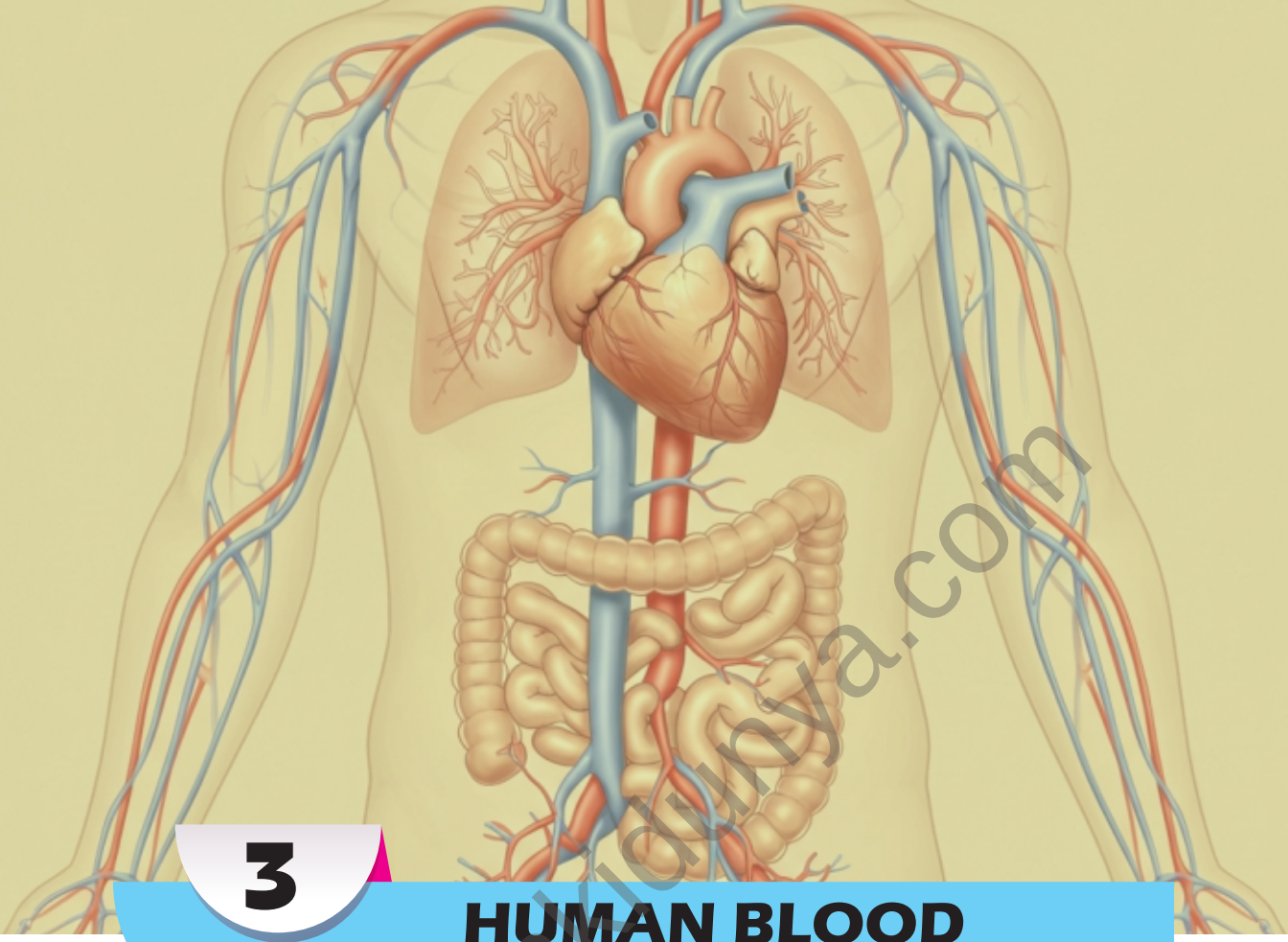


3 HUMAN BLOOD CIRCULARITY SYSTEM

Students Learning Outcomes

After studying this chapter, students will be able to:

- Describe how the blood is circulated inside the human body.
- Explain how blood is used to transport materials throughout the human body.
- Identify the different types of organs connected to the blood system and their roles.
- Identify the different components that make up the blood.
- Name the cell types found in blood and their roles.
- Explain the structure of the heart with a diagram.
- Explain common heart diseases (coronary heart disease, myocardial infarction, angina).
- Explain the harmful effects of smoking related to heart diseases.

The transport system consists of two key parts i.e., (i) blood circulatory system, and (ii) lymphatic system. In this chapter, you will study the details of the blood circulatory system. The main components of human blood circulatory system are blood, heart, and blood vessels.

3.1 BLOOD AND ITS COMPONENTS

Blood is a type of connective tissue. Its main function is to transport materials through the body. It carries important materials to where they are needed. It transports oxygen from the lungs to all body cells and carries carbon dioxide back to the lungs for removal. Blood also delivers nutrients from the digestive system to the cells, hormones from glands to target organs, and waste products from the cells to kidneys for excretion.

About 55% of blood is composed of a fluid portion called **plasma** while 45% of blood is made up of cells or cell-like bodies. The adult human has about 5 litres blood in the body.

