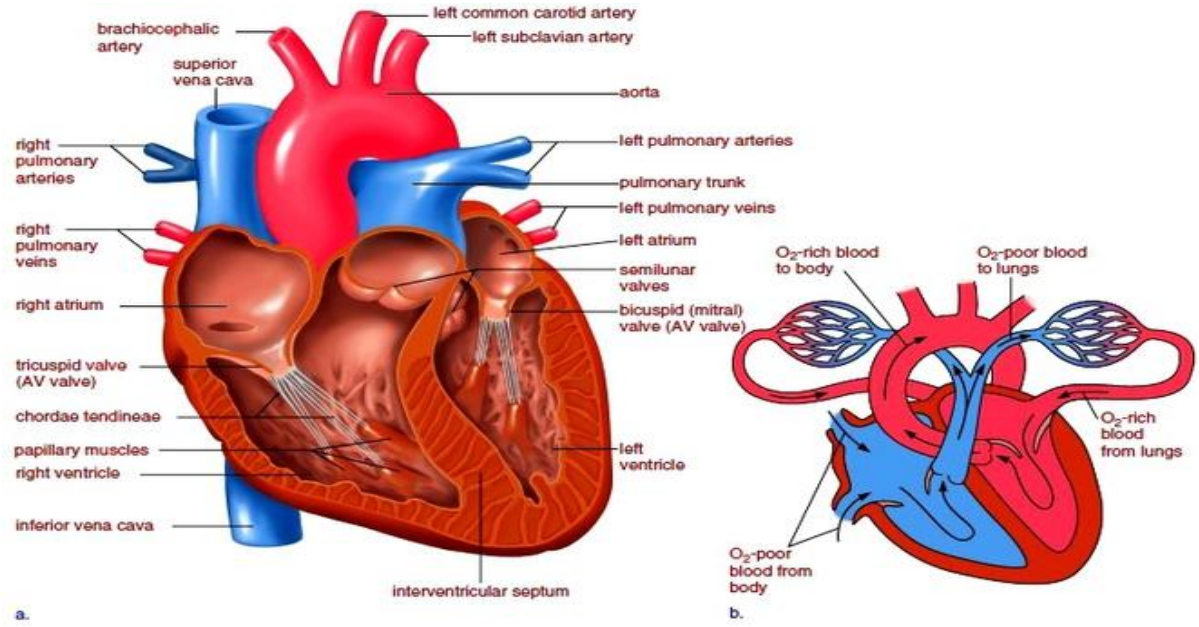
CARDIOVASCULAR SYSTEM

Cardiovascular system is the system of heart and blood vessels that circulates blood throughout the body. The blood circulating the body transports nutrients and oxygen to the tissues and removes carbon dioxide and waste products from the tissues. Heart is the central pump and the blood vessels are the series of distributing and collecting tubes. The thinnest blood vessels are in the form of extensive thin welled vascular channels called CAPPILLARIES through which interchange between cardiovascular system and tissues occurs. The cardiovascular system constitutes one of the major coordinating and integrating system of the body. The other two systems that have such actions are the nervous and endocrine system.

HEART



Heart is a muscular organ that pumps blood throughout the circulating system. It situated in between the two lungs in the mediastinum. It is made up of 4 chambers: 2 atria and 2 ventricles. The musculature is (more thick) thicker in the ventricles than in the atria. The force of contraction of the heart depends upon the muscles.

Right side of the heart

The right side of the heart has 2 chambers, the upper right atrium and lower right ventricles.

Right atrium is a thin walled and low pressure chamber. It has pacemaker known as sinoatrial node that produces cardiac impulses and atrioventricular node that conducts the impulses to the ventricles. It receives venous (deoxygenated) blood from 2 large veins:

1. Superior vena cava that returns the venous blood from the head, neck and upper limbs.

2. Inferior vena cava that returns the venous blood from lower parts of the body.

Right atrium communicates with the right ventricle through the tricuspid valve. The wall of right ventricle is thick. Venous blood from the right atrium enters the right ventricles through this valve.

From the right ventricles, pulmonary artery arises. It carries the venous blood from the right ventricles to the lungs. In the lungs, the deoxygenated blood is oxygenated

Left side of the heart

The left side of the heart has 2 chambers, the upper left atrium and lower left ventricles. The left atrium is a thin welled and lower pressure chamber. Left atrium receives oxygenated blood from the lungs through the pulmonary veins. This is the only exception in the body where an artery carries venous blood and vein carries the arterial blood.

