UNIT III CARDIOVASCULAR AND RESPIRATORY SYSTEM
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Cardiovascular System: Structure – Conduction System of heart – Cardiac Cycle – Cardiac output. Blood: Composition – Functions - Haemostasis – Blood groups and typing. Blood Vessels – Structure and types - Blood pressure - Respiratory system: Parts of respiratory system – Respiratory physiology – Lung volumes and capacities – Gaseous exchange.

Introduction to the Cardiovascular System

The cardiovascular system is sometimes called the blood-vascular, or simply the circulatory, system. It consists of the heart, which is a muscular pumping device, and a closed system of vessels called arteries, veins, and capillaries. As the name implies, blood contained in the circulatory system is pumped by the heart around a closed circle or circuit of vessels as it passes again and again through the various "circulations" of the body.

As in the adult, survival of the developing embryo depends on the circulation of blood to maintain homeostasis and a favorable cellular environment. In response to this need, the cardiovascular system makes its appearance early in development and reaches a functional state long before any other major organ system. Incredible as it seems, the primitive heart begins to beat regularly early in the fourth week following fertilization.

The vital role of the cardiovascular system in maintaining homeostasis depends on the continuous and controlled movement of blood through the thousands of miles of capillaries that permeate every tissue and reach every cell in the body. It is in the microscopic capillaries that blood performs its ultimate transport function. Nutrients and other essential materials pass from capillary blood into fluids surrounding the cells as waste products are removed.

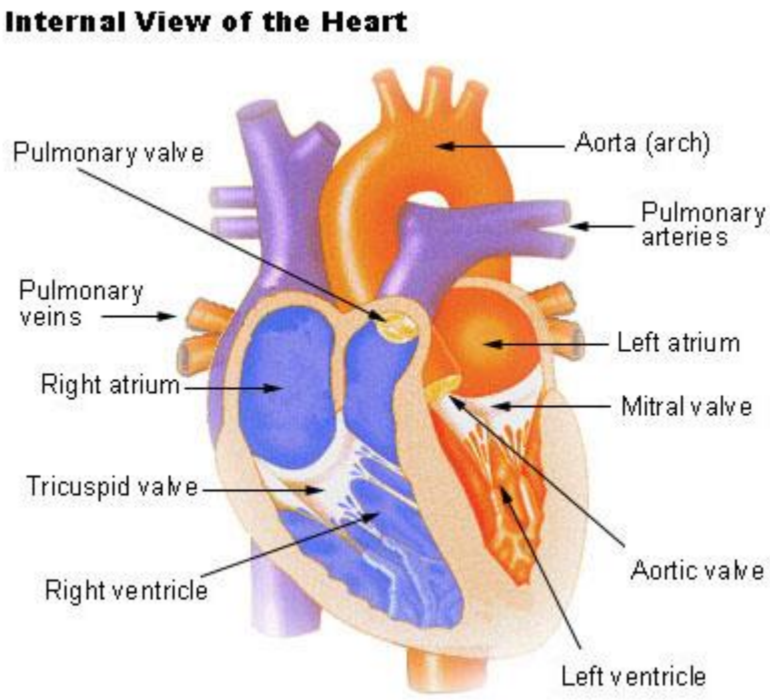
Numerous control mechanisms help to regulate and integrate the diverse functions and component parts of the cardiovascular system in order to supply blood to specific body areas according to need. These mechanisms ensure a constant internal environment surrounding each body cell regardless of differing demands for nutrients or production of waste products.

The heart is a muscular pump that provides the force necessary to circulate the blood to all the tissues in the body. Its function is vital because, to survive, the tissues need a continuous supply of oxygen and nutrients, and metabolic waste products have to be removed. Deprived of these necessities, cells soon undergo irreversible changes that lead to death. While blood is the transport medium, the heart is the organ that keeps the blood moving through the vessels. The normal adult heart pumps about 5 liters of blood every minute throughout life. If it loses its pumping effectiveness for even a few minutes, the individual's life is jeopardized.

Structure of the Heart

The human heart is a four-chambered muscular organ, shaped and sized roughly like a man's closed fist with two-thirds of the mass to the left of midline.

The heart is enclosed in a pericardial sac that is lined with the parietal layers of a serous membrane. The visceral layer of the serous membrane forms the epicardium.



Layers of the Heart Wall

Three layers of tissue form the heart wall. The outer layer of the heart wall is the epicardium, the middle layer is the myocardium, and the inner layer is the endocardium.

