**UNIT 7. THE CIRCULATORY SYSTEM**

Circulatory system refers to the heart, blood vessels (Arteries, veins and capillaries), and the blood. The heart is a pumping while blood vessels are carrying the blood. Arteries, carry blood away from the heart; veins carry blood back to the heart; and capillaries are microscopic blood vessels that connect the smallest arteries to the smallest veins.

Another term usually in use is the cardiovascular system, which refers the passages through which the blood flows—the heart, and the blood vessels. The human circulatory system is called a closed system because the blood is contained within either the heart or blood vessels at all time.

**7.1. Functions of the circulatory system**

The main functions of the circulatory system are:

1. Transport of nutrients, gases, hormones, [blood](http://en.wikipedia.org/wiki/Blood) cells, nitrogen waste products, etc. to and from [cells](http://en.wikipedia.org/wiki/Cells_%28biology%29) in the body
2. Help fight diseases and
3. help stabilize body temperature and [pH](http://en.wikipedia.org/wiki/PH) to maintain [homeostasis](http://en.wikipedia.org/wiki/Homeostasis).

**7.2. The blood**

Blood is a liquid connective tissue that constitutes the transport media of the circulatory system. Our body contains 4 to 5 litters of blood. Functions of the blood are:

* Transporting nutrients and oxygen to the cell,
* Transporting carbon dioxide and wastes away from the cells,
* Transfers heat to the body surface and involve in temperature regulation,
* Plays role in regulation of PH and electrolytes,
* Prevents accidental loss of blood from the body by forming blood clot,
* Plays a role in body defence against diseases

**7.2.1. Blood Composition**

Blood is composed of a liquid part (called blood plasma), and Cellular part ( called blood cells).

**a) Blood plasma**

Blood plasma, **a**pproximately 55% of blood, is made up of a straw coloured fluid. Plasma is 90% water and 10% dissolved fats, salts, sugars, and proteins called plasma proteins. There are 3 types of plasma proteins:

1. Albumins: is the most abundant plasma protein and help to regulate osmotic pressure
2. Globulins (antibodies): include antibodies that gives immunity.
3. Fibrinogens: responsible for blood clotting and prevent loss of blood from the body.

**b) Blood cells**

The cellular portion of the blood constitute 45% of the blood. It includes three types of cells:

1. **Erythrocytes or red blood cells (RBC):** RBCs found in large numbers. One microlitres of blood contains about 5 million RBCs. They are produced in the bone marrow and contain an iron containing protein called haemoglobin. Haemoglobin gives RBCs the ability to carry oxygen and responsible for the red color of RBCs. Matured RBCs do not have nucleus and organelles and stay in circulation for about 120 days.
2. **Leukocytes or white blood cells (WBC):** WBCs are produced by the red marrow, lymph nodes and spleen. They are larger than RBCs, almost colorless, do not have haemoglobin. they are less numerous than RBCs. WBCs have nucleus and can live for many months or years. The main function of WBCs is to protect the body against invasion by foreign cells or disease causing organisms. There are five groups of WBCs: Neutrophils, Eosinophils Basophils, Lymphocytes and Monocytes.
3. **Blood platelets:** are not cells, but are tiny fragments of other cells that are formed in the bone marrow. Platelets play important role in blood clotting to prevent blood loss. They help clotting process releasing proteins called **clotting factors**.

**7.2.2. Blood Cell Production**

The process of blood cells production is called hematopoiesis or **hemopoiesis** (hemo, hemato = blood; poiesis = to make).This process occurs in the red bone marrow. The tissues that produce blood are called *hemopoietic tissues.*

***Erythrocyte Production*:** The process is called ***erythropoiesis***. It generates about 2.5 million RBCs per second (20 mL/day). The sequence of cell transformations leading to an erythrocyte is hemocytoblast proerythroblast erythroblast normoblast reticulocyte erythrocyte. The overall process from hemocytoblast to reticulocytes takes 3 to 5 days.

**7.2.3. Blood Types**

Blood type is determined by the type of antigen present on the surface of RBC. An **antigen** is a protein or carbohydrate that acts as a signal, enabling the body to recognize foreign substances in the body. Three of the most important human blood antigens are called **A, B, and Rh**. An individual’s RBC may carry an A antigen, B antigen, both A and B antigens or no antigen at all. Based on this there are 4 blood types (groups) in humans: A, B, AB and O.

**Table 7.1** Types of blood and their antigen and antibody

|  |  |  |
| --- | --- | --- |
| **Blood type** | **Antigen type** | **Antibody type** |
| A | A | Anti B antibody |
| B | B | Anti A antibody |
| AB | AB | No antibody |
| O | No antigen | Anti A antibody and Anti B antibody |

Transfusion of blood is possible with compatible blood types. If incompatible, an antigen will react with antibodies and agglutination (clumping of RBCs) will occur. Type AB can receive any type of blood and is known as **universal receiver**. Type O can donate blood to any one and known as **universal donor**.

