Unit 5: Human Biology

Set by Ahmedrauf A.

5.1 The Digestive System

- Food substances are broken down into small soluble molecules as they pass through the gut.
- Because the **large molecules** cannot be absorbed into bloodstream and used by your body,
- so they need to be broken down into **smaller**, **simpler**, **soluble** molecules.
- The food consumed consists of protein, fat, and complex carbohydrates.

√ The working of your digestive system is based on two things:

① The physical (mechanical) digestion:

√ the food you eat is physically broken down into smaller pieces in two main ways.

> your teeth bite and chew the food up in your mouth.

> your gut, which is a muscular tube, squeezes the food and physically breaks it up, while mixing it with various digestive juices to make it easier to move.

② The chemical breakdown of the food:

√ the large insoluble food molecules must be broken down by hydrolysis rxn into small, soluble molecules so they can be absorbed into your body.

• it is controlled by enzymes.

* Enzymes are proteins that speed up (catalyse) other reactions.

❑ **The human digestive system is composed of four digestive processes:**

1. **Ingestion** - the taking in of nutrients, in the mouth,

2. **Digestion** - the breakdown of complex organic molecules into smaller components by enzymes step-wise, physical, and chemical processes that begins in the oral cavity and extends to the small intestine,

3. **Absorption** - the transport of digested nutrients from the small intestine to the cells of the body though finger like projection called villi in the small intestine, and

4. **Egesting** - the removal of food waste from the body.

- The distinction between excretion and egestion is based on the type of wastes excreted by an organism.
- Undigested food that remains after digestion is expelled in animals during the egestion process.
- **Excretion** is the process through which metabolic wastes are expelled in both plants and animals.

The Oral Cavity

- both physical and chemical digestion begins.
- It is the point of entry (**ingestion**) of food into the digestive system.
- The process that takes place in the mouth includes:

1. the food is broken into smaller particles by **mastication**, the chewing action of the teeth.

2. saliva, the watery fluid produced by the salivary glands contains amylase enzyme, and breaks down starches into simpler molecules.

3. saliva dissolves food particles and makes it possible to taste what is being eaten.

4. saliva lubricates the food so that it can be swallowed.

5. we detect the flavour when food particles dissolved in saliva penetrate the cells of the taste buds located on the tongue and cheeks.

6. the tongue, positions and mixes food and forms a ball of food called bolus ready to be swallowed.

◆ Functions of the Oral Cavity

1. **Sensory analysis**

• Of material before swallowing

2. **Mechanical processing**

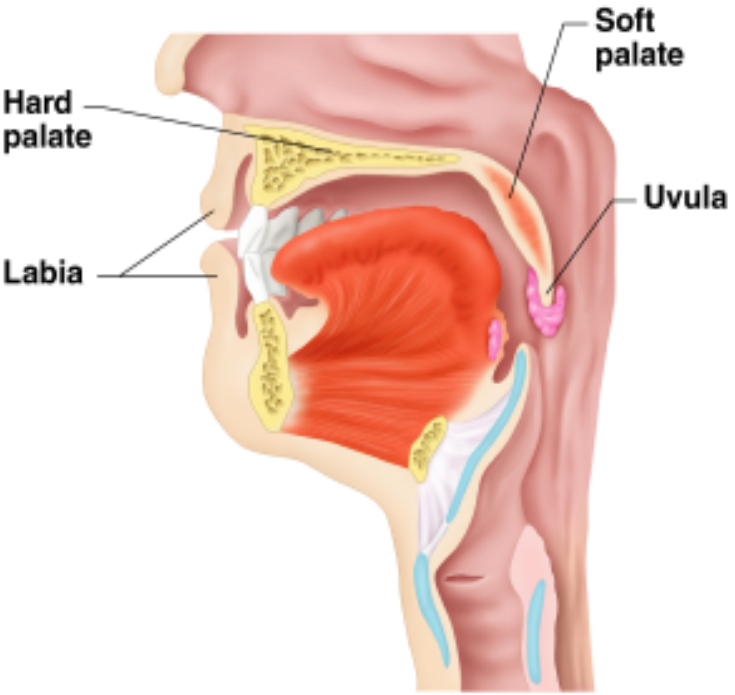
• Through actions of teeth, tongue, and palatal surfaces

3. **Lubrication**

• Mixing with mucus and salivary gland secretions

4. **Limited digestion**

• Of carbohydrates and lipids (enzyme lingual lipase)



The teeth

- The teeth are important structures for physical digestion.
- There are 4 types of teeth:

➢ **Incisors**: are eight chisel-shaped teeth at the front of your mouth specialized for cutting and biting.

➢ **Canine**: teeth that are sharp, dagger-shaped specialized for tearing.

➢ **Premolar**: teeth that are broad flattened specialized for grinding.

➢ **Molars**: teeth tend to be even broader and have cusps that are even more flattened.

- They are designed for crushing and grinding food.

- The last set of molars is the **wisdom teeth**, so-called because they usually do not emerge until we reach about 16 to 20 years of age.
- Each tooth is covered with **enamel**, which is the **hardest** substance in the human body.

