5.1 The Digestive System

What do you know about the digestive system?

- All living organisms need nutrients to survive
- Plants can obtain nutrients from their roots and the energy molecules required for cellular function through the process of photosynthesis.
- Animals, however, obtain their nutrients through the consumption of other organisms.
- At the cellular level, the biological molecules necessary for animal function are amino acids, lipid molecules, nucleotides, and simple sugars. However, the food consumed consists of protein, fat, and complex carbohydrates.
- Animals must convert these macromolecules into the simple molecules required for maintaining cellular function.
- The conversion of the food consumed to the nutrients required is a multi-step process involving digestion and absorption.
- During digestion, food particles are broken down into smaller components, which are later absorbed by the body.
- This happens by both physical means, such as chewing and by chemical means, via enzyme-catalysed reactions.
- These processes take place in the human digestive system step-wise.
- 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 digestive tract of adult humans is normally 6.5 m to 9m long.
- It stores and breaks down organic molecules into simpler components. Physical (mechanical) digestion begins in the mouth, where food is chewed and formed a bolus (the Greek word for the ball) by the tongue.
- Physical digestion breaks food into smaller pieces, increasing the surface area for chemical digestion.
- The chemical digestion of carbohydrate (starch) starts in the oral cavity by an enzyme called **salivary amylase** or **ptyalin.**
- The food is then swallowed and enters the esophagus a long tube that connects the mouth to the stomach.
- Using peristalsis, wave-like smooth- muscle contractions, the muscles of the esophagus push the food toward the stomach.
- The stomach contents are extremely acidic, with a pH between 1.5 and 2.5. This acidity kills micro-organisms, breaks down food tissues, and activates digestive enzymes.
- The chemical digestion of protein starts in the stomach by the enzyme pepsin.
- Further breakdown of food takes place in the small intestine where bile is produced by the liver, and enzymes produced by the small intestine and the pancreas, continue the process of digestion.
- The smaller molecules are absorbed into the bloodstream through the epithelial cells lining the walls of the small intestine.
- The waste material travels onto the large intestine where water is absorbed and the drier waste material is compacted into feces; it is stored in the rectum until it is excreted through the anus.

The Oral Cavity

What is the process of digestion that takes place in the mouth?

- In 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 the following.
  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 flavor 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.

The teeth

There are 4 types of teeth:

Incisors: are eight chisel-shaped teeth at the front of your mouth Specialized for cutting.

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.

External and internal structures of teeth.

- The teeth are the hardest substances in the human body.

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

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

Dentine: 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- are 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 cemented.

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 numbers of teeth in the human beings are represented Incisor (1), canines(C), molars (M) and premolars (P).
- It gives a set like I: C: P-M. For example, if it is given 2:1:2:3 for upper teeth then, it indicates 2 incisors, 1 canine, 2 premolars and 3 molars of the upper mouth on one side. Include the dental formula.
- The dental formula of human beings (adults): (2123/2123) x2 = 32 (2123/2123) × 2 = 32 There are 2 incisors, 1 canine, 2 premolars and 3 molars
- In a normal adult there are 32 teeth.
- There are two types of dentition**: temporary and permanent**.
- There are 20 teeth in the temporary dentition and 32 teeth in the permanent dentition.
- 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.
- Le. (2102/2102) × 2 =20 (2102/2102) x 2 = 20.These are two incisors, 1 canine and 2 molars.
- In order to represent the total number of the teeth in the jaw or mouth, the whole formula is multiplied by two as the formula for one side of the mouth.
- Both monkeys and human beings have the same set of teeth and the same dental formula.

Keeping teeth Health

- 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 these bacteria are given a sugar-rich diet (in other words, 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 al**l 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.
- ❖ This is particular Tooth and gum diseases 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.
  - 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.

. ***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 action will move food or fluid from the esophagus to the stomach. Look at the process of peristalsis in figure 5.2 on page 100

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 (Figure 5.3 (a)).
- The movement of food to and from the stomach is regulated by circular muscles called ***sphincters.*** Sphincters act like the draw strings on a bag.
- 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.
- A second sphincter, the pyloric sphincter, regulates the movement of food and stomach acids into the small intestine (Figure 5.3(b)).
- The J-shaped stomach has numerous ridges that allow it to expand so that it can store about1.51. Of food. 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***).

- ➢ Gastric fluid includes:
  (1) Mucus,
  (2) Hydrochloric acid (Hydrochloric acid (HCI)),
  (4) pepsinogens, and other substances.
- ➢ Hydrochloric acid kills many harmful substances that are ingested with food.
- ➢ It also converts **pepsinogen** into its active form**, pepsin**, which is **a protein-digesting enzyme**.
- ➢ Pepsin breaks the long amino acid chains in proteins into shorter chains, called **polypeptides**.
- ➢ 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.
- ➢ Pepsinogen passes across the cell membrane and is activated by Hydrochloric acid (HCl) to become pepsin.
- ➢ 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 **h*eartbu*rn.**
- ➢ 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.