**Table 7.2** Blood donor and receiver chart

|  |  |  |
| --- | --- | --- |
| **Blood type** | **Can donate to** | **Can receive from** |
| A | A, AB | A, O |
| B | B, AB | B, O |
| AB | AB | A, B, O |
| O | A, B, AB, O | O |

**7.3. The Heart**

The heart is a four-chambered, double pump, located in the thoracic cavity between the lungs. It is a hollow, cone-shaped, muscular organ about the size of a fist. It has a mass of between 250 and 350 grams. The heart is composed of cardiac muscle. The term "cardiac" (as in cardiology) means "***related to the heart***” and comes from the Greek word kardia, for "heart."

**7.3.1. Structure and function of the Heart**

The primary function of the heart is to pump blood through the blood vessels by repeated, rhythmic contractions. The heart has two separate pumps: a *right heart* that pumps blood through the lungs, and a *left heart* that pumps blood to peripheral organs. The heart keeps blood circulating properly.

***a) Coverings of the Heart***

The heart is surrounded by a double membrane called the pericardium, a sac with two layers:

i) ***The outer fibrous pericardium***: anchors the heart to the surrounding structures.

ii) ***The inner serous pericardium***: consists of an ***outer parietal layer*** and an ***inner visceral layer***. Between the parietal and visceral layers is pericardial cavity, containing a pericardial fluid. The fluid lubricates the heart wall and reduces friction when the heart glides.

***b) Layers of the Heart Wall***

The heart wall, richly supplied with blood vessels, is composed of three layers.

1. ***Epicardium***: is the superficial visceral layer of the serous pericardium
2. ***Myocardium*** (“muscle heart”): It is the middle layer composed mainly of cardiac muscle
3. ***Endocardium***: inside layer is a thin, smooth, endothelial, inner lining of the heart.

### c) Heart Chambers

The heart has four chambers (Fig. 7.1)—two superior **atria** and two inferior **ventricles**. Atria have thinner walls than ventricles. The **atria** are divided into right atria and left atria, which receive blood coming into the heart. The **ventricles** are divided into right ventricle and left ventricle, which pump blood out of the heart. The left ventricle is the thickest chamber of the heart because it pumps blood to all parts of the body. Vertically dividing the right and left sides is a common wall called **septum,** which prevents mixing of oxygenated and non oxygenated blood.

**Figure 7.1** The structures of a human heart

**Valves**: valves are presentin the heart and blood vessels. Valves prevent the backflow of blood to ensure the blood flow only in one direction. These valves are grouped into two main categories:

i) ***Semilunar Valves***: valves are present in the arteries leaving the heart. Two of the valves are:

*a) The pulmonary semilunar valve*: lies between the right ventricle & the pulmonary trunk; and

b) ***The aortic semilunar valve***: located between the ventricle and the aorta t blood from flowing back into the ventricles.

ii) ***Atrioventricular (AV***): are located between atria and ventricels. They prevent the back flow of blood from atria into the ventricles. These valves include:

a) ***The right AV valve***: it is also called the tricuspid valve, located between the right atrium and the right ventricle. The tricuspid valve allows blood to flow from the right atrium into the right ventricle when the heart is relaxed during diastole.

b) ***The left AV valve***: it is also called the bicuspid valve: This valve prevents flow of blood in the left ventricle from flowing into the left atrium.

**7.3.2. Circulatory pathways**

Blood returning from the lungs enters the left atrium, and passes through flaps of tissue called **atrioventricular (AV) valve**. The valve that separates the left atrium and ventricle is called the **bicuspid (mitral)valve**. From the left ventricle, blood is pumped trough a **semilunar valve** called the **aortic valve** into the aorta artery that carries it to every part of the body except the lungs. Aortic valve prevents blood from flowing back into the left ventricle.

**A. Types of circulation**

Blood moves through body in a continuous pathway, of which there are 2 major paths, i.e. pulmonary and systemic circulation.

1. **Pulmonary circulation:** carries blood between the heart and lungs. It begins at the right ventricle and ends at the left atrium. Deoxygenated blood is pumped out of right ventricle into the lungs through the pulmonary arteries, which are the only arteries that carry deoxygenated blood. Blood return to the heart through the pulmonary veins, which are the only veins to carry oxygenated blood.
2. **Systemic circulation:** starts at the left ventricle and ends at atrium, carries blood to the rest of the body. Oxygenated blood leaving the heart passes through aorta, a number of arteries and capillaries that lead to veins through which blood returns to the right atrium. The systemic circulation can be divided into 3 subdivisions. i)**Coronary circulation:** supplies blood to the heart. ii) **Renal circulation:** supplies blood to the kidney. iii) **Hepatic portal circulation:** nutrients are picked up by capillaries in the small intestine and are transported to the liver.