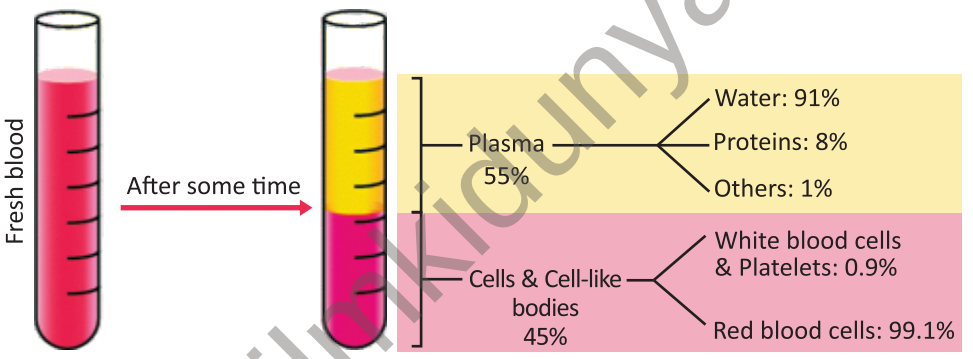


FIGURE 3.1: Percentage composition of blood

1. Blood Plasma

It is the liquid portion of blood. Plasma is composed 90-92% of water, 7-9% of proteins and 1% of other substances.

If fibrinogen is removed from blood plasma, the rest is called **serum**.

- **Proteins:** Antibodies are important plasma proteins. Antibodies defend the body against pathogens. Fibrinogen is also a plasma protein. It is responsible for blood clotting. Albumin is a plasma protein which maintains the osmotic pressure of blood.
- **Salts:** The important plasma salts are made of sodium, chloride, and bicarbonate ions. In addition, there are little amounts of calcium, magnesium, copper, potassium, and zinc.
- **Nutrients, wastes and hormones:** Plasma contains nutrients like

glucose, lipids, and amino acids etc. These nutrients enter into the blood from the digestive system. The wastes produced by cells are also present in plasma. Hormones secreted by endocrine glands are also carried by plasma.

- **Respiratory gases:**
  Small amounts of carbon dioxide and oxygen are dissolved in plasma. Oxygen is mainly carried by RBCs but about 1.5% of oxygen is also present in plasma in dissolved form. Similarly, about 5-7% of carbon dioxide is carried as dissolved in plasma mostly in the form of bicarbonate ions.

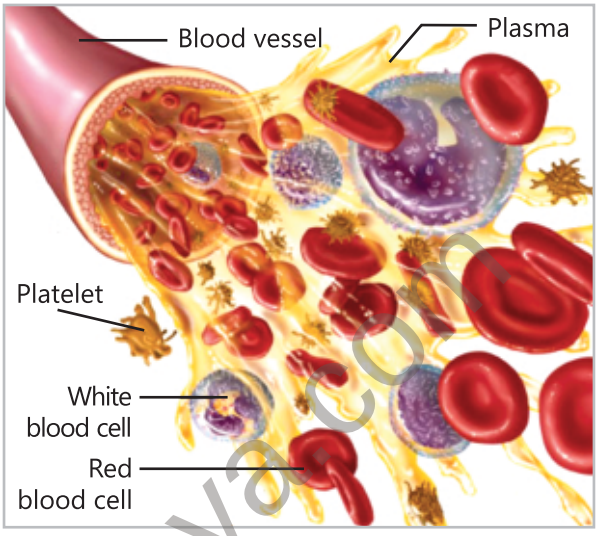


FIGURE 3.2: Blood composition

2. Blood Cells (and Cell-like Bodies)

Red Blood Cells (Erythrocytes)

Red blood cells (RBCs) are disc-shaped (biconcave) cells with a depression at the centre. They contain **haemoglobin** which turns bright red in presence of oxygen and dark red when deoxygnated. It transports oxygen and little amount of carbon dioxide. There are 4 to 5.5 million RBCs per mm^3 of blood. Before and immediately after birth, RBCs are formed in **liver and spleen**. In adults, they are formed in the **red bone marrow** of short bones (sternum, ribs and vertebrae). During the formation of an RBC, its nucleus and organelles are broken down. The average life span of an RBC is about 120 days. When RBCs complete their age, they are removed by spleen and liver.

There are more than 30 trillion RBCs throughout the body. About 2 million RBCs die and are replaced every second.

White Blood Cells (Leukocytes)

White blood cells (WBCs) are colourless and have irregular shapes. They are formed in the red bone marrow. Some WBCs mature in lymph nodes, tonsils, thymus, or spleen. WBCs are larger in size and less in number than RBCs. An average of 7000 WBCs per mm^3 of blood is present within the normal range for adults. They defend the body against diseases. Their life span depends upon the needs. There are several types of WBCs.

1. **Granulocytes:** These WBCs have granules in cytoplasm. They include **neutrophils, eosinophils,** and **basophils.** Their names tell the staining properties of their cytoplasm. Neutrophils destroy bacteria and clean up dead cells at infection sites. Eosinophils fight with parasites and cause allergic reactions. Basophils release histamine to cause inflammation and produce allergic reactions.
2. **Agranulocytes:** They have clear cytoplasm. There are two types of agranulocytes i.e., monocytes and lymphocytes. **Monocytes** make **macrophages** which engulf the germs and dead cells. **Lymphocytes** make antibodies against pathogens.