Chambers of the Heart

The internal cavity of the heart is divided into four chambers:

- Right atrium
- Right ventricle
- Left atrium

- Left ventricle

The two atria are thin-walled chambers that receive blood from the veins. The two ventricles are thick-walled chambers that forcefully pump blood out of the heart. Differences in thickness of the heart chamber walls are due to variations in the amount of myocardium present, which reflects the amount of force each chamber is required to generate.

The right atrium receives deoxygenated blood from systemic veins; the left atrium receives oxygenated blood from the pulmonary veins.

Valves of the Heart

Pumps need a set of valves to keep the fluid flowing in one direction and the heart is no exception. The heart has two types of valves that keep the blood flowing in the correct direction. The valves between the atria and ventricles are called atrioventricular valves (also called cuspid valves), while those at the bases of the large vessels leaving the ventricles are called semilunar valves.

The right atrioventricular valve is the tricuspid valve. The left atrioventricular valve is the bicuspid, or mitral, valve. The valve between the right ventricle and pulmonary trunk is the pulmonary semilunar valve. The valve between the left ventricle and the aorta is the aortic semilunar valve.

When the ventricles contract, atrioventricular valves close to prevent blood from flowing back into the atria. When the ventricles relax, semilunar valves close to prevent blood from flowing back into the ventricles.

Pathway of Blood through the Heart

While it is convenient to describe the flow of blood through the right side of the heart and then through the left side, it is important to realize that both atria and ventricles contract at the same time. The heart works as two pumps, one on the right and one on the left, working simultaneously. Blood flows from the right atrium to the right ventricle, and then is pumped to the lungs to receive oxygen. From the lungs, the blood flows to the left atrium, then to the left ventricle. From there it is pumped to the systemic circulation.

Blood Supply to the Myocardium

The myocardium of the heart wall is a working muscle that needs a continuous supply of oxygen and nutrients to function efficiently. For this reason, cardiac muscle has an extensive network of blood vessels to bring oxygen to the contracting cells and to remove waste products.

The right and left coronary arteries, branches of the ascending aorta, supply blood to the walls of the myocardium. After blood passes through the capillaries in the myocardium, it enters a system of cardiac (coronary) veins. Most of the cardiac veins drain into the coronary sinus, which opens into the right atrium.

Physiology of the Heart

The conduction system includes several components. The first part of the conduction system is the sinoatrial node . Without any neural stimulation, the sinoatrial node rhythmically initiates impulses 70 to 80 times per minute. Because it establishes the basic rhythm of the heartbeat, it is called the pacemaker of the heart. Other parts of the conduction system include the atrioventricular node, atrioventricular bundle, bundle branches, and conduction myofibers. All of these components coordinate the contraction and relaxation of the heart chambers.

Cardiac Cycle and cardiac output

The cardiac cycle refers to the alternating contraction and relaxation of the myocardium in the walls of the heart chambers, coordinated by the conduction system, during one heartbeat. Systole is the contraction phase of the cardiac cycle, and diastole is the relaxation phase. At a normal heart rate, one cardiac cycle lasts for 0.8 second.

Cardiac cycle is defined as the complete cycle of events in the heart from the beginning of one heartbeat to the beginning of the next. It comprises three stages – atrial systole, ventricular systole, and complete cardiac diastole. Cardiac output is defined as the amount of blood pumped out by the ventricles in a minute.

Heart Sounds

The sounds associated with the heartbeat are due to vibrations in the tissues and blood caused by closure of the valves. Abnormal heart sounds are called murmurs.

Heart Rate

The sinoatrial node, acting alone, produces a constant rhythmic heart rate. Regulating factors are reliant on the atrioventricular node to increase or decrease the heart rate to adjust cardiac output to meet the changing needs of the body. Most changes in the heart rate are mediated through the cardiac center in the medulla oblongata of the brain. The center has both sympathetic and parasympathetic components that adjust the heart rate to meet the changing needs of the body.