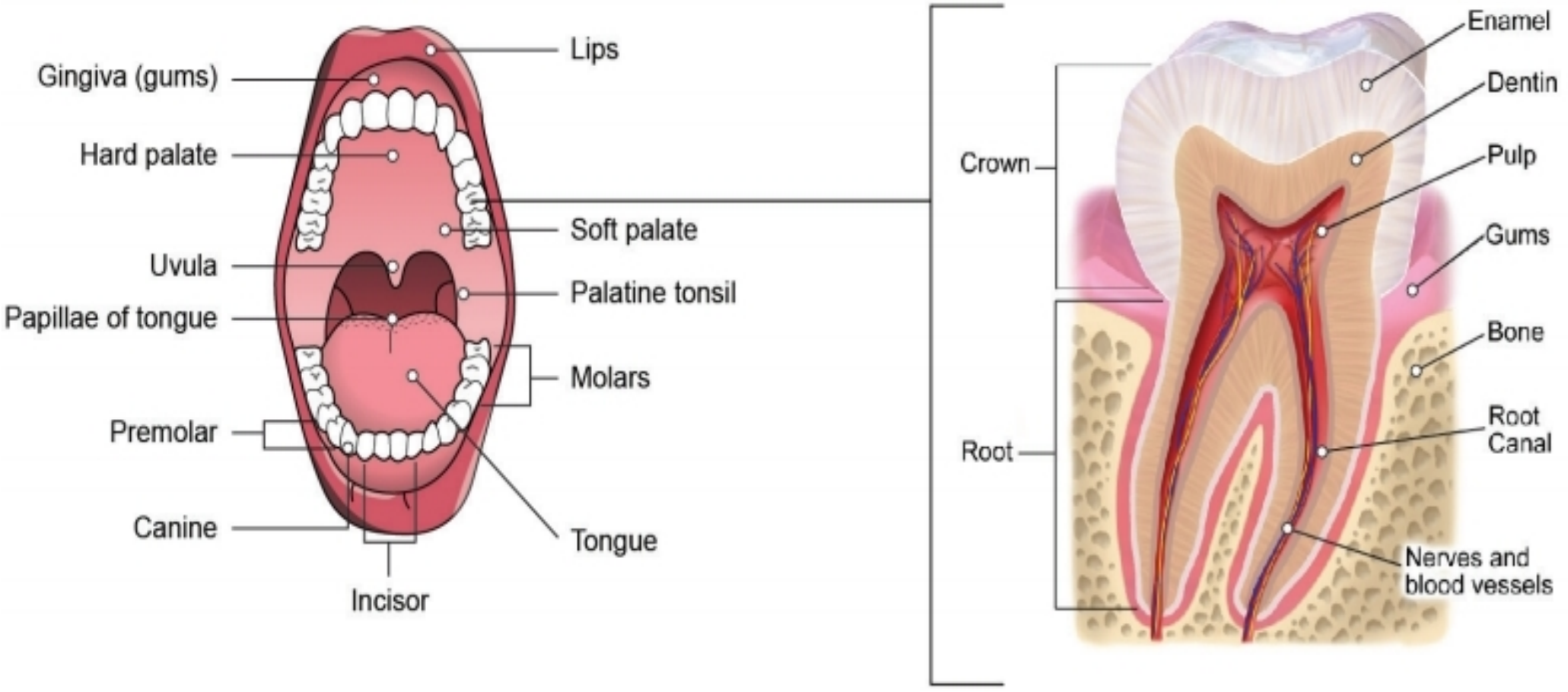


Figure 5.1 The structure and types of teeth

❑ External and internal structures of teeth

- The teeth are the hardest substances in the human body.
- Besides being essential for :

✓ chewing,

✓ play an important role in speech.

❑ Parts of the teeth include:

❖ **Enamel**: the hardest, white outer part of the tooth.

- Enamel is mostly made of calcium phosphate, a rock-hard mineral.

❖ **Dentin**: a layer underlying the enamel.

- It is a hard tissue that contains microscopic tubes.
- When the enamel is damaged, heat or cold can enter the tooth through these paths and cause sensitivity or pain.

❖ **Pulp**: the softer, living inner structure of teeth.

- Blood vessels and nerves run through the pulp of the teeth.

❖ **Periodontal ligament-** tissue that helps to hold the teeth tightly against the jaw.

❖ **Roots** - is the part of the tooth that extends into the bone and holds the tooth in place.

- It makes up approximately two-thirds of the tooth Gums.

❖ **Gums,** also called gingiva, are the fleshy, pink connective tissue that's attached to the neck of the tooth and the **cementum**.

❖ **Crown**: the crown of a tooth is the top portion of the tooth that is visible.

❖ Human dentition

- The conventional way of expressing the total number of teeth in the human beings are represented:
- incisor(I), canines(C), molars(M) and premolars(P).
- It gives a set like I:C:P:M.
- There are 2 incisors, 1 canine, 2 premolars and 3 molars of the upper mouth on one side.
- The dental formula of human beings (adults):
- (2123/2123) × 2 = 32(2123/2123) × 2 = 32
- (**I 2/2, C 1/1, P 2/2, M 3/3**)
- In a normal adult there are 32 teeth.
- In a child, there are 20 teeth present which are called **milk teeth** or **deciduous teeth**.

- These teeth grow at the age of 6 years. **i.e**.
- the dental formula of a child can be written as **2120/2120**
- (2120/2120)×2=20(2120/2120) × 2=20.
- These are two incisors, 1 canine and 2 molars.
- **There are two types of dentition**:

✓ **temporary** - are 20 teeth in the temporary dentition

✓ **permanent -** 32 teeth in the permanent dentition.

❑ Keeping teeth health

- your teeth can be affected by bacteria that cause dental caries.
- There are many different bacteria that are found naturally in your mouth.
- These bacteria, combined with food and saliva, form a thin film known as **plaque** on your teeth.

- if you eat a lot of sweet, sugary food they produce a lot of acid waste.
- This acid attacks and dissolves the tough enamel coating of your teeth.
- Once through the enamel, the acid also dissolves away some of the dentine and then the bacteria can get into the inside of your tooth.
- The bacteria will then reproduce and feed, eating away at your tooth until they reach the nerves of the pulp cavity causing **toothache**.
- The same bacteria can affect your gums, causing **periodontal disease**.

❖ **The symptoms** include

- tender gums, bleeding when you clean your teeth and eventually the possible loss of all your teeth, not from tooth decay but from gum disease.

- Taking in lots of acidic food and drink, such as fruits and cola, can also weaken the enamel on your teeth.
- **Tooth and gum disease** are extremely common all over the world.
- They cause **pain, bad breath, loss of teeth** and **difficulty eating**.
- The good news is that they can both be avoided, especially if you have good dental care available.

- **Ways to avoid tooth decay include**:

✓ Regular brushing of your teeth and gums twice a day.

- This removes the plaque from the teeth, preventing the build-up of a sticky, acidic film over the enamel.

✓ Avoiding sweet, sugary foods – if the bacteria in your teeth are deprived of sugar, they cannot make acidic waste and your teeth are safe.

✓ Have regular dental check-ups.

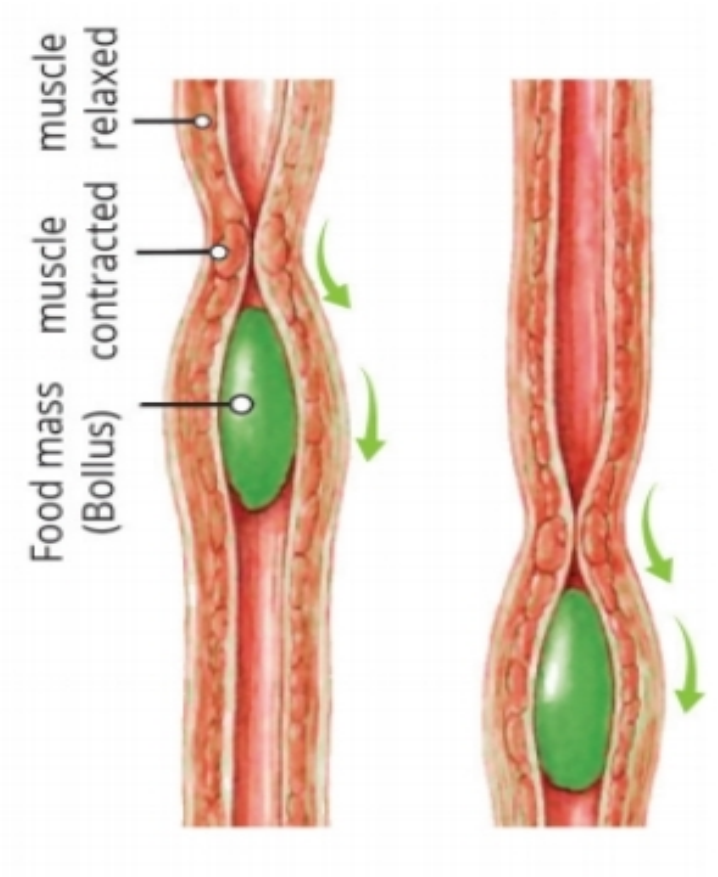
- A dentist can clean your teeth more thoroughly than you can, and any early signs of decay can be treated.
- Your teeth won't heal themselves, but any tooth decay can be removed and replaced by a filling.

❑ The Esophagus

- The swallowed food travels from the mouth to the stomach by way of the esophagus.
- The bolus of food stretches the walls of the esophagus, activating muscles that set up waves of rhythmic contractions called **peristalsis**.
- Peristaltic contractions, which are involuntary, move food along the gastrointestinal tract

Peristalsis

- Consists of waves of muscular contractions
- Moves a **bolus** along the length of the digestive tract



- **Figure 5.2** Rhythmic contractions of muscle move food along the digestive tract

The stomach

- The stomach is the site of food storage and initial protein digestion.
- The stomach contains three layers of muscle, which run in different directions so that the muscle contractions can churn the food.
- The movement of food to and from the stomach is regulated by circular muscles called **sphincters**.
- Contraction of the **lower esophageal sphincter** (LES) closes the opening to the stomach, while its relaxation allows food to enter.