Cell-like bodies i.e., Platelets (Thrombocytes)

Platelets are not whole cells. They are small fragments of large cells of bone marrow. Platelets lack a nucleus. Their life span is 7 to 12 days. A mm^3 of blood contains 250,000 platelets.

When a blood vessel is damaged, platelets gather at the damaged site. Here, they convert plasma protein fibrinogen into **fibrin**. The fibrin molecules form a net that traps RBCs. The mass of fibrin and RBCs hardens. This hard mass is called a **clot**. The clot prevents bleeding until the damaged vessel is repaired.

Macrophages die in the process of killing the germs. The dead cells accumulate and make the white substance called **pus**, seen at infection sites.

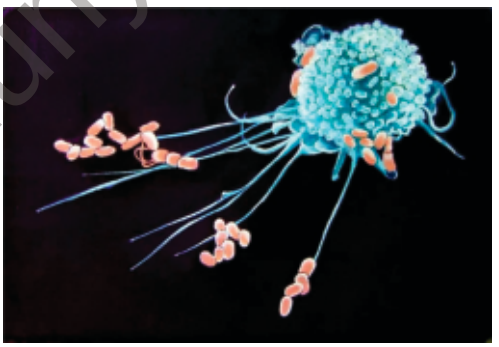


FIGURE 3.3: A macrophage engulfing the bacteria

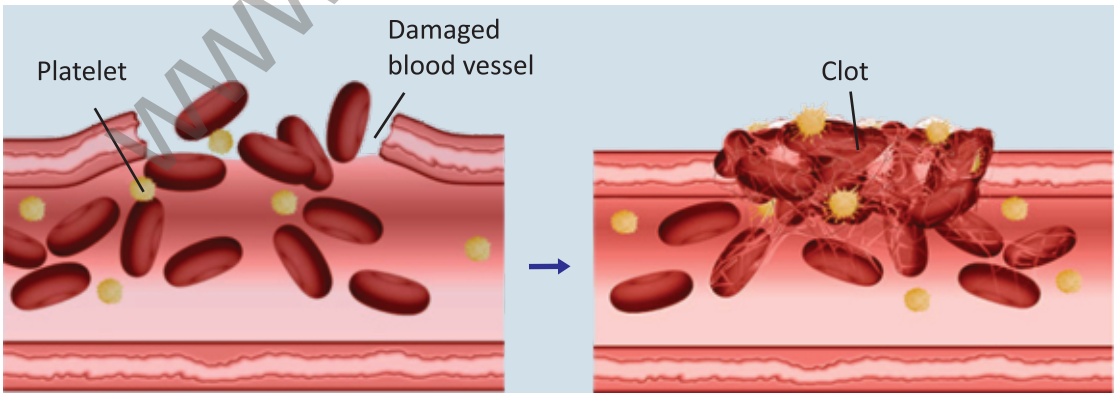


FIGURE 3.4: Formation of clot by platelets

3.2 HUMAN HEART

The heart is a muscular organ that pumps blood through a network of blood vessels. The heart lies within the chest cavity, beneath the sternum, between the two lungs.

Structure of the Heart

There is a tough, sac-like membrane around the heart. It is called **pericardium**. It secretes a fluid around heart. This fluid reduces friction between the pericardium and heart. Like birds and other mammals, human heart has two sides. The wall between the left and right sides is called **septum**. Each side is divided into two chambers. The upper chambers are called **atria** (singular: atrium), and lower chambers are called **ventricles**. The atria have thinner walls as compared to ventricles.

The left ventricle is the largest, thickest and strongest chamber in the heart.

Special flaps called **valves** are present between the chambers of both sides. The valves open in only one direction. The valve between right atrium and right ventricle is called **tricuspid valve** (made of 3 flaps). The valve between left atrium and left ventricle is called **bicuspid valve** (made of 2 flaps). As the ventricles contract, tricuspid and bicuspid valves close. So, the blood cannot flow back into atria. In this way, blood is pumped from the ventricles into large vessels. A **semilunar valve** is present between each ventricles and large vessels. These valves prevent blood from flowing back into the ventricles.