- Therefore, over time, 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

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 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 and
3. ***Ileum*** the third component

- The small intestine secretes digestive enzymes and moves its contents a long by peristalsis.
- The stomach absorbs some water, specific vitamins, some medicines, and alcohol, but most absorption takes place within the small intestine.
- 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**

The accessory organs

- Accessory organs add secretions and enzymes that break down food into nutrients.
- Accessory organ include:-
  - ***The salivary gland***
  - ***The Pancreases***
  - ***The liver and the gall bladder***

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- The secretions of the pancreas, liver, and gallbladder are regulated by hormones in response to food consumption.
- 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 ***(trypsin, amylase, and lipase)*** for the digestion of ***proteins, carbohydrates, and fats***, respectively'

Pancreas

- Contain enzymes that promote the breakdown of the three major components of food: ***proteins, carbohydrates, and lipids***.
- Contain the following digestive enzymes:
  - **Trypsin** a protein-digesting enzyme called ***trypsinogen*** is released from the pancreas.
- Once trypsinogen reaches the small intestine, an enzyme called ***enterokinase*** converts the inactive ***trypsinogen*** into **trypsin**, which acts on the partially digested proteins.
- Trypsin breaks down **long-chain polypeptides** into **shorter-chain peptides**.
  - **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.
  - **Amylase-** continue the digestion of carbohydrates that begun in the mouth by salivary amylase.
  - **Lipases**-enzymes released from the **pancreas t**hat breaks down lipids (fats). There are two different types of lipid-digesting enzymes:

    A/ Pancreatic lipase, the most common lipase, breaks down fats into fatty acids and glycerol.

    B/ Phospholipase acts on phospholipids.

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.Once inside the small intestine, the bile salts:

Emulsify or breakdown, large fat globules. The breakdown of fat globules into smaller droplets is physical digestion, not chemical digestion since chemical bonds are not broken.

Bile also contains pigments. The liver breaks down haemoglobin from red blood cells and stores the products in the gallbladder for removal. The characteristic brown colour of feces results from hemoglobin

breakdown. Stores glycogen and vitamins A, B12, and D. **Detoxify** many harmful substances in the body.

Large Intestine.

The human large intestine is much smaller in length compared to the small intestine but larger in diameter. 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 main functions of the colon are **to extract the water** and **mineral salts** from undigested food, and to store waste material The colon, the largest part of the large intestine, must store waste long enough to reabsorb water from it.

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

5.2 The circulatory and lymphatic system.

The circulatory system is a means by which blood moves throughout your body. The circulatory 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, and 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.*

A field of study about the heart is called **cardiolog**y and the scientists**, cardiologists**.

The heart is a muscular organ that pumps blood to circulate throughout the body. The heart wall consists of three layers: the **endocardium, myocardium**, and **epicardium.** The endocardium is the thin membrane that lines the interior of the heart, The myocardium is the middle layer of the heart. It is the heart muscle and is the thickest layer of the heart**.** The epicardium is a thin layer on the surface of the heart in which the coronary arteries lie. **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. ***Tricuspid valve*** (Right atrioventricular RAV) -valve separates the *right atria* from the *right ventricle*.

b. ***Bicuspid 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* (Pulmonary valve)

b. Valve that separate the left ventricle from the aorta(Aortic valve). 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

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 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.

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

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.

The second heart sound, "Dup" (or "Dub") is the sound of the closing of the semilunar valves during ventricular diastole.

Blood Pressure

Blood pressure is the force of the blood on the walls of the arteries. It can be measured indirectly with an instrument called **sphygmomanometer.** A gauge on sphygmomanometere measures the pressure exerted by the blood during ventricular contraction. This pressure is called *systolic blood pressure*. Normal systolic blood pressure is less than ***120 mmHg***. The blood flows into the artery during ventricular relaxation, or filling. This pressure is called *diastolic blood pressure*. Normal diastolic blood pressure is less than **80 mmHg**. A systolic pressure of 120 mmHg and a diastolic pressure of 80 mmHg would be reported as 120/80 (120 over 80).

Blood Vessels

Blood vessels are the channels or conduits through which blood is distributed to body tissues. The vessels make up two closed systems of tubes that begin and end at the heart. One system

The pulmonary vessels, transports blood from the right ventricle to the lungs and back to the left atrium.

The systemic vessels carries blood from the left ventricle to the tissues in all parts of the body and then returns the blood to the right atrium. Based on their structure and function, blood vessels are classified as ***arteries, capillaries, and veins***.

Blood

Blood is a constantly circulating fluid providing the body with *nutrition, oxygen*, and *waste removal*.

Liquid called plasma makes up about half of the content of the blood. Plasma contains *proteins* that help *the blood to clot, transport substances through the blood*, and *perform other functions*. Blood plasma also contains glucose and other dissolved nutrients. About half of blood volume is composed of blood cells.

Blood Components

Normally, 7-8% of human body weight comes from blood. This essential fluid carries out the critical functions of transporting oxygen and nutrients to our cells and getting rid of carbon dioxide, ammonia, and other waste products.