- The **lower esophageal sphincter** prevents food and acid from being regurgitated up into the esophagus.
- The **pyloric sphincter**, regulates the movement of food and stomach acids into the small intestine.

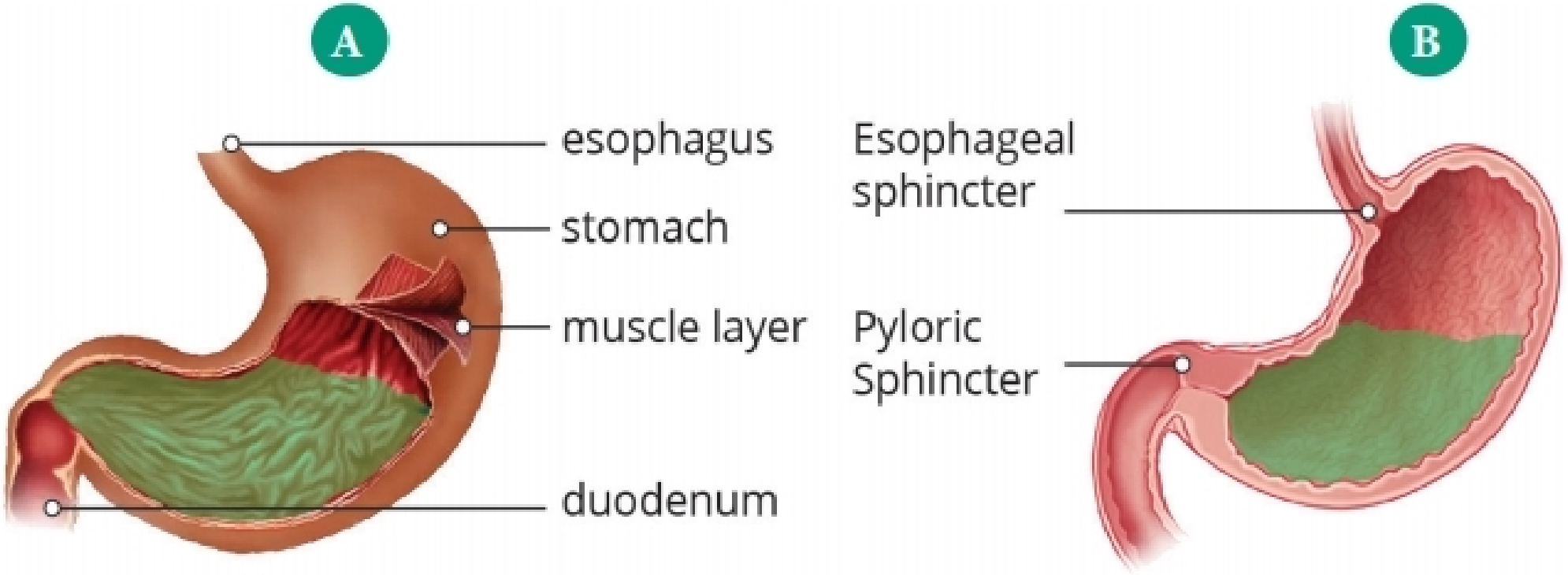


Figure 5.3 a) Muscle is responsible for the contractions of the stomach b) Sphincters regulate the movement of food.

- J-shaped muscular bag that can stores about 1.5L food you eat.
- Millions of cells line the inner wall of the stomach.
- **Activities in the stomach**:
- 1. the cells secrete the various stomach fluids, called **gastric fluids** or gastric juice, that aid digestion,
- 2. contractions of the stomach mix the food with the gastric fluids, and
- 3. it is involved in both **physical** (churning action if stomach wall) and **chemical digestion** (e.g. digestion of proteins by the action of enzyme pepsin).
- Approximately 500mL of the fluids in the stomach are produced following a large meal.
- **Gastric fluid includes**:

1.mucus,

2.hydrochloric acid (HCl),

3.pepsinogens, and other substances.

- **Hydrochloric acid** kills many harmful substances that are ingested with food.
- It also converts pepsinogen into pepsin (its active form).
- Pepsin breaks the long amino acid chains in proteins into shorter chains, called **polypeptides**
- The pH inside the stomach normally ranges between 2.0 and 3.0.
- It is the high acidity of hydrochloric acid that makes it:

✓ effective at killing pathogens and

✓ allows pepsin to do its work.

- A layer of alkaline mucus protects the stomach lining from being digested.
- The pepsin breaks down the proteins in the food,
- but not the proteins of the stomach's cells because these proteins are protected by the **mucous layer**.

- The esophagus does not have a protective mucous layer,
- so if the lower esophageal sphincter (LES) is weak, stomach acid may enter the esophagus and damage its lining.
- This causes pain known as **heartburn**.
- The partially digested food and gastric juice mixture are called **chyme**.
- Gastric emptying occurs within two to six hours after a meal.
- Only a small amount of chyme is released into the small intestine at a time.
- The movement of chyme from the stomach into the small intestine is regulated by **hormones**, **stomach distension**, and **muscular reflexes** that influence the **pyloric sphincter**.
- The low pH of the stomach will denature the **amylase** and **lipase** that were secreted in **the mouth**.
- the chemical digestion of starches and fats **will decrease** in the stomach and their further digestion will take place in the small intestine.

- **Absorption in the stomach**
- Although the stomach absorbs few of the products of digestion,
- it can absorb many other substances,
- including glucose and other simple sugars, amino acids, and some fat soluble substances, water, specific vitamins, and alcohol, etc.

Stomach Functions

✓ Acts as a storage tank for food
✓ Site of food breakdown
✓ Chemical breakdown of protein begins
✓ Delivers chyme (processed food) to the small intestine

☐ The small intestine

- The small intestine is up to 7 m in length, but only 2.5 cm in diameter.
- Most chemical digestion takes place in the small intestine.
- **Parts of the small intestine:**
- **1. duodenum** the first coiled tube which 25 cm to 30 cm of the small intestine where the majority of digestion occurs,
- **2. jejunum** is the second component of the small intestine which connect duodenum with ileum.
- **3. ileum** the third component
- wihin the ileum all digestive processes are completed and the soluble products are absorbed into the **blood stream**.

- The small intestine secretes digestive enzymes and moves its contents along by **peristalsis**.
- Most absorption takes place within the small intestine.
- Long finger like projections called villi (singular: villus) greatly increase the surface area of the small intestine.
- The cells that make up the lining of each villus have **microvilli**, which are fine, threadlike extensions of the membrane that further increase the surface for **absorption**.