The Circulation of Blood

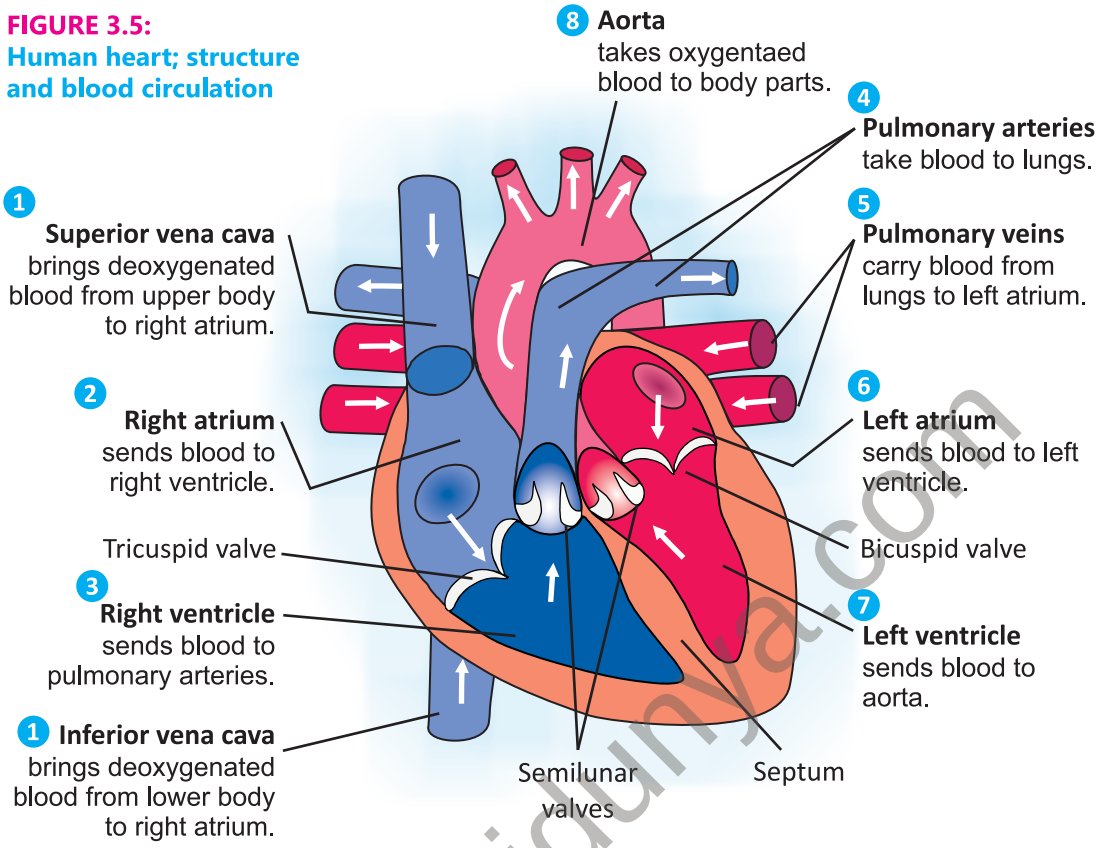
The right side of the heart collects blood from body and sends it to the lungs while the left side collects blood from the lungs and sends it to the body. It means that human heart works as a **double pump**. It is done in the following way.

Oxygenated blood is bright red. Deoxygenated blood is dark red.

Two veins i.e., superior and inferior vena cavae bring **deoxygenated blood** (with high concentration of CO_2 and low concentration of O_2) from parts of the body (other than lungs). These veins open in the right atrium. The right atrium contracts and sends this blood into the right ventricle. The right ventricle contracts and pumps this blood into pulmonary arteries. The pulmonary arteries take this blood to lungs. In lungs, CO_2 diffuses out of the blood, and O_2 diffuses into the blood.

From lungs, pulmonary veins carry the **oxygenated blood** (low concentration of CO_2 and high concentration of O_2) back. These veins open in the

FIGURE 3.5:
Human heart; structure and blood circulation



Due to high pressure in systemic circulation, blood can reach to all body parts. On the other hand, due to low pressure in pulmonary circulation, blood flows in lungs in slow speed. It gives sufficient time for gaseous exchange in lungs.

left atrium of heart. This blood is pumped into left ventricle. When left ventricle contracts it pumps the blood into a large blood vessel called **aorta.** From aorta, this blood is transported to all parts of the body.

Pulmonary and systemic circulations: The flow of blood from heart to lungs and then from lungs to heart is called **pulmonary**

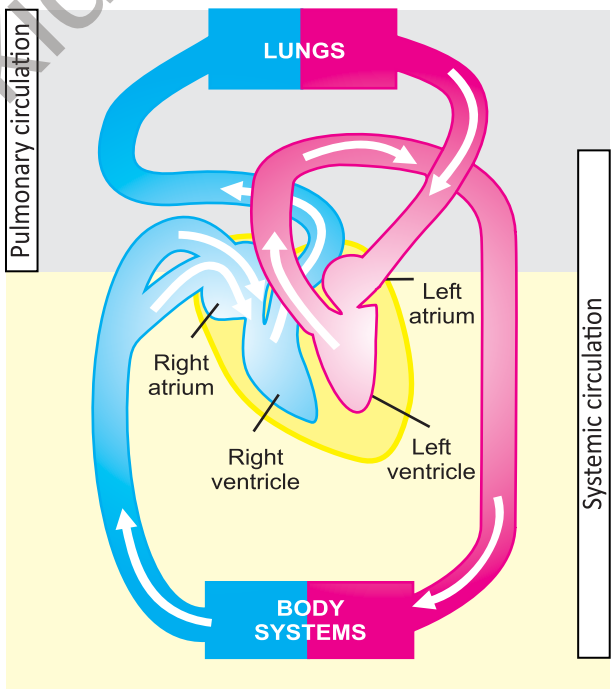


FIGURE 3.6: Pulmonary and systemic circulations

circulation. Similarly, the flow of blood from heart to the body tissues and then from body tissues to heart is called **systemic circulation**.

Heartbeat

The alternating contraction (systole) and relaxation (diastole) of heart chambers makes one heartbeat. The average human heart beats 70 times per minute. This is also called the heart rate. A heartbeat has two phases.

- **Systole** occurs when both ventricles contract to pump the blood into pulmonary arteries and aorta.
- **Diastole** occurs immediately after systole when both atria relax so that blood enters the atria. Contraction of the atria fills the ventricles.

During systole **"lubb"** sound is produced due to the closing of tricuspid and bicuspid valves.

During diastole **"dubb"** sound is produced due to the closing of semilunar valves.