In addition, it plays a vital role in our *immune system* and in *maintaining a relatively constant body temperature*.Three of the most important ones are:

Red blood cells which carry oxygen to the tissues.

White blood cells, which fight infections

Platelets, smaller cells that help blood clot Red blood cells (erythrocytes)

Red blood cells, or erythrocytes, are relatively large microscopic cells. without nuclei. Red blood cells normally make up 40-50% of the total blood volume. They transport oxygen from the lungs to all of the living tissues of the body and carry away carbon dioxide. The red cells are produced continuously in our *bone marrow* from stem cells at a rate of about 2-3 million cells per second. **Hemoglobin (containing iron)** is the gas transporting protein molecule that makes up 95% of a red cell. People who are anemic generally have a deficiency in red cells, and subsequently feel fatigued due to a shortage of oxygen.

Red blood cell adaptation for efficient oxygen transportation: RBC have nucleus at the young stage and lose its nucleus when matured. Not having a nucleus means that there is more space inside for hemoglobin, so each red blood cell can carry more oxygen

White blood cells (leukocytes)

White blood cells, or leukocytes, exist in variable numbers and types. but make up a very small part of blood's volume; in normally exists among only about 1% in healthy people. Leukocytes are not limited to blood. They occur elsewhere in the body as well, most notably in the *spleen, liver,* and *lymph glands*.

White blood cells (called lymphocytes) are*: the first responders to our immune system*. They seek out, identify, and bind to alien proteins on bacteria, viruses, and fungi so that they can be removed. Other white blood cells. (called granulocytes and macrophages) then arrive to surround and destroy the alien cells. Have the function of getting rid of dead or dying blood cells as well as foreign matter.

There are several different kinds of white blood cells (Table 5.3). The two important types are: **neutrophils** white blood cells that have a lobed nucleus, and **lymphocytes** white blood cells that are smaller than neutrophils and which have a large nucleus that takes up most of the cell.

Platelets or thrombocytes that are tiny cell fragments without nuclei enclosed in a membrane. Platelets play an essential role in blood clotting, Clotting has two important functions:

- it helps to stop blood from flowing out of the damaged vessel, and

- It prevents disease-causing pathogenic micro-organisms (viruses. bacteria) from getting into the body.
- They collect where a damaged blood vessel is leaking blood and form a temporary plug by combining with fibres of collagen, a protein of the blood vessel wall. They release an enzyme that sets off a chain of chemical reactions in the blood. The results of these reactions are to change fibrinogen, a soluble plasma protein into a network of insoluble fibrin threads. These networks of fibrin threads, then plug in the cut and clot the blood.

Plasma

Plasma is a yellow-tinted water, sugar, fat, protein, and salt fluid that transport red blood cells, white blood cells, and platelets. Plasma makes up 55 percent of our blood volume.

provides nutrients to cells while also removing metabolic waste, Blood clotting factors, carbohydrates, lipids, vitamins, minerals, hormones, enzymes, antibodies, and other proteins are all found in it, includes some of every protein generated by the body; so far, only about 500 proteins have been discovered in human plasma.

Blood groups

- The blood grouping depends on which **antigens** are on the surface of the **red blood cells**.
- Antigens are molecules. They can be either proteins or sugars. The types and features of antigens can vary between individuals due to small genetic differences.

Functions of Antigens

- Transporting other molecules into and out of the cell
- Maintaining the structure of red blood cells,
- Detecting unwanted cells that could cause illness.
- The two types of antigens to classify blood types:
  1. **ABO antigens** and
  2. **Rh antigens**.
- Antigens and antibodies play a role in the immune system's defence mechanism. White blood cells produce antibodies. These antibodies will target an antigen if they consider it a foreign object.
- If a person receives red blood cells with antigens that are not already present in their system, their body will reject and attack the new red blood cells. This can cause a severe and possibly life-threatening reaction.
- The ABO blood group system classifies blood types according to the different types of *antigens in the red blood cells and antibodies in the plasma.*

The four ABO groups.

1. **Group A**

- *The surface of the red blood cells contains* **A antigen**, and *the plasma has* **anti-B antibody**.
- *Anti-B antibodies* would attack blood cells that contain **B antigens**.

2. **Group B**

- *The surface of the red blood cells contains* **B antigen**, and *the plasma has* **anti-A antibody.** *Anti-A antibody would attack blood cells that contain A antigen*.

3. **Group AB:**

- *The red blood cells have both* **A and B antigens**, *but the plasma does not contain* **anti-A or anti-B antibodies**.
- Individuals with type **AB** can receive any **ABO blood type**.

4. **Group O:**

- *The plasma contains both* **anti-A and anti-B antibodies**, *but the surface of the red blood cells does not contain A or B antigens*
- Since these antigens are not present, a person with any ABO blood type can receive this type of blood.