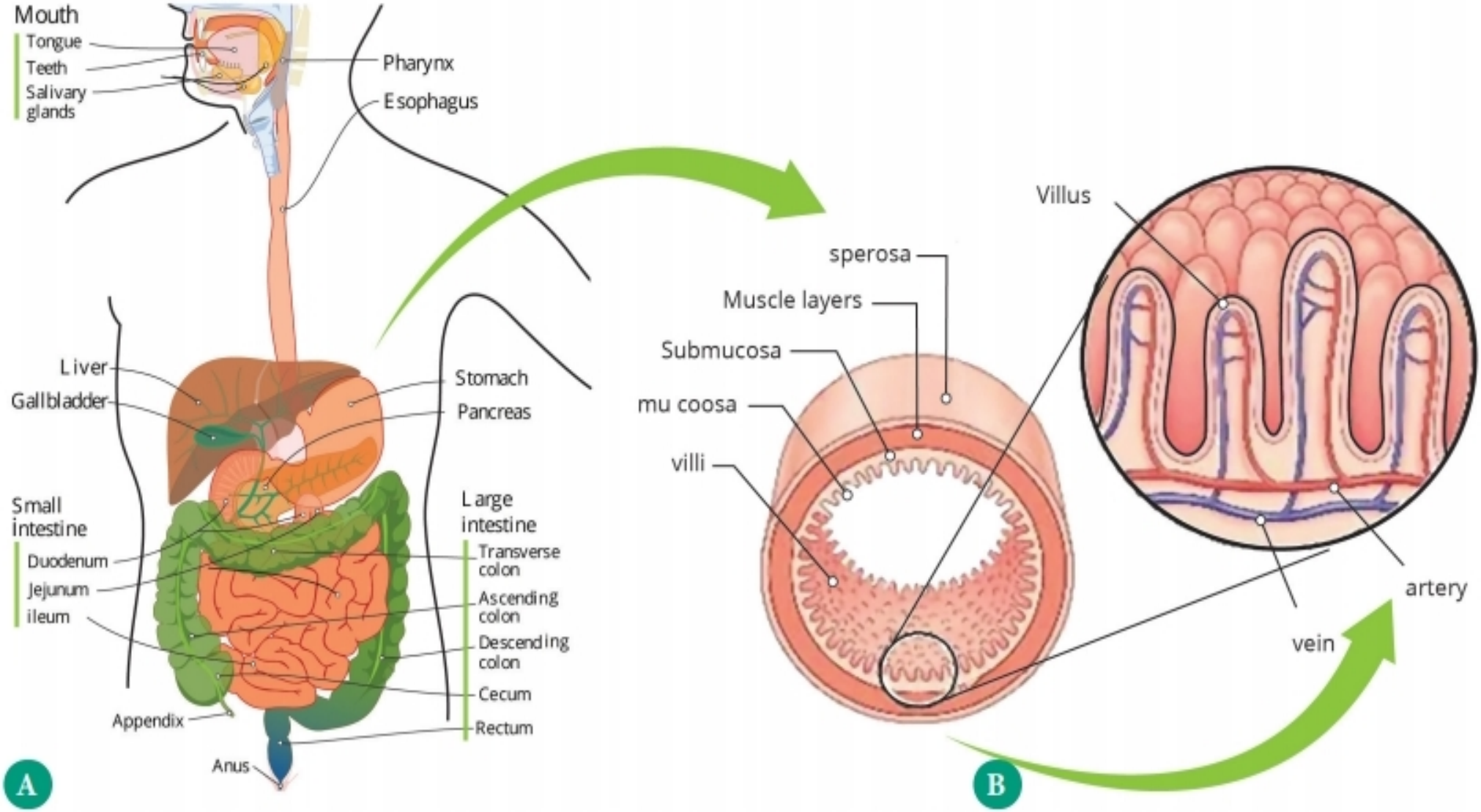


Figure 5.4 Parts of the digestive system and the absorption villi

- Each villus is supplied with a capillary network that intertwines with lymph vessels called **lacteals** that transport materials.

✓ Some nutrients are absorbed by **diffusion**,

✓ but some nutrients are **actively transported** from the digestive tract.

✓ Monosaccharides and amino acids are absorbed into the **capillary networks**;

✓ fats are absorbed into the **lacteals**.

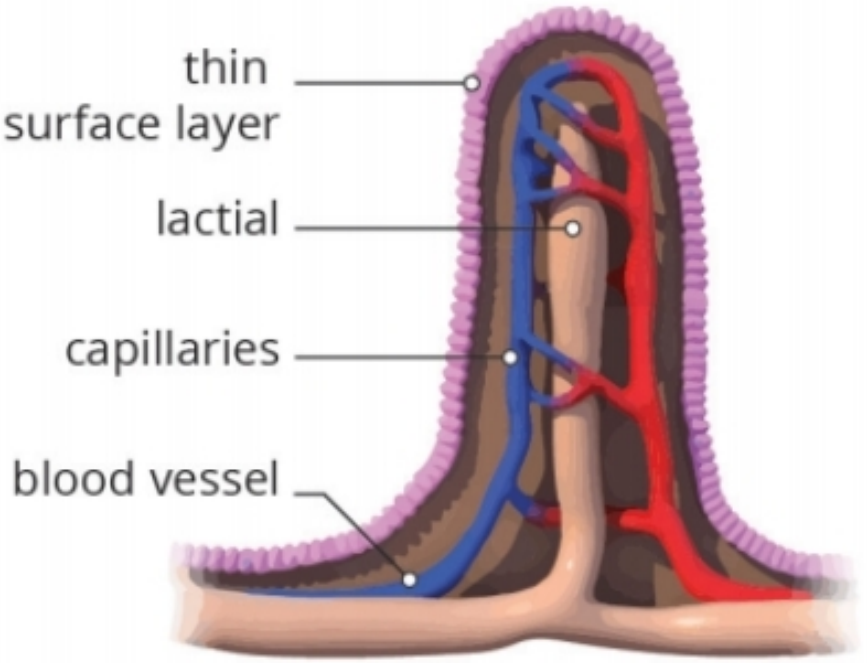


Figure 5.5Anatomy of a villus, with the lacteal

❑ The accessory organs

- Accessory organs add **secretions** and **enzymes** that break down food into nutrients.
- Accessory organs include:

➢ the salivary glands,

➢ the pancreas,

➢ the liver, and

➢ the gall bladder

❖ **The liver** is the largest internal organ in humans and

- it plays an important role in the digestion of fats and detoxifying blood.
- The liver produces **bile**, which is a digestive juice that is required for the breakdown of **fats** in the **duodenum**.
- The liver also processes the **absorbed vitamins** and **fatty acids** and **synthesizes many plasma proteins**.

❖ **The gallbladder** is a small organ that aids the liver by storing bile and concentrating bile salts.

❖ **The pancreas** secretes bicarbonate that **neutralizes** the **acidic chyme** and a **variety of enzymes.**

- The pancreatic secretions contain enzymes that promote the breakdown of the three major components of food:
- proteins, carbohydrates, and lipids.
- **Pancreatic secretions contain the following digestive enzymes**:

1. Trypsin- a protein-digesting enzyme called trypsinogen is released from the pancreas.

- **Enterokinase** converts the inactive trypsinogen into trypsin, which acts on the partially digested proteins.
- Trypsin breaks down **long-chain polypeptides** into **shorter-chain peptides**.

2. Erepsins - are released from the pancreas and small intestine.

- They complete protein digestion by breaking the bonds between short chain peptides, releasing individual amino acids.

3. Amylase - continue the digestion of carbohydrates that begun in the mouth by salivary amylase.

- The intermediate-size chains are broken down into disaccharides.
- The small intestine releases disaccharide enzymes, called **disaccharidases**, which complete the digestion of carbohydrates.

4. Lipases - enzymes released from the pancreas that breaks down lipids (fats).

- There are two different types of lipid-digesting enzymes:

✓ **Pancreatic lipase**, the most common lipase, breaks down fats into fatty acids and glycerol.

✓ **Phospholipase** acts on phospholipids.