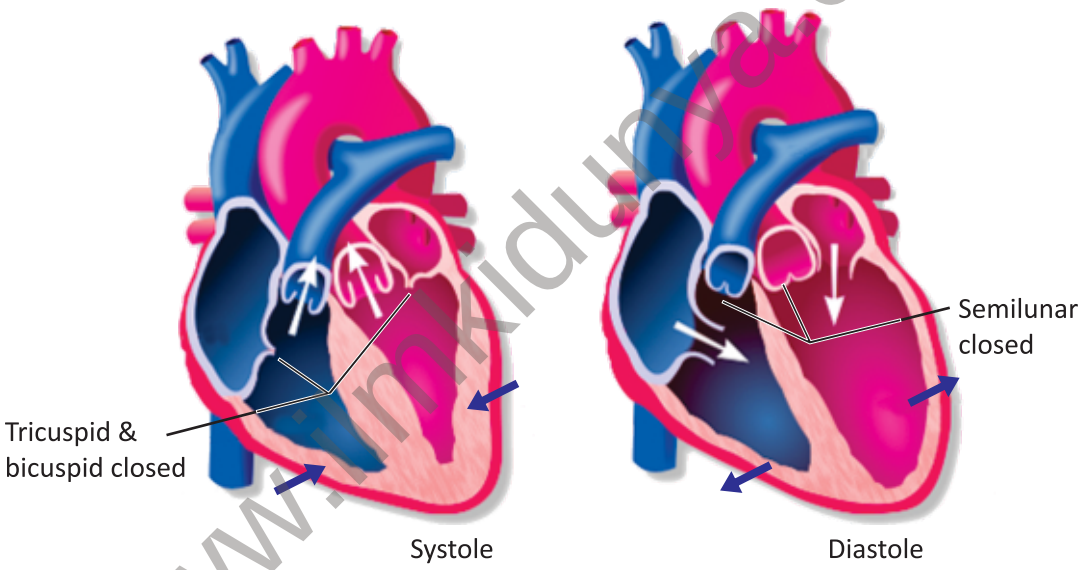


FIGURE 3.7: One Heartbeat

3.3 BLOOD VESSELS

1. Arteries

Arteries carry blood away from the heart. In adults, all arteries carry oxygenated blood, except of pulmonary arteries. The thick walls of arteries are made of: an inner layer of **endothelium**, a middle layer of **smooth muscles** and **elastic tissues**, and an outer layer of **connective tissue**. Arteries are strong and elastic. The hollow internal cavity of arteries in which the blood flows is called **lumen**. When arteries enter body organs, they divide into smaller vessels known

as arterioles. The arterioles enter tissues and divide into capillaries.

2. Capillaries

Capillaries are the smallest blood vessels. The walls of capillaries are composed of only a single layer of cells i.e., **endothelium**. This layer is so thin that water, nutrients and oxygen can pass through it to enter the tissue fluid. Similarly, carbon dioxide and other wastes present in tissue fluid can pass through it to enter blood. In tissues, capillaries unite to form small veins, called **venules**. The venules unite to form veins.

3. Veins

Veins carry blood towards the heart. In adults, all veins carry deoxygenated blood, except of pulmonary veins. The walls of veins are composed of the same three layers as are present in the artery wall i.e., an inner layer of **endothelium**, a middle layer of **smooth muscle** and elastic tissues, and an outer layer of **connective tissue**. In veins, the middle layer is comparatively thin as compared to arteries. It has lesser smooth muscles and elastic tissues. The lumen of the veins is broader than that of arteries. Most veins have **valves** that prevent the back flow of blood.