Generally

- *Blood group A has A antigen on the surface of RBC and Antibodies B in plasma.*
- *Blood group B has B antigens on the surface of RBC and Antibodies A in plasma*
- *Blood group AB have both A and B antigens on the surface of RBC and do not have Antibodies in plasma , this means it can receive blood from any blood group* ***(Universal donor)***
- *Blood group O have both A and B Antibodies in plasma and do not have antigens on the surface of RBC, this means it can donate blood to any blood groups* ***(Universal Recipient)***

Rhesus factor

- Rhesus factor is another antigen on the red blood cell, the Rhesus factor. Individuals who have this antigen are said to be **Rhesus positive (Rh^+).** Individuals who do not have this antigen are said to be **Rhesus negative (Rh^-).**
- *Individuals who are Rh may donate blood to Rh individuals, but should not receive Rh blood.*
- Rhesus-factor incompatibilities become important for Rh^+ babies of Rh^- mothers.
- If the baby inherits the Rh^+ factor from the father, a condition called *erythroblastosis fetalis* (a medical condition where an Rh negative mother's antibodies attack the red blood cells of an Rh positive fetus) can occur with these condition and subsequent pregnancies.
- The first child is spared because the blood of the mother and baby are separated by the placenta (a membrane inside the uterus. that exchanges materials between mother and baby). During birth, the placenta is shed from the uterus. Capillary beds rupture, and, for the first time, the blood of the baby comes into contact with the blood of the mother.
- The mother's immune system recognizes the Rh antigens and triggers the production of antibodies. But, by the time the antibodies are produced, the first baby is no longer connected to the placenta and has escaped the potentially dangerous situation.
- However, a second Pregnancy presents problems if the fetus is Rh. The mother retains many of the antibodies from her first encounter with Rh blood.
- If antibodies cross the placenta, they attach to the antigen on the red blood cells of the fetus, causing them to be destroyed. Symptoms when an Rh negative mother's antibodies attack the red blood cells of an Rh positive fetus include *anemia, jaundice*, and *an enlarged liver*.

5.2.1 Blood Donation

- Blood is a very vital component of the human body. In case of an injury, severe sickness, or during operations, loss of a large quantity of blood may result in death.
- In such cases, *blood from a healthy person* called the **donor** is given to *the sick or a person that lost blood* under some other unexpected condition. *The sick person who receives blood is called the* **recipient**.
- The process of transferring blood from a healthy person (donor) to a person deficient in blood (recipient) is called **blood transfusion**.

Blood group compatibility

- ✓ If the blood from two different blood groups is mixed and if it is not compatible, there may be a reaction between the antigen and the complementary antibody which makes the red blood cells stick together, a phenomenon known as **agglutination**.
- ✓ The agglutins block the capillaries and even larger blood vessels.
- ✓ Before a transfusion it is vital to know the blood groups of both the person giving the blood (the donor) and the person receiving the blood (the recipient). This means the right type of blood can be given to prevent agglutination. The blood groups must be compatible.

Blood group Compatibility (from figure 5.9 on page 120)

- *Blood group O can donate blood to any blood groups and receive blood from itself.*
- *Blood groups A can donate blood to A and AB and receive blood from O and itself.*

- *Blood group B can donate blood to B and AB and receive blood from O and itself*
- *Blood groups AB can donate blood to itself and receive from any blood groups*

The Lymphatic System

What is the lymphatic system?

✓ Lymph, a fluid similar to blood plasma, is transported through lymph vessels that are open-ended like veins.

✓ **Lymph nodes** are enlargements that appear in the lymph channel at regular intervals.These contain white blood cells that, through the process of phagocytosis, filter out any *bacteria present*. Lymph nodes store lymphocytes in addition to *screening damaged cells and debris from the lymph*. The lymph nodes in your neck can expand when you have a sore throat.

Functions of lymphatic system

What are the functions of the lymphatic system?

- Returns excess interstitial fluid to the blood.
- The absorption of fats and fat-soluble vitamins from the digestive system and the subsequent transport of these substances to the venous circulation. The blood capillaries absorb most nutrients, but the fats and fat-soluble vitamins are absorbed by the **lacteals.**
  Lacteals: *is a lymphatic capillary that is located in the villi of small intestine*. The lymph in the lacteals has a milky appearance due to its high fat content and is called **chyle**.
- Defense against invading microorganisms and disease. Lymph nodes and other lymphatic organs filter the lymph to remove microorganisms and other foreign particles. Lymphatic organs contain lymphocytes that destroy invading organisms.

Components of the Lymphatic System

- The lymphatic system consists of
  - ✓ a fluid (lymph),
  - ✓ Vessels that transport the lymph and organs that contain lymphoid tissue.
- **Lymph** is a fluid substance made up of *lymphocyte*s and *white blood cells* that is clear to white in colour. It transports white blood cells within lymph nodes and bones, removes interstitial fluid from organs, and fights disease-causing and infectious bacteria invading blood cells.
- Lymph serves a variety of purposes:
  - ✓ Removes metabolic wastes from tissue cells,
  - ✓ Provides the body with nutrition,
  - ✓ Aids in the invasion of microbe-caused pathogenic diseases,
  - ✓ Through lymphatic vessels, absorbs fat-soluble vitamins and other digested fat molecules from the small intestine, and Maintain the composition of tissue fluid.