**B. The heartbeat (cardiac cycle) and cardiac output**

The cardiac cycle is the sequence of events in one heartbeat, i.e. the simultaneous contraction of the 2 atria followed by the simultaneous contraction of the 2 ventricles.

The heartbeat has two phases:

1. **Systole:** refers to the contraction of the heart and occurs when the ventricle contracts, closing the AV valves
2. **Diastole:** refers to the relaxation, the ventricles relaxes, opening AV valves.

Each heartbeat produces 2 sounds, often called **lub-dup** that can be heard with a stethoscope. The first sound, the loudest and longest, is caused by ventricular systole closing the AV valves. The second sound is caused by the closure of the aortic and pulmonary valves (SL).

The following variables are measures of the capacity of the heart:

1) **Stroke volume** (SV) is the volume of blood ejected by each ventricle during a single contraction. The stroke volumes of the left and right ventricles are normally equal.

2) **Heart rate** (HR) is the number of heart beats per minute.

3) **Cardiac output** (CO) is the volume of blood pumped out of the right or left ventricle per minute. CO = SV x HR.

Cardiac output varies widely with the health of the individual and the state of activity at the time of measurement.

The Sino Atrial (SA) node is a natural pacemaker of the heart. **Pacemaker** initiates each heartbeat and sets the pace for the heart rate. The ANS influences the heart rate, in which the sympathetic nervous system increases the rate and the parasympathetic system decreases the rate. At rest our heart beats between 60 and 80 beats per minute.

**C. Blood Pressure**

Blood pressure is a measure of force that blood exerts against a blood vessel wall. Blood pressure is expressed as the systolic number over the diastolic number. The normal blood pressure of an adult male is 120/80 mm mercury(Hg) and that females is 110/70 mm mercury.

**7.4. Blood Vessels**

There are three types of blood vessels: arteries, capillaries and veins. With exception of capillaries and tiny veins, the walls of blood vessels are made up of 3 layers of tissues that provide strength and elasticity. The inner most layer is epithelial tissue, the middle layer is smooth muscle tissue and the outer layer is connective.

1. **Arteries**

Arteries carry blood from the heart to capillaries and the rest of the body. Except pulmonary arteries, all arteries carry oxygenated blood. The walls of arteries are generally thicker and made up of smooth muscle cells and elastic fibbers that enables them to withstand high pressure of blood as it is pumped from the heart.

The largest artery is called **aorta** and it carry oxygenated blood from left ventricle to all parts of the body, except the lungs. The aorta branches into smaller arteries that supply all parts of the body and the smallest arteries are called **arterioles**.

**B) Capillaries**

Arteries branch into networks of very small blood vessels called capillaries. Its wall is made up of only one layer of cells (thin-walled), through which materials (nutrients, oxygen, wastes, etc) can diffuse easily.

**C) Veins**

Blood flows from capillaries into veins. Veins collect blood from every part of the body and carries back to the heart. The largest veins are called **vena cava** and the smallest ones are called **venules**. There are 2 types of vena cava, superior and inferior that empty blood into right atrium. The **superior vena cava** brings blood from the upper part of the body to the heart and the **inferior vena cava** brings from the lower part of the body to the heart. Large veins contain valves that help to keep one directional flow of blood. Although blood pressure drops as the blood reaches the veins, blood flow in veins is helped by contraction of skeletal muscles and valves.

**7.5. The Lymphatic circulation**

Fluids from the blood can leak into tissue space as blood circulates throughout the body. A network of vessels known as **lymphatic system** collects and returns this fluid back to bloodstream. The **lymph**, **lymph nodes**, **lymphoid organs** and **lymph vessels** form the [lymphatic system](http://en.wikipedia.org/wiki/Lymphatic_system).

The fluid in the lymphatic system is called **lymph** and it is a transparent yellowish fluid. The lymph is collected in lymphatic capillaries and move to larger **lymphatic vessels** that contain valves to prevent back flow of lymph. The lymphatic system has no pump like the heart, lymph moved through vessels by the squeezing of skeletal muscles. These lymph vessels pass through small bean-shaped enlargement called **lymph nodes**. Lymph node act as filter for foreign bodies and also produces special WBCs called **lymphocytes** that are specialized to fight infections*.* The fluid is returned to the circulatory system.