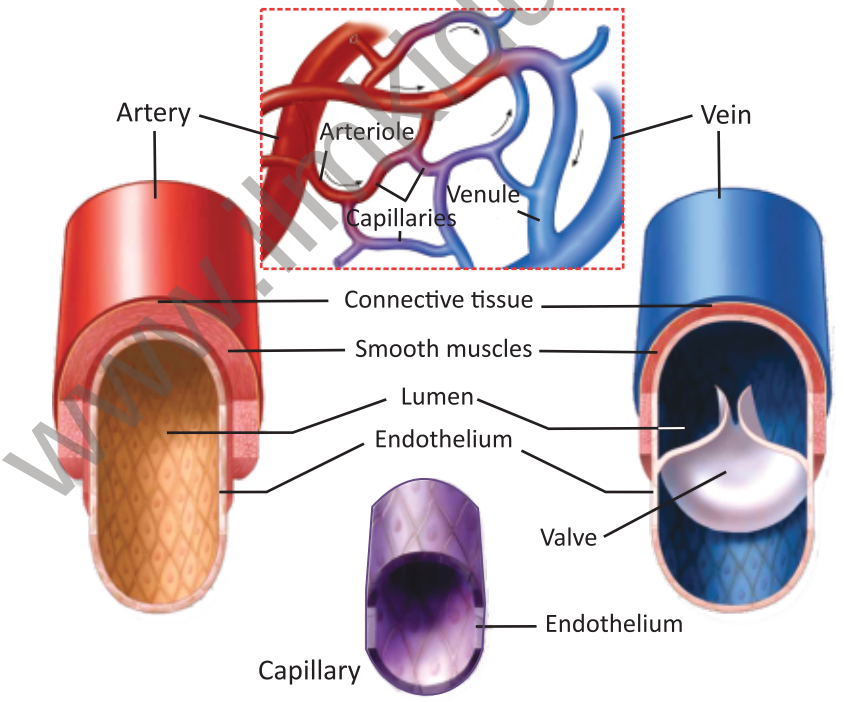
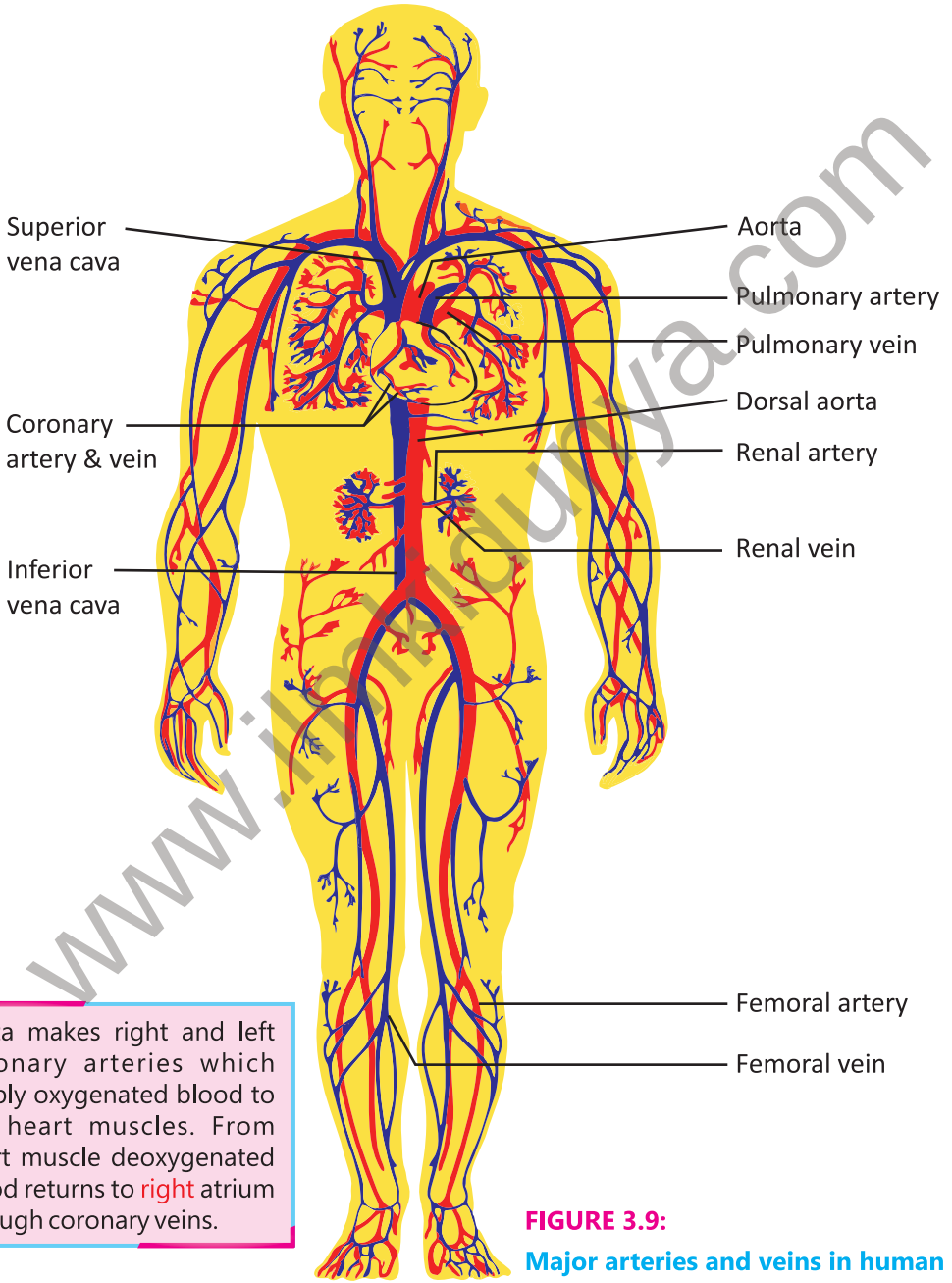


FIGURE 3.8: Blood vessels

3.4 ARTERIAL AND VENOUS SYSTEMS

Arterial System

- **Arteries of Pulmonary circulation:** A large artery called **pulmonary trunk** carries deoxygenated blood from right ventricle. It branches into two smaller pulmonary arteries, each artery supplying blood to each lung.



Aorta makes right and left coronary arteries which supply oxygenated blood to the heart muscles. From heart muscle deoxygenated blood returns to right atrium through coronary veins.

FIGURE 3.9:
Major arteries and veins in human body

- **Arteries of Systemic circulation:** Oxygenated blood is pumped from left ventricle into **aorta**. It forms arteries which supply blood to head, shoulders and arms. Aorta passes through the thorax and becomes **dorsal aorta**. It makes many arteries that supply blood to all parts of the lower region. For example, **hepatic artery** supplies blood to the liver and **renal arteries** supply blood to kidneys. Aorta divides and makes two **femoral arteries** which supply blood to legs.

Venous System

- **Veins of Pulmonary circulation:** Two **pulmonary veins** carry oxygenated blood from lungs to the left atrium of heart.

Veins are blue-looking, but the blood inside is actually dark red.