    Lymphatic vessels

    Lymphatic vessels transport only fluid away from tissues. The lymph capillaries are the smallest lymphatic vessels, beginning in the tissue spaces as blind-ended sacs.
- Lymph capillaries can be found in every part of the body except the bone marrow, the central nervous system, and tissues that lack blood vessels, such as the epidermis.
- Lymphatic vessels are formed when microscopic lymph capillaries are connected. Small lymphatic vessels connect to form larger tributaries known as ***lymphatic trunks***, which drain large areas.
- The lymphatic trunks join together until lymph enters the two lymphatic ducts. The right lymphatic duct drains lymph from the upper right quadrant of the body. The thoracic duct drains the remainder.

Organs of lymphatic system

Among the lymphatic organs are:

- Lymph nodes
- Tonsils
- Spleen, and
- Thymus.

Lymph nodes

- Lymph fluid flows in the lymph nodes throughout the body before finally making its way back to the blood stream. While doing so, it collects and traps harmful matter, such as *bacteria, viruses, and bodily waste* products.
- The lymph nodes filter the fluid and release it back into the bloodstream. Lymph nodes also contain immune cells that help fight infection by attacking the germs that the body's lymph fluid has collected.
- The lymph nodes may swell when a person has a temporary infection. The swelling occurs as a result of immune cell activity in the lymph nodes.
- The location of the swelling often relates to the affected area. For example, an ear injury/infection may cause swollen lymph nodes near the ear, while someone with an upper respiratory tract infection may notice swollen lymph nodes in their neck.

Tonsils

- Tonsils are lymphatic tissue clusters located just beneath the mucous membranes that line the nose, mouth, and throat (pharynx)
- The tonsils' lymphocytes and macrophages protect us from harmful substances and pathogens such as bacteria and viruses that enter the body through the nose or mouth.

Spleen

- The spleen is found in the upper left abdominal cavity, just below the diaphragm and posterior to the stomach
- Its shape and structure are similar to that of a lymph node, but it is much larger.

The functions of Spleen

- filters blood in the same way that lymph nodes filter lymph;
- lymphocytes in the spleen react to pathogens in the blood and attempt to destroy them; macrophages engulf debris, damaged cells, and other large particles
- removes old and damaged erythrocytes from the circulating blood and
- It produces lymphocytes, particularly in response to infection.

Thymus

- The thymus is a soft organ with two lobes anterior to the ascending aorta and posterior to the sternum.
- It is relatively large in infants and children, but after puberty, it begins to shrink in size until it is quite small in older adults.

The thymus function

- To process and mature special lymphocytes known as *T-lymphocytes or T-cells*.
- Pathogens and foreign agents are not recognized by lymphocytes while they are in the thymus.
- After maturing, lymphocytes enter the bloodstream and travel to other lymphatic organs, where they aid in disease defense.
- **Thymosin**, a hormone produced by the thymus, stimulates the maturation of lymphocytes in other lymphatic organs.

5.2.2 Disease of the circulatory and lymphatic system

- **Leukemia** is a type of cancer that affects blood-forming tissues, including bone marrow. There are several types of leukemia, including *acute lymphoblastic leukemia, acute myeloid leukemia,* and *chronic lymphocytic leukemia*. *For example, many patients with slow-growing*

leukemia are asymptomatic, and rapidly progressing types of leukemia can cause fatigue, weight loss, frequent infections, and easy bleeding or bruising. Treatment for slow-growing leukemia may include

- ✓ Monitoring.
- ✓ Chemotherapy, sometimes followed by radiation and stem-cell transplant, is used to treat aggressive leukemia.

- **Varicose veins** are enlarged, swollen, and twisting veins that often have blue or dark purple color. *They occur when faulty vein valves allow blood to flow in the wrong direction or pool.*
- It is common in *pregnant women are more prone to varicose veins*, and
- *Overweight people are more prone to varicose veins*

Symptoms of Varicose Vein

- *Aching legs, swollen ankles, and spider veins* are some of the symptoms. It occurs when the valves in the veins fail to function properly, allowing blood to flow inefficiently.
- **Elephantiasis** is a condition that causes a large enlargement of a part of the body; usually the limbs
- Elephantiasis is caused by a blockage in the lymphatic system, resulting in an accumulation of a fluid known as lymph in the affected areas. Elephantiasis is caused by parasitic worms transmitted by mosquitoes. ***Wuchereria bancrofti, Brugia malayi***, and **Brugia timori** are the three worms involved.
- **Cardiovascular diseases**:
  - ✓ Abnormal heart rhythms, also known as arrhythmias
  - ✓ Aorta disease and Marfan syndrome are two examples,
  - ✓ Congenital heart disease is a condition that occurs at birth.
  - ✓ Coronary artery disease is a condition that affects the arteries in the heart (narrowing of the arteries),
  - ✓ Deep vein thrombosis (DVT) and pulmonary embolism (PE),
  - ✓ A heart attack,
  - ✓ Heart failure and Muscle disease of the heart (cardiomyopathy).