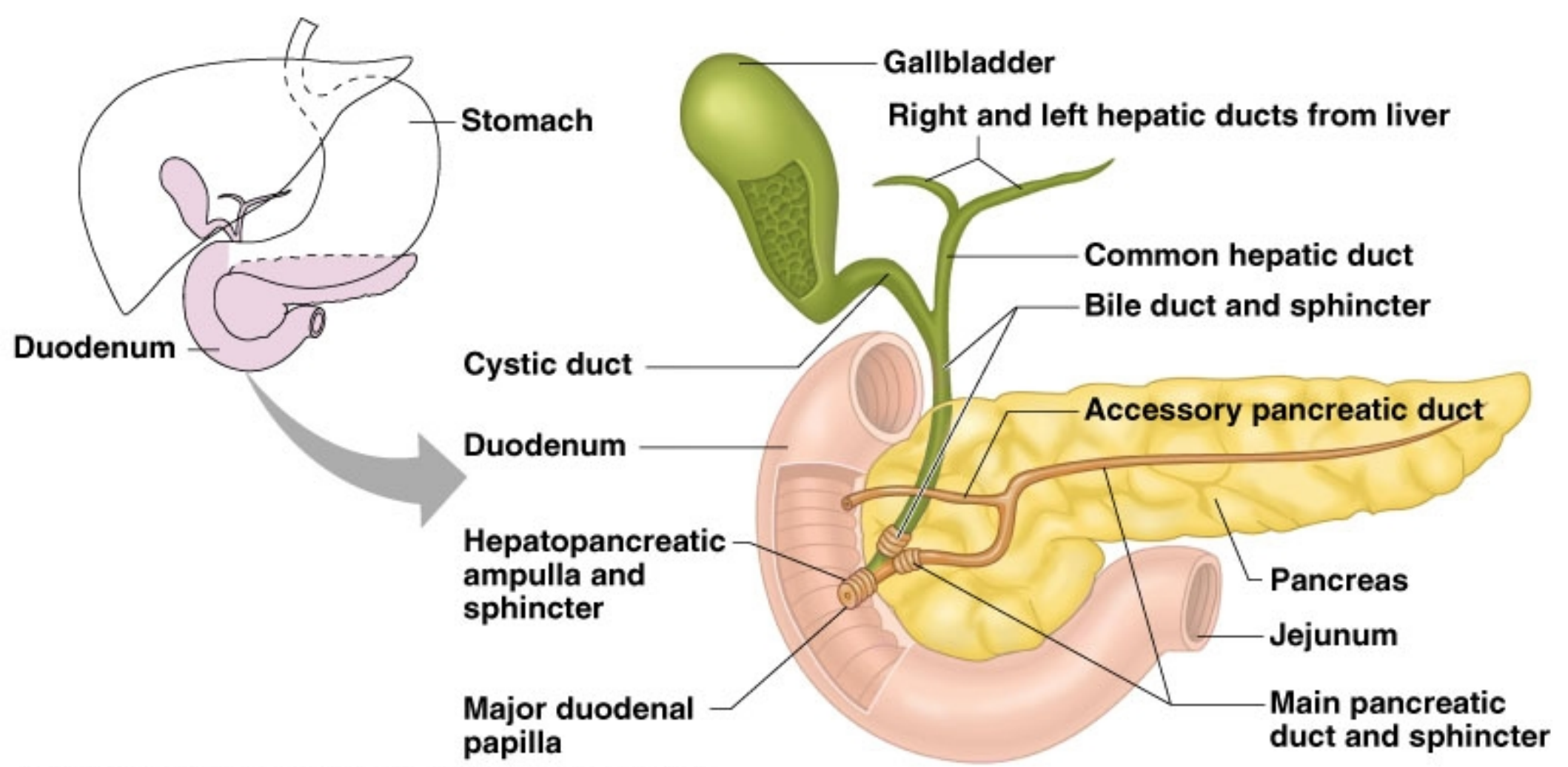
Table 5.1 Digestion in the Small Intestine

Enzyme	Produced by	Reaction
lipase	pancreas	fat droplets + H_2O → glycerol + fatty acids
trypsin	pancreas	protein + H_2O → peptides
erepsin	pancreas, small intestine	peptides + H_2O → amino acids
pancreatic amylases	pancreas	starch + H_2O → maltose
maltase	small intestine	maltose + H_2O → glucose

❖ Liver and Gallbladder

- The liver continually produces fluid called bile.
- Bile contains bile salts, which aid fat digestion.
- When the stomach is empty, bile is stored and concentrated in the gallbladder.
- When there are fats in the small intestine, the hormones trigger the gall bladder to release bile salts.

- **Emulsify** or breakdown, large fat globules into smaller droplets is physical digestion, not chemical digestion.
- **Bile** also contains **pigments**.
- The liver breaks down **haemoglobin** from **red blood cells** and stores the products in the gallbladder for removal.
- Stores glycogen and vitamins A, B12, and D.
- **Detoxify** many harmful substances in the body.
- Harmful chemicals are made soluble and can be dissolved in the blood and eliminated in the urine.
- One of the more common poisons is **alcohol**.


Stomach
Duodenum
Gallbladder
Right and left hepatic ducts from liver
Common hepatic duct
Bile duct and sphincter
Cystic duct
Accessory pancreatic duct
Duodenum
Hepatopancreatic ampulla and sphincter
Pancreas
Jejunum
Major duodenal papilla
Main pancreatic duct and sphincter

❑ Large Intestine

- is much smaller in length compared to the small intestine but larger in diameter.(About **1.5 meters** long)
- It has three parts:

✓ the cecum,

✓ the colon, and

✓ the rectum.

◆ **The cecum** joins the ileum to the colon and is the receiving pouch for the waste matter.

◆ **The colon** is home to many bacteria or intestinal flora that aid in the digestive processes.

- **The colon has four regions**,

➢ the ascending colon,

➢ the transverse colon,

➢ the descending colon and

➢ the sigmoid colon

◆ The colon:

- the largest part of the large intestine,
- must store waste long enough to reabsorb water from it.
- During this time, some inorganic salts, minerals, and vitamins are also absorbed with the water.
- It houses bacteria, such as **Escherichia coli** (E. coli), which are essential to life and
- use waste materials to synthesize vitamins B and K.

■ The main functions of the colon are

- to extract the water and mineral salts from undigested food,
- to store waste material.

- cellulose cannot be broken down by humans, it serves an important function: cellulose provides bulk.
- As wastes build up in the large intestine, receptors in the wall of the intestine provide information to the **central nervous system**, which, in turn, prompts a bowel movement.

◆ **The rectum** stores feces until **defecation**.