Blood from left atrium enters the left ventricles through the mitral valve (bicuspid valve). Wall of the left ventricles is very thick. Left ventricles pumps the arterial blood to different part of the body through systemic aorta.

Layers of the heart

Heart is made up of 3 layers of tissues:

1. Outer pericardium
2. Middle myometrium
3. Inner endocardium

Pericardium

Pericardium is the outer covering of the heart. It is made up of 2 layers which is separated by a space called **pericardial cavity**. The pericardial space is only a potential space. In healthy conditions, the 2 layers of pericardium lie in close approximation separated by a thin film of fluid.

The 2 layers of pericardium are:

i. Outer parietal pericardium: forms a strong protective sac for the heart. It helps also to anchor the heart within the mediastinum.it is made up of 2 layers:
    a. Outer fibrous layer: fibrous layer of the parietal pericardium is formed by thick fibrous connective tissue, because of the fibrous nature, it protects the heart from over stretching.
    b. Inner serous layer: serous layer is formed by mesothelium together with a small amount of connective tissue. Mesothelium contains squamous epithelial cells which secrete a small amount of fluid that lines the pericardial space. This fluid prevent friction and allows free movement of the heart within pericardium when it contracts and relaxes. The total volume of this fluid is only about 25-35mL.

ii. The inner visceral pericardium: closely lines the surface of the myocardium. It is made up of flattened epithelium cells. This layer is also known as epicardium.

Myocardium

Myocardium is the middle layer of the wall of the heart and it is formed by cardiac muscle fiber or cardiac myocytes (cardiac muscles are involuntary in nature). Myocardium is responsible for the pumping action of the heart. It forms the bulk of the heart. 3 types of cardiac muscles fibers are present in myocardium:

i. Muscle fibers which form the contractile unit of the heart (unlike skeletal muscles fiber, the cardiac muscle fiber are involuntary in nature)
ii. Muscles fiber which form pace maker (pace maker is structure in the heart that generate the impulses for heart beat).
iii. Muscle fiber which form the conducting system (the conducting system of the heart is formed by the modified cardiac muscle fiber that helps to transmit various impulse in the heart).

Endocardium

Endocardium is the inner most layer of the heart wall. It is a thin, smooth and glistening membrane. It is formed by a single layer of endothelial cells lining the inner surface of the heart. Endocardium continues as endothelium of the blood vessels.

SEPTA OF THE HEART

Atria of the heart are separated from another by a fibrous septum called interatrial septum. The ventricles are separated from one another by another septum called interventricular septum.

VALVES OF THE HEART

There are 4 valves in human heart. 2 of the valves are In-between the atria and the ventricles called atrioventricular valves. The other 2 are the semilunar valves, placed at the opening of the blood vessels. I.e. systemic aorta and pulmonary artery. The valves of the heart permit the flow of blood through the heart in one direction.

ACTIONS OF THE HEART

The actions of the heart are classified into 4 types

1. Chronotropic action
2. Inotropic action
3. Dromotropic action
4. Bathmotropic action

1. **Chronotropic action**

Chronotropic action is the frequency of heartbeat or heart rate. It is of 2 types:

   i. Tachycardia or increase in heart rate
   ii. Bradycardia or decrease in the heart rate

2. **Inotropic action**

   The force of contraction of the heart. It is of 2 types:

   I. Positive inotropic action or increase in the force of contraction.
   II. Negative inotropic action or decrease in the force of contraction.

3. **Dromotropic action**

   Is the conduction of impulse through the heart. It is of 2 types:

   i. Positive dromotropic action or increase in the velocity of contraction
   ii. Negative dromotropic action or decrease in the velocity of contraction

4. **Bathmotropic action**

   This is the excitability of cardiac muscle of the heart. It is of 2 types:

   1. Positive bathmotropic action or increase in the excitability of cardiac muscle.
   2. Negative bathmotropic action or decrease in the excitability of cardiac muscle.

All the actions of the heart are continuously regulated. It is essential for the heart to cope with the needs of the body. All the actions are altered by the stimulation of nerve supplying the heart or some hormones or hormonal substances secreted in the body.

INNERVATION OF THE HEART

The innervation of the heart refers to the network of nerves that are responsible for the functioning of the heart. The heart is innervated by sympathetic and parasympathetic fibres from the autonomic branch of the peripheral nervous system.

The network of nerves supplying the heart is called the cardiac plexus. It receives contributions from the right and left vagus nerves, as well as contributions from the sympathetic trunk. These are responsible for influencing heart rate, cardiac output, and contraction forces of the heart.