Heart disease

- Heart and blood vessel disease (also known as heart disease) encompasses a wide range of issues, many of which are linked to a process known as atherosclerosis. **Atherosclerosis** is a condition that occurs when a substance called plaque accumulates in the artery walls.
- Heart attack A heart attack occurs when a blood clot blocks blood flow to a portion of the heart. If the clot completely obstructs blood flow, the part of the heart muscle supplied by that artery begins to die.

Stroke

- Stroke is a *cerebrovascula*r disease. It occurs when a blockage or bleed of the blood vessels either interrupts or reduces the supply of blood to the brain. When this happens, the brain does not receive enough oxygen or nutrients, and brain cells start to die.
- There are 2 types of stroke:

  1. An ischemic stroke (the most common type of stroke) occurs when a blood vessel that supplies the brain becomes blocked, typically due to a blood clot.
  2. When a blood vessel in the brain bursts, it causes a **hemorrhagic stroke**. Uncontrolled hypertension is the most common cause of this (high blood pressure).

Heart failure

- Heart failure, also known as *congestive heart failure*, occurs when the heart does not pump blood as efficiently as it should.
- Heart failure does not imply that the heart ceases to beat Instead, the heart continues to beat, but the body's need for blood and oxygen is unsatisfied.

Arrhythmia

- An abnormal heart rhythm is referred to as **arrhythmia**. Arrhythmias in a variety of forms. The heart can beat too slowly, too quickly, or in an irregular pattern..

5.3 The breathing system

- The respiratory system, which includes muscles to move air into and out of the lungs
- Passageways through which air moves, and microscopic gas exchange surfaces covered by capillaries, allows carbon dioxide to be exhaled and oxygen to be inhaled, Gases are transported from the lungs to tissues throughout the body via the circulatory system
- The breathing system organs' primary functions are to:
  - Provide oxygen to body tissues for cellular respiration.
  - remove the waste product, carbon dioxide,
  - Help to maintain acid-base balance, and
  - Portions of the breathing system are also used for non-vital functions such as sensing odors, producing speech, and coughing.

The major structures of the breathing system.

- The **nose, larynx, pharynx, trachea, bronchi, bronchioles**, and **alveoli**
  - In humans, air enters the breathing system through the two nasal cavities or the mouth.
  - The tiny hairs that line the nasal cavities act as a filter, keeping foreign particles out of the lower breathing tract.
  - The nasal cavity contains mucus, which warms and moistens the incoming air, traps foreign particles and keeps the cells that line the cavity moist.

Major breathing structures and their functions

The Nose

- The nostrils are the main entry and exit points of breathing system, which are located in the nose.
- The air moves from the nasal cavities to the pharynx. Mucous membranes line portions of the nasal cavities, which contain sebaceous glands and hair follicles that prevent large debris, such as dirt, from passing through the nasal cavity.

Goblet cells, a type of specialized columnar epithelial cell that produces mucus to trap debris, are found in the nasal epithelium.

Pharynx

- The pharynx is a tube made up of skeletal muscle and mucous membrane that runs parallel to the nasal cavities. The pharynx, also known as the **throat**.
- *It receives air from the nasal cavity and air, food, and water from the oral cavity, serving the breathing and digestive systems.*
- It opens into the larynx and esophagus from the back.
- Only air can pass through the upper part of the pharynx (throat). Air, food, and fluids can pass through the lower parts

Larynx

- *The larynx is a structure that connects the pharynx to the trachea and helps regulate the amount of air that enters and leaves the lungs*
- **The epiglottis** is a thin, elastic cartilage that covers the trachea's opening and is attached to the thyroid cartilage.

Trachea

- The trachea (windpipe) extends from the larynx toward the lungs .

Bronchi and Bronchioles

- The right and left primary bronchi branch of the trachea towards the right and left lungs.
- The primary bronchi further branch into *the secondary and tertiary bronchi*.
- A bronchiole branches from the tertiary bronchi.

Breathing Gas Exchange

- Structures involved directly in gas exchange are found in the breathing zone.

Alveoli

- An alveolar sac is a cluster of many individual alveoli that are responsible for gas exchange.
- An alveolus with elastic walls, stretch during air intake which greatly increases the surface area available for gas exchange.

Table 5.5 Comparison of atmospheric and exhaled air.page 134

Breathing Movements

- Pressure differences between the atmosphere and the chest, or thoracic cavity determine the movement of air into and out of the lungs.
- Atmospheric pressure remains relatively constant, but the pressure in the chest cavity may vary. Gases move from an area of high pressure to an area of low pressure:
- **Inspiration occurs** *when the pressure inside the lungs is less than that of the atmosphere,*
- **Expiration occurs** when the pressure inside the lungs is greater than that of the atmosphere.

The diaphragm, a dome-shaped sheet of muscle that separates the thoracic, or chest cavity from the abdominal cavity, can regulate the pressure

During inspiration, *the diaphragm muscle contracts, or shortens pulling downward. The chest volume increases and pressure in the lungs decreases. The atmospheric pressure is now greater than the pressure in the chest cavity, and air moves into the lungs*.