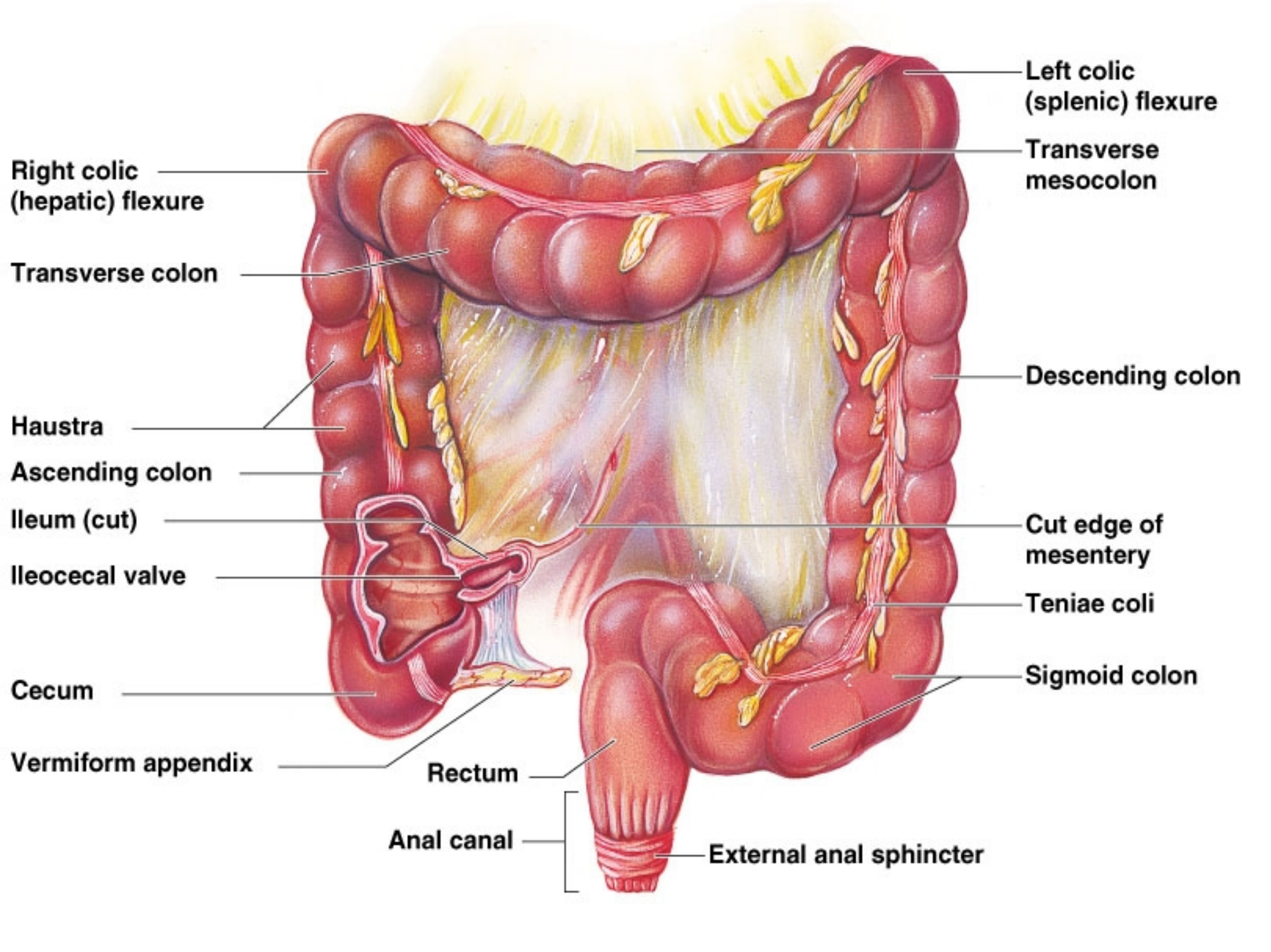
- The feces are propelled using peristaltic movements during elimination.

◆ **The anus** is an opening at the far-end of the digestive tract and is the exit point for the waste material.

- **Two sphincters regulate the exit of feces**,

✓ the inner sphincter is involuntary and

✓ the outer sphincter is voluntary.


Left colic (splenic) flexure
Transverse mesocolon
Right colic (hepatic) flexure
Transverse colon
Descending colon
Haustra
Ascending colon
Ileum (cut)
Cut edge of mesentery
Ileocecal valve
Teniae coli
Sigmoid colon
Cecum
Vermiform appendix
Rectum
Anal canal
External anal sphincter

• Functions of the Large Intestine

- ✓ Absorption of water
- ✓ Eliminates indigestible food from the body as feces
- ✓ Does not participate in digestion of food
- ✓ Goblet cells produce mucus to act as a lubricant

Table 5.2 Summary of digestion in human alimentary canal

Region of gut	Glands and secretion	Enzymes and optimum pH	Food digested, products and other activity
Mouth: mastication by jaws and tongue	Salivary glands :saliva 1-2 liters/daily	1. pH-7, slightly acid in adults, slightly alkali to neutral in children 2. amylase	1.mucin lubricates food bolus 2.(A) starch(amylase)----dextrins (B) cooked starch ----maltose
Oesophagus	None	None	Food bolus moves by peristalsis
Stomach churning action. Temporary storage 1 to3 hrs	Gastric gland, stomach wall-gastric juice 2-4L; stores daily	1. pH 1, strongly acidic 2. rennin(in young children) 3. lipase(in young children) 4. pepsin	1. Hydrochloric acid (HCl) is bacteriocidal 2. clots milk protein-caesin 3. lipids---fatty acids and glycerine 4. proteins—amino acids Absorption: water, salts, vitamins and ethanol

Duodenum(Accessory organ secretions)	1.liver- bile juice, 700CM3-1.2 litres daily 2 pancreas-pancreatic juices, 700Cm3 daily	1. pH 7-8, slightly alkaline 2. no enzyme	1. alters pH of stomach contents 2. bile salts emulsify or cream lipids
		1. pH 7-8,slightly alkaline 2. amylase 3. lipase 4. Trypsin 5.nuclease	1.food as chime propelled by peristalsis 2. starch(amylase)------maltose 3. lipids---- fatty acids and glycerol 4. peptones---- short peptides 5. nucleic acids----nucleotides
Small intestine and duodenum	Glands in intestine and duodenum wall-intestinal juice, 200cm3	1. pH 7-8 2. entrokinase changes trypsinogen into trypsin 3.lipase 4.glycosidases-maltase, lactase, sucrase	1---------- 2. dipeptides, peptides-------amino acids 3. lipids---fatty acids and glycerol(propanetriol) 4. maltase----maltose into glucose molecules Lactase-----lactose into glucose and galactose Sucrose---sucrose into glucose and fructose Absorption: large surface area, villi, and microvilli, main region of absorption of vitamins, minerals, amino acids, glucose, fatty acids and glycerol
Large intestine	Lining with mucous glands	pH 6-8 no enzymes	1. mucous lubricates faces 2. water absorbed from faces 3. bacteria synthesis vitamin B groups 4. faces mainly water 75%, bacteria, 8%, lipids, 6%, dietary fiber cellulose, 2% etc

5.2 The circulatory and lymphatic system

- The circulatory system is blood moves throughout your body.
- The circulatory system (cardiovascular system):

✓ carries nutrients to cells,

✓ remove wastes away from cells,

✓ carry chemical messages from cells in one part of the body to distant target tissues,

✓ distributes heat throughout the body and, along with the kidneys,

✓ maintain levels of body fluid,

✓ provide oxygen for the cellular respiration and

✓ transport of immune cells throughout the body to defend against invading organisms.

- your circulatory system has **96 000 km of blood vessels** to sustain your **100 trillion cells**.
- The human circulatory system consists of **blood**, **heart**, **blood vessels**, and **lymph**.

- The heart beats about 70 times/min from the beginning of your life until death.
- Every minute, 5L of blood cycles from the heart to the lungs, picks up oxygen, and returns to the heart.

❑ **The heart** is a muscular organ that pumps blood to circulate throughout the body.

- A field of study about the heart is called **cardiology** and the scientists, **cardiologists**.
- The heart wall consists of three layers:

1. The myocardium is the middle layer of the heart.

- It is the heart muscle and is the thickest layer of the heart, and

2. The epicardium is a thin layer on the surface of the heart in which the coronary arteries lie.

3. The pericardium is a thin sac the heart sits in, often filled with a small amount of fluid, which separates the heart from the other structures in the chest such as the **lungs**.