- **Veins of Systemic circulation:** Two major veins i.e., superior vena cava and the inferior vena cava carry deoxygenated blood from body to right atrium. The **superior vena cava** is made by joining of veins from head, shoulders and arms. The **inferior vena cava** is made of many veins from parts of the lower region. For example, two **femoral veins** from legs empty into inferior vena cava. **Renal** veins carry blood from the kidneys. The **hepatic portal vein** carries blood from alimentary canal to the liver. From liver, a **hepatic vein** carries blood to the inferior vena cava.

3.5 CARDIOVASCULAR DISORDERS

The diseases that involve the heart or blood vessels are collectively called **cardiovascular disorders** or cardiovascular diseases (CVDs).

1. Coronary Heart Disease (CHD)

It is the narrowing or blockage of the coronary arteries, which supply blood to the heart muscle. This condition is primarily caused by **atherosclerosis** i.e., accumulation of fatty deposits (plaques) inside arteries.

Arteriosclerosis is the general hardening and thickening of arterial walls.

Atherosclerosis is a specific type of arteriosclerosis. caused by the build-up of fats, cholesterol, and other substances (plaque) inside the arteries.

Causes: High levels of low-density lipoproteins (e.g., cholesterol) in blood, high blood pressure, smoking, diabetes, sedentary lifestyle.

Symptoms: Asymptomatic in early stages; may lead to chest pain or discomfort as the condition progresses.

According to the World Health organization (WHO), cardiovascular disorders are responsible for about 32% of all global deaths.

In Pakistan, CVDs contribute to nearly 29% of all fatalities

Risk Factors: Family history, obesity, high blood pressure, high cholesterol levels, and lifestyle factors.

Prevention: Healthy diet, regular exercise, smoking cessation, and management of blood pressure and cholesterol levels.

Complications: If left untreated, CHD can lead to more severe conditions, including myocardial infarction and heart failure.

2. Myocardial Infarction

"Myocardium" means heart muscle. "Infarction" means tissue death. The death of heart muscles is called myocardial infarction. It is commonly known as a **"heart attack"**. It occurs when blood flow to a part of the heart muscle is blocked for a prolonged period, leading to death of the heart muscle.

Sometime heart attack occurs without symptoms. It is called **silent heart attack.** It is more common in the elderly and in patients with diabetes

Causes: A blockage in one or more coronary arteries often caused by a blood clot that forms over atherosclerotic plaques.

World Heart Day is held on 29 September every year. Its objective is to give awareness to common people about the risks of cardiovascular disorders.

Symptoms: Chest pain, tightness, and pressure; shortness of breath; sweating; pain radiating to the arm, neck, or jaw.

Treatment: Emergency treatment (medicines to dissolve clots), angioplasty to open blocked arteries, and stenting to keep arteries open.

Complications:

Heart failure, arrhythmias (irregular heartbeats), and sudden cardiac arrest.

Prevention:

Maintaining weight with a healthy diet; avoid smoking; exercise regularly; control blood pressure, cholesterol and diabetes.

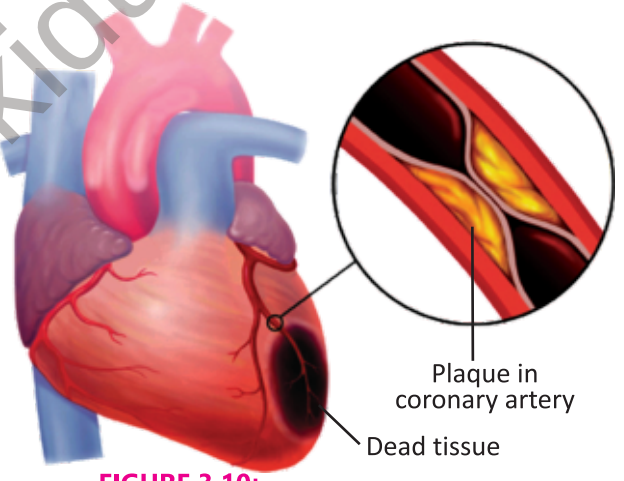


FIGURE 3.10:
Atherosclerosis and resulting Myocardial infarction

3. Angina Pectoris

Angina Pectoris (commonly called Angina) is chest pain or discomfort caused by reduced blood flow to the heart muscle, typically due to coronary

artery disease. Angina is a symptom of CHD and often indicates that the heart is not getting enough oxygen.

Symptoms: Chest pain or discomfort, chest pressure, squeezing, or heaviness. Pain can radiate to the shoulders, neck, or arms.

Treatment: Lifestyle changes, medications, procedures like angioplasty or stent placement.

Complications: If untreated, can progress to myocardial infarction and increase the risk of heart failure.

Harmful Effects of Smoking Related to Heart Diseases

Smoking is the major risk factor for the development of heart diseases. Here's an overview of how smoking adversely impacts heart health:

1. **Increased Risk of Atherosclerosis:** Smoking accelerates atherosclerosis by damaging the endothelium of arteries.
2. **Increased Risk of Blood Clot Formation:** Smoking increases the chances for blood to clot by promoting platelet aggregation. The clots that can block coronary arteries and lead to myocardial infarction.
3. **Elevated Blood Pressure:** Smoking contributes to elevated blood pressure by causing vasoconstriction.
4. **Heart Rate and Rhythm Abnormalities:** Arrhythmias are irregular heartbeats that can be dangerous. Smoking affects heart rhythm by increasing heart rate.