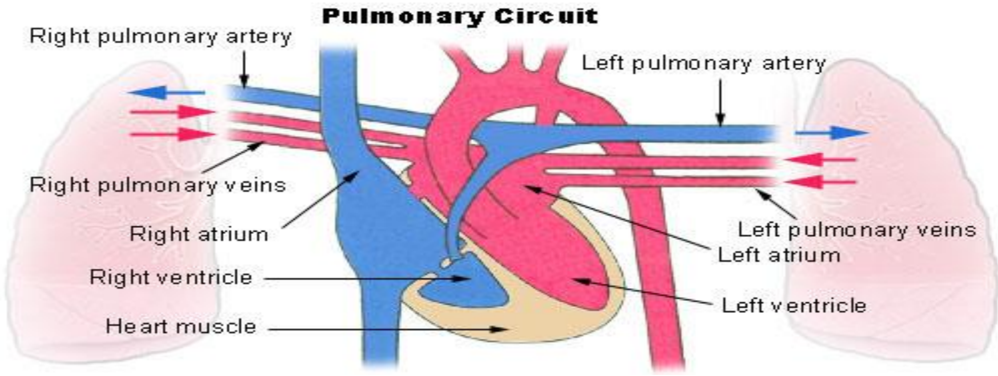
Peripheral factors such as emotions, ion concentrations, and body temperature may affect heart rate.

Circulatory Pathways

The blood vessels of the body are functionally divided into two distinctive circuits: pulmonary circuit and systemic circuit. The pump for the pulmonary circuit, which circulates blood through the lungs, is the right ventricle. The left ventricle is the pump for the systemic circuit, which provides the blood supply for the tissue cells of the body.

Pulmonary Circuit

Pulmonary circulation transports oxygen-poor blood from the right ventricle to the lungs, where blood picks up a new blood supply. Then it returns the oxygen-rich blood to the left atrium.



Systemic Circuit

The systemic circulation provides the functional blood supply to all body tissue. It carries oxygen and nutrients to the cells and picks up carbon dioxide and waste products. Systemic circulation carries oxygenated blood from the left ventricle, through the arteries, to the capillaries in the tissues of the body. From the tissue capillaries, the deoxygenated blood returns through a system of veins to the right atrium of the heart.

The coronary arteries are the only vessels that branch from the ascending aorta. The brachiocephalic, left common carotid, and left subclavian arteries branch from the aortic arch. Blood supply for the brain is provided by the internal carotid and vertebral arteries. The subclavian arteries provide the blood supply for the upper extremity. The celiac, superior mesenteric, suprarenal, renal, gonadal, and inferior mesenteric arteries branch from the abdominal aorta to supply the abdominal viscera. Lumbar arteries provide blood for the muscles and spinal cord. Branches of the external iliac artery provide the blood supply for the lower extremity. The internal iliac artery supplies the pelvic viscera.

Major Systemic Arteries

All systemic arteries are branches, either directly or indirectly, from the aorta. The aorta ascends from the left ventricle, curves posteriorly and to the left, then descends through the thorax and abdomen. This geography divides the aorta into three portions: ascending aorta, arotic arch, and descending aorta. The descending aorta is further subdivided into the thoracic arota and abdominal aorta.

Major Systemic Veins

After blood delivers oxygen to the tissues and picks up carbon dioxide, it returns to the heart through a system of veins. The capillaries, where the gaseous exchange occurs, merge into venules and these converge to form larger and larger veins until the blood reaches either the superior vena cava or inferior vena cava, which drain into the right atrium.

Fetal Circulation

Most circulatory pathways in a fetus are like those in the adult but there are some notable differences because the lungs, the gastrointestinal tract, and the kidneys are not functioning before birth. The fetus obtains its oxygen and nutrients from the mother and also depends on maternal circulation to carry away the carbon dioxide and waste products.

The umbilical cord contains two umbilical arteries to carry fetal blood to the placenta and one umbilical vein to carry oxygen-and-nutrient-rich blood from the placenta to the fetus. The ductus venosus allows blood to bypass the immature liver in fetal circulation. The foramen ovale and ductus arteriosus are modifications that permit blood to bypass the lungs in fetal circulation.

Conduction System of heart

Heart’s conduction system is the network of nodes (groups of cells that can be either nerve or muscle tissue), specialized cells and electrical signals that keep your heart beating.

Two types of cells control your heartbeat:

- **Conducting cells** carry the electric signals.
- **Muscle cells** control your heart's contractions.

Heart (cardiac) conduction system sends the signal to start a heartbeat. It also sends signals that tell different parts of your heart to relax and contract (squeeze). This process of contracting and relaxing controls blood flow through your heart and to the rest of your body.

What are the steps of the heart conduction pathway?