❖ Valves

- In the cardiovascular system of the heart four valves prohibit the backflow of blood:

a. Tri-cuspid valve (Right atrioventricular RAV) - valve separates the right atria from the right ventricle.

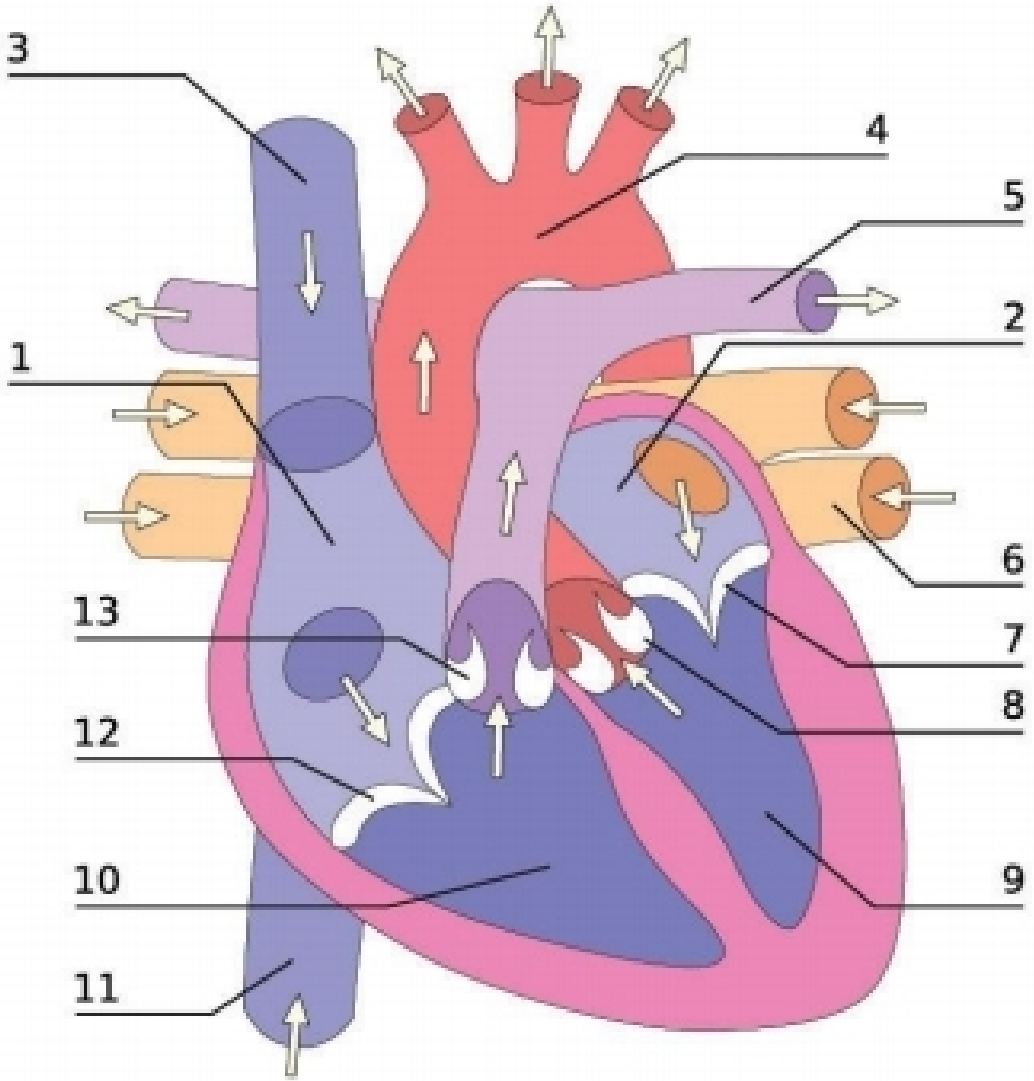
b. Bi-cuspid valve (Left atrioventricular LAV) -valve separates the left atria from the left ventricle

- **Semi-lunar valves**

a. Valve that separate the right ventricle from the pulmonary artery and

b. Valve that separate the left ventricle from the aorta.

- The semi-lunar valves are half-moon-shaped (hence, the name semi-lunar), and they prevent blood that has entered the arteries from flowing back into the ventricles



Description

1. Right atrium (Atrium dextra)
2. Left atrium (Atrium sinistrum)
3. Superior Vena Cave (Venea cava Superior)
4. Aorta
5. Pulmonary artery
6. Pulmonary vein
7. Bicuspide (Mitral) valve
8. Semilunar (Aortic) valve
9. Left ventricle
10. Right ventricle
11. Inferior Vena Cave (Venea cava Inferior)
12. Tricuspid valve
13. Semilunar (Pulmonary) valve