During expiration, *the diaphragm relaxes and returns to its dome shape due to the force exerted by the organs in the abdomen. The chest volume decreases and pressure increases. The pressure in the chest cavity is now greater than the atmospheric pressure, and air moves out of the lungs*

Changes in chest volume during inspiration and expiration:

A. The intercostals muscles contract and the rib cage pull upward. Because the pressure in the chest cavity is lower than the atmospheric pressure, air moves into the lungs.

B. The intercostals muscles relax and the rib cage falls. Because the pressure in the chest cavity is higher than the atmospheric pressure, air moves out of the lungs.

Table 5.6 Summary: Comparison of inspiration and expiration Refer page 136

Disorders of the Breathing System

Bronchitis

Breathing difficulties can be caused by bacteria or viral illnesses, as well as reactions to environmental pollutants. Bronchitis is a condition in which the airways narrow and the mucous lining of the bronchial tubes becomes inflamed. Excess mucus production, tissue swelling, constriction of the airways, and restricted airflow through the bronchi are all symptoms of this condition.

Emphysema

The alveolar walls become irritated in emphysema. The air sacs lose their flexibility, stretch, and eventually rupture as a result of this. As a result, exhaling becomes difficult, and air is trapped in the lungs. Because there are fewer alveoli, the surface area available for gas exchange is reduced, resulting in lower oxygen levels. Emphysema is caused by smoking, which is by far the most common cause.

Bronchial Asthma

The inflammation of the bronchioles is linked to bronchial asthma. Exhaling requires more work than inhaling in asthma. The imbalance between the amount of air entering and leaving the lungs must be addressed by increasing the exertion of expiration. Common causes for asthma are tobacco smoking, pollution, and allergens such as pollen, mold, dust, etc.

5.4 The Human Urinary system

External structure of kidney

- ✓ The **kidneys** are a pair of bean-shaped organs in the abdominal cavity that are placed directly below the liver. The endocrine system includes the adrenal glands, which are located on top of each kidney.
- ✓ Blood is purified and filtered by the kidneys.
- ✓ **Urine** is the filtrate that comes out of the kidneys.
- ✓ The **ureters,** which are around 30 cm long, transport urine from the kidneys to the urinary bladder.
- ✓ Urine from both ureters is collected in the **bladder**. Its capacity is diminished during late pregnancy because to compression by the increasing uterus, resulting in increased urination frequency.
- ✓ *Urine is transported from* ***the bladder to the exterior of the body via the urethra*****.**

Internal structure of kidney

- ✓ The kidney is divided into three sections on the inside:
    - an outer cortex,
    - a medulla in the middle, and
    - the renal pelvis in the hilum of the kidney.
- ✓ The **hilum** is the concave portion of the bean form where blood arteries and nerves enter and exit the kidney, as well as where the ureters exit.
- ✓ The presence of renal corpuscles causes the renal cortex to be granular, and nephron tubules can be observed throughout the renal cortex and renal pyramids, which make up the majority of the renal medulla.
- ✓ Each kidney has an average of eight renal pyramids.
- ✓ The urine produced by the nephrons passes via the ***renal pelvis*** and into the ***ureters,*** which transport it to the bladder
- ✓ The renal hilum is where the arteries, veins, and nerves that supply the kidney enter and exit.

Nephron: the functional unit of the kidney.Each kidney is made up of over one million nephrons that dot the renal cortex.

- ✓ A nephron consists of three parts: ***a renal corpuscle, a renal tubule****, and* ***the associated capillary network***.

Renal corpuscle

- ➢ The glomerulus, a network of capillaries that surrounds the renal corpuscle in the renal cortex, is made up of the glomerular or Bowman's capsule, a cup-shaped chamber that surrounds

Renal Tubule

The renal tubule is a long, convoluted structure that emerges from the glomerulus and can be split into three segments based on function:

1. The Proximal Convoluted Tubule (PCT),
2. The loop of Henle, which forms a loop (with descending and ascending limbs), and
3. The Distal Convoluted Tubule (DCT).

The DCT, or distal collecting duct, joins and discharges the nephron's contents into collecting ducts.

Urine will eventually pass via the renal pelvis and into the ureters.

Capillary Network within the Nephron

- ➢ The nephron receives blood that needs to be filtered via a capillary network that branches off from the renal arteries.
- ➢ Afferent arterioles are the branches that enter the glomerulus.
- ➢ Efferent arteriole refers to the branch that leaves the glomerulus.

- The glomerular capillary bed is the capillary network that runs through the glomerulus.
- The peritubular capillary network surrounds and interacts with portions of the renal tubule after the efferent arteriole exits the glomerulus.