Your heart is a pump that sends blood through your body. For each heartbeat, electrical signals travel through the conduction pathway of your heart. It starts when your sinoatrial (SA) node creates an excitation signal. This electrical signal is like electricity traveling through wires to an appliance in your home.

The excitation signal travels to:

1. Your atria (top heart chambers), telling them to contract.
2. The atrioventricular (AV) node, delaying the signal until your atria are empty of blood.
3. The bundle of His (center bundle of nerve fibers), carrying the signal to the Purkinje fibers.
4. The Purkinje fibers to your ventricles (bottom heart chambers), causing them to contract.

These steps make up one full contraction of your heart muscle. Your heart conduction system sends out thousands of signals per day to keep your heart beating.

How does electrical conduction perform with the rest of your heart?

The electrical signals that travel through your heart conduction system cause your heart to expand and contract. These contractions control how blood flows through your heart.

Ideally, the electrical conduction system keeps up a steady, even heart rate. It also helps your heart speed up when you need more blood and oxygen or slow down when it's time to rest.

parts of the cardiac conduction system

Your cardiac conduction system contains specialized cells and nodes that control your heartbeat. These are the:

- Sinoatrial node.
- Atrioventricular node.
- Bundle of His (atrioventricular bundle).
- Purkinje fibers.

Sinoatrial node

Your sinoatrial node is sometimes called your heart's natural pacemaker. It sends the electrical impulses that start the heartbeat.

The SA node is in the upper part of your heart's right atrium. It is at the edge of your atrium near your superior vena cava (vein that brings oxygen-poor blood from your body to your heart).

Your autonomic nervous system controls how fast or slowly your SA node sends electrical signals. This part of the nervous system directs hormones that control your heart rate based on what you are doing. For example, your heart rate increases during exercise and slows when you are asleep.

The autonomous nervous system includes your:

- **Sympathetic nervous system** (fight or flight response) makes your SA node work faster, which increases your heart rate.
- **Parasympathetic nervous system** (rest and digest response) makes your SA node work slower, which decreases your heart rate.

Atrioventricular node

The atrioventricular node delays the SA node's electrical signal. It delays the signal by a consistent amount of time (a fraction of a second) each time.

The delay ensures that your atria are empty of blood before the contraction stops. The atria are the heart's upper chambers. They receive blood from your body and empty it into the ventricles.

Your AV node is located in an area known as the triangle of Koch (located between the septal leaflet of the tricuspid valve, the coronary sinus and the membranous portion of the interatrial septum). This is near the central area of the heart.

Bundle of His

The bundle of His is also called the atrioventricular bundle. It is a branch of fibers (nerve cells) that extends from your AV node. This fiber bundle receives the electrical signal from the AV node and carries it to the Purkinje fibers.

The bundle of His runs down the length of the interventricular septum, the structure that separates your right and left ventricles. The bundle of His has two branches:

- **Left bundle branch** sends electrical signals through the Purkinje fibers to your left ventricle.
- **Right bundle branch** sends electrical signals through the Purkinje fibers to your right ventricle.

Purkinje fibers

The Purkinje fibers are branches of specialized nerve cells. They send electrical signals very quickly to your right and left heart ventricles.

Your Purkinje fibers are in the subendocardial surface of your ventricle walls. The subendocardial surface is part of the endocardium, the inner layer of tissue that lines your heart's chambers.

When the Purkinje fibers deliver electrical signals to your ventricles, the ventricles contract. As they contract, blood flows from your right ventricle to your pulmonary arteries and from your left ventricle to your aorta. The aorta is the body's largest artery. It sends blood from your heart to the rest of your body.

CONDITIONS AND DISORDERS

What conditions and disorders affect electrical conduction in your heart?

Several different conditions can affect your heart's electrical system. These problems cause issues with your heart's rhythm.

Some common heart rhythm disorders include:

- **Arrhythmia:** Irregular heart rhythm, including atrial fibrillation (Afib).
- **Bundle branch block:** A block in the Purkinje fibers on one side of your heart, causing arrhythmia.
- **Heart block:** Impaired electrical signals between your heart's atria and ventricles.
- **Long Q-T syndrome (LQTS):** Your ventricles contract and release too slowly, sometimes leading to fainting (syncope) or sudden cardiac arrest.
- **Premature ventricular contractions:** A too-early heartbeat in your ventricles, causing heart palpitations or a "skipped heartbeat."
- **Sudden cardiac arrest:** A severe malfunction in your heart's rhythm that causes your heart to stop, resulting in death if not treated immediately.