Figure 5.6 The heart anatomy

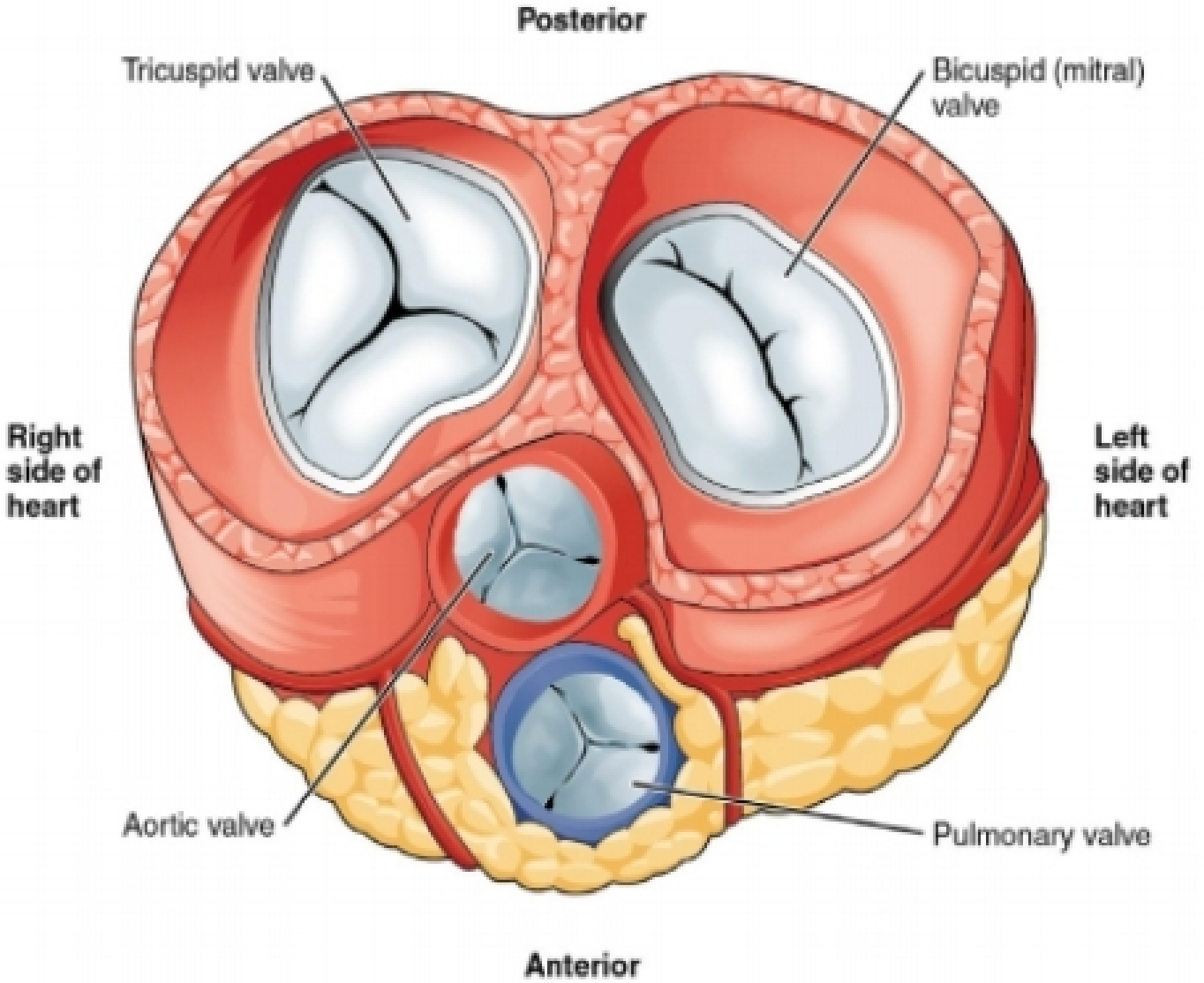


Figure 5.7 The valves of the heart

- The human circulatory systems are **a double circulatory system**.
- It has two separate circuits and blood passes through the heart twice: pulmonary and systemic circulation.

❖ **Pulmonary circulation** - the movement of blood from the heart to the lungs for oxygenation, then back to the heart again.

- Oxygen depleted blood from the body leaves the **systemic circulation** when it enters the right atrium through the **superior and inferior venae cavae**.
- **The blood** is then pumped through the **tricuspid valve** into the right ventricle.
- From the right ventricle, blood is pumped through the **pulmonary valve** and into the pulmonary artery.
- The pulmonary artery splits into the right and left pulmonary arteries and the blood in the arteries travel to each **lung**.

❖ **Systemic circulation** - is the movement of blood from the heart through the body to provide oxygen and nutrients to the tissues of the body while bringing deoxygenated blood back to the heart.

- **Oxygenated blood** enters the left atrium from the pulmonary veins.
- The blood is then pumped through the mitral valve into the left ventricle.
- From the left ventricle, blood is pumped through the aortic valve and into **the aorta**, the body's **largest artery**.
- The aorta arches and branches into major arteries to the upper body before passing through the diaphragm,
- where it branches further into the **iliac**, **renal**, and **suprarenal** arteries which supply the lower parts of the body.
- The arteries branch into smaller **arteries, arterioles**, and finally **capillaries**.
- Gas and nutrient exchange with the tissues occurs within the capillaries that run through the tissues.
- Metabolic waste and carbon dioxide diffuse out of the cell into the blood, while oxygen and glucose in the blood diffuse out of the blood and into the cell.

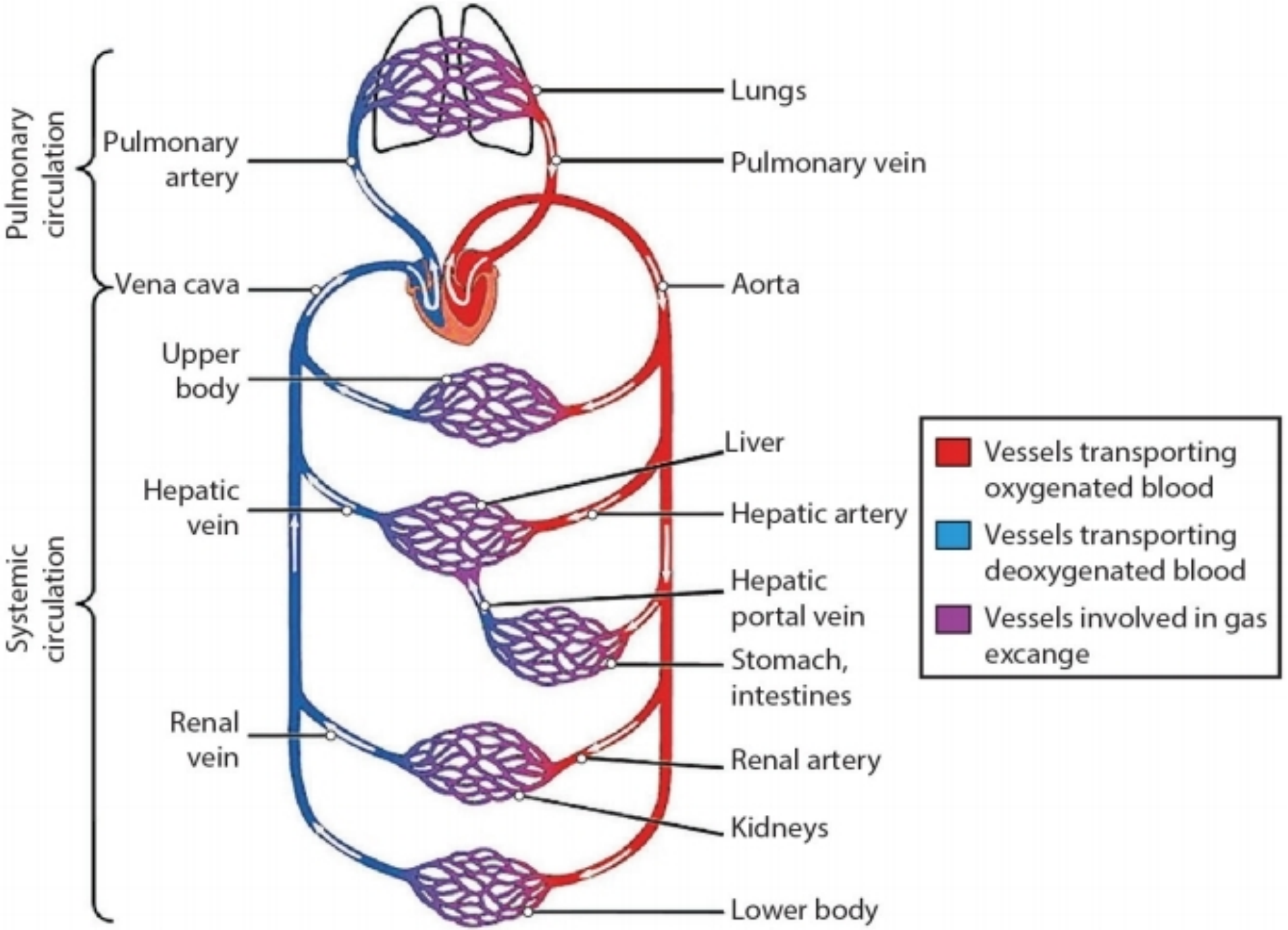


Figure 5.8 Pulmonary and systemic circulation

❖ Cardiac Cycle

- The period of time that begins with contraction of the atria and ends with ventricular relaxation is known as the **cardiac cycle**.
- The period of contraction that the heart undergoes while it pumps blood into circulation is called **systole**.
- The period of relaxation that occurs as the chambers filled with blood is called **diastole**.
- Both the atria and ventricles undergo systole and diastole, and
- it is essential that these components be carefully regulated and coordinated to ensure blood is pumped efficiently to the body.

Heart Sounds

- One of the simplest, yet effective, diagnostic techniques applied to assess the state of a patient's heart is **auscultation** (listening to various internal sounds) using a **stethoscope**.
- In a normal, healthy heart, there are only two audible heart sounds: Lub and Dup (or Dub).
- **Lub,** or rest heart sound is the sound created by the closing of the atrioventricular valves during ventricular contraction.
- "**Dup**" (or "Dub") is the sound of the closing of the semilunar valves during ventricular diastole.