The formation of urine

- Kidneys filter blood in a three-step process: The nephrons filter blood as it passes through the glomerulus' capillary network. Except for proteins, almost all solutes are filtered out into the glomerulus by a process known as **glomerular filtration**.
- The filtrate is collected in the tubules of the kidneys. Tubular reabsorption is the process by which most of the solutes are reabsorbed in the PCT.
- The filtrate continues to exchange solutes and water with the peritubular capillary network in the Henle loop. During this phase, water is also reabsorbed.
- Tubular secretion, which is essentially the inverse of tubular reabsorption, secretes extra solutes and wastes into the renal tubules.
- The collecting ducts collect filtrate from the nephrons, which are then carried into the renal pelvis and eventually to the ureters as urine.
- Each part of the nephron performs a different function in filtering waste and maintaining Homeostatic balance:

  1. The glomerulus forces small solutes out of the blood by pressure.
  2. The proximal convoluted tubule actively transfers toxins and medications from the interstitial fluid into the filtrate, reabsorbing ions, water, and nutrients from the filtrate. By selectively secreting ammonia (NH) into the filtrate, where it interacts with H+ to generate NH, the proximal convoluted tubule also regulates blood pH. More ammonia is secreted when the filtrate is acidic.
  3. Aquaporin-containing cells border the descending loop of Henle, allowing water to flow from the filtrate into the interstitial fluid.
  4. Na and Cl ions diffuse into the interstitial fluid in the thin section of the ascending loop of Henle. These same ions are actively transferred into the interstitial fluid in the thick region. The filtrate becomes increasingly dilute as it passes up the leg because salt but not water is lost.
  5. K and Hions are selectively secreted into the filtrate in the distal convoluted tubule, while Na', Cl, and HCO, ions are reabsorbed to maintain blood pH and electrolyte balance.
  6. Solutes and water from the filtrate are reabsorbed by the collecting duct, resulting in dilute urine.

5.5 The immune system

- **Immunity** is defined as the body's ability to prevent the invasion of pathogens. The immune system includes varieties of defenses against viruses, bacteria, fungal infections, and parasites (such as threadworms). The lymphatic system is part of the broader immune system.
- The types of immune systems include
  1. Innate/inborn/Natural and
  2. Adaptive (Acquired) immune systems,

  a) **Innate immune system**: The body's initial line of defense against invading microbial diseases is innate immunity. These are the non-specific, unchanging lines of defenses which include:
     - Physical and chemical barriers to pathogens.
     - To attract immune cells to infection locations, cytokines and other chemical agents are produced.
     - To recognize bacteria, stimulate cells, and facilitate the clearance of dead cells or antibody complexes, the complement cascade is activated.

- Specialized white blood cells identify and remove foreign compounds found in organs, tissues, blood, and lymph.

b/ Adaptive (Acquired) immune system : After an initial reaction to a new pathogen, adaptive (or acquired) immunity is formed, resulting in an increased response to future exposure to the same disease. Vaccination is based on this acquired immunity process.

Immunological memory is the process through which signature antibodies or T cell receptors "remember" each infection. If another infection arises, these memory cells can be summoned to eliminate the invader swiftly.

Cells of the immune system

Lymphocytes: White blood cells that travel between the bloodstream and the lymphatic system. They are crucial in the battle against infection. ***T cells, B cells***, and ***natural killer*** cells are the three most common types of lymphocytes.

- Lymphocytes are formed in the ***bone marrow***. Some move to the thymus and mature into ***T cells***, while others mature into ***B cells*** in the bone marrow.

Neutrophils: The most common form of white blood cell. Neutrophils play a vital role in the innate immune system.

- A type of phagocyte is neutrophils (cells that engulf and then digest cellular debris and pathogens).

***Macrophages*:** phagocytes that play a role in both the innate and adaptive immune systems are another form of phagocyte. Foreign chemicals, pathogenic bacteria, and cancer cells are all targets for them.

Dendritic cells: Antigen-presenting cells serve as intermediaries between the innate and adaptive immune systems.

They are frequently found in tissues that come into contact with the outside world, such as the skin, nose, lungs, stomach, and gut linings.

Antigens and antibodies

Antibodies (also called immunoglobulins) are Y-shaped proteins produced by B-cells that bind to antigens on the surface of foreign substances like bacteria and viruses.

Hormones and the immune system

The immune system producesa wide range of hormones. ***Lymphokines*** are the common name for these hormones.

5.6 Renowned Physicians in Ethiopia

1. Prof. Asrat Woldeyes (1928-1999) was the first distinguished Ethiopian surgeon and professor of medicine in Addis Ababa University. He was the first Ethiopian to qualify in this field of medicine in the West after medical studies at Edinburgh University. He devoted the majority of his working life to surgery at Addis Adaba's two main hospitals, as well as the deanship of medicine at the university. Prof. Asrat Woldeyes

2. Dr. Widad KidaneMariam was born to an Ethiopian emigrant family in Palestine during the Italian occupation of her country of origin. She studied medicine at the American University of Beirut and became the "first female" medical practitioner and topmost physician administrator in charge of the medical services division in the Ministry of Health in the 1960s-1970s. When she was asked to be the first Ethiopian gynecologist to volunteer for the Swedish Save the Children Fund project in Addis Abeba, she also became a founding organizer responsible for the establishment of the first Ethiopian Family Planning Association as well as Maternal and Child services for the homeless in Addis Abeba Municipality.

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End of the chapter