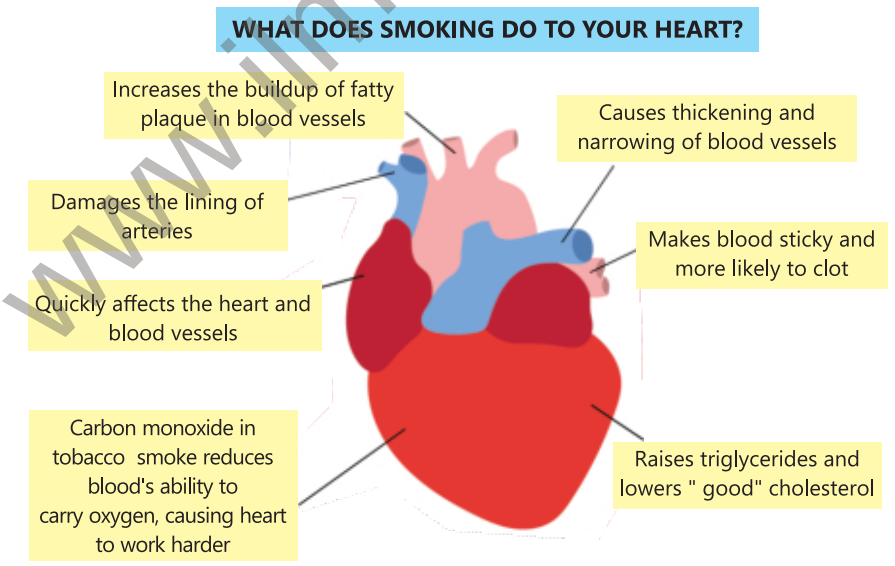


FIGURE 3.11: Public awareness poster on "Effects of Smoking on Heart"

5. **Reduced Oxygen Delivery:** Carbon monoxide from cigarette smoke binds to haemoglobin in RBCs more effectively than oxygen, reducing the blood's oxygen-carrying capacity.

6. **Impact on Overall Cardiovascular Health:** Smoking contributes to the narrowing of arteries in the legs, which can further strain the heart.

EXERCISE

A. Select the correct answers for the following questions.

1. Which component of blood is mainly responsible for carrying oxygen?
   a) White blood cells b) Platelets
   c) Red blood cells d) Plasma
2. A person with low platelet count is likely to face difficulty in:
   a) Fighting infections b) Breathing
   c) Clotting blood d) Transporting oxygen
3. Which of the following layer is found in all blood vessels?
   a) Smooth muscle b) Endothelium
   c) Skeletal muscle d) Connective tissue
4. Which of the following contains deoxygenated blood in an adult human?
   a) Left atrium b) Pulmonary artery
   c) Pulmonary vein d) Aorta
5. When fibrinogen makes blood clot it separates from blood and the rest is;
   a) Plasma b) Lymph c) Serum d) Pus
6. Which heart chamber has the thickest walls?
   a) Right atrium b) Left atrium c) Left ventricle d) Right ventricle
7. The exchange of materials between the blood and tissues occurs in;
   a) Arteries b) Veins
   c) Capillaries d) Arteries and veins
8. All veins carry deoxygenated blood except the _____ vein.
   a) Vena cava b) Hepatic portal
   c) Pulmonary d) Renal
9. Myocardial infarction is due to blockage of blood flow in;
   a) Aorta b) Pulmonary artery
   c) Coronary artery d) Hepatic artery

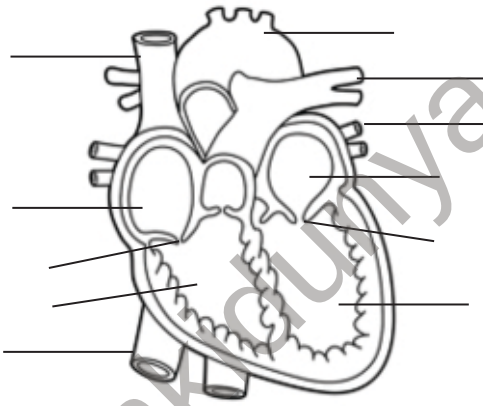
10. If the bicuspid valve is damaged, which flow of blood will be affected?

a) From left atrium to left ventricle b) From right atrium to right ventricle

c) From left ventricle to aorta d) From lungs to left atrium

B. Write short answers.

1. List the types of cells present in blood along with their functions.
2. Differentiate between atria and ventricles.
3. Trace the flow of blood from the vena cava to various body parts.
4. Identify the causes and treatments of myocardial infarction.
5. Colour the following diagram of heart to show oxygenated and deoxygenated blood. Label the different structures as marked.



C. Write answers in detail.

1. Describe the functions of the components of blood.
2. Explain how blood transports materials throughout the human body.
3. Explain the structure of the heart with a diagram.
4. Explain the harmful effects of smoking related to heart diseases.
5. Compare the structure and function of an artery, a vein and a capillary.

D. Inquisitive questions

1. Why is oxygenated blood separated from deoxygenated blood in heart?
2. How does regular exercise strengthen the circulatory system?
3. How can lifestyle choices prevent cardiovascular diseases?
5. If cholesterol levels in the blood are never regulated, how can it impact the heart and blood vessels over time?