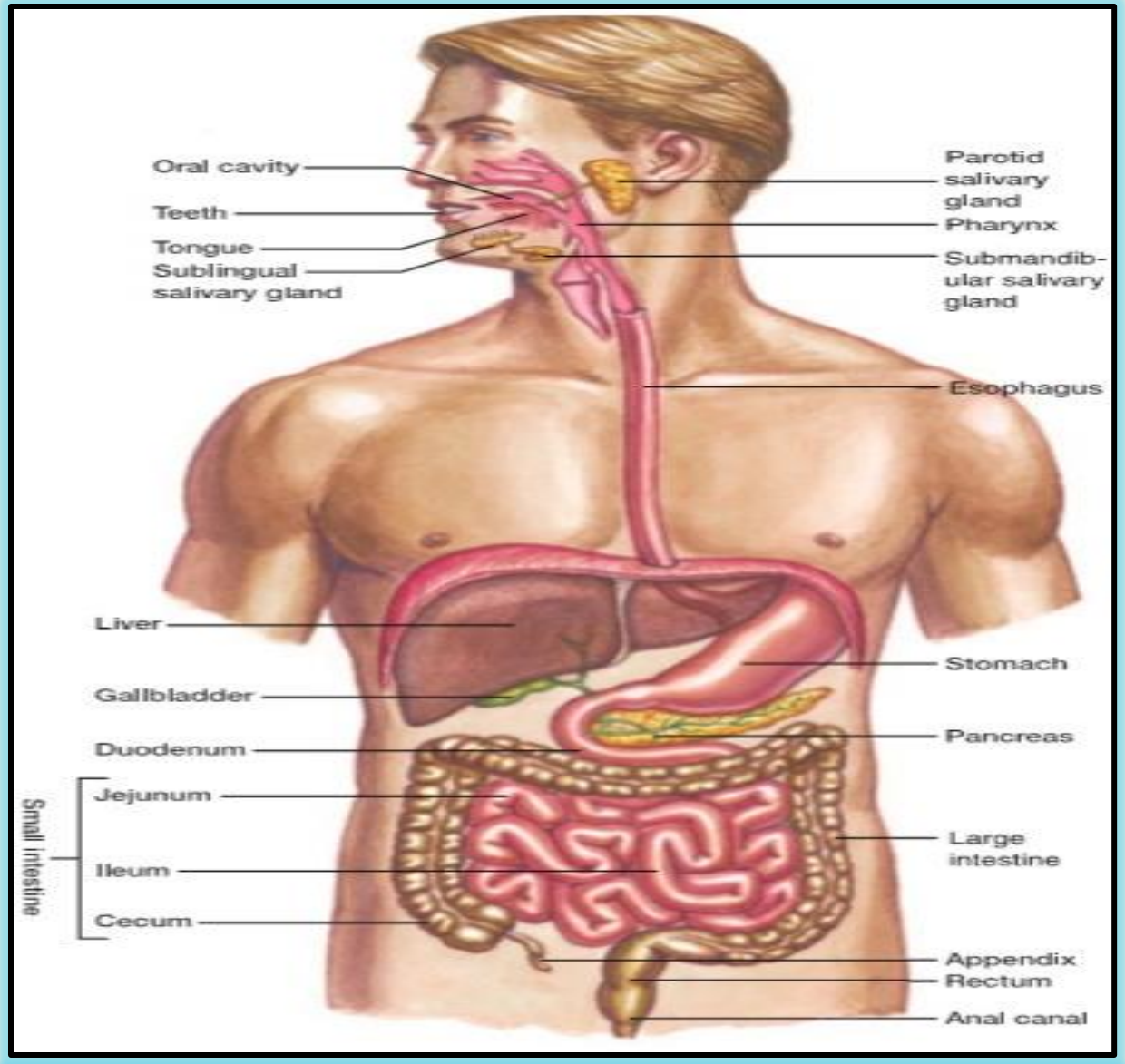


Fig: Major Organs and Parts of the Human Digestive System. Food passes from the mouth through the pharynx and esophagus to the stomach. From the stomach, it passes to the small intestine, where nutrients are broken down and absorbed into the circulatory and lymphatic systems. Nutrients then move to the large intestine, where water is reabsorbed, and feces form. Feces exit the body via the anal canal.