The cardiac plexus

The cardiac plexus is a network of nerves including both
the sympathetic and parasympathetic systems. It is split into two parts. The superficial part is located below the arch of the aorta, and between the arch and the pulmonary trunk.

The deep part lies between the arch of the aorta and the bifurcation of the trachea. Small mixed fibres (containing both sympathetic and parasympathetic fibres) branch off of the cardiac plexus and supply:

- the conduction system of the heart
- the coronary vasculature
- the myocardium (muscle) of the atria and ventricles

Parasympathetic innervation

The parasympathetic portions of the cardiac plexus receive contributions from the vagus nerve only. The preganglionic fibres, branching from the right and left vagus nerves, reach the heart. They enter the cardiac plexus by synapsing with ganglia within this plexus and walls of the atria. Parasympathetic innervation is responsible for:

- reducing the heart rate
- reducing the force of contraction of the heart
- vasoconstriction (narrowing) of the coronary arteries

Sympathetic innervation

The sympathetic part of the cardiac plexus is composed of fibres from the sympathetic trunk, arising from the upper segments of the thoracic spinal cord. Fibres from the sympathetic trunk reach the cardiac plexus via cardiac nerves. The preganglionic fibres branch from the upper thoracic spinal cord and synapse in the lower cervical and upper thoracic ganglia. Postganglionic fibres extend from the ganglia to the cardiac plexus.

Sympathetic nerves are responsible for:

- increasing heart rate
- increasing the force of contraction of the myocardium
- The 'fight or flight' response, causing our heart to beat faster.

The Microcirculation

The microcirculation is the terminal vascular network of the systemic circulation consisting of microvessels with diameters <20 μm. These microvessels consist of arterioles, post-capillary venules, capillaries, and their (sub) cellular constituents. The microcirculation is the final destination of the cardiovascular system and is ultimately responsible for oxygen transfer from the red blood cells (RBC) in the capillaries to the parenchymal cells where oxygen is delivered to meet the energy requirements of the tissue cells in support of their functional activity. Other functions of the microcirculation include the regulation of solute exchange between the intravascular and tissular space and is responsible for the transport of all blood-borne hormones and nutrients to the tissue cells including mediating the functional activity of the immune system and hemostasis. It is arguably the most important compartment of the cardiovascular system, since it is in direct contact with the parenchymal cells, which rely on its proper function to maintain their viability to support organ function.

Blood Flow and Blood Pressure Regulation

Blood Vessels

Functional classification

The blood vessels, together with the four chambers of the heart, from a closed system for the flow of blood; only if there is an injury to some part of the wall of this system does any blood escape. On the basis of function, blood vessels may be classified into three groups:

1. Arteries carry blood from the ventricles (pumping chambers) of the heart out to the capillaries in organs and tissue. The smallest arteries are called arterioles.

2. Veins drain capillaries in the tissues and organs and return the blood to the heart. The smallest veins are the venules.

3. Capillaries allow for exchanges between the blood and body cells, or between the blood and air in the lung tissues. The capillaries connect the arterioles and venules.

Structure of blood vessels

Arteries, veins and capillaries differ in structure. Three coats or layers are found in both arteries and veins. The outer most layer is called the tunica externa. Note smooth muscle is found in the middle layer or tunica media of arteries and veins. However, the muscle layer is much thicker in arteries than in veins. Why is this important? Because the thicker muscle layer in the artery wall is able to resist great pressures generated by ventricular systole. In arteries, the tunica medial plays a critical role in maintaining blood pressure and controlling blood distribution in the body. This is a smooth muscle, so it is controlled by the autonomic nervous system.

A thin layer of elastic and white fibrous tissue covers an inner layer of endothelial cells called the tunica interna in arteries and veins. The tunica interna is actually a single layer of squamous epithelial cells called endothelium that lines the inner surface of the entire circulatory system.

Veins have a unique structural feature not present in arteries. They are equipped with oneway valves that prevent the backflow of blood. When a surgeon cuts into the body, only arteries, arterioles, veins, and venules can be seen. Capillaries cannot be seen because they are microscopic. The most important structural feature of capillaries is their extreme thinness−only one layer of flat, endothelial cells composes the capillary membrane. Instead of three layers or coats, the capillary wall is composed of only one−the tunica interna. Substances such as glucose, oxygen, and wastes can quickly pass through it on their way to or from the cells. Smooth muscle cells that are called precapillary sphincters guard the entrance to the capillary and determine into which capillary blood will flow.

ASSIGNMENT

Location of common arteries and veins

Names of systemic arteries ; The Aorta and Its Parts, Branches of the Ascending Aorta

Anastomosis

Names of Systemic Veins

The structure of arteries, veins, and capillaries, and how blood flows through the body

Blood primarily moves through the body by the rhythmic movement of smooth muscle in the vessel wall and by the action of the skeletal muscle as the body moves. Blood is prevented from flowing backward in the veins by one-way valves. Blood flow through the capillary beds is controlled by precapillary sphincters to increase and decrease flow depending on the body's needs and is directed by nerve and hormone signals. Lymph vessels take fluid that has leaked out of the blood to the lymph nodes where it is cleaned before returning to the heart. During systole, blood enters the arteries, and the artery walls stretch to accommodate the extra blood. During diastole, the artery walls return to normal. The blood pressure of the systole phase and the diastole phase gives the two pressure readings for blood pressure

The blood from the heart is carried through the body by a complex network of blood vessels. **Arteries** take blood away from the heart. The main artery is the aorta that branches into major arteries that take blood to different limbs and organs. These major arteries include the carotid artery that takes blood to the brain, the brachial arteries that take blood to the arms, and the thoracic artery that takes blood to the thorax and then into the hepatic, renal, and gastric arteries for the liver, kidney, and stomach, respectively. The iliac artery takes blood to the lower limbs. The major arteries diverge into minor arteries, and then smaller vessels called **arterioles**, to reach more deeply into the muscles and organs of the body.

Arterioles diverge into capillary beds. **Capillary beds** contain a large number (10 to 100) of **capillaries** that branch among the cells and tissues of the body. Capillaries are narrow-

diameter tubes that can fit red blood cells through in single file and are the sites for the exchange of nutrients, waste, and oxygen with tissues at the cellular level. Fluid also crosses into the interstitial space from the capillaries. The capillaries converge again into **venules** that connect to minor veins that finally connect to major veins that take blood high in carbon dioxide back to the heart. **Veins** are blood vessels that bring blood back to the heart. The major veins drain blood from the same organs and limbs that the major arteries supply. Fluid is also brought back to the heart via the lymphatic system.

The structure of the different types of blood vessels reflects their function or layers. There are three distinct layers, or tunics, that form the walls of blood vessels (Figure 2). The first tunic is a smooth, inner lining of endothelial cells that are in contact with the red blood cells. The endothelial tunic is continuous with the endocardium of the heart. In capillaries, this single layer of cells is the location of diffusion of oxygen and carbon dioxide between the endothelial cells and red blood cells, as well as the exchange site via endocytosis and exocytosis. The movement of materials at the site of capillaries is regulated by **vasoconstriction**, narrowing of the blood vessels, and **vasodilation**, widening of the blood vessels; this is important in the overall regulation of blood pressure.

Veins and arteries both have two further tunics that surround the endothelium: the middle tunic is composed of smooth muscle and the outermost layer is connective tissue (collagen and elastic fibers). The elastic connective tissue stretches and supports the blood vessels, and the smooth muscle layer helps regulate blood flow by altering vascular resistance through vasoconstriction and vasodilation. The arteries have thicker smooth muscle and connective tissue than the veins to accommodate the higher pressure and speed of freshly pumped blood. The veins are thinner walled as the pressure and rate of flow are much lower. In addition, veins are structurally different than arteries in that veins have valves to prevent the backflow of blood. Because veins have to work against gravity to get blood back to the heart, contraction of skeletal muscle assists with the flow of blood back to the heart.

BLOOD FLOW THROUGH THE HEART

The heart is a muscular organ that pumps blood through the blood vessels of the circulatory system. Blood transports oxygen and nutrients to the body. It is also involved in the removal of metabolic wastes. This video describes how blood flows in and out of the heart.

Blood enters the heart through two large veins – the posterior (inferior) and the anterior (superior) vena cava – carrying deoxygenated blood from the body into the right atrium.

Blood flows from the right atrium into the right ventricle through the tricuspid valve. When the ventricle is full, the tricuspid valve shuts to prevent blood flowing backwards into the atrium.

Blood leaves the heart through the pulmonic valve into the pulmonary artery and flows to the lungs.

The pulmonary vein carries oxygen-rich blood from the lungs into the left atrium.

Blood flows from the left atrium into the left ventricle through the open mitral valve. When the ventricle is full, the mitral valve shuts to prevent blood from flowing backwards into the atrium.

Blood leaves the heart through the aortic valve into the aorta and to the rest of the body.